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ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
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UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN
BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
NACIONALNI INSTITUT ZA POLJOPRIVREDNU MEHANIZACIJU -
INMA BUKUREŠT
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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GEOMATIKA–SMOLČAK
STUPNIK

PRIČA O TRAKTORU S NASLOVNICE

WATERLOO BOY N – TRAKTORSKA LEGENDA

Waterloo Boy model N je status traktorske legende zaslužio zbog događaja povezanih s povijesnim razvojem traktora. Tvrtka Deere & Company, neuspješna u razvoju vlastitog traktora, odlučila je 1918. godine preuzeti proizvođača traktora Waterloo Gasoline Engine Company čiji je osnivač bio John Froelich. Deere & Co. je u početku traktore proizvodio pod imenom Waterloo Gasoline Engine Co., a ime John Deere je na traktorima prisutno od 1923. godine. Povjesničari s područja traktorske tehnike su uglavnom suglasni da je Froelich-ov traktor (preteča Waterloo boy-a) začetnik povijesti traktora i njihovog korištenja u poljoprivredi, kao prvi tehnički zadovoljavajući traktor s motorom s unutarnjim izgaranjem. John Froelich 1893. osniva u Waterloo-u, Iowa, tvrtku Waterloo Gasoline Traction Engine Company, no zbog slabe prodaje traktora proizvodnju fokusira na stacionarne motore s unutarnjim izgaranjem, te se 1895. tvrtka preimenuje u Waterloo Gasoline Engine Company. Jedan model stacionarnog motora iz 1905. godine nazvan je Waterloo Boy, a 1911. započinje proizvodnja traktora pod tim imenom. Na temelju prethodnih modela je 1916. nastao Waterloo Boy model N, koji je do 1924. proizveden u više od 20.000 primjeraka.

Waterloo Boy traktore su pogonili dvocilindrični motori snage 12 KS / 8,9 kW (na poteznici) i 25 KS / 18,6 kW na pogonskoj remenici (za pogon poljoprivrednih strojeva, priključno vratilo se na traktorima pojavljuje kasnije) pri nazivnih 750 o/min. Zanimljivo je da je na Nebraska testu traktora utvrđena snaga veća od deklarirane od strane proizvođača, na poteznici je izmjereno 15,98 KS / 11,9 kW, na pogonskoj remenici 25,97 KS / 19,4 kW. Svi glavni sklopovi traktora bili su pričvršćeni na čeličnom nosivom podvozju, karakteristično za sve traktore do 1917. godine i fordovog traktora Fordson koji je imao samonosivu konstrukciju. Waterloo Boy je za gorivo koristio petrolej, paljenje gorive smjese iskrom osiguravao je visokonaponski magnetni uređaj, a podmazivanje je riješeno jednostavno zapljuskivanjem. Traktor je imao jedan stupanja prijenosa za vožnju naprijed i jedan nazad, najveća brzina iznosila je gotovo 5 km/h (3 mph).

Upravo je Waterloo Boy N bio 1920. godine prvi traktor na svijetu ispitan na Nebraska testu traktora, koji je iste godine uveden kao obaveza da bi se uveo red na američkom tržištu traktora. Zakonom je bilo utvrđeno da se traktor koji ne zadovolji minimalne propisane kriterije ne može prodavati u Nebrasci. Kvaliteta ispitivanja obavljanih na Nebraska testu imala je velik utjecaj na industriju traktora u SAD, a kasnije i svijetu. Proizvođači traktora počeli su poštivati zahtjeve testa pri razvoju traktora, što je kupcima pri nabavci novog traktora pružalo veću sigurnost u istinitost karakteristika deklariranih od strane proizvođača. Ovlasti za provođenje testiranja dobila je nezavisna institucija, Nacionalni laboratorij za testiranje traktora (NTTL), Lincoln, Sveučilište u Nebrasci. U Europi je 1959. godine po uzoru na Nebraska test uveden OECD protokol za ispitivanje traktora koji se kontinuirano dopunjuje te danas obuhvaća i traktore za šumarstvo.

Tekst: Viktor Jejčič

Slika na naslovnici: Dušan Jejčič, ulje na platnu

IN MEMORIAM

Prof. dr. sc. Zlatko Gospodarić (1948.-2016.)

Dana 19. rujna 2016. godine napustio nas je umirovljeni profesor Zlatko Gospodarić, dugogodišnji djelatnik Agronomskog fakulteta Sveučilišta u Zagrebu. Prof. dr. sc. Zlatko Gospodarić rođen je 6. veljače 1948. godine u Zagrebu gdje je završio osnovnu školu i gimnaziju. Poljoprivredni fakultet Sveučilišta u Zagrebu, smjer Voćarstvo-vinogradarstvo-vrtlarstvo, završio je 1973. i iste godine se zaposlio u Institutu za mehanizaciju poljoprivrede, koji nakon integracije s Poljoprivrednim fakultetom 1978. godine mijenja ime u Institut za mehanizaciju, tehnologiju i graditeljstvo u poljoprivredi. Odmah po prelasku na fakultet uključuje se u nastavu i izvodi vježbe na više smjerova. Magistarski rad obranio je 1982. godine, a nakon izbora u znanstvenog asistenta 1984. godine uz izvođenje vježbi povjerena su mu i pojedina predavanja.

Jedno kraće vrijeme bio je i direktor Instituta za mehanizaciju, tehnologiju i graditeljstvo u poljoprivredi. Disertaciju je obranio 1993. godine, za docenta je izabran 1994. te postaje nositelj dva predmeta na studiju Bilinogojstvo. U zvanje izvanrednog profesora izabran je 2006. godine i u tom zvanju odlazi u mirovinu.

Tijekom svoje karijere na fakultetu objavio je više od 50 znanstvenih radova u domaćim i stranim časopisima i zbornicima radova, od čega 9 iz a1 kategorije, a objavio je i veći broj stručnih radova i studija. Do mirovine, uz obveze u nastavi, najviše se bavio uspostavljanjem i provođenjem sustava homologacije traktora u Republici Hrvatskoj, te prevođenjem i donošenjem hrvatskih normi u svojstvu predsjednika Tehničkog odbora 23 pri Hrvatskom Zavodu za norme. Višegodišnjim radom kao član uredništva doprinio je organizaciji međunarodnog simpozija „Aktualni zadaci mehanizacije poljoprivrede", te je u razdoblju od 1994. do 2000. godine nekoliko puta bio glavni urednik zbornika radova ovog tradicionalnog skupa. Bio je vrstan praktičar, stručnjak za poljoprivredne strojeve i mjernu tehniku, a najviše je volio rad na terenu i svima koji su ga poznavali ostat će u trajnom sjećanju.

Zagreb, rujan 2016.

Prof. dr. sc. Dubravko Filipović
Predstojnik Zavoda za mehanizaciju poljoprivrede

PREDGOVOR

Povodom 45. obljetnice valja se prisjetiti da su za danas tradicionalni simpozij prije svega zaslužni tadašnji profesori Zavoda za poljoprivredno strojarstvo, Poljoprivrednog fakulteta Sveučilišta u Zagrebu, koji su daleke 1970. godine organizirali prvi međunarodni simpozij ″Aktualni problemi mehanizacije poljoprivrede″, a naravno i svi koji su kroz godine doprinijeli radu i napretku: autori, recenzenti, sponzori i kolege mehanizatori svjesni da je tehnološki napredak sredstava mehanizacije temelj unapređenja poljoprivrede. Pokroviteljstvo ovogodišnjeg simpozija od strane međunarodnih udruga poljoprivredne tehnike CIGR, EurAgEng, AAAE i ASABE, kao i činjenica da su od 1997. godine radovi objavljeni u Zborniku simpozija uvršteni u baze podataka Thomson Reuters: CPCI i ISTP, te CABI potvrda su kvalitete i priznanje dugogodišnjem ustrajnom radu na organizaciji simpozija.

Ovogodišnji zbornik radova sadrži ukupno 70 radova iz Austrije (3), Češke (1), Estonije (4), Filipina (1), Hrvatske (4), Italije (3), Japana (1), Litve (6), Makedonije (1), Njemačke (5), Rumunjske (31), Slovenije (5), Srbije (4) i Turske (1) Pristup web izdanju je besplatan na adresi http://atae.agr.hr/proceedings.htm od 30. ožujka tekuće godine. Na potpori posebno zahvaljujemo Ministarstvu znanosti, obrazovanja i sporta Republike Hrvatske i Zakladi Hrvatske akademije znanosti i umjetnosti. Svim sudionicima želimo ugodan boravak u Opatiji za vrijeme održavanja Simpozija.

PREFACE

On the occasion of the 45th anniversary let us recall that the credit for today traditional symposium belongs to the professors of Agricultural Engineering Department, Faculty of Agriculture, University of Zagreb, who organized the first international symposium "Actual problems of agricultural engineering" in 1970, as well as all those who have contributed through the years to its work and progress: authors, reviewers, sponsors and colleagues from agricultural engineering profession aware that technological advances of mechanization recourses is foundation of agricultural development. Co-sponsorship of this year's symposium by CIGR, EurAgEng, AAAE and ASABE, and the fact that since 1997 papers published in the symposium Proceedings are included in the Thomson Reuters: CPCI and ISTP, and CABI is confirmation of the quality and acknowledgement of many years of persistent work in organizing the symposium.

This year's Proceedings contains 70 articles from Austria (3), Croatia (4), Czech Republic (1), Estonia (4), Germany (5), Italy (3), Japan (1), Lithuania (6), Republic of Macedonia (1), Philippines (1), Romania (31), Serbia (4), Slovenia (5) and Turkey (1). Access to the web edition is free at site http://atae.agr.hr/proceedings.htm from March 30th of the current year. Organizer especially thank the Ministry of Science, Education and Sports of the Republic of Croatia and Croatian Academy of Sciences and Arts for continuous sponsorship. We wish all participants a pleasant stay in Opatija during the Symposium.

Chief Editor

Zagreb, siječanj – January 2017 — Doc. dr. sc. Igor Kovačev

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 332.2/.3:551.583
Prethodno priopćenje
Preliminary communication

INNOVATIVE SUSTAINABLE LAND MANAGEMENT PRACTICES FOR LANDSCAPES UNDER CLIMATE CHANGES THREATS

RARES HALBAC-COTOARA-ZAMFIR[1], SORIN HERBAN[1], THORUNN PETURSDOTTIR[2], DAVID C. FINGER[3]

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ABSTRACT

Agricultural lands from Romania and other European countries are facing a series of environmental and land management challenges as result of the pressure generated by risks like land abandonment in some areas and the intensifying of agricultural activities in other areas. Large agricultural areas are affected by land degradation phenomenon (erosion, landslides, desertification), risks which may be intensified due to climate change dynamics. Moreover, most of land reclamation and improvement works are inadequate or with low operational potential.

Sustainable land management is of vital importance for Romania in its efforts to protect the unique rural environment and to conserve the ecosystems. The solutions for gaining a sustainable land management and for reducing the negative impact of climate change must be based on a large participatory approach in order to secure not only environment and land protection but also for achieving food security in the present and future.

This paper presents the results of a bilateral Romanian-Icelandic project carried out by "Research within Priority Sectors" program financed by EEA Grants.

Key words: sustainable land management, landscape, climate changes

INTRODUCTION

In the context of a continuous growing population when the need for high quantities of food and water presents a significant upward trend, agricultural lands and agricultural production are threatened by climate changes especially due to the severe changes in rainfall and temperatures variability. The increasing pressure on lands and agricultural water management stemming from complex water-food-energy linkages require an improved integrated land and water resources management (Ragab and Prudhomme, 2002).

There are many reasons for the degradation of agricultural lands. These include climate change and increased periods of drought as well as poor land management practices, which include overgrazing, bad cropping and irrigation practices, and deforestation, reducing soil quality and soil fertility, as well as disasters such as floods and fires resulting in impoverishment of the land, ecosystems services and the ability of people to live off the land. Causes of land degradation can be divided into proximate causes and root causes. Geist and Lambin (2004), basing on the results obtained from 132 study cases, identified 4 groups of proximate causes (agricultural activities, increasing on infrastructure, deforestation, fire and droughts) and 6 groups of root causes (demographic, economic, technological, climatic, institutional and cultural).

The results, however, are irrefutable. Conflicts, hardship, food and water insecurity arise in these affected lands resulting directly as well as indirectly in mass migrations, starvation and in some instances death. The consequences of inaction are an increased decline in the physical state of the land as well as in the socio-economic conditions in which people can live and support themselves, their families and their communities. The direct and indirect consequences can result in land abandonment, which in itself may exacerbate land degradation and impoverishment of people and in the worst-case scenario leads to migrations of people.

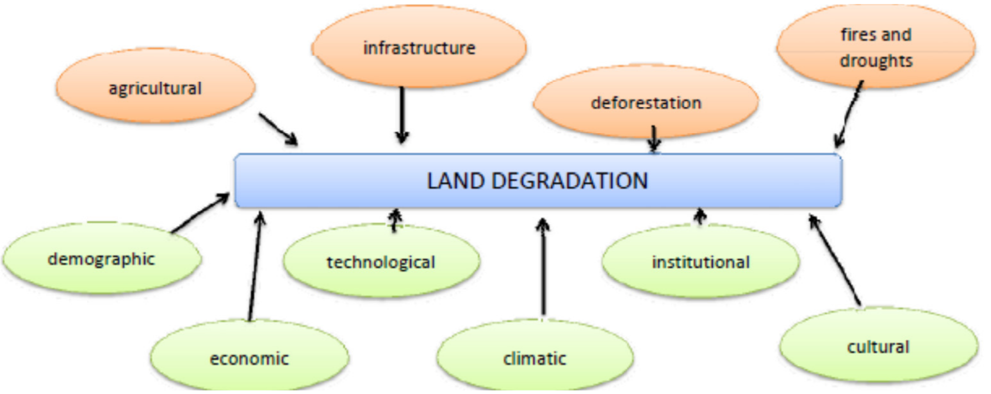

Figure 1 Proximate causes and underlying drivers for land degradation

Based on Romanian experience, a degraded land can be very valuable and useful even from ecosystem services point of view is highly degraded. The land doesn't have only an ecological value but also a financial one which allows to be used in financial speculations (e.g. lands located near cities, lands located near highways (future highways), lands located near industrial sites/ technological parks, lands having soils of high quality (agricultural areas)).

Thus, the transition from an actual reference point based on a certain value of land (even degraded) to a future reference point based on what we are expecting from a land managed in a sustainable way is complex and multiscaled, complicated by issues related to perception, politics, social vulnerability, ecosystem services, ecosystem dynamics, institutional resilience, available technology etc.

Sustainable land management was defined as the "use of land and water resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (UN Earth Summit, 1992).

In a report issued by World Bank (2006), sustainable land management has been defined as "a knowledge-based procedure that helps to integrate land, water, biodiversity, and environmental management to meet rising food and fiber demands while sustaining ecosystem services and livelihoods". Sustainable land management is in direct relation to the three UN environmental conventions. It helps to prevent desertification, to increase biodiversity and to make people less vulnerable to the effects of climate change. Sustainable land management also plays an important role in mitigating climate change through improving soil organic matter and increasing vegetation cover.

METHODS

Developing innovative practices in sustainable land management is a complex issue and requires breaking down disciplinary boundaries between engineers, ecologists, agronomists, economists, hydrologists and climate scientist and the appliance of some reliable climate-energy-economic models as well as land-use models with a sound involvement of different categories of stakeholders.

There are at least 5 key elements which should be considered in implementing an innovative sustainable land management as a response to climate change threats:

– Implementing applied multidisciplinary research in the restoration of degraded lands;
– A sound and reliable relation with main categories of stakeholders;
– A wider opening to the use of open-access databases for disseminating the results from different research activities;
– Adoption of a strategic approach to restoration in land use planning
– Strengthening the links between scientists and practitioners.

Moreover, a sustainable land management project has several purposes which can be classified as it follows:

– Productivity purposes;
– Security purposes;
– Protection purposes;
– To have economical applicability;
– To be socially acceptable.

Policy is another crucial factor im implementing successful a sustainable land management due to governments capacities to promote well informed land use decisions. As policy instruments we can identify here local, regional, and international legislation and regulations. However, the most effective policy tool for the implementation of innovative sustainable land management practices remains public education. A lack of efficient channels to transmit knowledge and technology between environmental science and policy can be identified having a negative impact on implementing and adopting these kinds of sustainable land management practices (Grainger, 2009; Thomas et al., 2012).

DISCUSSION

Nowadays, innovation is not a final destination or objective. While chronological definitions of innovation pass, a tendency of researchers to specify and deepen the meaning of this concept and its applied nature arises. According to Chesbrough (2006) innovation is the dynamic force that changes the economy of a country in the era of globalization. On the other hand, according to Rogers (2003), "innovation is an idea, a practice or object that is perceived as something new from its adopters". the OECD Report (2005) defines innovation as "the process of implementation of new or significantly improved products and processes, new marketing methods or new business practices etc". According to the report, the main activities of innovation are scientific, technological, organizational, financial, commercial activities that implement or intend to implement various innovative elements in the company.

Having an awareness of what we mean by different types of innovation, where the innovation impact is applied, how the innovation process works, and why we are innovating in the first place can add value when doing "new".

Innovation in sustainable land management as a response to climate changes threats become a problem of what aspects of land management we should innovate, where we should innovate land management practices and how we should implement the innovative aspects of land management.

A multidisciplinary approach is essential in tackling the complex issues of land degradation and identifying the effective solutions for land restoration. Creating local solutions very often needs the combined expertise of a number of disciplines. Restoration action in its many forms, including planting, water harvesting, combating soil erosion, integrating SLM practices, implementing FLM (functional land management) measures.

If sustainable land management represents the use of land and water resources for the production of goods to meet changing human needs simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions, the concept of functional land management aimes at optimizing the deliveries of these goods and is able to provide a simplified framework to support land use policies that are based on understanding the role of inherent land properties in defining many of these land functions (Schulte et al., 2014) and managing the expectations and consequences of land use decisions (Coyle et al.,2016). The five main soil functions proposed and included in FLM framework are:

- Primary productivity;
- Water purification and regulation;
- Carbon storage and regulation;
- Provision of a habitat for biodiversity;
- Cycling and provision of nutrients (Schulte et al., 2014).

Multi-functional land use makes it possible to meet the basic human needs consisting in food, water and energy. SLM pursues several goals simultaneously through multi-functional land use. It creates synergies that generate added economic and ecological value. In this case, integrating SLM practices in a FLM framework can be considered an innovative approach in mitigating land degradation or can be viewed as an effective strategy to mitigate the effects of climate changes? Based on the definition of SLM provided by Smyth and Dumanski (1993) the answer is mostly no because SLM must ensure ensuring long-term socioeconomic and ecological functions of the land but FLM can bring an added-value through its policy features. Coyle et al. (2016) states that an integrated framework is required to provide a clear understanding of such complex multi-faceted information and to disseminate it in a simplified, transparent and coherent manner to support the design of a tailored land use policy. Thus, bringing together science, practice and policy aspectes in the same strategy can be adopted as an innovative approach in land management.

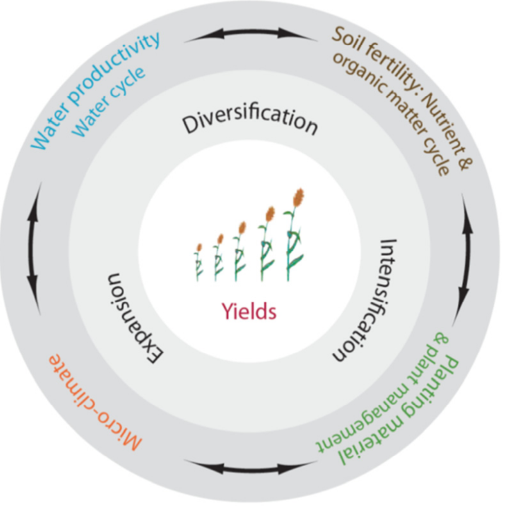

Figure 2 Key to improved land productivity and food security (Source: Liniger et al., 2011)

Land management is a typical multi-stakeholder issue, concerning individual and community land users, agricultural advisors, enterprises, natural resource managers, government authorities, civil society, land improvement engineers and researchers alike. An innovative approach may consist in discovering new ways for improving land planning and administration and by improving the stakeholders at a number of key levels: farmer/landowner, land agents and local authorities, NGOs, government and national departments. Local authorities can be made aware of past, present and future situations by incorporating into their daily routine methods and tools able to monitor the state-of-the-art on land degradation, land restoration and sustainable land management aspects.

Mitigating land degradation as well as implementing land restoration activities are usually focused on a specific site or on a plot scale. Environmental factors and conditions which include soils, climate, topography, hydrology, land management, water management and ecological systems can operate on much larger scales and are interconnected. Thus, sustainable land management practices needs to be conceived at a landscape or watershed scale, and not only at a plot scale. This needs to be disseminated to local stakeholders and supported by the UNCCD focal points. This will also facilitate a better understanding of land degradation and restoration at a strategic scale. Additionally, this strategic approach requires long-term research and monitoring of projects. An innovative aspect is to match restoration planning with administrative boundaries, since policies are usually tailored according to specific private or public limits, namely, properties, municipalities, counties, regions etc.

Access to relevant data is critical in implementing sustainable land management practices. Innovation is not necessary here a problem of data accessibility but of data readily accessible for practitioners and local stakeholders. Another aspect is emphasizing not only the best practices but also the projects which failed in implementing a sustainable land management.

CONCLUSIONS

Sustainable land management requires a better understanding of direct and indirect effects of land management on ecosystem functions. Concerted efforts to standardise documentation and evaluation of sustainable land management technologies must harmonize with traditional aspects and concepts in order to cover the whole range of ecosystem services and to encompass the ecological, social and economic values of local innovations and standard technologies.

An integrated approach to planning the use and management of land resources supposed to make optimal and informed choices on the future uses of the land. This can be achieved by strengthening the interactions (and negotiations) between farmers, researchers, local and regional authorities as well as other categories of stakeholders at national, provincial and local levels

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

SCANNING EQUIPMENT TO ASSESS PHYSICAL SOIL PROPERTIES

SEBASTIAN MURARU, VERGIL MURARU, PETRU CARDEI, CORNELIA MURARU-IONEL, LAURENTIU VLADUTOIU

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SUMMARY

The conception of a scanning equipment to assess the soil properties, which is the main purpose of the paper, involves mechanical, electronic and information technology components.

The paper addresses the main components of the equipment and the way that the process of sampling and data acquisition of the soil is lead, as well as, the commands needed to execute these operations.

The main components of the equipment are: mechanical system; the electro-hydraulic system; the command, control and data acquisition electronic system; the optical sensor; GPS equipment and the mobility ensuring system.

The equipment is designated to precision agriculture and was analyzed and designed at structural and simulation level, in order to its application and implementation widely.

The application area of the scanning equipment is large, because, agriculture is practiced globally and precision agriculture contributes substantially to development of agricultural production and environmental protection.

The possibility offered to farmers to know the quality of their land (soil) with resolutions of a few meters or tens of meters is an essential element in addressing sustainable agriculture that uses rationally the resources and achieves environmental protection simultaneously.

Keywords: soil properties, scanning, optoelectronics, GPS, environmental protection.

INTRODUCTION

The farmers want to know the quality of the soil at small surfaces to improve the agricultural production and to rationally use the resources [1].

As the name suggests, precision agriculture (PA) involves processing precisely in time, space and informational the data obtained by measurement and geolocation systems on an agricultural land, in order to increase and optimize the agricultural production and improve environmental protection [2].

PA opens the possibility to develop systems to determine the quality of soil on small surfaces.

The conception of equipment for scanning of soil properties involves a complex system including mechanical, electronic and information technology components [3].

Scanning soil requires a soil sampling with a resolution of a few meters up to tens of meters through taking samples and determining their properties in real time.

The properties that can be determined are: soil sample spectrum, soil moisture and soil temperature at depths up to 25 cm or more, through sampling and data acquisition automatically, in the same time with the geospatial data related to the global geographical position of the analyzed sample.

In order to achieve scanning of the soil properties, the system must be mobile, able to be moved on the soil surface, able to take soil samples or to scan somehow the soil surface, in order to retrieve data that will be pre-processed and then stored using an electronic memory.

The mobility can be ensured by using a mobile platform that can be towed by a self-propelled system or by a tractor. In this way, the system allows the collection of these properties (data) at distances on the row, starting at about 10 m up to 100 m or even more.

The distance between rows can take values from a few meters up to tens of meters, adjusting it manually or with the help of some adjustable markers or with the help of GPS.

The adjustment should be made at the same distance between rows, in order to have a uniform coverage of the samples taken on the surface (of the measured properties) that will contribute to a better quality of the soil properties scanning.

MATERIAL AND METHOD

Description of the measurement system

The main components of the system (that due to its structure is a mechatronic system (mechanics - electronics)) are: the mechanical system; the electro-hydraulic system; the command, control and data acquisition electronic system; the optical sensor; the GPS equipment; the mobility ensuring system.

In addition, a laptop or PC is necessary for:

- off-line data processing and interpretation;
- GIS software, Office programs and other software;
- data graphical representation;
- development kits for the control, command and data acquisition simulation and implementation.

The equipment was analyzed and designed at structural level and is presented below.

Mechanical system

The main components of the mechanical system are:

- ***the supporting structure*** **(**on 2 wheels with tires) which is coupled to the tractor or to other self-propelled equipment in a classical way through a bolt, on which the hydraulic system and command and control system with accessories are mounted;

– ***the sampling system*** consists of a bar structure of different profiles in the form of a parallelepiped, articulated in all the parallelepiped peaks in the vertical plane, on which the sampling device is mounted. This device (that can be a device such as a coulter) is hydraulically controlled and is being operated by the hydraulic system (hydraulic cylinder).

Also, on this structure (which is movable) the ***guiding plate*** which is solidary with the bar structure is mounted. On the coulter, an inductive transducer which follows its movement on the vertical is mounted.

The guiding plate has cut-outs and determines (depending on the transducer position) various commands for operating the cylinder (lift, descent, and stop). The board has a cutout for the middle position and the extremities are used as cut-outs for the top and down positions.

The main component of the sampling system is the sampling device which consists of a coulter that penetrates the ground up to a predetermined depth, ensured by the guiding plate.

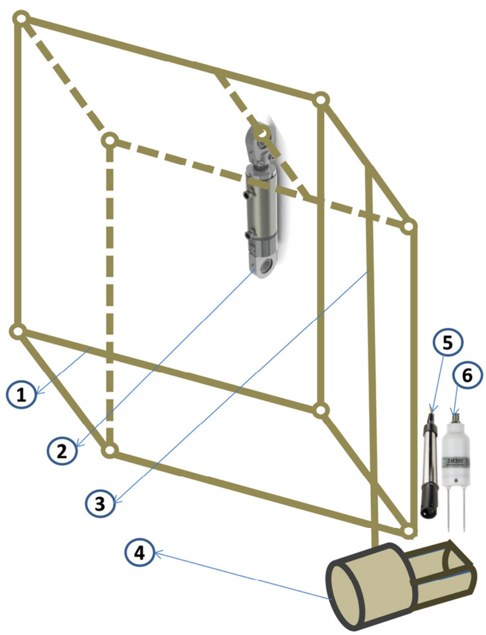

Fig. 1 Sampling device with the deformable parallelepiped

In Fig. 1 the elements of the sampling device are presented, as follows:

1. deformable parallelepiped;
2. hydraulic cylinder (part of the electro-hydraulic system);
3. support bar for the coulter (rigid with the side of the parallelepiped on which it is mounted);
4. coulter;

5, 6. temperature and moisture transducers.

Electro-hydraulic system

The electrical component of the hydraulic system is powered from the tractor battery. The hydraulic power is provided by coupling to the hydraulic system of the tractor.

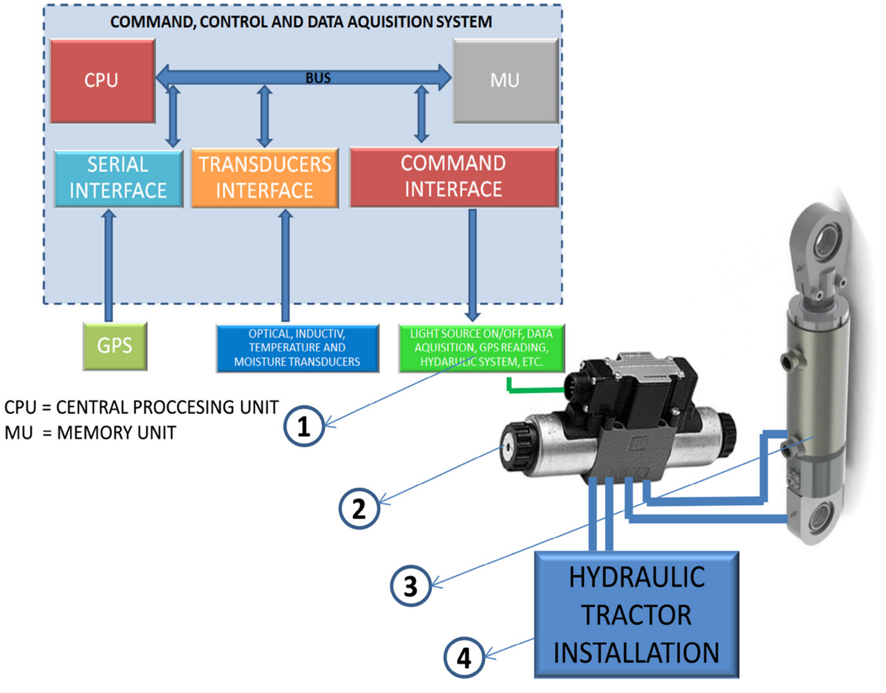

Fig. 2 Electro-hydraulic system

The main components of the hydraulic system, according to fig. 2 are:

2 - electro-hydraulic servo valve;
3 - hydraulic cylinder;
which are connected to:
1 - command, control and data acquisition system;
4 - hydraulic tractor installation.

Electro-hydraulic system acts through the hydraulic cylinder on the deformable parallelepiped and implicitly on the sampling device, ensuring its positioning in the three positions dictated by the guiding plate through the inductive transducer.

In the top position, the soil sample is in contact with the transducers and performs measurements of the moisture and the temperature.

In the middle position, the sampling device is at the ground level and waits for next measurement.

In the down position, the sampling device is in the soil at a depth of 5-25 cm and the data from the optical transducers is acquired.

Command, control and data acquisition electronic system

The command, control and data acquisition system is in interaction with the elements presented in Fig. 3 and is mounted on the supporting structure, being powered by the tractor battery.

This system performs:

- The command and control of the hydraulic installation through the inductive transducer, guidance plate and the valve actuation solenoid.
- Determination of time intervals for moisture, temperature and optical measurements and the ranges for soil sampling;
- Data acquisition from the moisture, temperature and optical transducer and storing;
- Acquisition of the geospatial coordinates and the GMT time from GPS (through the GPS satellites network) and storing;
- Calculation of the displacement speed based on the coordinates and the GMT time, provided by GPS, as well as, the distances between two samples.

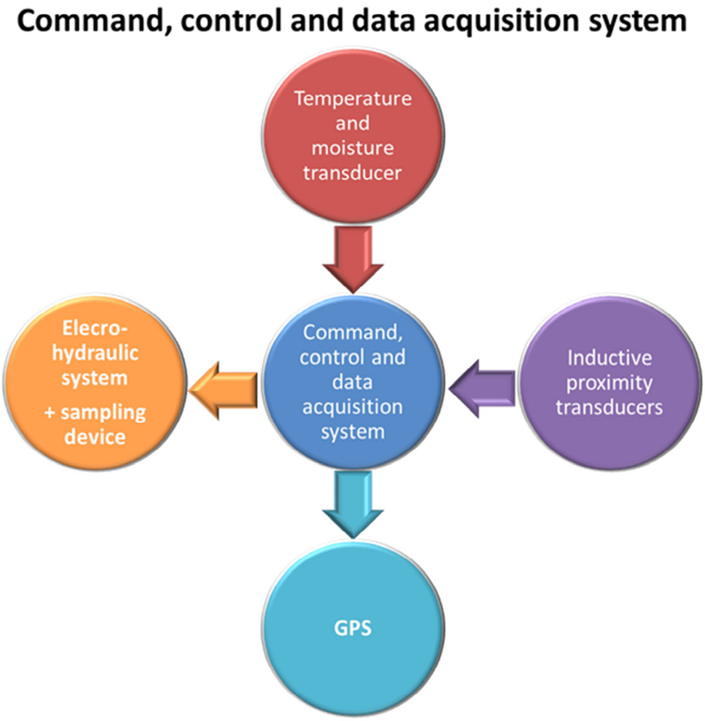

Fig. 3 The interaction of the command, control and data acquisition system with component elements of the complex measurement system

In Fig. 4 the scanning equipment architecture is presented. The main elements of the architecture are:

- command, control and data acquisition system;
- GPS;

– transducers (moisture, temperature, inductive);
– coulter with optical transducer;
– light source.

To these the executions, elements (those commands) comprised of the electro-hydraulic system are added.

The command, control and data acquisition system is coupled through a specialized interface with optical transducers, which takes over the absorbance spectra or the reflecting spectra of the soil at pre-determined distances or moments of time (settable). The optical transducer is activated by the light reflected by the ground from a light source.

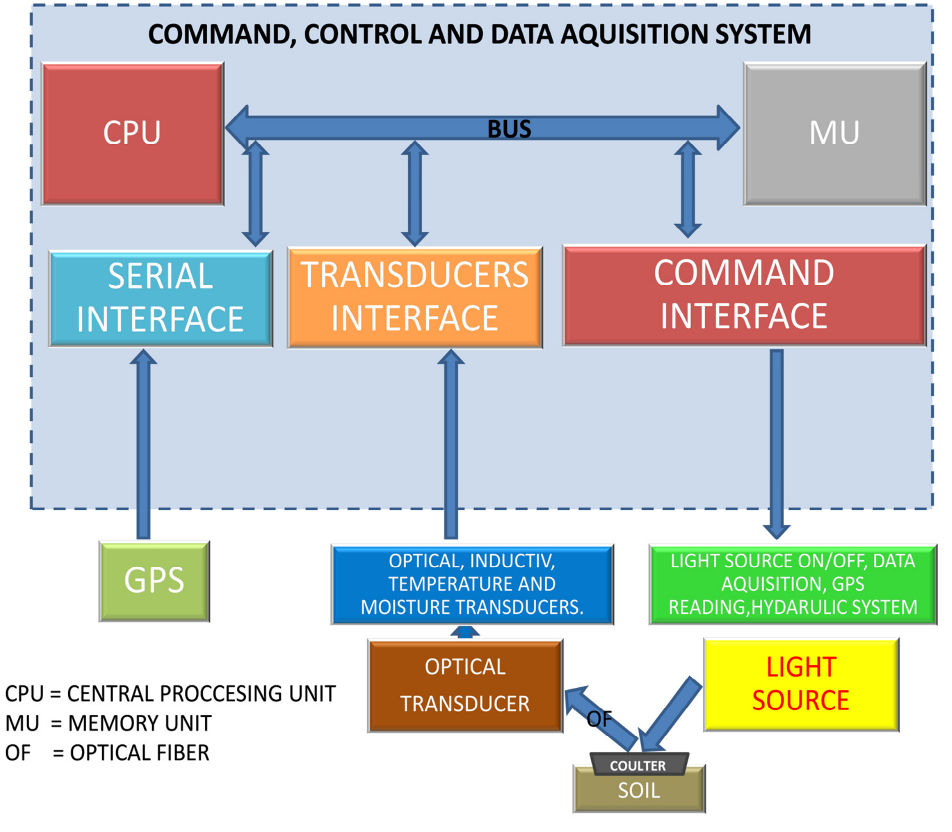

Fig. 4 Scanning equipment architecture

The process is stopped by an interruption generated by an ON / OFF switch or by a virtual button generated by a program in an interactive interface with the user.

The management of the process is implemented in an assembly (or high level programming language) depending on the chosen structure. A structure with microprocessor or microcontroller can be used as a central unit [4].

RESULTS AND DISCUSSION

For simulations of the scanning equipment a simulation program was designed in LabVIEW with a command and control front panel through a virtual interface. The front panel is shown in Fig. 5.

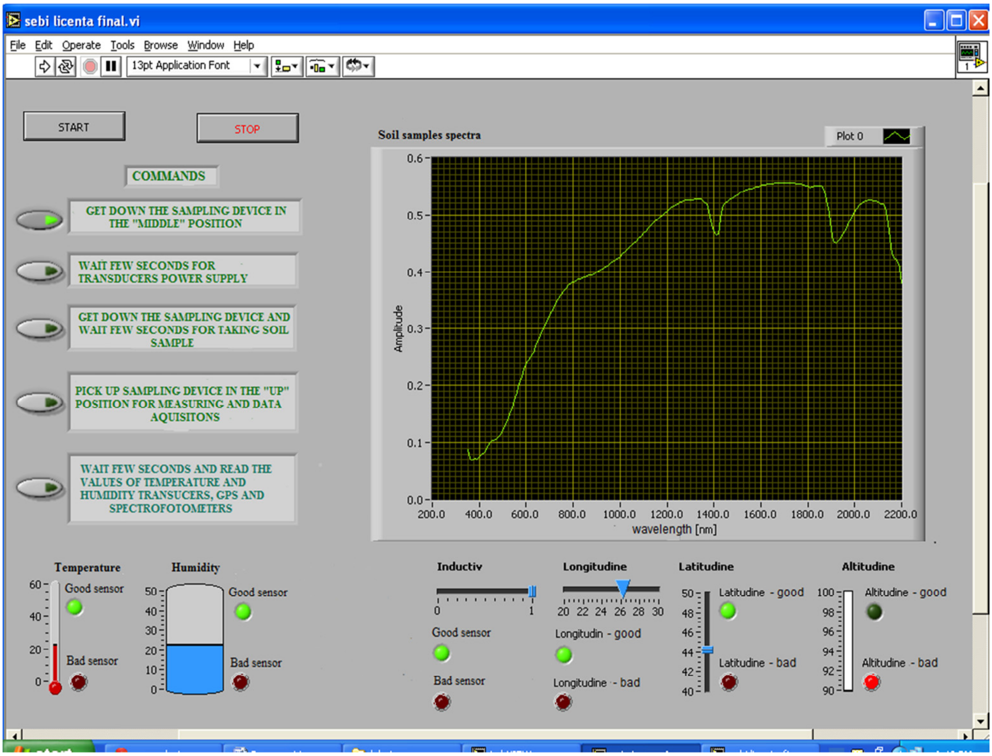

Fig. 5 Front panel for command and control

The designing of the equipment and the user interface are structured and easy to use. On the front panel elements of the monitoring and control system are presented.

The functioning of the scanning equipment is based on process control management synthesized in five main stages of actuating the mechanical, hydraulic, measurement and data acquisition and control system according to the command interface shown in Fig. 5:

1. get down the sampling device in the "middle" position;";
2. wait few seconds for transducers power supply;
3. get down the sampling device in the “low” position and wait few seconds for taking soil sample;
4. pick up sampling device in the "up" position for measuring (start data acquisition from transducers);
5. wait few seconds and read the measured values of temperature and humidity transducer, GPS and spectrophotometers.

To simulate the operation of the transducers files with the possible values of each transducer were used. For GPS system a file with geospatial coordinates (latitude, longitude and altitude properly for Romania) was used. For the operation of the inductive transducer a file with values of 0 and 1 corresponding to its position regarding to guidance plate was used.

We simulated the functioning of the transducer by reading values from files. The values were validated and displayed on the front panel. The functioning of the spectrophotometer was simulated using existing soil data in international databases. Also, running commands are displayed using green indicators. At the end of the process, all the data is stored in a file that will be processed offline in the laboratory.

Using the data acquired in real time, three-dimensional contour maps (or maps on color levels) can be achieved for each of the determined properties in different GIS systems or by graphic representation [5]. Their interpretation manually or automatically constitutes the decision support, in order to determine the required nutrients and water on the analyzed surfaces.

On the basis of the decisions, the required nutrients or water can be incorporated into the soil using appropriate technical equipment. The surfaces that require nutrients or water can be marked with a handheld GPS.

Also, if the user (the farmer) has equipment controlled by GPS, the maps can be inserted in the GPS memory (or in the equipment memory) and the distribution of nutrients can be made in semi-automatic or automatic mode.

CONCLUSIONS

Creating equipment for scanning the soil properties requires complex structure that includes mechanical, electronic and information technology components.

The equipment performs scanning of soil properties in real-time, in order to provide the decision support regarding the development and maintenance of agricultural crops on various agricultural areas of the farmers, administrators or their users.

Due to the relatively new field and the evolution of technologies, especially in electronics, optoelectronics, global positioning systems (GPS), computers and advanced sensors there are multiple possibilities for development and innovation for such system.

Romania has a high agricultural potential due to the size of the surfaces and the soil quality. The development of such equipment and sensors is an opportunity, not only for Romania but also globally. Integration of specialized electronic components contributes to the implementation in many farms, including small and medium ones by ensuring profitability, due to decrease of the cost of the system.

The need for food and farming across the globe (recently, including in arid, polar and even urban areas) further expands the market for such systems.

The possibility offered to farmers to know the quality of their land (soil) with resolutions of a few meters or tens of meters is an essential element in addressing sustainable agriculture that rationally uses the resources and achieves an environmental protection concomitantly.

A potential research direction consists in realization of dedicated circuits for the command and control system.

Based on data acquired in real time three-dimensional maps can be achieved for the measured soil properties. Their interpretation constitutes the decision support, for required nutrients and water on the analyzed surfaces and these can be incorporated into the soil using adequate technical equipment.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE RELATIONSHIP BETWEEN APPARENT SOIL ELECTRICAL CONDUCTIVITY AND PARTICLE SIZE DISTRIBUTION OF LIGHT-TEXTURED SOILS

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SUMMARY

Measurement of apparent soil electrical conductivity (ECa) is considered to be one of the most promising and widely used methods of research in precision agriculture. Several authors have shown strong correlations between ECa and the clay content in soil. In case of heavier soils high in clay content, ECa sensors are mainly used to set soil sampling locations. The relationship between soil ECa and particle-size distribution of light-textured soils was poorly investigated. The aim of this study was to determine the soil texture impact on ECa in light-textured soils. The ECa has been investigated at two soil layers: shallow (0-30 cm measurement depth) and deep (0-90 cm measurement depth). Firstly, research was undertaken to validate optimal technological parameters of the unit Veris 3150 MSP, that have been further used to find out relationships between sizes of individual soil particles and ECa. Using the device Mastersizer Hydro 2000MU, investigation of soil particle size distribution has been accomplished showing that increase in clay (< 2 μm) and silt (2-50 μm) contents in soil causes its electrical conductivity to increase. Particles of highly fine silt (50-100 μm) were found to have no effect on ECa. Increasing proportion of even larger particles of silt (> 100 μm) contained in soil results in decreased ECa.

Key words: soil texture, technological parameters, soil particle size, depth

INTRODUCTION

Soil suitability for crop cultivation is usually assessed based on agrochemical soil properties: soil type, soil texture, soil physical properties (structure, density, porosity, etc.) as well as other features (soil nutrients, humus content and soil response) (Liaghat and Balasundram, 2010).

Precision agriculture based on the physical and chemical properties of soil requires dense sampling to determine the spatial variability of these properties. This dense sampling is often expensive and time-consuming. A decreased density of sampling can lead to errors in estimating the spatial variability of soil nutrients and, consequently, errors in recommendation (Valente et al., 2012). The using of technique to reduce sample numbers involves defining management zones based on information collected in the field. One of the most promising and widely used research methods in precision agriculture is measurement of apparent soil electrical conductivity (*ECa*), i.e. a measurement of how much electrical current soil can conduct. The *ECa* has become one of the most common tools for characterizing the spatial variability of a field because it is reliable and easy to measure (Corwin and Lesch, 2005). In agricultural practice soil *ECa* sensors are used to devise management zones, set soil sampling locations, create variable rate seeding prescriptions, better manage nitrogen applications, and improve irrigation prescriptions (Lesch, 2005). Soil *ECa* enables to identify soil physic-chemical properties determining patterns of agricultural crop yield (Naderi-Boldaji et al., 2014). The earliest applications of *ECa* measurements in agriculture, primarily conducted by Rhoades et al. in the 1970s at the USDA-ARS Salinity Laboratory, were for the measurement of soil salinity (Corwin and Plant, 2005). Besides salinity, soil *ECa* is also influenced by soil texture (contained amount of clay particles), moisture content, density, organic matter content (humus) and temperature (Zhoua et al., 2012). Consequently, processing of research results is subject to the following findings: if *ECa* > 100 mS m^{-1}, then *ECa* measurement is prevailed by the salinity; and if *ECa* < 100 mS m^{-1}, then *ECa* measurement is prevailed by soil clay content, water content, organic matter content and density (Corwin et al., 2003).

Friedman (2005) divides the factors affecting *ECa* to three main categories. The first category describes the bulk soil and defines the respective volumetric fractions occupied by the three phases and possible secondary structural configurations (aggregation): porosity, moisture content and structure. Factors in the second and third categories are the important solid particle quantifiers (particle shape and orientation, particle-size distribution, cation exchange capacity) and soil solution attributes, respectively.

Naderi-Boldaji et al. (2014) studies have been conducted to examine whether *ECa* within the 0–30 cm depth could be helpful in detecting the topsoil strength. The results showed that *ECa* was strongly affected by soil moisture content and texture. The above mentioned studies were performed in predominantly clay loam soils. Several authors (Rhoades et al., 1999; Lesch, 2005) have shown strong correlations between *ECa* and clay content, whereas others (Valente et al., 2012) indicate that the correlation between *ECa* and clay content was either low or absent. The observed low correlation coefficient may be due to the low coefficient of variation of the clay content (Eberhardt et al., 2008) or low clay content in light-textured soils. The relationship between soil *ECa* and particle-size distribution of the light-textured soils was poorly investigated.

The aim of this study was to determine the soil texture impact on *ECa* in light-textured soils.

MATERIAL AND METHODS

Studies to examine soil penetration resistance, porosity, *ECa* and soil texture have been conducted in 2013–2014 in a field located in Šilalė District, Lithuania with total area of 6.65 ha, and coordinates as follows: 55.500743, 21.911763 (WGS); difference in heights in the field – 5.8 m.

In a course of research soil penetration resistance was measured using a digital soil meter Penetrologger (Eijkelkamp, Netherlands).

To determine soil porosity, the samples were dried until air-dry mass was obtained which then placed in the vacuum air pycnometer 08.60 (Eijkelkamp, Netherlands) and soil solids density was found.

Total soil porosity P_b (%) was calculated from the following equation (Maikštėnienė et al., 2008):

$$P_b = \left(1 - \frac{\rho_d}{\rho_{sf}}\right) \times 100 \tag{1}$$

where ρ_d – soil density, g cm^{-3}; ρ_{sf} – density of soil solids, g cm^{-3}.

Determination of *ECa*

Soil *ECa* of the selected field was measured at depths of 0–30 cm and 0–90 cm. For this purpose the mobile measurement unit *Veris* 3150 MSP (Veris Technogies Ltd., USA) was used aggregated with the tractor New Holland T7060. Mainly perennial grasses were growing in the field under investigation (grassland).

With the aim to conduct comparative analysis of *ECa*, under identical conditions, in ploughed and non-ploughed fields, the grassland was ploughed in 2.5 m strips over entire length of the field at each 20 meters.

Soil *ECa* has been measured indirectly, i.e., soil resistivity ρ ($\Omega \cdot$m) has measured which was then calculated into the electrical conductivity (mS m^{-1}).

The mobile unit *Veris* 3150 MSP was equipped with the GPS navigation system. Soil characteristic maps were created by using the software *SMS Advanced* (AgLeader Ltd., USA). *In situ* measurements were compared to laboratory analysis of 58 samples. Digital data of electric conductivity were grouped into value areas that were marked in respective colours. Value interval was dependent on the number of selected zones.

The influence of travel speed on the qualitative indicators (precision of mapping, sizes of individual areas in *ECa* map) of *Veris* 3150 MSP was examined while trailing it by the tractor over unploughed grassland, and afterwards – over ploughed strips. Travel speed was varied at intervals of 3 km h^{-1} (from 3 to 12 km h^{-1}).

Soil bulk density and moisture content

To find out the influence of soil physical properties (bulk density and porosity) on the qualitative indicators of *Veris* 3150 MSP, measurements at each stripe (in the beginning, at the end and in the middle) were taken at different speeds.

Soil bulk density and moisture content were found by means of weighing, while collecting samples with the portable soil sampling device (Eijkelkamp, Netherlands) at 0–10 cm depth.

The soil moisture content was determined by the dry residue after full evaporation of water from soil. The weight of samples was determined using scales Scalter SPO 51, and the samples were placed in a drying chamber. The samples were being dried at 105°C until stabilization of the weight of the sample rings with soil. The weight of the sample rings with dry soil was determined, and the amount of evaporated water was calculated.

Determination of soil texture

Soil texture is determined by the amount of mechanical components per mass unit of a dry soil. Using soil texture triangle method, soil texture is determined by the relative proportions of mechanical fractions of sand (2.0–0.05 mm), silt (0.05–0.002 mm) and clay (< 0.002 mm) (Dourado et al., 2012).

Soil texture analysis has been carried out at the Agro-Biology Laboratory of the Institute of Agroecosystems and Soil Sciences of Aleksandras Stulginskis University, Lithuania. The distribution of particles in fractions was measured by an integrated system Mastersizer Hydro 2000MU (Malvern Instruments Ltd, Malvern, UK). For the purpose of analysis soil samples have been prepared in accordance with the methodology provided by the manufacturer of the device. Samples collected in accordance with pre-defined sampling map have been dried first and milled in a blender to silt and sieved through a 2 mm sieve. Part of the obtained sample has been placed into the analysis tank of the device, filled with distilled water. The obtained analysis findings have been processed using the software Mastersizer Hydro 2000MU intended to determine soil sample texture – percentages of mechanical components. Using soil texture triangle method, a sample has been classified into one of the soil classes.

The obtained findings of soil texture analysis have been processed using the software *SMS Advanced* and, in result, maps of distribution of soil mechanical fractions (silt, clay particles, sand) in the field under consideration have been developed.

Statistical analysis

Each trial has been repeated for five times. Investigation findings were assessed using methods of dispersion and correlation-regression analysis (Olsson et al., 2000). Mean values, their standard deviations and confidence intervals under the 0.95 probability level were found.

RESULTS AND DISCUSSION

The *ECa* is defined as the soil capacity for conducting electric current which influenced by various factors such as soil physical and chemical properties including soil penetration resistance and soil porosity (Corwin and Lesch, 2005).

Soil penetration resistance on the top of non-ploughed field was found to amount for 1 MPa. At the depth of up to 10 cm soil penetration resistance has been observed to increase gradually to 3.5 MPa, whereas in even deeper layers remained almost constant (Fig. 1).

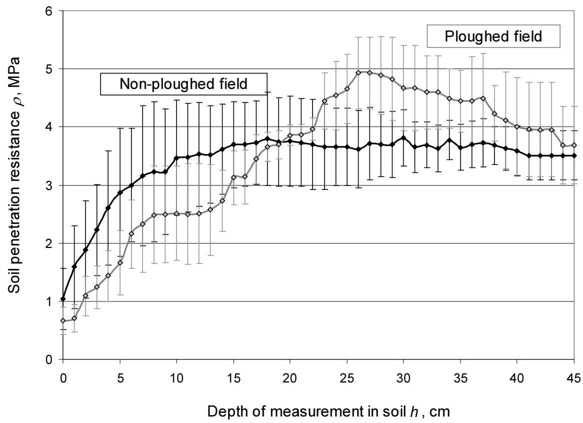

Fig. 1. Variation in soil penetration resistance of non-ploughed (grassland) and ploughed field

Ploughing the grassland caused soil top penetration resistance to decrease to 0.8 MPa, and at the depth of 1 to 14 cm, soil penetration resistance was by approximately 1 MPa lower when compared to that of the non-ploughed field. In depth ranging from 16 to 22 cm both ploughed and non-ploughed soil showed almost the same penetration resistance. However, in ploughed strips of the field under consideration, at the depth of over 22 cm, a significant increase in soil penetration resistance has been observed determined by the plow sole formed by the plough. Generally, the highest soil compaction using different soil tillage treatments is recorded in the deepest soil layer (20–30 cm), mainly with highly significant differences between ploughed and non-ploughed tillage treatments. Similar experiences have been noticed and described by Šarauskis et al. (2008): soil penetration resistance in tilled soil in the depth up to 20 cm was approximately 3–4 times less than in minimal soil tillage or no-tillage soils.

Ploughed soil has more total porosity and greater air permeability. Investigation of soil porosity in strips of ploughed and non-ploughed field showed that ploughing the perennial grassland caused total soil porosity (volume of pores filled with air or water) to increase by 3 percentage points, whereas air-filled porosity (volume of pores filled only with air) – by 8.9 percentage points. Total porosity of the grassland soil amounted for 48.3 ± 1.7%, of the ploughed field – 51.3 ± 3.0%, whereas air-filled porosity amounted for 27.1 ± 2.4% and 36.0 ± 2.9%, respectively. These research findings have been proved by other researches as well who undertook investigation of the influence of soil tillage on soil porosity (Buragienė, 2013).

Comparative investigation of *ECa* in ploughed and non-ploughed strips of 6.65 ha field showed that *ECa* of both shallow layer *EC SH* (0–30 cm), and deep layer *EC DP* (0–90 cm) was not the same over the length of field strips. *ECa* of deep layer was found to be higher that of the shallow layer and was found to be higher in non-ploughed field than in a ploughed one due to better contact with the soil under investigation. In non-ploughed field, *EC DP* amounted for 23.96 ± 1.27 mS m^{-1}, whereas in a ploughed field – *EC DP* – 20.47 ± 1.23 mS m^{-1}, respectively, in non-ploughed field *EC SH* = 6.96 ± 0.34 mS m^{-1}, whereas in a ploughed field – *EC SH* = 3.82 ± 0.18 mS m^{-1}.

Finding interrelation of electrical conductivity of soil shallow *EC SH* and deep *EC DP* layers in ploughed and non-ploughed fields enabled to obtained linear relations. Stronger correlation (R^2 = 0.89) was obtained through investigation of *ECa* in lower porosity soil, which was also harder than ploughed one (R^2 = 0.49). This proves the hypothesis that mobile unit for measurement of *ECa* delivers more precise results when better contact is ensured between its disc electrodes and the soil.

The effect of travel speed on *ECa*

The number of measurements taken in total length of the field strip, distance between adjacent measurements and productivity of the measurement unit influenced by increasing of travel speed of the measurement unit *Veris* 3150 MSP in steps of 3 km h^{-1}. Using *Veris* 3150 MSP, *ECa* has been recorded each 3 s In this case, when travelling at the speed of 3 km h^{-1}, distance between measurements amounted for 2.79 ± 0.38 m, whereas at the speed of 12 km h^{-1} – 7.57 ± 1.58 m. Productivity of measurement unit increase respectively: 6.5 ± 0.5 ha h^{-1} (working at the speed of 3 km h^{-1}) and 26.5 ± 2.2 ha h^{-1} (working at the speed of 12 km h^{-1}) (Table 1).

Combining measurement data of adjacent passes into corresponding areas and marking them with different colours resulted in maps of *ECa* dependent on the travel speed. All the numerical values of *ECa* have been grouped into 7 zones (from 0.60 to 14.40 mS m^{-1}). Each map showed an area covering a corresponding range of electrical conductivity.

Table 1. The effect of *Veris* MSP travel speed on technological parameters of operation

Indicator	Strip length L, m	Travel speed v, km h^{-1} (m s^{-1})			
		3 (0.83)	6 (1.67)	9 (2.50)	12 (3.33)
Number of measurements	338	125	65	48	41
	300	111	57	45	43
	270	91	52	38	36
Average distance between measurements, m		2.79 ± 0.38	5.22 ± 0.10	6.94 ± 0.59	7.57 ± 1.58
Productivity, ha h^{-1}		6.5 ± 0.5	12.8 ± 0.8	20.0 ± 1.5	26.5 ± 2.2

Analysis of maps of *ECa*, obtained while working in non-ploughed field (grassland) revealed that they were not so very different. Maps of electrical conductivity of shallow layer *EC SH*, created under different travel speeds of the measurement unit were very little influenced by the speed.

When increasing travel speed in a ploughed field the distinguished individual zones of *ECa* tended to be larger, however analysis of maps of *ECa* of shallow layer *EC SH* revealed that maps differed only insignificantly when travel speed of measurement unit ranged from 3 to 9 km h^{-1}. However increase in travel speed to 12 km h^{-1} caused part of *ECa* zones not to be distinguished at all.

It can be stated that when travel in a ploughed field, the optimal travel speed should not exceed 9 km h^{-1}, and in non-ploughed field it might be increased to 12 km h^{-1}.

After the relation between electrical conductivity of shallow layer *EC SH* and measured area was found, while working under different travel speeds in ploughed and non-ploughed fields, it was observed that in non-ploughed field higher numerical values of *ECa* were recorded in a larger area. According to findings of the investigation under consideration, in a ploughed field, the area of 10.15–14.40 mS m^{-1} electrical conductivity of shallow layer amounted for 0.14 ha (Fig. 2), whereas in non-ploughed field – 2.04 ha (Fig. 3).

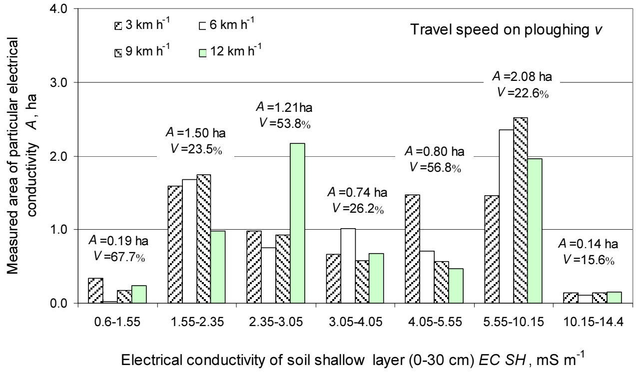

Fig. 2. Relation between the electrical conductivity of soil shallow layer *EC SH* and measured area while working at different speeds in a ploughed field

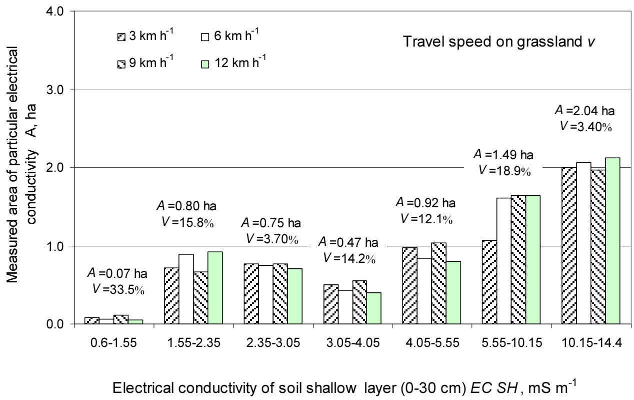

Fig. 3. Relation between the electrical conductivity of soil shallow layer *EC SH* and measured area while working at different speeds in non-ploughed field

The effect of *ECa* on soil texture

Soil texture is a significant determining factor for various processes of pedogenesis and nutrition of plants. Soil texture determines majority of physical and physic-chemical properties of soil (Dourado et al., 2012). For example, porosity, field moisture capacity, water permeability, capacity to raise water from deeper layers to the top, heat and air transfer regime. Soils are considered to be light-textured when their texture is prevailed by coarse fractions of mechanical components. These soils include sands and sandy loams. Soils are considered to be heavy when their texture is prevailed by small fractions, especially the sludge. These soils include heavy loams and clays.

The obtained maps show different *ECa* by distinguishing zones of individual electrical conductivity that reflect different soil texture.

Soil texture investigation showed that the selected ranges of *ECa*, namely 0.6–1.55, 1.55–2.35, 2.35–3.05, 3.05–4.05, 4.05–5.55 mS m^{-1}, were predominated by soil texture characteristic to sands and sandy loams. In the range of *ECa* of 5.55–10.15 mS m^{-1} soil texture was found to change into cohesive sand, the range of *ECa* of 10.15–14.40 mS m^{-1} featured soil texture of silty loam. Considering the obtained research findings, when making maps of *ECa* the number of electrical conductivity zones can be decreased to three. Dividing the map into less number of zones would enable decreasing the number of samples to be taken. Lower number of samples would in turn enable decreasing expenses allocated for soil texture studies.

Soil texture investigation showed that increasing soil content of clay (< 2 μm) (Fig. 4) and silt (2–50 μm) (Fig. 5) causes its *ECa* to increase. According to other researchers (Rhoades et al., 1999) *ECa* correlates with clay particles content in soil. The soil of field under investigation contained very small amounts of clay particles (Fig. 4) as the soil was related to sandy loam. A close relation was found to exist in such a case between soil *ECa* and its silt particles content.

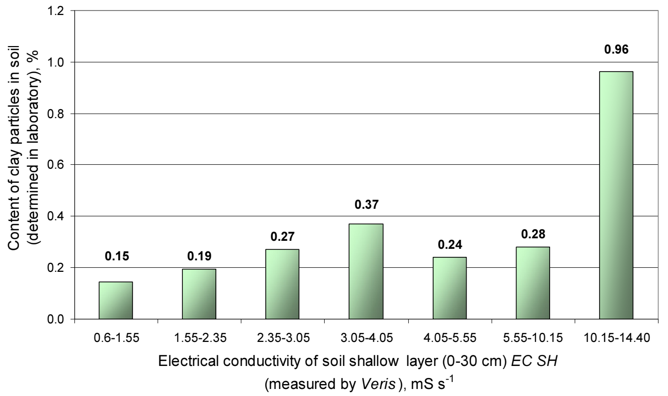

Fig. 4. Interrelation between the electrical conductivity of soil shallow layer *EC SH* and content of clay particles (< 2 μm) in soil

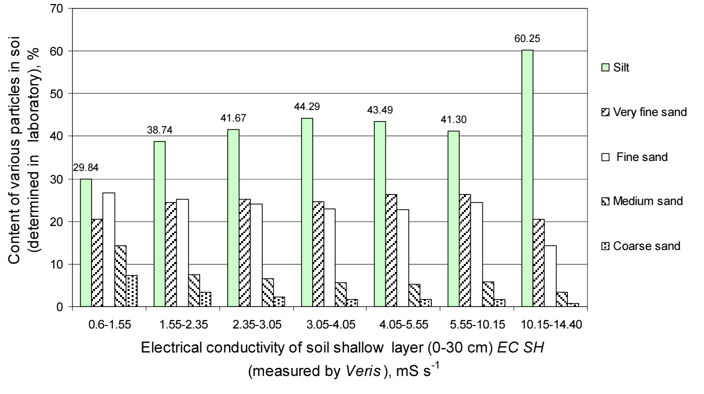

Fig. 5. Interrelation between the electrical conductivity of soil shallow layer *EC SH* and content of various particles in soil

Very fine particles of sand (50–100 µm) had no effect on *ECa*, whereas increase in content of even larger sand particles (> 100 µm) caused its *ECa* to decrease (Fig. 5).

In summary of soil texture investigation, a map of soil mechanical portion was developed – silt map (Fig. 6), divided into 7 groups of dustiness. It reflects well the distribution of zones of *ECa*.

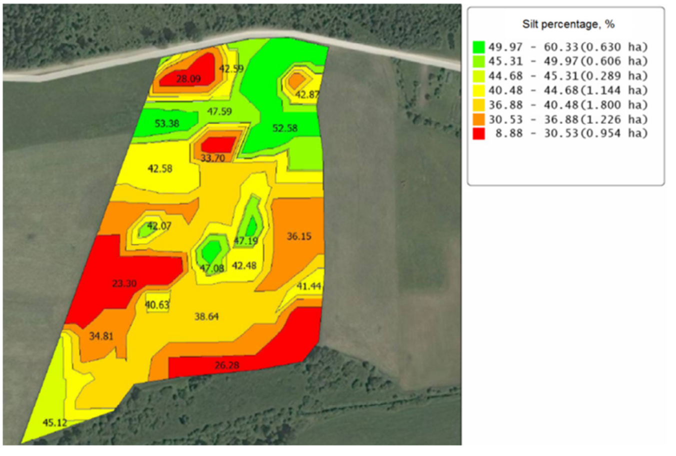

Fig. 6. The map of silt particles contained by soil

Reliability of investigations conducted on the *ECa* is proved by the obtained close linear (R^2 = 0.91) interrelation between the electrical conductivity of soil shallow layer $EC\ SH_{Veris}$ found using the measurement unit *Veris* 3150 MSP and found in a laboratory $EC\ SH_{Lab}$:

$$EC\ SH_{Lab} = 0.55\ EC\ SH_{Veris} + 3.87 \qquad (2)$$

Based on soil texture investigation, the range of 5.55–10.15 was found to be predominated by cohesive sand and the range 10.15–14.40 – by silty loam. Increase in the content of these chemical elements might be attributed to soil texture. Scientific researches show that heavier-textured soils feature lower leaching of chemical elements (McGrath and Fleming, 2007).

CONCLUSIONS

1. Investigation showed that when working in non-ploughed field with *Veris* 3150 MSP, apparent soil electrical conductivity of both shallow layer *EC SH* (0–30 cm) and deep layer *EC DP* (0–90 cm) is higher in non-ploughed field due to better contact with the soil under investigation. In non-ploughed field *EC DP* = 23.96 ± 1.27 mS m^{-1}, whereas in a ploughed field – *EC DP* = 20.47 ± 1.23 mS m^{-1}, an respectively, in non-ploughed field *EC SH* = 6.96 ± 0.34 mS m^{-1}, whereas in a ploughed field – *EC SH* = 3.82 ± 0.18 mS m^{-1}.
2. Soil texture analysis showed that increase in clay (< 2 µm) and silt (2–50 µm) proportion in soil causes its apparent electrical conductivity to increase. Very fine particles of sand (50–100 µm) had no effect on apparent soil electrical conductivity, whereas increase in content

of even larger sand particles (> 100 μm) caused its apparent electrical conductivity to decrease.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.311:631.51
Prethodno priopćenje
Preliminary communication

THE INFLUENCE OF BIOLOGICAL PREPARATIONS ON PHYSICAL SOIL PROPERTIES AND TILLAGE FUEL CONSUMPTION

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ABSTRACT

Different biological preparations became more widely used in agriculture to increase plants productivity, to accelerate plant residues decomposition processes and to improve soil properties. Change of soil properties has influence on tillage machines work process. The objective of this work was to establish the influence of different biological preparations on soil cone index, moisture content, total porosity and tractor fuel consumption for a specific tillage operation and to compare with control tests, when biological preparations are not used. The research was carried out in 2015–2016 in Experimental Station of Aleksandras Stulginskis University in Lithuania. The effect of three different biological preparations on soil properties and fuel consumption for deep ploughing and disc harrowing was investigated. The experimental results indicate that biological preparations influence soil cone index, total porosity and fuel consumption for soil tillage. It was estimated that for disc harrowing and ploughing of soil treated with biological preparations consumption of the fuel was up to 10–30% lower than in control soil, where biological preparations were not used.

Key words: soil tillage, biological preparation, fuel consumption, soil physical properties

INTRODUCTION

Soil is one of the most important parts of the ecosystem. Lots of different biological processes constantly are affecting the characteristics of the soil. Selection of tillage technology depends on soil properties. Currently, in Eastern Europe, and in the Baltic Countries the most common cultivation system is conventional tillage using mouldboard plough. However, it is energy intensive and expensive tillage technology requiring lots of work time (Filipovic et al., 2006; Šarauskis et al., 2012; Šarauskis et al., 2014). New solutions usually suggest minimizing number of the same technological operations and/or drives, but this does not solve the problem. Any tillage technology operation even minimized, however, remains energy consuming and very expensive (Koga et al., 2003; Šarauskis et al., 2012; Akbarnia and Farhani, 2014). Recently, use of the biological preparations is widespread in the agricultural technologies. It is noted that besides that the biological preparations improve the conditions for the development of the plants, after spraying with the biological preparations it is easier to cultivate the soil as well. Biological preparations promote decomposition of crop residues and weaken their mechanical breaking and cutting properties, which are important for the soil cultivation and sowing. Experimental studies have shown that using a biological preparation, almost in all cases, to brake and to cut rape and wheat stems is necessary significantly less forces to compare with without the use of a biological product (Vaitauskiene et. al., 2015). Longer period of crop residues maintenance on the soil surface decline requirement for the wheat and oilseed rape residues breaking and cutting force (Šarauskis et. al., 2015).

In Lithuania are used different types of biological preparations, such as ‘Amalgerol’, ‘Azofix’, ‘NitroTeam’, etc. ‘Amalgerol’ consists of essential plant oils, extracts of various herbs, mineral oils, etc. It is a liquid biological preparation functioning as a biological activator stimulation soil microorganisms and plant physiological functions. The rate of this biological preparation is 4.0 L ha^{-1}. The composition of biological preparation ‘Azofix’ includes nitrogen-fixing stem bacteria *Azotobacter vinelandii* and other biologically active components. The nitrogen-fixing bacteria accumulate nitrogen from the air. Part of the nitrogen is used for maintenance and growth of the bacteria, part of the nitrogen is included the soil in an easily available form for plants, and part of the accumulated nitrogen is used by other microorganisms in the decomposition of crop residues. The main purpose of this biological preparation is to compensate the shortage of mineral nitrogen in the soil and to convert nitrogen into forms readily accessible for plants without any influence on the accumulation of nitrate-nitrogen (Vaitauskienė et al., 2015). The usage rate of this biological preparation is 1.0 L ha^{-1}. Biological preparation ‘NitroTeam’ is used for improving soil chemical composition, increasing the quantity of soil nutrients, and promoting plant growth. It contains bacteria *Azotobacter chroococcum*, *Azospirillum brasilense* fixing and accumulating in the soil from 30 up to 90 kg ha^{-1} of nitrogen during the vegetation season. The use rate of this biological preparation is 1.0 L ha^{-1}.

The aim of this work is to determine the influence of three biological preparations on physical soil properties such as soil cone index and total porosity, and fuel consumption of disc harrowing and deep ploughing.

MATERIALS AND METHODS

Experimental researches were carried out in 2015–2016 at fields of Experimental Station of Aleksandras Stulginskis University. Experimental Station is in the Southwestern side of Kaunas city. Relief – little wavy, plain. The soil according to the WRB 2014 – Calc(ar)i-

Epihypogleyic Luvisol (Drainic). Research field was divided into four equal fields with a length and width of 200 m x 12 m in which winter wheat (variety 'Ada') was grown. Every year at the end of April winter wheat fields were sprayed with three types of biological preparations using sprayer Amazone UF 901 (tank capacity 1050 L, spraying boom width 12 m, pump capacity 115 L min^{-1}, weight of empty sprayer 660 kg, sprayer length 1.55 m, transport width 2.65 m, sprayer height 2.46 m).

The first field (the Control) was sprayed only with water (200 L ha^{-1}), in order to maintain the similar conditions of soil moisture. The second field was sprayed with biological preparation *Amalgerol* (4.0 L ha^{-1}) (I-AM), the third field – biological preparation *Azofix* (1.0 L ha^{-1}), (II-AZ), the fourth field – biological preparation *Nitro Team* (1.0 L ha^{-1}) (III-NiT). All biological preparations were mixed with water (200 L ha^{-1}). Every field was subdivided into four smaller fields (50 m x 12 m) for repeated tests of soil physical properties and fuel consumption.

Different soil properties were investigated. Soil hardness (soil cone index, CI) was measured up to 46 cm deep eight times throughout the research period (in 2015 – May 12, June 26, July 16, August 7, to 2016 – May 24, June 20, July 20, August 8) with Eijkelkamp electronic penetrometer Penetrologger. Soil samples from each field 0–10 cm depth were taken in early August and dried until the stabile weight for determination of soil density, moisture and porosity. The density of the soil solid phase was determined with vacuum air pycnometer. Total soil porosity was calculated according to the literature (Maiksteniene et al., 2008).

After the harvest of winter wheat every field was cultivated with disc harrow (working width 4 m and depth 10–12 cm, speed 12 km h^{-1}) and was ploughed with four furrow mouldboard plough (working depth 18–20 cm, speed 6.5 km h^{-1}, width – 1.2 m). Tractor ZETOR 10540 (engine – intercooled turbocharged diesel, 4-cylinder) was used for performance of soil tillage technological operations. Before carrying out experimental researches main indicators of the tractor have been inspected by complete testing according to standard method (OECD Standard Codes for the Official Testing of Agricultural and Forestry Tractors – 2015). During researches work indicators of the tractor (operating speed, hourly fuel consumption and the time of recording) were recorded regularly every five seconds. Fuel flow meter 'VZO 4OEM' was fitted in the tractor. It measured hourly fuel consumption. Data were transferred from data registrar – logger 'SKRT–21 Lite', to the PC using the software 'SKRT–Manager'.

Data obtained from the experimental researches were processed by ANOVA, evaluating the least significant difference $LSD_{0.05}$ at 95% probability level using software SYSTAT 12.

RESULTS AND DISCUSSION

Penetrometer data are typically reported as the resistance to soil penetration in terms of penetration force per unit area. Soil penetration resistance has been described as the cone index (CI), expressed in pressure units of megapascals. The soil cone index in different treatments was evaluated every year four times per vegetation period. Results obtained in 2015 are provided in the Fig 1.

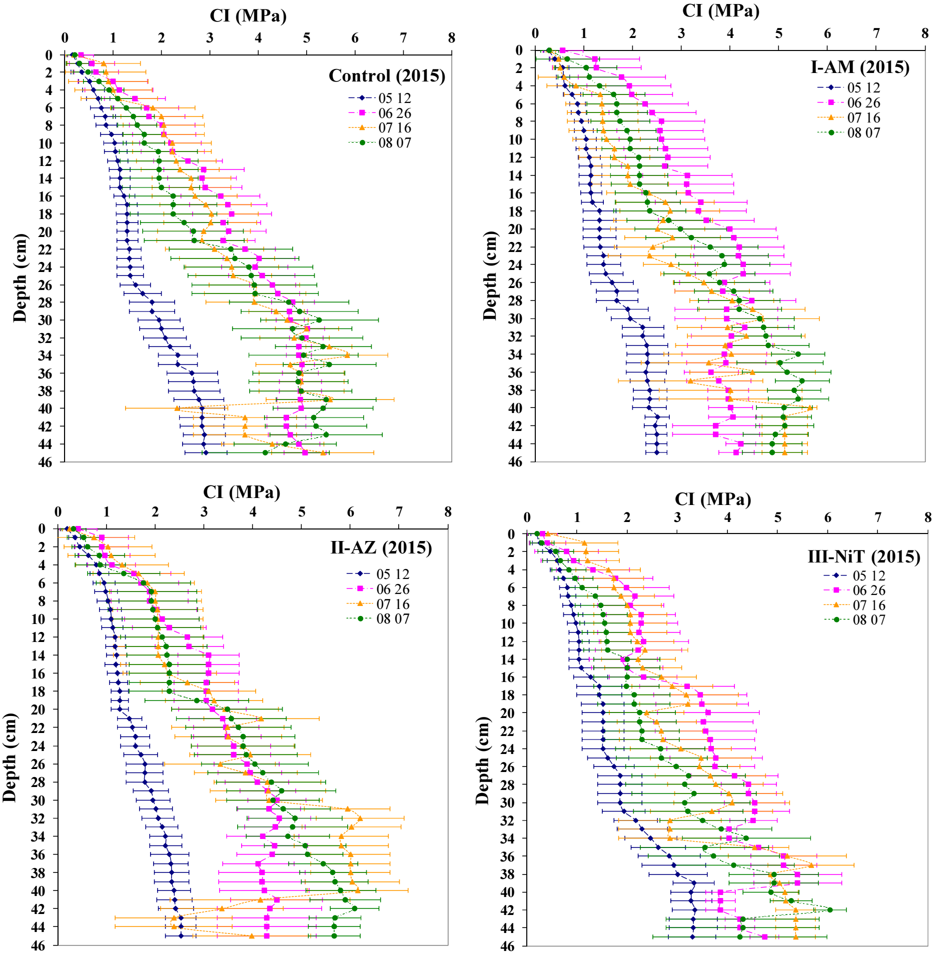

Fig.1. Dynamic of soil cone index (CI) during vegetation in 2015

The soil cone index very strongly depended on the soil moisture. The minimum CI within investigated depth range was recorded in May when the soil moisture of all treatments within layer 0–10 cm was 18.0%. The dynamics of soil strength show that in later months, when the moisture content of the soil was 13–16%, the soil cone index increased. Analogous soil cone index and moisture correlation results were obtained in 2016 (Fig. 2). The moisture content of the soil during the vegetation period increased. In 24th May moisture content was 14%, in 20th June and 20th July it was 17.5%, in 8th August – 19.5 %. The studies showed that, after the harvest, the soil cone index up to of 20 cm depth in soils sprayed with biological preparations (in particular, I-AM and II-AZ) was lower than in the Control.

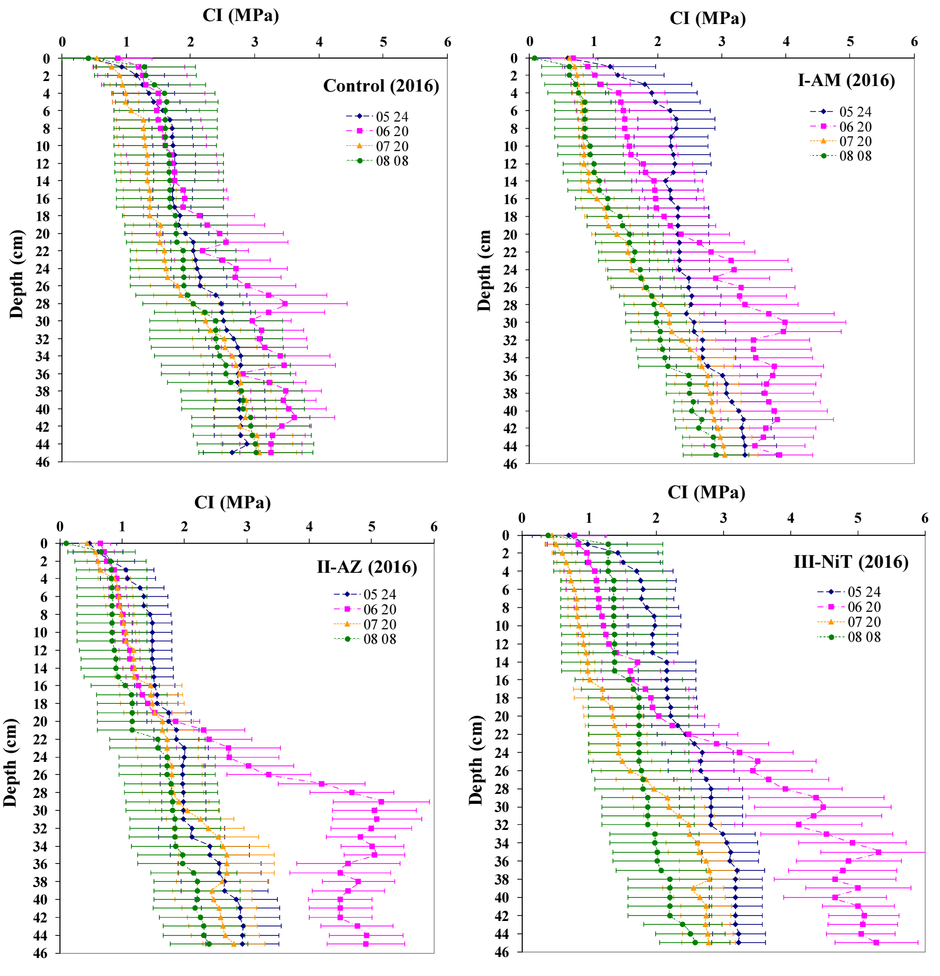

Fig.2. Dynamic of soil cone index (CI) during vegetation in 2016

Another very important soil physical feature is soil porosity. The total porosity of the soil is considered to be optimal when it is greater than 50%. The total porosity of soil was established every year after the winter wheat harvest, before the soil cultivation. The research results (Fig. 3) show that the total porosity of the soil increased using II-AZ and III-NiT biological preparations comparing to Control variant. Biological preparation I-AM had no significant effect on soil porosity.

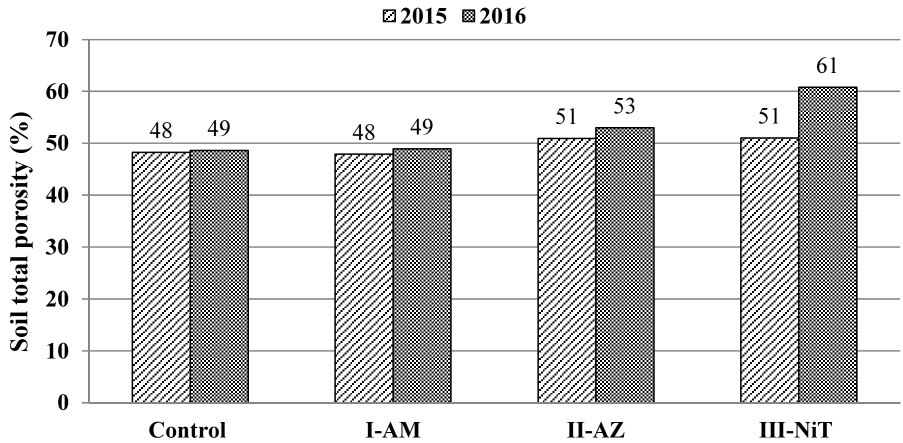

Fig. 3. Total soil porosity using different biological preparations in 2015–2016, LSD_{05}(2015) =2.27; LSD_{05}(2016) =3.65

Fuel consumption of cultivation technological operations, is an important energy indicator for assessing inputs of agricultural production. After consecutive use of biological preparations for two years and evaluation of their impact on the fuel consumption for disc harrowing, it was found that in all treatments the fuel consumption was lower than in the Control, where biological preparations were not applied (Fig. 4). The lowest fuel consumption obtained in variant II-AZ.

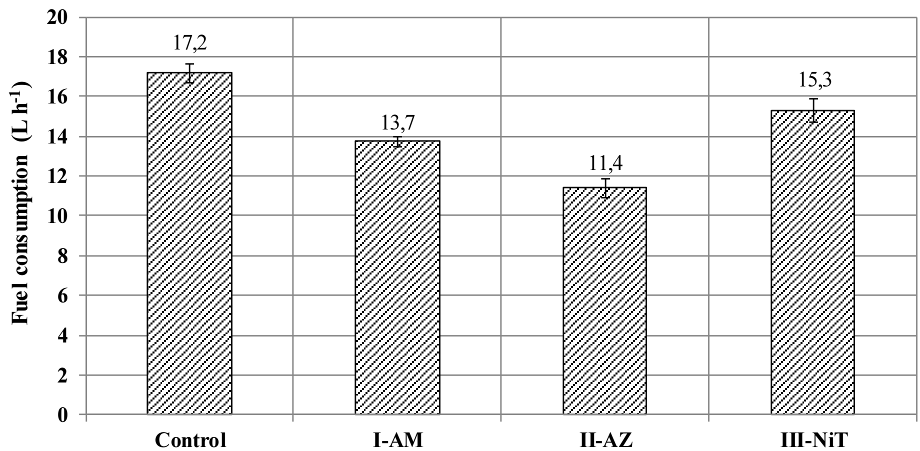

Fig. 4. Fuel consumption for disc harrowing in soils sprayed with different biological preparations, at operational speed 12 km h^{-1}, 2016, LSD_{05} =1.17

Fuel consumption for disc harrowing was investigated by other authors (Moitzi et al., 2014). They found that when working with disc harrow, which working width 3.0 m, at speed of 8.2 km h^{-1}, and working depth of 10 cm, the fuel consumption was 17.7 L h^{-1}. This corresponds to the results of our research in the control.

Ploughing, in comparison with disc harrowing, is even more complex and energy consuming technological operation of cultivation, allowing a better comparison of different factors affects to fuel consumption. After experiments of ploughing, it was found that the biological preparations II-AZ and III-NiT had a significant effect on the reduction of the fuel consumption in comparison with the control (Fig. 5). Fuel consumption for ploughing using the I-AM biological preparation was at similar level as in control, it had no significant effect. Moitzi et al. (2014) carried out the experiments with four furrow reversible mouldboard plough when the working depth 20 cm, speed 7.0 km h^{-1}, and estimated similar fuel consumption level (15.85 L h^{-1}), as in our control, and I-AM treatments.

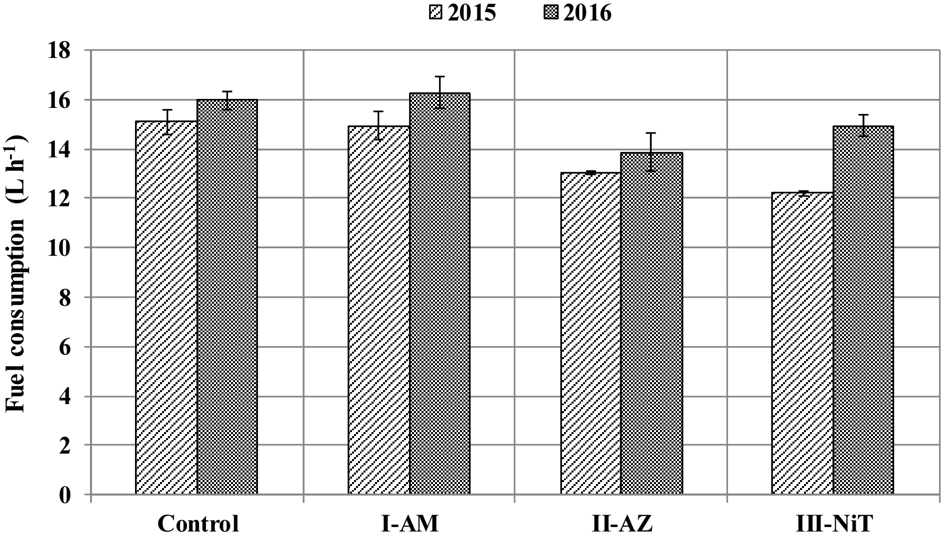

Fig. 5. Fuel consumption for ploughing in soils sprayed with different biological preparations, at operational speed 6.5 km h^{-1}, 2015–2016, LSD_{05}(A)=0.19; LSD_{05}(B)=0.76; LSD_{05}(AB)=2.14

To sum up results of the experimental researches, it can be stated that use of different types of biological preparations affects soil physical properties therefore influences fuel consumption level. The fuel consumption for ploughing depended on the total soil porosity. In treatments where the soil total porosity was higher fuel consumption was significantly lower comparing to other treatments. According to the results of the experiments carried out by other authors, it can be assumed that the biological preparations containing bacteria and biologically active substances intensify crop residues degradation process in the soil (Jakienė, 2011; Kriaučiūnienė et al., 2012). Furthermore, it changes physical characteristics of the soil, which affects fuel consumption of tillage machinery.

CONCLUSIONS

1. Biological preparations have an influence on the following soil physical properties: soil cone index and total porosity. The soil cone index at 20 cm depth after the use of the biological preparations for two consecutive years in all treatments was lower (1.16–1.74 MPa) than in the control soil (1.78 MPa), where biological preparations were not used.
2. After the evaluation of the impact of biological preparations on soil total porosity, it was found that after the first year of biological preparations II-AZ and III-NiT usage the total soil porosity increased by 3%, and after the second year – from 4% to 12%, to compare with control soil.
3. The results of experimental research showed that all three investigated biological preparations lowered fuel consumption for disc harrowing by 1.9 L h^{-1} (III-NiT) and by 3.6 L h^{-1} (II-AZ) compared to the control.
4. The lowest fuel consumption for ploughing was in soil where biological preparations II-AZ and III-NiT where applied for two consecutive years. In the first year, the fuel consumption was from 1.3 to 1.8 L h^{-1}, and in the second from 1.1 to 1.3 L h^{-1} lower than in control. These results are closely correlated with the results of total soil porosity.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

THE INFLUENCE OF BIOLOGICAL PREPARATIONS AND ORGANIC FERTILISER ON SOIL TEMPERATURE, ELECTRICAL CONDUCTIVITY AND CO_2

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SUMMARY

The model field experiments carried out in Experimental Station of Aleksandras Stulginskis University in 2015–2016. Researches aim to identify and assess the impact of biological preparations and organic fertiliser (slurry) on soil properties (temperature and electrical conductivity) and CO_2 emissions after different periods of time: 1) after measures application (beginning of experiment); 2) after 2 months (in autumn); 3) after 7 months (in spring). It was estimated that at the beginning of the model field experiment biological preparations and organic fertiliser application had no significant effect on soil temperature and CO_2 emissions in autumn at the beginning of the experiment and after 2 months of measures application. In spring, after 7 months of measures application soil temperature was significantly higher in treatment where organic fertiliser with biological preparation (SBio2) was used to compare with control and soil treated with biological preparation (Bio1). Soil electrical conductivity at the beginning of the model field experiment after measures application was significantly lower, but CO_2 emissions was significantly higher in the treatments were organic fertiliser was applied with (SBio2) and without biological preparation (S) to compare with control and soil treated with biological preparation (Bio1). In spring, after 7 months of measures application soil electric conductivity was significantly higher in treatment where organic fertiliser with biological preparation (SBio2) was used to compare with other treatments. CO_2 emissions were higher in treatments where biological preparations were used to compare with control and slurry (S). Evaluating all experimental period was estimated correlation between the CO_2 emissions rate and temperature after 2 (r=0.45) and 7 (r=0.66) months of measures application.

Key words: soil temperature, soil electrical conductivity, CO_2 emission, biological preparations, slurry.

INTRODUCTION

Recently biological preparations of different origin are used more widely in agriculture with the aim to have a direct and/or indirect impact on the yield amount and quality (Pekarskas, 2008; Jakienė, 2011; Pusenkova et al., 2016; Velička et al., 2016). It is used to increase crop residue decomposition rate, to improve moisture retention capacity and nutrients balance in soil (Vaitauskiene et al., 2015; Šarauskis et al., 2015). Biological preparations also improve agroecosystems stability and persistence to abiotic environmental factors and stress (Brussaard et al., 2007). Sole biological preparations or in mixtures with organic fertilisers (slurry) affects not only plants, but also soil properties, and entire environment (Henning, 1997). Currently still there is the lack of the results, showing how biological preparations change the electrical conductivity of the soil, the soil temperature and the CO_2 emissions from the soil.

The electrical conductivity is one of the soil properties, which are associated with the nature of soil composition (particle size and distribution), structure (porosity, pore size and distribution), water content, and temperature (Bai et al., 2013). The electrical conductivity of the soil is also one of the widely used research methods in precision farming (Corwin and Lesch, 2003). This method is quick, easy, but an important tool to determine the physical and chemical properties of the soil, which are influencing agricultural and energy crops yield and its alteration regularities. The first soil electrical conductivity researches are related to the problems of soil salinity. Electrical conductivity of the soil is affected by physical and chemical factors, soluble salts, clay particles and the water content of the soil, density, organic matter content, soil temperature, etc. (Friedman, 2005; Bai et al., 2013).

Soil is one of the important sources of greenhouse gases, in particular CO_2. These effects arise because soil respiration intensities differ based on different soil properties, the types of plant residue, the depth of plant residue incorporation, the amount of nutrients in the soil, the tillage intensity, climatic conditions and other factors, such as soil texture, soil physical-mechanical properties, the soil organic C content, fertilisation and crop rotation (Sainju et al., 2008; Carbonell-Bojollo et al., 2011; Mangalassery et al., 2013, Buragiene et al., 2015). No less important are the air and soil temperature fluctuations, which affect the intensity of soil microorganisms activity and at the same time determines the intensity of the global warming causing CO_2 emissions into the atmosphere (Davison and Janssens, 2006; Buragiene et al., 2015). Experimental results obtained by Buragiene et al. (2015) indicate that tillage processes influences soil temperature. However there is the lack of knowledge of the effects on soil temperature and CO_2 emissions applying biological preparations and/or their mixtures with organic fertilizers.

The aim of this work is to determine the influence of biological preparations and organic fertiliser on soil temperature, electrical conductivity and CO_2 emission from soil.

METHODS

Model field experiments. Experiments were performed in 2015–2016 at the Experimental Station of Aleksandras Stulginskis University (54°53' N, 23°50' E) in Kaunas region, Lithuania. This study investigated the influence of biological preparations and organic fertiliser (slurry) on soil properties and CO_2 emissions from soil. The soil at the experimental site was classified as Calc(ar)i-Endohypogleyic Luvisol (Drainic), according to the WRB 2014. The soil agrochemical properties at the beginning of the experiment were as follows: pH 7.04, humus 2.96%, total N 1.56 g kg^{-1}, and mobile nutrients P_2O_5 236.8 mg kg^{-1} and K_2O 359.5 mg kg^{-1}. Slurry agrochemical characteristics were estimated before biological preparation application: pH 8.20, dry matter 6.64%, organic matter 5.38%, total N 2.90 g kg^{-1}, and mobile nutrients P_2O_5 140.0 mg kg^{-1} and K_2O 350.0 mg kg^{-1}.

Treatments of the experiment: 1) soil without measures application (Control); 2) soil with biological preparation application (Bio1); 3) soil with slurry application (S); 3) soil with slurry and biological preparation application (SBio2).

Soil properties measurements. Soil temperature, electrical conductivity and CO_2 emissions rate were evaluated after different periods of time: 1) after measures application (beginning of experiment); 2) after 2 months (in autumn); 3) after 7 months (in spring). Experiment carried out in three replications. The area of one experimental plot was 18 m^2 (6 x 3 m).

Biological preparations composition. Biological preparation Bio1 is used for the soil activation and composting. In the composition three carrier materials included: dolomite, molasses and magnesium sulphate. Biological preparation Bio2 is used for aerobic conversion of slurry. In the composition two carrier materials included: calcium carbonate and molasses.

Agrochemical characteristics of the soil and slurry were estimated prior to the experiment in three replications. Combined soil samples were taken with a Nekrasov auger from the 0–25 cm soil layer. Soil and slurry pH was determined potentiometrically in 1 n KCl extract, total nitrogen (g kg^{-1}) – Kjeldahl method, mobile phosphorus (P_2O_5) and mobile potassium (K_2O) (mg kg^{-1}) – Egner-Riehm-Domingo (AL) method, and the humus content in the soil (%) – Tiurin method.

Soil temperature, electrical conductivity and CO_2 emissions were measured in six spots of each plot using two devices (Fig. 1.). Soil temperature and electrical conductivity was measured using Delta-T HH2 Moisture Meter, and CO_2 emission rate with ADC BioScientific LCpro+ System.

(a) (b)

Figure 1. Soil temperature, electrical conductivity (a) and CO_2 emission rate (b) portable measuring devices (Buragiene et al., 2015).

Statistical analyses. Data from these experiments were statistically evaluated for quantitative characteristics using a one-way ANOVA and corelation-regresion methods by software package 'Statistica.10'. Correlation coefficient *r* was estimated.

RESULTS AND DISCUSSION

Meteorological conditions. In 2015, temperature and precipitation of September was close to the long-term average (Fig. 2). The average temperature of October was also similar to the long-term average, though precipitation was 2.8 times lower. The monthly average temperature for November and December was 2.0°C and 5.4°C above the long-term average and amount of precipitation was 1.9 and 1.5 times higher, compared with the long-term average precipitation.

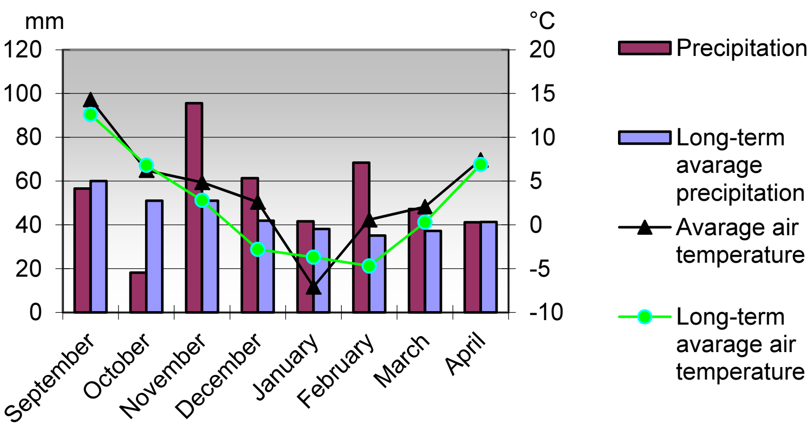

Figure 2. Meteorological conditions during experimental period and long-term average, 2015–2016

In 2016, during January precipitation was regular, but temperature dropped down markedly and was by 3.4°C lower, compared with the long-term average. February was wet and warm, the average temperature was 5.3°C and rainfall was 33.3 mm above the long-term average indices. In March and April temperature and precipitation was close to the long-term average.

At the beginning of the experiment (0 months) after application of biological preparations and slurry there were no significant differences estimated between soil temperatures in different treatments (Fig. 3).

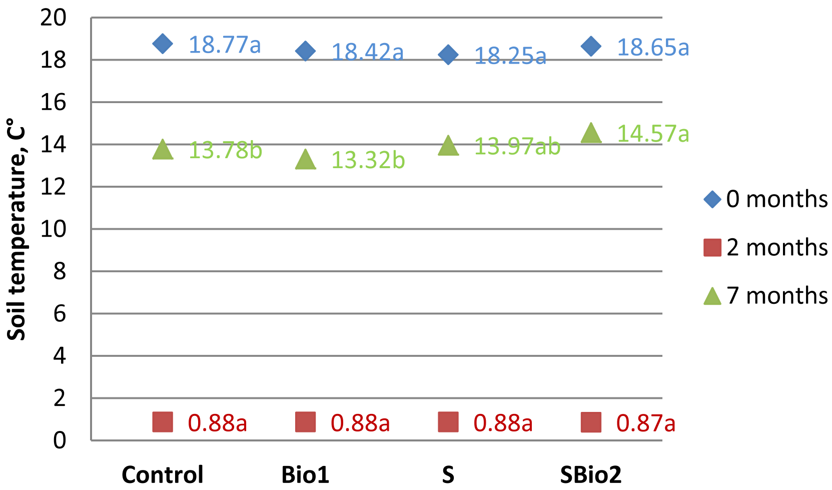

Figure 3. Soil temperature after application of biological preparations and slurry in autumn (0, 2 months) and in spring (7 months). ***P*****≤0.05.**

After 2 months no significant influence of biological preparations and slurry on soil temperature was estimated. In spring, after 7 months of biological preparation and slurry application it was estimated, that soil temperature was significantly higher in the treatment where slurry with biological preparation (SBio2) was applied to compare with control and treatment (Bio1) where only biological preparation was used. It shows that biological processes in soil treated with slurry, especially, with slurry and biological preparation are more intensive.

Electric conductivity of the soil indicates ability of material to transmit current. In the soil it depends on the dissolved nutrients and soil moisture content. In our experiment the highest electrical conductivity of the soil was at the beginning of the experiment (Fig. 4). It was significantly higher in soil treated with biological preparation (Bio1) (178.3 m S m^{-1}) and control soil (169.0 m S m^{-1}).

In order to be able to measure soil electrical conductivity it should be sufficient moisture content of the soil. In autumn at the end of the vegetation and after two months of measures application the soil was dry therefore was not possible to measure electrical conductivity in two treatments (Bio1) and (SBio2). Electrical conductivity in control and soil with slurry (S) application was very similar, approximately 101.0 mS m^{-1}. In spring, after 7 months of biological preparations and slurry application electrical conductivity of the soil decreased to compare with measurements in autumn. It was significantly higher in SBio2 treatment to compare with control, Bio1 and S. Results indicate that nutrients in spring were leaching, but the higher amounts remained in soil treated with slurry and biological preparation (SBio2).

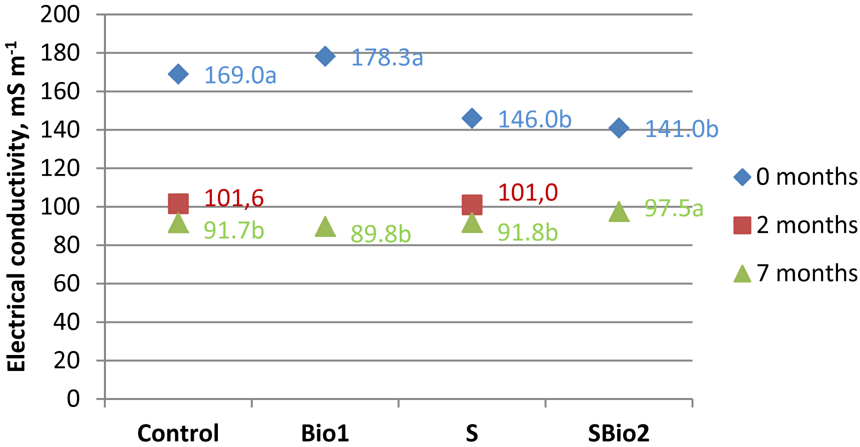

Figure 4. Soil electrical conductivity after application of biological preparations and slurry in autumn (0, 2 months) and in spring (7 months). *P*≤0.05.

Measurements of CO_2 emissions from the soil at the beginning of the experiment (0 months) after biological preparation and slurry application showed significantly higher CO_2 emissions from the soil where slurry with or without biological preparation additive were used (Fig. 5). Biological preparation for slurry (SBio2) tended to decrease CO_2 emission from the soil, but differences were not significant to compare with sole slurry application without additives (S).

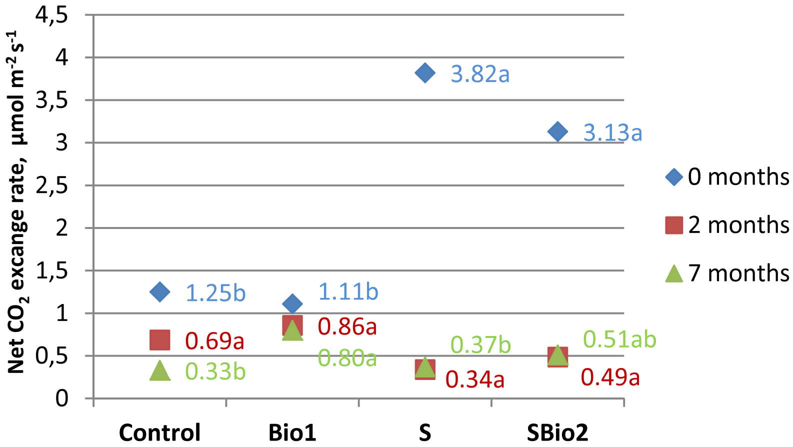

Figure 5. CO_2 emissions from soil after application of biological preparations and slurry in autumn (0, 2 months) and in spring (7 months). *P*≤0.05.

CO_2 emissions from the soil after 2 months (in autumn) and 7 months (in spring) decreased to compare with the beginning of the experiment (0 months). There were no significant differences between CO_2 emissions from the soil between different treatments after 2 months of biological preparations and slurry application. In spring, after 7 months of measures application the highest emissions were estimated from the soil where biological preparation Bio1 was used. It was significantly (2.2–2.4 times) higher than in the control or soil with slurry application (S). These results indicate activated biological processes in the soil treated with Bio1. Evaluating whole experimental period was estimated correlation between CO_2 emissions rate and temperature after 2 (r=0.45) and 7 (r=0.66) months of measures application.

CONCLUSIONS

It was estimated that at the beginning of the model field experiment after biological preparations and organic fertiliser application soil electrical conductivity was lower in the treatments were organic fertiliser was applied with SBio2 and without biological preparation S to compare with control and soil treated with biological preparation Bio1. Biological preparations and organic fertiliser had no influence on soil temperature, but CO_2 emissions were significantly (2.5–3.4 times) higher to compare with the control soil and Bio1.

In autumn, after two months of measures application there were no significant differences between temperatures of the soil and CO_2 emissions in different treatments.

In spring, after 7 months of measures application soil temperature and electric conductivity was significantly higher in treatment where organic fertiliser with biological preparation SBio2 was used to compare with control and soil treated with biological preparation Bio1. CO_2 emissions were higher in soil where biological preparations Bio1 and SBio2 were applied.

Evaluating all experimental period was estimated correlation between the CO_2 emissions rate and temperature after 2 (r=0.45) and 7 (r=0.66) months of measures application.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

THE USE OF OZONE IN COMBINATION WITH ELECTROCHEMICAL TREATMENT FOR THE REMEDIATION OF ORGANIC POLLUTED SOILS

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SUMMARY

In the last decades the researches have been concentrated on the soil treatment optimization due to the rising problem of contaminated soils around the world. The ozone is a highly reactive form of oxygen, capable of converting organic molecules to water and carbon dioxide. Ozone will rid contaminated soil of a variety of pollutants such as: MTBE (Methyl-Tertiary-Butyl-Ether), hydrocarbons, diesel, pesticides, VOCs (Volatile Organic Carbons), benzene, toluene, ethylbenzene, xylene, tricholoroethylene, aromatics. Ozone Treatment has evolved from water treatment to soil remediation. Recently, ozone has been used to clean up sites containing variety of soil contaminants. The reason for using ozone is to target those compounds that are not biodegradable or the ones which are biodegradable over a long period of time.

The present paper will present the results obtained after the use of ozone as a part of a chemical oxidation treatment and will give the preliminary results for the combined treatment (ozone and electrochemical remediation).

The ozone proved to be effective for the simple test, but for an exposure period longer than 6 hour for our quantity. It is for sure that for a higher quantity the efficiency of treatment will be higher with the increase of the exposure period. The combined treatment will be used also for difficult types of soil matrix.

Key words: ozone, soil pollution, electrochemical treatment

INTRODUCTION

Due to different economic activities, both historical and recent and in the absence of a legal framework for pollution prevention and protection of soils, in Romania, according to the National Strategy for Contaminated Sites Management, there are a number of sites 1,682 contaminated / potentially contaminated inventoried at the level of 2013. During the harmonization process of national policies with those of the European Union and transposition and implementation of EU rules and regulations, the problem of soil and groundwater pollution represents a fundamental aspect of environmental protection.

Romania, as in many other European countries, has a history of long industrialization and because of that it can be noticed a significand pollution of soil and water. The contaminated sites have a significant impact on the environment and on human health [2,3].

After 1989, Romania took the last two decades through a major transition, where many companies and industries active in the socialist period were closed or were restructured. This period can be coupled with a decreased ability to remediate contaminated sites in order to reuse them.

The highest number of potential contaminated sites are a result of the oil extraction industry (a total number of 215, according to the National Agency for Environmental Protection) and the highest number for contaminated sites, already identified, and are due to the activities of the same industry [2].

The present paper presents the results obtained during an experimental research, where it was applied only the treatment based on the ozone, in comparison with what it is intended to be done in another research where apart the single treatment with ozone it is wanted to apply a combined method between ozone and electrochemical treatment.

METHODS

The two method that will be presented in the present paper are: the treatment based on the use of ozone (chemical oxidation) and the one based on the electric field created in the polluted area (electrochemical remediation).

Chemical Oxidation is a patented technology to remediate hydrocarbon and/or halocarbon contamination in groundwater and soil, and it can be ex-situ or in situ [1, 7, 12, 15].

Ex-situ chemical oxidation involves mixing an oxidizing compound with contaminated groundwater or soil in a vessel. The oxidizing compound can be a solution (e.g., sodium hypochlorite in water) or a gas (e.g., ozone). The oxidizing agents most commonly used for the chemical treatment of organic contaminants are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide. The treatment chemicals typically mineralize most organic compounds to carbon dioxide, water, and salts [4,5].

The main advantage of ex situ treatment is that it generally requires shorter time periods than in situ treatment, and there is more certainty about the uniformity of treatment because of the ability to homogenize, screen, and continuously mix the soil. Ex situ treatment, however, requires excavation of soils, leading to increased costs and engineering for equipment, possible permitting, and material handling/worker exposure conditions [6].

Ozone (O_3) is a strong oxidant in a gas phase, that has a standard oxidation potential of about 2,1 V. This type of oxidant can be used for a large type of pollutants like petroleum hydrocarbons, benzene, phenols, polycyclic aromatic hydrocarbons (PAHs), chlorinated ethenes (PCE, TCE, DCE, VC), energetics (RDX, HMX) etc. Ozone is one of the strongest oxidants available for in situ chemical oxidation. It is an allotrope of oxygen and is more soluble than oxygen in water. It is usually generated on site using ozone generators (ozonators). Commercial generators using an air or oxygen stream usually generate ozone within the 2–10 wt% range. When ozone is introduced via the gas phase, the application rate is controlled by the phase equilibrium between gases and liquids.

Many of the reactions that take place produce additional dissolved oxygen. For most ozone injection systems that use an oxygen feed supply (as opposed to atmospheric air) to the ozone generator, a significant amount of oxygen can also be directly injected into groundwater (in some cases, ozone generators using an oxygen feed supply may be injecting approximately 90% oxygen and 10% ozone). Due to the significant amount of oxygen being injected into the subsurface and the oxygen producing reactions, dissolved oxygen levels during ozone–hydrogen peroxide injection are typically very high and can help promote aerobic bioremediation down gradient of the injection points [1, 7].

Electrochemical Oxidation is a technology used at the beginnings for the inorganic polluted soils or liquids, but in the last years it proved to be efficient also for organic polluted soils [5, 7, 13]. In this paper it will be discussed the second case.

This type of treatment uses an electric field created between two electrodes (an anode and a cathode) placed in the polluted area. The applied voltage is constant and depends on the initial level of contamination. The application of electro-kinetic process is governed by electromigration and electro-osmosis with electrolysis reactions at the electrodes. During the application of electrochemical treatment apart the physical phenomena, some chemical phenomena also take place. In the anode part there are oxidation reactions that can be observed while in the cathode part we have the reduction reactions. Also, regarding the pH, it can be noticed that in the anode part there is an acid front and in the cathode part there is a basic one. The tendency of the acid front is to move towards the basic one two times faster.

In this paper the results obtained after the application of chemical oxidation using ozone, will be presented. Also, the foreseen results for the experiments that will be done in the future on the combination of the two technologies, will be mentioned.

RESULTS AND DISCUSSION

The test performed with ozone was done on a column through which a constant volume of gas had passed. These tests were conducted with a PVC column (internal diameter 2.5 cm and length 35 cm) where the contaminated sample (total weight 100g) was inserted, and an ozonator (fig.1).

The contaminated soil was obtained from a canal in the northern part of Italy, which for several decades had received industrial effluents polluted by organic and inorganic compounds (mainly by solvents, phenols and poly-aromatic hydrocarbons).

Several samples (total weight about 10 kg) were collected from the first 30-40 cm layer at the bottom of the canal; these samples were then mixed together and mechanically stirred to produce a final, homogeneous, sample.

Firstly, a fine net is inserted at the bottom of the column, in order to avoid the soil to leak out from the bottom of the column. Then a layer of clean sand (width about 2 cm) is inserted with the aim to make the hydrodynamic flux regular and homogeneous within all the sample section; then the sample was inserted in the column, and it was compacted so to reach approximately the same density of natural soil (1.5 – 1.6 kg/dm^3).

Fig.1. The ozonator linked to the column, used for the simple test [6]

After the specimen, another layer of clean sand and then another fine net was inserted at the top of the column, to avoid the liquid flux of reactants to drag particles from the soil specimen while flushing it.

For the tests with ozone, the ozone-gas is produced by an ozonator from pure oxygen, provided by an oxygen tank. The oxygen enters the ozonator from the top and while inside, it is crashed by electrical discharges that result in the production of a certain quantity of ozone in the outgoing flux. The gaseous oxidant is introduced in the reaction column from the bottom, then it flows inside the specimen with up flow stream and finally it leaves the reaction column.

The outstream, which contains residual unreacted ozone, is diffused in outdoor air or it flows inside an active carbon bed to consume the excess of ozone.

In order the ozone to be produced, the pressure of the oxygen flow inside the ozonator must be ≤ 0.5 bar ($0.5*10^5$ Pa). During the tests, the flux was set to about 2.5 NL/min, and the pressure to 0.3 – 0.4 bar. For the particular ozonator used, this values of flux and pressure result in the production of about 4 g of ozone per hour. This quantity is very small related to the quantity of oxygen that comes into the ozonator and through column we will have both oxygen and ozone.

During the test, ozone in the gaseous phase was used because is more stable than in aqueous solution and is more readily transported through soil in the gaseous phase.

We observed that at first almost all the water must be removed from our sample through the same process but using only O_2, because we meet some resistance from the sediments. Because of this resistance during the first minutes we were not able to set the right pressure and flux.

In total three experiments have been developed, with different exposure time: 3 hours, 6 hours and 24 hours. Due to some problems encountered with the last one, the results obtained for 24 h will not be presented, but in the next research activity, this test will be done again.

The first experiment of ozonation lasted for 3 hours. After this time, the generation of ozone was stopped and the system was briefly fluxed with oxygen only. Then the sediments were removed from the column and analysed.

The results for the analysed PAH are presented in table 1, for each type of PAH, and also for light PAH, heavy PAH and total PAH. From table 1, it can be noticed that an exposure of 3 hours is not enough, because for almost all PAHs have a mean or poor removal.

If the analysis is done for each of the PAH, the highest removal efficiency is obtained for fluorine, which had a significant initial concentration, of about 119 mg/kg_{dw} followed by fluorantene, pyrene and acenaphthene with 61% removal efficiency.

According to the same table, even though the initial concentration of the light PAH was significantly higher than the one of the heavy PAH, after the treatment the final concentration was lower for the first category compared with the second one.

At the end, the removal efficiency is of the order of magnitude of 60%, with (figure 2).

Table 1. Results after the treatment with ozone for 3 hours

	PAHs	Untreated	After the treatment	
		mg/kg_{dw}	mg/kg_{dw}	removal (%)
1	naphthalene	59.22	44.99	24
2	acenaphthylene	5.58	5.70	-
3	acenaphthene	211.38	81.83	61
4	fluorene	119.06	42.51	64
5	phenanthrene	660.06	189.46	71
6	anthracene	56.67	24.66	56
7	fluorantene	481.73	181.19	62
8	pyrene	368.80	142.50	61
9	crysene	157.00	65.40	58
10	benzo(a)anthracene	118.80	54.00	55
11	benzo(b)fluorantene	194.60	107.50	45
12	benzo(k)fluorantene	72.00	37.00	49
13	benzo(a)pyrene	142.70	72.60	49
14	dibenzo(a,h)anthracene	17.40	9.10	48
15	benzo(g,h,i)perylene	72.40	49.60	32
16	indeno(1,2,3-cd)pyrene	79.00	49.70	37
Total Light PAHs (1-7)		1593.70	570.36	64
Total Heavy PAHs (8-16)		1222.70	587.40	52
Total PAHs		2816.405	1157.76	59

Table 2 presents the results obtained after treatment with ozone with an exposure time of 6 hours.

Table 2. Results after the treatment with ozone for 6 hours

	PAHs	Untreated	After the treatment	
		mg/kgSS	mg/kgSS	removal (%)
1	naphthalene	59.22	11.24	81
2	acenaphthylene	5.58	0.55	90
3	acenaphthene	211.38	32.70	84
4	fluorene	119.06	16.87	86
5	phenanthrene	660.06	64.75	90
6	anthracene	56.67	9.05	84
7	fluorantene	481.73	76.83	84
8	pyrene	368.800	69.70	81
9	crysene	157.00	34.00	78
10	benzo(a)anthracene	118.80	49.00	59
11	benzo(b)fluorantene	194.60	58.80	70
12	benzo(k)fluorantene	72.00	20.10	72
13	benzo(a)pyrene	142.70	37.50	74
14	dibenzo(a,h)anthracene	17.40	3.70	79
15	benzo(g,h,i)perylene	72.40	31.90	56
16	indeno(1,2,3-cd)pyrene	79.00	18.50	77
Total Light PAHs (1-7)		1593.70	211.99	87
Total Heavy PAHs (8-16)		1222.70	323.20	74
Total PAHs		2816.40	535.19	81

We had a better removal efficiency for this treatment with ozone with an exposure time of 6 hours for which the removal is around 74% for heavy PAHs (figure 3). The smallest removal efficiency it is registered for benzo (g,h,i) perylene (the same was also for the treatment with ozone and an exposure time of 3 hours). It can be noticed that also for this treatment the light PAHs had a higher removal efficiency compared with the heavy PAHs.

It was noticed that pH has a great influence on the ozonation of PAHs. The rate of PAHs disappearance is usually decreased when the pH is increased

Another research activity that will be developed at laboratory level is the combination of two technologies, more specific, the chemical oxidation with ozone and electrochemical oxidation.

The main challenge of the chemical oxidation treatment is the matrix that must be treated and that has a low permeability like clay. Because of that the electrochemical treatment will be used due to the fact that was proven, in previous research, that the results are promising when an inorganic contaminated clay is treated.

The electrochemical treatment will help on one side the ozone to be transported in a difficult matrix, and on the other side will participate also at the treatment of soils by removing the organic contaminants.

The treatment efficiency only for electrochemical treatment has reached up to 70% for a treatment period of one month. This research was performed during a PhD and has already been presented in some previous research.

In the literature, it was noticed that pH has a great influence on the ozonation of PAHs. The rate of PAHs disappearance is usually decreased when the pH is increased. This aspect could be favorable for the combined treatment due to the fact that if the polarity is not change the sample would have the tendency to be acidified which will help the ozonation process [1,2].

O'Mahony et al (2006) have obtained a removal efficiency around 50% for phenanthrene levels from soils, while Rivas et al (2209) have obtained 50, 70 and 60% of acenaphthene, phenanthrene and anthracene.

CONCLUSIONS

In our days there are a large number of available treatments for the remediation of contaminated soils. These treatments can be classified according to the main processes that take place during their application.

When a method must be identified as the most suitable for the remediation of a PAHs contaminated soil, the main parameters that must take into account are the initial concentration, the remediation goal and the assessment of human health risk.

In this paper two types of treatments have been presented, one can be included in the chemical treatments and the other in the physical and chemical treatments.

The paper presented only the results for the chemical oxidation treatment that used as oxidant the ozone, because it had the purpose to underline the possibilities that this method can offer and how it can be improved if it is combined with another one. Through this combination, the limitations of both technologies could be overcome.

Regarding the chemical oxidation, only the use of ozone as an oxidant for chemical oxidation treatment can assure an efficiency of more than 60%. The results can be improved by increasing the treatment period. While for electrochemical treatment, the results can vary from 50% up to 75%.

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CLASSICAL AND QUANTUM WATER DROPLET DYNAMICS: CHALLENGES AND OPPORTUNITIES

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SUMMARY

The aim of this work is to give an as much as possible comprehensive alternative to classical "reductionist" approaches to analyse water droplets dynamics in the quantum form, in order to better understand the challenges and opportunities feasible to assess spray flow related phenomena. On the whole, such approach allows to recast the classical fluid dynamic equations into the so-called quantum equations, permitting to overcome both the presence of non-linearities and the inter-particle reciprocal affection for many-particle systems.

Key words: spray particles kinematics; sprinkler jet flow; single and many droplet systems quantum mechanics; density functional framework; numerical modelling

INTRODUCTION

The problem of moving particles crossing a gaseous mean is one of the most challenging in science. For instance, the full understanding of thermo-fluid dynamics of droplets during their aerial path is associated to the problem of better assess the evaporation phenomenon. With this regard, a detailed understanding of the droplet evaporation process, which is part of the whole evaporation phenomenon together with soil evaporation and canopy evaporation, is fundamental in order to implement water conservation strategies [Uddin, 2010; Steiner et al., 1983].

However, quantifying evaporation losses in practice, for instance, in sprinkler irrigation, is very difficult, and this is mainly due to the large variety of factors involved (air temperature, air friction, wind velocity, operating pressure, etc.). At this regard many authors have investigated the factors affecting evaporation losses in order to determine their magnitude and therefore each effect on the evaporative phenomenon [Lorenzini 2004; Kohl et al., 1987; Hermsmeier, 1973; Frost and Schwalen, 1955; Christiansen, 1942]. Yet, the results achieved are often conflicting. Recent works have tried to handle the issue adopting a statistical approach in order to quantify the contributes of the factors involved [Bavi et al. 2009; Tarjuelo et al., 2000; Trimmer, 1987; Yazar 1984] but, nonetheless, this kind of approach has proved to be still strictly related to the particular case studied, failing to describe a reliable picture of the actual phenomenon. Such intrinsic limit characterizes also some experimental studies describing case-bond irrigation processes, since they not proceed to a closed form solution of the physical governing laws. It has been hence necessary to partially abandon case-dependent approaches introducing necessary simplifying hypotheses regarding the flight-event of the water droplet. Examples of this “classical viewpoint” are given in [Edling, 1985; Keller and Bliesner, 1990; Thompson et al., 1993; Lorenzini, 2004]. In general, the hypothesis adopted consist in considering just the Newtonian force applied to the droplet on one hand and in adopting particular initial conditions for the system droplet-environment on the other.

Yet, the problem becomes even more complicate when not just a single droplet is considered but a multi-droplet system is studied, in which the inter-particle reciprocal affections, mainly due to electrical interactions between the hydrogen and the oxygen atoms of the different water molecules, has to be assessed too.

The aim of this paper, which is a completion of previous works [Medici et al., 2014], is to give an as much as possible comprehensive alternative to classical approaches. The analysis of water droplets dynamics in the form of quantum approach, performed in order to better understand of spray flow related phenomena, includes here the so-called density functional theory (DFT) applied to the description of many-particle systems within a single-particle framework in a 3-D space.

CLASSIC DYNAMIC FRAMEWORK

The traditional analysis about water droplet dynamic scan be made adopting the Newtonian approach. A set of equations based on classical force describes how a droplet moves in its aerial path from the starting point to the ground. It is hence possible to obtain results in terms of coordinates, velocities and accelerations along the horizontal and vertical axes. Several authors have developed droplet evaporation models, many of them including also heat transfer processes. At this regard a thorough review is given by [Uddin et al., 2010], in which the authors conclude that heat and mass transfer approaches combined with ballistic theory is in reasonable agreement with experimental data for low Reynolds numbers (< 1000), but, at the same time the models need to be appropriately validated through experimentation. Among all, it is worth to cite the contribution of Lorenzini [Lorenzini, 2004], Edling [Edling, 1985] and Thompson et al. [Thompson et al. 1993], which can be considered the most complete model available [Uddin et al., 2010]. From a ballistic point of view, the aerial path of a single droplet can be described using Newton’s Second Law:

$$m\frac{d\,v(t)}{dt} = F(t) \qquad (1)$$

where F is the classical force, m is the droplet mass and v is the droplet velocity. Considering now a many-droplet system composed of N droplets, Eq.(1) can be written as:

$$m_k\frac{dv_k(t)}{dt} = -\nabla_k V \cdot F(t) \qquad 1 \le k \le N \qquad (2)$$

being ∇_k is the 3-D gradient operator referred to the k-th droplet and V a potential function accounting for time dependence [Bird et al., 1960].

The so-called classical force may include the presence of several forces like weight, buoyancy and friction applied to the droplet in air. Also, the estimation of the interaction of several factors, both climatic (air temperature, relative humidity, air friction, wind velocity, solar radiation) and operating (droplet initial diameter, nozzle height, operating pressure, etc.) needs to be performed. Generally, in experimental applications it is particularly hard to quantify the evaporation losses, and this is due to several factors, including differences in definition of the losses themselves and accuracy of experimental techniques. Recent studies have tried to treat the issue adopting a statistical approach in order to quantify the contributes of climatic and operating factors [Bavi et al. 2009; Tarjuelo et al., 2000; Trimmer, 1987; Yazar 1984]. Even if such approach represents the only way to circumvent the difficulties [Uddin et al., 2010], it is often strictly related to the particular case studied and therefore it almost fails in depicting general-purpose regression models.

QUANTUM DYNAMIC FRAMEWORK

Although the classic dynamic framework can be useful for some particular practical cases, it is not completely exhaustive, as the use of simplifying hypotheses and the adoption of particular environmental characteristics makes it not fully reliable in depicting the actual phenomena. The classic dynamic framework based on Newton's second law of Dynamics almost fails in considering droplet trajectory depending only on starting conditions, without taking into account the influence of other moving droplets in the vicinity. In order to overcome the limits of this approach, a quantum viewpoint is herewith described.

QUANTUM DYNAMICS FOR A SINGLE PARTICLE

The kinematic approach may turn into the quantum, by considering the quantum potential into Newton’s second law already described in Eq.(2). Applying the Bohm’s interpretation to quantum mechanics, the trajectory of a particle could be expressed in form of a Bohmian trajectory [Bohm, 1952; Goldstein *et al*., 2011]. In this way the analysis is still maintained as deterministic, although the relationship between the system's wave function and the observable properties of the system may appear to be non-deterministic. Eq.(2) takes the following form [De Wrachien *et al.*, 2012]:

$$m_k \frac{d\, v_k(t)}{dt} = -\nabla_{\mathrm{k}}(V \mid Q^{\Psi_t}), \qquad 1 \le k \le N \tag{3}$$

where Q^{Ψ_t} is the quantum potential:

$$Q^{\Psi_t} = -\sum_{j=1}^{N} \frac{\hbar^2}{2m_j} \frac{\nabla_j^2 |\Psi|}{|\Psi|}, \qquad 1 \le j \le k \le N \tag{4}$$

being $\hbar$ the Dirac constant, $\Psi(\vec{x},t) = R(\vec{x},t) \cdot e^{S(\vec{x},t)}$ the wave function, R the wave amplitude and S the wave phase. As one can note, the description of each single particle dynamics is intrinsically probabilistic. The wave function Ψ is a probability amplitude describing the quantum state of a particle while the pattern of the wave function over time can be described by the Schrödinger’s equation:

$$D^2\nabla^2\Psi(\vec{x},t) - \frac{1}{2} mV(\vec{x},t)\Psi(\vec{x},t) = -i \cdot D \frac{\partial\Psi(\vec{x},t)}{\partial t} \tag{5}$$

where $D = \frac{\hbar}{2m}$ is the diffusion coefficient.

A geometric framework in which motion laws are completed by scale laws is given by Nottale [Nottale, 1992] who overcame the arbitrary assumption of differentiability of the space-time continuum in quantum mechanics, as the typical paths of quantum mechanical particles are continuous but non-differentiable according to Nottale [Nottale, 1996] and

Feynman [Feynman and Hibbs, 1965]. Thus, the Schrödinger's equation can be modified by means of Nottale's Scale Relativity theory using a probability density function for a semi-infinite domain [Hermann, 1997] to recast the second law of dynamics in the complex field (u is a scalar potential, W is a complex velocity):

$$-\nabla u = m \cdot \frac{\eth}{dt}\boldsymbol{W} \tag{6}$$

where u is the scalar potential and $\boldsymbol{W}$ is the complex velocity. Considering the imaginary part of $\boldsymbol{W}$, U, Eq.(6) takes the following form:

$$\begin{cases} -D \cdot \Delta U - (\mathrm{U} \cdot \nabla)U = -\nabla u \\ \frac{\partial}{dt} U = 0 \end{cases} \tag{7}$$

Note that the first equation (7) can be written as a Riccati equation for a 1-D path [Al-Rashid et al., 2011]:

$$\frac{d}{dx}U(x) = -\frac{m}{\hbar} \cdot U^2(x) + \frac{2}{\hbar} \cdot (u(x) - c \cdot m) \tag{8}$$

$$\frac{d^2}{dx^2}y(x) - \frac{2 \cdot m}{\hbar^2} \cdot (u(x) - c \cdot m) \cdot y(x) = 0 \tag{9}$$

where c is a constant and $y(x)$ an arbitrary function of x. Within one dimensional domain (i.e. a droplet vertical downfall, for instance), equations (8) and (9) are very useful tools as they allow quantum particles computations without taking into account Schrödinger's equation. In this context Eq.(6) can be re-written in the form of continuity and Euler-type "quantum fluid-dynamic equations", respectively as [Wyatt, 2005; Ghosh, 2011; Medici et al., 2014]:

$$\frac{\partial}{\partial t}\rho(\vec{x},t) + \nabla[\rho(\vec{x},t) \cdot \vec{v}(\vec{x},t)] = 0 \ (10)$$

$$\frac{d}{dt}\vec{v}(\vec{x},t) \equiv \left[\frac{\partial}{\partial t} + \vec{v}(\vec{x},t) \cdot \nabla\right]\vec{v}(\vec{x},t) = -\frac{1}{m} \cdot \nabla[V(\vec{x},t) + Q(\vec{x},t)] \tag{11}$$

where ρ is the fluid density, $\vec{v}$ the velocity, V the classic potential, and Q the quantum potential.

QUANTUM DYNAMICS FOR A MANY-PARTICLE SYSTEM

For a N-particles system the time-dependent Schrödinger's equation needs to be re-adapted, as one has to consider also the electrostatic contribution that may originate between molecules or within different parts of a single molecule. This results in [Ghosh, 2011]:

$$\left[\frac{1}{2}\sum_j \left(-2iD\nabla_j - \vec{K}(\vec{x_j},t)\right)^2 + \frac{1}{m}V(\vec{x}^N,t)\right]\psi(\vec{x}^N,t) = 2iD\frac{\partial}{\partial t}\psi\left(\overrightarrow{x^N},t\right) \tag{12}$$

where $\vec{x}^N$ are the N-particles coordinates, V the electric potential, and ϕ the external time-dependent scalar potential. Eq.(12) can be transformed similarly into a single-droplet system using the polar form in Eq.(13), obtaining, respectively, the continuity (14) and the Euler-type equations (15) :

$$\psi(\vec{x}^N,t) = R(\vec{x}^N,t)exp[\mathrm{S}(\vec{x}^N,t)] \tag{13}$$

$$\frac{\partial}{\partial t}\rho^N(\vec{x}^N t) + \sum_{k=1}^N \nabla_k \overrightarrow{J_k}(\vec{x}^N,t) = 0 \tag{14}$$

$$\frac{\partial}{\partial t}\overrightarrow{v_k}(\vec{x}^N,t) + \sum_j\left(\overrightarrow{v_j}(\vec{x}^N,t)\nabla_k\right)\overrightarrow{v_j}(\vec{x}^N,t) + \sum_j\left(1-\delta_{jk}\right)\overrightarrow{v_j}(\vec{x}^N,t) \times (\nabla_k \times)\overrightarrow{v_j}(\vec{x}^N,t) =$$
$$-\left(e\vec{E}(\vec{x}_k,t) + \frac{e}{c}\vec{v}_k(\vec{x}^N,t) \times \vec{B}(\vec{x}_k,t)\right) - \frac{1}{m}\nabla[V_0(\vec{x}^N,t) + U(\vec{x}^N,t) + Q(\vec{x}^N,t)] \tag{15}$$

Where $\nabla_k$is the gradient operator related to the coordinate $\vec{x}_k$ of the k-th particle, $\rho^N(\vec{x}^N,t) = R^2(\vec{x}^N,t)$ the N-particle density, $\overrightarrow{J_k}(\vec{x}^N,t) = \rho^N(\vec{x}^N,t) \cdot \vec{v}_k(\vec{x}^N,t)$ the fluid current density, $\vec{v}_k(\vec{x}^N,t) = \frac{\hbar}{m} \cdot \nabla_k S(\vec{x}^N,t) - \frac{e}{mc} \cdot \vec{A}(\vec{x}^N,t)$ the velocity field of the k-th particle, $\vec{E}(\vec{x}_k,t) = -\nabla\phi(\vec{x}_j,t) - \frac{1}{c} \cdot \frac{\partial}{\partial t}\vec{A}(\vec{x}^N,t)$ the external electric field, $\vec{B}(\vec{x}_k,t) = curl\,\vec{A}(\vec{x}^N,t)$ the external magnetic field.

Eq. (14) and (15) were carried out by Madelung [Madelung, 1926], who gave birth to the so-called quantum fluid dynamics (QFD). The work was successively extended by Bohm [Bohm, 1952-I and 1952-II].

QUANTUM DYNAMICS WITHIN A SINGLE PARTICLE FRAMEWORK

The quantum fluid-dynamic framework QFD framework can be interesting when the related equations describe a 3-D space in terms of the basic variables of density and current density. The single-particle density provides a useful tool to describe many-particle systems within a single-particle framework. At this regard, the Kohn-Sham equations provides a mapping between the particle density $\rho(\vec{x})$ of a many-particle system and the external potentials [Gosh, 2011]. This framework was derived from the pioneering Hohenberg-Kohn theorem [Hohenberg and Kohn, 1964], later extended by Peuckert [Peuckert, 1978], Bartolotti [Bartolotti, 1981], Deb and Ghosh [Deb and Ghosh, 1982], Runge and Gross [Runge and Gross, 1984], and Ghosh and Dhara [Ghosh and Dhara, 1988], who broadened the applicability of former Kohn-Sham equation. The results are time-dependent equations, in particular Schrödinger-like equations, containing at the same time the contribution of external potentials and electric and magnetic fields:

$$\{-(\hbar^2/2m)\nabla^2 + V_0(\vec{x}) + V_{ext}(\vec{x},t) + V_{SCF}(\vec{x},t)\}\psi_k(\vec{x},t) = i\hbar(\partial/\partial t)\psi_k(\vec{x},t) \quad (16)$$

Where $V_{ext}$is the additional oscillating external potential, $V_{SCF} = V_{COUL}(\vec{x}) + V_{XC}(\vec{x})$ is the effective self-consistent potential, sum of both the classical Coulomb energy $V_{COUL} = (\partial U_{int}/\partial\rho)$ and the exchange correlation energy $V_{XC} = (\partial E_{XC}/\partial\rho)$.

The particle density and the current-density can be obtained using the following equations:

$$\rho(\vec{x},t) = \sum_k \psi_k^*(\vec{x},t)\psi_k(\vec{x},t) \quad (17)$$

$$\vec{J}(\vec{x},t) = -(i\hbar/2m)\sum_k[\psi_k^*(\vec{x},t)\nabla\psi_k(\vec{x},t) - \psi_k(\vec{x},t)\nabla\psi_k^*(\vec{x},t)] \quad (18)$$

Note that, for a N-particles system, the current density $\vec{J}(\vec{x},t)$ assesses both the single particle density and the time-dependent potentials [Ghosh, 2011]. Therefore it is possible to treat the energies as functions of both the current and the particle density.

QUANTUM DYNAMICS WITHIN A DENSITY FUNCTIONAL FRAMEWORK

The QFD adopted for many-particle systems leads to the continuity (14) and Euler (15) equations in configuration space, involving the N-particle density $\rho^N(\vec{x}^N,t)$ within a 3-D velocity field. However, as shown in the last section, the QFD equations may be re-adapted in order to partition the space according to the basic variables related to particles of density and current density. In this way, the density functional framework (DFF) provides a single-particle based approach useful for the description of the motion of many- particle systems in a 3-D space. Thus, the single particle density and the current density associated to the *k-th* particle trajectory are, respectively, given by [Ghosh, 2011]:

$$\rho_k(\vec{x},t) = R_k^2(\vec{x},t) \quad (19)$$

$$\vec{J}_k(\vec{x},t) = \rho_k(\vec{x},t) \cdot \vec{v}_k(\vec{x},t) \quad (20)$$

where the single particle velocity can be expressed as:

$$\vec{v}_k(\vec{x},t) = (\hbar m)\nabla S_k(\vec{x},t) + (e/mc)\vec{A}_{eff}(\vec{x},t) \tag{21}$$

Within this ground the continuity equation can be written as:

$$\frac{\partial}{\partial t}\rho_k(\vec{x},t) + \nabla\vec{J}_k(\vec{x},t) = 0 \tag{22}$$

The quantum potential, which is trajectory dependent, can be now expressed as:

$$Q_k(\vec{x},t) = \frac{\hbar^2}{8m}\nabla\rho_k(\vec{x},t)\frac{\nabla\rho_k(\vec{x},t)}{\rho_k^2(\vec{x},t)} - \frac{\hbar^2}{4m}\frac{\nabla^2\rho_k(\vec{x},t)}{\rho_k(\vec{x},t)} \tag{23}$$

The Euler equation takes the following form:

$$\frac{\partial}{\partial t}\vec{v}_k(\vec{x},t) = -\frac{e}{m}\left[\vec{E}_{eff}(\vec{x},t) + \frac{1}{c}\vec{v}_k(\vec{x},t)\times\vec{B}_{eff}(\vec{x},t)\right] - \frac{1}{m}\nabla\left[V_{eff}(\vec{x},t) + Q_k(\vec{x},t)\right] \tag{24}$$

where $\vec{E}_{eff}(\vec{x},t) = -\nabla\Phi(\vec{x},t) - \frac{1}{c}\frac{\partial}{\partial t}\vec{A}_{eff}(\vec{x},t)$ represents the effective electric field, while the effective magnetic field is equal to $\vec{B}_{eff}(\vec{x},t) = curl\ (\vec{A}_{eff}(\vec{x},t))$.

The Euler equation can be recast into the Navier-Stokes equation as [Holland, 2011]:

$$\frac{\partial}{\partial t}\vec{J}_k(\vec{x},t) = -\frac{e}{m}\left[\rho_k(\vec{x},t)\vec{E}_{eff}(\vec{x},t) + \frac{1}{c}\vec{J}_k(\vec{x},t)\times\vec{B}_{eff}(\vec{x},t)\right] - \frac{1}{m}\rho_k(\vec{x},t)\nabla V_{eff}(\vec{x},t) + \nabla\vec{T}_k(\vec{x},t) \tag{25}$$

where the stress tensor, due to the contributions of both the quantum potential $Q_k(\vec{x},t)$ and the current density of the k-th particle trajectory, can be expressed as:

$$\vec{T}_k(\vec{x},t) = \left(\frac{\hbar}{2m}\right)^2\nabla\nabla\rho_k(\vec{x},t) + \frac{1}{\rho_k(\vec{x},t)}\left[\vec{J}_k(\vec{x},t)\vec{J}_k(\vec{x},t) - \left(\frac{\hbar}{2m}\right)^2\nabla\rho_k(\vec{x},t)\nabla\rho_k(\vec{x},t)\right] \tag{26}$$

The jet flow can be seen as a mixture of N particles in which each component, described by Euler equation, is characterized by common effective electric and magnetic fields, and by a trajectory-dependent quantum force of stress tensor [Gosh, 2011].

For many-particle systems the DFF represents a versatile tool for the description of equilibrium as well as dynamical characteristics of the system. The basic picture is that of a many-component fluid mixture moving in common effective electric and magnetic fields and component-specific quantum potentials. This approach leads to the concept of quantum trajectory, in analogy to the well-established concept of classical trajectory and, in general, can represent an exciting area of research for all droplet applications.

QUANTUM DYNAMICS: NUMERICAL FRAMEWORK

The hydrodynamical picture of quantum mechanics shown in this work is intuitively appealing. The quantum potential and its associated force formally appear on the same frame of that of the classical potential and force in the equations of motion, as previously shown. Nonetheless, analytical 'closed form' solutions of the equations describing the quantum kinematics of particles are still extremely hard to obtain.

This is why different forms of approximation have been recently introduced in order to treat the QFD problem: in particular, literature reports numerical and dynamical approximations [Kendrick, 2011]. Numerical approximation relies upon three approaches based on Lagrangian, Eulerian and Arbitrary Lagrangian-Eulerian (ALE) frames. Whether is the approach adopted, a numerical problem can be further subdivided into different algorithms for evaluating derivatives and propagating in time. In this regard, one of the most successful methods for evaluating quantum dynamics derivatives is the meshless Moving Least Squares (MLS) [Kendrick, 2011, Lopreore and Wyatt, 1999]. This method averages out any numerical error which may be accumulating in the solution, and it is characterized by computational efficiency, high resolution, accuracy and stability. On the other hand, dynamical approximations rely on the presence of intrinsic, even if good-sense, errors. They consist in imposing some particular condition to the original fluid dynamic equations: for instance, the fluid can be considered incompressible, or some fluid features may be neglected since they are considered not so relevant to the whole picture. Unfortunately, due to the non-linear nature of the quantum hydrodynamic equations, this goal is difficult to achieve in practice. However, several approximate methods have been recently developed, such as the Linearized Quantum Force (LQF), the Derivative Propagation Method (DPM) and the Vibrational Decoupling Scheme (VDS). In general, a combination of both numerical and dynamical approximations may be adopted to achieve a practical numerical solution.

CONCLUSIONS

Albeit the process of a liquid particle moving within a gaseous phase is present in many different applications belonging to various scientific sectors, a whole, clear and generally applicable mathematical modelling is still far from having been achieved. In this work an overview of quantum fluid dynamical approach applied to water jets has been described, along with the related challenges and opportunities. The presence of electric and magnetic fields in a 3-D space for a many-particle system has been considered, and the Kohn-Sham time dependent equations have been used to describe the multi-component fluid mixture. The time-dependent Schrödinger equations may be employed to study the evaporative phenomenon and a parallel classic-quantum description may be achieved, both for single and multi-droplet systems. Future studies will deepen the modelling approach suggested to make it more and more suitable for practical applications on one hand, and to investigate more deeply the area of energy density functional on the other.

NOTATION (List of abbreviations and acronyms)

$\vec{A}$	Vector potential of the classic force
$\vec{B}$	Magnetic field
c	Numerical coefficient
D	Diffusion coefficient
e	Elementary charge
$\vec{B}$	External electric field
F	Force
$\hbar$	Dirac constant
$\vec{J}$	Fluid current density
$\vec{K}$	vector potential for the electromagnetic field
m	particle mass
Q	Quantum potential
R	Wave amplitude
Re	Reynolds number
ρ	Particle density
S	Wave phase
$\vec{T}$	Stress Tensor
U	Mutual inter-electrical Coulomb repulsion
V	Potential function
$\vec{v}$	Velocity vector
Φ	External time-dependent scalar potential
Ψ	Wave function
∇	3-D gradient operator

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 626/627
Prethodno priopćenje
Preliminary communication

APPLIED HYDROTECHNICS IN AGRICULTURE – AN ANSWER TO WATER SCARCITY

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ABSTRACT

The hydrotechnical response to water scarcity phenomenon and its subsequent effects consists mainly in works from rural areas (irrigation systems, water storage, land and water resources management works, ground water pumping) and will represent the main subject of this paper. The problem is not just of the water quantity but also water quality. Water harvesting, water recycling and re-use in irrigation, reduction of water losses, improvement of crop water productivity are all based on principles of hydrotechnics and can be achieved with sustainable hydrotechnical measures. Integrated planning of hydrotechnical measures offers opportunities for the enhanced management of water demand. This paper will review a series of technical options which can serve as a basis for developing a sustainable agricultural system in response to growing water scarcity.

Key words: applied hydrotechnics, sustainable land management, agriculture, water scarcity

INTRODUCTION

Water scarcity is defined in many cases as the situation where water availability in a region presents values below water demands. Even there are significant opinions in drawing a typology of water scarcity, scientists agreed of defining water scarcity as a relative concept generated both by nature and humanity. Other concepts related to water scarcity are the water stress (an imbalance on medium term) and water shortage (which is defined only in terms of comparison (between minimum requirements and existing resources) without having attached a reference value). Using these terms (generally and mainly having a man-made character) in comparison with natural phenomenon (dryness, drought, aridity), we can define some links, from temporal point of view, between dryness and water shortage (short-time defined elements), between drought and water stress (medium term) and between aridity and water crisis as long time defined concepts. If we will pass in the social and economic sectors, water crisis may appear anywhere on scale time because in many areas, today, water crisis is not an issue of scarcity, but of access to fresh water.

METHODS

Water scarcity and droughts are two complex issues faced by our world. Fresh water resources recorded a continuous decreasing relative to societal use. This problem is driven by several key factors like climate change, land use changes, socio-economical changes, population growth, population migration, industrial activities etc.

One of the main economic sectors which strongly influence water scarcity increasing and spreading is agriculture. Clay (2004) mention that globally, the agricultural sector consumes about 70% of the planet's accessible freshwater which represents more than twice that of industry (23%), and dwarfing municipal use (8%). In a report from 2009, EEA states that agriculture only represents 24% of total water use at EU level but its share can reach up to 80% of water use in Southern Europe as a result of the high reliance on irrigation. Concluding, a sustainable managing of water use in agriculture represents a key theme in relating to water scarcity and drought.

Agricultural water management represents a part of a process of resource management that provides a key input to agricultural production and farmer incomes. Agricultural water management is mainly based on applied hydrotechnical techniques like irrigation and drainage but also on water management in rainfed agriculture, recycled water reuse, water and land conservation and watershed management. The strategy in implementing agricultural water management systems presents a transition from controlling water schemes to a more holistic one aiming to mitigate the environmental costs and risks of irrigation (land degradation, salinization, and erosion; reduction or loss of environmental flows; pollution; destruction of natural habitats and livelihoods through drainage of wetlands etc.) (World Bank, 2006).

A key aspect in developing an effective water resources management in agriculture was mentioned by Bossio et al. (2010) which argue that it must be well understand it the inextricably link between water cycle and land management.

DISCUSSION

The Millennium Ecosystem Assessment report from 2005 defines the ecosystem services as being the benefits which people obtain from ecosystems and distinguishes four categories of ecosystem services (supporting services, provisioning services, regulating services and cultural services), where the so-called supporting services are regarded as the basis for the services of the other three categories.

The applied hydrotechnical measures dedicated to mitigate water scarcity include several categories ranging from land reclamation and improvement works to water saving, water efficiency and the use of non-conventional water resources. For a better understanding on the measures needed to counteract the negative impact of water scarcity we need to perform a more profound analysis on what water scarcity means.

According to a document issued by Water Scarcity Drafting Group (E.U.) the term “water scarcity” has the following specific meanings: - an imbalance of supply and demand under prevailing institutional arrangements and/or prices, - an excess of demand over available supply, - a high rate of utilization compared to available supply, especially if the remaining supply potentials are difficult or costly to tap (MED Joint Process WFD/EUWI Water Scarcity Drafting Group).

In line with the 2007 European Commission Communication on Water Scarcity and Droughts, and as agreed by the EU MS6 water scarcity is a man-made phenomenon. It is a recurrent imbalance that arises from an overuse of water resources, caused by consumption being significantly higher than the natural renewable availability. Water scarcity can be aggravated by water pollution (reducing the suitability for different water uses), and during drought episodes (Strosser et al., 2012).

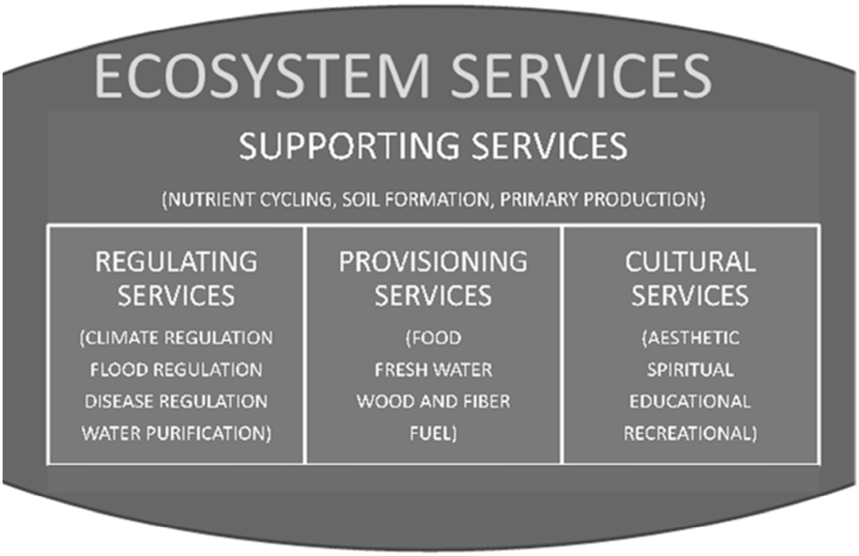

Figure 1 Categories of ecosystem services (reproduced after Millennium Ecosystem Assessment report from 2005, www.millenniumassessment.org)

Several water scarcity policy options were develop to answer these challenges:

- Environmental flows (The establishment of E-Flows will have significant direct or indirect benefits from well-functioning ecosystem services. From another perspective, restoring the E-flows regime will likely add value to a region in terms of qualitatively better ecosystems and services provided by them.);
- Sustainability of water efficiency targets;
- Incentives for increasing the efficiency of water use;
- Implementing sustainable and functional land management to avoid and/or counteract water scarcity and achieve water efficiency objectives (Sustainable land management is seen as the key to overcoming many land and water constraints, addressing globally important issues such as climate change adaptation and mitigation, scarcity of land and water etc. A sustainable implementation of a land management system can also provide a wide range of ecosystem services which in return will sustain water regulation, adaptation and mitigation of climate change (including here water scarcity too) (Almagro et al., 2013; Howden et al. 2007; Lal 2013))

– Implementing a sustainable management of the trade-offs and synergies between water use rights and environment.

Integrating irrigation and drainage works, water harvesting systems, wetlands, water re-use techniques in the water scarcity – ecosystem services – sustainable applied hydrotechnics nexus is an actual challenge and links between these components are under several pressures, natural or anthropic. The core of this nexus is represented by the necessity to achieve a balanced water cycle for achieving water use security.

A key aspect in this nexus is represented by water productivity. Water productivity is the amount of beneficial output per input unit of water. In some cases it is known (presented) as water efficiency. Water productivity is usually defined as a mass (kg) or monetary value of produce per unit of water losses due to evapotranspiration (Molden et al. 2010; Kijne et al. 2003). An increase of water productivity will result in using a smaller amount of water necessary to achieve a specific target. As a result, increasing water productivity is a method of water conservation or a sustainable way to cover a higher demand with less availability.

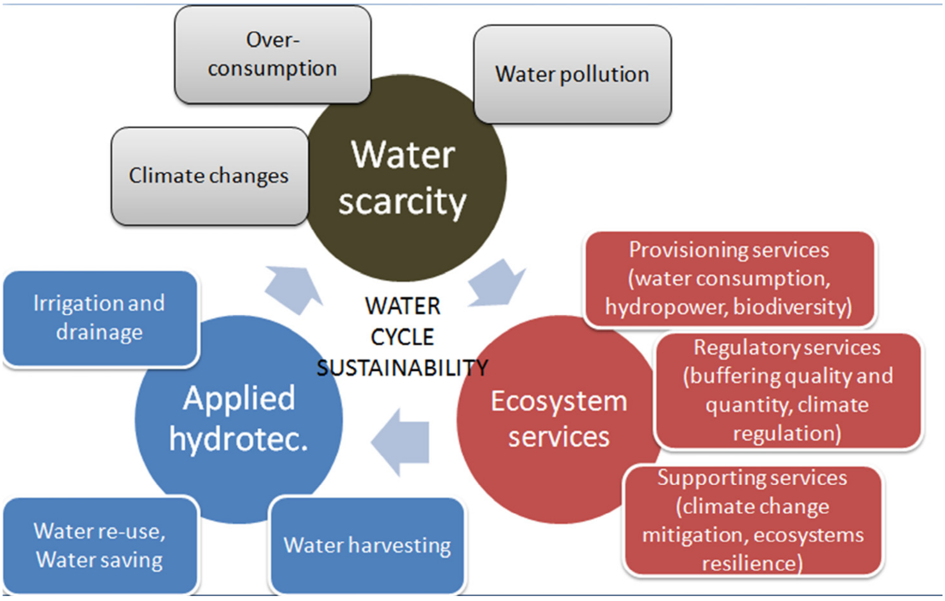

Figure 2 Conceptual framework: water scarcity – ecosystem services – applied hydrotechnics

Water productivity using applied hydrotechnical measures has a great importance mainly in agricultural systems. Peden et al. (2005) demonstrated that pro-active integration of irrigation and livestock management can lead to increased sustainability also having a positive impact on irrigation investments profitability. Other researchers concluded that supplemental irrigation with a better soil management practices (improving soil fertility) can play a significant role in improving the productivity of (rainfed) agriculture (Fischer et al. 2009).

Moreover, a proper combination of water from rainfall with a well-targeted irrigation, can result in higher agricultural production with the same amount of water in many areas which are 100% irrigated or 100% rainfed (Oweis and Hachum 2006; Geerts and Raes 2009).

Irrigation schemes must be adapted to on-demand systems leading this way to water saving and also providing better availability of water for ecosystems and other uses. Stuyt et al. (2009) mentioned the importance of new drainage techniques using variable drainage depths which should be introduced in agricultural water management systems. De Vries et al. (2010) emphasize the importance of alternative irrigation techniques in achieving a substantial reduction of water consumption.

CONCLUSIONS

Sharing a scarce resource and to limit environmental damage, it is imperative to limit future water use. In the context of current water scarcity which affects large areas worldwide, increasing water use efficiency (water productivity) for different purposes and simultaneously preserving the functioning of water bodies in a context of increased demand for food and energy, is a real challenge.

Applied hydrotechnical measures promote the coordinated development and management of water, land and related resources. However, this field of activity requires a shift in the management of water from water for food to water for multifunctional agroecosystems, considering the whole ecosystem base of provisioning, regulatory, cultural and supporting services.

An integrated approach of multiple ecosystem services of agroecosystems linked with elements of integrated water resource management and maximizing the benefits of sustainable applied hydrotechnical measures can be a powerful and sustainable response to freshwater scarcity.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.4:631.6.02
Stručni rad
Expert paper

3SWQM – WATERMARK FOR POLLUTION CONTROL OF SURFACE WATER

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SUMMARY

This paper presents the concept of a "watermark" model 3SWQM for monitoring surface water quality with possibility of real-time warning in case of accidental pollution or ecological risk. The idea of switching from a theoretical concept of intelligent monitoring station for the quality of surface waters, obtained through the CAE computational technology, to a superior level of technological readiness which will take effect as an experimental demonstrator (the *3SWQM* live-online-dynamic monitoring model), is illustrated in the current images from this paper. The special structure of the monitoring integrates IQ sensors and multiparameter probes for the measurement of the physicochemical and biological factors of the water body which is subject to pollution pressures. Anchored in the offshore of the flowing water the special mechanical structure of the station allows it to float in a fixed point for the monitoring of quality indicators at water surface. At the command of the onboard controller which equips the station this one can be immersed both for the monitoring of the quality indicators at different water levels (profile monitoring) as well as for frost protection during cold season. Thus equipped, the special monitoring station becomes an operational watermark in the infrastructure of the networks for surface water quality monitoring. The physical model thus designed allows the continuous evaluation in situ of the surface water "health status" with the purpose of warning in case of pollution.

Key words: buoy water quality monitoring, water pollution control, smart water quality monitoring systems, remote water quality monitoring network, AUV's.

INTRODUCTION

The present theoretical and experimental researches of the authors have been carried out for the realization of a special station for aquatic environment monitoring. Being thought as a "watermark" for pollution warning of surface flowing waters, the designed station achieves the "live-online-dynamic monitoring" of the quality indicators of investigated aquatic environment, through its set up directly in situ.

In order to establish the ecological quality of the aquatic ecosystems based on the biological quality/condition/health, the following factors should be taken into consideration: hydromorphic, chemical, physical-chemical as well as the specific pollutants with role in modulating of the biological factors/indicators [1]. The analyses of these factors give information about the environmental conditions including their further modifications with an anthropic implications as well as water surfaces in a certain period.

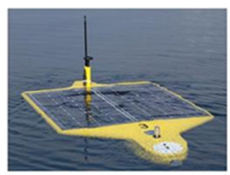
Today's tendency in the implementation of the monitoring systems of environmental water component is of decentralisation through data measuring and validation directly in situ, followed by on-line transmission to the regional centres for off-line processing and analysis [2]. Performing in real time the warnings to environment protection agencies and institutions for emergency situations, is made when the concentration values of environmental polluters exceed the values of the alert thresholds *MAC* prescribed – a concept promoted by the Water Framework Directive (2000/60/EC) on the state of water.

a) - Land fixed station [11, 12]

b) - Land semi-mobile station [13]

c) - Buoy monitoring [14, 15]

d) - *ROV* monitoring [16]



e) - .*AUV* monitoring [17]

Fig.1. Monitoring stations for the aquatic environment

From a functioning and in situ positioning point of view, the monitoring stations can be executed in the following constructive alternatives: fixed stations or semi-mobile onshore; buoy monitoring or floatable platforms on water; *ROV*s - remotely operated underwater vehicle, or *AUV*s - autonomous underwater vehicle for monitoring of the investigation (Fig.1).

We approach the atypical constructive alternative, namely a floatable structure with the possibility of immersion *3SWQM* model. Through the embedding of real time informational systems, *3SWQM* station distributes the informational architecture of environmental integrated systems monitoring to an architecture centred on device [3]. So, *3SWQM* station integrates multiparameter probes with different sensor configurations *IQ* in three positions on station for water quality indicators monitoring, and a powerful *IT* hardware-software system for data acquisition processing and transmission to the local terrestrial system centre.

	Parameter:	Range [MU], (Resolution; Response speed)
1)	Optical Dissolved Oxygen (ROX):	0 to 500%, (0.1%; < 5 sec);
2)	Dissolved Oxygen (DO):	0 to 50 mg/L, (0.01 mg/L; < 5sec);
3)	Conductivity:	0 to 200mS/cm, (<0.01mS/cm;<2sec);
4)	pH:	0 to 14 units, (0.01 units; < 3 sec);
5)	Temperature:	-5 to +35°C, (0.001 °C; < 1 sec);
6)	Turbidity:	0 to 4000 FNU, (0.1 FNU; < 2 sec);
7)	Redox Potential (ORP):	-999 to +999 mV, (0.1 mV; < 5 sec);
8)	Depth:	0 to 100 m, (0.001 m; < 2 sec);
9)	Ammonium:	0 to 200 mg/L, (0.01 mg/L; < 30 sec);
10)	Nitrate:	0 to 200 mg/L, (0.01 mg/L; < 30 sec);
11)	Chloride:	0 to 18000mg/L, (0.01mg/L; <30sec);
12)	Rhodamine:	0 to 200 μg/L, (0.1 μg/l; < 2 sec);
13)	Chlorophyll:	0 to 400 μg/L, (0.1 μg/l; <2 sec);
14)	Blue-Green Algae:	0 to 100 μg/L, (0.01 μg/L; < 2 sec);
15)	Total Dissolved Solids (TDS):	0 to 100,000 mg/L (variable);
16)	Total Suspended Solids (TSS):	0 to 1500 mg/L (~ < 2 sec).

Fig.2. *YSI* type multiparameter probe for monitoring the aquatic environment [18]

Fig. 2 shows the structure of *3SWQM* based on devices equipped with multiparameters probes. Multiparameters probes were built by a pool of sensors which are easy to change *in situ*. These probes are frequently used within the integrated monitoring systems because they allow a simultaneous dynamic (live) monitoring of many parameters from the same water area. The number and type of parameters that can be monitored live-online-dynamic by a single device in a particular area are written in the equipment specifications of the *YSI* multiparameter probes (Fig.2) [18].

METHODS FOR DESIGN AND OPTIMIZATION OF THE MECHANICAL STRUCTURE FROM THE 3SWQM STATION

The research of the design to build the special construction to monitor surface waters was based on a two-way flux between input data and output data modulated by the mechanical design, hardware-software and environmental conditions. There had been used 2D and 3D designs based on *CAE* (computer-aided engineering) software such as *CAD* (CatiaV5), *CFD* (Ansys Fluent V6.3) and *FEM* (Nastran Ansa V3).

CAE flowchart algorithm is shown in Fig. 3. The new concept of *3SWQM* station brings extra novelty in the area of water quality monitoring stations through geometry and versatility. Depending on the fitted equipment, *3SWQM* can be used both as a watermark for surveillance monitoring, and as investigation monitoring, for all surface water classes.

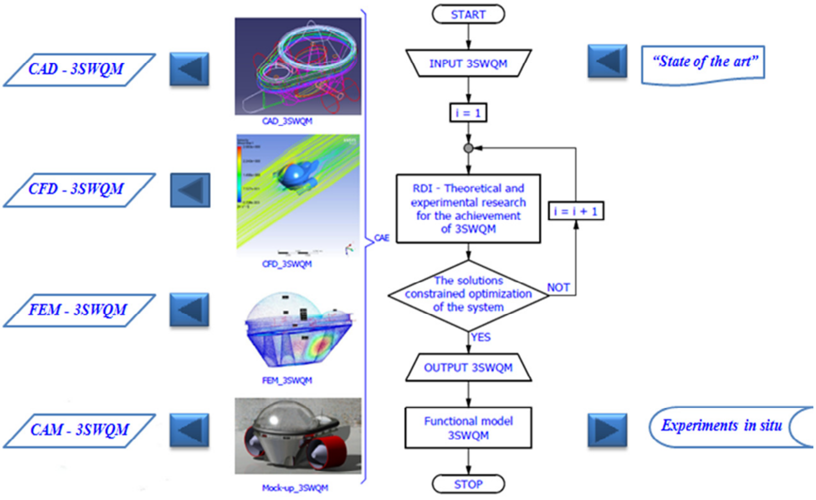


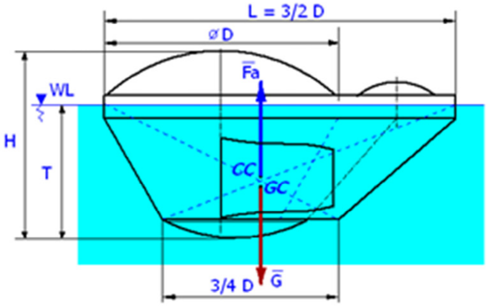
Fig.3. ***CAE*** **flowchart regarding the design of the** ***3SWQM*** **station**

Geometrical design of the *3SWQM* station

The geometrical shapes (cylinder, sphere, double cone) are frequently used as floater devices incorporated to the autonomous monitoring station, mode „Buoy Monitoring". In general, these stations are designed to monitor meteorological oceanographic and saline offshore parameters, but with some major modifications, these stations could be used to monitor lakes and rivers too.

For fresh surface waters, the geometry of the anchored float is characterized by maximum two key sections: (1) longitudinal section (float plane); (2) cross section to the direction of the river flow in the vertical plane of the center hull (the couple's master plane). These sections determine the fineness of the float coefficients that define the geometry and classify the special monitoring station.

To get a float with little water flow resistance, an oval section of the station in the floating plane was designed. The section was obtained from two circles of diameter *D*, respectively $d = D / 2$, which are tangent and connected externally. This form generates in horizontal planes the geometry of the underwater fairing of the special monitoring workstation, throughout the entire height of its draft mark. The 2D drawing of the monitoring station is shown in Fig. 4. The two dimensions $\{D, H\}$ are representative in the calculus of the *3SWQM* station indices (volume, displacement, mass of the on-board equipment, pumped water at immersion, etc.). Through a preliminary calculation program (D-V-Δ) made in MS Excel, the results from the table included in Fig. 4 were determined in accordance to the values of $D \in (5, 10)$ in [dm].



D [dm]	Vs [dm3]	Δv [kg]	M_{ech} [kg]
5	58.34269	40.97457	23.60644
6	100.8162	70.80406	40.79194
7	160.0924	112.4342	64.77608
8	238.9717	167.8318	96.69199
9	340.2546	238.9637	137.6728
10	466.7416	327.7966	188.8516

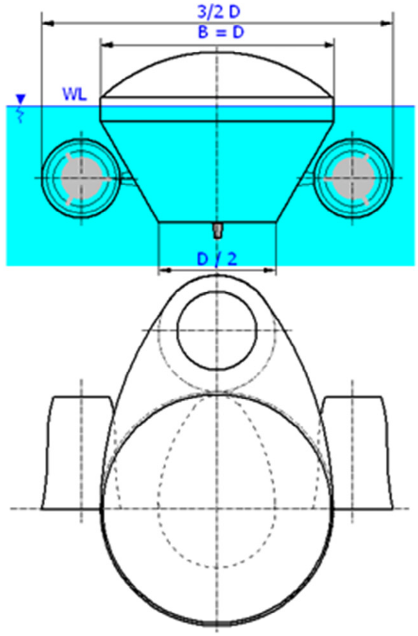


Fig.4. 2D geometry representation and the tabulation parameters characteristic of *3SWQM*

The methodology for calculating the overall geometry of the *3SWQM* station contain the following determinations according to the diameter D:

– Size of the *3SWQM* maximum section in water floatation plane is:

$$S_D = k_S \, \pi D^2 \tag{1}$$

where:

$k_S = 0{,}345319725 \cong 0.345$, represents the coefficient of horizontal section;

– Total volume of *3SWQM* station is given by relation:

$$V_S = \sum_{i=1}^{3} V_i = 0.1486\, \pi D^3 \tag{2}$$

where:

$$V_1 = \frac{7\sqrt{3}}{48} k_S \pi D^3 \tag{3}$$ is the volume of the *3SWQM* station underwater part, that has the geometry as an elliptical truncated cone;

$$V_2 = \frac{1}{10} k_S \pi D^3 \tag{4}$$ is the volume of the elliptical cylinder of the *3SWQM* station floating surface;

$$V_3 = 0.027 \pi D^3 \tag{5}$$ is the volume of spherical cap of the *3SWQM* dome.

– The *3SWQM* displacement for a draft mark $T = \frac{2}{3} H$ [dm] is given by relation:

$$\Delta_V = (V_1 + \tfrac{1}{2} V_2)\rho = \left(\frac{7\sqrt{3}}{48} + \frac{1}{20}\right) k_S \pi D^3 \rho \tag{6}$$

where ρ is the water density for temperate-continental regions.

– The volume of water required for immersion is given by:

$$V_{H2O} = V_3 + \tfrac{1}{2}V_2 = \left(0.027 + \tfrac{1}{20}k_S\right)\pi D^3 \qquad (7)$$

– *Smoothness coefficient* corresponding to the floating of the surface for Δ_V, on *3SWQM* station is given by relation:

$$C_w = \frac{A_{CWL}}{B*L_{CWL}} = \tfrac{2}{3}k_S\,\pi = 0.72 \qquad (8)$$

– *Fineness block coefficient* (volumetric) corresponding to the value Δ_V, on *3SWQM* station is given by relation:

$$C_B = \frac{V}{T*B*L_{CWL}} = \left(\frac{7\sqrt{3}}{48} + \frac{1}{20}\right)k_S\pi = 0.328 \qquad (9)$$

where:

$B = D$	= 0.600	[m]	(10)
$L_{CWL} = \frac{3}{2}D$	= 0.900	[m]	
$A_{CWL} = S_D = k_S\,\pi D^2$	= 0.389988	[m^2]	
$T = \frac{2}{3}H = \frac{2}{3}D$	= 0.400	[m]	
$V\rho = \Delta_V$	= 70.804	[kg]	
$\rho = 1$ (for water at 4°C)		[kg/dm^3]	

Analyzing the values that are characteristic to the station geometry (table of Fig.4) and based on the imposed constraints, the optimum size *D = 0.600* [m] was chosen. Discussion is made in chapter 3 of the paper. The parameter values (10) become input for *3D - CAD* software for *3SWQM* station. Also, the values for the finesse coefficients of the float station *3SWQM* $\{C_W = 0.72;\ C_B = 0328\}$ classify the station under "special ship fast", according to the theory of ships [7].

Design of the mechanical structure of the *3SWQM* station

The raising interest for reduced size monitoring systems generated the creation of the *3SWQM* station designed to monitor the ecological impact on aquatic system. *CAE* methodology and *CAD* (CatiaV5) software were used. The characteristic of specific structure is presented in Fig. 5 b). For *D = 0.600* [m], the overall dimensions of the station resulting by design are: *{L*, B*, H*} = {1.200 x 0.900 x 0.700}* [m], where: *L**- is the length of the monitoring station equipped with anchoring devices and helm; *B**- is the width of the monitoring station equipped with hydro-generators; *H**- is the height of the monitoring station equipped with a landing and holding platforms.

In order to visualize the inner compartments, the following sections were made (Fig.5): a) transversal section-plan (‖yOz); c) longitudinal section-plan (xOz). At this stage the monitoring station isn't equipped with onboard equipment. The "nude" structure of the special construction consists of hull, closed bodywork surfaces for dipping, and the boundary of the interior compartments.

a) The transversal section b) The 3SWQM station c) The longitudinal section

Fig.5. ***CAD*** **design for the structure of** ***3SWQM*** **station**

The nude structure of the *3SWQM* station has an internal architecture consisting of the following compartments:

– Permanent dry compartment bordered by central elliptical cylinder, ovoid floating scheme, spherical calotte, visiting hatch and the closing surfaces. In this area there are batteries, tapping water pumps, controller, acquisition and transmission data system, photovoltaic panels, sealed connectors, multiparameter probes, cables and other devices;
– Permanent wet compartment bordered by the surface of three inversed circular truncated cones with a communication trap under the floating level for water circulation/flowing. This area protects the *IQ* sensors from mechanical stress;
– Flooding compartment is the volume border by the hull and by the exterior surfaces of the other two adjacent compartments. This compartment is used for submerging the monitoring station by inserting water under pressure provided by the flooding pumps. The immersion of the monitoring system is controlled automatically and it is activated to protect the monitoring station against frost, vandalism or underwater monitoring (profile).

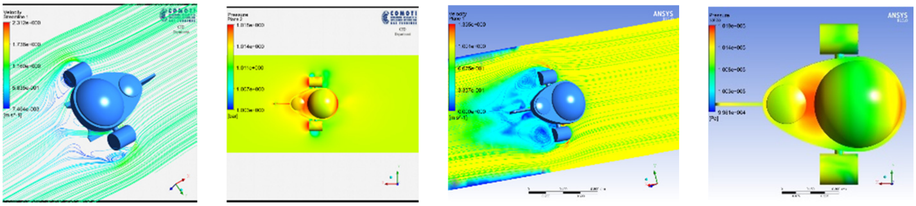
The input model construction of the monitoring station will be made by Al 99.5 nonmetallic panels/sheets with 1.5 mm thickness, density of ρ = 2.7 [kg/dm^3] and tensile strength $\sigma \in$ (105 ÷ 145) [MPa]. Based on *CAD*-3D analysis, the total mass of the monitoring station M_{SC} = 29.968 [kg] was calculated. The next steps of the theoretical methodology (*CAE*) for the *3SWQM* experimental model, are numerical simulations with *CFD* and *FEM* software (*CAE* flowchart of Fig. 3).

Hydrodynamic simulation was done with *ANSYS CFX* software. The station was considered a solid body with the geometry volume corresponding for diameter $D = 0.600$ [m]. Water flow was considered ideal fluid (incompressible and without viscosity), with stationary flow through a tube current (a hydrological channel). The Ω field established for the working fluid has a volumetric size of 6 x 6 x 12 [m].

The mathematical model of the simulation program is based on the Navier-Stokes equations for incompressible Newtonian fluids. In this case we have [10]:

$$\rho\left(\frac{\partial v}{\partial t} + v \cdot \nabla v\right) = -\nabla p + \mu \nabla^2 \mathrm{v} + \mathrm{f} \qquad (11)$$

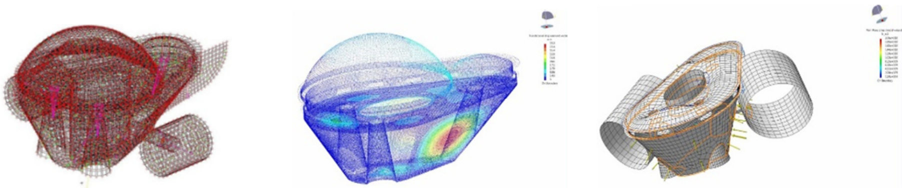
Simulations were made for the two possible states of operation of the monitoring station: buoyancy and immersion of *3SWQM*. In the buoyancy state, water speeds were simulated in the area $v \in$ (0.1 ÷ 10) [m/s]. Dipping status was simulated for steps of 1 [m], up to the depth of 100 m (max 1 MPa). At greater depths, low speeds were simulated. Speed and pressure charts for *CFD* numerical simulation for station *3SWQM* are shown in Fig. 6. Discussion is made in chapter 3 of the paper.



a) Velocity [m/s] b) Pressure [bar] c) Velocity [m/s] d) Pressure [bar]

Fig.6. ***CFD*** **numerical simulation for the nude structure of** ***3SWQM*** **station**

For material selection and dimensioning of the monitoring station structure, the finite element method (*FEM*) was used. Strains and stress values (nodal values) for the *3SWQM* station structure were determined with *Nastran Ansa V3*. The *3SWQM* station structure was meshed with an average mesh size of 20 x 20 [mm] (Fig.7.a.).



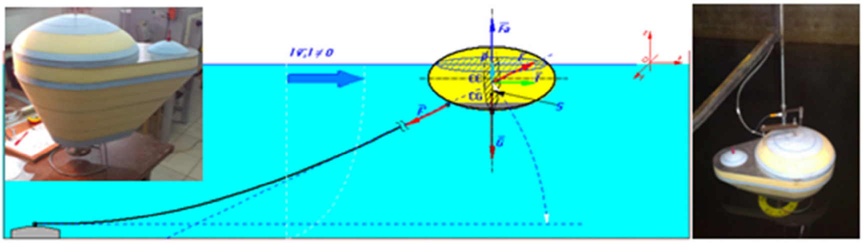
a) Mesh network b) Translational displacement c) Stress in selected nodes

Fig.7. ***FEM*** **numerical simulation for the nude structure of** ***3SWQM*** **station**

Maximum loads determined by *CFD* numerical simulation and analysis are input data for *FEM* simulation and numerical analysis. For the buoyancy state of the station, critical stress is not given by the speed of surface water flow, but by the force of impact with various foreign floating bodies. Fig.7. b) shows the strains for maximum stress of the structure in the area of hydro-generators. For the submerged status, critical load is given only by the hydrostatic pressure of water at high depth, on the station hull. Fig.7. c) shows the stress in some selected nodes for the structure immersed at 100 [m]. Discussion is made in chapter 3 of the paper. The prototype station *3SWQM* has mechanical structure made of Al 99.5, with a density ϱ=2.7 [kg/dm3], tear strength $\sigma \in$ (105 ÷ 145) [MPa] and thicknesses of 1.0; 1.5; 2.0 and 5.0 [mm].

Preliminary experiments on the physical model of *3SWQM*

The physical "mock-up" model the *3SWQM* station is shown in Fig.8 a). It is made of extruded polystyrene tiles and is reinforced with horizontal sections of sheet Al 99.5 2 [mm] thick. In order to perform hydrostatic and hydrodynamic experiments for numerical simulations validate, traditional methods were used in the hull basin (Fig.8. c) [10, 11].



a) Mogk-up *3SWQM;* b) Schematic representation of buoyancy state; c) Buoyancy model

Fig.8. Experiments with the physical "mock-up" model of the *3SWQM* station

The *3SWQM* model was attached on a mobile device which allows floatability of the structure as well as loading of the monitoring station for immersion. The device has a load cell which measures at lengthening or compression on the scale (0 ÷ 100) [daN] and a sensor based on vibrations (called velomitor) with a measurable range of (0 ÷ 10) [mm/s].

DISCUSSION

The *3SWQM* station is made from a double-shell floating structure, from Al 99.5, which is compartmented at the interior for the onboard equipment. The station is equiped with *IQ* sensors, communication and *IT* hardware, devices to supply "green energy" required to run the watermark quality monitoring aquatic environment. The station geometry has little water flow resistance due to the fineness of the float coefficient values {$C_W = 0.72$; $C_B = 0.328$}. Thus, the section of the the anchoring traction cable and the mass ballast (dead body) are reduced.

For stations with a diameter in the range $D \in (0.5 \div 1.0)$ [m], the station displacement varies: $41.0 \leq \Delta_V \leq 239$ [kg]. They are designed as floating stations for monitoring surface waters (rivers and lakes). We recommend mean values for sizing the structures within this interval, in order to obtain maximum configuration equipment in a minimum volume of the monitoring station. For the suitable diameter $D = 0.600$ [m] of the *3SWQM* station, the displacement value of $\Delta_V = 70.80$ [kg] is achieved when net weight is $M_{ech} = 40.80$ [kg]. In this case handling and capacity constraints on optimizing station equipment can be regarded as fulfilled.

A special structure was obtained by means of the partitioning of the station, using 3D CAD modelling. First, the station structure allows the installation and protection of multiparameter probes necessary for monitoring by immersing them in the aquatic area subjected to direct investigation. Second, using double walls as ballast compartments allows the station to be flooded in order to monitor the profile at various depths and to protect the station during winter.

CFD numerical analysis for *3SWQM* station highlighted the disruptive influence of hydro-generators on stationary flow of the working fluid (water) and their interference with the hull. The mechanical grip system of the hydro-generators on the station body will be changed by changing overall components, and by positioning and clamping the surface profiling. Changes of the anchoring positions for various water current speeds were also simulated: front (bow) or rear (aft). Analysing the turbulences from the speed charts, one can conclude that the position for anchoring device should be changed.

FEM analysis shows that the most loaded part of the mechanical structure is the area where the hydro-generator struts are fastened to the float body. The gripping position of the hydro-generators will also be changed due to technological reasons. The *3SWQM* station was considered as submerged vehicle with double shell structure. Three types of material for manufacturing were taken into account: stainless steel, aluminum and carbon fiber composite material. Aluminium was prefered in order to reduce the structure weight and to increase the mass of the useful equipment.

The displacement of the *3SWQM* station is given by the weight of the displaced water volume for a certain floatability condition, which in fact is the fully equipped station weight. According to the measurements, we have Δ^{*}_{V} = M_{sc} + M_{ech} = 30.50 + 39.20 = 69.70 ~ 70.00 [kg]; where: M_{SC} - mass structure; M_{ech} – mass useful of board equipment.

During the hydrodynamic measurements, the water flow resistance was determined by means of mock-up traction, for a immersion i = 0.55 [m] and for speeds $v \in$ (1.00 ÷ 2.00) [m/s], with a step of 0.25 [m/s]. Results are shown in Fig. 9. The drag force of the nude structure has values in the range $Rt \in$ (6.00 ÷ 21.0) [daN].

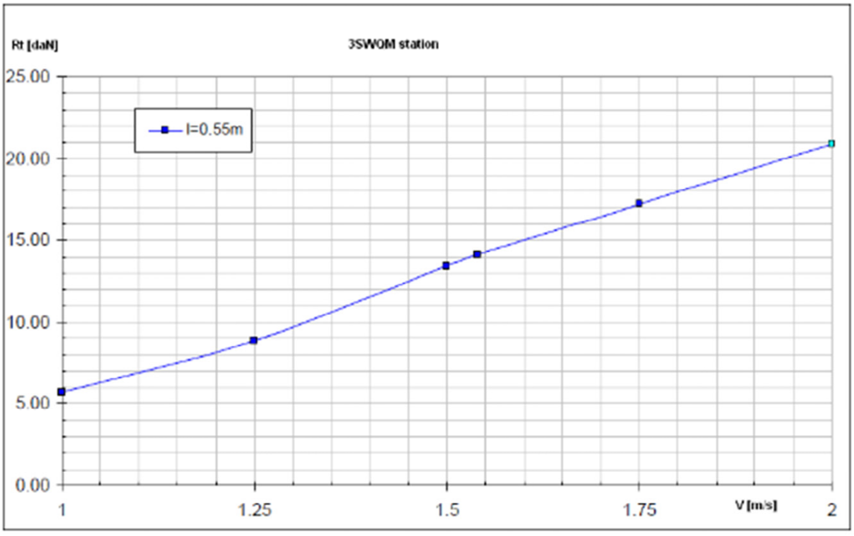


Fig.9. Drag force a physical model *3SWQM*

CONCLUSIONS

The *3SWQM* station, designed to monitor the pollution of surface water, adds new features and versatility to the already existing water quality monitoring systems. It is easy to install and manouver in situ (Δ^{*}_{V} ~70.00 [kg]), and it allows a dynamic monitoring of the aquatic system (surface and deep waters) based on a variety of multiparameter probes carried by the monitoring system.

Depending on the onboard equipment, the *3SWQM* station can be used for research and full monitoring mode on all surface waters. A network of monitoring systems is very useful in providing continuous information regarding the characteristics of the aquatic system, allowing a specific and fast reaction to solve any potential harmful situation from the monitored area.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

CRITICAL POINT DETERMINATION OF THE CLARIFYING CURVE OF AQUEOUS DILUTED SUSPENSIONS

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SUMMARY

In the present paper there are presented an algorithm and a program for determining the position of the critical point of the clarifying curve drawn on the basis of data obtained from sedimentation experiments of dilute aqueous suspension of solid particles in stationary column, conducted in the laboratory. The algorithm and the program have been designed for accurate determination of the critical point coordinates of a clarifying curve of dilute aqueous suspension of solid particles, fast and convenient. It is to point out that the critical point of a clarifying curve corresponds to the initial moment from which, in the stationary column, there are only two characteristic areas, namely: *a zone of clarified water* and *a zone of concentrated settled sludge in the compaction process.* Knowing the position of the critical point of the clarifying curve of an aqueous suspension of solid particles is particularly important to the design of water treatment plants based on gravity separation (sedimentation), the coordinates of the critical point, namely: *the critical point time* and *the critical point height,* representing the essential dimensioning parameters.

Key words: sedimentation of aqueous suspension in stationary column, algorithm, program, clarifying curve, critical point.

INTRODUCTION

If in a glass column there is introduced a certain amount of diluted suspension, composed of water and settleable solid particles and let it rest, it can be observed, after a period of time, the appearance of three distinct characteristic areas, namely: *a zone of clarified water* at the top of the column, *a zone with an aqueous suspension of solid particles in the process of sedimentation* at the middle of the tube and and *a zone with concentrated settled sludge* at the bottom of the column [3, 4, 7]. These three areas are separated by two interfaces, namely: *a clarified water – aqueous suspension of solid particles interface* and *an aqueous suspension of solid particles – concentrated settled sludge interface*. It is to be noted that the zone with *aqueous suspension of solid particles* is usually vertically layered, as a function of the concentration of particles in suspension in the settling process.

Over time, the clarified water – aqueous suspension of solid particles interface descending, while the aqueous suspension of solid particles – concentrated settled sludge interface is lifting. At a certain point, the two interfaces are overlapping, forming a common interface, namely, clarified water – concentrated settled sludge interface, in column remaining only two distinct characteristic zones: a clarified water zone and one of concentrated settled sludge.

If the experiment is continued, it is observed that the *clarified water - concentrated settled sludge interface* descends very slowly over time (the speeds are much lower than the descend speed of *clarified water-suspension interface* from the first part of this process) properly to the settled sludge compaction process, and after a long period of time the interface position of *clarified water - concentrated settled sludge* is stabilized at a certain height that does not undergo changes.

If in a coordinate system *time / height* is plotted the variation of the positions of the interface *clarified water - aqueous suspension of solid particles* against time, is obtained the *clarifying curve* of the *aqueous suspension of solid particles,* and if is plotted the variation of the positions of the interface *aqueous suspension of solid particles - concentrated settled sludge* against time is obtained the *settling curve of the settled sludge.* At some point in time, the two curves are intersecting at a point C called *the critical point*, and then are overlapping. The significance of the critical point on the clarifying curve of a dilute aqueous suspension of solid particles is as follows: delimiting the field of aqueous suspension clarification process by the field of concentrated settled sludge compacting process (see Figure 1) [6].

The coordinates of the critical point, for a given dilute aqueous suspension of solid particles, namely: *the critical point time* and *the critical point height,* are also extremely significant, *the critical point time* indicating the period of time after which the clarification process of the dilute aqueous suspension of solid particles is completed, and *the critical point height* indicating the maximum height that may have the concentrated sediment sludge layer [5, 7]. It is to be mentioned that the critical point coordinates are constitute in the essential dimensioning parameters for the design of water treatment equipment based on gravity separation type sedimentation.

Also, the slope of the clarifying curve tangent at the critical point is a highly significant parameter, this indicating which is the speed of the *clarified water – aqueous suspension of solid particles interface* at the end of the diluted aqueous suspension of solid particles clarification process.

It is to be mentioned [7] that in the case of aqueous suspension of solid particles with low concentration, at the solid particles settling, the effect of the interface between the particles is negligible and the settling velocity can be determined with a good accuracy on the basis of Stokes' Law (specific to the sedimentation in the laminar regime). With the increase of the suspended solid particles concentration, the particles settling conditions are modified, because of the interferences between them, appearing the so-called "hindered settling", the settling velocity being unable determined by Stokes's Law.

Also, is to be noted that the significant negative effects on sedimentation in the laminar regime [7] are produced with the variation of the *size range of the solid particles from the aqueous suspension* and because of *the proximity of the column walls.*

Thus, if the range of the particle size variation is not more than 6:1, then at the sedimentation of the aqueous suspension of solid particles, the interfaces *clarified water – aqueous suspension of solid particles,* respectively *aqueous suspension of solid particles - concentrated settled sludge* are sharp and their evolution can be monitored accurately. In addition, the stratification zones from the column are clearly defined. In this case, if it is known the rate of the *clarified water – aqueous suspension of solid particles interface* in the period in which the particles sedimentation is unhindered, can be determined by the Stokes's law an equivalent diameter of the suspended solid particles.

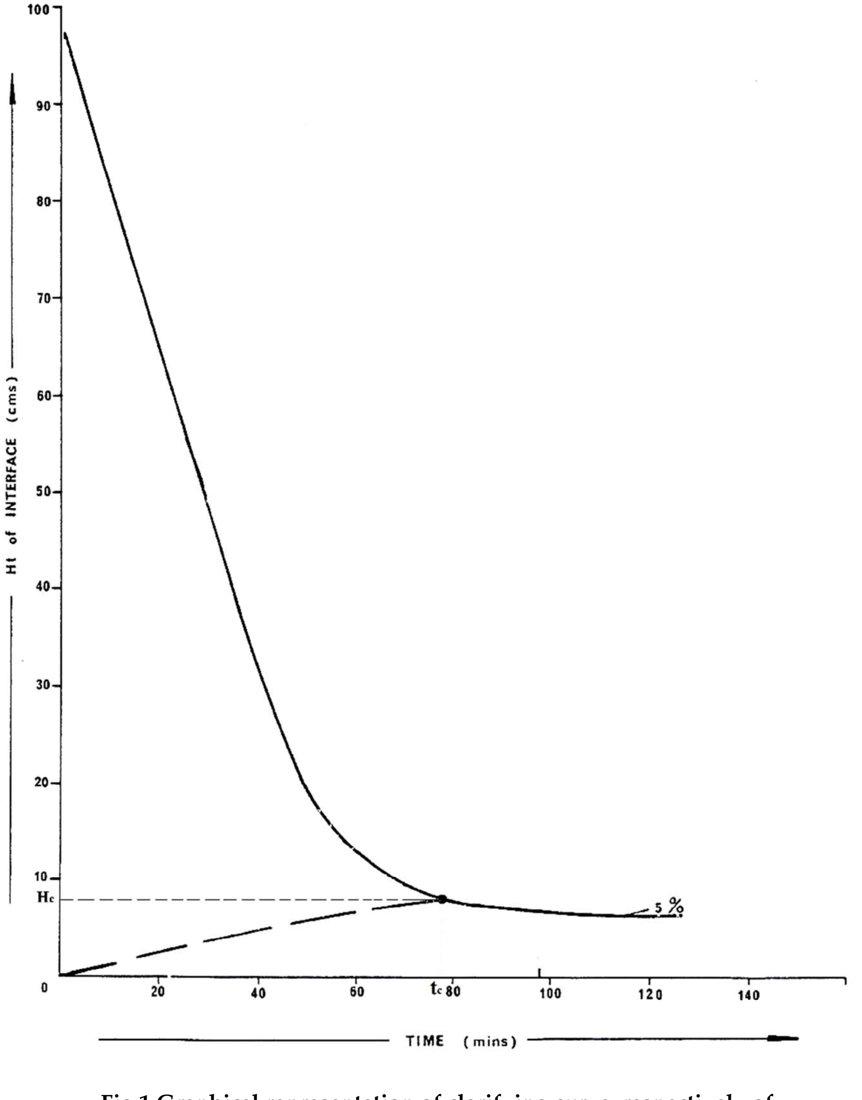


Fig.1 Graphical representation of clarifying curve, respectively of settling curve [7]

If the range of the particle size variation is greater than 6:1, then both the clarified water – aqueous suspension of solid particles interface, respectively aqueous suspension of solid particles - concentrated settled sludge interface, and the layered zones from the column are becoming less and less defined, as the range of size particles variation increases compared to a value of 6:1. In this case, it becomes increasingly difficult to follow the evolution of the clarified water – aqueous suspension of solid particles interface, respectively aqueous suspension of solid particles - concentrated settled sludge interface, particularly that of the aqueous suspension of solid particles - concentrated settled sludge interface is very difficult to distinguish [1].

The effect of the stationary column walls proximity on the aqueous suspension of solid particles sedimentation becomes negligible if the ratio between the equivalent diameter of the solid particles in the suspension and the stationary column diameter is more than 1:100.

If during the sedimentation experiments of various aqueous suspension of solid particles, conducted in stationary column, to which following the evolution of the *aqueous suspension of solid particles - concentrated settled sludge interface* is extremely difficult to put out, if not impossible, for determining the position of the critical point on the clarifying curve an approximate graphical method is used [7], considering that the critical point is found (see Figure 2) at the intersection with the clarifying curve of the angle bisector formed by the tangents to the clarifying curve in the unhindered sedimentation areas (corresponding to the initial domain of the clarifying curve), respectively to the sludge compaction (corresponding to the final domain of the clarifying curve).

The approximate graphical method provides a good estimation of the critical point position.

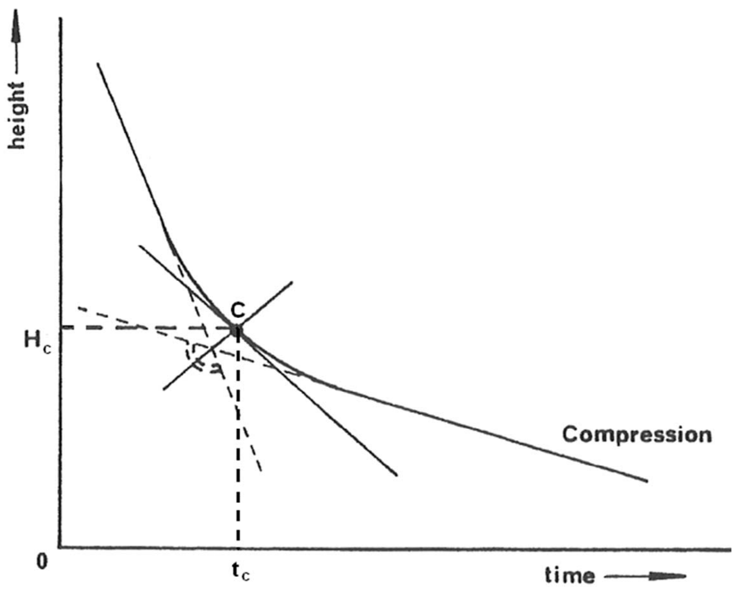


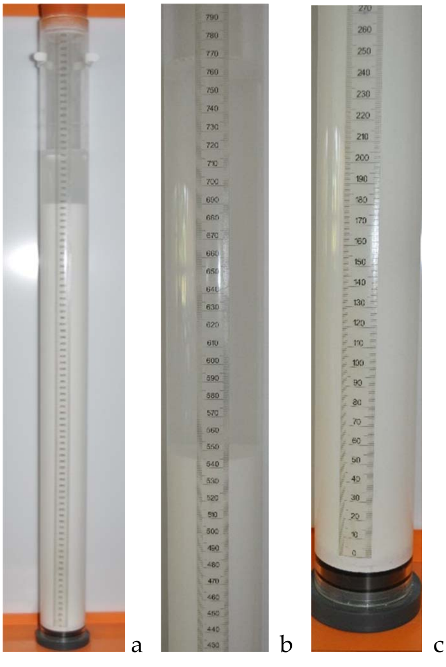
Fig.2 The graphical method for determining the critical point position [7]

METHODS

The experimental study was conducted on a laboratory stand, W2 Sedimentation Studies Apparatus - Armfield Limited, UK, which is equipped with 5 glass columns with an inside diameter of 50 mm and the useful height (with scale) of 940 mm (see Figure 3).

During the experiment, the researches were carried out using an aqueous suspension of calcium carbonate with a concentration of 8 % (see Figure 4 a).

Fig. 3 **Laboratory stand W2 Sedimentation Studies Apparatus – Armfield Limited**



a b c

Fig. 4 The appearance of column with the studied suspension during the experiment

During the experiment, it was found that the interfaces *clarified water – aqueous suspension of solid particles*, respectively *aqueous suspension of solid particles - concentrated settled sludge* are not clearly delineated and their evolution can be monitored with difficulty (particularly the evolution of *aqueous suspension of solid particles - concentrated settled sludge interface* is practically impossible to follow – see Figure 4 b and c).

In this case, have been recorded only the interface positions *clarified water – aqueous suspension of solid particles* for a period of 24 hours, as follows: from 0.1 to 0.1 hours during the first 1.5 hours of the experiment, and then every hour up to 6 hours and at 24 hours.

The results registered will be entered in the calculation program in a form compatible with it. It is to be mentioned that in a previous paper [2] was presented the methodology for plotting the clarifying curves of aqueous suspensions of solid particles.

RESULTS

The program for determining the critical point position, if the critical point position is estimated by graphical method, was developed based on a sequential algorithm whose structural scheme is shown in Figure 5.

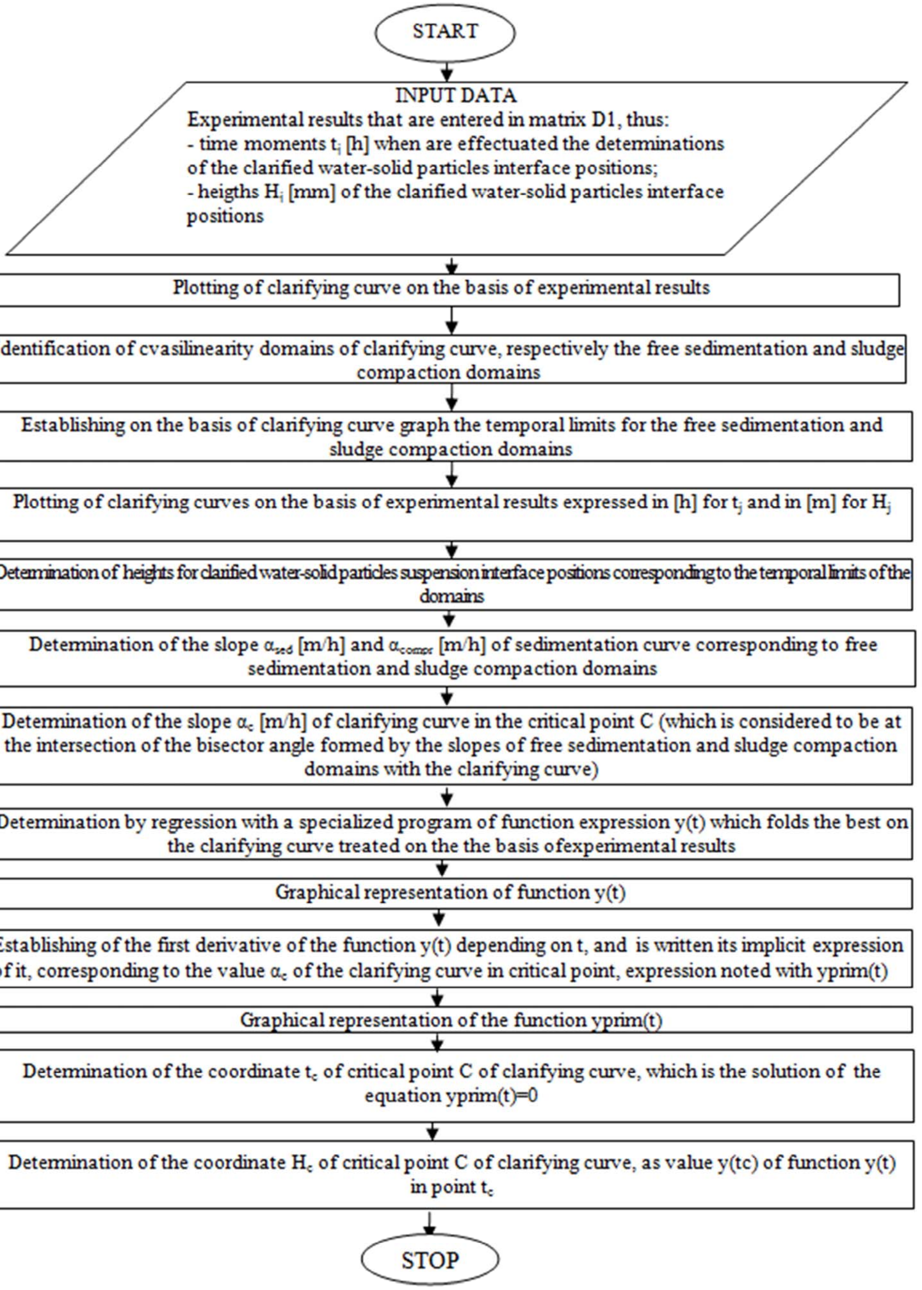


Fig. 5 Structural scheme of the sequential algorithm

The program, was developed in the MathCad programming software, interactive and very easy to use, is given below.

ALGORITHM FOR DETERMINING THE CLARIFYING CURVE CRITICAL POINT COORDINATES OF AN AQUEOUS SUSPENSION OF SOLID PARTICLES

Clarifying curve is plotted on the basis experimental results of clarification in stationary column of a specific suspension of solid particle. It is noted than in the DEMO application, there are used experimental results obtained at clarification in stationary column in laboratory conditions of a volume of 1.5 dmc of aqueous suspensions of calcium carbonate powder, with concentration of 8%.

Are entered experimental results in the input data matrix DI, thus:

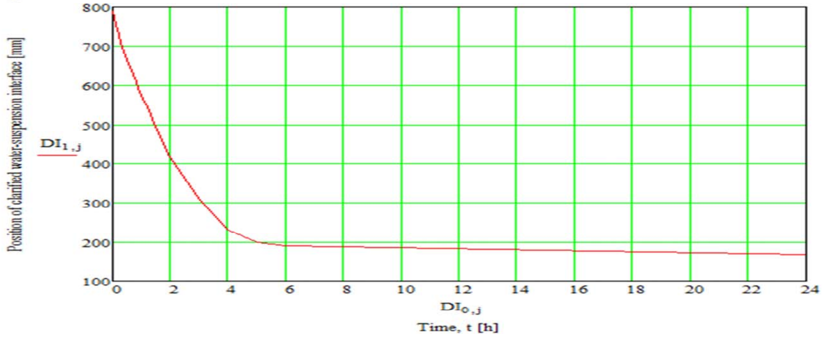
- on the row 0 of the matrix DI are written the time moments tj [h] when are effectuated the determinations of the clarified water-solid particles aqueous suspension interface, denoted by DI 0,j;
- on the row 1 of the matrix DI are written the heights Hj [mm] of the clarified water-solid particles aqueous suspension interface position denoted by DI 1,j;

where, with j is noted the current number of the determination which is effectuated and whose maximum value corresponds to the number of columns of the matrix DI.

$$j := 0..21$$

$$DI := \begin{pmatrix} 0 & 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 & 1 & 1.1 & 1.2 & 1.3 & 1.4 & 1.5 & 2 & 3 & 4 & 5 & 6 & 24 \\ 790 & 756 & 731 & 708 & 686 & 665 & 646 & 627 & 609 & 591 & 574 & 557 & 543 & 527 & 512 & 497 & 418 & 305 & 229 & 198 & 190 & 167 \end{pmatrix}$$

It is plotted the variation curve of the positions Hj of the clarified water-solid particles aqueous suspension interface, depending on the time moments tj, for considered suspension, which is named *clarifying curve*.



It is plotted the variation curve of the positions Hj of the clarified water-solid particles aqueous suspension interface, depending on the time moments tj, for considered suspension, which is named *clarifying curve*.

It is noted that the plotting of the variation Hj of clarified water-solid particles suspension interface, depending on time moment tj , using the measurement units [mm] for Hj and [h] for tj, is only useful for highlighting areas of its quasiliniarity, which are corresponding to characteristic domain of clarifying:

- of free sedimentation (in initil period);
- of compaction of sludge (in final period).

Are established, using the graph, temporal limits of free sedimentation domain, respectively of sludge compaction, thus:

- previous limit of free sedimentation domain is initial moment t0 [h]:

$t0 := DI_{0,0}$ $\qquad t0 = 0$

$tlimsed := DI_{0,17}$ $\qquad tlimsed = 3$

- previous limit of sludge compaction domain is considered the moment tlimcomp [h]:

$tlimcomp := DI_{0,20}$ $\qquad tlimcomp = 6$

- posterior limit of sludge compaction domain is the infinite time tinf [h] (in calculation is taken a finite value of time, after which is considered that the compaction process is completed):

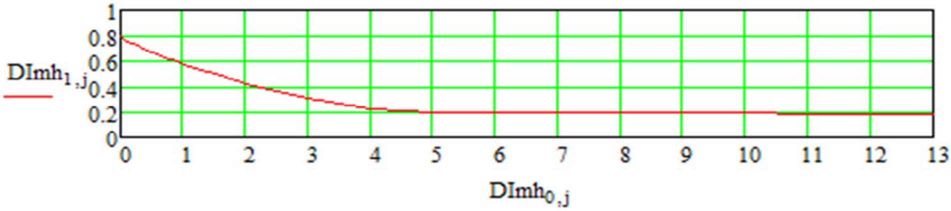
$tinf := DI_{0,21}$ $\qquad tinf = 24$

Because is the previous calculations Hj and tj will be expressed in units of measurements, [m] for Hj, respectively [h] for tj, further will be used the matrix DImh in which experimental data are entered in [m] for Hj and [h] fot tj.

$$DImh := \begin{pmatrix} 0 & 0.1 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 & 0.7 & 0.8 & 0.9 & 1 & 1.1 & 1.2 & 1.3 & 1.4 & 1.5 & 2 & 3 & 4 & 5 & 6 & 24 \\ 0.790 & 0.756 & 0.731 & 0.708 & 0.686 & 0.665 & 0.646 & 0.627 & 0.609 & 0.591 & 0.574 & 0.557 & 0.543 & 0.527 & 0.512 & 0.497 & 0.418 & 0.305 & 0.229 & 0.198 & 0.190 & 0.167 \end{pmatrix}$$

It is plotted the variation curve of the position Hj of the clarified water-solid particles suspension interface, depending on the time moments tj, in measurement units [m] for Hj and [h] for tj, curve in which the curve slopes appear in real size (because an unit from time axis has the same size with an unit from the clarified water-solid particles suspension interface axis).

It is noted that for reasons of writing in the graph is represented only the significant part of the curve (for tj between 0..13 h), but in calculations are used all data .



It is determined the heights of clarified water-solid particles suspension interface corresponding to the temporal limits of free sedimentation domain, respectively of sludge compaction:

- height H0 [m] of initial position of clarified water-solid particles suspension interface, corresponding to initial moment t0 [h]:

$$H0 := DImh_{1,0} \qquad H0 = 0.79$$

- height Hlimsed [m] of clarified water-solid particles suspension interface position, coresponding to moment tlimsed [h]:

$$Hlimsed := DImh_{1,17} \qquad Hlimsed = 0.305$$

- height Hlimcomp [m] of clarified water-sludge in compaction interface position, coresponding to moment tlimcomp [h]:

$$Hlimcomp := DImh_{1,20} \qquad Hlimcomp = 0.19$$

- height Hinf [m] of clarified water-sludge in compaction at infinite interface position, coresponding to moment tinf [h]:

$$Hinf := DImh_{1,21} \qquad Hinf = 0.167$$

It is calculated the slope lsed [m/h] of clarifying curve for free sedimentation zone (which is actually the velocity of the free sedimentation), thus:

$$\alpha sed := \operatorname{atan}\left(\frac{Hlimsed - H0}{tlimsed - t0}\right) \qquad \alpha sed = -0.16$$

It is calculated the slope lcomp [m/h] of clarifying curve for sludge compaction zone (which is actually the velocity of the free sedimentation), thus:

$$\alpha comp := \operatorname{atan}\left(\frac{Hinf - Hlimcomp}{tinf - tlimcomp}\right) \qquad \alpha comp = -0.001$$

It is calculated the slope lC [m/h] of clarifying curve in its critical point C as average between the slopes from quasiliniear zone of free sedimentation, respectively of sludge compaction of curve, if is considered that the critical point C of clarifying curve is found at its intersection with the angle bisector between slopes in cvasilinear ares of free sedimentation, respectively of the sludge compaction of the curve:

$$\alpha C := \frac{\alpha sed + \alpha comp}{2} \qquad \alpha C = -0.081$$

The critical point of clarifyingg curve represents its point of intersection with the variation curve of sludge compaction height and correspond to the moment in which interfaces clarified water-suspensions and suspensions-compacted sludge are overlapping and in the column in which the sedimentation process take place there are only two areas: one of clarified water and one of sludge in compaction, ie the clarifying process is over. The slope of clarifying curve in critical point represents velocity of clarified water-suspension interface in moment of overlapping with suspension-sludge in compaction interface. It is to be noted that the sedimentation process in stationary column, sludge layer in compacting corresponding to crtitical point has the greater height.

The critical point of clarifying curve is defined by its coordinates tC and HC, ie the moment of time respectively the height of clarified water-sludge in compaction interface position corresponding to critical point.

It is determined by regression with a specialized program expression off function y(t) that folds (fitting) the best on clarifying curve plotted on experimental results.

The function y(t) taken into account has the form:

$$y(t) := \frac{a + c\cdot t + e\cdot t^2 + g\cdot t^3}{1 + b\cdot t + d\cdot t^2 + f\cdot t^3}$$

having the coefficients:

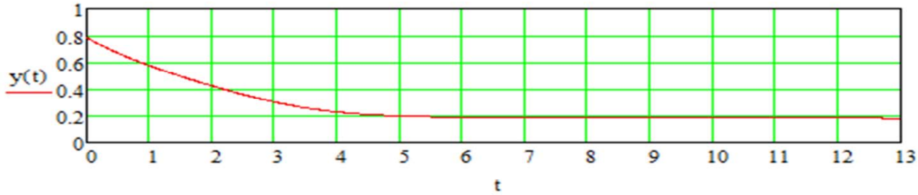
$a := 0.78555862 \qquad b := 0.073287875 \qquad c := -0.2245318 \qquad d := -0.089613717$

$e := 0.015269109 \qquad f := 0.027113179 \qquad g := 0.0036344411$

and the value of the regression factor: $r^2 := 0.99988691$

The graphical representation of the function y(t) is the following:

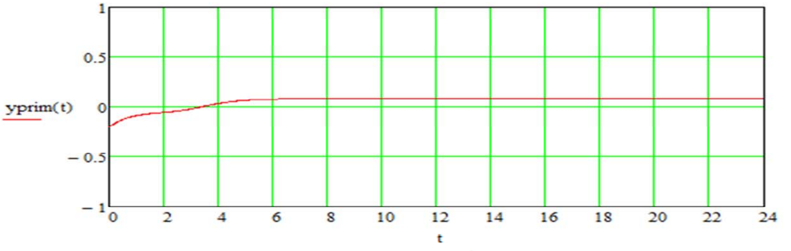
It is noted that for reasons of writting in the next graph is represented only the significant part of the function y(t), (for tj between 0...13 h).



It is established the expression og the first derivative of the function y(t) depending on t, and it is written its implicit expression corresponding to the slope value of the clarifying curve C [m/h] in the critical point, expression noted with yprim(t), which is the following:

$$yprim(t) := \frac{\left(c + 2\cdot e\cdot t + 3\cdot g\cdot t^2\right)\cdot\left(1 + b\cdot t + d\cdot t^2 + f\cdot t^3\right) - \left(a + c\cdot t + e\cdot t^2 + g\cdot t^3\right)\cdot\left(b + 2\cdot d\cdot t + 3\cdot f\cdot t^2\right)}{\left(1 + b\cdot t + d\cdot t^2 + f\cdot t^3\right)^2} - \alpha C$$

The graphical representation of the function yprim(t) is the following:



It is determined the moment of time tC [h] corresponding to the critical point C of clarifying curve, which is even the solution of the equation yprim(t)=0:

sol := root(yprim(t), t, 2, 4) sol = 3.39

tC := sol tC = 3.39

It is determined the height HC [m] of clarified water-sludge in compaction interface position corresponding to the critical point C, which is the value of function y(t) at the moment of time tC:

Hc := y(tC) Hc = 0.268

CONCLUSIONS

The paper presents an algorithm, based on which, a program was set up for determining the critical point position, when the critical point position is estimated by the approximate graphical method.

The program was designed for an interactive, rapid and convenient processing of the data obtained from sedimentation experiments in stationary column of aqueous suspensions of solid particles.

Knowing the position of the critical point of the clarifying curve of an aqueous suspension of solid particles is particularly important to the design of water treatment equipment based on gravity separation (sedimentation). The coordinates of the critical point, namely: *the critical point time* and *the critical point height,* representing essential dimensioning parameters.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 661.722:662
Stručni rad
Expert paper

ENDURANCE TEST METHODOLOGY AND ASSESSMENT OF COMMON RAIL FUEL SUPPLY SYSTEM WEAR WHILE USING BIOETHANOL FUELS

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SUMMARY

Using biofuels has become very important nowadays, but it has an impact on vehicle fuel system's components. One of the biggest problems is corrosion in the fuel supply system, caused by biofuels. It also may produce elastomeric seal failures, increased dilution of engine sump oil and injector pressure. Similar tests have been carried out with fuel mixtures consisting of 5% to 20% bioethanol and showing high wear both on the injector and pump's parts.

This article gives an overview of the methodology of determining diesel fuel supply system wearing while using bioethanol fuels. There are many different standards, although they are not for conducting the whole test. Another importance of this methodology is that there are many different fuel supply system parts that have not been covered in any other methodology yet. The given methodology foresees measurements for tested parts before and after using them in test bench. The measurement methodology is based on the standard ASTM D6898 - 03(2010), which has been made to test the fuel supply system lubricity with diesel fuel. There are also methodologies from the United States of America and Russian Federation that have been created for fuels with lower ethanol content.

An important part of this methodology is to have figured out all test bench parameters to run the tests in same manner every time. There are parts of the pump and injectors that must be measured before and after running the test: injector nozzle needle, backflow valve plunger and plunger sockets, pump eccentric shaft, driver roller, housing inside, plungers and plunger tappets. Measurements should also be carried out in similar conditions, because room temperature may influence the part's size.

Methodology has been developed to evaluate common rail supply system in endurance test bench.

Key words: biofuel, diesel engine, test condition, measure methodology, roundness

INTRODUCTION

Production and development of technology have considerably worsened the environmental conditions on Earth. One of the reasons for this is the global warming, which is directly related to the rising emissions of greenhouse gases during the last hundred years. This has led to increasing concerns about the reductions of global CO_2 emissions (Paris Climate Conference 2015). The Paris Agreement for reducing global warming by 2 °C in the long run was initiated (COP21). One of the options for reducing CO_2 emissions is the more effective use of energy and the other is replacing fossil fuels with biofuels (Demirbas, 2009).

The problem related to the use of biofuels is that their physical and chemical properties are different from regular fuels. The main problems are the wear of the fuel supply system, inefficient combustion process which results in increased waste gas emissions, and starting the engine (Kalpakjian et al. 2010; Kitchen et al. 2003; Küüt et al., 2010; Küüt et al., 2012; Olt et al., 2011; Steinbach et al., 2006, Govindarajan, 2008; Ma et al. 2004). The wear of the fuel supply system mostly manifests itself while using ethanol fuels. The lubrication properties of bioethanol are better than those of petrol (Ilves et al. 2015, Olt et al., 2011), but worse than diesel fuel (Li et al., 2004). Several studies have been performed in the field to describe the wear of diesel fuel supply system (Terry, 2005; Lacey, 1992). At the same time, the existing studies do not share a fixed methodology for which parts of the pumps should be measured and what should be the level of precision in order to ensure uniform results. There exist standards for performing wear tests on diesel fuel supply systems, however, these mostly describe the environment for testing and there is no precise description of the measuring points. In addition, the standards presume that diesel fuel, biodiesel fuel or their mixtures are used for the wear tests. There is no methodology for assessing the impact of bioethanol fuel on modern diesel fuel supply systems (common rail). The existing test methodology for common rail fuel supply systems is incomplete and needs further clarifications (Terry, 2005; ASTM D6898).

The aim of this study is to develop a test methodology for common rail type diesel fuel supply system wear while using bioethanol fuels and to assess the results. The developing of the methodology was based on the problems and shortcomings of existing methodologies.

MATERIAL AND METHODS

In order to develop the endurance test methodology for common rail type fuel supply systems, an analysis of literature was performed, which involved covering the relevant standards and scientific articles from the databases Scopus, Thomson Reuters, etc. As a result of the analysis, a methodology was prepared for performing the endurance tests of common rail fuel supply systems. In order to perform endurance tests and map working surfaces, measuring methods were developed to ensure the replicability of the tests. Each component of the fuel supply system has been discussed separately and measuring methods have been prepared for it, developed on the basis of the standards ASTM D6898 - 03(2010) and ISO 4008. Additional special literature used was Terry, 2005, Bhushan B, 2000, Lacey, 1992. Tests were performed to examine the geometry and dimensions of working surfaces, which assessed the maximum allowed variation of measuring points, if the working surfaces are located on two different parts (for example, injector nozzle needle and nozzle body socket).

RESULTS AND DISCUSSION

The developed test methodology prescribes measuring the working surfaces before and after the endurance tests and additionally taking photos of the working surfaces to assess wear and the effect of fuel on the working surfaces of the fuel supply system. The endurance test is performed simultaneously on the pump and the injectors. The minimum duration of the test must be 200 hours. The vital parameters of the endurance test are the following (Terry 2005):

– rotational speed of the pump's shaft is n_p = 1000 ± 25 rpm. This rotational speed is the common working range of pumps working on tractors and heavy vehicles.
– minimum duration of the test t_d = 200 hours;
– fuel temperature in the system T = 40 ± 5 °C;
– maximum temperature of the fuel rail may not exceed T_m = 150 °C;
– fuel pressure in the common rail p = 1350 ± 10 bar;
– for each t_t = 20 hours ± 1 hour, intermediate measuring must be performed to ensure the working order of the injectors.

In order to perform the endurance test, the working surfaces of the diesel fuel supply system must be first measured. Measurements should also be carried out in same conditions, because room temperature influences the part's size (± 0.5 °C). Measuring methodology was developed for measuring working surfaces. This methodology varies for the majority of fuel supply systems as the shapes and working surfaces of the parts are different. (Terry 2005)

The geometries and dimensions of injector nozzle needle and backflow valve and the geometry of backflow valve opening must be mapped to assess the wear of the working parts of the injector of common rail fuel supply system. Figure 1 has been prepared to assess the working surface of the injector nozzle needle with measuring points marked. The working surface of the injector nozzle needle is divided into three parts and the measuring points for assessing the working surface of the nozzle needle are located at three distances from the tip surface c of the injector nozzle needle's working surface. For example, the first measuring point is l_1 = 2 mm, the second l_2 = 6 mm and third l_3 = 12 mm from the edge of the nozzle needle's working surface (Figure 1, A).

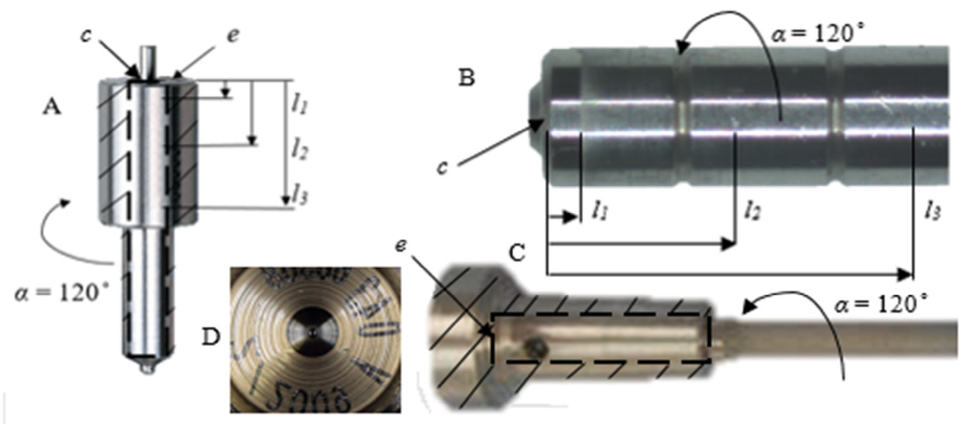

Figure 1. Injector nozzle needle and nozzle body socket (A), close-up of the backflow valve plunger surface (B), backflow valve plunger's sleeve with backflow valve plunger (C) and backflow valve opening (D)

The measurements must be performed at the abovementioned height by turning the part α = 120 degrees. The aim of such a measuring is to determine the roundness of the part. In addition, the working surfaces are recorded with the microscope to assess whether the working surface of the part has changed during the endurance test, whether there has been overheating (change of working surface's colour) or the adhesion of deposits (metal particles) due to the interaction of fuel and working surfaces. The measuring of the nozzle body socket is performed in the same way as the nozzle needle by measuring from the tip of the nozzle needle e. The tests showed that the variation δ = ± 1 mm of the measuring points of the working surface does not have a significant impact on the measuring results.

This means that, as an example, at the measuring point l_2 = 6 mm of the nozzle needle, the geometry of the nozzle needle differs little from the measuring points of 5 mm and 6 mm and this does not affect the dimensions of the working part. It is not important to record the working surfaces of the sleeve using a microscope as the most important changes are seen on the working surfaces of the nozzle needle.

The working surface of the backflow valve plunger is also divided into three parts at three different distances from the tip of the plunger's working surface. The measuring points are l_1 = 1 mm, l_2 = 5 mm and l_3 = 10 mm from the tip surface c of the working surface. All measurements are performed by turning the part α = 120 degrees. The working surfaces are recorded using a microscope. The same is performed while measuring the working surfaces of the backflow valve plunger's sleeve. The dimensions and geometry of the backflow valve plunger's sleeve are recorded at the same distance as the working surfaces of the backflow valve plunger by measuring distances from the bottom surface e of the plunger's sleeve (see Figure 1, B, C). It is not important to record the working surfaces of the backflow valve plunger's sleeve using a microscope as the most important changes are seen on the working surfaces of the nozzle needle. The variation of measuring points can be δ = ± 1 mm.

The geometry of the backflow valve opening is determined visually using a microscope. A steel ball is used in the backflow valve plunger, which affects the geometry of the valve opening. Therefore, it is important to determine the shape of the opening's edges (see Figure 1, D).

The most important parts of the pump are the plungers as they ensure the operating pressure in the common rail of the fuel supply system. The measurement methodology of the plunger is similar to the measuring methodology of the injector's parts, however, it is important that at least two measuring points should be located on the working surface and at least one away from the working surface as this helps to reveal deviations of form. The plunger is divided into three parts as shown in Figure 2. Figure 2 displays the plunger of a common rail type fuel supply system with marked measuring points l_1 = 2 mm, l_2 = 12 mm and l_3 = 22 mm from the tip surface c of the plunger. The measurements must be performed at α = 120 degree angle of rotation in all measuring points (Figure 2, A, C). The plunger's socket is measured at the same heights as the plunger by determining the measuring point's distance from the tappet's tip surface e_1, to which the high pressure valve is supported. The measuring points of the plunger's tappet have been shown in Figure 2, B and C. The variation of the measuring points may be δ = ± 1 mm. The working surfaces are recorded using a microscope to assess whether the working surface of the part has changed during the endurance test, whether there has been overheating (change of working surface's colour) or the adhesion of deposits (metal particles) due to the interaction of fuel and working surfaces.

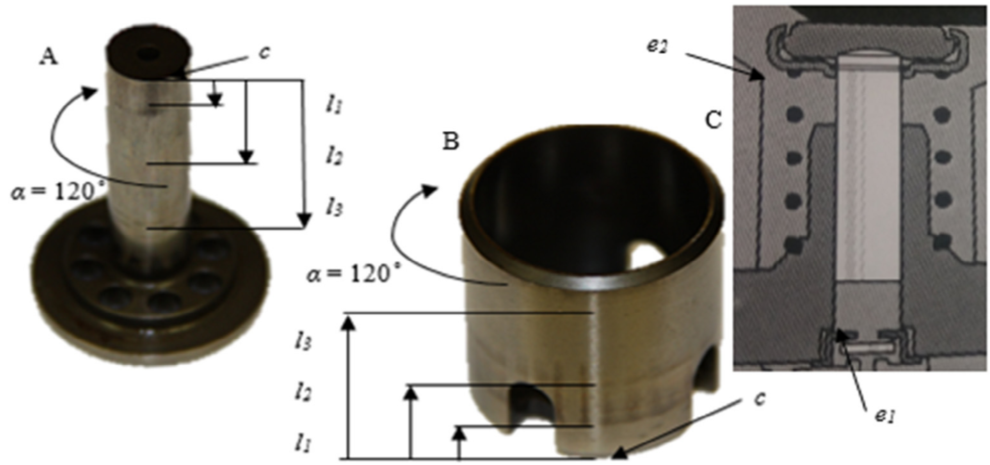

Figure 2. Pump's plunger (A), plunger's tappet (B), plunger socket and tappet socket (C) (Bosch Gmbh, 2014)

The geometry of the workings surfaces of the tappet of the pump's plunger is measured similarly to the working parts of the injector. The tappet is divided into three parts. The measurements are performed at three measuring points, for example, l_1 = 3 mm, l_2 = 10 mm and l_3 = 20 mm from the bottom surface c of the tappet. Likewise, the measurements are taken at each α = 120 degree sectors. The distances of the measuring points of the tappet's socket are the same as the tappets's, measured from the tip surface e_2 of the tappet's socket, which is located inside the pump. The variation of the measuring points may be δ = ± 1 mm. The geometry of the working surfaces is recorded using a microscope.

The camshaft of the common rail type fuel supply system's pump eccentric shaft is divided into three parts (Figure 3). Parts I and III are the working contact surfaces under the plain bearings of the pump's camshaft and part II is the working contact surface under the plunger's drive roller. Usually the plain bearings of the common rail type fuel supply system have been covered with a layer of teflon and, therefore, visual inspection is very important in assessing their condition. The same parameters are used for determining the dimensions of the plain bearings and the contact working surfaces (eccentric shaft working surfaces). It is important that the measurements are performed in the centre of the working surfaces of the plain bearings (I and III). Generally, the variation of the measuring points may be δ = ± 1 mm. Working surface II is additionally divided into two parts where one measuring point must be located before the centre of the working surface and the second after the centre. To be more exact, the measuring points must be located from the working surface II at the distance c, which is 25% and 45% of the width l_{ws} of the working surface II. The dual point measurement of this surface is important for verifying the axiality of the drive roller driving the plungers towards the eccentric shaft. The axiality of the drive roller is important for avoiding its cramming to the eccentric shaft. The drive roller is meant to work without additional alignment mechanisms.

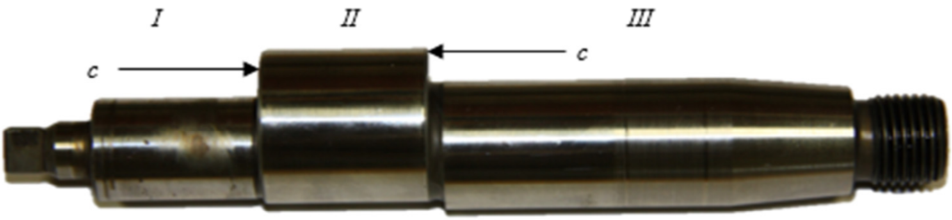

Figure 3. Measuring points of the pump's eccentric shaft

After measuring the dimensions of the fuel supply system, the conformity of common rail fuel supply system's injectors and pumps to the manufacturer's test plans must be assessed. During the endurance test it is important to check the injectors' feed and backflow amount after each 20 ± 1 hours. The test plans may represent the fuel feed in cm^3/min, cm^3/n_c or as cyclic feed V_f, which is expressed using the formula (ISO 4008):

$$V_f = \frac{10^3 \cdot \sum_1^4 V_i}{n_c},$$

where V_f – cyclic feed, mm^3/cycle; V_i – section's productivity, cm^3/min; n_c – sum of cycles. The peak factor σ_f of the injectors' feed is expressed by:

$$\sigma_f = \frac{2(V_{i.\max} - V_{i.\min})}{V_{i.\max} + V_{i.\min}} \cdot 100,$$

where $V_{i.max}$ – section's maximum productivity, cm^3/min; $V_{i.min}$ – section's minimum productivity, cm^3/min; σ_f – fuel's peak factor, %. Hourly consumption of fuel B_f is expressed using the formula:

$$B_f = 60 \cdot 10^{-3} \cdot \sum_1^4 V_i \cdot \rho_f,$$

where ρ_f – fuel density, kg/m^3. The abovementioned parameters allow assessing the technical condition of the fuel supply system.

In addition, it must be checked whether the injector pump is capable of ensuring the prescribed pressure p in the common rail. The feed and backflow of the injectors must be checked using the fuel from the endurance test in order to avoid the additional lubrication of the pump's part with the test bench liquid. After endurance tests, the geometry of the fuel supply system must be determined using the abovementioned measuring methods. All measurements should be performed four times in order to ensure the possibility of determining error of measurement and to avoid the occurrence of errors of measurement.

A block scheme which describes the performance and order of the endurance tests has been prepared to describe the measuring methodology in detail (Figure 4).

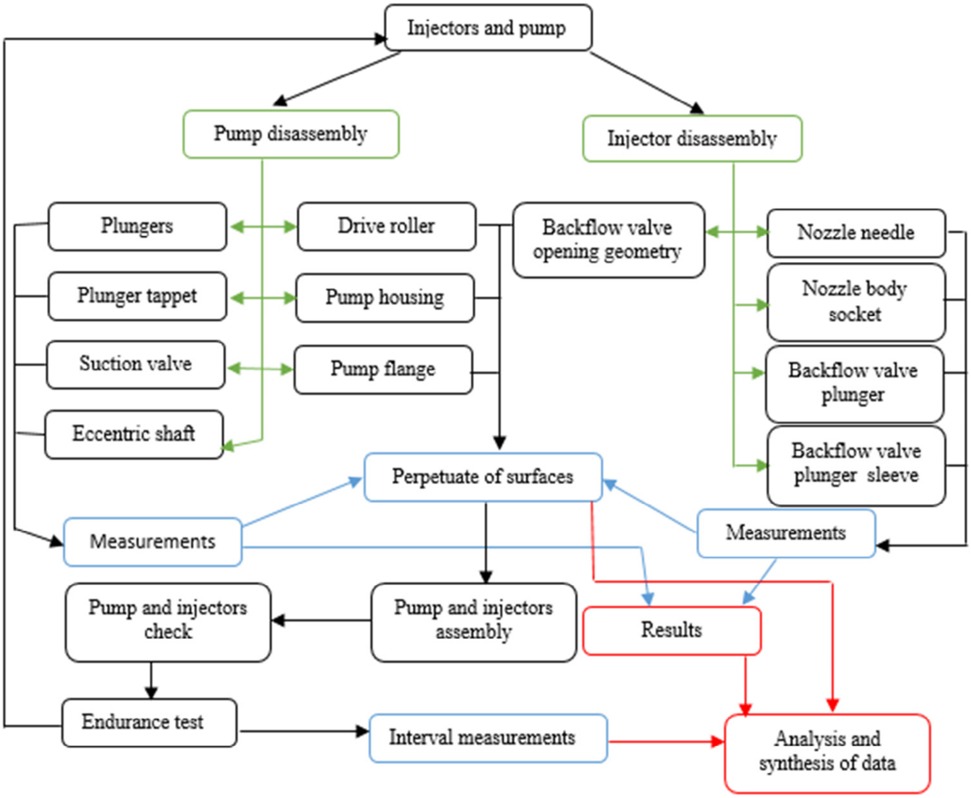

Figure 4. Scheme for performing endurance test

The abovementioned test methodology allows performing endurance tests of common rail fuel supply systems.

CONCLUSIONS

The problem related to the use of bioethanol fuel in common diesel engines is the lubrication properties of the fuel. The common rail diesel fuel supply system is especially vulnerable to the poor lubrication properties of the bioethanol fuel. This study discussed the testing methodology developed for the endurance test of the diesel fuel supply system while using bioethanol fuel. The used test equipment was the injector pump Bosch CP3 (0 445 020 175) and Bosch injectors (0 445 110 076). The test methodology was developed on the basis of scientific literature and partly on the basis of the standard ASTM D6898 - 03(2010). This test methodology prescribes pre- and post- measurements of the working surfaces of the working parts of the fuel supply system and the assessment of the quality of surfaces which affect the reliability of the supply system and fuel feed. The measuring methodology developed within the testing methodology discusses the pre- and postmeasurements of the working parts, which is needed in the beginning and final phase of the endurance tests. Measuring methodology was developed for measuring the pump's parts such as plungers and plunger's tappets, plunger's pushers and pusher's sockets and the pump's eccentric shaft. From the parts of the injector, measuring methodology was developed for injector's nozzle needle, nozzle needle's body socket, backflow valve and backflow valve socket. During the development of the methodology, measuring process was performed to assess the possibility and reasonability of measuring the measuring points of the parts.

In conclusion, it can be said the test methodology for assessing the wear of the parts of the common rail fuel supply system during endurance testing was developed. The performance of endurance tests to assess the quality of the developed test methodology has been started. The analysis of these results allows improving the developed test methodology, if necessary.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

THEORETICAL RESEARCH ON ENHANCING THE PERFORMANCE OF CULTIVATORS WORKING BODIES

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SUMMARY

This paper presents a theoretical study of the optimal operation and exploitation of the working bodies of agricultural cultivators so their support to withstand varying loads, of different intensities, for different specific resistance of the soil and for different operating conditions. It is considered that the flexible support of the working body deforms during the working process and this deformation must be within such limits to ensure self-vibration of the working body, to reduce energy consumption and to ensure proper orientation of the working body, so that the forces arising at the interaction with the soil to ensure the remaining of the working body in the soil. For the study theory was used the Finite Element Method for analyzing the stress and strains in three types of flexible supports of working bodies of the cultivator, for which it was pursued their angle of attack and orientation, for different values of resistant forces.

Keywords: agricultural cultivator, tillage tool, vibrations, finite element method

INTRODUCTION

It is known that agricultural machines for seedbed preparation before seeding are the largest consumers of energy in agriculture [6]. In this category belong the agricultural cultivators. Efforts made over the years, in case of these machines, had as main objective the finding of technical solutions to lead to reduced fuel consumption needed to perform the works and to enhance the efficiency of works performed by the working bodies of these machines [4, 10, 11, 12].

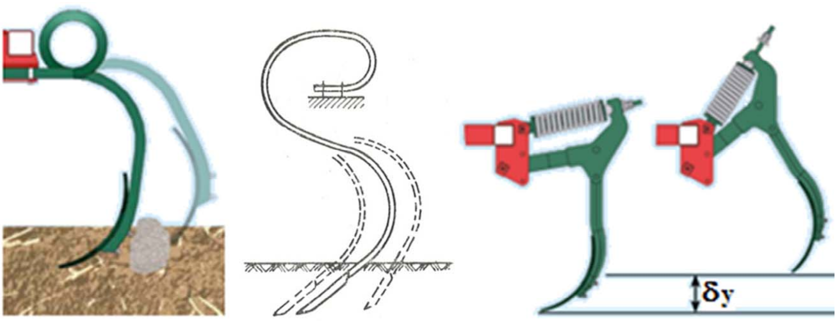

Fig. 1. Supports for the working bodies of cultivator [10]

In agricultural cultivators, the support of the working body has a very important role because, besides providing a secure fixation on the machine frame, the support must ensure the protection of the working body when there is impact with an obstacle (stone), for which are used various technical solutions (Fig. 1), with spiral spring or helical spring [10].

In case of working bodies mounted on elastic supports, while working, because soil specific resistance varies continuously, the supports vibrate in longitudinal plane, thus executing a stronger action on the layer of soil, favoring its loosening and crumbling. Vibration of the working bodies for soil tillage leads to reduced coefficient of external friction between soil and the active surface of the tool, depending on soil moisture and frequency of oscillatory motion [7]. The need to correlate the vibration parameters with the factors influencing the working process has led to the implementation, in vast majority, of technical solutions that provide the use of forced vibration [5, 7]. From studies conducted so far, it results that there is the possibility of using the principle of free vibrations especially in case of cultivators and chisel plows, for whose construction are used elastic supports, which during the working process produce vibrations due to the inhomogeneity of soil and micro-relief, increasing the effectiveness of machinery [9].

Currently, it is possible to shorten spectacularly the cycle of design concept - test - production of this type of equipment by using the Finite Element Method to analyze the distribution of stress and strains of their resistance elements (frames, tool holders, working bodies, etc.) [1, 2]. The finite element method is based on the principle of the overall potential energy, which states that a structure or a body is deformed or displaced in a position that minimizes the potential energy (overall potential) [1]. The finite elements method was imposed by the need to solve complex problems in the mechanics of deformable bodies. Finite elements analysis of structures emerged as a necessity [1, 3] to simplify and reduce the cost of testing in operation or under simulated and accelerated regimes, it can approximate to within acceptable precision the areas of maximum (critical) stress [1], the maximum stress and even the lifetime of a structure.

MATERIAL AND METHODS

From the wide variety of technical solutions for elastic supports for cultivator tools for the study and analysis were chosen 3 types of Vaderstad company: NZ Aggressive (Fig. 2.a), Rexius Twin (Fig. 2.b) and Swift (Fig. 2.c). For each of these three types of supports was created a geometric model Solidworks software (Fig. 3).

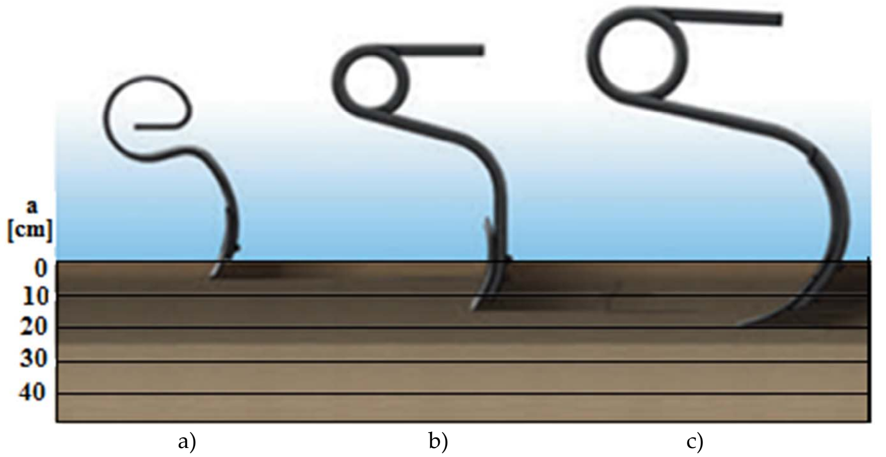

Fig. 2. Working bodies of the cultivator [12]

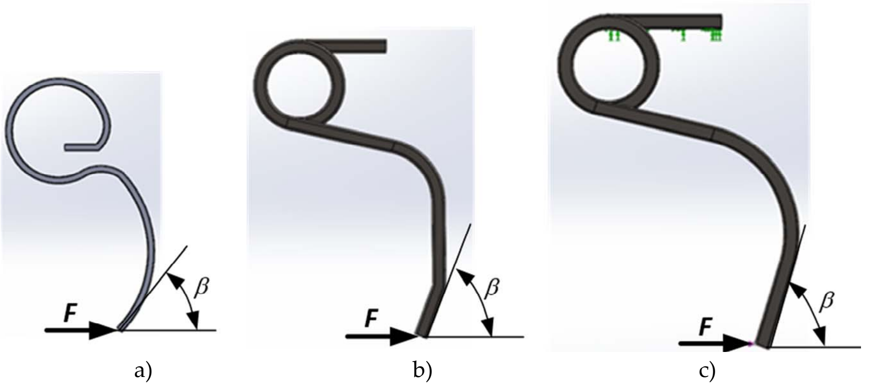

Fig. 3. Geometric models of the supports used in the analysis

On each supports acts the force resulting from the interaction with the soil (*F*), applied to the top of the support (Fig. 3) [8]. For various conditions of exploitation, in the analysis were used different values of force *F* (500, 1000, 1500, 2000, 3000 N). An important parameter for the proper geometric and functional configuration is the angle of attack β. For an optimal functioning must be ensured such conditions that the flexible support of the tool to vibrate, the tool to move easily in the soil and the resulting forces not tend to rise the tool out of the soil during the working process. For this, the angle β must not exceed values of approximately 80º. For these three models of supports was conducted the analysis of stress and deformations distribution using FEM, by means of SOLIDWORKS Motion™ program.

RESULTS AND DISSCUSSION

The results of analysis of the models of supports for the analyzed working bodies of the cultivator are presented in the following Figures. They consist of the distribution of equivalent stress according to the Von-Mises criterion, and the distribution of total deformations for the three types of supports, at different values of draft force *F*.

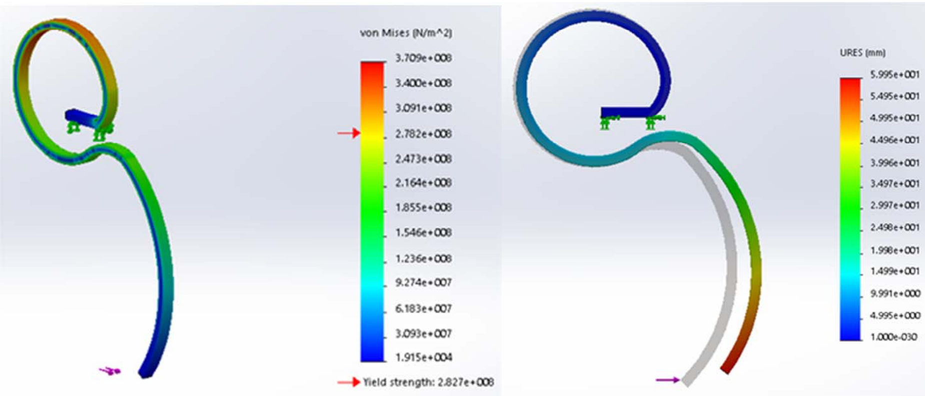

Fig. 4. Distribution of stress and deformations for F=500 N (Option 1 - Fig. 3.a)

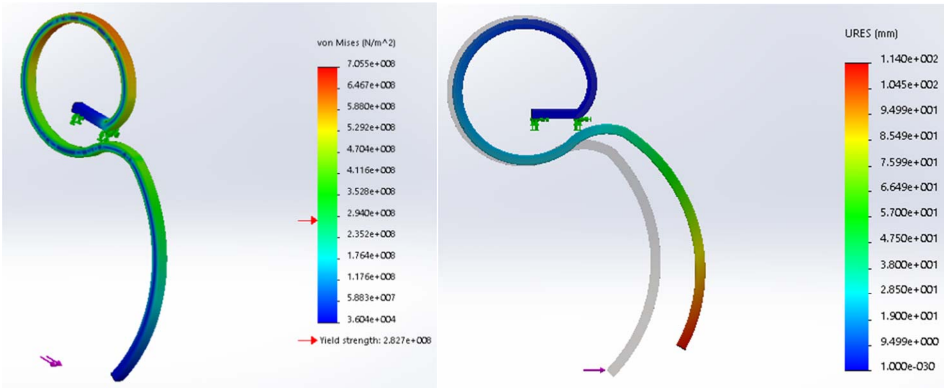

Fig. 5. Distribution of stress and deformations for F=1000 N (Option 1 - Fig. 3.a)

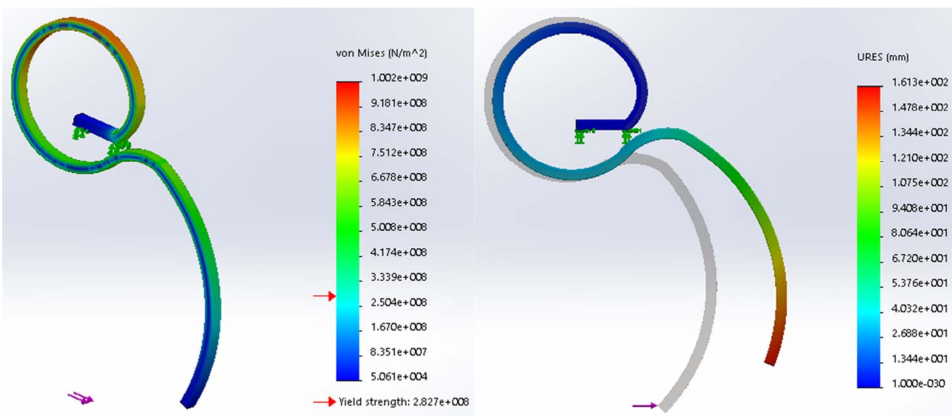

Fig. 6. Distribution of stress and deformations for F=1500 N (Option 1 - Fig. 3.a)

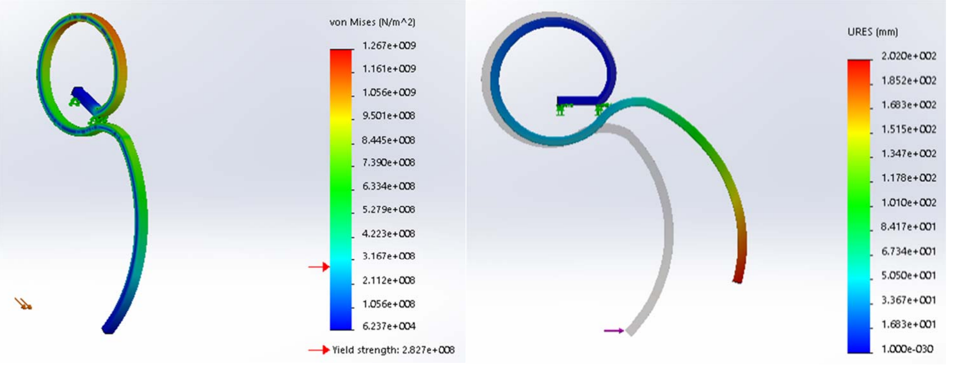

Fig. 7. Distribution of stress and deformations for F=2000 N (Option 1 - Fig. 3.a)

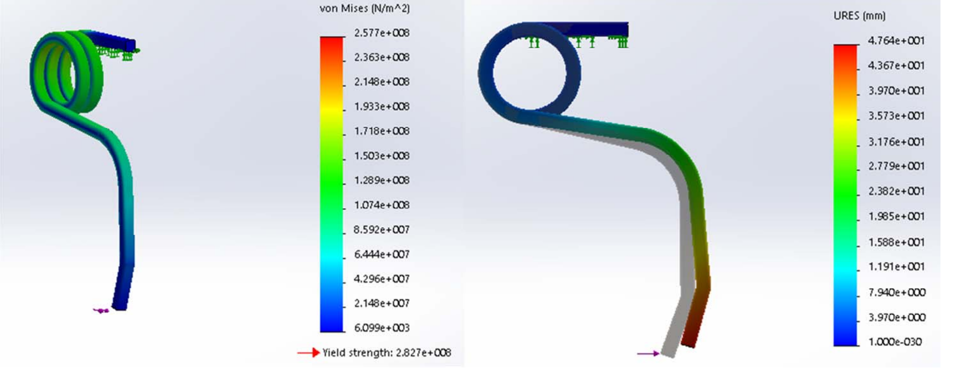

Fig. 8. Distribution of stress and deformations for F=1000 N (Option 2 - Fig. 3.b)

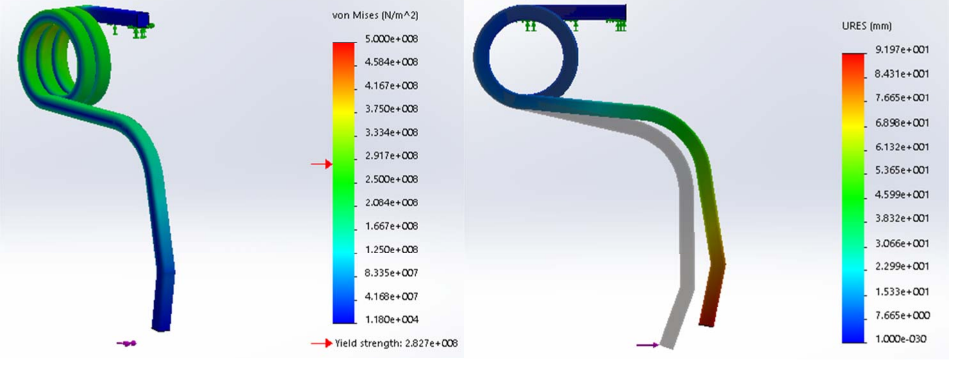

Fig. 9. Distribution of stress and deformations for F=2000 N (Option 2 - Fig. 3.b)

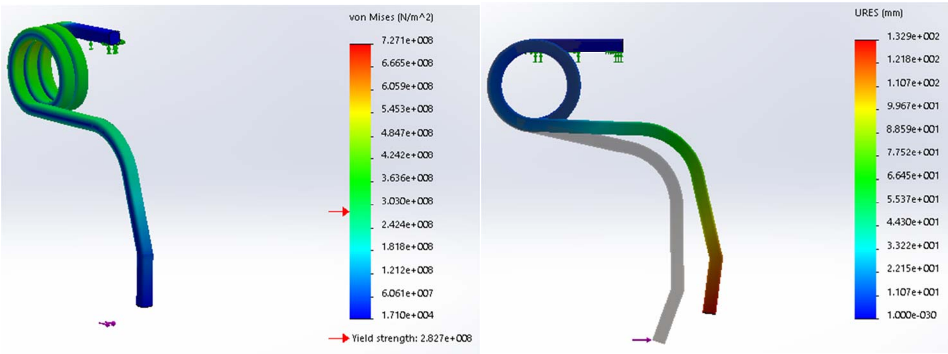

Fig. 10. Distribution of stress and deformations for F=3000 N (Option 2 - Fig. 3.b)

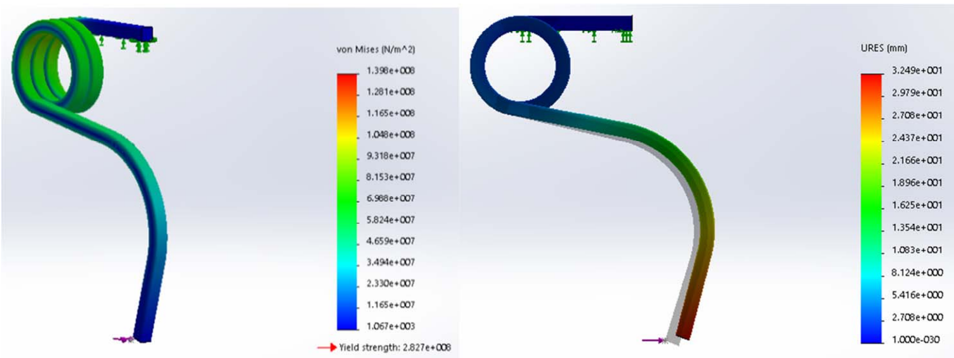

Fig. 11. Distribution of stress and deformations for F=1000 N (Option 3 - Fig. 3.c)

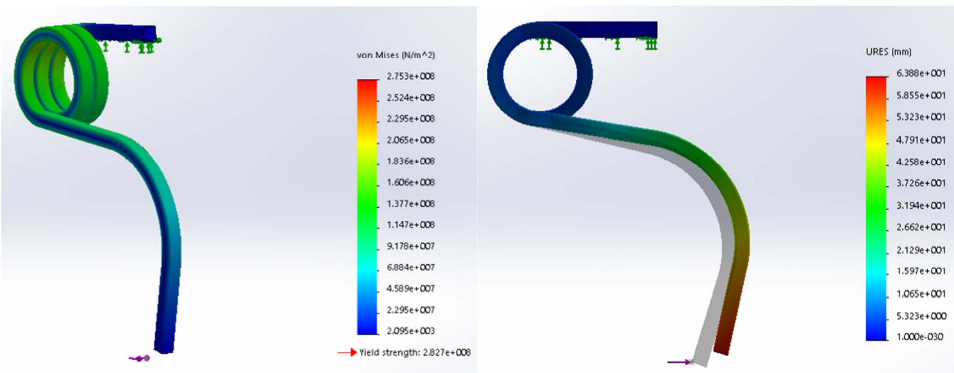

Fig. 12. Distribution of stress and deformations for F=2000 N (Option 3 - Fig. 3.c)

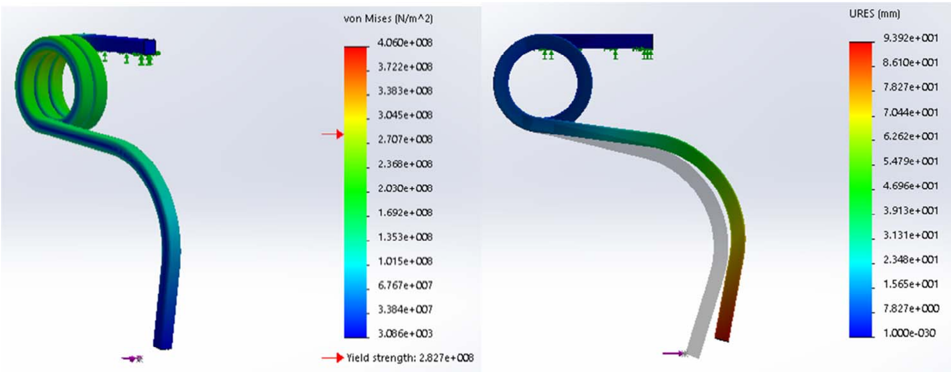

Fig. 13. Distribution of stress and deformations for F=3000 N (Option 3 - Fig. 3.c)

In all Figures showing the distribution of equivalent stress may be identified areas where the maximum values are recorded and comparison may be made to determine if these values exceed the allowable stress. Also, from these figures can be identified, in addition to the distribution of total deformations, the values of deformations in the points of application of force *F*. Figure 14 presents the variation of total deformations of the point of application of force *F* on the supports and Figure 15 shows the variation of the angle of attack β, depending on the value of draft force for three analyzed types of supports.

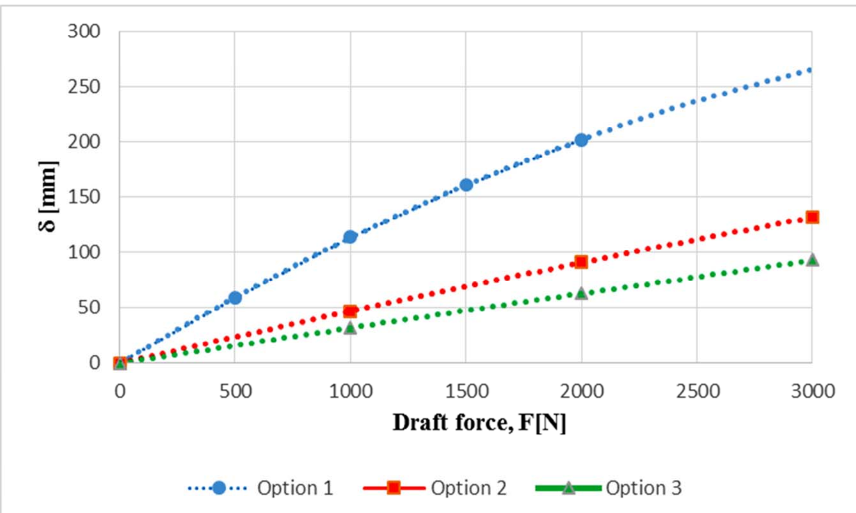

Fig. 14. Variation of total deformations with draft force and the type of support

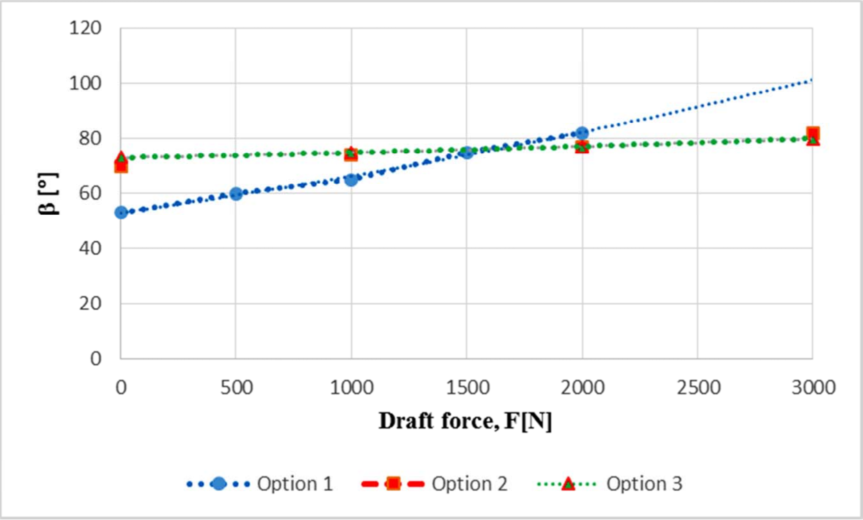

Fig. 15. Variation of the angle of attack with draft force and the type of support

CONCLUSIONS

- From the analysis of equivalent stress distribution in the studied supports (Fig. 4-13) it results that stresses above the allowable value occur in the case of option 1 if the draft force is larger than 1000 N, in the case of option 2 if the draft force exceeds 2000 N, and in the case of option 3 the draft force can reach values up to 3000 N.
- From the analysis of deformations distribution (Fig. 4-13) and the graphical variation of the size of deformations in the point of application of force *F* (Fig. 14) it results that option 1 of support has deformations higher than 100 mm if the draft force exceeds 1000 N.
- From the analysis of Fig. 15 it results that angle β exceeds values of 75-80º, which represent the upper limit to ensure tool stability in the soil, if *F* is larger than 1500 N for option 1 and higher than 2000 N for option 2, respectively values higher than 2500 N for option 3.
- Starting from the graphs in Fig. 15 it can be considered the need to find technical solutions to automatically guide the tool support depending on the exploitation conditions of the cultivator and depending on the soil conditions, so that the angle of attack β to be optimal.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

FIELD AND LABORATORY WEAR TESTING OF INTEGRAL SEEDBED IMPLEMENT'S CHISEL TINES POINT

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SUMMARY

Within the work of preparing the seedbed using the Combiner, the chisel type active bodies are the most subjected to wear. This is due to the contact (friction) with soil/sand, but also to the draft resistance encountered on the frontal part of the body. The paper presents the results of experimental researches conducted to determine the wear of two active bodies for soil tillage in the field (in real conditions), respectively on laboratory stand (in accelerated regime, in sand). The tested active bodies were hardened through two different methods. Field tests showed that the smallest wear (1.51%) was obtained for chisels hardened by MAG procedure, using cored wire as filling material, and highest wear (4.11%) was obtained for chisels loaded with an electrode coated by tungsten carbide.

Key words: soil loosening, tillage, chisel, active bodies, wear

INTRODUCTION

Conservation tillage is an alternative solution to the conventional tillage, and it contributes to the sustainability of agriculture because it increases soil water content, prevents soil erosion and reduces soil degradation by minimum-tillage, no-tillage, and crop covering [8].

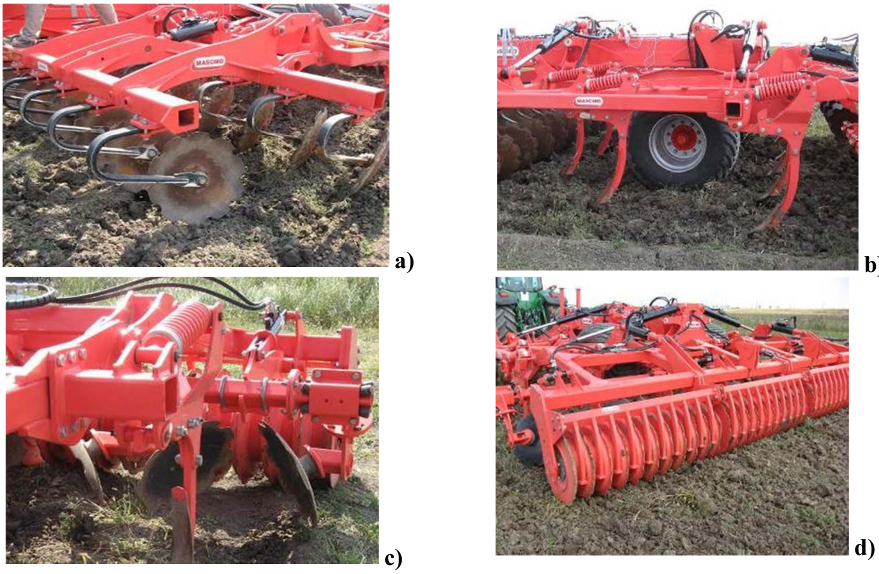
Under the need to apply conservation tillage, it became widely used the Dracula Combiner, an integral implement that can also perform soil crumbling in a single pass.

Dracula Combiner can be equipped with various types of active bodies (notched disks, chisel and leveling). By active bodies we further refer to the cultivator's working elements which are used for soil tillage, breaking soil structure during work. The chisel type active bodies are most subjected to intense wear due to their shape that comes directly in contact with the soil.

Fig. 1. Equipment for soil tillage in conservation system

The Combiner for conservation tillage of soil is designed as a complex aggregate, consisting of 4 Modules with different active bodies, mounted in series. In a single pass, the Combiner can perform multiple operations, resulting in a high quality of soil tillage.

Module 1 (Fig. 2a) consists of a battery of notched disks mounted in front of the equipment on elastic curved supports, which performs the initial crumbling of soil and the shredding of crop residues. Module 2 (Fig. 2b) consists of two rows chisel type bodies active, the one at the front (behind the battery of disks) with delayed supports, with the second row placed with the bodies in line, that performs deep tillage by breaking soil structure. Module 3 (Fig. 2c) consists of a battery of disks mounted in pairs in V, to perform the crumbling and smoothing of the bumpy soil resulting at the crossing of chisel type active bodies. Finally, Module 4 (Fig. 2d) is formed by a leveler, which is designed to ensure the crumbling of lumps (of small sizes), and soil leveling, so that in the end to obtain a well tilled soil, crumbled and leveled, for sowing.



a) b) c) d)

Fig. 2. Modules of the equipment for soil tillage in conservation system:
a) Module 1; b) Module 2; c) Module 3; d) Module 4

In mechanized agriculture, the wear of chisel type active bodies used for seedbed preparation is a consequence of metal interaction with sharp and hard particles of soil, which are continuously supplied, as the chisel breaks the soil and has to overcome frictional forces and resistance to draft [7].

Because the wear of active bodies is more intense than that of other machine parts, they are also named wear bodies [5]. The lifespan of an active body is determined by its wear. The material of which the active bodies are manufactured (usually an alloy), the physical-mechanical properties of soil (type, structure, density and moisture), the amount of stones in the soil, and field working conditions (the relative velocity, the impact angle between the soil and active body) [2, 3, 4, 10], are important factors determining the character and intensity of abrasive wear for the active bodies of equipment for soil tillage.

Materials used in the manufacturing of the active bodies should be hard enough to resist wear and strong enough to resist distortion and impact [2]. An increase in material hardness will result in decrease of the wear rate. It was found that soil moisture has a stronger effect upon wear than soil type characterized by its granular composition, and an increase in the former decreases wear, with sandy soil as the exception [7].

High hardness of sandy soil particles (having diameters of 0.02-2 mm) makes this type of soil more abrasive. While operating in sandy soils, the active bodies are more subjected to premature wear, and hence their geometry (especially that of the cutting part) modifies [9] with higher wear rates, which is in contrast with the plough resistance of soil [6]. This leads to increased resistance during soil tillage and thus, to increased fuel consumption [9]. Since worn active bodies are less effective in terms of weed control, tillage or seeding efficiency [1], they must be replaced several times during an agricultural campaign, in order to perform soil works of proper quality. So, determining the abrasive wear of chisel type active bodies is necessary because it represents a problem in terms of: huge losses of material, increased costs and time required to replace the worn parts [2], production planning and costs, tillage quality and power losses [7].

METHODS

A. Experiments conducted in the field

In the experiments was used an experimental model of technical equipment for conservation soil tillage, i.e. an integrated implement (Cultivator) presented in Figure 3. The Cultivator can process the superficial layer (by mixing the debris in the soil, respectively the deeper layer of soil through a ripping action. This equipment is semi-mounted type and works in aggregate with tractors of 330-550 HP.

Fig. 3. Equipment for soil tillage in conservation system during the experiments

The equipment consists of: chassis formed by a central frame provided with a draw-bar, two lateral frames (left and right), on which are mounted the chisel type active bodies with extension and transport train; two rear modules with operating elements type notched disks, mounted individually on "C"- shaped elastic supports; two frontal modules on which is mounted a bar with leveling notched disks that has adjustable tilting and a roller with steel rings and a hydraulic system for the control of draw-bar height, vertical folding of lateral frames in transport position and control of working depth for the frontal disks.

The cultivator point body type chisel used on the equipment was previously analyzed by FEM (Fig. 4 and Fig. 5), determining the geometric model and soil pressure on its surface.

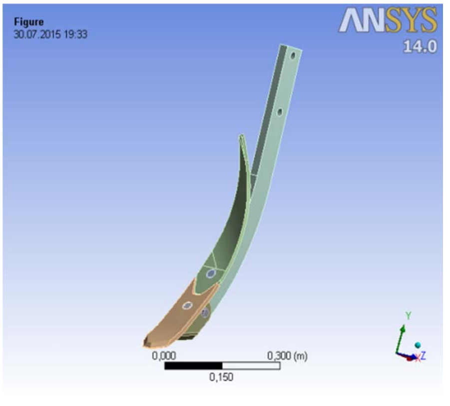


Fig. 4. Geometric model of the analyzed body

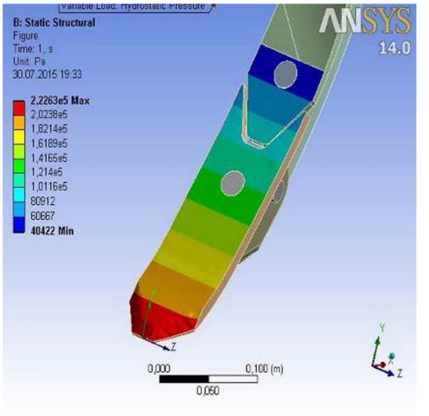


Fig. 5. Soil pressure onactive body surface

Experiments to determine the wear of chisel type active bodies (of the control ones, mounted on the equipment for seedbed preparation in conservation system, namely of those hardened by different methods) were performed in Chisineu Cris, Arad County, on a field of 35 ha (Fig. 6).

Fig. 6. Experimental field in Chisineu Cris, Arad County

Experiments were carried out in unprocessed field (of one year), slightly fallow (Fig. 7).

Fig. 7. Aspects during the experiments with the equipment for conservation soil tillage

B. Experiments conducted in the laboratory

Experiments under simulated and accelerated regime of the chisel knife for soil tillage in conservation system were conducted on a testing stand (Fig. 9) consisting of: basin with sand (1); drive reducer type worm-worm wheel (2); overall support arms for the working bodies (3); force transducer arm (4); command and control system (5); force transducer (6); laptop (7); acquisition system with amplifier (8).

The stand allows to modify the following parameters: working depth, side angle towards the moving direction and velocity due to speed of motor drive. With set overall and functional dimensions, the stand allows to test different type of chisel bodies on a circular path of 1600 mm diameter at maximum depth of 300 mm.

Aiming to reduce the influence of various physical parameters of the agricultural soil and to maximize its effect on the wear of chisel knives for soil tillage, experiments were conducted in a medium favoring basic observations on chisel knife-soil interaction.

Fig. 9. Laboratory stand for the testing of chisel type active bodies for soil tillage in conservation system

Testing medium was fine quartz sand for dry adhesive mortars with commercial application, obtained by washing and mechanical classifying, falling within the granulometric class of coarse sand and fine sand (after Attenberg scale), with particle sizes between 0 and 0.3 mm.

The testing medium used in the experiments is a frictional medium, without cohesion and without structure, with effect of maximum wear (the wear is maximum when the percentage of abrasive particles with a size of 0.25 mm has a maximum value).

Table 1. Types of chisel knifes tested on the laboratory stand

3M	Chisel loaded by MAG procedure using as filling material SK ABRA MAX O cored wire
3W	Chisels loaded by WIG procedure using as filling materials metalic rods of steel and composite core with tungsten carbide
3H	Chisels loaded with alloy plates type BWG Abraguard 55 and hardening by welding of adjacent areas (a buffer layer of E307 (18/8/6) electrode and thereupon two layers of wire - Postalloy 2832- SPL)
3E	Chisels loaded with an electrode experimentally coated by tungsten carbide, brand SUDOTIM AS
Control	Chisel made of 30MnCrB5

Aspects from determining the penetration resistance and moisture of the testing medium, respectively the drag force are presented in Figure 10.

Fig. 10. Aspects from the experiments conducted in the laboratory

To determine the *overall wear*, the gravimetric method was used prior to the measurements, and the bodies were washed and dried.

Aspects from determining the wear of chisel type active bodies, consisting in the placing of chisel knife on the assembly support arms, respectively weighing of chisel knife are presented in Figure 11.

Fig. 11. Aspects from determining the wear of chisel type active bodies

RESULTS

A. Results obtained from field experiments

For the chisel type active body was determined the wear resulting from its friction with the soil (Table 2), considering the active body mounted on the equipment (control), respectively four types of bodies hardened by various methods.

Table 2. Wear level of hardened active bodies, after tilling a field of 35 ha

	Type of chisel and hardening	Chisel mass before tillage [g]	Chisel mass after tillage [g]	Wear [%]
1M	Chisels loaded by MAG procedure using as filler material the SK ABRA MAX O cored wire	1656.92	1631.90	1.51
2M		1695.17	1668.03	1.60
1W	Chisels loaded by WIG procedure using as filling materials metalic rods of steel and composite core with tungsten carbide	1610.43	1559.14	3.18
2W		1628.27	1567.98	3.70
1H	Chisels loaded with alloy plates type BWG Abraguard 55 and hardening by welding of adjacent areas (a buffer layer of E307 (18/8/6) electrode and thereupon two layers of wire - Postalloy 2832- SPL)	1609.48	1557.31	3.24
2H		1628.99	1572.04	3.49
1E	Chisels loaded with an electrode experimentally coated by tungsten carbide, brand SUDOTIM AS	1646.11	1578.48	4.11
2E		1633.37	1570.43	3.85
Control	Chisel made of 30MnCrB5	1902.05	1855.86	2.43

The final aim was to identify a method that allows to increase wear resistance and thus, the lifespan of chisel type active bodies.

Wear was determined by measuring the initial mass of active body (chisel) and their mass after the tillage of 35 ha of soil with the integrated implement.

B. Results obtained from laboratory experiments

Table 3. Penetration resistance of testing medium

No.	Penetration resistance [N] to depth of: 50/100/150/200/250/300 [mm]					
	50	*100*	*150*	*200*	*250*	*300*
R1	2.0	4.0	7.0	1.0	12.0	14.0
R2	2.1	4.2	6.8	9.5	11.5	13.5
R3	2.2	4.4	7.2	9.8	12.2	13.8
R4	1.9	3.8	7.4	10.2	11.8	14.2
R5	1.8	4.2	6.8	10.5	12.2	14.4
Mean	2.0	4.08	7.04	10.0	11.94	13.98

Table 4. Punctual moisture in the testing medium, measured by the moisture sensor

Repetition	R1	R2	R3	R4	R5	Mean
Moisture [%]	4.0	4.2	4.0	3.8	3.6	3.92

Table 5. Values obtained from determining chisel wear on the laboratory stand

Chisel type	Frequency [Hz]	Time [s]	Initial mass [g]	Final mass [g]
E3	15	20	1688.45	1685.23
Control 1	15	20	1902.95	1899.17
E3	20	28.19	1685.23	1680.46
Control 1	20	28.19	1899.17	1897.63
E3	20	31.05	1680.46	1680.07
Control 1	20	31.05	1897.63	1897.16

Values of draft force measured to depths of 15 cm, 20 cm and 30 cm, were subsequently processed by segmenting the values corresponding for starting and stopping the stand. Variation of draft force at the three depths is presented in Figure 12.

Mean values of draft force at the studied working depths were: 0.094 kN at 15 cm; 0.252 kN at 20 cm; 0.747 kN at 30 cm.

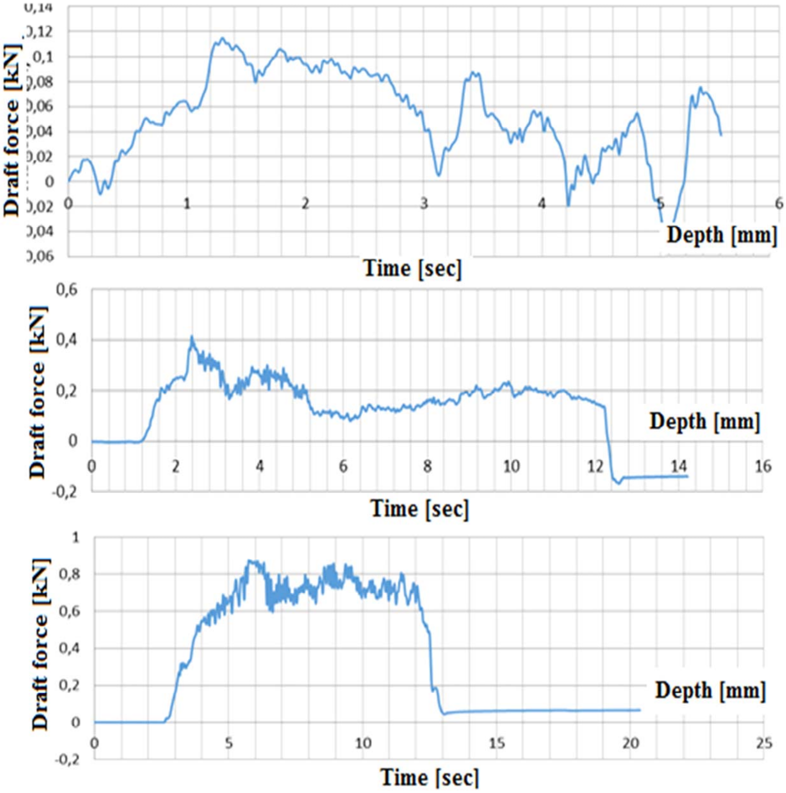


Fig. 12. Values of draft force at a depth of 15/20/30 cm

CONCLUSIONS

Experimental research aimed to identify a solution of hardening for the chisel type active bodies so that they can be used longer for soil tillage (higher resistance to wear).

Analyzing the results obtained in the field, with the four types of hardened active bodies by different methods, compared to the control active body mounted on the equipment, in hard conditions of operation, in a sandy soil, it can be observed that the lowest wear was obtained when using the active bodies (chisels) hardened by MAG procedure, using as filling materials SK ABA MAX O the cored wire (approx. 1.5%, compared to 2.4% in case of the control active body).

This method of hardening can be a solution, because is not expensive and the technology of application is relatively simple.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

PRINOS ZRNA KUKURUZA SJETVOM U UDVOJENE REDOVE SIJAČICOM MATERMACC TWIN ROW – 2

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SAŽETAK

U radu su prikazani rezultati primjene twin row tehnologije u Republici Hrvatskoj uporabom sijačice talijanske tvrtke MaterMacc (twin row 2). Istraživanja su provedena u okolici grada Osijeka u istočnom dijelu Hrvatske gdje su zabilježene optimalne količine oborina kroz cijelu vegetaciju (2016. godine) uzgoja kukuruza. Istraživanja su provedena uporabom dva hibrida sjemenske kuće Pioneer iz FAO grupe 520 „P0 412“ i hibrid iz FAO grupe 400 „P0023“ zasijanih u standardnoj tehnologiji s razmakom redova od 70 cm i u twin row tehnologiji s razmakom udvojenih redova od 22 cm. Standardna sjetva obavljena je pneumatskom sijačicom „PSK-4“ tvrtke MIO OLT Osijek 16.04.2016.godine. Standardna sjetva hibrida P0023 obavljena je na predviđeni sklop od 64253 biljke/ha. Utvrđeni stvarni sklop poniklih biljaka bio je oko 60.705 kom/ha. Prinos ovog hibrida u berbi 26.09.2016. iznosio je 13.814 kg sa standardnom devijacijom od 1.025 i koeficijentom varijacije od 7,42%. Prosječna vlažnost zrna iznosila je u standardnoj sjetvi 16,2% sa standardnom devijacijom od 1,313 i koeficijentom varijacije od 8,11%. Prinos hibrida kukuruza P0023 u sjetvi twin row tehnologijom s ostvarenim sklopom poniklih biljaka od 61.415 komada iznosio je 15.245 kg/ha ili 10,35% više u odnosu na standardnu sjetvu. Povećanjem sklopa u twin row tehnologiji s 92.655 izniklih biljaka ostvaren je prinos od 19.263 kg s koeficijentom varijacije od 7,83% pri čemu je ostvaren razmak biljaka unutar reda od 31,20 cm. Standardna sjetva hibrida P0412 obavljena je na predviđeni sklop od 64.253 biljke/ha. Procijenjeni stvarni sklop poniklih biljaka bio je 63.723 kom/ha. Prinos ovog hibrida u berbi iznosio je 15.427 kg sa standardnom devijacijom od 338,9 i koeficijentom varijacije od 2,20%. Prosječna vlažnost zrna iznosila je u standardnoj sjetvi 28,22% sa standardnom devijacijom od 0,740 i koeficijentom varijacije od 2,62%. Prinos hibrida kukuruza P0412 u sjetvi twin row tehnologijom s ostvarenim sklopom poniklih biljaka od 63.190 komada iznosio je 17.060 kg/ha ili 10,59% više u odnosu na standardnu sjetvu. Povećanjem sklopa u twin row tehnologiji s 79.520 izniklih biljaka ostvaren je prinos od 18.399 kg s koeficijentom varijacije od 6,53% pri čemu je ostvaren razmak biljaka unutar reda od 36,07 cm.

Ključne riječi: kukuruz, sjetva, Twin Row sijačica, prinos

UVOD

Kukuruz (*Zea mays* L.) je jedna od najznačajnijih ratarskih kultura kako u svijetu tako i kod nas u Hrvatskoj. Uz pšenicu i rižu ona je, jedna od tri vodeće poljoprivredne kulture u svijetu. Od svih žitarica kukuruz ima najveći potencijal rodnosti kojega se i te kako treba u ovom i narednom razdoblju iskoristiti. U Hrvatskoj kukuruz je u 2015. godini prema podacima Državnog zavoda za statistiku o biljnoj proizvodnji, zasijan na ukupno 263.000 ha s ukupnom proizvodnjom zrna od 1.708.000 tona i s prosječnom proizvodnjom od 6.500 kg/ha. Sjetva kukuruza u 2014. godini obavljena je na 252.567 hektara pri čemu je proizvedeno 2.046.966 tona zrna , a prosječni prinos iznosio je 8.100 kg/ha, što je više nego u 2013. godini kada je iznosio 6.500 kg/ha. Kako su zemljišni i klimatski uvjeti za proizvodnju kukuruza u Hrvatskoj među najboljima u svijetu upravo tu spoznaju trebali bi iskoristiti i dati veći značaj kukuruzu kao strateškoj žitarici u proizvodnji stočarske hrane za razvitak ukupne stočarske proizvodnje. Kukuruz bi trebao biti osnova ratarske, stočarske pa i cijele poljoprivredne proizvodnje, a isto tako mogao bi biti i baza mnogih industrijskih proizvoda. Bez obzira na česte i brze promjene cijene kukuruza, on se i dalje tradicionalno uzgaja na značajnijim poljoprivrednim površinama s različitim razinama plodnosti. Razlog tome je tradicionalan i relativno lagan uzgoj kukuruza bez posjedovanja značajnije mehanizacije. Većina proizvodnje se ostvaruje na području između rijeka Drave, Save i Dunava, a poglavito na području istočne Hrvatske (Slavonija, Baranja i zapadni Srijem). Sjetva kukuruza na našem prostoru obavlja se na razmak redova od 70 i 75 cm. U novije vrijeme provode se znanstvena istraživanja sjetve kukuruza u udvojene redove, poznate u svijetu kao twin row tehnologija. Ovisno o proizvođačima sijačica udvojeni redovi zasijavaju se na razmak od 20, 22 ili 25 cm, a središnji razmak susjednih udvojenih redova iznosi 70 ili 75 cm tako da se berba može obaviti sa standardnim beračima za kukuruz. Ova tehnologija sjetve omogućava bolje iskorištenje tla, sunčeve svjetlosti i u većini pokusa doprinosi ostvarenju jednakog ili većeg prinosa po hektaru. Veliki dio nepoznanica što se zapravo događa u proizvodnji kukuruza i drugih kultura s ovom novom twin row tehnologijom u Hrvatskoj i okruženju biti će poznato nakon završetka započetog trogodišnjeg istraživanja na 25 lokaliteta diljem Hrvatske.

Prema literaturnim navodima koji se mogu pronaći u dijelu znanstvene biliografije primjena tehnologije sjetve tzy. "*Twin-Row tehnologije*" primjenjuje se već početkom devedesetih godina u SAD-u kao težnja da se poveća prinos s povećanjem sjetve većeg broja biljaka (sklopa) po proizvodnoj površini (ha). U našem okruženju o navedenoj problematici, na prostorima bivše Jugoslavije započeo je eksperimente sa sjetvom kukuruza u udvojene redove dr. Lazar Tadić (Tadić, 1988), davne 1976. godine, navodi Čuljat (1989) s osnovnim ciljem povećanja prinosa preko povećanja sklopa. Sjetva u trake smanjivala je zasjenjivanje biljaka, a nije se povećao broj poleglih i polomljenih biljaka navodi isti autor. Ovom tehnologijom omogućena je kultivacija i berba kukuruza bez ikakvih preinaka na kultivatorima ili kombajnima. Te davne godine istraživanjima se priključuje i Poljoprivredni institut Osijek odnosno dr. Mile Čuljat koji u suradnji s metalskom industrijom Osijek odnosno u OLT-u razvija i radi na razvoju sijačice za sjetvu kulturnog bilja u udvojene redove. Njihovim zajedničkim radom proizvedena je tijekom 1986. godine prva sijačica te je nosila jedinstveni naziv PSK-T dodavši oznaku broja redova. Prema navodima istog autora došlo je do znatnijeg povećanja prinosa u svim sjetvama od 6 do 18%. Tako je krajem 1988. godine na prostorima bivše Jugoslavije proizvedeno 5 sijačica za sjetvu u udvojene redove s njihovim razmakom od 10 cm s tzv. “cik-cak” rasporedom sjetve sjemenki. Na tržištu poljoprivredne tehnike danas se mogu pronaći sijačice većeg broja proizvođača od kojih prednjače tvrtke Great Plains, John Deere, Monosem, MaterMacc CrustBuster Speed King Inc, Kinze Manufacturing, Gaspardo i mnogi drugi. Razlike između ponuđenih modela navedenih tvrtki zasigurno su u sjetvenom sustavu kao i razmaku između udvojenih redova koji iznosi 20, 22 ili 25 cm. Tvrtka Grapak (Grapak, 2016) je 2014. kao i 2015. godine obavila pokusnu sjetvu Dekalb hibrida kukuruza s Matermacc Twin row sijačicom na većem broju lokaliteta u RH. Prinos sjetve 2014. godine s Dekalb DKC 5031 u Severinu bio je veći od 19 t/ha s ostvarenim sklopom od 95.000 biljaka po hektaru. Kako novorazvijeni hibridi navedene sjemenske kuće posjeduju visoku tolerantnost na poveći sklop pa se uporabom Twin Row tehnologije može i taj potencijal iskoristiti te postići sjetva od 10 do 12 biljaka/m^2.

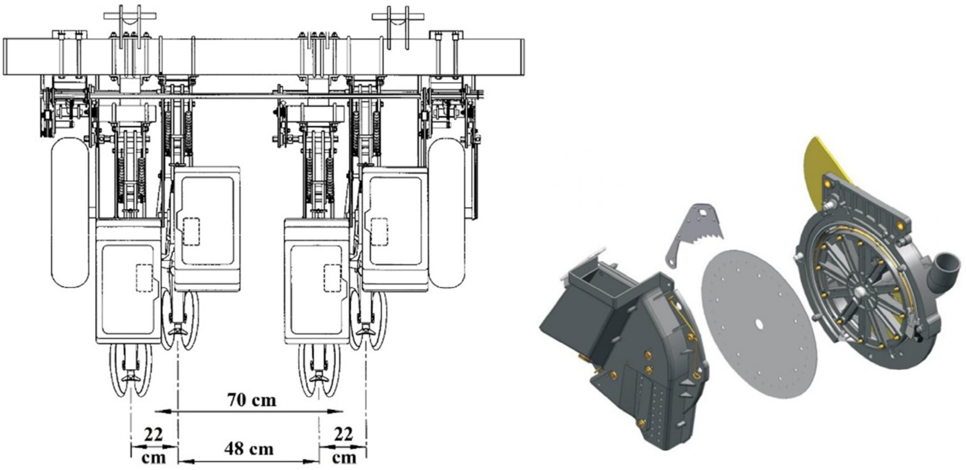
Ispitivanje twin row tehnologije u Italiji prema navodima Blandino i sur. (2013) provedeno na 12 lokacija na različitim tlima i klimatskim uvjetima u pokrajinama Alessandria, Cuneo, Ferrara, Milanu, Mantovi, Padovi, Torinu, Udinama i Veroni. Zasijan je hibrid DKC 6815, FAO grupe 600, zasijan na različite sklopove, od 7,5 do 9,5 pa čak i 10 biljaka/m^2. Dobiveni rezultati ukazuju na povećanje prinosa na 8 lokacija u prosjeku za 5,5%. Povećanje prinosa iznosilo je od 0,6 t/ha (+3,6%) te 0,9 t/ha što je iznosilo povećanje prinosa za 6,2%. Prema navodima Mackey i sur. (2016) sve veći je interes za proizvodnju kukuruza u uskim redovima (<30 inča) radi povećanja prinosa. Pokusi su postavljeni u okolici gradova Lexington i Hodgenville u saveznoj državi Kentucky tijekom 2011. i 2012. godine s tri hibrida u sjetvi na razmaku redova od 15 inča, te udvojeni redovi na 8 inča (20,32 cm) i standardna sjetva na 30 inča (76,2 cm) sa sklopovima od 30.000; 35.000; 40.000; i 45.000 biljaka po akri. Na području Hodgenville u 2011. godini, twin row sjetva polučila je 6,7% veći prinos u odnosu na standard što nije bio slučaj u sljedećoj godini. Pod povoljnim uvjetima uzgoja u Lexingtonu u 2011. godini prinos zrna povećan je za 101 kg/ha. Međutim u narednoj godini, pod vrućim i suhim uvjetima proizvodnje prinos zrna bio je nešto manji od standardne sjetve za 59 kg/ha. Prema navodima autora Ogrizović (2015) i po njegovim saznanjima iz literaturinih navoda s prostora SAD-a sjetva *Twin-Row tehnologijom* ima prednosti u odnosu na klasičnu sjetvu kukuruza jer se povećava sklop (broj biljaka/ha). U tom slučaju biljke bolje koriste svjetlost i vegetacijski prostor, korijen biljaka manje jedan drugo konkurira za hranjiva. Fiziološki izgled biljaka se poboljšava i ostvaruje se nešto veći prinos po hektaru. Isti autor navodi da su Robles i sur. (2012) potvrdili svojim rezultatima nastalo poboljšanje primjenom *Twin-Row* tehnologije. Isto tako jedan dio autora u svojim radovima, prema navodima istog autora, iznosi rezultate u kojima nema značajnih razlika u visini prinosa između sjetve na standardni razmak redova i sjetve *Twin-Row* sijačicama (Roth et. al., 2002; Jones, 2007). Kako navodi isti autor posijan je veći broj lokaliteta od 2003. godine, a posebno 2012. i 2013. godine. Rezultati europskih autora prema navodima istog autora potvrđuju rezultate američkih autora koji tvrde da postoji djelomično povećanje prinosa (Gutiérrez López et. al., 2013; Blandino et. al., 2013).

Zadatak ispitivanja je primjenom standardnih metoda utvrditi opravdanost primjene Twin Row tehnologije u sjetvi kukuruza na prostorima istočne Slavonije. Temeljem dobivenih znanstvenih rezultata doći će se do cilja tj. do saznanja o eksploatacijskoj pouzdanosti sijačice tvrtke MaterMacc Twin Row-2 primijenjene u ovim istraživanjima.

MATERIJAL I METODE RADA

Tvrtka MaterMacc osnovana je početkom 1980-ih, a od siječnja 2015. godine, postala je članica odnosno dio Foton LovoI International Heavy Industry Group. Ovaj važan korak odražava progresivnu internacionalnu strategiju tvrtke, što je posebno značajno za razvoj tehničkih vještina i izvrsnost talijanske industrije u području poljoprivredne tehnike. Njihovi proizvodni pogoni nalaze se u San Vito al Tagliamento, pokrajini Pordenone, u industrijskom središtu sjeveroistočnog dijela Italije, nedaleko od grada Venecije i Treviso aerodroma. Ova lokacija pruža tvrtki MaterMacc najbrže veze s prodajnim područjima u svijetu gdje MaterMacc prodaje svoje proizvode.

Slika 1. MaterMacc sijačica Twin Row-2 (izvor: MaterMacc, 2016)
Figure 1. MaterMacc Twin Row-2 planter (source: MaterMacc, 2016)



Slika 2. Razmak redova u sjetvi MaterMacc sijačicom Twin Row -2 i njen sjetveni sustav (izvor: MaterMacc, 2016)
Figure 2. Row spacing obtained with MaterMacc Twin Row -2 planter and it's metering unit (source: MaterMacc, 2016)

Razvojem sustava ulagača i sjetvenih sekcija pneumatskih sijačica došlo se i do proizvodnje sijačice s udvojenim redovima ili tzv. *Twin Row* sijačice. Neke tehničke karakteristike novonastalih sijačica iz serije Twin Row prikazane su u tablici 1.

Tablica 1. Osnovne tehničke karakteristike sijačica serije MS 8100 Twin Row
Table 1. Twin row planter MS 8100 series tehcnical data

Broj redova/ No. of rows	Razmak redova/ Row spacing (cm)	Radna / Working width (cm)	Masa / Weight (kg)		Potrebna snaga/ Power required (kW)	Kapacitet spremnika (l)		
			Osnovna izvedba/ Basic	S uređajem za gnojidbu/ w fetilizer		Sjeme/ Seed	Insektici di/ Microgr an.	Gnojivo/ Fertil.
2x2	70/75	140/150	630	720	29/37	140	12x2	215
4x2	70/75	280/300	1270	1450	74/81	280	12x4	215x2
6x2	70/75	420/450	1480	1760	81/89	420	12x6	215x2
8x2	70/75	560/600	1870	2250	89/96	560	12x8	650x2
12x2	70/75	840/900	2310	2750	110/118	840	12x12	650x2

REZULTATI I RASPRAVA

Klimatske prilike u vegetacijskoj 2016. godini

Srednja temperatura zraka u travnju, u mjesecu sjetve, iznosila je 11,5°C s 12 kišnih dana s ukupno 58,7 mm oborina. Isti broj kišnih dana zabilježen je i u lipnju s količinom oborina od 82,9 litara/m^2. Srednja temperatura zraka u lipnju iznosila je 19,8°C da bi u srpnju dosegla maksimum od 21,6°C (Tablica 2).

Tablica 2. Ukupne mjesečne količine oborina (mm) i srednja temperature zraka (^{0}C) u 2016. godini izmjerene na području pokušališta "Kraš" Poljoprivrednog fakulteta u Osijeku
Table 2. Total monthly precipitation (mm) and mean air temperature (^{0}C) in 2016, at experimental station „Kras", Faculty of Agriculture in Osijek

Meteorološka postaja Osijek / Osijek meteo. station	Mjesec / Month IV.	V.	VI.	VII.	VIII.	IX.	Ukupno / Total
Srednja temperatura zraka / Mean air temperature (^{0}C)	11,5	16,5	19,8	21,6	20,8	16,7	-
Suma sunčanih sati / Sum of hours with sunshine (h)	179,3	223,9	244,4	272,7	258,4	192,8	1371,5
Količina oborina / Total precipitation (mm)	58,7	69,3	82,9	60,7	58,9	55,0	385,5
Broj vedrih dana / No. of clear days	5	5	6	9	11	9	45
Broj dana s kišom / No. of days with rain	12	13	12	10	9	9	65
Broj dana s mrazom / No. of days with frost	2	0	0	0	0	0	2
Broj toplih dana / No. of warm days ($t_{max} \geq 25^0$C)	2	11	18	24	23	13	91
Broj vrućih dana / No. of hot days ($t_{max} \geq 30^0$C)	0	0	5	11	10	3	29

Temeljem utvrđenih meteoroloških podataka na području pokušališta Poljoprivrednog fakulteta u Osijeku može se zaključiti da je vegetacijska godina (2016.) bila povoljna za proizvodnju kukuruza. U proizvodnom razdoblju zabilježeno je ukupno 385,5 litara oborina sa 91 toplim danom ($t_{max} \geq 25^0$C), te 45 vedra i sunčana dana.

Rezultati utvrđivanja statističkih vrijednosti tla na pokušalištu "Kraš"

Temeljem odlika tla prikazanih u tablici 3. možemo vidjeti da su istraživani hibridi bili zasijani u tlo teksturne oznake „praškasta ilovača" sa sadržajem 3,71% humusa. Isto tlo na pokušalištu imalo je umjerenu razinu opskrbljenosti P_2O_5 (15,58 mg/100 g tla) i dobru opskrbljenost K_2O od 24,29 mg/100 g tla. Iz gore navedenog možemo zaključiti da je sjetva obavljena u vrlo kvalitetno tlo.

Tablica 3. Tip tla i njegove odlike na području pokušališta "Kraš"
Table 3. Soil properties and soil type at experimental station „Kras“

Lokacija / Location	Dubina / Depth	pH			Humus / Humus content	
	cm	H_20	KCl	Ocjena / Eval.	%	Ocjena / Evaluation
Kraš - Osijek	0-30	8,44	7,55	alkalno / alkaline	3,71	dosta humozno / enough humus
Karbonati / Carbonates		AL-P_2O_5			AL-K_2O	
%	Ocjena / Eval.	mg/100g		Ocjena / Eval.	mg/100g	Ocjena / Eval.
9,63	srednje karbonatna / medium carbonat.	15,58		umjerena / moderate	24,29	dobra / good
Krupni pijesak / Coarse Sand	Sitni pijesak / Fine Sand	Krupni prah / Coarse Silt		Sitni prah / Fine Silt	Glina / Clay	Teksturna oznaka / Texture
2,0- 0,2 mm	0,2-0,05 mm	0,05-0,02 mm		0,02-0,002 mm	< 0,002 mm	
0,60%	3,48%	42,62%		27,63%	25,67%	Praškasta ilovača / Silty Loam

Slika 3. Twin row sjetva kukuruza s razmakom udvojenih redova od 22 cm (lijevo) i standardna sjetva na razmak redova od 70 cm (desno)
Figure 3. Twin row (22 cm row spacing) corn planting (left) and standrd planting at 70 cm rows (right)

Rezultati vrijednosti eksploatacijskih pokazatelja kvalitete rada sijačica u vrijeme sjetve kukuruza

Ostvarene radne brzine te radne dubine u vrijeme sjetve na pokušalištu "Kraš" Poljoprivrednog fakulteta u Osijeku prikazane su u tablici 4.

Tablica 4. Neke statističke vrijednosti eksploatacijskih pokazatelja kvalitete rada
Table 4. Some statistical indicators of planting quality

Sijačica / Planter	Brzina rada / Speed (km/h)			Dubina rada / Depth (cm)		
	$v_{average}$	s.d.	CV (%)	$a_{average}$	s.d.	CV (%)
PSK – 4, OLT Osijek	7,69	1,170	15,30	5,02	1,026	20,43
MaterMacc Twin Row - 2	8,28	0,183	2,21	5,75	0,563	9,80

U vrijeme sjetve planirana brzina rada je bila oko 8 km/h kod obje sijačice. Nešto manju prosječnu radnu brzinu ostvarila je sijačica PSK – 4, OLT Osijek od 7,69 km/h uz dosta veliki koeficijent varijacije od 15,30%. Isto tako kod iste sijačice ostvarena je manja dubina rada, a iznosila je u prosjeku od 5,02 cm uz također vrlo veliki koeficijent varijacije od 20,43%. Ujednačena brzina rada ostvarena je pri uporabi sijačice MaterMacc Twin Row -2 a iznosila je 8,28 km/h uz ostvarenje standardne devijacije od 0,183 i koeficijentom varijacije od svega 2,21%. Prosječna radna dubina pri sjetvi iznosila je 5,75 cm uz koeficijent varijacije 9,80 % što je i razumljivo radi posjedovanja novorazvijenog sustava ulaganja sjemena.

Rezultati postignutih sklopova posijanih hibrida nakon nicanja

Tablica 5. Utvrđen broj i razmak biljaka unutar reda nakon nicanja kukuruza
Table 5. Number of plants and spacing inside rows after emergence

Red. br. / Row No.	Hibrid / Hybrid	Sjetvena norma / Sowing rate (seeds/ha)	Sklop biljaka po ha u vrijeme nicanja / Number of plants per hectare after emergence			Razmak biljaka unutar reda nakon nicanja / Plants spacing inside row (cm)		
			X_i	s.d.	CV (%)	X_i	s.d.	CV (%)
1.	P0023 PIONEER	Standard I - 64253	60705	5616	9,25	21,33	6,608	30,98
		Twin Row I – 65841	61415	7731	12,59	46,67	5,551	11,89
		Twin Row II -84523	79520	5034	6,33	36,00	3,273	9,09
		Twin Row III – 99649	92655	4785	5,16	31,20	8,801	28,21
2.	P0412 PIONEER	Standard I - 64253	63723	3169	4,97	23,60	3,135	13,28
		Twin Row I - 66355	63190	3036	4,80	44,53	3,502	7,86
		Twin Row II -73575	72420	6222	8,59	39,40	2,746	6,97
		Twin Row III – 80453	79520	4148	5,22	36,07	4,803	13,32

Tablica 6. Ostvareni prinosi zrna kukuruza (svedeno na vlagu od 14%) kod standardne i Twin row sjetve hibrida PIONEER P0023
Table 6. Corn yield (calculated at 14% grain moisture) with standard and Twin row planting of PIONEER P0023 hybrid

Standardna sjetva - 60350 biljaka/ha u berbi / Standard planting – 60350 plants/ha in harvest				
Datum berbe / Harvest date			26. September 2016.	
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
13814,71	1025	7,42	12566,84	14739,61
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
16,2	1,313	8,11	14,20	17,80
TWIN ROW I – 60480 biljaka/ha / Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
15245,67	1335	8,76	14072,93	17047,70
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
19,36	1,874	9,68	17,80	22,40
TWIN ROW II – 79200 biljaka/ha / Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
18207,65	990	5,44	17080,79	19453,12
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
16,57	0,563	3,40	15,70	17,20
TWIN ROW III – 91440 biljaka/ha / Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
19263,74	1508	7,83	17799,25	21178,85
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
21,1	2,206	10,45	19,70	25,00

Iz navedenih tablica 6. i 7. možemo vidjeti da su oba ispitivana hibrida u twin row sjetvi kod istoga sklopa polučili nešto veće prinose od 9,39 i 9,57 %. Povećanjem sklopa na 91.440 biljaka/ha u twin row tehnologiji sjetve kod hibrida sjemenske kuće Pioneer „P0023“ ostvaren je prinos 19.263 kg/ha. Isto tako kod većeg sklopa od 78.470 biljaka/ha u istim uvjetima proizvodnje hibrid Pioneer „P0412“ polučio je prinos od 18399 kg/ha suhog sjemena kukuruza.

Tablica 7. Ostvareni prinosi zrna kukuruza (svedeno na vlagu od 14%) kod standardne i Twin row sjetve hibrida PIONEER P0412
Table 7. Corn yield (14% grain moisture) with standard and Twin row planting of PIONEER P0412 hybrid

Standardna sjetva - 61770 biljaka/ha u berbi / Standard planting – 61770 plants/ha in harvest				
Datum berbe / Harvest date			22. Septembr 2016.	
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
15427,09	338,876	2,20	15172,67	15912,80
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
28,22	0,740	2,62	27,10	29,10
TWIN ROW I – 62510 biljaka/ha / Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
17060,65	1413,442	8,28	15656,33	18692,70
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
26,74	1,108	4,14	25,00	27,80
TWIN ROW II – 71150 biljaka/ha / Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
17996,45	1469,245	8,16	16203,79	19742,55
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
28,36	1,394	4,92	26,60	30,40
TWIN ROW III – 78470 biljaka/ha/ Plants/ha				
Prinos / Yield (kg/ha)	s.d.	CV (%)	Minimum (kg/ha)	Maximum (kg/ha)
18399,41	1200,940	6,53	17207,07	20012,57
Vlaga zrna u vrijeme berbe / Grain moisture in harvest (%)				
%	s.d.	CV (%)	Minimum (%)	Maximum (%)
28	0,430	1,54	27,30	28,40

ZAKLJUČCI

Na temelju dobivenih saznanja mogu se donijeti slijedeći zaključci:

- Temeljem meteoroloških podataka prvenstveno promatrajući srednje mjesečne temperature zraka i mjesečne količine oborina možemo zaključiti da je vegetacijska godina 2016. bila pogodna za proizvodnju kukuruza na lokalitetu "Kraš" Poljoprivrednog fakulteta u Osijeku,
- U standardnoj sjetvi s pneumatskom sijačicom "PSK-4" tvrtke MIO OLT Osijek hibrid sjemenske kuće Pioneer P0023 u sklopu od 60705 biljaka/ ha nakon nicanja ostvario je prinos od 13814,71 kg/ha suhog zrna s prosječnom vlažnošću od 16,2%,

- Twin row sjetva sa ostvarenim sklopom od 61415 biljaka/ha kod istog hibrida polučila je prinos od 15245,67 kg/ha suhog zrna s prosječnom vlažnošću od 19,36% što čini povećanje u odnosu na standardnu sjetvu od 10,35%.
- Standardnom sjetvom hibrida P0412 u sklopu od 63723 biljaka/ha nakon nicanja ostvaren je prinos od 15427,09 kg/ha suhog zrna s prosječnom vlagom 28,22%,
- Twin row sjetva istog hibrida s sijačicom tvrtke MaterMacc "Twin Row-2" sa ostvarenim sklopom od 63190 biljka/ha dobiven je prinos od 17060,65 kg/ha suhog zrna s prosječnom vlagom od 26,74% što predstavlja povećanje od 10,59% u odnosu na standardnu sjetvu,
- Jednogodišnjim istraživanjem problematike razmaka redova u sjetvi kukuruza na veći broj međusobno povezanih čimbenika među kojima je svakako prinos u potpunosti sa znanstvenog stajališta nismo u mogućnosti dobivene rezultate i potvrditi kao statistički opravdane, te se predlaže nastavak postupka istraživanja.

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YIELD OF CORN GRAIN BY SOWING IN TWIN ROWS WITH MATERMACC - 2 PLANTER

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SUMMARY

The paper presents result of application of twin row technology in Republic of Croatia with Italian seeder MaterMacc (twin row – 2). Researches are conducted near the city of Osijek, in eastern part of Croatia, where are recorded the optimal quantities of precipitation through entire vegetation (2016.) of corn cultivation. Average air temperature in April was 11.5 °C with 12 rainy days and with 58.7 mm of rainfall in total. The same number of rainy days was observed in June with total rainfall of 82.9 mm. Average air temperature in June was 19.8 °C, with an average maximum of 21.6 °C. The researches were conducted with two Pioneer hybrids form FAO group 500 (PO 412) and 400 (PO 023), seeded in standard technology of sowing with 70 cm between rows, and in twin row technology with 22 cm between pairwise rows. Standard sowing was conducted with pneumatic seeder PSK4 (MIO OLT) at 16th of April 2016. Standard sowing of PO 023 hybrid was conducted with 64 253 plants per ha. The real number of plants per ha (after germination) was 60 705. Yield of this hybrid, harvested at 26th September 2106. was 13 814.71 kg with CV of 7.42%. Average grain moisture in standard sowing was 16.2% with CV of 8.11%. Yield of PO 023 hybrid in twin row technology with 61 415 plants per ha was 15 245.67 kg or 10.35 % more than in the standard sowing. With increment numbers of plants per ha with twin row technology (92 655 plants/ha), yield of 19 263.74 kg is realized (CV of 7.83%; 31.20 cm plant spacing inside the row). Standard sowing of PO 412 hybrid was conducted with 64 253 plants per ha. The real number of plants per ha (after germination) was 63 723. Yield of this hybrid was 15 427.09 kg/ha with CV of 2.20%. Average grain moisture in standard sowing was 28.22% with CV of 2.62%. Yield of PO 412 hybrid in twin row technology with 63 190 plants per ha was 17 060.65 kg or 10.59 % more than in the standard sowing. With increment numbers of plants per ha with twin row technology (79 520 plants/ha), yield of 18 399.41kg is realized (CV of 6.53%; 36.07 cm plant spacing inside the row).

Key words: corn, sowing, twin row seeder, yield

45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.312.02
Izvorni znanstveni rad
Original scientific paper

AN AUTOMATIC PLUG SEEDLING TRANSPLANTER: DESIGN AND PERFORMANCE EVALUATION

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ABSTRACT

Automatic seedling transplanters are designed for large holdings from operational and economic reasons; in Romania, the share of vegetable farms with land surfaces under 2 hectares is over 70%. The paper presents the development of a small farm technology for automatic seedlings transplanting, which includes a simple equipment with gravitational extraction, transport and distribution of the seedlings with prefabricated plug substrate, raised in plastic rigid air-pruning trays. The experiments were conducted in a laboratory rig using a soil bin in order to perform studies regarding the agrotechnical and economical indices of the planting process. The statistical analysis and interpretation of experimental data allowed the comparison of the prototype's performances with the agrotehnical requirements imposed for transplanters. The results proved that the transplanter ensures, for several planting schemes, working speeds, planting frequency and productivities higher than those of the semi-automatic machines and comparable with the automated equipment used worldwide.

Key words: seedling; plug; transplanter; automatic.

INTRODUCTION

In comparison with manual planting, the automatic transplanters must ensure, from a technical and economic efficiency point of view, high productivity through high-speed working process and reduced auxiliary times; they also must provide the opportunity of making multiple operations simultaneously, of setting up of several types of crops, and lead to a better quality of the operation (Harstela, 2004). These equipments are complicated, difficult to maintain and adjust, and therefore expensive (Rantala *et al*., 2009).

There is no automatic vegetables seedlings transplanter machine designed for the microfarms located in developing countries, which are facing a decline in the specialized labor force and have insufficient financial resources for investment in an automatic transplanter and for the seedlings production system.

The automatic transplanting technology designed for the mentioned conditions must include a simple equipment, with gravitational extraction, transport and distribution of the Jiffy plug seedlings, grown in rigid plastics trays. There are three main objectives which must be reached in order to achieve this goal:

– Construction of an experimental automatic transplanting machine;
– Establishment of the methodology to obtain results in a general experiment research, performed under laboratory conditions, on a soil bin;
– Statistical analysis and interpretation of experimental data, for the comparison with the agro technical rules imposed for transplanters.

METHODS

The designed model of the automatic planting machine must meet the agrotechnical and economic indicators referring the planting process. In order to attain these objectives experimental tests were performed in a soil bin; the results were then compared with the requirements imposed for the transplanting machines.

Considerations regarding the design of the seedlings automatic transplanting machine

The seedling machine (Fig. 1) consists of the following components: frame with clamping device for coupling to a two-wheel tractor (1), planting driving wheel (2), transmission (3), planting device (4), distribution device (5), supply system (6), seedlings tray (7) and seedlings soil covering device (8).

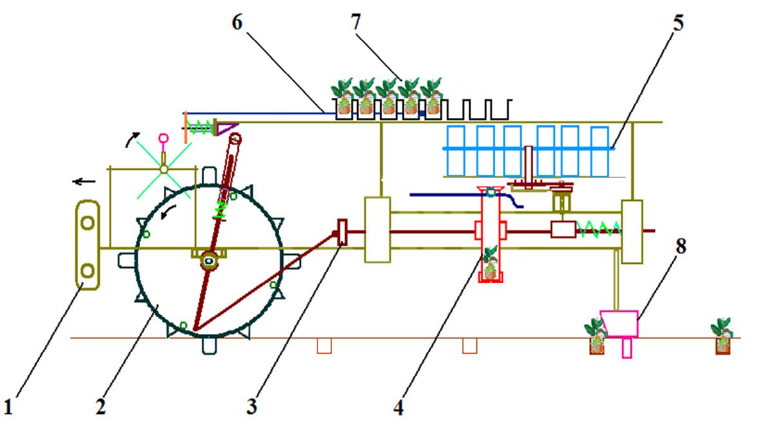


Fig. 1 - Seedlings transplanting machine
1 − frame with coupling system; 2 − planting driving wheel; 3 − transmission;
4 − planting device; 5 − distribution device; 6 − supply system; 7 − seedlings tray;
8 − soil seedlings fastening device.

The planting wheel, due to the contact with the ground, is driving the other systems via transmission levers. The material for planting is supplied from the tray, at regular intervals, into the distribution tubes; the planting device delivers the seedlings at zero speed relative to the ground, in the hole opened by the wheel planting spurs. The planting material is fixed into the soil by vertical winged pads, in a combined action: the base plate of the pads presses soil and vertical wings move it towards the center of planted row.

Considerations Concerning the Alveolar Tray and Plug Seedlings

The alveolar tray includes growing cells arranged lengthwise in straight rows, and on in arched rows on the width of the tray, according to the arrangement of the distribution tubes (Fig. 2).

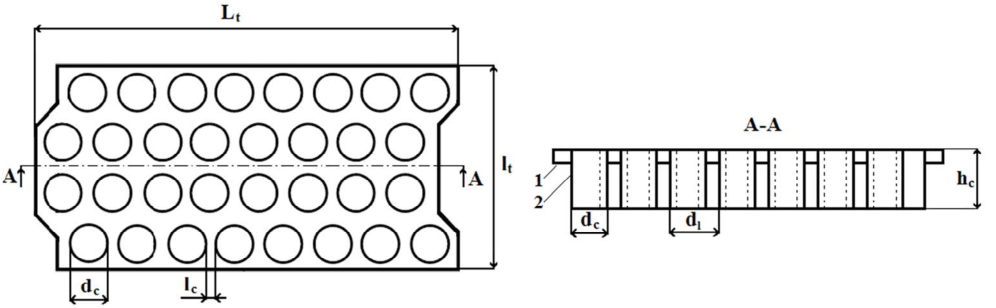


Fig. 2 - Alveolar tray
1 – tray body; 2 – growing cell; d_c – cell growth diameter; h_c – growing cell height; d_l – the distance between two consecutive cells in rows.

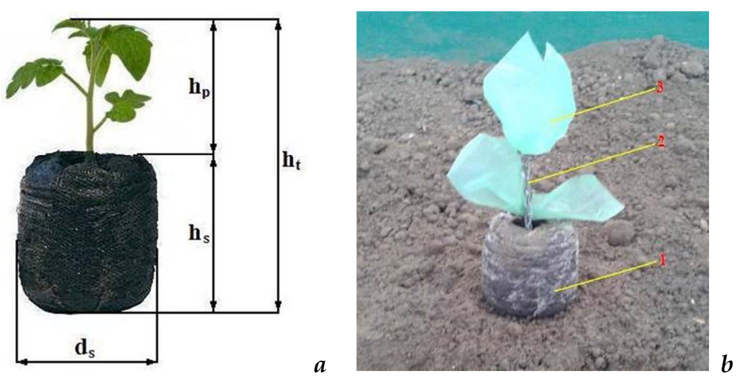


Fig. 3 - Plug seedling
a – real seedling: d_s – the diameter of substrate nutrient; h_s – the height of substrate; h_p – plant height; h_t – total height of seedling;
b – plug seedling simulacrum: 1 – plug; 2 – wire stem; 3 – pseudo-foliar system.

The seedling dimensions and configuration dictate the configuration of the machine and the entire planting process. Its parameters are related to the two components: nutrient growing substrate and the organic item, the plant itself.

After water is absorbed by the peat, the diameter and the height of the plug (Fig. 3*a*) are linked to the characteristics of the tray and the following conditions must be met:

– Cell diameter must be greater than the diameter of substrate $d_c > d_s$, to allow the phenomenon of air-pruning, and to facilitate the extraction when planting;
– Cell height must be greater than the height of substrate $h_c > h_s$, so that it does not distort over the cell's edges, making the extraction through the bottom end impossible.

During tests it is appropriate to use a pseudo-seedling (Hallonborg, 1998), made up from a real Jiffy in which a plastic imitation of leaves, with a thin wire metallic stem (Fig. 3*b*), is inserted. The simulacra of seedlings shall be carried out in variations within 20%, limits, except for plug, where uniformity variations are limited at 5% (Table 1).

Table 1 - The characteristics ranges of seedlings simulacra

Seedling total height h_t [mm]	Stem height h_p [mm]	Plug height h_s [mm]	Plug diameter d_s [mm]	Foliage diameter d_c [mm]	Number of leaves [Qty.]	Plug weight m_r [g]
120-160	64-96	38-42	38-43	48-72	2-4	42-47

Soil Bin Characteristics

The transplanting machine testing and measurements of parameters were carried out on a soil bin test rig (Fig. 4) (Ţenu *et al*., 2012). The rig is composed of: soil bin, carriage, trolley traction system, load charging system of the wheel and compacting roller and traction force measurement systems.

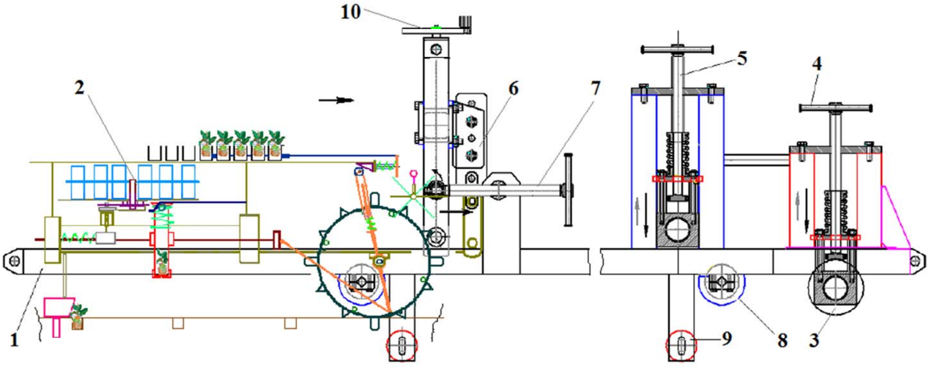


Fig. 4 - The trolley stand with the automatic transplanter
1 −carriage frame; 2 −transplanter; 3 − roller ; 4 − roller mechanism;
5 − wheel loading mechanism; 6 − mounting bracket of the machine;
7 − adjusting device for the extent of tilt; 8 − upper reel; 9 − lower reel;
10 − tool for adjusting the vertical mounting of the machine.

The carriage with the transplanter was towed with a cable by an electric motor (5.5 kW; 1000 RPM); LAUMAS SL C3 1000 daN strain gauge load cells were attached the tow line in order to measure the traction force.

Design of experimental tests

A polifactorial experiment was designed in order to evaluate the quality and operating indicators of the automatic seedling transplanter.

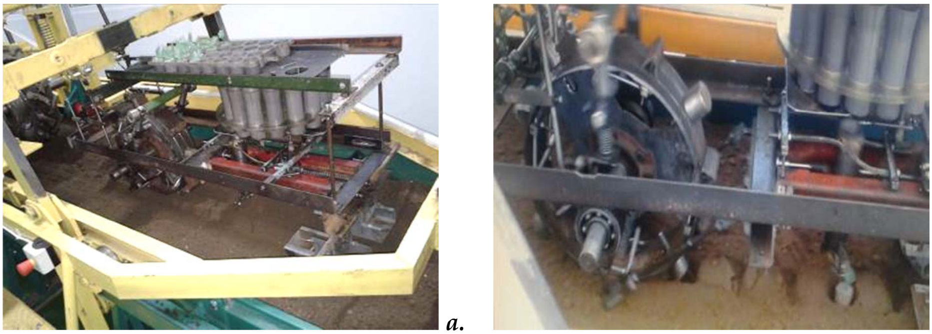
The experiment carried comprised two directions, determined by the two planting schemes, according to the distance between plants on the row obtained by using three and respectively four spurs on the periphery of the wheel planter. Three major differentiation factors were taken into account: the equipment speed, the distance between the axes of the fastening device wings and the angle made by the wings with working direction. Considering three individual values for each differentiation factors resulted in a total number of 54 variants; due to the three repetitions taken into account for each variant, the total number of experimental determinations was 162.

The transplanter (Fig. 5) parameters that will receive significant value for highlighting the machine performances were:

- theoretical distance between plants on the row d_{pt}, given by the number of spurs on the planter wheel, namely: n = 4 spurs, d_{pt} = 0.321 m and respectively n = 3 spurs with d_{pt} = 0.429 m;
- the machine speeds: V_{1m} = 0.150 m/s, V_{2m} = 0.227 m/s and V_{3m} = 0.285 m/s;
- the distance between the pads' wings axis w: 0.130 m, 0.160 m and 0.200 m ($3d_s$, $4d_s$, $5d_s$) (Fig.6 a);
- the angle between the wings and the traveling direction β: 10, 15 and 20º (Fig.6 b).

In order to calculate the specific indicators the values were measured (Balan, 1998; Ciubarin, 1972; Trandafir *et al.*, 1976):

1. The deviation from the planted row **a** (Fig.7), determined by measuring the distance from the stem to a laser beam emitted parallel to the row.
2. The distance between plants per row $\mathbf{d_p}$ (Fig.8), which was measured using a tape measure.
3. The planting depth **u** (Fig.9), which was measured by the means of a depth gauge caliper.
4. The seedling insertion into the ground was established by comparing the force necessary to extract fixed seedling from the soil (Fig. 10), with the tensile force thereof.
5. The tilt degree in the longitudinal direction $\mathbf{g_{rl}}$, respectively transverse direction $\mathbf{g_{rt}}$, was measured with a device equipped with an angle measurement tool and a water level (Fig. 11).
6. The traveling speed $\mathbf{V_m}$ was modified by changing the speed of the electric motor by the means of a variable frequency drive.
7. The traction force $\mathbf{F_m}$ was measured by the means of the load cells mounted on the towing cable.

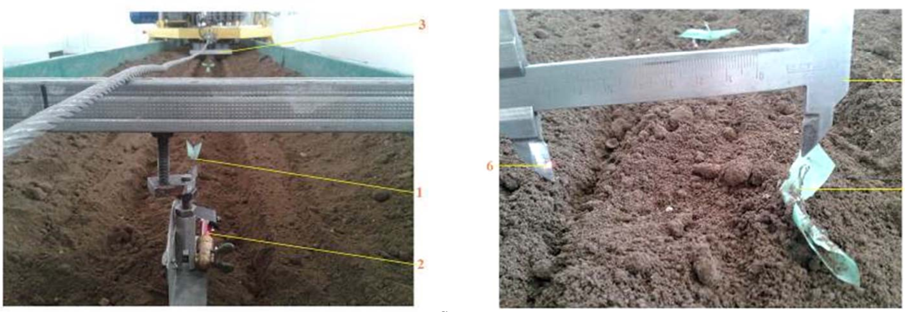


a. b.

Fig.5 - Seedling transplanter
a. on the trolley's stand; *b.* during transplanting operation

a. b.

Fig. 6 - The parameters of the pads
a. w -distance between the pads' wings axis; *b.* β -wings angle with the motion direction



a. b.

Fig. 7 - Measuring deviation of the planted row
a) 1 – row planted; 2 – laser; 3 – point laser;
b) 4 – seedlings; 5 – sliding calliper; 6 – laserpoint on the calliper beak.

Fig. 8 - Measuring distance between plants per row.

Fig. 9 Measuring planting depth

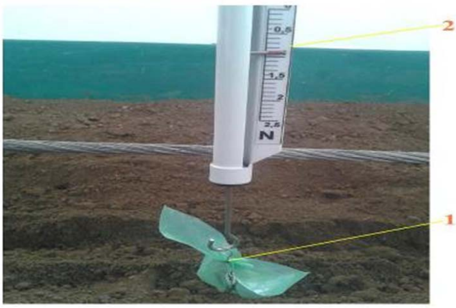


Fig.10 - Extraction force measurement

Fig. 11 - Measuring the inclination degree

RESULTS AND DISCUSSION

The prototype was designed to transplant seedlings at different speeds, without transmission adjustments, according to soil, planting operation and operator specific factors. It was necessary to study if the transplanter had constant operating behaviour, for random groups of similar planting scheme variants (presented in Table 2), from both directions of the experiment, carried out at all the three indicates working speeds. The results presented in Fig. 12, Fig.13 show that the main indices referring to the operating process of the seedling transplanter have trends.

Table 2 - Random variants characteristics used in working behaviour comparison

Experiment's direction							
I (n=4)				II (n=3)			
Variants Groups	Working Speed v	Pads' wings distance w	Wings angle β	Variants Groups	Working Speed v	Pads' wings distance w	Wings angle β
Var4	V_{1m}	$3d_s$	15º	Var49	V_{1m}	$5d_s$	20º
Var5	V_{2m}	$3d_s$	15º	Var50	V_{2m}	$5d_s$	20º
Var6	V_{3m}	$3d_s$	15º	Var51	V_{3m}	$5d_s$	20º

In order to calculate the operating indices six variants from the both sets of variants were chosen, taking into account the tested distances between plants on the row, covering all the parameters values which were used: the three working speeds, the three angles and distances between the wings. The data in Table 3 were supplemented by specifying the planting faults, contained in the column "Observation": a figure for the number of errors, the indicator symbol, for its type, and a pointer for the type of error, such as 3u(n): incorrect depth of planting for three seedlings, 3u(b) fully buried, d_{p}- void planting place, r_{v} bent strain seedling.

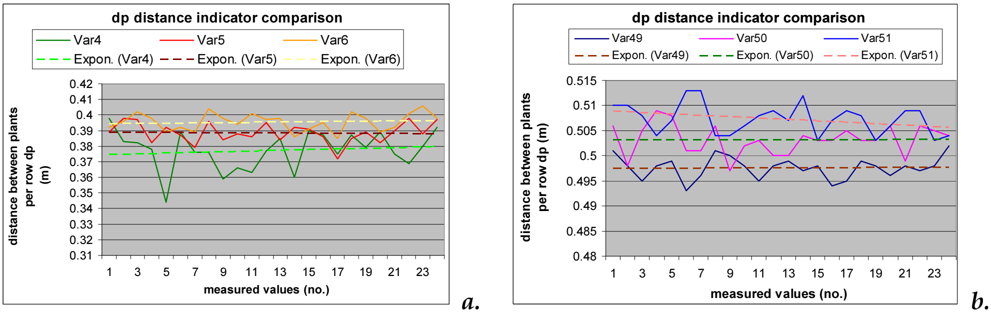


Fig. 12 Distance between seedlings per row d_p comparison:
a. Var4, Var5, Var6 (direction I); *b.*Var49, Var50,Var51 (direction II)

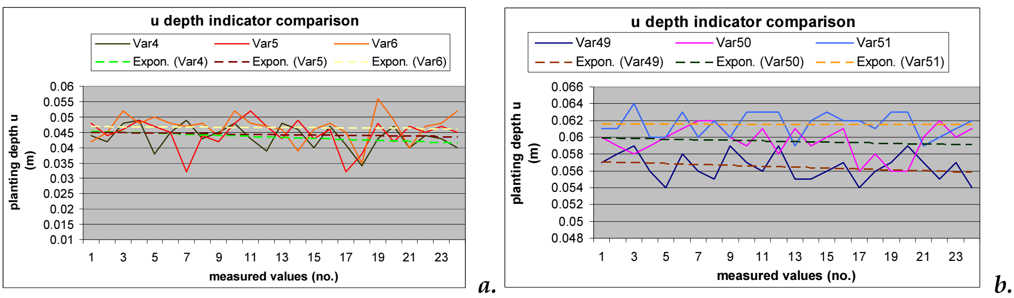


Fig. 13 - Planting depth u comparison:
a. Var4, Var5, Var6 (direction I); *b.*Var49, Var50,Var51 (direction II)

Table 3 - Experimental data corresponding to selected variants

No.	Variants	Statistical Indicator	Measured Values							Obs.
			a [m]	d_p [m]	u [m]	Φ [N]	g_{rl} [°]	g_{rt} [°]	F_m [N]	
1.	Var9	minimum	0.000	0.393	0.044	0.9	0	0	254.972	
	n=4,V_{3m}	maximum	0.005	0.414	0.066	1.6	46	5	264.779	1g_{rl}
	w=3d_s	average	0.0015	0.404	0.058	1.20	11.67	2.79	259.875	1u(b)
	β=20º	St Dev	0.0015	0.0070	0.0057	1.1954	9.01	1.215	5.6620	
2.	Var14	minimum	0.000	0.389	0.000	0.0	0	0	254.972	
	n=4,V_{2m}	maximum	0.005	0.404	0.065	1.5	16	5	264.779	1 d_{p}-
	w=4d_s	average	0.0012	0.397	0.054	1.16	8.91	2.25	259.912	1Φ
	β=15º	St Dev	0.0011	0.0037	0.0122	0.3573	4.19	1.452	5.6623	1u(n)
3.	Var19	minimum	0.000	0.378	0.043	0.6	5	0	254.972	
	n=4,V_{1m}	maximum	0.007	0.389	0.061	1.6	15	3	264.779	1u(n)
	w=5d_s	average	0.0015	0.382	0.052	1.10	10.37	1.25	259.875	1Φ
	β=10º	St Dev	0.0015	0.0027	0.0052	0.2062	2.29	1.073	5.6620	
4.	Var31	minimum	0.000	0.488	0.046	0.6	0	0	245.166	
	n=3,V_{1m}	maximum	0.005	0.499	0.057	1.4	18	5	254.972	1Φ
	w=3d_s	average	0.0014	0.494	0.053	1.13	7.62	2.33	250.069	1 r_v
	β=15º,	St Dev	0.0013	0.0029	0.0027	0.1465	4.78	1.37	5.6614	
5.	Var44	minimum	0.000	0.501	0.053	0.5	2	0	254.972	
	n=3,V_{2m}	maximum	0.005	0.513	0.063	1.4	48	5	264.779	1Φ
	w=4d_s	average	0.0017	0.507	0.057	1.22	9.79	2.50	259.875	1g_{rl} 1r_v
	β=20º	St Dev	0.0014	0.0034	0.0023	0.2187	8.45	1.61	5.6620	
6.	Var48	minimum	0.000	0.501	0.044	0.5	7	0	254.972	
	n=3,V_{3m}	maximum	0.005	0.512	0.062	1.5	15	4	264.779	1u(n)1r_v
	w=5d_s	average	0.0014	0.505	0.054	1.16	11.38	2.20	259.875	2Φ
	β=10º,	St Dev	0.0011	0.0027	0.0027	0.2039	1.996	1.250	5.6620	

Table 4 lists the calculated quality, energy and economic indices as well as the peak reference values given by the literature (Balan and Crăciun, 2005; Ciubarin, 1972; Huang and Ai, 1972; Trandafir *et al.*, 1976).

Table 4 - Calculated values of quality, energy and economic indices

No.	Indicator Type	Indicator Name	Symbol	Var9	Var14	Var19	Var31	Var44	Var48	Set Point Value
1.	Quality	Maximum deviation from the planted row	A_{rmax} (m)	0.0035	0.0038	0.0055	0.0036	0.0033	0.0036	0.02
2.	Quality	Distance deviation plants per row	A_d (%)	1.73	0.93	0.70	0.58	0.67	0.53	10
3.	Quality	Planting gaps number	G_p (%)	0.00	4.16	0.00	0.00	0.00	0.00	5
4.	Quality	Planting depth deviation	A_u (%)	9.82	22.22	10.00	5.09	4.03	5.00	10
5.	Quality	Soil seedling fixing degree	F_r (%)	100	91.66	95.83	95.83	95.83	91.66	95
6.	Quality	Planted seedling inclination	$Î_{rl}$ (%)	4.16	0.00	0.00	0.00	4.16	0.00	5
			$Î_{rt}$ (%)	0.00	0.00	0.00	0.00	0.00	0.00	5
7.	Quality	Right planted seedlings	Z_c (%)	95.83	95.83	100	95.83	95.83	95.83	95
8.	Quality	Planting frequency	F_d (s^{-1})	0.70	0.57	0.40	0.30	0.44	0.56	0.40
9.	Energy	Working speed	v (m/s)	1.026	0. 817	0. 540	0. 540	0.817	1.026	0.3
10.	Energy	Traction force	F_m (N)	259.875	259.912	259.875	250.069	259.875	259.875	–
11.	Energy	Traction power	P_t (W)	74.064	59.00	38.98	37.51	58.99	74.06	–
12.	Energy	Slippage coefficient	α (%)	20.14	19.14	15.96	13.15	15.38	15.04	20
13.	Economic	Working capacity (50.000 plants/ha)	Ω (ha/h)	0.050	0.041	0.028	0.021	0.032	0.040	0.014

CONCLUSIONS

1. The parameters that exceed the imposed limits for semi-automatic and reach the values corresponding to the automatic transplanters are: maximum calculated deviations from the row, deviation of the seedlings distance on the row, inclined seedlings in longitudinal and in transverse direction, seedlings planted correctly, working speed and working capacity.
2. Frequency planting has a minimum value lower than the ones recorded by the human operated semi-automatic planters (20 to 25 seedlings/min), for only one variant with the lowest working speed corroborated with increased planter wheel slip; the others are between or higher than the values indicated above, reaching the automatic transplanters standards.
3. Planting depth, seedlings fixed in the ground and planter wheel slip has singular values which exceed the imposed rule, generated by a fault of planting, which by its nature (a random isolated phenomenon) could induce a major deviation in a relatively reduced number of repetitions, the others five variants being in the given limits.
4. The tractive force and the power required for transplanter towing are with one magnitude order lower than the parameters developed by a 8 HP walk-behind tractor, a machinery available for a small farmer.
5. Due to the favorable values of the majority of the required planting indices for plug seedlings transplanters, the achieved automatic transplanter is comparable to other existing planting machines.
6. The automatic equipment calculated indices allow to establish that the agrotechnical requirements imposed for the human operated semi-automatic planters are met and, in some cases, substantially exceeded, reaching the automatic planters limits, so that the present equipment may be considered a valuable transplanter for developing countries' microfarms.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PRODUCTIVITY AND FUEL CONSUMPTION OF TRACTOR DRIVEN INTER-ROW MULCHER LOTTI IT 26 A IN A DIFFERENT SLOPE LEVEL VINEYARDS

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SUMMARY

During the vegetation of vine in 2013 and 2014, we estimated the productivity and fuel consumption of Holder L 780 tractor equipped with the inter-row mulcher Lotti IT 26 A. The experiment was conducted in five vineyards with different slope level 13%, 19%, 24%, 31% and 41%. The average fuel consumption increased significantly from 5.30 lh^{-1} at minimal slope (13%) to 6.78 lh^{-1} at maximal slope (41%). At the same time, the average productivity decreased from 2.24 hha^{-1} (13%) to 2.73 hha^{-1} (41%) whereby the total fuel consumption per hectare increased from 13.12 lha^{-1} at the smallest slope (13%) to 18.50 lha^{-1} at the biggest slope (41%). In addition, it was found out that the turning around the end of rows amounted 36% of total time whenever mowing 120 m long rows, which is significantly higher in comparison with 230 m long rows when amounted 12% of total time.

Keywords: vineyard, inter-row mulcher, productivity, fuel consumption

INTRODUCTION

Weed management is one of the most challenging issues faced by organic grape growers, because it controls of weeds without using synthetic herbicides and minimal disruption to the soil needs to be adopted to each vineyard separately, especially whenever growing in steep hills (Madge, 2007). In the last decade, a wide range of acceptable techniques was developed for weed management, however appropriate selection of proper technologies i.e. machines should be implemented according to particular vineyard, soil type and weed flora. The real and perceived status of plants as ‘weeds’ can vary significantly between vineyards and regions because of differences in soil, climate, vineyard age, management practices, end use of the crop and the philosophy of individual grape growers (Buckerfield and Webster, 2000). For example, grasses are often encouraged in cool climate vineyards on fertile soils where their competition for nitrogen is used to reduce excess vine vigor. Summer ground cover does however help to reduce vineyard temperature. Because of these differences, it is important that grape growers assess the weed status of plants in their own particular situation. Weed management should be prioritized by the impacts on vineyard, and potential impacts on your neighbours.

For decades, the herbicide treatment of weeds was determined as the most effective and low cost method. However its negative impact on the environment forced the introduction of integrated weed management, which helps growers to achieve the most effective weed management outcomes in the short and long-term on a new way including mowing, heat treatment, mulching and mechanical cultivation (Rass, 2014).

Mowing is often used by organic grape growers to keep cover crops and weeds to a manageable height. It is a relatively fast operation that causes minimal soil disturbance, although soil compaction may become an issue where mowing is frequent. Thermal weeding uses heat in various forms (radiant, flame, steam, hot water) to kill plant tissue. This technique has been researched and used for weed control for many years, but is generally economically effective only against small seedlings. For this reason, thermal weeding is most commonly used on row-crop seedbeds, to kill the new flush of weed seedlings before the crop germinates (Lind, 2010). It has however also been used in vineyards and orchards. Mulch inhibits weed growth and germination of weed seeds by blocking sunlight and light rainfall from reaching the soil surface. It also forms a physical barrier to weed growth. Almost any organic material can be used as mulch, with straw being commonly used in vineyards. Grape marc and composted green municipal waste is also used. Other materials include shredded paper, wet paper pulp (sprayed on) and jute matting. Mechanical cultivation destroys or buries weeds, disrupting their growth and preventing seed set. Most forms of cultivation are very disruptive to soil structure and to soil organisms. Cultivation can also spread seeds, tubers and rhizomes of noxious weeds, is relatively energy-expensive and increases the risk of soil compaction. Despite these costs, cultivation is common practice in organic viticulture. Vine rows are often cultivated for weed control in organic vineyards (Walg, 2011). Standard tools such as disc or chisel/tine ploughs are generally used to cultivate the vineyard inter-row area. These tools are mounted on manually or automatically operated retractable arms, so they can be moved around vines and irrigation risers. With this equipment, experienced operators can clean vine rows of weeds relatively quickly, with little if any damage to the vines. Some growers use these or other tools to control annual weeds with the scrape-off/throw-on strategy. Soil is repeatedly shuffled on and off the under-vine area to destroy weeds where the soil is removed, and smother those where the soil is dumped. In hot dry climates, under bare soil, grapevine roots usually avoid the top 100 mm or so of soil, so the root system will be largely unaffected by shallow cultivation (Zimmer 2011). In cooler regions, or where mulch has been applied, shallow roots will develop and these will be destroyed by under vine cultivation.

The main purpose of our article represents the determination of working productivity, the fuel consumption and related costs of the inter-row mowing with the Lotti IT 26 A platform equipped with TRF50 cutting head in five vineyards with slope level from 13% to 41%.

MATERIAL AND METHODS

The experimental site was located on the family viticulture Tement owing 27 hectares close to Ciringa 46°40′42.73″N 15°36′19.38″E (north Slovenia), from which five different vineyards with slope increasing (13, 19, 24, 31, 41%) were selected for the experiment (Table 1).

In the field experiment we used a combination consisted from tractor Holder L 780, double-headed inter-row platform with front ballast support Lotti IT 26 A equipped with TRF50 cutting head, and independent hydraulic system completed with oil tank, double pump, hydraulic oil cooling radiator and double distribution valve CP21. (Figure 1).

A Holder L 780 is 56.5 kW vineyard tractor, full-time all-wheel drive via four wheels of equal size front and rear, simultaneous electro-hydraulic actuation via toggle switch, 100% lock-up of both axles (Holder, 2015).

Table 1: List of vineyards included in the experiment

Parcel name	Slope (%)	Variety	Growing distance
Ragan 2	13	'Sauvignon'	2.3 x 0.9 m
Ciringa mladi	19	'Sauvignon'	2.3 x 0.9 m
Ragan 1	24	'Sauvignon'	2.3 x 0.9 m
Ciringa	31	'Sauvignon'	2.3 x 0.9 m
Štampfer	41	'Sauvignon'	2.3 x 0.9 m

The IT26A platform is supplied with an electro-hydraulic distributor controlled by a joystick placed on the tractor (Lotti, 2015). In all vineyards, the inter-row was mulched at the 8 cm height of grass. The fuel consumption was measured by refilling of fuel after each repetition. For eliminating the effects of variety and growing form, in all vineyards the same variety 'Sauvignon' ages from 6 to 8 years was growing. All row width was on average 2.3 m (i.e. from 2.2 to 2.4 m), whereby the spacing of plants in the row was 0.92 m and the turning path width between 5 and 6 m. Also, all surfaces are provided with the same armature, in which the final columns are of the concrete, the type of metal, poles on grapevines are made of PVC, and sealed with a clip on the base wire. Such conditions allow straight stems vines and excellent working conditions for inter-row mulchers.

Figure 1: Lotti IT 26A platform during operation (left) equipped with CP21 pump unit (middle) and TRF50 cutting head (right)

Procedure for evaluating time and fuel consumption

During field tests, the chronography was used to record the time needed to process the entire parcel at operating speed (not maximal), which assured regular mown inter-row space in the vineyard. Significant time consumption represents turning at the end of rows and re-entering into the beginning of the next row, because the driver need to avoid the anchor and set the machine precisely into inter-row. Simultaneously, it took some time before the CP21 pump unit enables enough rotation of cylinder with cords for cutting the weed. Without precise adjustment of the entering point, up to 3 m of row would remain unprocessed. The correction of machine position might amount up to 30 % of the working time, therefore, we decided to measure the total time spent on the plot. The time needed for single mowing of particular plot was later calculated as the average time from all passes recorded in two years. From the average time of single mowing, the time needed for proceed one hectare [hha^{-1}] was estimated.

Since all experimental plots were located 1 to 2 km from our own diesel dispenser - HDM eco 80, we used volumetric method to measure and record fuel consumption. After all experiments, data transfer was done from HDM to PC and further analysis were performed with MS Excel.Simultaneously, we estimated also the fuel consumption for one working hour [lh^{-1}] from the time of single mowing.

From the time of single mowing [hha^{-1}], normalized costs [$EURha^{-1}$] and expenses for PVC cords [EUR ha^{-1}] we also estimated the cost of single mowing [$EURha^{-1}$] for each parcel separately.

Data were analysed with IBM SPSS Statistics 21 package.

RESULTS

Frequency of mowing and time for mowing

The average time [h] for single mowing depend significantly from the acreage of parcel, so the maximal time was recorded on the parcel 'Ciringa' and the minimal time for 'Ciringa mladi' (Table 2). However, the correlation between increasing slope and time needed for single mowing is possible to compare whenever express in productivity of single mowing of one hectare [hha^{-1}]. In this case, significant increase in time from 2.47 hha^{-1} on 13 % slope to 2.73 hha^{-1} on 41 % slope is calculated. The parcel 'Ciringa' outstood from this correlation due to longer rows (230 m) in comparison to other parcels (120 m), so subsequently less time was required for turning at the end of the rows.

Table 2: Number of mowing and average mowing time

Parcel name	Slope (%)	Acreage (ha)	Number of mowing 2013+2014	Average time for single mowing [h]	Productivity of single mowing [hha^{-1}]
Ragan 2	13	0.65	5+6	1.61	2.47^{a}
Ciringa mladi	19	0.45	5+6	1.12	2.49^{ab}
Ragan 1	24	0.45	5+6	1.14	2.53^{b}
Ciringa	31	9.25	5+6	22.57	2.44^{a}
Štampfer	41	2.28	5+6	6.22	2.73^{c}

^{a,b,c}… statistically significant at $p<0.05$ (Duncan test)

As seen from Table 3, the biggest average total fuel consumption was measured on the parcel 'Ciringa' (141.15 l) and the smallest on the parcel 'Ciringa mladi' (6.05 l). Contrary, the fuel consumption expressed in lh^{-1} as well as lha^{-1} increases from 5.30 lh^{-1} (13.12 lha^{-1})('Ragan 2') to 6.78 lh^{-1} (18.50 lha^{-1})('Štampfer').

Table 3: Average fuel consumption

Parcel name	Slope (%)	Acreage (ha)	Average total fuel consumption [l]	Average fuel consumption [lh^{-1}]	Average fuel consumption [lha^{-1}]
Ragan 2	13	0.65	8.53	5.30	13.12
Ciringa mladi	19	0.45	6.05	5.41	13.44
Ragan 1	24	0.45	6.53	5.72	14.51
Ciringa	31	9.25	141.15	6.25	15.26
Štampfer	41	2.28	42.19	6.78	18.50

Costs for mowing

Viticulture Tement determined the cost of working hour for each process in their vineyards separately, so the costs for tractor and mulcher amounts to 29.73 EUR per hour. When multiplying the costs with the average time of mowing for particular parcel, once again the correlation with increasing slope was determined. As seen from Table 4 the rises constantly by increasing slope, so the total costs for mowing of inter-row in the dry summer (2013) was amounted from 338.16 to 372.64 EUR ha^{-1}. Contrary, in the wet summer (2014) even six passes were required for controlling the grass height so 507.24 to 558.96 EUR ha^{-1} was spent for mowing different parcel, which may be paid back only in organic vineyards or with producing expensive vines.

Table 4: Cost for mowing with Lotti IT 26 A

Parcel name	Slope (%)	Costs (EUR ha^{-1})
Ragan 2	13	86.03
Ciringa mladi	19	85.43
Ragan 1	24	87.22
Ciringa	31	84.54
Štampfer	41	93.16

CONCLUSIONS

The inter-row mulcher Lotti IT 26 A in combination with a tractor Holder L 780 was proved to be a good solution for the mowing of inter-row space in steep vineyards. The results of our research showed close correlation between the increased inclination and fuel consumption. In the areas with extreme slope of more than 40 % up to 18.50 l per one hectare of vineyard was used. Maybe, with another smaller tractor, a lower fuel consumption would be measured, but Holder L 780 delivers excellent results in terms of working productivity, which shows that the tractor is operated solid at all slopes.

The average working productivity differed from parcel to parcel, increasing between 2.53 hha^{-1} (13 %) and 2.73 hha^{-1} (41 %), which represented also reasonable working costs for bigger organic viticulture. On the other hand, for the most of smaller winemakers, which are dominated in Slovenia, the costs of a new Lotti IT26 A inter-row mulcher (25,000 EUR) is usually too high and would not be reasonable for use. On the other side, the possible solution for someone who cannot provide its own the machine, the use of ring-service, which offered single mowing passage for a price of 100 EUR ha^{-1} is quite promising.

Nevertheless, in the conventional viticulture the use of herbicide is still much cheaper and quicker than any other environmental friendly method of grass and weed control. However, we believe that the use of Lotti IT 26 A platform with inter-row mulcher might represent efficient weed control and grass mowing at reasonable costs for eco-winegrower.

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PRODUKTIVNOST I POTROŠNJA GORIVA MEĐUREDNOG MALČERA LOTTI IT 26 A NA RAZLIČITIM NAGIBIMA VINOGRADA

SAŽETAK

Tijekom 2013. i 2014 godine procijenjena je produktivnost i potrošnja goriva rednog malčera Mulcher Lotti IT 26 A u kombinaciji sa traktorom Holder L 780 u pet vinograda sa različitom kosinom; 13%, 19%, 24%, 31% i 41%. Prosječna potrošnja goriva je značajnoj je korelaciji sa rastom strmine padine i kreče se od 5,30 lh^{-1} na najmanjem nagibu (13 %) do 6,78 l h^{-1} na maksimalnim nagibom (41 %). Istovremeno, prosječna produktivnost smanjena je od 2,24 hha^{-1} na 2.73 hha^{-1} što znači da je ukupna potrošnja goriva po hektaru povećana od 13,12 lha^{-1} na najmanjem nagibu (13 %) do 18,50 lha^{-1} na najvećem nagibu (41 %). Osim nagiba, duljina redova značajno utječe na vrijeme potrebno za okretanje na kraja redova te se može povećati do 36 % ukupnog vremena.

Ključne riječi: vinograd, redni malčer, radna produktivnost, potrošnja goriva

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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A THEORETICAL INVESTIGATION OF CONCAVE BARS FOR CORN EARS THRESHING

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SUMMARY

The most important constructive parameters by corn ears threshing are design, height, number of concave crossbars and their position in respect of threshing cylinder. There is a lack of research evaluating an impact of concave crossbars design on corn grains detaching from cob, grains damage and separation through the concave. A major hypothesis of the study is that a concave crossbars form has an impact on corn ear threshing efficiency.

It is known that the corn ear threshing process depends on effectiveness of first interaction between the cylinder rasp bar and corn ear in threshing apparatus. The theoretical study has been based on investigations of three different forms of concave crossbars: rectangular, rounded and oblique. The force of ear gravity (G); the reaction force (N_1) of concave bar on corn ear; the reaction force (N_{22}) of ear cob reaction on grain which is in contact with concave bar; the reaction force (N_{12}) of subsequent grain on grain which is in contact with concave bar; the reaction forces (N_2 and N_3) of longitudinal rod reaction on ear (based on touch of ear with two grains on longitudinal rod of concave) have been evaluated. Acting frictional forces have been expressed as products of reaction forces and coefficients of friction. Five equilibrium equations with five unknown have been composed. Acting reaction, frictional and gravity forces have been designed to x and y coordinates axes for this reason. Furthermore, moments of acting forces around the chosen points have been fixed. Using the Maple software, numerical values of unknown forces have been found. It has been determined that numerical values of the reaction forces N_1 and N_{12} were the biggest at oblique design of concave bars. Accordingly, it seems possible that then threshing process at the first corn ear contact with the rasp bar will be more effective. The values of forces obtained from calculations have been as follows: N_1=89.10 N and N_{12}=22.51 N (by given rectangular concave bars), N_1=56.08 N and N_{12}=5.50 N (by given rounded concave bars), N_1=320.76 N and N_{12}=116.70 N (by given oblique concave bars).

Keywords: corn, ear, separation, threshing cylinder, rasp bar, concave

INTRODUCTION

Most countries, practising the application of modern technologies in agriculture have been noted to use self-propelled combine harvesters with a tangential, longitudinal axial flow, or tangential-longitudinal axial flow threshing devices for corn grain harvesting (Miu, 2015). Nonetheless, frequent unfavourable meteorological conditions and the ineffectiveness of the combine structure under the respective conditions often result in grain harvest processing losses above the permissible thresholds (Špokas et al., 2013). The reasons mentioned above imply the need for improvement of the threshing unit design on the basis of a detailed analysis of the process of corn ear threshing (Yu et al., 2013; Kiniulis et al. 2016). The threshing process depends on the corn variety, the design of the threshing apparatus, and its adjustment (Petkevichius et al., 2008; Poničan et al., 2009). One of the key design parameters of a threshing unit critical for corn ear threshing is the shape, height, number of the concave crossbars and the position of the crossbar relative to the cylinder, as well as the active separation area of the concave (Norris and Wall, 1986; Miu, 2015). Modern combine harvesters use concaves with rectangular crossbars for grain crops and rounded crossbars for corn. The concave wrapping radius is a constant, meaning that the clearance between the cylinder rasp bar and concave crossbars is subject to uneven variation. For the higher intensity of processes in the threshing unit as mentioned above, a variable radius concave has been designed, manufactured, tested and patented. The variable radius concave provides flexibility in terms of the number of crossbars, i.e. it allows changing the step of crossbars in the concave and their surface shape (Pužauskas, 2016). Previous studies have demonstrated that the variable radius concave improves the efficiency of corn grain separation through the concave grating by 2.5. (Rakauskas et al., 2015). The authors suggest that further studies are required for optimisation of the crossbar surface shape and their step.

A process of a corn ear stroke by rasp bar has been investigated by viewing high-speed film (15000 frame per second) at Aleksandras Stulginskis University in 2015 (Stončius et al., 2015). On the basis of results evaluation, the investigation process has been divided into seven stages of a corn ear stroke by rasp bar. Displacements, velocities and deformations of corn ear have been determined at each stage. In addition, turning angle of corn ear, angular velocity and corn ear shelling rate have been evaluated. It has been determined that grain separation from the corn cob is directly proportional to the height of concave crossbar. Giving one corn ear stroke by rasp bar, the best shelling performance (79.7 ± 3.28%) has been achieved by using concave crossbar height of 12 mm. However, cob splits into fractions of various sizes during the shelling operation. If the cobs split, the combine cylinder is unable to remove all grains from the cob segments and consequently shelling losses increase. Researchers consider that the concave crossbar heights should not be more than 9 mm during the shelling operation. Furthermore, there is a lack of research of concave crossbar design, an impact to damage and separation on corn grain.

Most of the studies on corn threshing have been based only on experiments and there is a lack analysis of the action between the threshing cylinder rasp bar, concave bar and the corn ear grain. The literature review revealed little information concerning the concave bars shape and their influence upon grain separation and injury during the threshing process.

Aim of the Paper. To substantiate the shape of the concave crossbars by theoretical investigations.

RESULTS AND DISCUSSION

It is assumed that corn ears are pushed down the bottom (2) of a feeder conveyor (1) by the slats (3), with the longitudinal axis of the ears being parallel to the slats (Fig. 1). As a result, the majority of the ears enter the clearance between the cylinder rasp bar (8) and the concave crossbar (5) positioned in parallel to the rasp bars. The threshing of corn ears fed at the first concave crossbar (5) is often inefficient due to the lack of sufficient support for the corn ears. Moreover, corn ears, which have entered the cavity between the rasp bars, are immediately passed to the second concave crossbar (6), i.e. they usually have no contact with the first crossbar. For the reasons mentioned above, the theoretical analysis of the cylinder rasp bar, corn ear and concave is performed for the second concave crossbar. The entire corn ear threshing process is known to depend on the efficiency of the interaction between the first cylinder rasp bar and the corn ear (Petkevičius et al., 2012). In contrast to conventional combine harvesters, the concave covering the cylinder is not circular, but has a variable radius, similar to an Archimedean spiral. This type of concave has been validated by respective research studies and patented (Pužauskas, 2016).

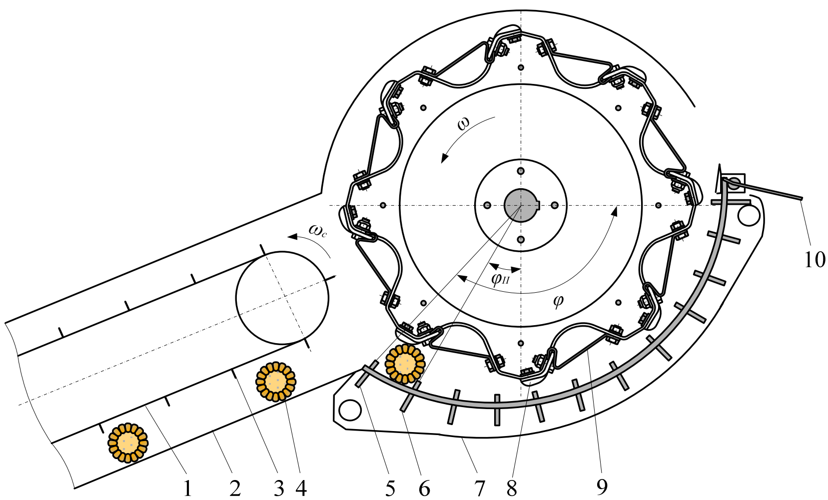

Fig. 1. Corn ear threshing unit diagram (Pužauskas et al., 2016): 1 – feeder conveyor; 2 – feeder house bottom; 3 – slats; 4 – corn ear; 5, 6 – the first and second concave crossbars; 7 – concave; 8 – cylinder rasp bars; 9 – cylinder filler plates; 10 – rod grating; ϕ – concave wrapping angle (ϕ=130°); ϕ_{II} – angle of the second concave crossbar relative to the vertical (ϕ_{II}=30°); ω – angular velocity of the cylinder; ω_c – angular velocity of the feeder conveyor

The theoretical analysis has been conducted by analysing the crossbars of three different shapes (Fig. 2), which are installed in the variable radius concave referred to above.

Traditional continuum mechanics analysis methods can be applied to analyse the force applied to a single corn ear, cob, and grain in the corn threshing process (Yu et al., 2015). The analytical study of the threshing process under this research involves the application of a Ø46 mm corn ear *II*, which interacts with a Ø0.8 m threshing cylinder rasp bar *I* and the second concave crossbar *III* (Fig. 3). The corn cob is surrounded by 14 grains at any of its cross-sections; single grain height – 9 mm, width – 8.4 mm. Three accurate process calculation schemes have been developed for the static equilibrium study in order to determine the numeric values of the reaction forces (only the structure of an oblique concave crossbar is depicted in Fig. 3).

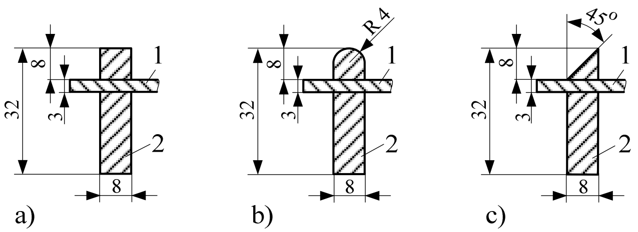

Fig. 2. Concave crossbars (Pužauskas et al., 2016): a – rectangular; b – rounded; c – oblique; 1 – concave rod; 2 – concave crossbar

Force *P* is applied to the grain by the striking rasp bar. This force tends to push the grain toward the centre of the ear (force P_n), simultaneously rotating the ear in the clockwise direction and moving it in a lateral direction to the right (force P_τ). The corn ear bottom rests with a single grain on the concave rod *IV* and crossbar *III*. Reaction forces N_2 and N_1 are applied to these contact points. The process of detaching the corn grains from their supporting structure, the cob, is defined as shelling or threshing. Shelling occurs when the forces applied to the grains overcome the holding strength of the grain attachment to the cob. In addition, the corn cob reaction to grain force N_{22} and grain reaction to grain forces N_{12} are applied.

The active friction forces are expressed as the multiplication of the normal reaction forces and friction coefficients: $F_f= f_1 \cdot P_n$; $F_{fN1}= f_1 \cdot N_1$; $F_{fN2}= f_2 \cdot N_2$; $F_{fN3}= f_2 \cdot N_3$; $F_{fN12}= f_2 \cdot N_{12}$; $F_{fN22}= f_3 \cdot N_{22}$. The friction coefficients f_1 between the corn grain and steel section of the working tool of the threshing unit are equal to 0.33, friction coefficients between the contacting grains $f_2 = 0.25$, and the grain to corn cob friction coefficients $f_3 = 0.42$ (Petkevičius et al., 2012).

Five equilibrium equations with 5 unknowns are composed. For this purpose, the acting forces are expressed on the *x* and *y* axes of the coordinate system:

$$\begin{aligned}\Sigma F_x &= P\cdot\cos\alpha_P - F_f\cdot\cos\alpha_F + N_{22}\cdot\cos\alpha_2 - F_{fN22}\cdot\sin\alpha_2 + N_{12}\cdot\cos\alpha_3 + \\ &+ F_{fN12}\cdot\sin\alpha_3 - N_1\cdot\cos\alpha_4 + F_{fN1}\cdot\sin\alpha_4 + N_2\cdot\cos\alpha_5 + F_{fN2}\cdot\sin\alpha_5 + \\ &+ N_3\cdot\cos\alpha_6 + F_{fN3}\cdot\sin\alpha_6 = 0\end{aligned} \quad (1)$$

$$\begin{aligned}\Sigma F_y &= -P\cdot\sin\alpha_P + F_f\cdot\sin\alpha_F - G - N_{22}\cdot\sin\alpha_2 - F_{fN22}\cdot\cos\alpha_2 + N_{12}\cdot\sin\alpha_3 - \\ &- F_{fN12}\cdot\cos\alpha_3 + N_1\cdot\sin\alpha_4 + F_{fN1}\cdot\cos\alpha_4 + N_2\cdot\sin\alpha_5 - F_{fN2}\cdot\cos\alpha_5 + \\ &+ N_3\cdot\sin\alpha_6 - F_{fN3}\cdot\cos\alpha_6 = 0\end{aligned} \quad (2)$$

In addition, the moments of the acting forces have been written down for the chosen points C_1, C_2, and C_3:

$$\begin{aligned}\Sigma M_{C1} = &-P \cdot l_{PC1} + F_f \cdot l_{FfC1} + G \cdot l_{GC1} + N_{22} \cdot l_{N22C1} - F_{fN22} \cdot l_{FfN22C1} + N_{12} \cdot l_{N12C1} + \\ &+ F_{fN12} \cdot l_{FfN12C1} - N_1 \cdot l_{N1C1} + F_{fN1} \cdot l_{FfN1C1} - N_2 \cdot l_{N2C1} + F_{fN2} \cdot l_{FfN2C1} - N_3 \cdot l_{N3C1} + \\ &+ F_{fN3} \cdot l_{FfN3C1} = 0\end{aligned} \tag{3}$$

$$\begin{aligned}\Sigma M_{C2} = &-P \cdot l_{PC2} + F_f \cdot l_{FfC2} + G \cdot l_{GC2} + N_{22} \cdot l_{N22C2} - F_{fN22} \cdot l_{FfN22C2} + \\ &+ N_{12} \cdot l_{N12C2} - F_{fN12} \cdot l_{FfN12C2} - N_1 \cdot l_{N1C2} + F_{fN1} \cdot l_{FfN1C2} + N_2 \cdot l_{N2C2} + \\ &+ F_{fN2} \cdot l_{FfN2C2} + N_3 \cdot l_{N3C2} + F_{fN3} \cdot l_{FfN3C2} = 0\end{aligned} \tag{4}$$

$$\begin{aligned}\Sigma M_{C3} = &-P \cdot l_{PC3} + F_f \cdot l_{FfC3} + G \cdot l_{GC3} - N_{22} \cdot l_{N22C3} + F_{fN22} \cdot l_{FfN22C3} - \\ &- N_{12} \cdot l_{N12C3} + F_{fN12} \cdot l_{FfN12C3} - N_2 \cdot l_{N2C3} + F_{fN2} \cdot l_{FfN2C3} - N_3 \cdot l_{N3C3} + \\ &+ F_{fN3} \cdot l_{FfN3C3} = 0\end{aligned} \tag{5}$$

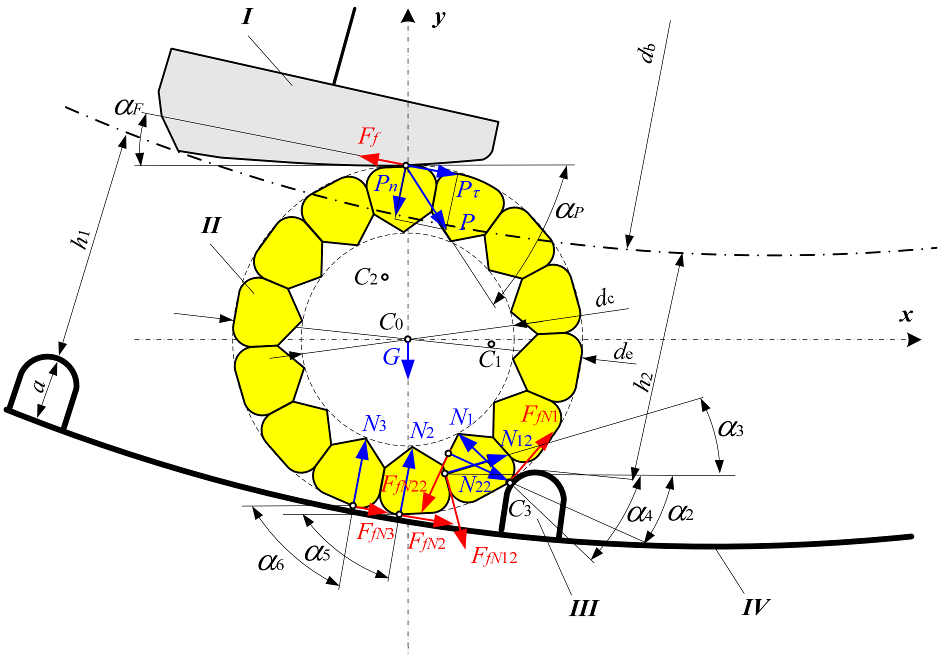

Fig. 3. Interaction between the rasp bar, corn ear and second concave crossbar: *I* – cylinder rasp bar; *II* – corn ear; *III* – the second concave crossbar; *IV* – concave rod; C_0, C_1, C_2 – points referred to by the equations of the moments of force; *a* – height of the concave crossbars (*a*=8 mm); h_1, h_2 – distances of the rasp bar to the first and second concave crossbars (h_1=36 mm, h_2=34 mm); d_b, d_e, d_c – diameters of the cylinder, corn ear and corn cob (d_b=800 mm, d_e=46 mm, d_c=28 mm); β – tilt angle of the working plane of the concave crossbars (β=45°); (other designations are provided in Table 1)

The angles of all the forces marked in Fig. 3 and distances to points C_0, C_1 and C_2 have been calculated using the *AutoCAD* 2006 application (Table 1). The table also contains data of the other two structures (for rectangular and rounded crossbars).

Table 1. Model values (see Fig. 3)

Indicator	Designation, dimension	Crossbar shape		
		rounded	rectangular	oblique
Rasp bar force acting on the corn ear grain	P, N	29.18	31.99	32.00
Force P components: tangential normal	 P_τ, N P_n, N	 22.60 18.46	 31.44 5.89	 31.39 6.23
Rasp bar to corn ear grain friction force	F_f, N	6.092	1.944	2.056
Corn ear gravity force	G, N	3.924	3.924	3.924
Angle of the rasp bar force P acting on the grain relative to the horizontal	α_P, °	60.80	23.00	23.89
Force F angle relative to the horizontal	α_F, °	12.24	12.40	11.77
Angle of the corn cob reaction to grain force N_{22} relative to the horizontal	α_2, °	26.14	26.14	26.14
Angle of the grain reaction to grain force N_{12} relative to the horizontal	α_3, °	16.00	16.00	16.00
Angle of the concave crossbar reaction to grain force N_1 relative to the horizontal	α_4, °	42.86	45.00	45.00
Angle of the concave rod reaction to grain force N_2 relative to the horizontal	α_5, °	80.66	80.08	79.04
Angle of the concave rod reaction to grain force N_3 relative to the horizontal	α_6, °	79.47	79.29	80.01
Distance between force P vector and parallel straight line crossing point: C_0 C_1 C_2 C_3	 l_{PC0}, mm l_{PC1}, mm l_{PC2}, mm l_{PC3}, mm	 10.98 2.52 11.53 8.70	 21.41 17.99 17.82 31.52	 20.85 17.30 17.35 33.10
Distance between force F_f vector and parallel straight line crossing point: C_0 C_1 C_2 C_3	 l_{FfC0}, mm l_{FfC1}, mm l_{FfC2}, mm l_{FfC3}, mm	 22.42 20.83 17.86 37.98	 22.51 20.89 17.97 36.23	 22.32 20.81 17.23 38.56

Table 1 (Continued)

Distance between force G vector and parallel straight line crossing point:				
C_0	l_{G0}, mm	0	0	0
C_1	l_{G1}, mm	9.99	9.99	9.99
C_2	l_{G2}, mm	3.68	3.68	3.68
C_3	l_{G3}, mm	13.10	14.93	13.57
Distance between force N_{22} vector and parallel straight line crossing point:				
C_0	l_{N22C0}, mm	10.35	10.05	10.05
C_1	l_{N22C1}, mm	13.63	13.97	13.97
C_2	l_{N22C2}, mm	13.33	13.33	13.33
C_3	l_{N22C3}, mm	0.721	1.075	1.395
Distance between force F_{fN22} vector and parallel straight line crossing point:				
C_0	$l_{FfN22C0}$, mm	11.47	12.48	12.48
C_1	$l_{FfN22C1}$, mm	2.260	3.269	3.269
C_2	$l_{FfN22C2}$, mm	17.18	18.19	18.19
C_3	$l_{FfN22C3}$, mm	8.56	8.56	8.26
Distance between force N_{12} vector and parallel straight line crossing point:				
C_0	l_{N12C0}, mm	18.43	18.89	18.89
C_1	l_{N12C1}, mm	15.16	15.61	15.61
C_2	l_{N12C2}, mm	24.70	25.15	25.15
C_3	l_{N12C3}, mm	3.22	1.89	3.51
Distance between force F_{fN12} vector and parallel straight line crossing point:				
C_0	$l_{FfN12C0}$, mm	0	0.952	0.951
C_1	$l_{FfN12C1}$, mm	9.455	8.504	8.504
C_2	$l_{FfN12C2}$, mm	2.037	2.989	2.989
C_3	$l_{FfN12C3}$, mm	7.42	8.63	6.75
Distance between force N_1 vector and parallel straight line crossing point:				
C_0	l_{N1C0}, mm	4.94	1.69	4.13
C_1	l_{N1C1}, mm	11.30	8.37	10.81
C_2	l_{N1C2}, mm	6.46	2.95	5.38
C_3	l_{N1C3}, mm	0	0	0

Table 1 (Continued)

Distance between force F_{fN1} vector and parallel straight line crossing point:				
C_0	l_{FfN1C0}, mm	22.35	22.81	23.32
C_1	l_{FfN1C1}, mm	14.63	15.36	15.88
C_2	l_{FfN1C2}, mm	28.76	29.28	29.79
C_3	l_{FfN1C3}, mm	0	0	0
Distance between force N_2 vector and parallel straight line crossing point:				
C_0	l_{N2C0}, mm	2.85	4.13	4.60
C_1	l_{N2C1}, mm	7.10	5.81	5.31
C_2	l_{N2C2}, mm	7.37	8.70	9.26
C_3	l_{N2C3}, mm	13.12	13.57	12.41
Distance between force F_{fN2} vector and parallel straight line crossing point:				
C_0	l_{FfN2C0}, mm	22.79	22.75	22.67
C_1	l_{FfN2C1}, mm	23.88	23.94	24.04
C_2	l_{FfN2C2}, mm	27.58	27.50	27.33
C_3	l_{FfN2C3}, mm	6.40	8.26	6.20
Distance between force N_3 vector and parallel straight line crossing point:				
C_0	l_{N3C0}, mm	2.72	1.66	1.85
C_1	l_{N3C1}, mm	12.64	11.58	11.78
C_2	l_{N3C2}, mm	1.90	2.98	2.72
C_3	l_{N3C3}, mm	19.03	19.55	18.59
Distance between force F_{fN3} vector and parallel straight line crossing point:				
C_0	l_{FfN3C0}, mm	22.81	22.80	22.78
C_1	l_{FfN3C1}, mm	24.11	24.14	23.98
C_2	l_{FfN3C2}, mm	27.51	27.48	27.52
C_3	l_{FfN3C3}, mm	6.76	8.55	6.02

The solution of equations 1–5 under the numerical method using the *Maple14* application provides the numerical values of the forces under consideration (Table 2). Equations 1–5 have been solved by the application of the *Maple* program – Gaussian linear algebraic equations algorithm. In Fig. 4 is shown schematic flowchart of general procedures for calculation the numerical values of the reaction forces.

Static verification is then conducted by writing down the equations of the moments of the acting forces for point C_0:

$$\Sigma M_{C0} = -P \cdot l_{PC0} + F_f \cdot l_{FfC0} + N_{22} \cdot l_{N22C0} - F_{fN22} \cdot l_{FfN22C0} + N_{12} \cdot l_{N12C0} - \\ - F_{fN12} \cdot l_{FfN12C0} - N_1 \cdot l_{N1C0} + F_{fN1} \cdot l_{FfN1C0} + N_2 \cdot l_{N2C0} - F_{fN2} \cdot l_{FfN2C0} - \\ - N_3 \cdot l_{N3C0} + F_{fN3} \cdot l_{FfN3C0} = 0 \quad (6)$$

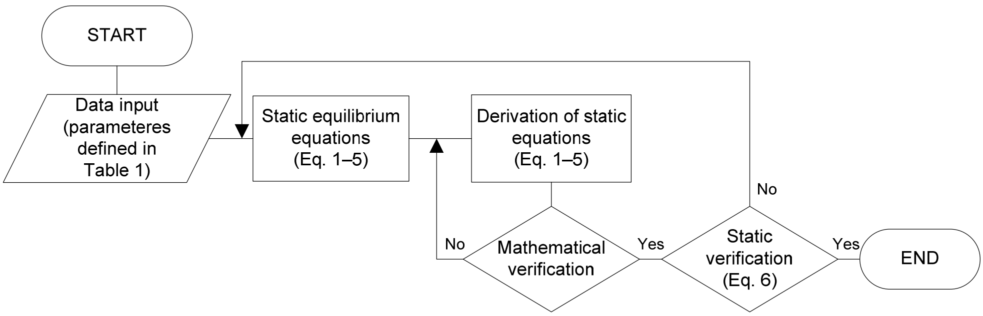

Fig. 4. Schematic flowchart of general equations solution procedures

The theoretical analysis has demonstrated that oblique concave crossbars provide maximum numerical values of the force N_1 of the concave crossbar reaction to grain and force N_{12} of the grain reaction to grain. This suggests that the threshing process using oblique crossbars would probably be more efficient that using any of the other two shapes of crossbars.

Table 2. Calculated numerical values of the reaction forces

Indicator	Designation, dimension	Crossbar shape		
		rectangular	rounded	oblique
Force of the corn cob reaction to grain	N_{22}, N	24.99	23.16	343.73
Force of the grain reaction to grain	N_{12}, N	22.51	5.50	-116.70
Force of the concave crossbar reaction to grain	N_1, N	89.10	56.08	320.76
Force of the concave rod reaction to grain	N_2, N	-19.58	-29.59	-0.028
Force of the concave rod reaction to grain	N_3, N	-32.54	24.65	0.003

The theoretical analysis has been conducted by using the concave with oblique crossbars and a working plane tilt angle β of the crossbars equal to 45°. It would therefore be reasonable to focus comparable experimental tests on using the oblique crossbars with β=45°; however, the oblique crossbars would probably be subjected to more rapid wear during prolonged operation. Additionally, it would be reasonable to focus further experimental tests on a determination of the effect of oblique crossbars wider than 8 mm and having a smaller angle than 45° β (e.g., 35°) on the efficiency of the corn ear threshing.

CONCLUSIONS

1. A numerical analysis of the corn ear threshing process has been conducted, and a mathematical model of the corn ear threshing has been developed. A process calculation scheme has been developed for the static equilibrium analysis and the numerical values of

the reaction forces in the threshing process have been determined. The efficiency of the threshing process has been found to depend on the geometrical shapes of the concave crossbars.

2. It has been determined that numerical values of the reaction forces N_1 and N_{12} were the biggest at oblique design of concave bars. Accordingly, it seems possible that then threshing process at the first corn ear contact with the rasp bar will be more effective. The values of forces obtained from calculations have been as follows: N_1=89.10 N and N_{12}=22.51 N (by given rectangular concave bars), N_1=56.08 N and N_{12}=5.50 N (by given rounded concave bars), N_1=320.76 N and N_{12}=116.70 N (by given oblique concave bars).

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 633.353
Prethodno priopćenje
Preliminary communication

INFLUENCE OF FIVE TILLAGE PATTERNS ON FABA BEAN PRODUCTIVITY PARAMETERS

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SUMMARY

A long-term stationary field experiment (since 1988) was carried out at the Experimental Station of the Aleksandras Stulginskis University (ASU, 54º52′ N, 23º49′ E). The soil of the experiment is silty light loam Endohypogleyic-Eutric Planosol (PLe-gln-w). Since 1988, wheat, barley, rape, beet, and maize crops were investigated in the conditions of five different tillage patterns: 1) conventional (22–25 cm) ploughing by a mouldboard plough, 2) shallow (12–15 cm) ploughing by a mouldboard plough, 3) deep (25–30 cm) tillage by a chisel cultivator, 4) shallow (10–12 cm) tillage by a disc harrow, 5) no-till. Results of investigations showed that in long-term conditions of reduced tillage, the productivity of main crops in Lithuania was similar and mainly insignificant. Since 2015, the EU Greening program requested increasing the area of leguminous crops. Lithuanian conditions are the most favorable for pea and faba bean cultivation. Therefore, the area of these crops increased several times. Unfortunately, there is no precise scientific background of faba bean growing technologies in Lithuania. The aim of the experiment was to investigate the influence of five reduced tillage patterns on the parameters of faba bean productivity.

The results of the experiment showed that the reduction of primary tillage from annual deep ploughing to no-till had no any significant effect on the parameters of faba bean productivity. The key parameter, which initiated some variation between factors and indexes, was the density of crop.

Key words: reduced tillage systems, *Vicia faba* L., grain yield, yield components

INTRODUCTION

In most European countries, mouldboard ploughing stills the main tillage method (Arvidsson et al., 2013). During the last 30 years, traditional tillage methods have been changed to reduced ploughless tillage technologies. In these countries, the use of ploughless tillage technologies reached more than 70% (Alvarez and Steinbach, 2009). No-till (NT) technology, as the edge of tillage practice, is currently used on 117 million hectares worldwide and 1.15 million hectares in Europe (Lopez et al., 2012).

The reduction of tillage intensity has many positive outcomes. The reduction of technological costs, conservation of moisture and fertility of the soil, CO_2 sequestration, the stabilization of crop productivity and energy level along with other aspects are of great importance (Šimanskaitė, 2007; Morris et al., 2010; Rusu et al., 2011; Soane at al., 2012; Arvidsson et al., 2013; Lozano-García and Parras-Alcántara, 2014; Šarauskis et al., 2014; Kazemi et al., 2015).

Many legumes have the ability to form nitrogen-fixing symbioses with soil bacteria, which is broadly called "rhizobia". The amount of CO_2 respired from the root systems of N_2-fixing legumes is higher than CO_2 generation during N-fertilizer production. N_2O emission from faba bean per one growing season is 0.41 kg N_2O–N ha^{-1}. In comparison, the emission from alfalfa crop is 1.99, soybean – 1.58, N–fertilized pasture – 4.49, N–fertilized wheat and maize – 2.73. Therefore, the development of faba bean area in crop rotations may decrease the emission of Greenhouse effect (GHE) gas. On the other hand, faba bean residues might be used as biofuel; grains have about 31 % of protein and 1 % of fat (Jensen et al., 2012). Most of grain legumes have more fat, so faba bean might be used for humans with surplus weight diet.

Reduced soil tillage technologies were widely investigated, but there are very few such studies on legume crops, especially faba bean. The results from the Mediterranean conditions, carried out for over 18 years on a Vertisol showed that no-tillage (NT) system affected on a higher faba bean grain yield than conventional tillage (CT). NT decreased the costs and avoided the negative impacts of tillage on the physical, chemical and biological properties of the soil. The success of NT depends on the effectiveness of weed control (Giambalvo et al., 2012).

The EU Greening program requested increasing the area of leguminous crops. Lithuanian conditions are the most favorable for pea and faba bean cultivation and the area of these crops increased several times. Unfortunately, there is no precise scientific background of faba bean growing technologies in Lithuania. One of the leading parameter of technology is a tillage system. Therefore, the aim of our investigations was to determine the influence of long-term reduced tillage systems on the parameters of faba bean productivity in the conditions of Lithuanian subarctic climate.

METHODS

Since 1988, a stationary long-term field experiment has been performed at the Experimental Station (54º52′ N, 23º49′ E) of the Aleksandras Stulginskis University (ASU), Lithuania. No-till (NT) treatment was included in 2001. In this manuscript, the data of 2016 are presented. The soil of the experiment is a silty loam (45.6% sand, 41.7% silt, 12.7% clay) Planosol *(Endohypogleyic-Eutric – Ple-gln-w)* (WRB, 2014). Table 1 show some chemical properties of the soil in the experiment.

Table 1 Soil chemical properties during faba bean vegetation at 0-15 cm sampling depth

Soil tillage system	Sampling time	pH_{HCl} mol L^{-1}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	MgO mg kg^{-1}	N_{total} %
DP	B	7.1	231.5	85.0	360.0	0.131
	E	7.4	237.0	104.0	437.0	0.129
SP	B	7.0	248.5	108.0*	347.0	0.143
	E	7.4	257.0	122.0	434.0	0.139
DC	B	7.4	250.5	120.5**	446.0	0.142
	E	7.3	194.0	101.5	346.0	0.130
SC	B	7.1	284.5	149.0**	408.0	0.144
	E	7.1	284.0	138.0*	324.0	0.144
NT	B	6.7	233.5	116.5**	274.0	0.168**
	E	7.0	250.0	119.0	312.0	0.157*

* - significantly different at $P \leq 0.05$ from the control treatment (DP) within rows; ** - at $P \leq 0.01$. DP - conventional deep (22–25 cm) ploughing with a mouldboard plough; SP - shallow (12–15 cm) ploughing with a mouldboard plough; DC - deep (25–30 cm) cultivation with a chisel cultivator; SC - shallow (10–12 cm) cultivation-discing with a disc harrow; NT - no-till. B – beginning of vegetation, E – end of vegetation.

The climate of the experimental site is subarctic, with wet winters and moderate summers. The long-term (60 years) average annual precipitation rate is 625.5 mm. Average air temperatures and rates of precipitation during the faba bean vegetation in 2016 are presented in Table 2.

Meteorological conditions during faba bean vegetation in 2016 were unusual. Beginning of vegetation was warmer and the end was colder than it normally is. April and May were dry and that limited the development of faba bean. June was more humid – it had been raining for 12 days and precipitation rate was a little bit higher than long-term average. In July, it had been raining for 22 days and the precipitation rate was about 1.7 times higher than it usually is. This month had three extremely rainy days - 3-th (45.7 mm), 11-th (20.5 mm) and 28-th (21.6 mm).

Table 2 Meteorological conditions during faba bean vegetation. Kaunas Meteorological Station

Months	April	May	June	July	August
Air temperature (°C)	7.4	15.7	17.2	17.9	16.9
Average since 1974	6.9	13.2	16.1	18.7	17.3
Precipitation rate (mm)	41.2	36.4	83.9	162.9	114.9
Average since 1974	41.3	61.7	76.9	96.6	88.9

In our experiment, in the faba bean cropping technology, only the soil tillage system, as factor was changed (except for the weed control in the NT plots) (Derpsch et al., 2014). Five different reduced primary soil tillage systems were used in autumn: 1. deep conventional (22–25 cm) ploughing with a mouldboard plough (DP); 2. shallow (12–15 cm) ploughing with a mouldboard plough (SP); 3. deep (25–30 cm) cultivation with a chisel cultivator (DC); 4. shallow (10–12 cm) cultivation-discing with a disc harrow (SC); 5. no-till (NT). We described the tillage systems according to the Gruber et al. (2011) manner in Table 3. The experimental treatments are designed with four replications in a randomized distribution. The initial size of the experimental plot is 70 m^2, total number of plots - 20. The pre-crop of faba bean was winter wheat. Crop rotation in the experiment since 2016: winter wheat, faba bean, spring barley, winter oilseed rape. Since 2001, legumes were not grown in the experiment. Organic fertilizers were also not applied.

Table 3 Tillage practice in the experiment

Tillage system	Stubble tillage	Primary tillage	Implement	Depth of tillage (cm)	Pre-crop residue cover (%)
DP	Yes	Inversion	Mouldboard plough	22–25	2.8
SP	Yes	Inversion	Mouldboard plough	12–15	2.8
DC	Yes	Non-inversion	Chisel cultivator	25–30	42.5**
SC	Yes, twice	No	Disc harrow	10–12	43.5**
NT	No	No	None	0	87.0**

Notes: DP - conventional deep (22–25 cm) ploughing with a mouldboard plough; SP - shallow (12–15 cm) ploughing with a mouldboard plough; DC - deep (25–30 cm) cultivation with a chisel cultivator; SC - shallow (10–12 cm) cultivation-discing with a disc harrow; NT - no-till.

The primary soil tillage was performed in late October. The DP and SP plots were tilled with a Gamega PP-3-43 plough (Lithuanian producer) with semi-helical shellboards, DC - with a chisel cultivator KRG-3.6, and the SC with a disc harrow Väderstad Carrier 300.In spring, before sowing of faba bean, the NT plots were sprayed with the herbicide Glyphogan (glyphosate 360 g L^{-1}) at the rate of 5 L ha^{-1}. Pre-sowing tillage was performed with a complex cultivator Laumetris KLG-3.6 (Lithuanian producer). Faba bean sowing was performed with a sowing machine Väderstad Rapid 300C Super XL. The distance between rows was 25 cm. The sowing rate was 200 kg grain per ha. The sowing depth was 5-6 cm. In the experiment we applied faba bean variety 'Fuego' (C2, mass of 1000 grain – 630 g). The variety was created by Norddeutsche Pflanzenzucht Hans–Georg Lembke KG, German. According to the investigations of this variety in Lithuanian Varieties Research Stations in 2007-2008, the average yield of grain was 6.47 t ha^{-1}, mass of 1000 grain –654.43 g, content of protein – 31.1–32.7%, average height of plant – 120 cm. In our experiment, before sowing, the sowing material was inoculated with a *Rhizobium leguminosarum* bacterial preparation (about 200 ml of preparation for 100 kg seeds). In the soils of less fertility, the usage of bacterial preparation mainly increases productivity and quality of faba bean crop (Denton et al., 2013). A complex fertilizer NPK 7:16:32 (300 kg ha^{-1}) was incorporated into seedbed directly during bean sowing. Next day after sowing, cultivation of faba bean was sprayed with the herbicide Fenix (aclonifen 600 g L^{-1}, 3.0 L ha^{-1}, Amazone UF-901 sprayer). Pests in faba bean cultivation were controlled at the beginning of crop flowering (BBCH 60-63) with insecticide Karate Zeon 5 SC (lambda-cyhalothrin, 150 g ha^{-1}). We used fungicide Signum (26.7% w/w boscalid and 6.7% w/w pyraclostrobin, 1 L ha^{-1}) against diseases at the same time. Faba bean crop was harvested at the beginning of September with a plot combine Winterstager Delta (Winterstager AG, Austria).

The agrochemical properties of the soil were analyzed in the Lithuanian Research Centre for Agriculture and Forestry, Laboratory of Agrochemical Research as follows: the pH was measured with a potentiometer (standard ISO 10390), phosphorus and potassium were measured with an Egner-Riehm-Domingo (AL) method, magnesium – according to the standard LVP D-13:2016, N_{total} – standard ISO 11261 (Kjeldahl method). The sampling depth was 0–15 and 15–25 cm. Samples for faba bean productivity tests were collected at 5 separate places of each experimental plot.

Experimental data was statistically evaluated by using one-way analysis of variance (ANOVA) with Selekcija software (Tarakanovas, Raudonius, 2003). Significant differences between mean values were evaluated with the Fisher's LSD test. The marking of the significant differences between treatments and the control treatment (conventional ploughing) was designated in the following way: * – differences are significant at the 95% probability level ($P<0.05$), or ** – differences are significant at the 99% probability level ($P<0.01$). For data correlation analysis we used STAT_ENG for EXEL vers. 1.55 software.

RESULTS AND DISCUSSION

In our previous experiments on the basis of the described experiment, we did not find any significant influence of soil tillage treatments on sugar beet and maize productivity (Romaneckas et al., 2006; Romaneckas et al., 2009; Avižienytė et al., 2013).

Table 4 The influence of tillage systems on faba bean crop density and biological parameters

Soil tillage system	Crop density per m^2	Number of pod per m^2	Number of pod per plant	Number of grain per pod	Mass of 1000 grain
DP	55.6	399.6	7.2	2.9	594.22
SP	50.4	370.4	7.3	3.0	599.92
DC	50.8	369.2	7.3	3.1	576.04
SC	46.4*	338.0*	7.3	3.0	610.17
NT	51.6	352.8	6.9	3.0	583.94

Notes: * - significantly different at *P≤0.05* from the control treatment (DP) within rows; DP - conventional deep (22–25 cm) ploughing with a mouldboard plough; SP - shallow (12–15 cm) ploughing with a mouldboard plough; DC - deep (25–30 cm) cultivation with a chisel cultivator; SC - shallow (10–12 cm) cultivation-discing with a disc harrow; NT - no-till.

In our experiment with faba bean crop, different tillage systems mainly had no singificant effect on crop density before harvesting, except for shallow cultivation (SC) treatment (Table 4). In these plots, 46.4 plants per square meter were found. Plant residues on the soil surface often clogs tillage and sowing machines with ordinary coulters, deteriorates seedbed preparation, and increases working time and energy consumption (Šarauskis et al., 2013). In our experiment, winter wheat residues coated 87% (Table 4), but this had no effect on sowing quality and final crop density. Less number of plants in SC treatment negatively influenced the number of pods per square meter. We found strong correlation between crop density and the number of pod per square meter (r = 0.901*). In SC plots faba bean plants formed significantly lower number of pod – 338 units per square meter. However, the differences between number of pod per one plant and grain per one pod were insignificant. The lowest crop density in SC plots initiated the highest mass of 1000 grain (r = -0.454); however, the differences were insignificant.

Highest faba bean plants developed in SC plots (104.6 cm), because crop was less dense (r=-0.893*) compared with other tillage trestments (Table 5). The differences between treatments were not significant.

Dry biomass of faba bean canapy is suitable for fuel pellet production. We found that dry biomass of canopy in experiment varied from 12.81 (DP) to 11.37 (DC, SC) t ha^{-1}. The amount of biomass strongly depended on crop density (r = 0.874).

The yield of faba bean grain was not significantly affected by the different tillage systems. Despite that, the highest yield of grain was observed in control (DP) plots and the lowest one – in SC plots. The productivity of grain strongly denended on the crop density (r = 0.946*) and the number of pod per square meter (r = 0.950*).

Table 5 The impact of tillage systems on faba bean canopy productivity parameters

Soil tillage system	Height of plant, cm	Dray biomass of canopy, t ha^{-1}	Yield of grain, t ha^{-1}	Grain moisture content, %
DP	95.9	12.81	4.95	20.1
SP	102.7	11.82	4.33	20.4
DC	99.3	11.37	4.55	20.3
SC	104.6	11.37	4.04	20.5
NT	102.3	11.87	4.35	21.9**

Notes: ** - significantly different at $P \le 0.01$ from the control treatment (DP) within rows; DP - conventional deep (22–25 cm) ploughing with a mouldboard plough; SP - shallow (12–15 cm) ploughing with a mouldboard plough; DC - deep (25–30 cm) cultivation with a chisel cultivator; SC - shallow (10–12 cm) cultivation-discing with a disc harrow; NT - no-till.

Grain moisture content may depend on the height, density of crop and weeds and other factors. In tilled plots, grain moisture content was similar and varied from 20.1 to 20.5%. In the weedest NT plots, grain moisture content reached 21.9% and was significantly higher comparing to control (DP) plots. Higher moisture content leads additional expencies for yield drying.

CONCLUSIONS

1. Different tillage systems mainly had no significant effect on the density of faba bean crop, except from shallow cultivation (SC) treatment. In these plots, the crop density was significantly lower than in control, which significantly affected a lower number of pod per square meter (r = 0.901*).
2. The differences between the number of pod per one plant and grain per one pod were insignificant. The lowest crop density in SC plots initiated the highest mass of 1000 grain (r = -0.454).
3. The highest faba bean plants developed in SC plots (104.6 cm) because of a lower crop density (r = -0.893*).
4. Different tillage systems had insignificant effect on faba bean shoot biomass and grain productivity. Productivity mainly varied in the dependence of crop density ($r_{biomass}$ = 0.874; r_{grain} = 0.946*).

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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VIBRATION ANALYSIS USING POWER SPECTRAL DENSITY OF A GENERATED SIGNAL IN A VIBRATING FEEDER

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ABSTRACT

The product development through simulation technology has become the most used tool for the development of more innovative products. The simulation technology compress the product development process and result in reduced costs of production. Power spectral density is a very useful tool in determining the frequencies and the amplitudes of an oscillatory signals per unit time. It shows the distribution of power variations (energy) as a function of frequency. In other words, it shows on which the frequency variations may be strong or weak. Using the power spectral density function (PSD) we determined the frequencies on which the peaks of amplitude shows the highest values for a vibrating feeder, with the vibration generator mounted in two position.

The purpose of these experiments was to verify the hypothesis that the vibration amplitude is attenuated if the position of the vibration source and their means of transmission thereof change. We conducted two experiments in which the vibration generator was placed first on the back of the vibrating feeder, and then in a central position. The signal obtained during the measurements was filtered in the work program MatLab using Fast Fourier Transform (FFT). To highlight the strong signal variations measured, we determinated, using PSD, the frequencies on which the elastic elements for suspension of the vibrating feeder have high amplitudes. The measured amplitude provides information about the existing gaps between the component parts of the vibrating feeder and identifies the frequency on which the amplitude has the highest value.

Key words: power spectral density, vibrating feeder, frequency, amplitude.

INTRODUCTION

The product development through simulation technology has become the most used tool for the development of innovative products. The simulation technology compress the product development process and results in reduced costs of production.

When the energy of a generated signal is concentrated around a finite time interval, especially if the total energy is finite, we can calculate the power spectral density (or simply the power spectrum). Power spectral density (PSD) shows the distribution of power (energy) variations as a function of frequency per time unit in which the measurements are made, [4]. In other words, it shows on which frequency the amplitude variations are strong and weak. PSD is a very useful tool in determining the frequency and the amplitude of an oscillatory signals per unit time.

Using PSD we can determine the frequencies on which the elastic elements for suspension of the vibrating feeder have high amplitudes. The measured amplitude provides information about the existing gaps between the component parts of the vibrating feeder and on which frequency the amplitude has the highest value. Its measurement is performed in low frequencies, typically corresponding to the speed of the vibrating generator.

The analyzed vibratory feeder is part of the machine used for removing impurities from seeds built at INMA Bucharest. The machine (Figure 1) is equipped with ferrite magnetic drums and is designed in order to eliminate impurities from seeds of legumes, flax, hemp, carrots, onions, chives, spinach, tomatoes, etc., [3]. The transport of the particles on the surface of the feeder is achieved by providing them a relative movement thereof. The relative movement of the particles is obtained by printing a linear vibratory movement from the vibration generator, preferably on the Z direction. Also, vibrations on the other 2 axes, X and Y are to be maintained out minimum amplitude, in order to obtain a high degree separation factor.

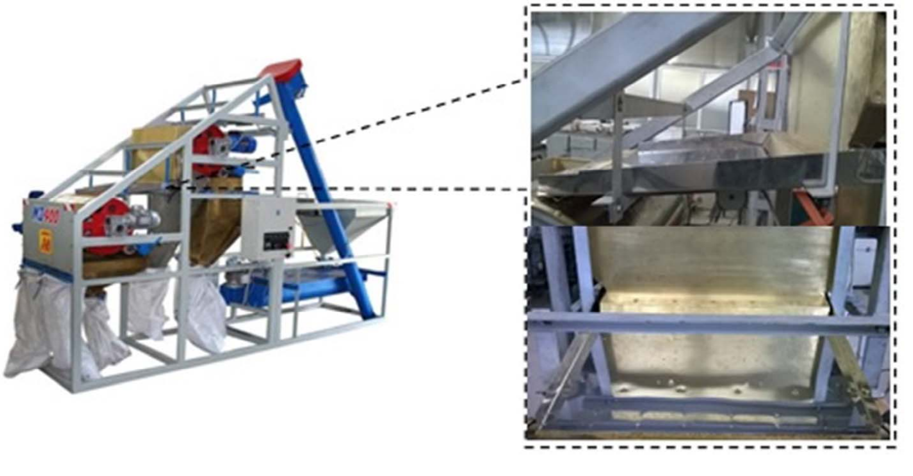


Figure 1 General view of the vibrating feeder

METHODS

Power spectral density of a generated signal X (t) is defined as the average squared Fourier transform (Figure 2), in a long period of time, [7]

$$S_{X(f)} = \lim_{T \to \infty} \frac{\overline{|F\{X_T(t)\}(f)|^2}}{T} \tag{1}$$

where X_T (t) is the restriction of the generated signal X (t) on the interval [-T, T], and F {X (t)} (f) is the Fourier transform of the signal x (t).

The power spectral density can be calculated for any type of vibration signal, but it is particularly appropriate for random vibration, [4]

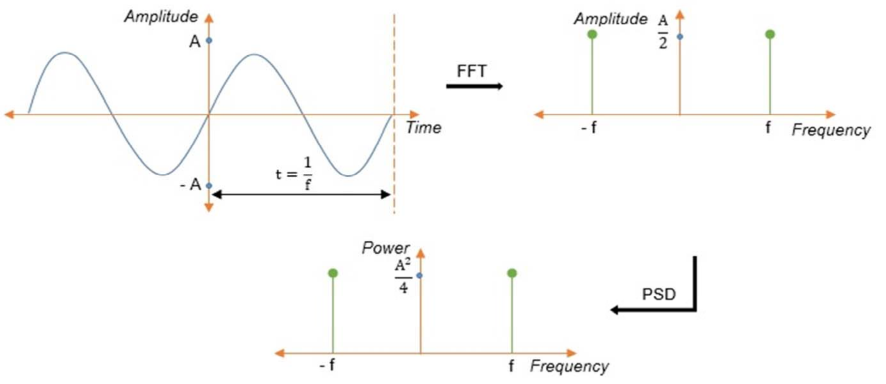
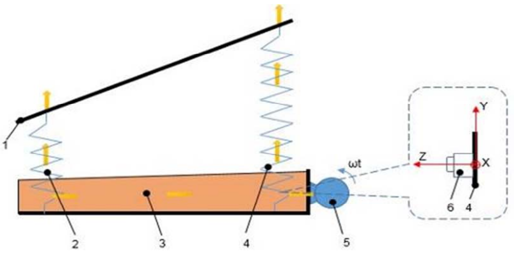
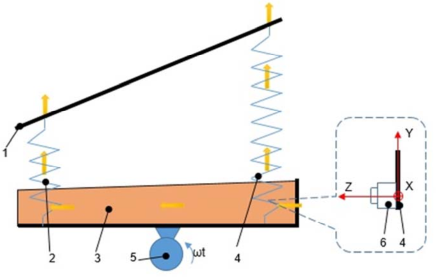


Figure 2 The conversion of a generated signal in power spectral density, [8]

We used an accelerometer mounted so as to measure the accelerations received by the elastic element from the vibration generator according to the diagram below. The experiments were performed within INMA Bucharest and aimed at studying the behavior of the suspending elastic elements of the vibrating machines. The mounting of the vibration generator was conducted in two positions, located in the back of the vibratory feeder and in a central position (see Figure 3).



a)
The vibration generator placed behind the feeder



b)
The vibration generator placed in center

Figure 3 The means of vibrations transmission and the position of the accelerometer
1 - the frame of the machine; 2,4 - elastic suspension elements; 3 – the transport gutter; 5 – the vibration generator; 6 – the accelerometer.

Using the measured accelerations and the work program MatLab, we determined the power of each frequency component. The power can be displayed in linear or logarithmic scale and is calculated as follows, [7]

$$P_x(f) = X(f)X^*(f) \tag{2}$$

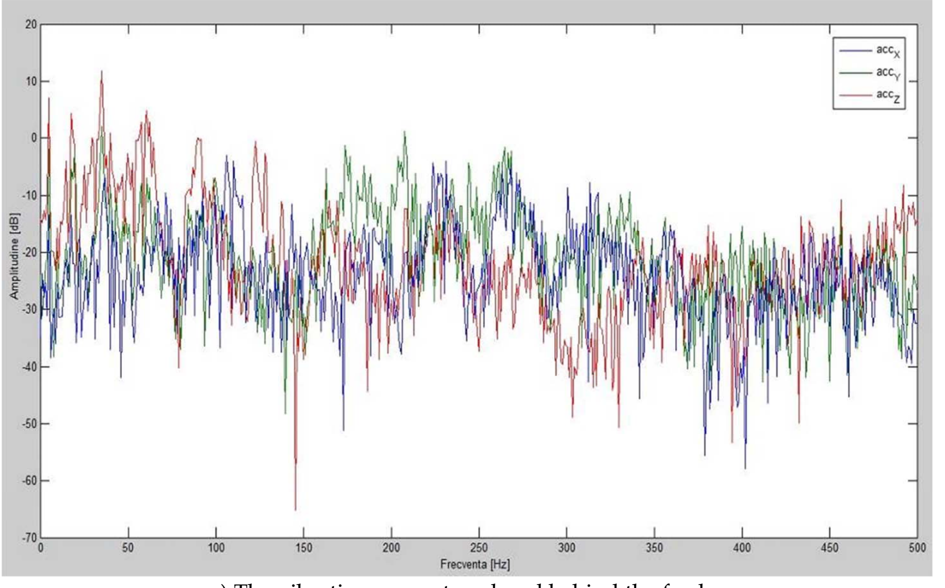
where X (f) is the frequency domain of the signal x (t)

In MatLab the power must be calculated in terms of coresponding scale (whereas the signal length and the Fast Fourier Transform length can vary from case to case), [7]

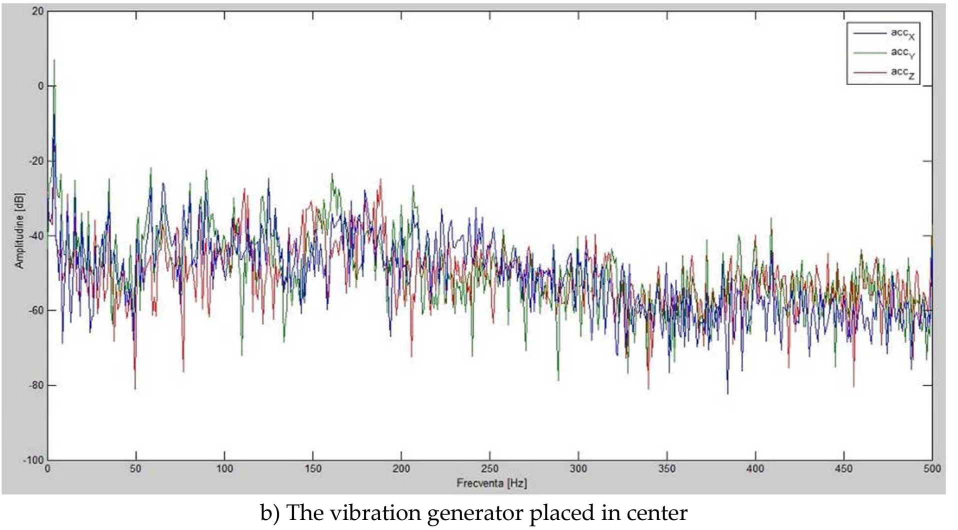
RESULTS AND DISCUSSION

Individual effects are more easily to be identified using frequency analysis. A vibration signal represented in the time domain can be converted into a graph amplitude – frequency using Fast Fourier transform (FFT) in the work program Mat Lab (see Figure 4).

The accelerations were measured on the elastic element (see the mounting scheme in Figure 3) for both cases, but, as we can see from the pictures below (Figure 4), the graphical representation of the accelerations in the frequency domain using FFT is one difficult to interpret. We can determine the frequencies at which the elastic elements show higher amplitudes (which require bending moment) using PSD.



a) The vibration generator placed behind the feeder



b) The vibration generator placed in center

Figure 4 The graphical representation of the accelerations in the frequency domain

The frequencies are determined by applying a filter in the work program MatLab and power spectral density determination. The steps for determining the PSD in MatLab program could be represented by, [9]

- Apply the FFT to the measured signal;
- Determine the power of each frequency components;
- Represent the PSD dependency of the frequency only displaying the positive frequency (the negative frequency part of X axis is omitted).

The figures below provide the power spectral density depending on the frequency for the case when the vibration generator is placed behind the feeder. The PSD is displayed only for the frequency range from 0 to 50 Hz because the higher amplitudes of the vibrations generator appears in this range. The measurements were made for a working speed of the vibration generator of 2750 rot / min.

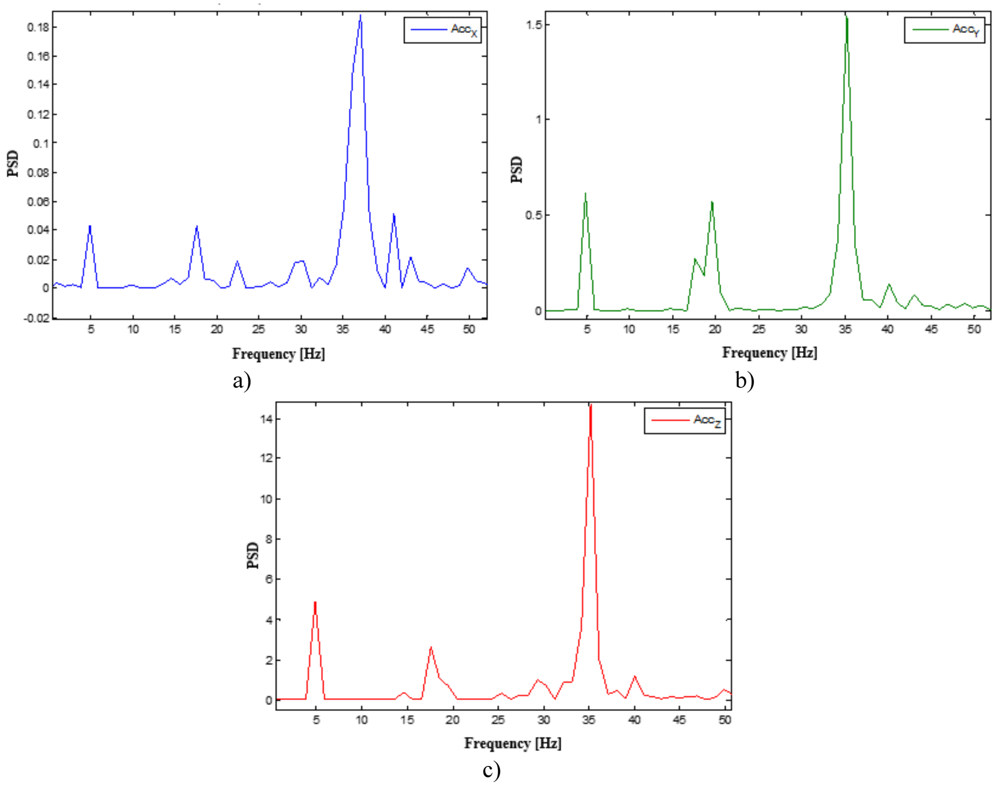
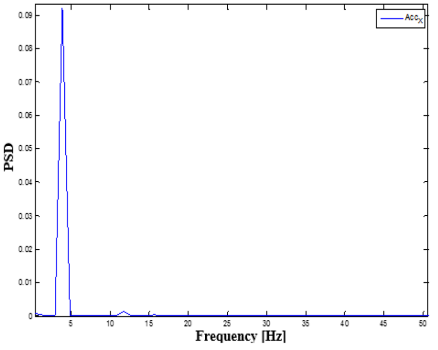


Figure 5 The variation of the spectral power density function of frequency for the initial position of the vibration generator); X direction; b) Y direction; c) Z direction

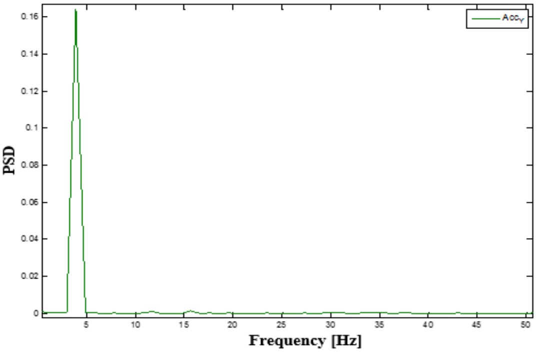
As we can see, the amplitude has the highest value on the Z direction that coincides with the direction of movement of the feeder. The higher amplitude appears around the frequency of 35 Hz, but we can see high amplitude peaks also at 5 Hz and 17 Hz.

It appears that at low frequency the vibration amplitude of the vibration generator is high, causing undesirable effects on the working process. Also the elastic elements are severely stressed out, fact which could lead to mechanical failure. We can observe also considerable amplitudes on Y direction, which produce a jumping effect on the processed seeds.

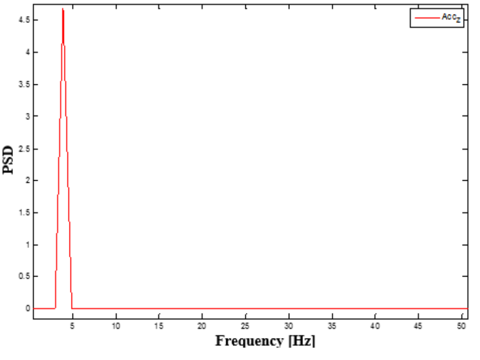
For the second case when the vibration generator is placed in a central position, the PSD dependency of frequency is shown in the figures below. The high amplitude peaks were reduced considerably, the high amplitude positioning itself only around 4 Hz. Thus the central position of the vibration generator provides optimum low working amplitudes which are most desirable for the working process.



a)



b)



c)

Figure 6 The variation of the spectral power density function of frequency for the second position of the vibration generator; a) X direction; b) Y direction; c) Z direction

CONCLUSIONS

The measurements carried out and the calculations performed resulted in the following:

– After the analysis using the spectral power density were determined the frequencies on which the amplitude variations are high and which are low;

– For both cases the highest value of the amplitude is on the Z direction that coincides with the direction of movement of the feeder;

– For the first case (the vibration generator mounted on the back of the feeder), the higher amplitude appears around the frequency of 35 Hz, but we can see high amplitude peaks also at 5 Hz and 17 Hz.

– There are also high amplitude in the Y direction (direction perpendicular to the direction of movement), around the frequency of 5 Hz, axial bending the elastic elements and printing high speeds for the material on that direction;

– For the second case (the vibration generator placed in a central position), the high amplitude peaks were reduced considerably, the high amplitude positioning itself only around 4 Hz;

– After changing the position of the vibration generator the amplitude in the Y direction were reduced considerably.

– Using PSD, we managed to determine a central ideal position for the vibration generator so the generated vibrations do not cause various damage in the functioning of the feeder.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.362:634.73
Stručni rad
Expert paper

TESTING THE ADJUSTABLE DRUM BELT SORTER FOR BLUEBERRY SIZE SORTING

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SUMMARY

One area of post-harvesting processing for berries, where the process concerns technology, is the fractioning of berries by size. Nowadays, a large amount of complex machinery is involved in this job. The hi-tech solutions that are generally in use are too expensive for the smaller farms. A more affordable solution for processing berries is to use a simple solution like belt sorters. Unfortunately, the opportunities to be able to use belt sorters are limited. In order to increase the functionality of the belt sorter, the fractioning slot width between belts must be adjustable. The main objective of this study was to conduct fractioning tests using a patented belt sorter with a smoothly adjustable belt drum and study belt sorter in a working situation using real blueberries. Fractioning tests were carried out at five regulation levels. With each test blueberries were divided into three fractions according to their size. In order to identify the uniformity of the fractionation process, the diameter and height of the blueberries were measured in each fraction. Data obtained were analysed according to the fractioning rules that have been introduced in this paper. The results showed that the belt sorter prototype with its smoothly adjustable belt drum was effective, with an overall fractioning uniformity of 82.67%. The most problematic area concerned the uniformity of the fraction of larger blueberries. The decrease in the uniformity of the fraction for larger blueberries was connected to the increase of a fractioning slot width between the belts. Fractioning uniformity could further be improved with a longer sorting area for the belt sorter and also with a new technical solution to help separate blueberries that are stuck to each other.

Keywords: blueberry, post-harvest treatment, belt sorter, adjustable belt drum.

INTRODUCTION

Harvested berries contain a mixture of berry sizes if harvesting was carried out with a berry rake or berry harvesting machine (Arak & Olt, 2014; Käis & Olt, 2010). Post-harvest processing of berries needs to take into account their shape, geometric dimensions, mass, volume, density, elasticity, colour, aerodynamic characteristics and friction properties (Bower & Rohrbach, 1976; Brown et al., 1996; Rohrbach et al., 1982; Rolle et al., 2015; Soots et al., 2014). In order to be able to fractionate berries by size, their geometric dimensions must be measured before they can be fractionated according to the rules for fractioning. For example, a fractioning rule for blueberries can be established in which all blueberries with a diameter below 8 mm are designated as being for food industries and any that are above 8 mm are designated as being for food stores (Starast et al., 2005). A widely used solution for fractioning is the use of a belt sorter during which berries are fractionated according to the setting of the fractioning slot width between belts. When changing the variety of berry being sorted, the belt sorter's fractioning slot width between belts needs to be readjusted, which may be a time-consuming and troublesome process (Soots et al., 2014). Estonian University of Life Sciences has developed two patented technical solutions for a smoothly adjustable belt drum which are described in patent EE05642 B1, (2012) (which hereinafter is referred to as the 1st generation solution), and in patent application P201400049, (2014) (which hereinafter is referred to as the 2nd generation solution). In Soots et al., (2014) it was discovered that the smoothly adjustable belt drum of the 1st generation solution (patent EE05642 B1, 2012) had problems with the belt pulley's backlash relative to the fixing point, something that was causing fractionation non-uniformity. The backlash concerned was caused by a constructional particularity in which the belt pulleys were fixed to the key structure at one point (Soots et al., 2014). To be able to solve this problem, a new patented technical solution was introduced in patent application P201400049, (2014). In Soots et al., (2016) comparisons were made between the smoothly adjustable belt drums of both 1st and 2nd generation solutions. The results showed that the maximum backlash of the belt pulleys relative to the fixing point for the 2nd generation solution was smaller than that of the 1st generation solution by 8.26 mm on average, but the backlash between two neighbouring belt pulleys of the 2nd generation solution was greater than that of the 1st generation solution by 0.31 mm on average (Soots et al., 2016). In the same paper it was found that the prototyping method for components of the key structure in the smoothly adjustable belt drum of the 2nd generation solution was not suitable. More precisely, components of the key structure in the smoothly adjustable belt drum of the 2nd generation solution were 3D printed using fused deposit modelling (FDM) technology, and this technology did not ensure a smooth thread surface finish (Soots et al., 2016). In addition, the clearance between components of the key structure in the smoothly adjustable belt drum of the 2nd generation solution was not sufficient (Soots et al., 2016). The problems mentioned here will cause belt sorter fractionation non-uniformity, and these problems need to be solved.

The main objective of the research presented in the paper was to conduct fractioning tests using a patented belt sorter with a smoothly adjustable belt drum and a study belt sorter in a working situation using real blueberries. Building and testing experimental prototypes is the part of the concept development phase in product development (Ulrich & Eppinger, 2000). When compared to previous work, in which components of the key structure of the smoothly adjustable belt drum of the 2nd generation solution was 3D printed, in this study these components were manufactured using CNC milling and turning.

METHODS

Before conducting the fractioning tests, the backlash between two neighbouring belt pulleys and the backlash of these belt pulleys relative to the fixing point were measured in order to determine whether the use of CNC-milled and turned components in the key structure resulted in smaller backlashes with belt pulleys than similar backlashes using 3D printed components. When it came to taking measurements, the same method was used as in Soots et al., (2016). According to Soots et al., (2016), both backlash values must be under 0.5 mm.

After measuring the aforementioned backlash values, the smoothly adjustable belt drum of the 2nd generation solution, with a key structure that used CNC-milled and turned components, was installed onto the belt sorter prototype that was used in our previous study (Soots et al., 2014). The most important technical parameters for the belt sorter prototype are given in Table 1.

Fractioning tests were carried out at five regulation levels, and the fractioning slot width between belts (the measuring points are shown on the test scheme given in Fig 1) for every regulation level is given in Table 2.

Table 1 Technical parameters for the belt sorter prototype

Belt linear speeds	0.12 m s^{-1}
Length of the sorting area	758 mm
Sorting area width at measuring point *A1*	233 mm
Sorting area minimum width at measuring point *A3*	281 mm
Sorting area maximum width at measuring point *A3*	406 mm
Belts diameter	10 mm
Number of belts used	17 pcs
Number of fractioning slots	16 pcs

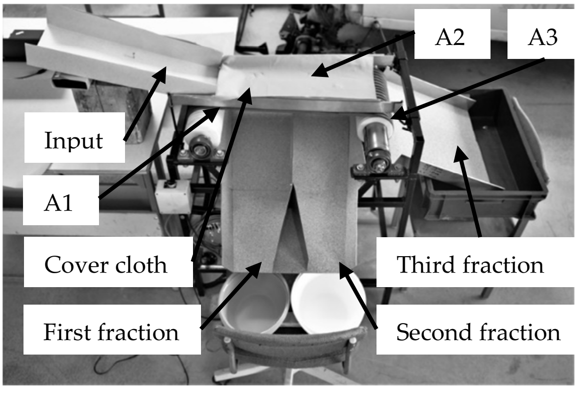

Figure 1 Test scheme

Table 2 Measuring results for fractioning slot widths

Measuring position	Fractioning slot widths between belts *W*, mm				
	Test 1	Test 2	Test 3	Test 4	Test 5
A1	4.05	4.05	4.05	4.05	4.05
A2	5.41	6.11	7.37	8.19	9.0
A3	6.59	8.07	10.64	11.70	14.08

As part of this study, fractioning tests were carried out with a mixture of wild blueberries and cultivated lowbush blueberries. Blueberries are in high demand and which can successfully be cultivated in Estonia (Strik, 2005; Starast at al., 2009). Blueberries were harvested two days before the fractioning tests were carried out, and a total of 7 kg of blueberries was used. Blueberries were divided using the belt sorter into three fractions depending on their size. After each fractioning test, a total of twenty blueberries were selected randomly from each fraction and the diameter D and height H of each blueberry was measured. Measurements were made using the Mitutoyo Ablsolut AOS Digimatic calliper (code no 500-161-30) with an accuracy of ±0.02 mm. The data obtained were analysed using MS Excel software. Due to the fact that the shape of blueberries is not evenly round, the diameter and height were analysed separately. A fraction uniformity of 90% was considered to be the minimum permissible scenario. In addition, a clearance C of ±0.5 mm for the height and diameter of blueberries was considered permissible. Something that also had to be defined was whether or not the blueberry must be of a certain fraction, so for the sake of this the following fractioning rules were established for use in data analysis. The first fraction pass rules are as follows:

$H \leq W_{A2,n} + C$ and $D > W_{A2,n} + C$
$H > W_{A2,n} + C$ and $D \leq W_{A2,n} + C$
$H \leq W_{A2,n} + C$ and $D \leq W_{A2,n} + C$
where: n is a test figure.

The first fraction fail rule is as follows:

$H > W_{A2,n} + C$ and $D > W_{A2,n} + C$

The second fraction pass rules are as follows:

$H \geq W_{A2,n} - C$ and $D \geq W_{A2,n} - C$ and $H \leq W_{A3,n} + C$ and $D \leq W_{A3,n} + C$
$H \geq W_{A2,n} - C$ and $D \geq W_{A2,n} - C$ and $H > W_{A3,n} + C$ and $D \leq W_{A3,n} + C$
$H \geq W_{A2,n} - C$ and $D \geq W_{A2,n} - C$ and $H \leq W_{A3,n} + C$ and $D > W_{A3,n} + C$

The second fraction fail rules are as follows:

$H < W_{A2,n} - C$ and $D < W_{A2,n} - C$
$H < W_{A2,n} - C$ and $D \geq W_{A2,n} - C$
$H \geq W_{A2,n} - C$ and $D < W_{A2,n} - C$
$H > W_{A3,n} + C$ and $D > W_{A3,n} + C$

The third fraction pass rule is this:

$H \geq W_{A3,n} - C$ and $D \geq W_{A3,n} - C$

The third fraction fail rule is this:

$H < W_{A3,n} - C$ and $D \geq W_{A3,n} - C$
$H \geq W_{A3,n} - C$ and $D < W_{A3,n} - C$
$H < W_{A3,n} - C$ and $D < W_{A3,n} - C$

For example, according to the third fraction pass rule, each blueberry that has a height and diameter that is greater or equal than that of the fractioning slot width between belts W minus the permissible clearance of 0.5 mm at measuring point A_3 at test n must be of the third fraction. However, when one or both dimensions are smaller, then the blueberry must be graded into another fraction. In cases in which a blueberry is in the fractioning slot in such a way that its greater dimension is parallel to that of the fractioning slot width between belts then the blueberry will be sorted incorrectly. In order to avoid that problem, the cover cloth shown in Fig 1 was installed above the belts. The main idea behind the use of the cover cloth was to roll blueberries that are on the belts and to separate any blueberries that may be stuck together.

RESULTS AND DISCUSSION

The measuring results for backlash between the smoothly adjustable belt drum of two neighbouring belt pulleys of the 2nd generation solution with 3D printed and CNC-milled and turned key structure components are given in Fig 2.

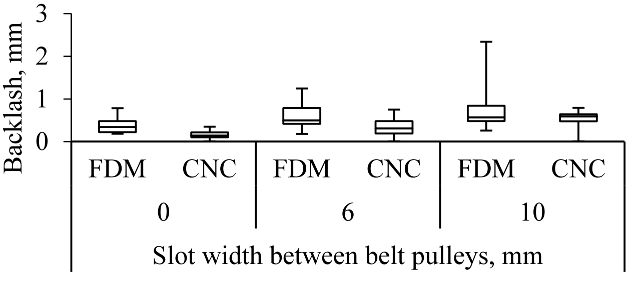

Figure 2 Backlash between the smoothly adjustable belt drum of two neighbouring belt pulleys of the 2nd generation solution with 3D printed (FDM) and CNC-milled and turned (CNC) key structure components

The 2nd generation solution smoothly adjustable belt drum with its CNC-milled and turned key structure components has a smaller backlash between two neighbouring belt pulleys when it comes to all of the belt pulley slot widths that were tested, and this decreased by an average of 0.23 mm. With 3D printed and CNC-milled and turned key structure components, the increase in the backlash between two neighbouring belt pulleys was connected to an increase in the slot width between the belt pulleys of the smoothly adjustable belt drum. Test results showed that the backlash in the smoothly adjustable belt drum for the 2nd generation solution between two neighbouring belt pulleys was below the permissible maximum value of 0.5 mm when using CNC-milled and turned key structure components and when the belt pulley slot width was at 0 mm and 6 mm.

The measuring results for the belt pulley backlash in the smoothly adjustable belt drum of the 2nd generation solution relative to the fixing point using 3D printed and CNC-milled and turned components for key structure are given in Fig 3.

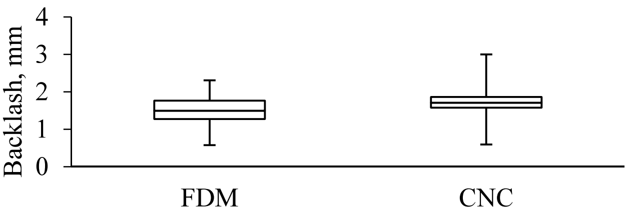

Figure 3 Belt pulley backlash relative to the fixing point for the 2nd generation solution's smoothly adjustable belt drum using 3D printed (FDM) and CNC-milled and turned (CNC) key structure components, with a belt pulley slot width of 6 mm

The average belt pulley backlash relative to the fixing point increased by 0.3 mm with CNC-milled and turned key structure components when compared to the 3D printed key structure components. The average belt pulley backlash from the 2nd generation solution's smoothly adjustable belt drum relative to the fixing point of 1.78 mm was over the permissible value of 0.5 mm, and no positive effect was achieved with CNC-milled and turned key structure components. In future work, clearances for the smoothly adjustable belt drum's key structure components need to be clarified.

When considering previously recorded fractioning pass and failure rules, the overall fractionation uniformity figures are shown in Fig 4.

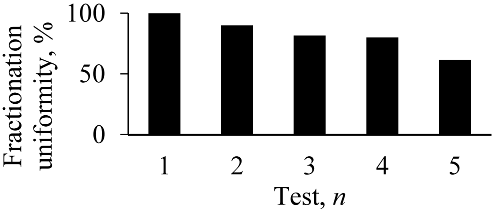

Figure 4 Overall fractionation uniformity

Overall fractionation uniformity was at 82.67%. The decrease of fractionation uniformity was connected to an increase of the fractioning slot width between belts W at the measuring point A3. The best results showed up in Test 1 in which the average fractionation uniformity was at 100% and the most problematical was Test 5, where the average fractionation uniformity was at 61.67%. In order to be able to study fractionation uniformity in more depth, the fraction uniformity for all tests that are carried out are given separately in Fig 5.

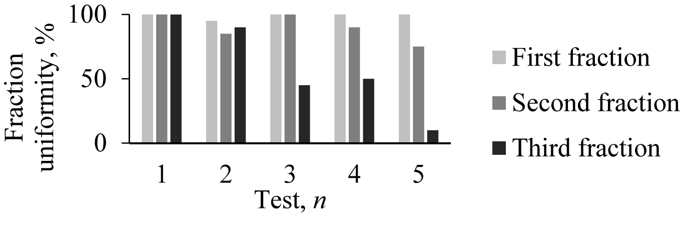

Figure 5 Fraction uniformity

The uniformity of the first fraction results fulfils the permissible lowest value in all fractioning tests. The uniformity of the second fraction did not fulfil the permissible lowest value in Tests 2 (85%) and 5 (75%). The most problematical of the tests were those that involved third fraction uniformity. This was the reason why more detailed analysis needed to be carried out.

Third fraction uniformity was fully acceptable in Tests 1 (100%) and 2 (90%) but, for example, Test 5 showed a third fraction uniformity figure that was only 10%. Such a low result required more attention, and a much more detailed analysis regarding the third fraction in Test 5 is shown on Fig 6.

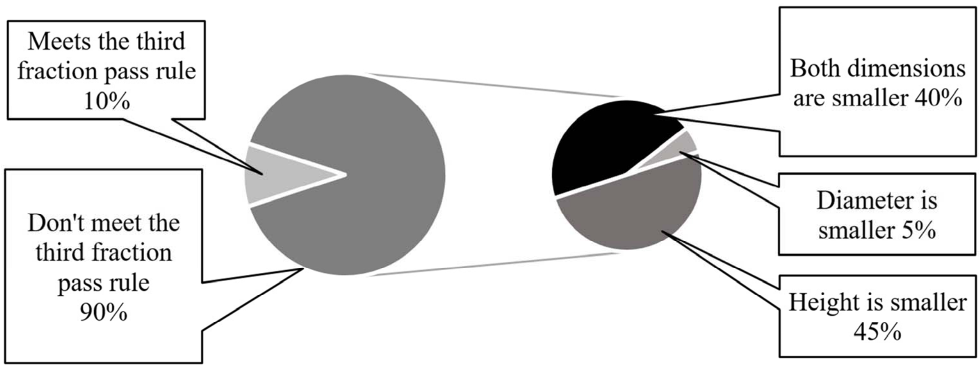

Figure 6 Third fraction composition in Test 5

Blueberries that fail to meet the third fraction pass rule can be divided into two groups: the first one in which blueberries have a smaller diameter or height and the second one in which blueberries have a smaller diameter and height. In order to study blueberries of a smaller diameter or height in conjunction with the third fraction, a calculation that will help evaluate the influence of belt pulley backlash relative to the fixing point where this was below the desired maximum value of 0.5 mm for third fraction uniformity can be made. When the maximum backlash value relative to the fixing point (3 mm) is subtracted from the fractioning slot width between belts *W* (14.08 mm) at measuring point A3 in Test 5, then the third fraction uniformity figure will be 60%, and will also still be under the minimum permissible value of 90%. The most problematical area of third fraction tests are blueberries that have a smaller diameter and height. Both dimensions of these blueberries are smaller than the fractioning slot width between belts *W*, and they should drop freely. Results show that, in addition to the inadequate belt pulley backlash relative to the fixing point, there were others factors that affected third fraction uniformity. The authors suggest that the most likely fraction uniformity figures were also influenced by the belt sorter prototype having too short a sorting area, as well as the insufficient effect of the cover cloth which led to a situation in which any blueberries that failed to meet the third fraction pass rule were still carried onto the third fraction because they managed to stick to bigger blueberries.

CONCLUSION

When compared to previous studies, it can be concluded that the tested adjustable 2nd generation solution smoothly adjustable belt drum with CNC-milled and turned components for the key structure was acting better in a working situation than were the 3D printed key structure components, mainly due to a smaller backlash between two neighbouring belt pulleys that was below the permissible maximum value of 0.5 mm. The belt pulley backlash relative to the fixing point for the 2nd generation solution's smoothly adjustable belt drum with CNC-milled and turned key structure components was greater than with 3D printed key structure components and was not below the permissible maximum value of 0.5 mm. According to the fractioning test results that have been obtained and problems that have so far been revealed, the authors would like to propose several future improvements. Firstly, to avoid any of the problems with fraction uniformity that were revealed in this study, the sorting of blueberries should be conducted immediately after harvesting and blueberries should be sorted only once in order to avoid any spoilage of the blueberries. Secondly, in the future a more suitable solution to separate blueberries that are stuck together must be developed instead of using a cover cloth for this purpose. This development also helps to maintain the protective natural layer on the blueberries. Thirdly, the belt pulley backlash relative to the fixing point has to be reduced in order to fulfil the desired maximum value of 0.5 mm. Fourthly, to increase the fractioning uniformity, additional tests should be conducted in order to determine the optimal length of the belt sorter's sorting area.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.51.013
Izvorni znanstveni rad
Original scientific paper

STRUCTURAL AND KINEMATIC ANALYSIS OF THE MECHANISM FOR ARABLE DEEP SOIL LOOSENING

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SUMMARY

Deep soil loosening works require a high consumption of power and thus, implicitly, high power tractors to work in aggregate with. In order to reduce the fuel consumption necessary to achieve the operation of average soil loosening (50-60 cm), the paper presents the structural and kinematic analysis (positions, velocities, accelerations) of a mechanism aiming to drive the active bodies of an equipment that performs this work, this mechanism induces vibrations into the soil through a tool placed in front of the active body, determining the destruction of soil cohesion in the adjacent areas and eventually, a substantial reduction in fuel consumption.

Keywords: structural analysis, kinematic analysis, loosening mechanism, soil

INTRODUCTION

Deep soil loosening aims to enlarge the pore space of soil horizons that are subjacent to arable layer, without mixing, overturning or reversing the soil horizons. This is an operation appropriate to heavy and settled soils, alternatively affected by both the excess and lack of humidity, as well as other categories of soil with limited production capacity determined by salinization, alkalinisation, pollution, etc, [1, 4, 9]. Excess of humidity frequently appears during the rainy periods with reduced consumption of evapotranspiration, in soils presenting a compact and impermeable clay layer under the arable one [10, 11]. Due to diminished permeability of this layer, the precipitation water cannot be seeped in depth and is accumulated at the profile upper part or at soil surface [7, 8].

Deep loosening, without the furrow's overturning is performed in order to break the soil impermeable layer and determine the water to seep in upper horizons [3, 2]. In arid areas, the water accumulated in depth represents an important stock for periods without precipitations and in humid areas; this water must be removed by draining systems, [3]. At the same time, the deep loosening enables to improve the conditions of aeration, water permeability and precipitation stocking capacity, as well as the development of a deeper root system and to enhance the biological activity in the soil, [17].

The machine's good functioning is closely linked to the kinematic and kinetostatic study of the mechanism that drives the working parts, [12, 13]. This can be obtained by optimizing the parameters that determine the loosening process, [16, 18]. Therefore, the regime of loosening operation system related to oscillation frequency, value and direction of speed and accelerations of the points on the active elements [14], reactions from mechanism kinematic coupling, torque (driving moment), should be analyzed comparing to loosening requirements, [5, 6, 15, 19].

Within this paper, the structural kinematic and kinetostatic analyses of the mechanism of soil loosening machine, are performed.

MATERIALS AND METHODS

In figures 1 and 2, the principle scheme of loosening equipment, respectively the kinematic scheme of loosening active parts, are shown.

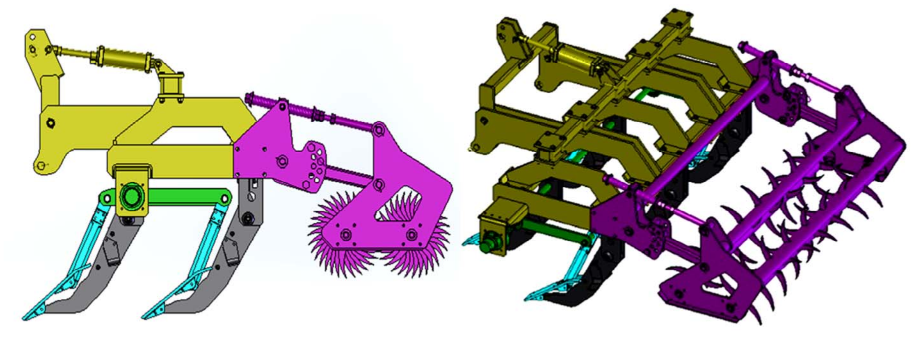


Fig. 1. Principle scheme of loosening equipment

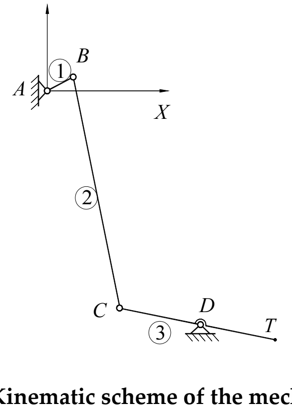
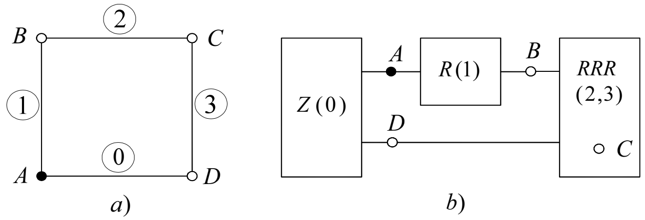


Fig. 2. Kinematic scheme of the mechanism

For determining the kinematic parameters of the mechanism elements one should perform the mechanism structural analysis. The loosening mechanism comprises the handle 1, connecting rod 2 and balancer 3 (fig. 3).



$Z(0) + R(1) + RRR\ (4,5)$

c)

Fig. 3. Mechanism structural analysis
***a*) structural scheme; *b*) multipolar scheme; *c*) mechanism structural relation**

RESULTS

Mechanism structural analysis

If we take into consideration the relative movement between elements, the following lower couplings of the mechanism will be observed:

$$A(0R1), B(1R2), C(2R3) \text{ and } D(3R0)$$

Number of upper couplings is zero.

Mobile elements of the mechanism are: $1(A,B)$, $2(B,C)$, $3(C,D)$.

Applying the formula of the level of mobility, it results $M=1$ [1, 4, 6, 7, 8, 9, 10, 11], namely, it is necessary a unique driving engine, in order to make elements' determinate movements.

In figure 3 are presented: *a*) mechanism structural scheme, *b*) multipolar scheme, *c*) structural relation. Following the structural and multipolar scheme, the scheme comprises the base $Z(0)$, motor group $R(1)$ and dyad, aspect 1, $RRR(2,3)$.

Mechanism kinematic analysis

In order to perform the kinematic analysis of the mechanism, several stages have to be developed:

a) make the calculation program for finding out the kinematic parameters of mechanism elements, considering 36 equidistant positions of element **1** ($\Delta\varphi_1 = 0.1745329$ radian);
b) trace the variation diagrams of speed and angular acceleration of the mechanism elements depending on angle φ_1;
c) trace the hodographs of speed and acceleration appropriate to tracking point *T*.

Kinematic analysis of RRR dyad

In figure 4, the kinematic scheme of dyad *RRR* [6, 7] is given. This structural group contains two kinematic elements and three couples (two input elements and an internal one).

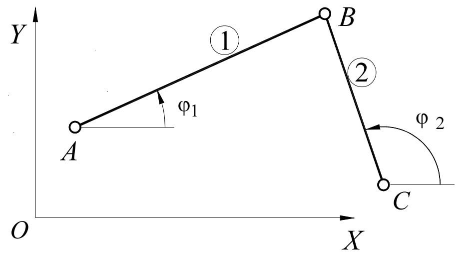


Fig. 4. Kinematic scheme of dyad *RRR*

For determining the kinematic parameters of dyad *RRR* we should know the length of elements and kinematic parameters of input couplers *A* and *C*.

Angles of vectors $\overline{AB}$ and $\overline{CB}$, attached to elements **1** and **2**, angles measured from the positive direction of axis *Ox*, as well as the elements' angular speed and acceleration, are necessary.

<u>Analysis of RRR dyad positions</u>

System of equations of positions by designing the contour vector $\overline{OA} + \overline{AB} = \overline{OC} + \overline{CB}$, on the axes of coordinate system, is :

$$\begin{cases} AB\cos\varphi_1 - BC\cos\varphi_2 - k = 0; \\ AB\sin\varphi_1 - BC\sin\varphi_2 - h = 0, \end{cases} \tag{1}$$

where: k = XC - XA, h = YC - YA.

System of equations of position, non-linear in the unknowns φ_1 şi φ_2, is solved by iterative method Newton-Raphson, starting from an initial solution given. The system solution at iteration $(i + 1)$ is:

$$\begin{Vmatrix}\varphi_1\\ \varphi_2\end{Vmatrix}^{(i+1)} = \begin{Vmatrix}\varphi_1\\ \varphi_2\end{Vmatrix}^{(i)} - W^{-1}(\varphi_1^{(i)},\varphi_2^{(i)})\begin{Vmatrix} f_1(\varphi_1^{(i)},\varphi_2^{(i)})\\ f_2(\varphi_1^{(i)},\varphi_2^{(i)})\end{Vmatrix} \tag{2}$$

where:

$$f_1(\varphi_1,\varphi_2) = AB\cos\varphi_1 - BC\cos\varphi_2 + XA - XC;\quad W = \begin{Vmatrix} -AB\sin\varphi_1 & BC\sin\varphi_2 \\ AB\cos\varphi_1 & -BC\cos\varphi_2 \end{Vmatrix}$$
$$f_2(\varphi_1,\varphi_2) = AB\sin\varphi_1 - BC\sin\varphi_2 + YA - YC;$$

Iterative process will stop when the difference between the two solutions consecutively calculated is smaller than an impulse ε , namely:

$$\begin{Vmatrix}\varphi_1\\ \varphi_2\end{Vmatrix}^{(i+1)} - \begin{Vmatrix}\varphi_1\\ \varphi_2\end{Vmatrix}^{(i)} < \varepsilon \tag{3}$$

In the current case, it was considered ε = 0.00001 radians.

Analysis of speed at RRR dyad

The system of position equations is differentiated with respect to time and is obtained:

$$\begin{cases} -AB\sin\varphi_1.\dot{\varphi}_1 + BC\sin\varphi_2.\dot{\varphi}_2 = \dot{k} \\ AB\cos\varphi_1.\dot{\varphi}_1 - BC\cos\varphi_2.\dot{\varphi}_2 = \dot{h} \end{cases} \tag{4}$$

where: $\dot{k} = \dot{X}C - \dot{X}A, \dot{h} = \dot{Y}C - \dot{Y}A$.

A system of two linear equations was obtained in the unknowns $\dot{\varphi}_1$ and $\dot{\varphi}_2$. Using the method of reverse matrix for solving the linear systems, we obtain:

$$\begin{Vmatrix} \dot{\varphi}_1 \\ \dot{\varphi}_2 \end{Vmatrix} = W^{-1} \begin{Vmatrix} \dot{k} \\ \dot{h} \end{Vmatrix} \tag{5}$$

Analysis of accelerations at dyad RRR

By differentiating the speed equation system related to time, we may obtain:

$$\begin{cases} -AB\sin\varphi_1.\ddot{\varphi}_1 + BC\sin\varphi_2.\ddot{\varphi}_2 = A1 \\ AB\cos\varphi_1.\ddot{\varphi}_1 - BC\cos\varphi_2.\ddot{\varphi}_2 = A2 \end{cases} \tag{6}$$

where:

$$A1 = \ddot{k} + AB\cos\varphi_1.\dot{\varphi}_1^2 - BC\cos\varphi_2.\dot{\varphi}_2^2$$
$$A2 = \ddot{h} + AB\sin\varphi_1.\dot{\varphi}_1^2 - BC\sin\varphi_2.\dot{\varphi}_2^2.$$

System is also linear in the unknowns $\ddot{\varphi}_1$ and $\ddot{\varphi}_2$, so:

$$\begin{Vmatrix} \ddot{\varphi}_1 \\ \ddot{\varphi}_2 \end{Vmatrix} = W^{-1} \begin{Vmatrix} A1 \\ A2 \end{Vmatrix} \tag{7}$$

By means of the above relations, a routine calculus **d1pva.m** is developed for analyzing the dyad *RRR*.

Numerical example

For kinematic analysis, one should define the initial position of the deep loosening mechanism of arable soil (fig. 5), kinematic calculus routine appropriate to modules on which the mechanism relies, routines **A1R.m**, **A1RALFA.m** and **d1pva.m** must be approached in the main calculation program and the diagrams of kinematic parameters must be traced.

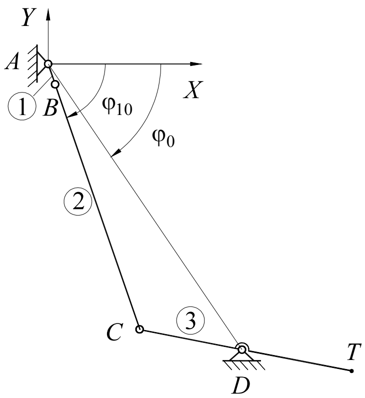


Fig. 5. Defining the initial position of the mechanism

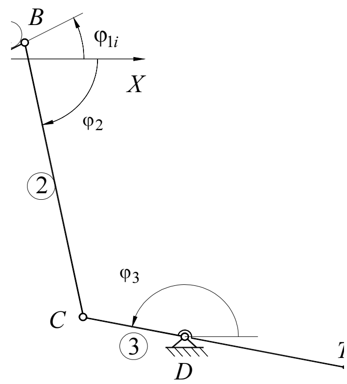


Fig. 6. Defining the position parameters of loosening mechanism

For the analysis of the mechanism, the following data are necessary:

a) mechanism's kinematic scheme;

b) dimensions of elements and positions of couplings adjacent to base, as it follows: *AB* = 0.009 m, *BC* = 1.300 m, *CD* = 0.250 m, *DT* = 0.245 m;

c) mechanism's initial position: $\varphi_1 = \varphi_{10} = -1.3537$ [radian] (Fig. 5);

d) element's angular speed 1: $\omega_1 = 57.596$ [s^{-1}];

e) angular acceleration of the element 1: $\varepsilon_1 = 0.0$ [s^{-2}].

Calculations have been performed for 36 equidistant positions of element **1**, starting from the initial position: $\varphi_1 = \varphi_{10} = -1.3537$ [radian].

In table 1 are presented the angles $\varphi_1, \varphi_2, \varphi_3$, angular speed ω_2, ω_3 and angular accelerations: $\varepsilon_2, \varepsilon_3$.

Table 1

Position	φ_1	φ_2	φ_3	ω_2	ω_3	ε_2	ε_3
0.	-1.3537	-1.3537	2.8879	-0.3987	-0.0000	11.7697	-134.9284
1.	-1.1791	-1.3548	2.8873	-0.3572	-0.4065	15.6081	-132.7305
2.	-1.0046	-1.3558	2.8855	-0.3045	-0.8006	19.0700	-126.7069
3.	-0,8301	-1.3566	2.8825	-0.2421	-1.1708	22.0352	-117.0372
4.	-0.6555	-1.3573	2.8784	-0.1716	-1.5065	24.3895	-103.9924
5.	-0.4810	-1.3577	2.8734	-0.0950	-1.7980	26.0309	-87.9274
6.	-0.3065	-1.3578	2.8676	-0.0146	-2.0367	26.8756	-69.2718
7.	-0.1319	-1.3578	2.8611	0.0670	-2.2157	26.8645	-48.5215
8.	0.0426	-1.3574	2.8542	0.1473	-2.3292	25.9686	-26.2294
9.	0.2171	-1.3569	2.8471	0.2235	-2.3737	24.1929	-2.9967
10.	0.3917	-1.3561	2.8399	0.2930	-2.3471	21.5778	20.5352
11.	0.5662	-1.3551	2.8329	0.3535	-2.2496	18.2051	43.6950
12.	0.7407	-1.3540	2.8263	0.4027	-2.0833	14.1861	65.7929
13.	0.9153	-1.3527	2.8204	0.4390	-1.8526	9.6667	86.1363
14.	1.0898	-1.3513	2.8152	0.4610	-1.5638	4.8168	104.0504
15.	1.2643	-1.3499	2.8109	0.4680	-1.2251	-0.1784	118.9038
16.	1.4389	-1.3485	2.8078	0.4599	-0.8468	-5.1277	130.1387
17.	1.6134	-1.3471	2.8058	0.4372	-0.4405	-9.8456	137.3039
18.	1.7879	-1.3459	2.8051	0.4007	-0.0191	-14.1624	140.0852
19.	1.9625	-1.3447	2.8057	0.3519	0.4039	-17.9337	138.3316
20.	2.1370	-1.3437	2.8076	0.2927	0.8147	-21.0466	132.0710
21.	2.3115	-1.3430	2.8106	0.2251	1.2000	-23.4236	121.5133
22.	2.4861	-1.3424	2.8148	0.1515	1.5472	-25.0221	107.0402
23.	2.6606	-1.3420	2.8200	0.0742	1.8453	-25.8320	89.1822
24.	2.8351	-1.3419	2.8259	-0.0043	2.0849	-25.8705	68.5878
25.	3.0097	-1.3421	2.8325	-0.0818	2.2589	-25.1755	45.9861
26.	3.1842	-1.3424	2.8395	-0.1562	2.3624	-23.8000	22.1508
27.	3.3587	-1.3430	2.8468	-0.2254	2.3927	-21.8057	-2.1344
28.	3.5333	-1.3438	2.8540	-0.2878	2.4397	-19.2601	-26.1045
29.	3.7078	-1.3447	2.8609	-0.3417	2.2355	-16.2335	-49.0361
30.	3.8823	-1.3458	2.8675	-0.3857	2.0543	-12.7983	-70.2655
31.	4.0569	-1.3471	2.8733	-0.4189	1.8120	-9.0302	-89.2015
32.	4.2314	-1.3484	2.8784	-0.4402	1.5165	-5.0088	-105.3355
33.	4.4059	-1.3497	2.8825	-0.4491	1.1769	-0.8203	-118.2485
34.	4.5805	-1.3511	2.8855	0.4451	0.8034	3.4417	-127.6170
35.	4.7550	-1.3524	2.8873	-0.4283	0.4073	7.6751	-133.2174
36.	4.9295	-1.3537	2.8879	-0.3987	0.0000	11.7695	-134.9281

The diagrams of speed and angular accelerations of the elements 2 and 3 are shown in figures 7 and 8.

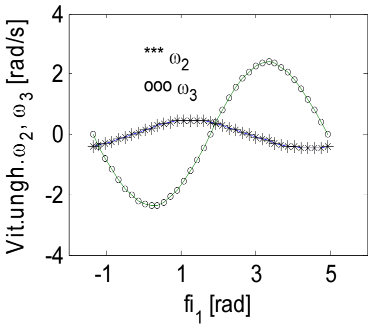


Fig. 7. Variation diagrams of speed and acceleration

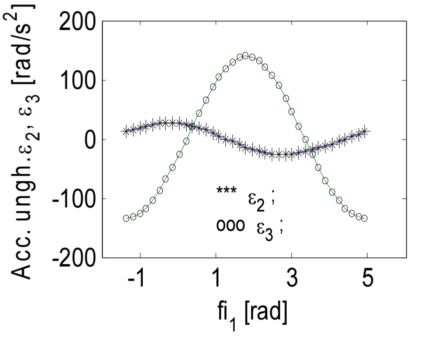


Fig. 8. Diagrams of variation of angular accelerations of elements 2 and 3

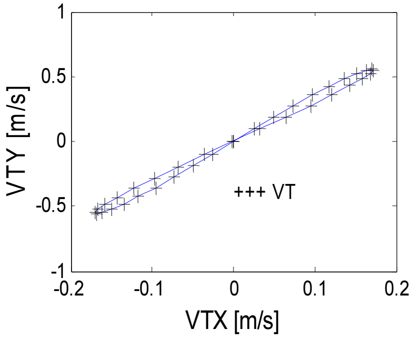


Fig. 9. Hodograph of linear speed

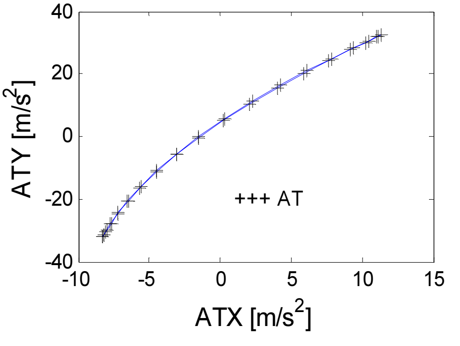


Fig. 10. Hodograph of linear accelerations of T point

The hodographs of speed and linear accelerations to tracking point T are shown in figures 9 and 10

CONCLUSIONS

Based on analysis of numerical data and diagrams of distribution of speed and acceleration have resulted the size and directions of speed and acceleration vectors, so that the loosening process be as efficient as possible. These parameters values will be also used in the mechanism's kinetostatic calculus, for determining the reaction forces from kinematic couples. Knowing the reaction forces allows us to find out the appropriate dimensions of kinematic elements.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

KINETOSTATIC ANALYSIS OF THE MECHANISM OF DEEP LOOSENING SYSTEM OF ARABLE SOIL

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SUMMARY

The paper presents the kinetostatic analysis of the mechanism in the composition of a machine for deep loosening of arable soil. For a proper sizing of the elements of the mechanism for deep loosening, it is necessary to know the forces and moments acting on its elements. For the kinetostatic analysis is performed the reduction of applied forces and inertia forces to the centers of gravity of the elements, and then are used the appropriate functions to each individual structural group. Finally, is obtain the torque to be applied to coupling A, for setting in motion the mechanism. For the accuracy of the calculation, the driving moment is also determined by the method of virtual powers.

Key words: soil loosening, mechanism, kinetostatic analysis, force, coupling

INTRODUCTION

The traffic of heavy agricultural machinery can compact the subsoil to a certain extent, and the effects can be partly reduced by deep loosening (subsoiling, or deep ploughing), which must be carried out when the soil is sufficiently dry. Usually, deep loosening does not completely alleviate the effects of machinery-induced subsoil compaction, and its effects can sometimes be even negative. In most cases, within a few years, a loosened subsoil becomes recompacted and once a field has been subsoiled, this operation must be repeated periodically [7]. Studies on the mechanization technology for aeration and deep decompaction of deficient soils, aspects regarding soil penetration resistance after deep loosening works and energetic consumption during these works highlighted the need to perform deep loosening works at least once every 4 years [2].

Deep loosening of compacted soil is an expensive operation, that requires a high consumption of power and implicitly, the equipment performing it must work in aggregate with high power tractors. The equipment for soil loosening are mechanisms that induce vibrations in the soil through a tool placed in front of the active body, determining the destruction of soil cohesion in the adjacent areas and in the end, a substantial reduction in fuel consumption.

To achieve high quality works of soil loosening, according to agro-soil requirements, with low costs and diminished power consumption, equipment with superior constructive and functional parameters must be used [9]. The equipment for deep soil loosening with active working bodies have coulters driven by a quadrilateral mechanism from the tractor power sockets, producing soil cutting and also its loosening [3].

Kinetostatic analysis examines the behavior of a mechanism under the action of the applied static forces and the inertial forces produced by movement. It aims at finding the reaction forces, friction forces, and friction torques between each member of a mechanism, and it can be used for computing mechanical efficiency, friction power, shaking forces and moments, and the required input power under various loadings, etc [8]. Hence, the kinetostatic analysis determines the forces acting on the elements during movement.

METHODS

Kinetostatic analysis is a method that allows treatment of dynamic forces as though the problem were a static equilibrium problem [12] starting with the kinematic elements in the composition of the structural groups [6]. The kinetostatic analysis applies Newton's laws of motion to a mechanism in a given configuration, solving for the body and inertial forces acting on the links, assuming that the linear and angular accelerations of the links are known [12].

The kinetostatic analysis of a mechanism can be carried out by the same sequence of the mechanism formation [5]. Force analysis sequence begins with the last group added to the mechanism, and it ends with the driving links [1].

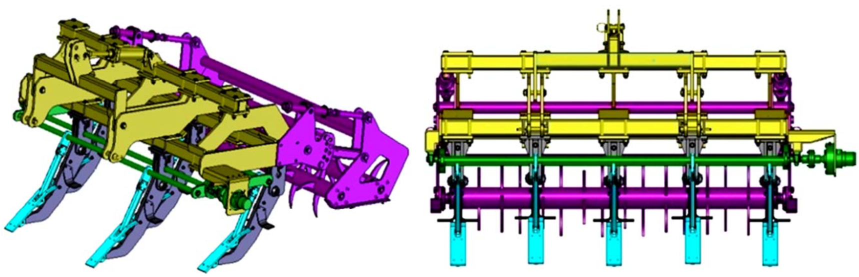

Fig. 1. Basic diagram of the equipment for deep loosening

Figure 1 presents the basic diagram of the equipment for deep loosening and Figure 2 shows the scheme of the kinematic mechanism of deep loosening of arable soil, and the forces acting on the kinematic elements.

On element **3** of the mechanism are acting the technological forces $\overline{Q}_{\max 1}$ and $\overline{Q}_{\max 2}$, forces acting on points *P* and *P'*, and also the drag forces of the machine, $\overline{F}_{R1}$ and $\overline{F}_{R2}$.

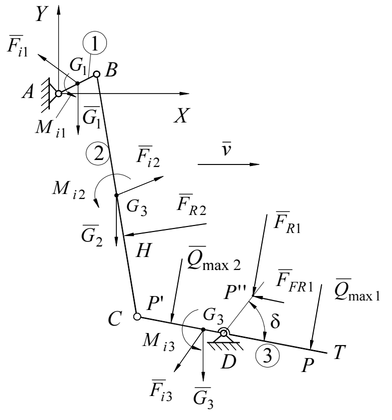

Fig. 2. Kinematic scheme of the mechanism of deep loosening system, showing the forces acting on the kinematic elements

Following the structural and kinematic analysis of the mechanism, presented in paper [4], is performed its kinetostatic analysis, i.e. determining the forces and moments acting on the kinematic elements.

Kinetostatic analysis of the mechanism comprises several stages, namely:

a) kinetostatic study of each modular group;
b) development of the program to determine the reactions in the kinematic couplings of the mechanism, and also of the equilibrium moment (torque) in the active coupling A;
c) tracing the graphs of corresponding reactions in couplings A, C and D;
d) tabular presentation of the reactions in the kinematic coupling *A*, for 36 equidinstaced positions of the element **1**, and of the moment of equilibration calculated by the kinetostatic method and by the method of virtual power.

RESULTS

Kinetostatic analysis of the mechanism

Kinetostatic analysis of the mechanism starts from the extreme position, i.e. the position in which the crank and connecting rod of the quadrilateral mechanism 4R (1,2,3) lies in extension.

For the kinetostatic analysis of the mechanism are reduced the applied forces and inertia forces to the centers of gravity of the elements, then are used the appropriate functions to each structural group. It is mentioned that the kinetostatic analysis is done in reverse to the kinematic analysis, i.e. starting from the last structural group analyzed kinematically (dyad *RRR*(2, 3)) and ending with the first group (driving group *R*(1)).

Kinetostatic analysis of dyad *RRR* (theoretical presentation) [10, 11]

To determine the reactions in kinematic couplings of the dyad *RRR* (Fig. 3), are known:

- $F_{1X}, F_{1Y}, F_{2X}, F_{2Y}$ - components of known resultants forces acting on the elements 1 and 2 of the dyad;
- CM_1, CM_2 - moment of resulting couples, which act on the two elements;
- XA, YA, XB, YB, XC, YC - the coordinates of the poles *A*, *B* and *C*;
- XA^*, YA^*, XB^*, YB^* - the coordinates of the reduction points of systems of forces on the two elements.

There are determined: R_{i1X}, R_{i1Y}, R_{12X}, R_{12Y}, R_{j2X}, R_{j2Y}; $\overline{R}21 = -\overline{R}12$, the compoments of reactions in kinematic couplings *A*, *B* and *C*.

The force equations are obtained by canceling the twister force $(\overline{F}, \overline{M})$ for each element of the dyad, as follows:

$$\begin{aligned} &R_{i1X} - R_{12X} + F_{1X} = 0 \\ &R_{i1Y} - R_{12Y} + F_{1Y} = 0 \\ &R_{12X} + R_{j2X} + F_{2X} = 0 \\ &R_{12Y} + R_{j2Y} + F_{2Y} = 0 \end{aligned} \tag{1}$$

$$(YB - YA) \cdot R_{i1X} - (XB - XA) \cdot R_{i1Y} + (YB - YA^*) \cdot F_{1X} - (XB - XA^*) \cdot F_{1Y} + CM_1 = 0 \tag{2}$$

$$(YB - YC) \cdot R_{j2X} - (XB - XC) \cdot R_{j2Y} + (YB - YB^*) \cdot F_{2X} - (XB - XB^*) \cdot F_{2Y} + CM_2 = 0 \tag{3}$$

It was obtained a system of 6 linear equations, with the unknowns $R_{i1X}, R_{i1Y}, R_{12X}, R_{12Y}, R_{j2X}, R_{j2Y}$.

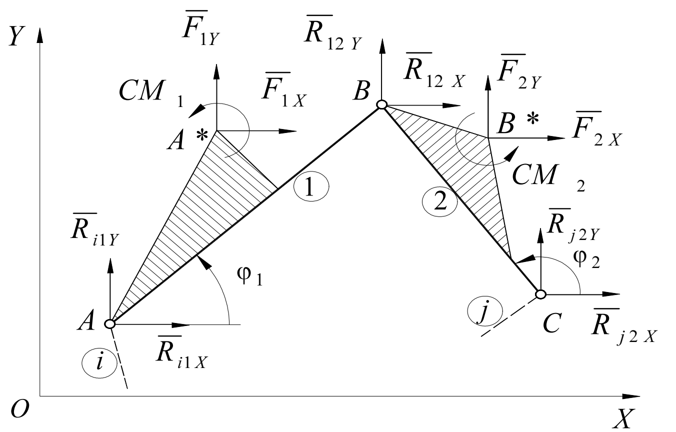

Fig. 3. Kinetostatic scheme of dyad *RRR*

Kinetostatic analysis of the mechanism of loosening system

The kinetostatic analysis of the mechanism of loosening system begind with dyad RRR(2,3) and finishes with the driving group R(1).

Dyad *RRR*(2, 3)

On the elements of dyad are acting (Fig. 3a):

- the forces of gravity: $\overline{G}_2 = -m_2\overline{g}$ and $\overline{G}_3 = -m_3\overline{g}$;
- the resultant inertia forces: $\overline{F}_{i2} = -m_2\overline{a}_{G2}$ and $\overline{F}_{i3} = -m_3\overline{a}_{G3}$;
- the resultant moments of inertia forces: $\overline{M}_{i2} = -IG_2 \cdot \overline{\varepsilon}_2$ and $\overline{M}_{i3} = -IG_3 \cdot \overline{\varepsilon}_3$;
- the technological forces $\overline{Q}_{\max 1}$ and $\overline{Q}_{\max 2}$;
- the drag forces $\overline{F}_{R1}$ and $\overline{F}_{R2}$;
- the friction forces between the soil and working bodies, as a result of machine movement, namely: $FFQ_{\max 1} = \mu Q_{\max 1}$, $FFQ_{\max 2} = \mu Q_{\max 2}$, $FFR_1 = \mu F_{R1}$, $FFR_2 = \mu F_{R2}$.

Figure 3b presents the kinetostatic scheme of dyad RRR(2,3). The reduction points of force systems are considered to be in the center of gravity, G_2 and G_3, of elements **2** and **3**. The kinematic parameters of these points are calculated by means of **A1R.m** function.

Accelerations of reduction points G_2 and G_3, of force systems, are known by the components on the axes of coordinates, namely:

$$\overline{a}_{G2} = a_{G2X}\,\overline{i} + a_{G2Y}\,\overline{j}, \quad \overline{a}_{G3} = a_{G3X}\,\overline{i} + a_{G3Y}\,\overline{j} \tag{4}$$

where a_{G2X} and a_{G2Y} are the projections on the axes of coordinates of linear accelerations of points G_2 and G_3.

Because the accelerations of reduction points are known by the projections on the axes of coordinates, it results that the inertial forces are:

$$\overline{F}_{i2} = F_{i2X}\,\overline{i} + F_{i2Y}\,\overline{j}, \quad \overline{F}_{i3} = F_{i3X}\,\overline{i} + F_{i3Y}\,\overline{j} \tag{5}$$

Resultants of applied forces, of inertia and weight are of the form:

$$\overline{F}_{R2} = \overline{F}_{2X} + \overline{F}_{2Y}\,j, \quad \overline{F}_{39} = \overline{F}_{3X} + \overline{F}_{3Y} \tag{6}$$

or:

$$\overline{F}_{R2} = F_{2X}\,\overline{i} + F_{2Y}\,\overline{j}, \quad \overline{F}_{R3} = F_{3X}\,\overline{i} + F_{3Y}\,\overline{j} \tag{7}$$

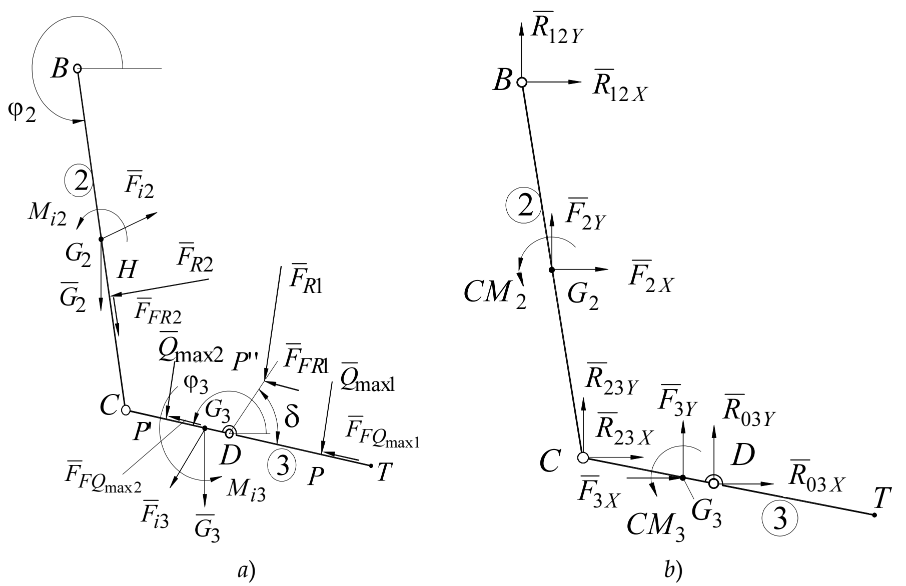

Fig. 4. Dyad *RRR*(2, 3); *a*) highlighting the forces and moments acting on the elements of dyad *RRR*(2,3); *b*) kinetostatic scheme of dyad *RRR*(2,3)

The projections on the axes coordinates of the resultants of applied forces, inertia and weight, and the resultant moments are:

$$F_{2\mathrm{X}} = -m_2 \cdot a_{\mathrm{G2X}} + F_{RHX} \tag{8}$$

$$F_{2\mathrm{Y}} = -m_2 \cdot (a_{\mathrm{G2Y}} + g) + F_{RHY} \tag{9}$$

$$F_{3\mathrm{X}} = -m_3 \cdot a_{\mathrm{G3X}} + F_{RQ\mathrm{max}1X} + F_{RQ\mathrm{max}2X} + F_{R1NX} \tag{10}$$

$$F_{3\mathrm{Y}} = -m_3 \cdot (a_{\mathrm{G3Y}} + g) + F_{RQ\mathrm{max}1Y} + F_{RQ\mathrm{max}2T} + F_{R1NY} \tag{11}$$

$$CM_2 = -IG_2 \cdot \ddot{\varphi}_2 + F_{RHX}(YG2 - YH) - F_{RHY}(XG2 - XH) \tag{12}$$

$$\begin{aligned} CM_3 = &-IG_3 \cdot \ddot{\varphi}_3 - F_{R1X}(YP''-YG3) + F_{R1Y}(XP''-XG3) + F_{RQ\max 1X}(YG3 - YP) - \\ &- F_{RQ\max 1Y}(XG3 - XP) + F_{RQ\max 2X}(YG3 - YP') - F_{RQ\max 2Y}(XG3 - XP') \end{aligned} \tag{13}$$

where:

$$F_{RHX} = \sqrt{F_{R2} \cdot F_{R2} + F_{FR2} \cdot F_{FR2}} \cdot \cos(\varphi_2 - \varphi - \pi / 2)$$

$$F_{RHY} = \sqrt{F_{R2} \cdot F_{R2} + F_{FR2} \cdot F_{FR2}} \cdot \sin(\varphi_2 - \varphi - \pi / 2)$$

$$F_{RQ\max 1X} = \sqrt{F_{FQ\max 1} \cdot F_{FQ\max 1} + Q_{\max 1} \cdot Q_{\max 1}} \cdot \cos(\varphi_3 - \varphi + \pi / 2)$$

$$F_{RQ\max 1Y} = \sqrt{F_{FQ\max 1} \cdot F_{FQ\max 1} + Q_{\max 1} \cdot Q_{\max 1}} \cdot \sin(\varphi_3 - \varphi + \pi / 2)$$

$$F_{RQ\max 2X} = \sqrt{F_{FQ\max 2} \cdot F_{FQ\max 2} + Q_{\max 2} \cdot Q_{\max 2}} \cdot \cos(\varphi_3 - \varphi + \pi/2)$$

$$F_{RQ\max 2Y} = \sqrt{F_{FQ\max 2} \cdot F_{FQ\max 2} + Q_{\max 2} \cdot Q_{\max 2}} \cdot \sin(\varphi_3 - \varphi + \pi/2)$$

$$\varphi = \tan(\mu)$$

and μ este is the friction coefficient between the soil and the working bodies.

Reactions in the kinematic couplings *B*, *C* and *D* are forming the output data of function **D1RC.m**.

Driving group *R*(1)

On the element of driving group *R*(1) are acting (Fig. 4a):

– - the force of gravity $\overline{G}_1 = -m_1 \overline{g}$;
– - the resultant inertia force: $\overline{F}_{i1} = -m_1 \overline{a}_{G1}$;
– - the resultant moments of inertia forces: $\overline{M}_{i1} = \overline{0}$ (it was considered $\varepsilon_1 = 0$);
– - the reactions of element **2**, of dyad *RRR*(2,3), on element **1** of driving group *R*(1), and namely: $\overline{R}_{21X} = -\overline{R}_{12X}$, $\overline{R}_{21Y} = -\overline{R}_{12Y}$.

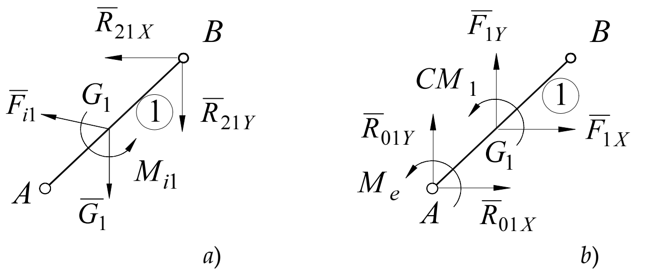

Fig. 5. Driving group *R*(1); *a*) highlighting the forces and moments acting on the group; *b*) kinetostatic scheme of diving group

The resultant of forces of weight and reaction is:

$$\overline{F}_{R1} = \overline{F}_{1X} + \overline{F}_{1Y} \tag{14}$$

or:

$$\overline{F}_{R1} = F_{1X}\,\overline{i} + F_{1Y}\,\overline{j} \tag{15}$$

The projections on the axes of coordinates of resultant forces are:

$$F_{1X} = -R_{12\mathrm{X}};\ F_{1Y} = -m_1 \cdot g - R_{12\mathrm{Y}} \tag{16}$$

In relation to the reduction point *A*, the resultant moment is:

$$CM_1 = R_{12X}(YB - YA) - R_{12Y}(XB - XA) \tag{17}$$

The reactions in the active coupling *A*, and also the moment of equilibration *ME* form the output data of procedure **A1RRC.m**. The equilibration moment (torque) in active coupling *A* can also be calculated using the equation of virtual powers, namely:

$$\begin{aligned}\sum \overline{P}\cdot\overline{v} = {} & \overline{M}_{e1}\cdot\overline{\omega}_1 + (\overline{F}_{i1}+\overline{G}_1)\cdot\overline{v}_{G1} + (\overline{F}_{i2}+\overline{G}_2)\cdot\overline{v}_{G2} + (\overline{F}_{i3}+\overline{G}_3)\cdot\overline{v}_{G3} + + \overline{M}_{i1}\cdot\overline{\omega}_1 + \overline{M}_{i2}\cdot\overline{\omega}_2 + \\ & \overline{M}_{i3}\cdot\overline{\omega}_3 + \overline{F}_{R1X}\cdot\overline{v}_{P''X} + \overline{F}_{R1Y}\cdot\overline{v}_{P''Y} + \overline{F}_{RHX}\cdot\overline{v}_{HX} + \overline{F}_{RHY}\cdot\overline{v}_{HY} + \overline{F}_{RQ\max 1X}\cdot\overline{v}_{PX} + \\ & + \overline{F}_{RQ\max 1Y}\cdot\overline{v}_{PY} + + \overline{F}_{RQ\max 2X}\cdot\overline{v}_{P'X} + \overline{F}_{RQ\max 1Y}\cdot\overline{v}_{P'Y} = \overline{0}\end{aligned} \tag{18}$$

Using the above relationship, it results:

$$\begin{aligned}M_{e1} = {} & (m_1(a_{G1X}\cdot v_{G1X} + (a_{G1Y}+g)\cdot v_{G1Y} + IG_1\cdot\omega_1\cdot\varepsilon_1 + + m_2(a_{AG2X}\cdot v_{VG2X} + (a_{AG2Y}+g)\cdot v_{BY} + \\ & + IG_2\cdot\omega_2\cdot\varepsilon_2 + + m_3(a_{G3X}\cdot v_{G3X} + (a_{G3Y}+g)\cdot v_{G3Y} + IG_3\cdot\omega_3\cdot\varepsilon_3 - F_{RHX}\cdot v_{HX} - \\ & - F_{RHY}\cdot v_{HY} - F_{RQ\max 1X}\cdot v_{PX} - F_{RQ\max 1Y}\cdot v_{PY} - F_{RQ\max 2X}\cdot v_{P'X} - F_{RQ\max 2Y}\cdot v_{P'Y} - \\ & - F_{R1X}\cdot v_{P''X} - F_{R1Y}\cdot v_{P''Y})/\omega_1\end{aligned} \tag{19}$$

For the kinetostatic analysis of the mechanism, are known:

a) the kinematical scheme of the mechanism;
b) the sizes of elements and the positions of couplings to the base, as follows: AB = 0.009 m, BC = 1.300 m, CD = 0.250 m, DP = 0.162 m, DP′ = 0.165 m, DP′′ = 0.067 m, BG2 = BC/2 m, DG3 = 0.035 m, XA = 0.0 m, YA = 0.0 m, XD = 0.524 m, YD = -1.341 m, δ = 1.398 rad.
c) the initial position of mechanism: $\varphi_1 = \varphi_{10} = -1.3537$;
d) the rotational speed of element 1: $\omega_1 = 57.596\,\mathrm{s}^{-1}$;
e) the angular acceleration of element 1: $\varepsilon_1 = 0.0\,\mathrm{s}^{-2}$;
f) the masses of mechanism elements: m_1 = 3.5 kg, m_2 = 20.88 kg, m_3 = 17.95 kg;
g) the moments of inertia of the elements, relative to an axis perpendicular to the plane of movement and passing through the center of mass: IG_2 = 2.62 kgm2, IG_3 = 0.367 kgm2;
h) the technological forces: $Q_{\max 1} = 14800$ N, $Q_{\max 2} = 10570$ N;
i) the drag forces: $F_{R1} = 12220$ N, $F_{R2} = 944.954$ N;
j) the friction coefficient: $\mu = 0.4$.

Based on the above data was compiled a computer program to determine the reactions in the kinematic couplings of the mechanism, and its torque. In the main program were used the calculation routines mentioned above. In Table 1 are given the reactions in coupling *A* and the torque in active coupling *A*, for various positions of the mechanism.

Table 1. Reactions in coupling *A* and the torque in the active coupling *A*, depending on the position of the mechanism

position	f11	r01x	r01y	me	me1
0	-1.3537	-1181.1	10137.4	9.208	9.209
1	-1.1791	-1199.2	10104.7	24.622	24.622
2	-1.0046	-1214.5	10052.3	39.140	39.140
3	-0.8301	-1226.8	9981.6	52.266	52.266
4	-0.6555	-1235.7	9894.7	63.570	63.569
5	-0.4810	-1241.1	9794.1	72.703	72.703
6	-0.3065	-1242.9	9682.6	79.414	79.413
7	-0.1319	-1241.3	9563.6	83.548	83.547
8	0.0426	-1236.3	9440.4	85.051	85.050
9	0.2171	-1228.1	9316.6	83.960	83.959
10	0.3917	-1217.0	9195.8	80.391	80.390
11	0.5662	-1203.2	9081.8	74.529	74.528
12	0.7407	-1187.1	8977.8	66.610	66.609
13	0.9153	-1169.1	8887.2	56.910	56.909
14	1.0898	-1149.6	8813.0	45.726	45.725
15	1.2643	-1129.0	8757.6	33.373	33.373
16	1.4389	-1108.0	8723.1	20.172	20.172
17	1.6134	-1087.0	8710.9	6.448	6.448
18	1.7879	-1066.7	8721.6	-7.469	-7.469
19	1.9625	3217.1	-9786.8	6.980	6.980
20	2.1370	3250.0	-9717.4	22.395	22.395
21	2.3115	3272.9	-9612.8	36.853	36.853
22	2.4861	3285.4	-9476.7	49.832	49.832
23	2.6606	3287.0	-9314.3	60.904	60.903
24	2.8351	3277.8	-9131.4	69.748	69.747
25	3.0097	3258.2	-8934.5	76.160	76.160
26	3.1842	3229.0	-8730.3	80.048	80.047
27	3.3587	3191.2	-8525.5	81.417	81.416
28	3.5333	3146.1	-8326.5	80.358	80.357
29	3.7078	3095.0	-8139.2	77.024	77.023
30	3.8823	3039.6	-7968.8	71.616	71.615
31	4.0569	2981.6	-7819.9	64.362	64.361
32	4.2314	2922.6	-7696.3	55.509	55.508
33	4.4059	2864.4	-7601.1	45.310	45.310
34	4.5805	2808.7	-7536.5	34.022	34.021
35	4.7550	2757.0	-7503.8	21.901	21.901
36	4.9295	2710.8	-7503.8	9.209	9.209

where:

Me – represents the mechanism driving moment (driving moment), determined by kinetostatic method (formulas 5,….17, plus certain formulas from calculation procedures)

Me1 - represents the mechanism driving moment too, but determined by virtual exponents method (formulas 18, 19).

Figures 6, 7 and 8 show the reaction curves corresponding to the kinematic couplings *A*, *C* and *D*. In Figure 9 is presented the diagram of torque variation.

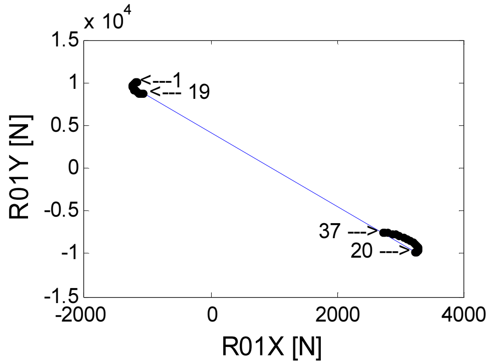

Fig. 6. Diagram of reactions in coupling *A*

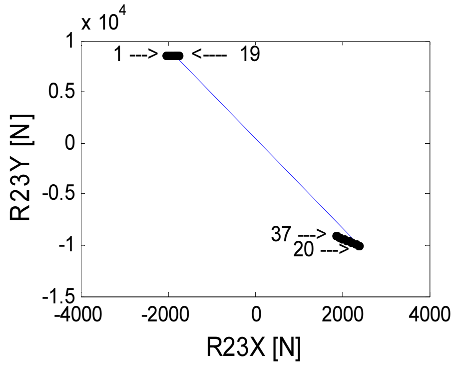

Fig. 7. Diagram of reactions in coupling *C*

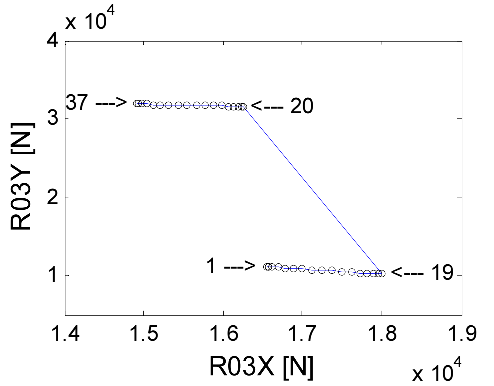

Fig. 8. Diagram of reactions in coupling *D*

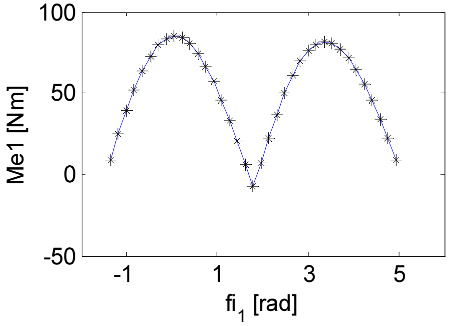

Fig. 9. Diagram of the torque

CONCLUSIONS

Obtaining the values of the reactions in kinematic couplings of the mechanism allows the passage to the next stage, i.e. the actual design of kinematic elements.

If there is a calculation error in the two methods, the results are different, which means that the calculation algorithm has not been fully complied with, and the solution is not good. As seen in Table 1, the results are similar to the third decimal, which means that all calculations were correct by both methods.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.4:631.331:631.53.04
Izvorni znanstveni rad
Original scientific paper

VALIDATION OF MATHEMATICAL MODEL REGARDING THE HORIZONTAL MOVEMENT OF SEEDS DETACHED FROM THE ORIFICES OF DISTRIBUTING DISK

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ABSTRACT

The paper presents the experimental researches conducted to validate a theoretical mathematical model, by using an ultra-rapid camera (ideal for high-definition applications at mid-range speeds) that allows to film and record seeds detached from the orifices of the distributing disc of a sowing station fitted on a specialized testing stand, for operating speeds of 2 km/h, so that the correlation between experimental data and the data estimated theoretically can be verified.

Keywords: precision planter, seed-metering device, row unit

INTRODUCTION

In order to obtain a production calculated on a field surface, a certain density established by agro-technical norms, must be ensured. [4] Mathematically speaking, plant density per hectare is represented by points arranged in plan, in the seed rows respecting the constructive distance between the sowing stations. [1, 2, 6]

Heterogeneous seeds (not all have the same shape, size and weight) physically represent the main cause that hinders the distribution apparatus to place the seeds at the exact distance provided by agro-technical norms for each type of crop [3, 7].

Due to the great number of distribution apparatus types with different operating systems, a series of indices by means of which the seed distribution quality is evaluated, has been adopted, namely: if the distance between two consecutive grains is framed within the limit of spacing allowed by agro-technical norms, then it is considered as “appropriate” and if it is bigger, it is considered as „gap”, and when it is smaller it is considered as „double”.

The number of distances of a certain category expressed in percentages in comparison with the number of row grains represents important indicators that influence the grain production. [8]

Manner in which the constructive elements of seed distribution apparatus influence these indexes is studied on specialized stands (endowed with transducers that transform the falling time between seeds in distances), the results obtained being processed as statistics. Whatever the distribution apparatus operation principle is, the distance between the consecutive grains is measured and then, the values of the above indexes are calculated according to input data: sowing norm, distance between rows, number of orifices on the distributing disc and sowing machine working speed (aggregate tractor – sowing machine) [5].

MATERIAL AND METHODS

In order to thoroughly understand the phenomena on which the distribution process of seeds for distributor of section SEMO 8 are based, a mathematical model was developed. This model studies in terms of kinematics the limiting factors and geometry of certain constructive elements of the mechanical system used when sowing.

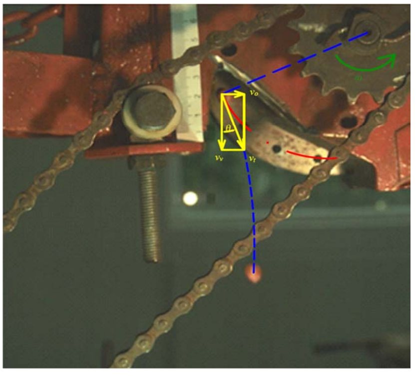

Fig.1. Detachement of seeds from the distributing disc

Seed detached from the hole of distributing disc after it passes over the depression chamber in its trajectory to the ditch opened by ploughshare, has an horizontal movement, Δx comparing to detaching point.

$$\Delta_x = \frac{-ctg\theta + \sqrt{ctg^2\theta + \dfrac{2 \cdot g \cdot h}{v_t^2 \cdot \sin^2\theta}}}{\dfrac{g}{v_t^2 \cdot \sin^2\theta}} \tag{1}$$

where:

v_t – represents the speed of seed movement on its trajectory towards the ditch opened by the ploughshare (m/s);

h – represents the seed detaching height comparing to soil (m);

θ – represents the seed detaching angle (º);

g – represents the gravity acceleration (m/s^2).

For experimentally validate the mathematical model obtained, 6 high fidelity films by means of which were measured the distances to reference system in vertical and horizontal plan for 6 working speeds, (2, 4, 6, 8, 10, 12 km/h), for 4 falling height values and 7 or 8 filmed grains (depending on the number of available frames), were performed. Measurements were performed between the reference system chosen and geometrical centre of corn grains filmed.

Experimental researches were performed with section SEMO 8, especially prepared for this purpose. Films were made by means of a camera Phantom V 10 that can take a maximum number of 2400x1800 pixels.

Fig.2 – Phantom v10 camera [9]

RESULTS AND DISCUSSION

For processing the experimental data, the following software was used: Phantom Camera Control Application.

Working steps:

Step 1 – loading the video raw file;

Step 2 – calibrating the frame dimensional measures;

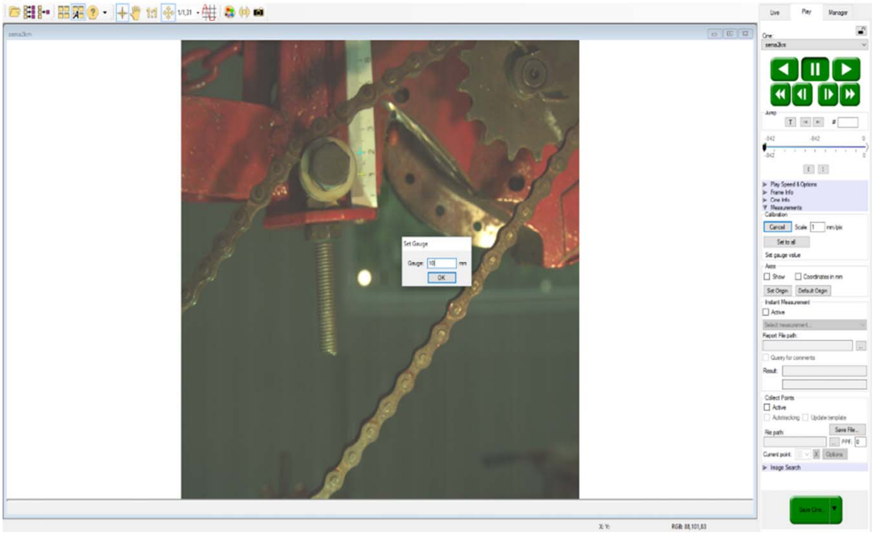

Fig.3 – Calibration of dimensional measurements on frames

Step 3 – setting the reference system origin. It corresponds to the moment when grains detach from the disc;

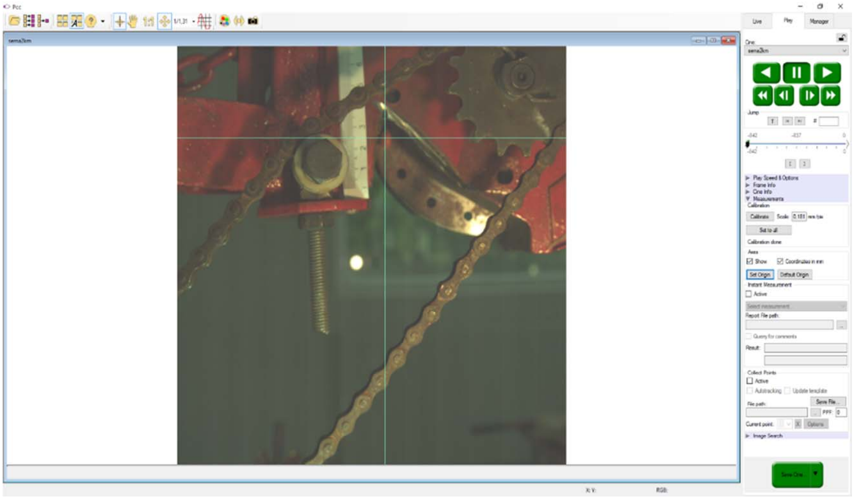

Fig.4 – Setting the reference system origin

Step 4 – activating the remote measurement on vertical and horizontal of reference system and performing it after a pre-established number of frames per second, respectively: 20, 30, 40 and 47 fps, necessary to travel the whole distance reproduced in images;

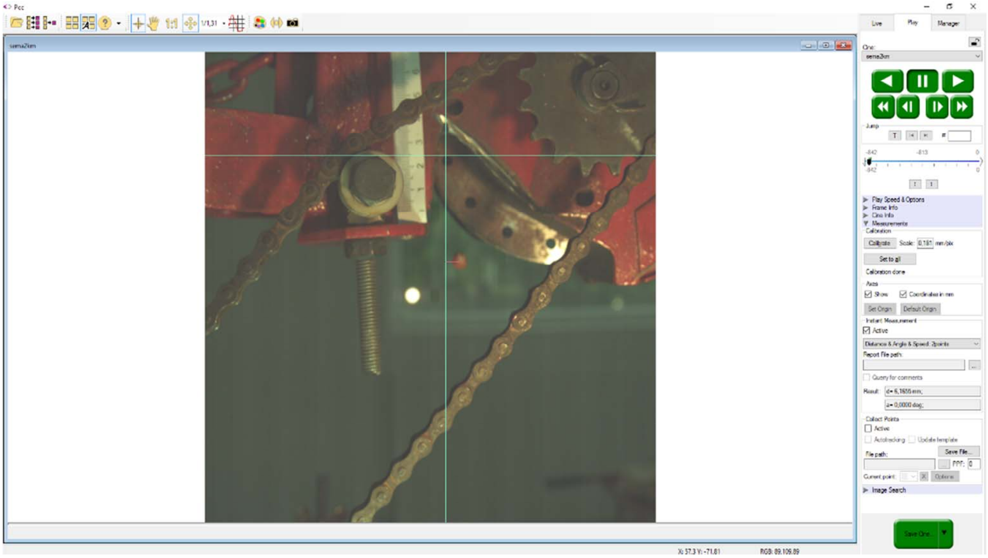

Fig.5 – Activation of remote measurement on the horizontal of reference system

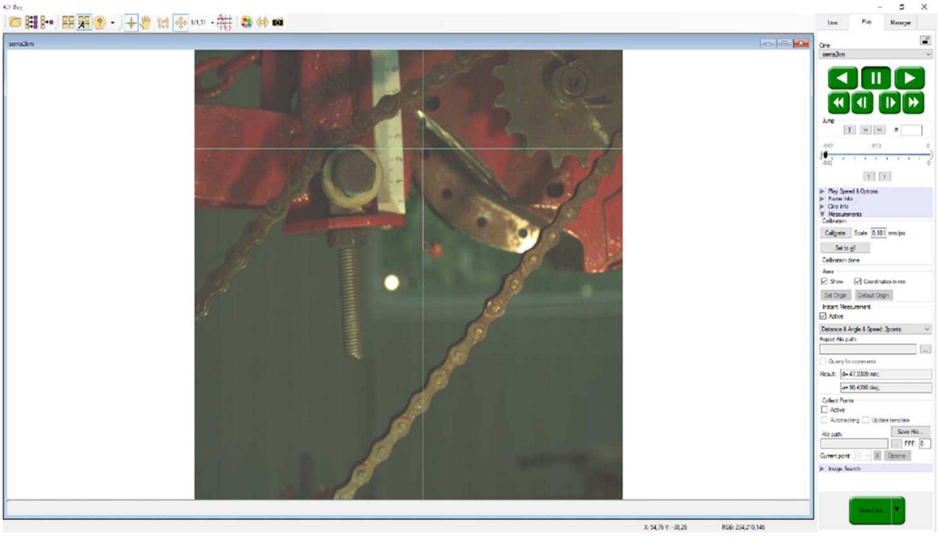

Fig.6 - Activation of remote measurement on the vertical of reference system

Step 5 – repeating three times the step 4;

Step 6 – measuring the grain detchaing angle by activation of angle measurement by 3 points;

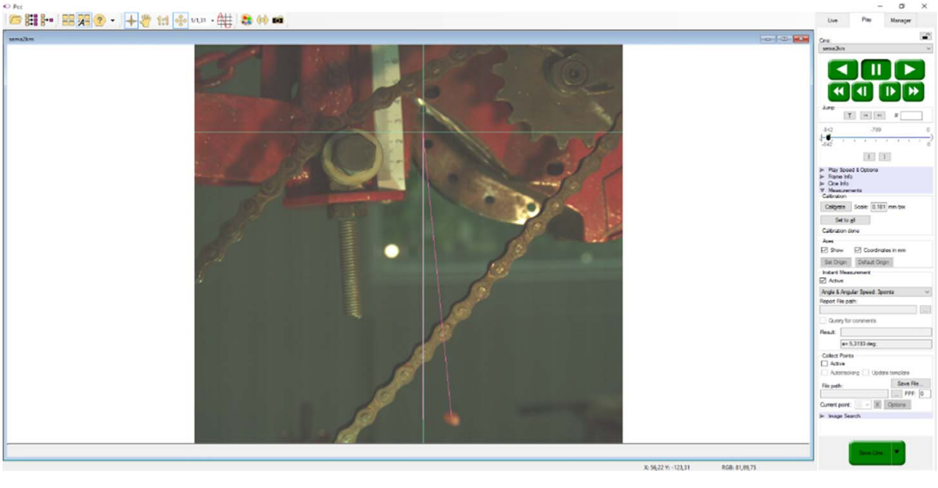

Fig.7 – Measurement of grain detaching angle

Step 7 – repeating steps 4, 5 and 6 for other 7 grains.

In table 1 are given the results of measurements of real horizontal movement, Δ_x to the detaching point from the disc, for a detaching speed of 2 km/h.

Table 1 Results of grains real horizontal movement measurements for a detaching speed of 2 km/h

	Δ_{x1} [mm]	Δ_{x2} [mm]	Δ_{x3} [mm]	Δ_{x4} [mm]	θ [degrees]
h [mm]	25	50	100	150	
No. frames	20	30	40	50	
Seed 1	*1.92*	*4.38*	*7.00*	*9.64*	3.27
Seed 2	*8.41*	*12.98*	*18.24*	*22.63*	8.47
Seed 3	*4.05*	*5.61*	*7.54*	*10.87*	4.50
Seed 4	*4.38*	*7.71*	*11.92*	*15.61*	6.11
Seed 5	*4.38*	*7.19*	*9.64*	*12.98*	4.79
Seed 6	*5.09*	*9.65*	*12.63*	*17.01*	6.67
Seed 7	*1.57*	*2.63*	*3.35*	*4.03*	1.59

In figure 8 is shown the dependence of real horizontal movement, Δ_x on the seed detaching height for a detaching speed of 2 km/h.

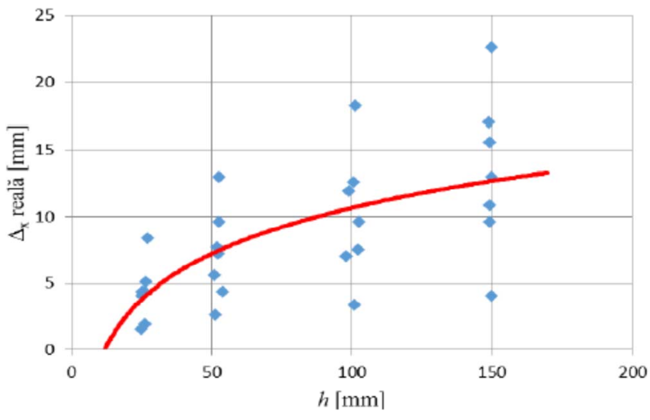

Fig.8 – Dependence of real horizontal movement Δ_x = f(*h*, 2 km/h)

In table 2 are given the values of estimated movement Δ_{xe} and measured movement Δ_{xm} depending on seed detaching height, seed detaching angle and detaching speed from the disc.

Table 2 Estimated movement and real movement of seeds noticed according to influence factors for a detaching speed from the disc of 2 km/h

No.of seed	θ [degrees]	Δ_{xe} [mm]	Δ_{xm} [mm]	No.of seed	θ [degrees]	Δ_{xe} [mm]	Δ_{xm} [mm]	$\overline{\Delta}_{xe}$ [mm]	$\overline{\Delta}_{xm}$ [mm]
1	3.27	*1.12*	*1.92*	7	1.59	*0.52*	*1.57*	*3.93*	*8.68*
		1.98	*4.38*			*0.92*	*2.63*		
		3.03	*7.00*			*1.50*	*3.35*		
		4.01	*9.64*			*1.95*	*4.03*		
2	8.47	*3.04*	*8.41*						
		5.05	*12.98*						
		8.03	*18.24*						
		10.43	*22.63*						
3	4.5	*1.50*	*4.05*						
		2.62	*5.61*						
		4.29	*7.54*						
		5.52	*10.87*						
4	6.11	*2.11*	*4.38*						
		3.61	*7.71*						
		5.70	*11.92*						
		7.50	*15.61*						
5	4.79	*1.61*	*4.38*						
		2.84	*7.19*						
		4.58	*9.64*						
		5.90	*12.98*						
6	6.67	*2.33*	*5.09*						
		3.96	*9.65*						
		6.30	*12.63*						
		8.18	*17.01*						

Correlation between data obtained experimentally and data estimated by means of mathematical model is presented in figure 9.

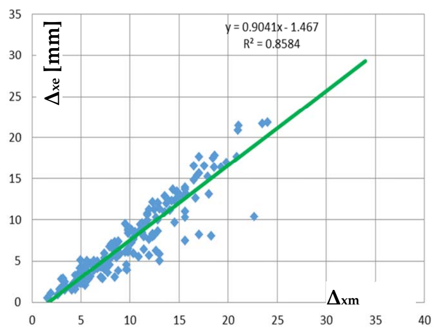

Fig.9 – Correlation between data related to experimentally measured movement and estimated movement

Correlation between real movement and theoretically determined movement for seeds studied was estimated by means of coefficient of correlation R, calculated with the formula:

$$R = \frac{\sum(\Delta_{xm_i} - \overline{\Delta}_{xm}) \cdot (\Delta_{xe_i} - \overline{\Delta}_{xe})}{\sqrt{\sum(\Delta_{xm_i} - \overline{\Delta}_{xm})^2 \cdot \sum(\Delta_{xe_i} - \overline{\Delta}_{xe})^2}} \tag{2}$$

Replacing in relation 2 the values of horizontal movement of seeds from tables 2-7 , a correlation coefficient has been obtained R = 0.9265, that led to the validation of theoretical model, because a very strong correlation between experimental data and theoreatically estimated data, has been noticed.

CONCLUSIONS

Achieving a correct and uniform distance of seeds in furrow is essential for maximizing the production of sown crops. The first step for obtaining a uniform spacing consists in precision distribution of seeds, one by one at the appropriate moment. This „selective separation" (singling out) represents a reference point for manufacturing operational distribution mechanical or pneumatical apparata.

For economic reasons, it is aimed to increase the sowing precision from values framed between 93 – 97 % up to 98 – 99 %. In latest years, distribution apparata of sowing machines for hoeing plants were able to reach a sowing precision of 99%, for certain types of seeds being necessary some adjustments for getting this performance. On the other side, the particular design of such apparata make them less able to obtain a high yield, as a result of manufacturing tolerances.

In conclusion, the very strong correlation between the experimental data and those theoretically expressed has led to the validation of theoretical model.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.4:631.316
Izvorni znanstveni rad
Original scientific paper

THE SYNTHESIS OF THE DIGGING PITS MECHANISMS FOR SHRUBS WITH THE PRECISE-MATHEMATICAL DRAWING OF A CURVE

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SUMMARY

In the structure of the machines used for digging pits for shrubs there are different mechanisms with bars. These mechanisms move the tracer point, point where the auger is attached, after a curve that approximate a parallel line to the vertical axis. In this paper we have done the synthesis of some mechanisms that draw, with a precise-mathematical accuracy a parallel line to a certain established direction. These mechanisms have a reduced number of elements and a relatively simple construction.

Key words: synthesis, mechanism with bars, pantograph, connecting rod curves

INTRODUCTION

The mechanisms belonging to digging pits machines for shrubs have to lead a tracer point after a vertical direction. The tracer point is the point where the auger is attached and which support drilling of the pit. This tracer point belongs to a connecting rod of the mechanism.

The mechanisms from the structure of the digging pits machines for shrubs can approximate a given curve by points or can draw some precise mathematical curves.

In paper [10] it has been achieved the synthesis of a mechanisms with bars, a driving tryad, used to design a digging pits machine for shrubs. The kinematic scheme of the full mechanism is presented in figure 1 and the multipolar scheme in figure 2. The mechanism synthesized in paper [10] has its own acting system, but is brought in the working position by using the lifting system of the tractor.

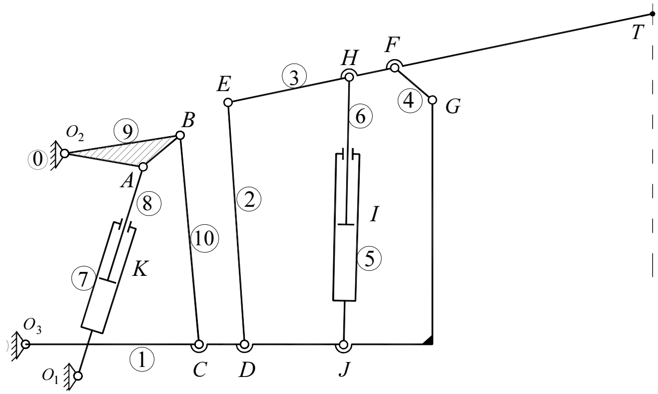
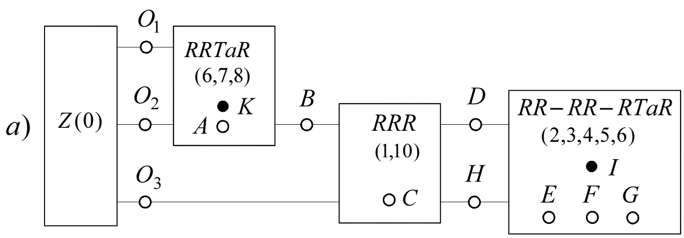


Fig. 1. The kinematic scheme of the digging pits mechanism for shrubs



$$b)\quad Z(0) + RRTaR\,(6,7,8) + RRR\,(1,9) + (RR - RR - RR)(2,3,4,5)$$

Fig. 2. The multipolar scheme of the digging pits mechanism for shrubs; b) the mechanism's structural relationship

In figure 3 is presented the kinematic scheme a) and the structural scheme b) of a digging pits mechanism for shrubs, and in figure 4 there are presented the multipolar scheme and the structural relationship of the same mechanism. The mechanism has in its structure a tryad with revolution pairs (RR-RR-RR).

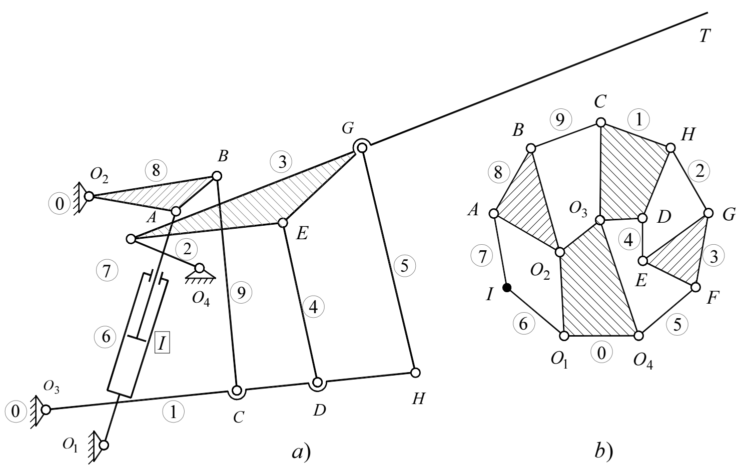
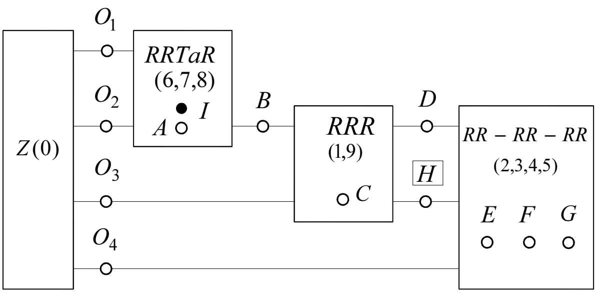


Fig. 3. Digging pits mechanism for shrubs *a*) kinematic scheme *b*) structural scheme

a)



b) $Z(0) + RRTaR\ (6,7,8) + RRR\ (1,9) + (RR - RR - RR)(2,3,4,5)$

Fig. 4. The kinematic scheme
a) and structural relationship b) of the mechanism from figure 3

These mechanisms approximate a straight line parallel to the vertical axis.

To establish the synthesis of these mechanisms, there are written the equations vector on the independent outlines of the mechanisms [7, 8, 11, 12, 14], there are projected on the axes of the 3D coordinates system, it results a certain number of nonlinear scalar equations and then the system of nonlinear equations [2, 4, 6, 9, 13] is solved and there are finally obtained the elements' dimensions of the mechanisms. As it can be noticed, the synthesis of these mechanisms demands a considerable effort to be done. Another disadvantage is represented by the great number of elements of these mechanisms.

MATERIAL AND METHODS

In this paper is done the synthesis of some mechanisms, as simple as possible, used for digging pits for shrubs. These mechanisms are based on the pantograph mechanism principle.

Pantograph – is a device used to reproduce a drawing, a plan etc., to the same size with a given pattern or at a different scale from the pattern's scale [5].

The pantograph mechanism has the opposite sides parallel and equal, as it can be seen in figure 5. To copy a certain pattern, it must that the points *A*, *F* and *T* be on a line. For instance, if the tracer point T is moving on the horizontal axis, then the point *F* will do the same motion.

By applying the formula for the degree of mobility for planar mechanisms [1, 7, 8, 11, 12, 14], the pantograph mechanism from figure 5 has the degree of mobility 2, namely M = 2. This means that the tracer point *T* (the same point *F*) can follow any curve in plane.

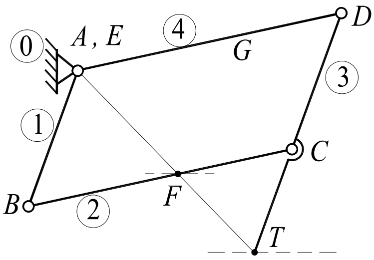


Fig. 5. The kinematic scheme of the pantograph mechanism

In the figures 6 and 7 there are presented other kinematic schemes of pantograph mechanisms. Let's consider a straight line Δ, perpendicular on the direction *AF*. Let's consider the point *F* as the point that follows the pattern and the point *H* as the point doing the technological operation. If these two points are in the same semi-plane against the straight line Δ, then the geometric figures described by these points are similar and on the same side of the straight line *AF*. If these two points are opposite to the straight line Δ, then the geometric figures described by the mentioned points are in the mirror against the straight line *AF*.

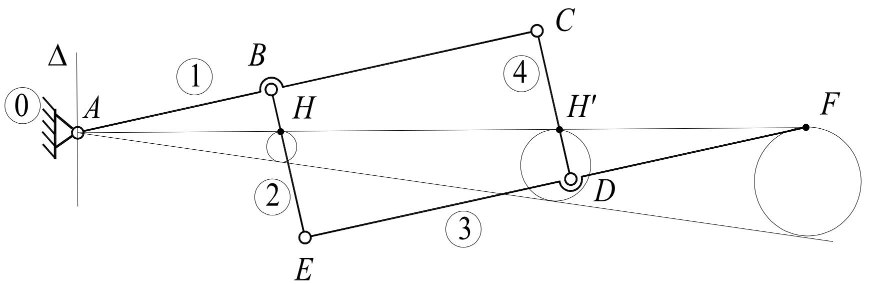


Fig. 6. Other kinematic scheme of the pantograph mechanism

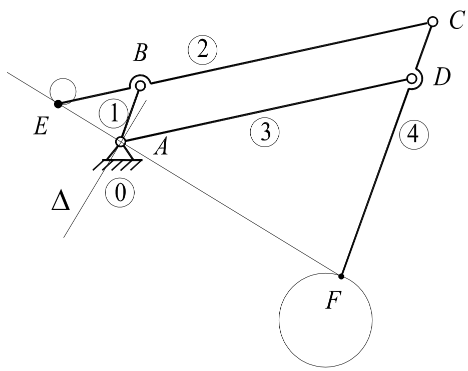


Fig. 7. Other kinematic scheme of the pantograph mechanism

RESULTS

Connection relationships between the dimensions of the elements

In figure 8 is considered the straight line *FG* parallel to *AB*. From the similarity of the triangles *AGF* and *ADT*, can be written the relationships:

$$\frac{AG}{AD} = \frac{FG}{DT} = \frac{AF}{AT} = k\,, \tag{1}$$

where k is the ratio of similarity.

By taking into consideration the equality of the segments $FG = AB$, $AG = BF$, it results:

$$\frac{BF}{AD} = \frac{AB}{DT} = \frac{AF}{AT} = k\,. \tag{2}$$

From the similarity of the triangles $AF'F''$ and $AT'T''$, can be written the relationships:

$$\frac{AF'}{AT'} = \frac{AF''}{AT''} = \frac{F'F''}{T'T''} = k \tag{3}$$

From the similarity of the triangles AFF''' and ATT''', can be written the relationships:

$$\frac{AF}{AT} = \frac{a}{b} = k \tag{4}$$

By using the relationships (2), (3) and (4), it results:

$$\frac{BF}{AD} = \frac{AB}{DT} = \frac{F'F''}{T'T''} = \frac{a}{b} = k\,. \tag{5}$$

If it is imposed a certain ratio of similarity k, a certain stroke of the point *T* (or *F*) and certain distances *a* and *b*, then the dimensions of the elements of the mechanism can be established, so to achieve certain demands given in the design theme, as it will be seen further on.

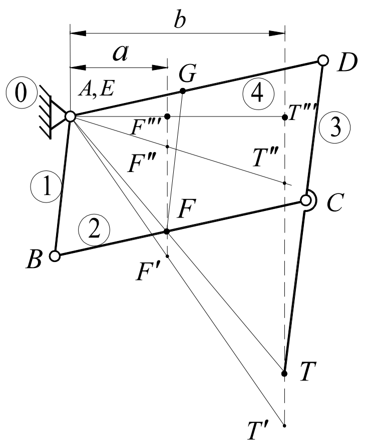


Fig. 8. Pantograph mechanism

The synthesis of the mechanisms for a precise mathematical drawing of the connecting rod curves

By using the above relationships will be established the dimensions of some mechanisms used to achieve digging pits machines for shrubs. These mechanisms have to lead a tracer point, point located on one of the connecting rod of the mechanism, on a straight line parallel to the vertical axis.

In figure 9 is presented the kinematic scheme of a digging pits mechanism for shrubs, with the precise mathematical drawing of a straight line. The mechanism proceeds from the pantograph mechanism is presented in figure 8.

The structural and multipolar schemes of the mechanism from figure 9 are presented in figure 10.

The point F is moving on the straight line Δ and the point T will move also after a straight line, δ, parallel to Δ, according to the reciprocal theorem of Thales.

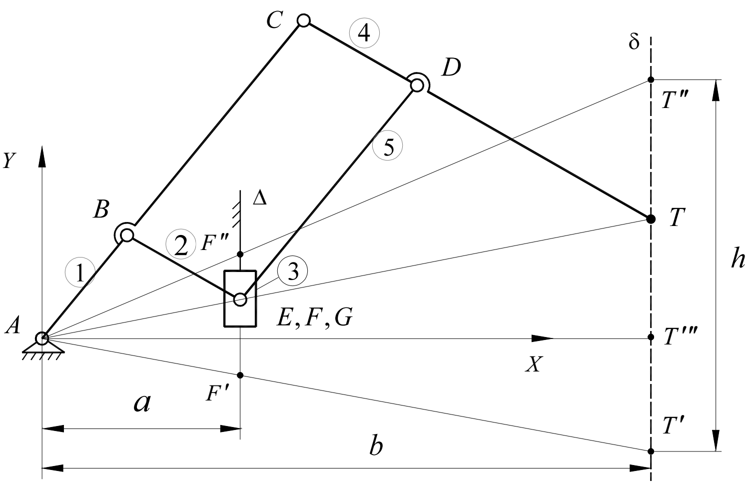


Fig. 9. The kinematic scheme of the digging pits machine for shrubs (variant 1)

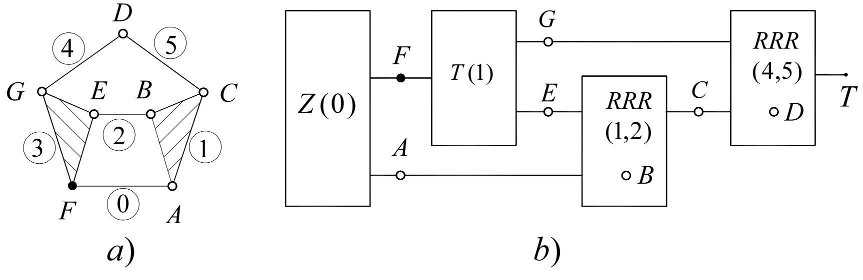


Fig. 10. The structural and multipolar schemes of the mechanism from figure 9

For the mechanism from figure 9 there are known:

a – the horizontal distance from point A to the straight line Δ;

b – the horizontal distance from point A to the straight line δ;

AB - the distance from A to B;

BF – length of the element 2;

YT'' – the ordinate of point T'';

h – the displacement distance of the auger

Then, there are established the dimensions of the elements of the mechanism.

The ratio of similarity is given by the formula: $k = a / b$.

By using the formula (5), adapted to the new notations, it results:

$F'F'' = h \cdot k$ - the stroke of the element 3;

$CT = BF / k$ - length of the element 4;

$AC = AB / k$ - distance from A to C;

$YF'' = YT'' \cdot k$ - the initial position of the point F.

The actuation of the digging pits mechanism for shrubs is made by using an own system (figure 11) or by using the lifting system of the tractor (figure 12) as well.

To optimize the mechanism, can be imposed limits for the pressure angles, minimum clearance gauge, minimum stroke at the driving cylinder etc.

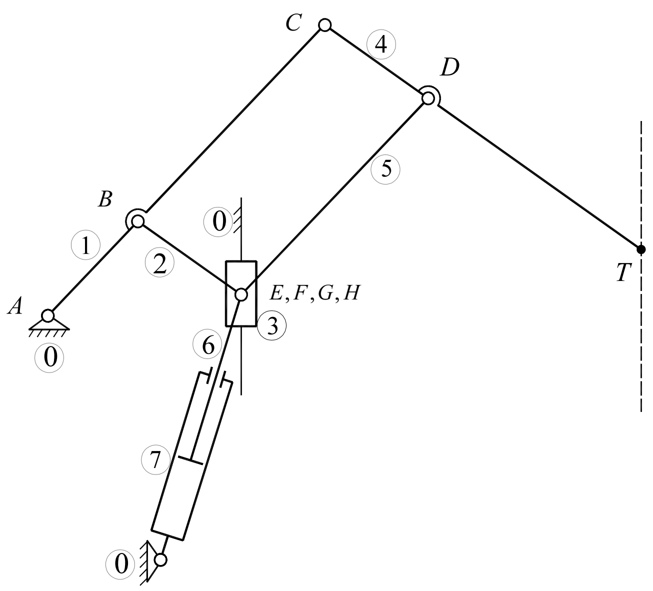


Fig. 11 The actuation by using own system

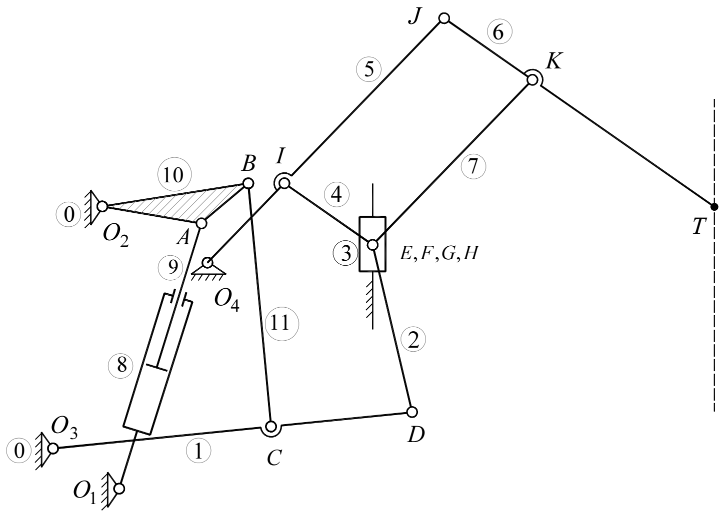


Fig. 12 The actuation by using the lifting system of the tractor

In the same way, can be established the dimensions of the elements for the mechanism from figure 7 (it is considered the vertical motion of the point E).

CONCLUSIONS

The digging pits mechanisms for shrubs can be easily obtained from the pantograph mechanisms. The necessary relationships to establish the dimensions of the elements are simple and based on the similarity of triangles. Running of these mechanisms can be done by using an own driving system or by using the lifting system of the tractor, as it was noticed in figures 11 and 12.

To optimize the mechanism, can be imposed limits for the pressure angles, minimum clearance gauge, minimum stroke at the driving cylinder etc.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 582.542:62-79:621.384.8
Izvorni znanstveni rad
Original scientific paper

KINETOSTATIC ANALYSIS OF SEPARATOR WITHIN MISCANTHUS RHIZOME HARVESTING MACHINE

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SUMMARY

Within this paper is presented the kinetostatic analysis of mechanism which drives the eccentric separator comprised by the technical equipment of harvesting Miscanthus rhizomes, where the driving momentum and joint reactions, are determined. The kinetostatic analysis of the mechanism which drives the eccentric separator allows to identify the constructive parameters in order to improve the mechanism structure by avoiding its undersizing or oversizing with direct impact on the performance of the technical equipment.

Keywords. kinetostatic analysis, numerical study, eccentric separator, optimisation, operation and constructive parameters

INTRODUCTION

The quality of the seedling material plays an extremely important role in establishing the Miscanthus culture. In this context, rhizomes harvesting represents one of the most important operations with major influence on biomass production [6], [7], [9].

In general, the technical equipment for harvesting root crops is composed of digging parts and separating parts. Knowing the kinetostatic parameters of this type of parts is an objective that needs to be fulfilled for the operational and constructive optimisation of the respective equipment.

The technical equipment for harvesting Miscanthus rhizomes (fig. 1) is composed of an eccentric separator driven by a quadrilateral mechanism consisting of a crank, connecting rod and working beam represented by the separator rods.

The eccentric separator (fig. 2) is intended for cleaning, by shaking, the ground off the Miscanthus rhizomes dug towards the back of the machine. It consists of two oscillating grates which take over the ground mass dug together with the rhizomes and an oscillating eccentric mechanism that has a vibrating effect which makes the ground fall off the rhizomes through the grate rods.

Fig. 1. Equipment for harvesting Miscanthus rhizomes [7]

Fig. 2. Excentric separator [7]

MATERIAL AND METHOD

We are going to determine the forces and torques acting on and stressing different parts of the quadrilateral mechanism operating the eccentric separator which is part of the technical equipment for harvesting Miscanthus rhizomes. Figure 3 presents the forces driving the quadrilateral mechanism.

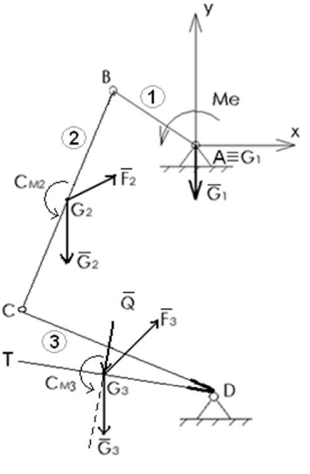

Fig. 3. Forces acting on the elements of eccentric separator driving mechanism

Forces acting on the separator:

A. External forces:

– Separator action forces, in oscillation movement, upon soil determining its acceleration, Q;
– Weight forces acting on each element of the mechanism (G_1, G_2, G_3);
– Driving force acting on the mechanism and determining momentum M_e;

B. **Internal forces,** the reacting forces: R_{01x}, R_{01y}, R_{12x}, R_{12y}, R_{23x} R_{23y}, R_{03x} and R_{03y}, acting on mechanism kinematic coupling *A*, *B*, *C* and *D*.

C. **Forces of inertia** of mechanism elements [1], [2], [3], [4], [5].

Forces acting on mechanism connecting rod, are presented in figure 4:

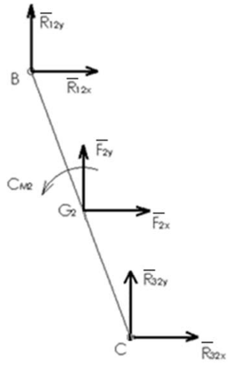

Fig. 4. Forces acting on mechanism connecting rod

To write the equilibrium equations, the applied and inertia forces are reduced at twist. For element 2, presented in figure 4, the equilibrium equations are:

$$\begin{cases} \sum F_x = 0 & R_{12x} + R_{32x} + F_{2x} = 0 \\ \sum F_y = 0 & R_{12y} + R_{32y} + F_{2y} = 0 \\ \sum M_C = 0 & -R_{12x}(y_b - y_c) - R_{12y}(x_c - x_b) - F_{2x}(y_{g2} - y_c) - F_{2y}(x_c - x_{g2}) + C_{M2} = 0 \end{cases} \tag{1}$$

Considering that:

$$\left|\overline{R_{32x}}\right| = \left|\overline{R_{23x}}\right|; \overline{R_{32x}} = -\overline{R_{23x}}$$
$$\left|\overline{R_{32y}}\right| = \left|\overline{R_{23y}}\right|; \overline{R_{32y}} = -\overline{R_{23y}}$$

It results that:

$$\begin{cases} \sum F_x = 0 & R_{12x} - R_{23x} = -F_{2x} \\ \sum F_y = 0 & R_{12y} - R_{23y} = -F_{2y} \\ \sum M_C = 0 & -R_{12x}(y_b - y_c) - R_{12y}(x_c - x_b) - F_{2x}(y_{g2} - y_c) - F_{2y}(x_c - x_{g2}) + C_{M2} = 0 \end{cases} \tag{2}$$

where:

$$\begin{cases} F_{2x} = -M_2 \cdot a_{g2x} \\ F_{2y} = -M_2 \cdot (g + a_{g2y}) \\ C_{M2} = -\varepsilon_2 \cdot I_{G2} \\ I_{G2} = \dfrac{M_2 \cdot BC^2}{12} \end{cases} \tag{3}$$

Forces acting on working beam are presented in figure 5:

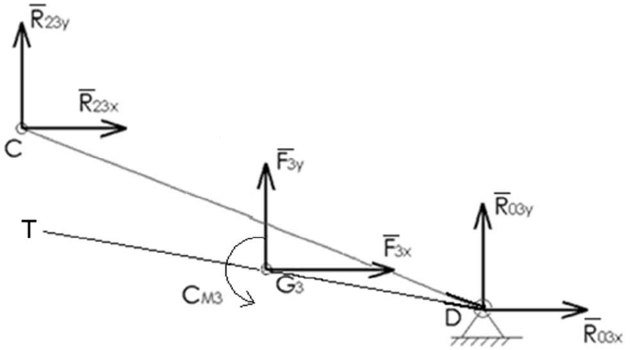

Fig. 5. Forces acting on working beam [8]

CD working beam, the forces presented in Fig. 5 act upon, has the following equilibrium equations:

$$\begin{cases} \sum F_x = 0 \quad R_{23x} + R_{03x} + F_{3x} = 0 \\ \sum F_y = 0 \quad R_{23y} + R_{03y} + F_{3y} = 0 \\ \sum M_C = 0 \quad R_{03x}(y_c - y_d) + R_{03y}(x_d - x_c) + F_{3x}(y_c - y_{g3}) + F_{3y}(x_{g3} - x_c) + C_{M3} = 0 \end{cases} \tag{4}$$

where:

$$\begin{cases} F_{3x} = -M_3 \cdot a_{g3x} + Q_x \\ F_{3y} = -M_3 \cdot (g + a_{g3y}) + Q_y \\ C_{M3} = -\varepsilon_3 \cdot I_{G3} \\ I_{G3} = \dfrac{M_3 \cdot BC^2}{12} \\ \beta = \varphi_3 + \gamma + \dfrac{\pi}{2} \\ Q_x = Q \cdot \cos\beta \\ Q_y = Q \cdot \sin\beta \end{cases} \tag{5}$$

Forces acting on element 1 are presented in figure 6:

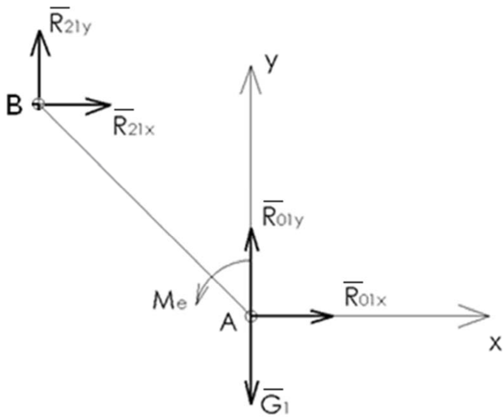

Fig. 6. Forces acting on crank [8]

Equilibrium equations are:

$$\begin{cases} \sum F_x = 0 & R_{21x} + R_{01x} = 0 \\ \sum F_y = 0 & R_{21y} + R_{01y} - M_1 \cdot g = 0 \\ \sum M_A = 0 & -R_{21x}(y_B - y_A) - R_{21y}(x_A - x_B) + M_e = 0 \end{cases} \tag{6}$$

Considering that:

$$\left|\overline{R_{12x}}\right| = \left|\overline{R_{21x}}\right|; \overline{R_{12x}} = -\overline{R_{21x}}$$
$$\left|\overline{R_{12y}}\right| = \left|\overline{R_{21y}}\right|; \overline{R_{12y}} = -\overline{R_{21y}}$$

It results that:

$$\begin{cases} \sum F_x = 0 & -R_{12x} + R_{01x} = 0 \\ \sum F_y = 0 & -R_{12y} + R_{01y} = M_1 \cdot g \\ \sum M_A = 0 & R_{12x}(y_B - y_A) + R_{12y}(x_A - x_B) + M_e = 0 \end{cases} \tag{7}$$

Reactions in mechanism coupling and crank driving momentum are determined after solving the following equation system:

$$\begin{cases} R_{12x} - R_{23x} = -F_{2x} \\ R_{12y} - R_{23y} = -F_{2y} \\ R_{23x} + R_{03x} = -F_{3x} \\ R_{23y} + R_{03y} = -F_{3y} \\ -R_{12x}(y_b - y_c) - R_{12y}(x_c - x_b) = F_{2x}(y_{g2} - y_c) + F_{2y}(x_c - x_{g2}) - C_{M2} \\ R_{03x}(y_c - y_d) + R_{03y}(x_d - x_c) = -F_{3x}(y_c - y_{g3}) - F_{3y}(x_{g3} - x_c) - C_{M3} \\ -R_{12x} + R_{01x} = 0 \\ -R_{12y} + R_{01y} = M_1 \cdot g \\ R_{12x}(y_b - y_a) + R_{12y}(x_a - x_b) + M_e = 0 \end{cases} \tag{8}$$

Coefficient matrix of unknowns M and absolute terms TL is:

$$M = \begin{vmatrix} 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ y_c - y_b & x_b - x_c & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & y_c - y_d & x_d - x_c & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ y_b - y_a & x_a - x_b & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{vmatrix} \tag{9}$$

$$TL = \begin{vmatrix} -F_{2x} \\ -F_{2y} \\ -F_{3x} \\ -F_{3y} \\ F_{2x}(y_{g2} - y_c) + F_{2y}(x_c - x_{g2}) - C_{M2} \\ -F_{3x}(y_c - y_{g3}) - F_{3y}(x_{g3} - x_c) - C_{M3} \\ 0 \\ M_1 \cdot g \\ 0 \end{vmatrix} \tag{10}$$

The solution of the system is: $R = lsolve(M, TL)$ (11)

RESULTS AND DISCUSSION

Reactions in the pivots of separator driving mechanism have been determined using kinetostatic analysis program of eccentric separator driving quadrilateral mechanism.

The projections on the x-coordinate and y-coordinate of crank pivot (A) reaction (R_{01x} and R_{01y}) depending on its position (ϕ_1) are presented in figure 7. Graphic representations and establishment of regression functions have been calculated using EXCEL.

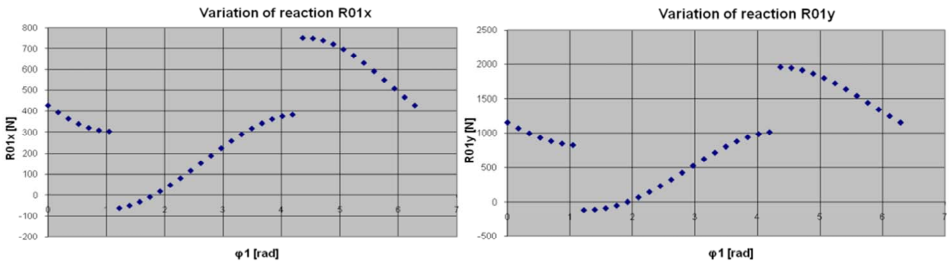

Fig. 7. Variation of reaction R_{01x} and R_{01y}

Reaction variation in the second fix pivot of mechanism (D) on x axis and y axis direction is presented in Fig. 8.

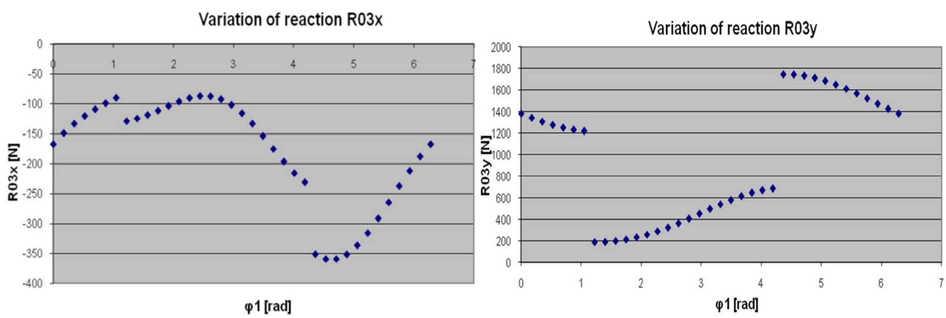

Fig. 8. Variation of reaction R_{03x} and R_{03y}

The connecting rod is tensile stressed if $\omega_3<0$ and compression stressed when $\omega_3>0$. Variation of reaction R_{12} on x and y axis direction, depending on crank rotating angle, is presented in figure 9.

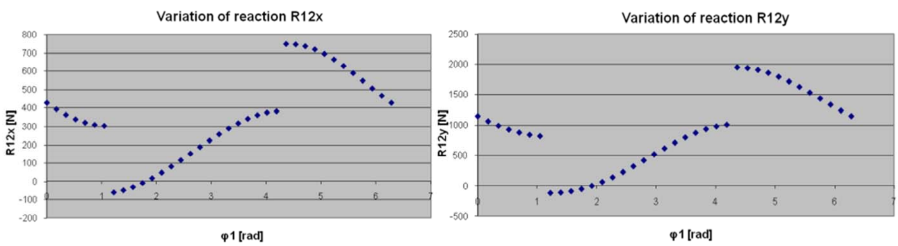

Fig. 9. Variation of reaction R_{12x} and R_{12y}

Variation of reaction R_{23x} and R_{23y} in connecting rod pivot C is presented in figure 10.

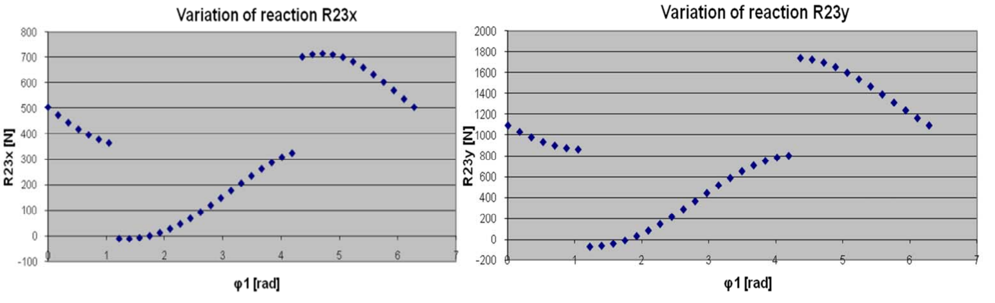

Fig. 10. Variation of reaction R_{23x} and R_{23y}

Connecting rod is tensile stressed if ω3 <0 and compression stressed if ω3> 0:

- The maximum tensile force appears at position 25, corresponding to the crank rotating angle ϕ1=4.36 rad. For this position, the tensile force in point B has the value R_{12}=2087.20 N and in the point C, R_{32} =-R_{23}=-1872.42 N;
- Maximum compressive force appears at position 24, corresponding to the crank rotating angle ϕ1=4.19 rad. For this position, compressive force in point B has the value R_{12}=1077.85 N and in the point C, R_{32}=-R_{23}=-864.65 N;
- Maximum stress force appears at stretching, at position 25;

Variation of driving momentum of quadrilateral mechanism crank is presented in figure 11. Given that the Miscanthus rhizomes harvesting machine is composed of two such mechanisms, arranged in opposite phases, the variation of the total driving momentum to the drive shaft of the machine is shown, also, in Figure 11.

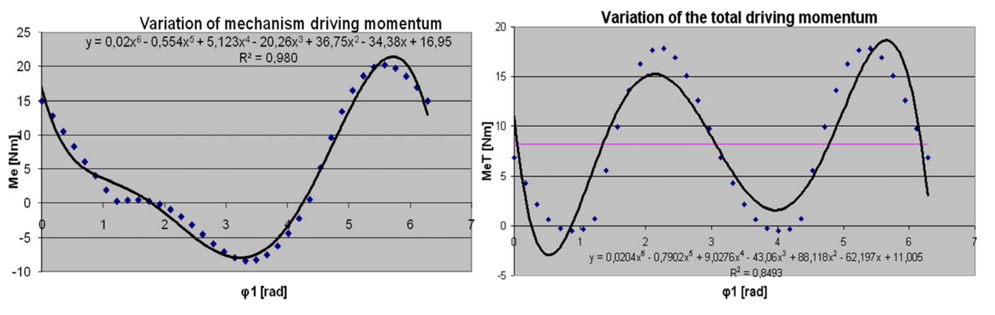

Fig. 11. Variation of mechanism driving momentum and the total driving momentum

The maximum total driving momentum appears at position 13 and 31, corresponding to the crank rotating angle ϕ1=2.27 rad and 5.41 rad respectively. Maximum total driving momentum for these positions is MeT=17.869 Nm.

Minimum total driving momentum appears at positions 4 and 22, corresponding to the crank rotating angle $\phi 1$=0.70 rad and 3.84 rad respectively. Minimum total driving momentum for these positions is MeT=-0.230 Nm.

CONCLUSIONS

The possibility of determining the reactions in mechanism pivots allows studying the behavior to stress of components in order to optimize their design. Maximum and minimum values of reactions in every pivot can be determined, in correlation with crank pozitions at specific time.

Taking into account the theoretical approximation of the forces acting on the separating grate rods, maximum and minimum values of mechanism driving momentum, linked to the crank position, are obtained. This information allows appropriate choosing of driving mechanism energetic sourse.

To calibrate the mathematical model the driving momentum can be experimentally determined and, after that, with a good approximation, the forces acting on the separating grate rods are established.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

COMPARISON OF ENERGY CONSUMPTION OF A HAMMER MILL DURING CHOPPING MISCANTHUS STALKS AND ENERGETIC WILLOW

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ABSTRACT

According to the E.U Strategy 2020 climate/energy targets should be met (including an increase to 30% of emissions reduction if the conditions are right). Thus alternative energy is an important source of energy that needs to be considered, studied and innovated at all times. In order to fulfil this target it is necessary to obtain alternative energy from agricultural biomass such as pellets and briquettes. For these to be used by the consumer biomass needs to be shredded/grinded. The energy consumption required for these operations is usually higher than the one necessary for the main operation. Agricultural biomass and biomass from energy crops remained on the field is mostly formed out of straws, cobs, chaff, etc. The paper presents experimental researches conducted for determining the energy consumption resulted when shredding Miscanthus stalks and energetic willow, using 4 shapes of hammers, mounted on the rotor of a mill (shredders), 4 screens and one rotor speed, in order to identify a correlation between these parameters.

Key words: Miscanthus, energetic willow, energy consumption, hammer mill, shredding

INTRODUCTION

Global warming is regarded today as a major concern for our planet, taking into consideration the negative effects like climate change. Greenhouse gases are believed to be the main problem when it comes to an increase in Earth temperature. CO_2 produced by burning fossil fuels is the most influential factor in global warming. Seeking and implementing new sources of energy besides fossil fuels is the only way to decrease the effects of global warming, and protect the climate and the environment.

Biomass has been regarded for centuries as a valid replacement for fossil fuels when it comes to heating equipment. We now see a large development of heating equipment's that use biomass as fuel that are increasingly effective. Pellets seem to be the best feeding material for this equipment's to work properly and be effective. Now the major issue is how to cut prices for pellet production, the biggest costs being in biomass grinding. There is a large number of biomass grinding equipment, but it seems that hammer mills are the best option when we take into consideration purchase costs, maintenance costs, and energy consumption [9].

For hammer mills, hitting the material by hammers articulated on a rotor is what the grinding process consists of. But it is very important when designing such equipment, that the percussions applied on the hammer are not transmitted to the articulation. The percussion given by collision with the particles of material is applied in the center of percussion, without this fine tuning connection percussions appear and produce supplementary perturbations. These will have negative effects on both energy saving and grinded material [3]. Material grinding is widely considered the most important part in a large scale lignocellulosic fuel industry, the efficiency of the later processes involved in pellet production is dependent on the quality of the grinded material [6]

In a study by Yancey et al (2014), grinding energy and particle size were put in comparison at different moisture content. Grinding energy for corn stover, switchgrass and wheat straw were compared at moisture contents of 10–25% in 5% increments. Grinding energy for corn stover and switchgrass showed a steep increase in grinding energy as Key terms Moisture content in straw had less effect on grinding energy, although the same pattern was observed. Operating speed, moisture content and initial particle size appear to be crucial in minimizing effective specific energy requirements for biomass size reduction [7]. It seems that grinding can consume as much as one-third of the total energy required to convert biomass into fuel, its logical to look for improvements in these strategies to cut costs to a minimum.

Biomass size reduction process changes the particle size and shape, increases bulk density, improves flow properties, increases porosity, and generates new surface area [2].

Hammer mills have achieved merit in the field of biomass grinding because of their ability to finely grind a greater variety of materials than any other machine [5]. Himmel et al. (1985) [4] observed that total specific energy for size reduction of wheat straw using 1.6 mm hammer mill screen was twice that for a 3.2 mm screen. They used an indirect method of measuring electric power with a wattmeter and corrected with power factors, though motor efficiency was unaccounted. Austin and Klimpel (1964) [1] noted that strain energy stored in the material before breaking was converted to energy, other than new surface development energy, such as propagated stress wave energy, kinetic energy of fragments, and plastic deformation energy. Fraction of total energy converted to surface energy will be extremely variable, depending on the operating conditions of mill.

Venkata et al. (2009) used a hammer mill to test its performances on grinding wheat straw, switchgrass and corn stover, on different humidity contents. Their results showed that an increase in speed from 1500 to 3500rpm lead to an increase in energy consumption for all types of material used for experimentation by 37, 30 respectively 45%. The hammer mill produced better quality grinding for wheat straw than for switchgrass or corn stover. S. Rosin–Rammler equations fitted the size distribution data with high $R^2>0.995$. Uniformity coefficient was <4.0 for wheat straw, which indicated uniform mix of particles, and it was about 4.0 for switchgrass and corn stover, which indicated a moderate assortment of particle size [8].

The main objective of this paper was to determine the specific energy consumption of a hammer mill when shredding Miscanthus stalks and considering different sieves orifices and types of hammers. Thus, in this paper an experiment regarding energy consumption for a revolution of 50 Hz was a part of the general objective, and also the energy consumption variation in correlation to the sieves orifices dimensions and energy consumption variation in correlation to testing time necessary to shred Miscanthus and energetic Willow.

MATERIAL AND METHODS

Both experimental researches in order to determine energy consumption for grinding Miscanthus stems and energetic willow were realized on a hammer mill - TCU (fig.1). This equipment was equipped with an inclined plan (material feeding chamfer), collecting the hash in bags, through a two way evacuation system. Also, the hash was directed with the help of a shutter. The grinding process was realized through hitting and shearing between hammers mounted on the hammer disk, and counterknives.

Figure 1 - Vegetal waste mill (hammer mill) - TCU

It is necessary to mention that the main characteristics of the milling equipment are: electric motor power: 22 kW; electric motor speed: 2.940 rot·min^{-1}; milling capacity: 900 m^3/h, interchangeable grinder sieve with different orifice sizes.

For experimentation ø7; ø10 şi ø25 mm orifices were used, on four types of knives (A, B, C and D) and a speed which was varied with the help of a frequency converter from 50 Hz (2.940 rot·min^{-1}); 47.5 Hz; 45 Hz; 42.5 Hz and 40 Hz. The energy consumption was determined using a frequency convertor and volt-amperemeter clipper.

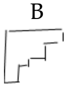
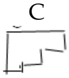
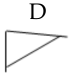
The samples used were energetic plants such as Miscanthus and energetic willow. The conditions were similar for both testing times. The obtained results were processed with the help of Excel program in order to realize the variation graphs of energy consumption. Based on the values in table 1 the energy consumption variation in correlation to the sieves orifices dimensions and energy consumption variation in correlation to testing time necessary to grind the Miscanthus and energetic willow samples were drawn. All the results presented in table 1 are presented for a revolution of 50 Hz.

RESULTS AND DISCUSSION

A series of tests regarding shredding process have their origin since 1964 when Balk used a wattmeter during his researches in order to determine the specific energy consumption correlated with the feed flow of the equipment and the humidity content of the grinded material [1].

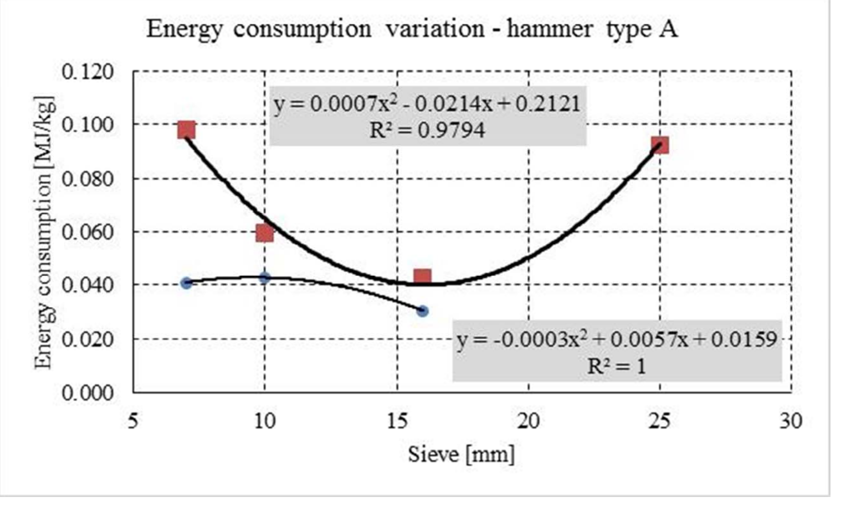
Results obtained from the experimental research are being presented in table 1. Using the data obtained and presented in table 1, the curves for specific energy consumption caused by the sieves orifices dimensions were drawn in figure 2. As it could be seen, the value grouping for the four sets of experiments proves the influence of the sieve dimensions on the plant grinding energy. Analyzing the first energy variation curve it can be observed that the energy consumption decreases for the sieves orifices of ϕ16 and ϕ10 and then increases for the sieve of ϕ7 for Miscanthus samples while for energetic willow in could be seen that the specific energy consumption was lower than for Miscanthus.

Table 1. Experimental results obtained during experimental testing

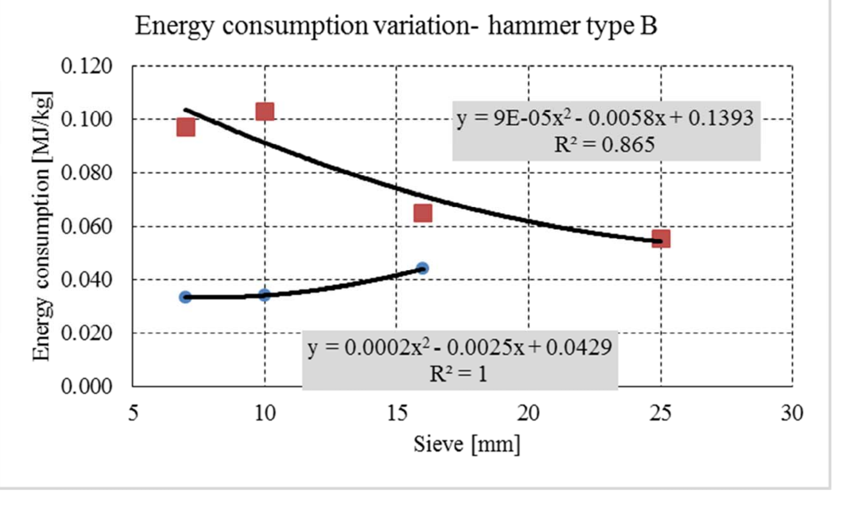
Hammer type	Sieve Mm	Miscanthus		Energetic willow	
		Time s	Energy consumption MJ/kg	Time s	Energy consumption MJ/kg
A 	25	34.65	0.092		
	16	22.24	0.043	13	0.030
	10	23	0.060	15	0.043
	7	36	0.098	12	0.041
B 	25	17	0.056		
	16	20	0.065	14	0.044
	10	31	0.103	9	0.034
	7	41	0.097	10	0.033
C 	25	20	0.052		
	16	29	0.111	10	0.033
	10	27	0.095	14	0.048
	7	42	0.114	15	0.058
D 	25	19	0.052		
	16	16	0.045	13	0.059
	10	26	0.072	9	0.037
	7	37	0.115	9	0.034

For energetic willow the energy consumption was higher for sieves orifices of φ10. Also the best correlation coefficient for type A hammer used during tests was obtained using regression analysis, for both samples the a polynomial function was applied and the correlation coefficient was each time higher than R^2=0.9794. These values shown the correlation between the two data analyzed.

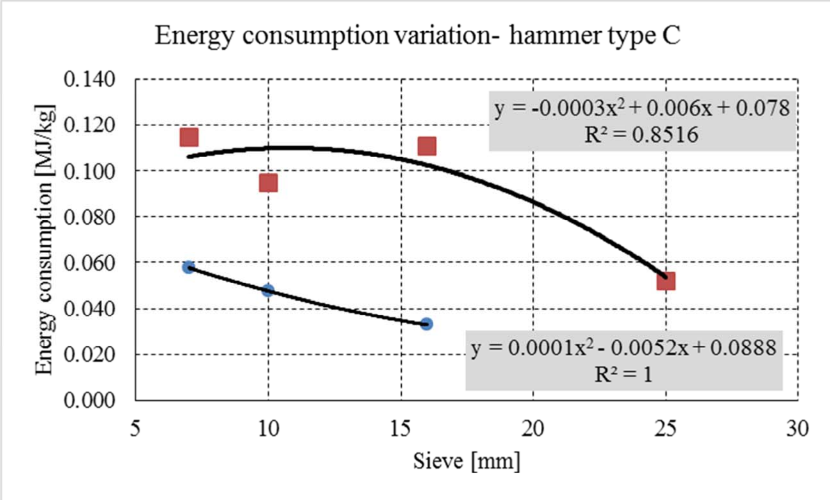
For hammer type B (figure 2b) the highest value of the energy consumption was given for sieve ϕ10, E = 102833.89 J/kg for Miscanthus while for energetic willow resulted for sieve ϕ16, E = 44031.76 J/kg. Using for both samples the polynomial regression analysis the correlation coefficient was higher than R^2=0.8516. As it can be seen the specific energy consumption for energetic willow was below the lower point of energy consumption for Miscanthus samples. The same statement as for hammer type B can be said for the specific energy consumption for both types of hammers C and D. Each time the energy consumption was lower for energetic willow than for Miscanthus. The correlation coefficient showed a connection between sieves and energy consumption for both cases. The regression analysis applied was a polynomial function.



a.



b.



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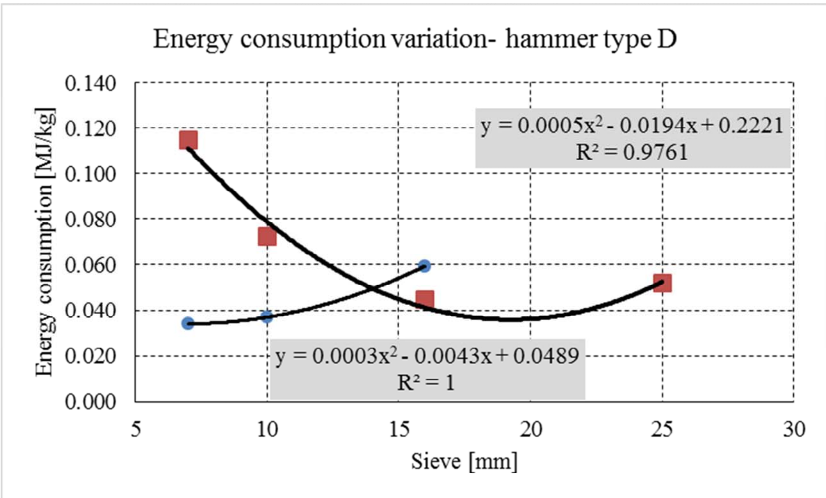
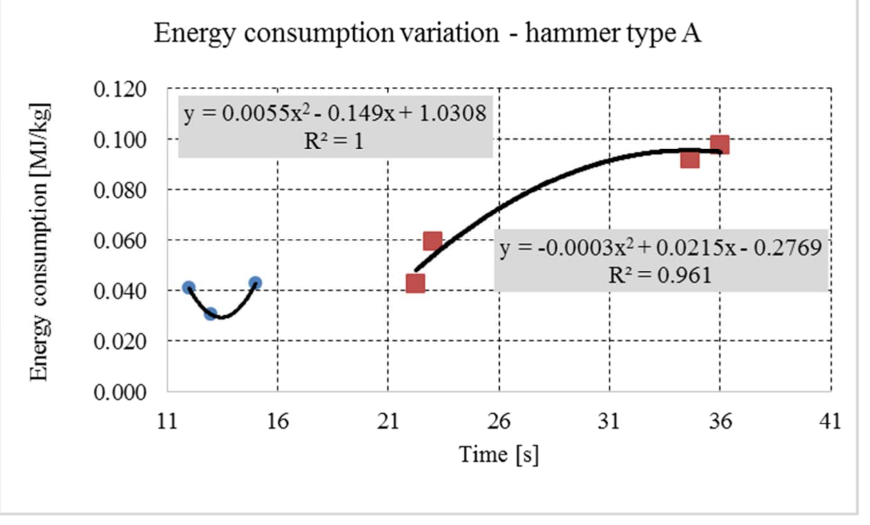


d. .

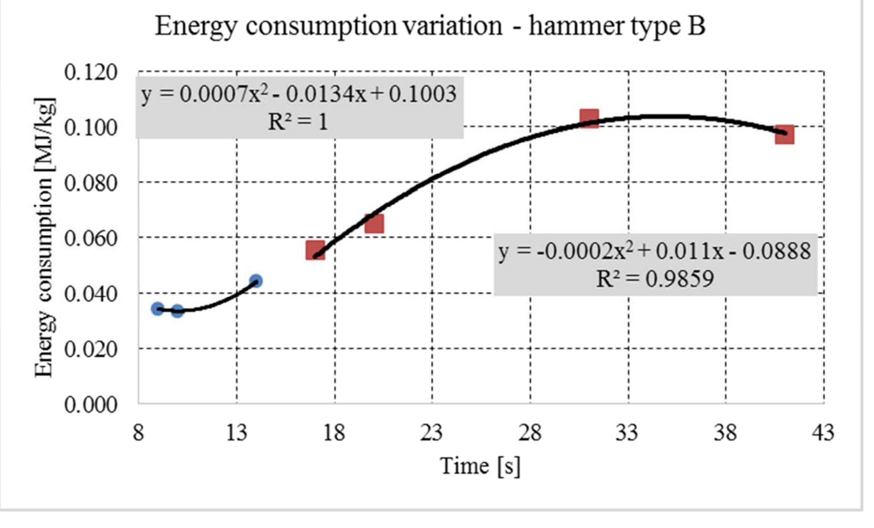
Figure 2 - Energy consumption variation depending on sieves orifices
a. hammer type A; b. hammer type B; c. Hammer type C; d. hammer type D)
■ Miscanthus testing results; ● energetic willow testing results.

For hammer type C the highest energy consumption was registered for sieves orifices of φ7 for both Miscanthus and energetic willow while for hammer type D the highest energy consumption was registered for sieves orifices of φ7 for Miscanthus and sieves orifices of φ16 for energetic willow.

The variation curves drown in figure 3 it was considered the energy consumption in correlation to the testing time for each sample for both plants. A polynomial regression analysis was applied for all four types of hammers and samples. The correlation coefficient obtained for all four samples was higher than 0.961 for Miscanthus and higher than 0.9891 for energetic willow. The values of the correlation coefficient express the accurate estimation of the energy consumption in correlation to the time necessary for testing materials. As it can be seen in all the figures resulted the time used for grinding willow was each time lower that the time necessary for Miscanthus grinding. While for Miscanthus the grinding time was between 13 to 43 s for energetic willow was between from 8 to 15 s



a.



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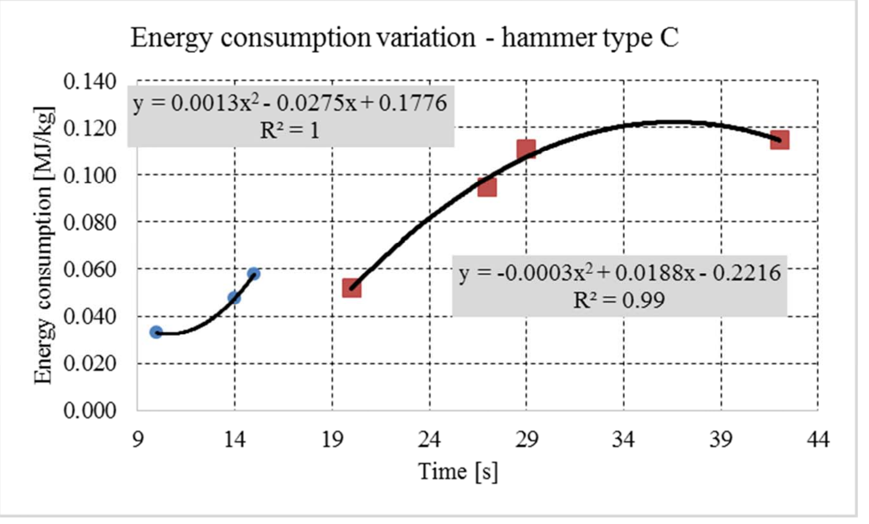

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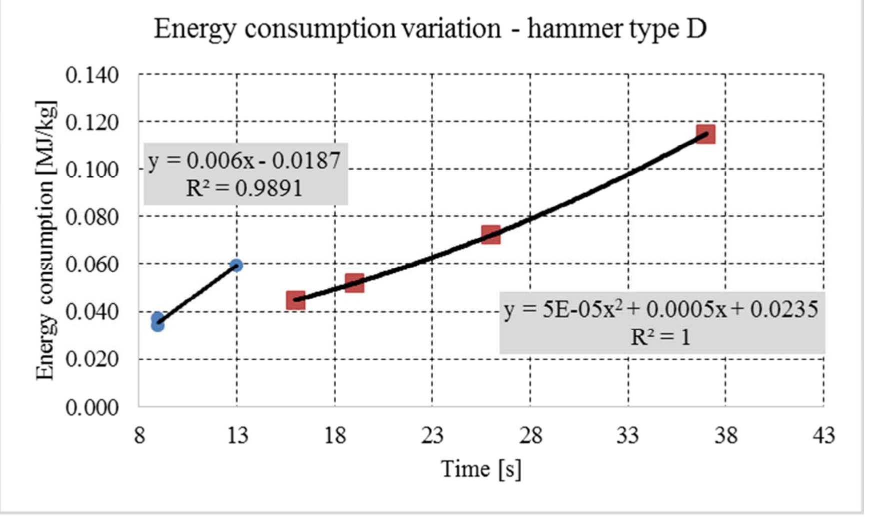

d.

Figure 3. Energy consumption variation depending on testing time (a. hammer type A, b. hammer type B, c. Hammer type C, d. hammer type D)

CONCLUSIONS

In order to reveal a small part of this process in this paper using a TCU hammer mill, the influence of the sieves orifices dimensions on the energy consumption of the equipment could be highlighted. Also, the energy consumption variation curves in correlation to testing time were drawn. As it can be seen from figures drawn the results obtained for energetic willow were significantly lower than those for Miscanthus. For both samples for φ7 the energy consumption was higher. Another aspect that can be mentioned is that the correlation coefficient was for both aspects analyzed higher than $R^2 \geq 0.851$ for energy consumption variation in correlation to sieves orifices dimensions and higher than $R^2 \geq 0.961$ for energy consumption variation in correlation to testing time for both Miscanthus and energetic willow. In order to analyze data at a higher correlation value it is necessary in later data analyses to apply Rosin–Rammler equations fitted the size distribution and literature energy equations.

Our experimental results can be used as a starting point for new experimental research regarding the needed power for biomass homogenization in anaerobic fermenter, briquetting, pelleting biomass.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.347/.348
Prethodno priopćenje
Preliminary communication

IMPACT OF TECHNICAL SPRAYING FACTORS ON LEAF AREA COVERAGE IN A VINEYARD WITH HARDI ARROW RADIAL FAN MISTBLOWER

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ABSTRACT

Research is conducted in a vineyard with Hardi Arrow radial fan mist blower. The influence of major technical spraying factors (type of nozzle, working speed and spray volume) were observed on coverage of the treated area. The working speed of mist blower was set at 6 and 8 kmh^{-1}, and spray volume on 250, 300 and 350 lha^{-1}. In research, Lechler blue (TR 8003C), yellow (TR 8002C) and green (TR 80015C) nozzles are used. The research was set as three - factorial field experiment with 18 treatments in 4 repetitions. Sixty water sensitive papers (WSP) were used for the treatment, which was processed with digital image analysis (DIA) and ImageJ software. The major technical spraying factors have a high significant statistical impact (**) on the main property of the research. By decreasing the ISO number of nozzles and by increasing the working speed and spray volume, we found the increase of leaf area coverage.

Key words: radial mistblower, working speed, nozzle, spraying norm, area coverage, water sensitive paper

INTRODUCTION

Agriculture is an inseparable part of the overall global ecological system, where humans, animals, plants, climate factors and agricultural engineering are in interaction. Therefore, aim is to improve, enhance or develop new technical solutions for agricultural machinery to introduce measures and procedures that would result in minimal interventions in the ecosystem [7]. With the technical correctness of the working machine in plant protection, it is particularly important to adjust the technical parameters of spraying – working speed of mist blower, working pressure, air flow and velocity, spraying norm, type of nozzle, etc. Only synergy of properly configured technical parameters and technical accuracy of the machine provide adequate results. The most commonly used method, to test the settings of technical parameters in field conditions on the area coverage, is with water sensitive papers and with digital (computerized) image analysis [2,4]. One of the main technical factors is droplet diameter, which is decreasing by increasing the working pressure [11]. Also, by increasing the working pressure, the number of droplets in spray is increasing [10]. This implies that by reducing the droplet diameter and by increasing the working pressure, coverage of treated area is increasing [2]. Coverage of treated area is the main thing of whole plant protection, and the main task of technical spraying factors is to increase this property. This research is a part of the modern world trends where the application of agricultural engineering in plant protection aspires to achieve the highest possible coverage of the treated area with the least losses of liquid in the form of drift [5].Also, it is particularly important to further investigate the technical spraying factors of the plant protection, because in Croatia the new law is in the force (NN 14/14), linked to sustainable use of pesticides and mandatory inspection of all technical systems in plant protection (European Directive: 2009/128/EC and 2006/42/EC)[1]. The objective of this research is to determine the influence of major technical spraying factors (type of nozzle, working speed and spray norm) on average area coverage. This will be examined through the exploitation of radial fan mist blower with different settings of the major technical factors of spraying. Some of the research in a vineyard with axial fan mist blower (*Hardi Zaturn*) [9] show that the best area coverage was 51.45 %, achieved with green nozzle*(TR80015C),* working speed of 8 kmh^{-1}, spray volume of 350 lha^{-1}, and working pressure of 19.53 bar.

MATERIAL AND METHODS

In this study mounted vineyard radial fan mist blower is used with the axis symmetric air flow (Fig.1) mist blower is tested according *EN 13790* standard [1] through European directive 2009/128/EC and 2006/42/EC.

Figure 1. Hardi Arrow mistblower

The study used three types of nozzles as a technical spraying factor A in statistical analysis: *Lechler TR 80015C*, *TR 8002C* and *TR 8003C*. All selected nozzles are marked according ISO 10625 standard, where TR denotes the type of spray (hollow cone); 80 is spray angle; 015, 02 and 03 are nozzle flows in U.S. gallons at 2.75 bar and C is the material of which they are made (polyoxymethylene with a ceramic insert). Adjustment of air flow and nozzles are shown in Table 1.

Table 1. Air flows and velocity with nozzle adjustment

Statistical parameters	Air velocity, ms^{-1}		Nozzle orientation	
	Left side	Right side	Position	Angle, °
x	14.95	16.25	1.	Off
σ	0.57	0.35	2.	+10
C.V. (%)	3.81	2.18	3.	+10
	Air flow, m^3h^{-1}		4.	0
	6 kmh^{-1}	8 kmh^{-1}	5.	-5
Q_r	6 248.33		-	-
Q_t (f=2)	7 176.00	9 568.00	-	-
Q_s, m^3km^{-1}	38.09	50.79	-	-

f – foliation factor

Second technical spraying factor of this research is a working speed of mist blowers (factor B) which is set to the two speeds - 6 and 8 kmh^{-1}. Working speed of the mist blower is followed by tractor board computer and is checked by the stopwatch at the exact distance in the vineyard. The third technical spraying factor in the study is spraying norm - factor C. The study used three spraying norms: 250, 300 and 350 lha^{-1}. After determination of vineyard volume and spraying norm, the next step of mist blower calibration is to calculate required nozzle flow and pressure [3]. In Table 2 overall calibration of mist blower is shown.

Table 2 Calibration parameters for *Hardi Arrow* radial fan mist blower

Nozzle	N_r, lha^{-1}	v_r, kmh^{-1}	Q_m, $lmin^{-1}$	p, bar	Nozzle	N_r, lha^{-1}	v_r, kmh^{-1}	Q_m, $lmin^{-1}$	p, bar
TR 8003C	250	6	0.87	1.51	TR 8002C	250	8	1.16	5.78
TR 8003C	300	6	1.05	2.18	TR 8002C	300	8	1.40	8.33
TR 8003C	350	6	1.22	2.97	TR 8002C	350	8	1.63	11.34
TR 8003C	250	8	1.16	2.69	TR 80015C	250	6	0.87	5.60
TR 8003C	300	8	1.40	3.88	TR 80015C	300	6	1.05	8.07
TR 8003C	350	8	1.63	5.29	TR 80015C	350	6	1.22	10.99
TR 8002C	250	6	0.87	3.25	TR 80015C	250	8	1.16	9.96
TR 8002C	300	6	1.05	4.68	TR 80015C	300	8	1.40	14.35
TR 8002C	350	6	1.22	6.38	TR 80015C	350	8	1.63	19.53

Velocity of an air current is measured with a mobile meteorological station, *Kestrel, Weather and Environmental meters – model 4500* (wireless data transmission). Three air flows are calculated: real air flow – Q_r, theoretical air flow –Q_t [3], and specific air flow – Q_s [6], Table 1. For determination of spray pattern WSP are used (water sensitive papers - yellow rectangular strips). On surface they have a thin layer of bromophenol, which in contact with water turns blue. Therefore, the droplets that fall on a WSP are used for determination of average area coverage. The study used WSP from the Swiss manufacturer Syngenta. Papers are placed on 3 levels of canopy: peak, the middle and lower levels. On each level 5 papers are set on both sides of the leaves, with the use of 4 vines in repetition. So, for each vine we used 15, and for each treatment 60 WSP 36 treatments in total = 2160 WSP. WSP are also used for the evaluation of drift intensity. Drift is measured in 2 untreated side rows in 4 repetitions for each treatment. In each repetition we used 6 WSP (3 verticals and 3 horizontally). WSP with droplets is shown in Fig. 2. Right WSP achieved significantly greater area coverage then the left WSP.

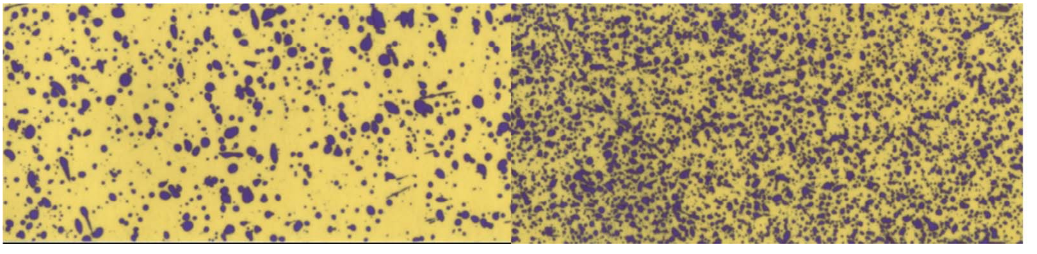

Figure 2 Water sensitive paper

After field research, the WSP samples were collected and each one was analyzed by using the DIA - digital image analysis and by using *ImageJ*software [8]. *STATISTICA* (*StatSoft, Inc., 2011 – data analysis software system, version 10.0*) was used for statistical analysis of data.

RESULTS

In Table 3. are shown average weather condition during the research, and average *LAI* and *LAD* for vines in research, where is: E_e is solar radiation; T_z is air temperature in the vineyard; ω_z is relative air humidity in the vineyard; v_v is wind speed; ↑ is wind direction; *LAI* is leaf area index and *LAD* is leaf area density.

Table 3 Weather conditions and leaf factors

Statistical parameters	Weather conditions during the experiment					Leaf area	
	E_e, Wm^{-2}	T_z, °C	ω_z, %	v_v, ms^{-1}	↑, °	LAI, m^2m^{-2}	LAD, $m^{-2}m^{-3}$
$\overline{X}$	232.63	16.10	61.39	1.15	186.60	1.65	15.45
σ	104.85	1.65	3.79	0.21	10.07	0.17	2.16
C.V., %	45.07	10.24	6.17	18.35	5.40	10.49	13.97

In Table 4 are shown the main properties and results of the research with radial fan mist blower – *Hardi Arrow*, where is: A_p - average area coverage; A - type of nozzle (A$_1$ – *TR 8003*; A$_2$ – *TR 8002*; A$_3$ – *TR 80015*), B – working speed (B$_1$ – 6 kmh^{-1}; B$_2$ – 8 kmh^{-1}), C – spraying norm (C$_1$ – 250 lha^{-1}; C$_2$ – 300 lha^{-1}; C$_3$ – 350 lha^{-1}).

Table 4 Analysis of variance for coverage of WSP

ANOVA		$\overline{A}_p$, %			
		X	$LSD^*_{0,05}$	$LSD_{0,01}$	F - test
A	A_1	46.18	5.42	7.36	21.78**
	A_2	54.64			
	A_3	58.49			
B	B_1	*51.50*	2.48	3.26	4.21*
	B_2	*54.70*			
C	C_1	*46.15*	3.73	5.06	23.79**
	C_2	*53.49*			
	C_3	*59.22*			
AB			4.78	6.70	0.19 n.s.
AC			7.23	10.52	3.02*
BC			5.58	7.82	9.68**
ABC			12.31	20.43	3.39*

Table 4 show that the main technical spraying factors (nozzle type, working speed and spraying norm) have a statistically significant impact on the main property of the research - average area coverage. The highest area coverage is achieved with green nozzle, working speed of 8 kmh^{-1} and spraying norm of 350 lha^{-1}. With decreasing of ISO nozzle number (from TR 8003C to TR 80015C) and with increasing of working speed (from 6 to 8 kmh^{-1}) and spraying norm (from 250 to 350 lha^{-1}), the average area coverage is statistically increasing. With the same nozzle and spraying norm but with higher working speed, higher working pressure was required for spraying default norm (ex. with TR 80015C nozzle, spraying norm of 250 l/ha and with working speed of 6 km/h required working pressure was 5.60 bar; with the same nozzle and spraying norm but with working speed of 8 km/h required working pressure was 9.96 bar, Tab. 2), so with pressure increasement, the average area coverage is also increasing. In comparison this results with the results form research conducted with axial fan mist blower (*Hardi Zaturn*) in the same vineyard [9], it is noted that the main properties have similar trend of movement, but radial fan mist blower (*Hardi Arrow*) achieves greater area coverage from 11.65 % (*TR8003C*, working speed of 6 kmh^{-1}, spray volume of 250 lha^{-1}) to 16.42 % (*TR80015C*, working speed of 8 kmh^{-1}, spray volume of 350 lha^{-1}).

CONCLUSION

According to the measurements of weather conditions during the study, the application is carried out according to the rules of plant protection in almost ideal conditions (wind speed less than 3 m/s, air temperature less than 22 °C and air humidity higher than 50 %). Used spraying norms are suitable for the form and volume of the vineyard, and they follow global trends of spray norm reduction. Also, the working speeds of the orchard mist blower are located within the optimal agrotechnical operational speeds. Used nozzles and working pressures are suitable to the row width and they are ensuring required spraying norms. The major technical spraying factors have a high significant impact on the main properties of the research. By decreasing the ISO number of nozzles and by increasing the working speed and spray volume, we found increasement of area coverage. During the settings of the technical spraying parameters, the main object must be the largest area coverage with the minimal liquid drift. This is possible only with technical correctness of the orchard mist blower and with spraying in good weather conditions. The results and scientifically based conclusions can serve all agricultural producers, because so far in Croatia there is no scientifically based research related to this issue. Also, it is particularly important to further investigate the technical spraying factors of the plant protection, due to the bigger reduction of production costs with the same ecological effect.

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UTJECAJ TEHNIČKIH ČIMBENIKA RASPRŠIVANJA NA POKRIVENOST LISNE POVRŠINE U VINOGRADU SA HARDI ARROW RADIJALNIM RASPRŠIVAČEM

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SAŽETAK

Istraživanja su obavljena u vinogradu sa Hardi *Arrow* radijalnim raspršivačem. Istraživan je utjecaj glavnih tehničkih čimbenika raspršivanja (tip mlaznice, brzina rada i norma raspršivanja) na pokrivenost tretirane površine. Brzina rada raspršivača podešava se na 6 i 8 kmh^{-1}, a norma raspršivanja na 250, 325 i 400 lha^{-1}. Koriste se plave (TR 8003C), žute (TR 8002C) i zelene (TR 80015C) *Lechler* mlaznice. Istraživanje se postavlja kao trofaktorijalni poljski pokus sa 18 tretmana u 4 ponavljanja, za svaki tip raspršivača. Po tretmanu se na stablo postavlja 60 vodoosjetljivih papirića koji se obrađuju pomoću računalne analize slike i računalnog programa *ImageJ*. Glavni tehnički čimbenici raspršivanja ostvaruju statistički vrlo značajan utjecaj na glavna svojstva istraživanja. Smanjivanjem ISO broja mlaznice, povećanjem brzine rada raspršivača te povećanjem norme raspršivanja povećava se pokrivenost tretirane površine.

Ključne riječi: radijalni raspršivač, radna brzina, norma raspršivanja, pokrivenost površine, vodoosjetljivi papirić

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.34(497.4)
Stručni rad
Expert paper

ANALIZA NAPRAV ZA VARSTVO RASTLIN V SLOVENIJI

TOMAŽ POJE

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IZVLEČEK

Iz podatkovne baze Uprave Republike Slovenije za varno hrano, veterinarstvo in varstvo rastlin je ugotovljeno, da je bilo med leti 2010 in 2016 pregledanih 21.963 naprav za nanašanje FFS. Od tega je bilo 68,4 % škropilnic in 31,4 % pršilnikov. Škropilnice so starejše kot pa pršilniki. Največ škropilnic je bilo izdelanih v obdobju med 1986 in 1990. V Sloveniji prevladujejo naprave domačih proizvajalcev, izstopa zlasti Agromehanika s 65,4 % deležem med škropilnicami in pršilniki. Po Popisu kmetijstva 2010 imamo v Sloveniji 37.204 naprav za nanašanje FFS. 20.999 je traktorskih škropilnic, 10.738 nahrbtnih motornih škropilnic in pršilnikov ter 5.467 traktorskih pršilnikov. Največ teh naprav je na kmetijskih gospodarstvih, ki imajo od 5 do 20 ha zemlje v uporabi in v občinah Brežice, Krško in Ormož. Zakonsko sicer ustrezne naprave so v velikem deležu tehnično zastarele.

Ključne besede: škropilnice, pršilniki, število, starost, proizvajalec

UVOD

Sodobnega kmetijstva si danes ne predstavljamo brez uporabe fitofarmacevtskih sredstev (FFS). V Sloveniji se je sicer poraba FFS od leta 2008 do 2013 zmanjševala. V letu 2014 pa se je glede na leto 2013 povečala za 10,1 %. Tudi v letu 2015 se je prodaja FFS povečala za 3,7 % glede na leto 2014. V letu 2015 je bilo v Sloveniji prodanih 1.047 ton FFS oziroma njihovih aktivnih snovi. Največ je bilo prodanih fungicidov, 759 ton ali 72,5 %. Sledijo pa jim herbicidi z 224 tonami (21,4 %) (Maver, 2016).

Aplikacija FFS se izvaja z napravami za nanašanje fitofarmacevtskih sredstev. Te naprave pa morajo ustrezati številnim zakonskim zahtevam. Zakonske zahteve so tako za nove naprave, ki se dajejo v promet, kot tudi za rabljene naprave.

Za nove naprave za nanašanje FFS je sedaj v Evropski skupnosti v veljavi direktiva 2009/127/ES, ki dopolnjuje osnovno direktivo 2006/42/ES o strojih. Direktiva 2009/127/ES določa bistvene zahteve varstva okolja, ki jih morajo upoštevati proizvajalci ob zasnovi in izdelavi novih strojev za nanašanje pesticidov (Direktiva 2009/127/ES…, 2009). Te zahteve morajo biti tudi v skladu z zahtevami za vzdrževanje in pregledovanje strojev za nanašanje pesticidov v okviru Direktive 2009/128/ES »trajnostna raba pesticidov«. Slovenija je leta 2010 te zahteve prenesla v Pravilnik o spremembah in dopolnitvah Pravilnika o varnosti strojev v katerem v prilogi 1 določa bistvene zdravstvene in varnostne zahteve, povezane z načrtovanjem in izdelavo strojev - tudi strojev za nanašanje pesticidov (Pravilnik o spremembah in dopolnitvah…, 2010). Od leta 2012 naprej proizvajalec škropilnice ali pršilnika s CE oznako in izjavo o skladnosti zagotavlja, da njegov proizvod ustreza zahtevam slovenske (in evropske) zakonodaje.

Do novembra 2012 pa smo v Sloveniji imeli glede na Pravilnik o pridobitvi certifikata o skladnosti za naprave za nanašanje fitofarmacevtskih sredstev v veljavi sistem certificiranja novih naprav, preden so šle v prodajo. Ta pravilnik je določal tehnične zahteve, ki so jih morale izpolnjevati naprave za nanašanje fitofarmacevtskih sredstev, da so pridobile certifikat, ki je omogočal dajanje v promet (prodajo) v Sloveniji (Pravilnik o pridobitvi…, 2001).

V Sloveniji se za nanašanje FFS lahko uporabljajo le naprave, ki imajo potrdilo o rednem pregledu in znak o rednem pregledu. To je v skladu s Pravilnikom o zahtevah glede pravilnega delovanja naprav za nanašanje fitofarmacevtskih sredstev in o pogojih ter načinu izvajanja njihovih pregledov iz leta 2013. Lastnik nove naprave mora pred prvo uporabo naprave oziroma najpozneje v šestih mesecih od nakupa pri pregledniku podati predlog za pridobitev znaka o rednem pregledu ter potrdila o pravilnem delovanju naprave. Za nove naprave velja potrdilo 5 let, vse ostale pa morajo biti pregledane vsaka tri leta (Pravilnik o zahtevah…, 2013). Začetki testiranja naprav za nanašanje FFS v uporabi pa v Sloveniji segajo v leto 1991. Pregledi naprav se v Sloveniji izvajajo v skladu z Zakonom o fitofarmacevtskih sredstvih, s katerim se izvajajo določbe Direktive 2009/128/ES o trajnostni uporabi pesticidov (člen 8 in Priloga 2).

Nove in rabljene naprave za nanašanje FFS morajo zagotavljati kakovostno aplikacijo FFS in varno delo. Prav tako se s fitofarmacevtskimi sredstvi ne sme preobremenjevati okolja in pridelkov. Za kakovostno aplikacijo FFS pa ni dovolj samo tehnično neoporečna naprava, ampak je aplikacija FFS odvisna še od drugih faktorjev kot je znanje uporabnika FFS, vremenske razmere, pravilne rabe naprav itd. Namen tega prispevka pa je analiza slovenskih kmetijskih gospodarstev z napravami za nanašanje FFS.

METODIKA

Za analizo opremljenosti slovenskih kmetij z napravami za nanašanje FFS smo uporabili dve podatkovni bazi. Uprava Republike Slovenije za varno hrano, veterinarstvo in varstvo rastlin ima podatkovno bazo o pregledanih napravah v skladu z zahtevami Pravilnika o zahtevah glede pravilnega delovanja naprav za nanašanje fitofarmacevtskih sredstev in o pogojih ter načinu izvajanja njihovih pregledov. Iz te podatkovne baze smo uporabili podatke o testiranih napravah med leti 2010 in 2016 (za sedemletno obdobje). Vsaka naprava se v naši analizi pojavi le enkrat.

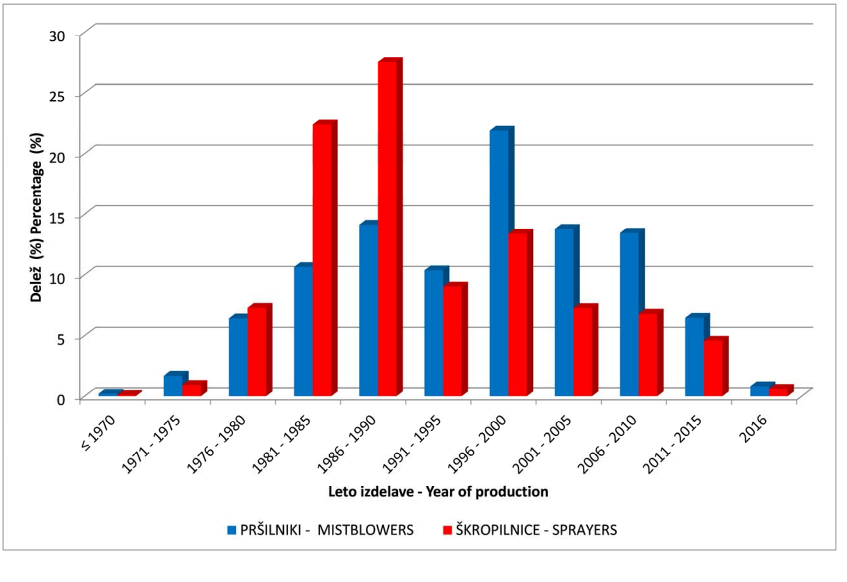
Drugi vir za našo analizo pa je bila podatkovna baza Statističnega urada Republike Slovenije. Ta naprave za nanašanje FFS zajame v Popisih kmetijstva med kmetijsko mehanizacijo. V letu 2010 so pri napravah za nanašanje FFS ugotavljali škropilnice in pršilnike (traktorski priključki) ter nahrbtne motorne škropilnice in pršilnike. Ti slednji so prvič zajeti v Popisu. Podatki iz obeh baz so statistično analizirani z opisnimi statistikami.

REZULTATI IN DISKUSIJA

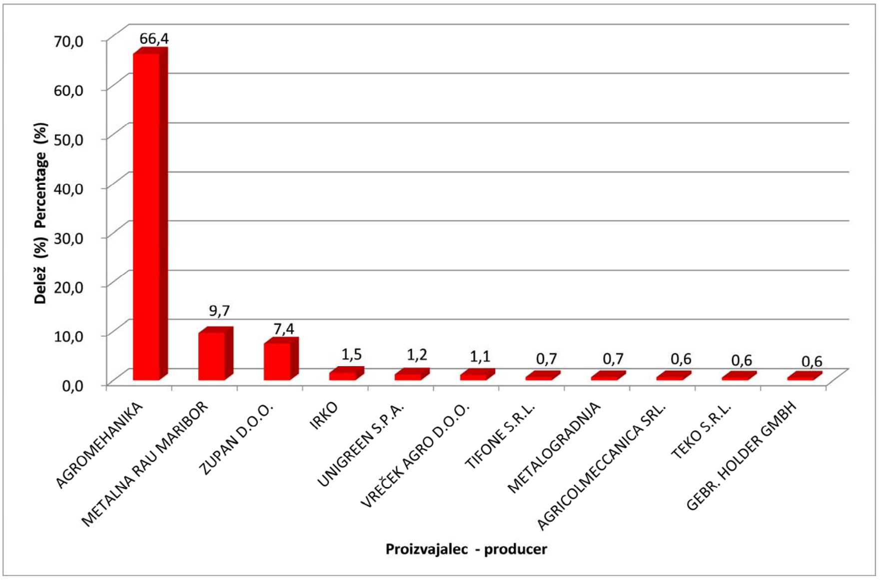
Uprava RS za varno hrano, veterinarstvo in varstvo rastlin zbira podatki o pregledanih napravah za nanašanje FFS. Iz tega registra naprav smo v analizo zajeli naprave, ki so bile pregledane v sedem letnem obdobju, od leta 2010 do 2016. Vsaka naprava je prikazana v tem obdobju samo enkrat, zato smo odstranili naprave, ki so bile v tem obdobju pregledane dvakrat. Hkrati pa je iz tega razvidno, da nekateri lastniki naprav za nanašanje FFS ne dajejo svojih naprav v pregled v predpisanih zakonskih rokih.

Analizirali smo 21.963 naprav za nanašanje FFS, ki so bile pregledane med leti 2010 in 2016. Od tega je bilo 15.040 škropilnic (68,4 %) in 6.901 pršilnikov (31,4%). Ostali – neznaten delež pa so predstavljale naprave za kemično obdelavo semenskega materiala, ročno vožene naprave itd.

Iz registra pregledanih naprav za nanašanje FFS smo analizirali tudi starost naprav oziroma leto izdelave. Na sliki 1 je prikazan delež pršilnikov in škropilnic glede na leto izdelave. Iz podatkov je razvidno, da so škropilnice starejše kot pa pršilniki. Največ škropilnic je bilo izdelanih v obdobju med 1986 in 1990. In to kar 27,5 %. Sledijo jim škropilnice z letnico izdelave 1981 do 1985. Teh je bilo 22,4 %. Pri pršilnikih je največ - 21,9 % naprav izdelanih med leti 1996 in 2000. Sledi jim 14,1 % pršilnikov izdelanih med leti 1986 in 1990. Najstarejša škropilnica je bila izdelana 1966, najstarejši pršilnik pa izvira iz leta 1968. Kar pomeni da je najstarejša testirana škropilnica stara ravno pol stoletja! Pri pršilnikih je za leto izdelave modus 1999. Pri škropilnicah pa se najpogosteje pojavi letnica izdelave 1988. Pri pršilnikih 15 naprav ni imelo poznane letnice izdelave, pri škropilnicah pa je bilo takih naprava 67.



Slika 1: Leto izdelave pršilnikov in škropilnic, ki so bili testirani med leti 2010 in 2016
Figure 1: Year of production of mistblowers and sprayers, which have been tested between 2010 and 2016

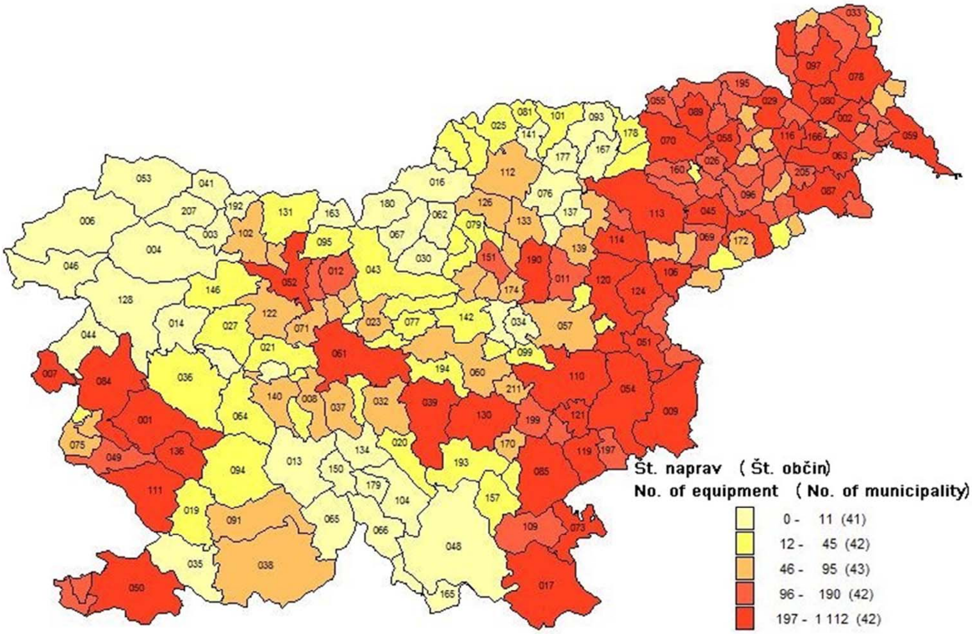


Slika 2: Delež posameznega proizvajalca (prvih 11) med napravami za nanašanje FFS testiranimi med leti 2010 in 2016
Figure 2: Share of individual producers (top 11) of pesticide application equipment tested between 2010 and 2016

Med testiranimi napravami v letih 2010 do 2016 je največ naprav domačega proizvajalca Agromehanike. K njim smo prišteli še naprave proizvajalca KŽK, ki je bil predhodnik Agromehanike. Teh naprav je 14.587 ali 65,4 %. Na drugem in tretjem mestu med proizvajalci je Metalna Rau Maribor z 2.020 napravami oziroma 9,7 % in Zupan d.o.o. s 7,4 % deležem ali 1.636 napravami. Nato sledijo v zelo majhnih deležih še številni proizvajalci, med katerimi je tudi nekaj takih, ki imajo samo 1 napravo. Zanimiv je tudi podatek, da je 23 naprav lastne izdelave oziroma domače izdelave.

Popis kmetijstva v Sloveniji izvaja Statistični urad Republike Slovenije na vsakih deset let. V njem spremljajo tudi kmetijsko mehanizacijo. Med napravami za nanašanje FFS so spremljali škropilnice in pršilnike, pri zadnjem Popisu pa so vključili še nahrbtne motorne škropilnice in pršilnike. Popis kmetijstva iz leta 2010 je naštel 37.204 lastnih in skupnih naprav za nanašanje FFS. Kar 80,13 % v popisu ugotovljenih naprav za nanašanje FFS prihaja iz vzhodne kohezijske regije. 19,87% teh naprav pa je iz zahodne kohezijske regije. V celotni Sloveniji prevladujejo škropilnice, saj jih je naštetih 20.999 oziroma 56,44 %. Sledijo nahrbtne motorne škropilnice in pršilniki, ki so jih v Popisu našteli 10.738 ali 28,86 %. Na tretjem mestu so pršilniki, kjer navajajo 5.467 naprav oziroma 14,69 %. V prvi in tretji skupini gre za traktorske škropilnice oziroma traktorske pršilnike.

Na sliki 3 je prikazano število škropilnic in pršilnikov po posameznih občinah v letu 2010, ko je bil Popis kmetijstva. Največ teh naprav imajo v občini Brežice in sicer kar 1.112 kar predstavlja 4,37 %. Sledi jim občina Krško, kjer je teh naprav 986 oziroma 3,87 %. Nato pa z relativno visokim deležem sledijo še občine Ormož, Brda in Moravske toplice. Devetnajst občin pa nima zabeležene niti ene naprave za nanašanje FFS (pršilnikov ali škropilnic). Te občine so povečini v alpskem svetu ali pa v občinah, kjer prevladuje gozd.

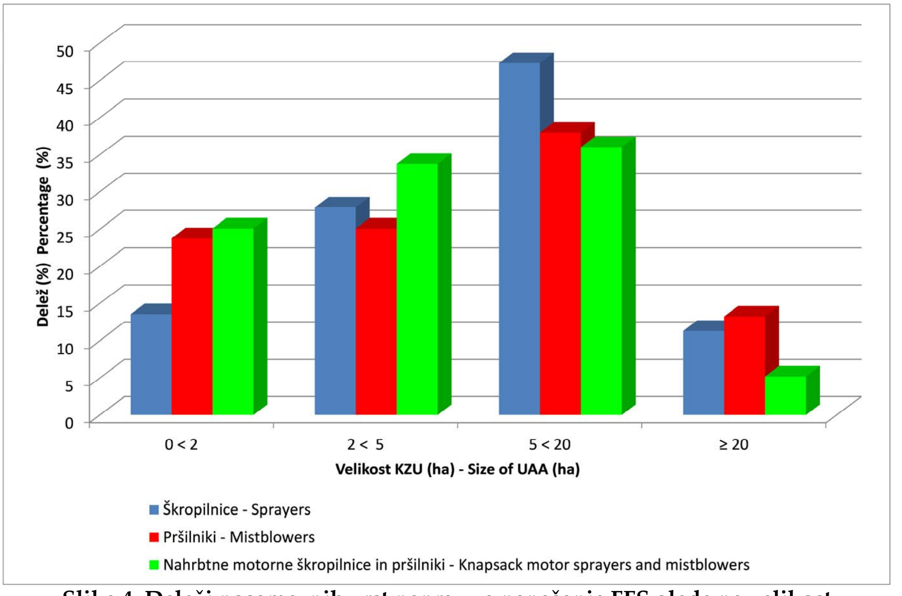


Slika 3: Število traktorskih škropilnic in pršilnikov po občinah glede na Popis kmetijstva 2010. Število naprav je razvrščeno v razrede po metodi kvantila Vir: Statistični urad Republike Slovenije
Figure 3: Number of tractor sprayers and mistblower in municipalities according to the Agricultural Census 2010. The number of equipment is classified into classes according to the method of quantile. Source: Statistical Office of the Republic of Slovenia

Na sliki 4 je prikazano delež naprav za nanašanje FFS glede na velikost kmetijske zemlje v uporabi (KZU). Razvidno je, da imajo največ naprav kmetijska gospodarstva, ki imajo od 5 pa do 20 ha kmetijske zemlje v uporabi. In to velja za vse tri kategorije naprav za nanašanje FFS. Pri kmetijskih gospodarstvih, ki imajo manj kot 2 hektara kmetijske zemlje v uporabi, je značilen relativno visok delež pršilnikov in nahrbtnih motornih škropilnic in pršilnikov v primerjavi z deležem škropilnic.

V Sloveniji je 20 % škropilnic in pršilnikov na kmetijskih gospodarstvih, kjer nimajo živinoreje. 26,9 % teh naprav pa je na kmetijskih gospodarstvih, kjer imajo 10 ali več glav velike živine (GVŽ).

Iz prikazanih podatkov o napravah za nanašanje FFS lahko rečemo, da vsaj tiste iz registra naprav Uprave Republike Slovenije za varno hrano, veterinarstvo in varstvo rastlin zadostijo zakonskim zahtevam za pravilno delovanje oziroma zahtevam Pravilnika o zahtevah glede pravilnega delovanja naprav za nanašanje fitofarmacevtskih sredstev in o pogojih ter načinu izvajanja njihovih pregledov. V redni uporabi pa so celo škropilnice stare 50 let. Sama starost naprav nam kaže dokaj zaskrbljujoče stanje. To velja še zlasti za škropilnice. Uradna amortizacijska doba za škropilnice je 12 let (Pravilnik o seznamu kmetijske in gozdarske mehanizacije ter katalogu stroškov kmetijske in gozdarske mehanizacije).



Slika 4: Deleži posameznih vrst naprav za nanašanje FFS glede na velikost kmetijske zemlje v uporabi (KZU)
Figure 4: Percentage of different types of of pesticide application equipment in relation to the size of utilised agricultural area (UAA)

Naprave so dejansko stare (po letih) in zastarele, čeprav se da z njimi opravljati še normalno aplikacijo FFS. Sodobnejše naprave pa imajo lahko vgrajene sklope, ki bistveno vplivajo na natančnost aplikacije FFS in na varnost uporabnika. Glede na starost naprav in majhno prostornino glavnega rezervoarja je relativno malo naprav opremljenih z elektronsko regulacijo - procesorsko vodenimi napravami za spremljanje in avtomatsko uravnavanje škropiva na napravah. V Sloveniji se šele v zadnjih letih lastniki škropilnic odločajo tudi za sisteme vodenja traktorja preko satelitske navigacije. Le novejše in večje naprave imajo tudi polnilne posode, ki sicer po zakonodaji niso obvezne. Omogočajo pa lažje rokovanje in polnjenje škropilnice, tudi pranje embalaže je z njimi enostavnejše. Manjše je tudi tveganje, da se bo uporabnik FFS kontaminiral ali pa da pride do točkovnega onesnaženja okolja. V Sloveniji tudi niso predpisani CTS sistemi. To so zaprti sistemi odvzema koncentriranega škropiva iz embalaže. Taki sistemi so predpisani v Kaliforniji (ZDA) za določene skupine pesticidov. Velikokrat pravimo, da zakonodaja preprečuje napredek, vendar na področju naprav za nanašanje FFS zakonske zahteve in standardi pomenijo višji tehnični nivo.

SKLEPI

Iz podatkov o pregledanih napravah, ki jih zbira Uprava Republike Slovenije za varno hrano, veterinarstvo in varstvo rastlin je ugotovljeno da je bilo med leti 2010 in 2016 pregledanih 21.963 naprav za nanašanje FFS. Od tega je bilo 68,4 % škropilnic in 31.4 % pršilnikov. Zaskrbljujoča je starost naprav. Generalno lahko rečemo, da so škropilnice starejše kot pa pršilniki. Največ pregledanih škropilnic (27,5 %) je bilo izdelanih med leti 1986 in 1990. Najstarejša delujoča škropilnica ima letnico izdelave 1966. Največ naprav je proizvod domače Agromehanike in to kar 65,4 %. Sledijo jim naprave Metalne Rau Maribor in Zupan d.o.o.

Popisu kmetijstva 2010 pa je naštel v Sloveniji 37.204 lastnih in skupnih naprav za nanašanje FFS. 56,44 % je traktorskih škropilnic, 28,86 % je nahrbtnih motornih škropilnic in pršilnikov ter 14,69 % traktorskih pršilnikov. Največje število teh naprav je v občini Brežice, Krško in Ormož. Devetnajst občin pa nima zabeležene nobene naprave.

Zakonsko sicer ustrezne naprave pa so v pretežni meri dejansko tehnično zastarele. Z njimi se sicer lahko ob pravilni uporabi izvaja varstvo rastlin, vendar bi z novejšimi napravami opremljenimi s sodobnejšimi tehničnimi rešitvami aplikacijo FFS lahko opravili bolj natančno in bolj varno. Dejansko bi zamenjavo starih naprav morala bolj podpreti tudi država s sistemom subvencioniranja ustreznejših naprav.

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ANALYSIS OF PESTICIDE APPLICATION EQUIPMENT ON SLOVENIAN FARMS

ABSTRACT

In Slovenia 21,963 units of pesticide application equipment were inspected between 2010 and 2016 with regard to the database of the Administration of the Republic of Slovenia for Food Safety, Veterinary and Plant Protection. 68.4 % of them were sprayers and 31,4 % were mistblowers. Sprayers are older than mistblowers. Most sprayers were made between the years 1986 and 1990. Most of the equipment in Slovenia is made by domestic manufacturers, Agromehanika in particular stands out with 65,4 % share of the sprayers and mistblowers. According to Agricultural Census 2010 we have 37,204 units of pesticide application equipment in Slovenia. There are 20,999 tractor sprayers, 10,738 J and 5,467 tractor mistblowers. Most of this equipment is found on farms, which have from 5 to 20 ha of land in use and in the municipalities of Brežice, Krško and Ormož. Most of the pesticide application equipment in Slovenia is out-of-date, but they are adequate to valid acts.

Keywords: sprayers, mistblowers, number of units, age, manufacturer

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.348(497.7)
Stručni rad
Expert paper

CONDITION OF THE PESTICIDE APLICATION EQUIPMENT IN PART OF THE MEDITERRANEAN REGION IN THE REPUBLIC OF MACEDONIA

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SUMMARY

The *Directive 2009/128 / EC o*f the European Parliament establishes a framework for the implementation of National Action Plan referring to the sustainable use of pesticides in every country. One of the areas covered by the Directive relates directly to the introduction of mandatory monitoring and inspection of pesticide application equipment (PAE). Considering that the Republic of Macedonia does not have a compulsory inspection, and as an EU candidate member country is bound to harmonize its regulations, the basic aim of this research is to determine the current condition of the pesticide application machines. The survey was conducted in a part of the Mediterranean region in the Republic of Macedonia, i.e. the municipality of Sveti Nikole and Stip. 84 machines were visually and operationally checked. The results of this research will be a good basis for further research and implementation of mandatory inspection of these machines in the Republic Macedonia.

Key words: plant protection, pesticides, inspection, visual flows

INTRODUCTION

The overuse and misuse of pesticides pose a threat to the environment and health hazards for the farmers in the agricultural production. Pesticide residues in food affect directly the health of consumers and the increasing number of people suffering from pesticide contamination. In addition, exporters of food must comply with the standards on the minimum allowed presence of residues in processed foods, fresh fruits and vegetables. The non-compliance with these standards can have catastrophic effect on the increasing of export, which is one of the primary economic objectives of our country.

With the new law on plant protection, the agricultural policy of our country pays special attention to the protection of agricultural land from pollution and to the principles of environmental protection. The law deals with the economic, health, environmental and social role of agriculture and establishes the principle of agricultural policy measures that are to be aimed at encouraging sustainable agricultural activities. The measures are aimed at maintaining the diversity of animal and plant species, conservation of soil and of its fertility and protection of natural conditions necessary for life in soil, water and air.

However, the outdated machines in Macedonia, worn and poorly maintained machinery and pesticide application equipment (PAE) cause directly the increased number of treatments, poor protection and uncontrolled spread of diseases and pests in the agricultural production.

Last few years, the European Commission adopted a whole set of rules (directives) and broadened the scope of all those regulations. According to the guidelines presented in the directives, all national regulations in the Member States must be harmonized when the countries introduce new laws. The *Directive 2009/128/EC* of the European Parliament establishes a framework for the implementation of the National Action Plan in each country, which refers to the sustainable use of pesticides. One of the areas covered by the Directive relates directly to the introduction of mandatory monitoring and inspection of pesticide application equipment (PAE). Considering that in the Republic of Macedonia the inspection is not mandatory, and as a country candidate it is bound to harmonize its regulations, the main goal of this research is to determine the current condition of the pesticide application equipment. The results are a good basis for further research and an opportunity to apply standardized procedures for mandatory inspection of machinery for pesticide application.

In the Republic of Macedonia at the end of 2014 began a process of harmonization of the old law for plants protection with new rules and regulations required by the European Commission. The new rules and regulations, inter alia, pay special attention to the pesticides application equipment and to their mandatory inspection at specific time intervals.

Because of that, within the Phytosanitary Administration are established committees whose objective is to work on alignment of the law and on collecting experiences from other member states of the European Union that have undergone this process or are at an advanced stage. This year in collaboration with the Phytosanitary Administration were organized several meetings with farmers, with the distributors of pesticides as well as with economic operators who sell machines for pesticide application. The goal is to consider all aspects for optimizing the new laws and regulations, and in terms of machinery for pesticide application, establishment of monitoring and rapid onset of inspection. EU Member States several years ago introduced the mandatory inspection of pesticide application equipment [3], [5], [8], [9], [10]. Experience in Croatia shows that the entry into the EU, the introduction of compulsory inspection and use of standard *EN13790* is a legal obligation that must be carried out. Many scientists their research in the field of pesticide application equipment they used for the application of standard *EN 13790* and compulsory inspection in their countries [1], [10].

METHODS

The research was conducted in the eastern part of the Mediterranean region of the Republic of Macedonia embracing the municipalities Sveti Nikole and Stip. The instrument used during the field research was the questionnaire including data divided into three groups:

a) General information about the owner

b) General information on the pesticide application equipment (PAE)

c) Visual and operational flaws of the machines

RESULTS AND DISCUSSION

Mediterranean region in Macedonia is one of the major agricultural regions in the Republic of Macedonia, where crops, vine crops, fruits and vegetable are grown. In the municipalities Sveti Nikole and Štip, where the research was conducted crops are prevalent, and recently new vineyards and orchards are renewed and raised.

The objective of this research is to determine the current condition of the machines for application of pesticides and to learn how many of them correspond to the requirements of the *European Standard EN 13790* and the new *EN ISO 16122*, which relate directly to the inspection of machinery and equipment for application of pesticides.

Table 1 provides general information about farmers who own equipment for application of pesticides. According to the data in the table it can be concluded that most of the farmers 25 (44.64%) are not registered and most farmers have secondary education (69.64%).

The fact that all surveyed farmers have not attended any training on quality and on handling these machines is worrying. This means that these machines are used according to their personal experience or according to the experience of their relatives and friends which is often misleading and unsafe. According to the data presented in the table it can be concluded that, in this part of the municipality, the most common are field crops (88.24%).

Table 1. General data on farmers

Total number of interviewed person	Registered farmers			Education of the farmer/manager			Attendance on trainings for (PAE)	
	Yes	No	Enterprise	Primary	Secondary	High	Yes	No
56	22	**25**	13	9	**39**	8	/	**56**
%	39,29	44,64	23,21	16,07	69,64	14,29	0	100

Table 2 shows machines for application of pesticides that are most common in the eastern Mediterranean region. According to the data we can conclude that the most common brand of machines for application of pesticides is Agromehanika Kranj 36 (42.86%). The fact that these machines are old, frequently between 10-20 years (15 or 17.86%) and 24 over 20 years (28.57%) is worrying. If these machines are not properly maintained and used, they can be major contributors to increased pollution of the environment. As a result of the aid and subsidies that farmers receive for the purchase of new machinery in the last 7-8 years we have notices an increased number of new machinery for pesticide application - 28 machines (33.33%).

Table 2. General information on PAE in part of the Mediterranean region

	Pesticide application equipment (PAE)							
	Brand	Number of machines	Age				Functioning properly	Malfunctioning
			< 5	5 - 10	10- 20	20 <		
1.	Morava	20	2	3	3	12	16	4
2.	Agromehanika Kranj	36	15	10	6	5	36	/
3.	Mitterer	4	/	/	1	3	4	/
4.	Metalbraneks Prokuplje	2	1	1	/	/	2	/
5.	Sprayer	1	1	/	/	/	1	/
6.	Sampo 20	1	/	/	1	/	1	/
7.	Leško	4	1	1	2	/	4	/
8.	SVL Aseta	1	/	/	/	1	1	/
9	Agrin	1	1	/	/	/	1	/
10	Agrimir Vistula	1	/	/	/	1	1	/
11	Agroproizvodzac	1	/	/	1	/	1	/
12	TCM	1	/	/	/	1	1	/
13	Evrotech	1	/	/	1	/	1	/
14	Agron Nis	7	7	/	/	/	7	/
15	Fisher	1	/	/	/	1	1	/
16	Vrecek Kranj	1	/	1	/	/	1	/
17	Atomizatori	1	/	/	/	1	1	/
	Total	84	28	16	15	24	80	4
	%	100	33,33	19,05	17,86	28,57	95,24	4,76

Table 3 shows the proportion of machinery for application by way of hitching to the tractor and the type of the machine. According to the table the most common are carried tractor machines for application of pesticides for agricultural crops 41 (48.81%). Certain gradual rise of the number of air assisted sprayers (machines for application with fan) for the growing number of vineyards and orchards is noticeable.

The survey of the pesticide application equipment included the determination of visual and operational flaws of the machines. The flaws of the machines were determined and are presented in Tables 4 and 5.

Table 3. Data on PAE in part of the Mediterranean region

Types of PAE	Carried		Trailered	
	Horizontal boom sprayers	Air assisted sprayers	Horizontal boom sprayers	Air assisted sprayers
Total (84)	41	23	2	18
%	48,81	27,38	2,38	21,43

Table 4. Visual flaws of PAE in part of the Mediterranean region

Parts of the machine	Visual flaws of PAE		Total	%
	No parts	Modifications		
Chassis	/	11	11	14,29
PAE hitching device	/	1	1	1,30
Power take-off	/	0	0	0
Wheels / Tires	2	/	2	2,60
Tank	1	10	11	14,29
Agitator	/	/	0	0
Pump	/	2	2	2,60
Filters	4	/	4	5,19
Command valve	/	9	9	11,69
Pressure gauge	5	/	5	6,49
Hoses	/	8	8	10,39
Sprayer boom	/	15	**15**	**19,48**
Nozzles	1	3	4	5,19
Fan	/	5	5	6,49
Total	**13**	**64**	**77**	**100**
%	16,88	83,12	**100**	

According to the data in the table 4 it can be noted that upon the visual inspection of the machines most defects and modifications are present in the machine's sprayer boom or the part on which nozzles are placed. The sprayer boom was often altered from field crops to vine and fruit crops or reinforced due to kinking, cracking etc.

Analysing the current state of pesticide application equipment it can be concluded that the most common malfunction in machines is determined in the pressure gauge 20 machines (23,81%), and three machines did not have any pressure gauge at all (Table 5). It should be noted that this tool directly shows the operating pressure in the system and is one of the main control tools for proper and quality application of pesticides. Regarding the modifications of these machines they are usually observed in the hoses 40 (47,62%) of the total number of machines. The great pressure and the quality of hoses affect directly the length of their use and the need for replacement.

Table 5. Operating flaws of PAE in part of the Mediterranean region

Parts of the machine	Current state of the parts of the machines							
	Functioning properly	%	Malfunctioning	%	Functioning properly with modification /leaking oil	%	No parts	%
Chassis	77	91,67	/	0	7	8,33	/	0
PAE hitching device	78	92,86	/	0	5	5,95	1	1,19
Power take off	78	92,86	1	1,19	4	4,76	1	1,19
Wheels/Tires	13	68,42	3	15,79	2	10,53	/	0
Tank	80	95,24	/	0	4	4,76	/	0
Agitator	80	95,24	4	4,76	/	0	/	0
Pump	70	83,33	2	2,28	12	14,29	/	0
Filters	78	92,86	5	5,95	/	0	1	
Command valve	67	79,76	7	8,33	10	11,90	/	0
Pressure gauge	61	72,62	**20**	**23,81**	/	0	3	3,57
Hoses	42	50,00	2	2,28	**40**	**47,62**	/	0
Sprayer boom	61	72,62	5	5,95	16	19,05	2	2,28
Nozzles	69	82,14	3	3,57	11	13,10	1	1,19
Fan	27	84,38	5	15,63	/	0	/	0

During the conversation with the farmers about their experience the most common defects and problems encountered when using these machines were discussed. According to the results of the research it can be concluded that most defects occur in the hoses 18 (33, 33%) and pump 15 (27, 78%) of the pesticide application equipment from the total number of defects (54). A smaller number of defects are observed on nozzles (7), and on sprayer boom and filters (4).

CONCLUSIONS

Unfortunately, according to the first results, it can be concluded that a large number of controlled machines can not meet the requirements of European Standard *EN 13790* and the new *EN ISO 16122.* All surveyed machines have only one tank and many of them have modifications that are not in accordance with the above mentioned standards.

According to the survey results it can be concluded that the number of registered and non-registered farmers is almost the same and most of the farmers have secondary education. The fact that all surveyed farmers have not attended any training on quality and safe handling of these machines is worrying.

The most represented brand of pesticide application machine is Agromehanika Kranj. Many of these machines are 15-20 years old and even more than 20 years old. If they are not properly maintained and used, they can be major contributors for the increased pollution of the environment.

The visual inspection of the machines showed that most defects and modifications are present in the sprayer boom of the machine in the part on which nozzles are set. The sprayer boom is usually altered from field crops to vine and fruit crops or it is reinforced due to kinking, cracking etc.

Analyzing the current state of the functioning of the pesticide application equipment, it can be concluded that the most common malfunction in machines is in the manometer. Regarding the modifications of these machines they are mostly observed in the hoses and the sprayer boom of the machinery. The great pressure and the quality of hoses affect directly the length of their life and the need for replacement.

During the conversation with the farmers they declared that from their extensive experience most failures occur in the hoses and pumps of pesticide application equipment. All farmers, owners of these machines have said that they would like to expand their knowledge by attending training for proper and safe exploitation.

In the Republic of Macedonia there is no compulsory inspection of pesticide application equipment. But as a candidate country, Macedonia is bound to apply and harmonize its laws and standards with the European Union laws and standards. The introduction of mandatory inspection, as well as other laws regarding the proper use and handling of waste pesticides affect directly the protection of the environment and human health. The presented data will be very important when Macedonia is to adapt European laws and measures in agriculture, which will have to implement Ministry of Agriculture Forestry and Water Economy.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

COORDINATE CONTROLLED PLACEMENT OF SUGAR BEET SEEDS

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ABSTRACT

A seeding system has been developed which places seeds of sugar beets in geometric regular formations. The seed drill has been equipped with an electrical drive which is controlled by a positioning system, consisting of a multi-sensor system able to generate current positions within the seeding frequency. The aim of the research activity was to place seeds at predefined locations. Two features are related to the approach: a) to know exactly the position of every plant which means the plant can be treated as an individual b) the field traffic can be applied bidirectional in row crops. The accuracy of the seeding operation was studied under aspects of positioning errors and irregularities of seed placing. In a field trial the system was tested by recording the coordinates of the emerged sugar beet plants in 4 leave stage. Standard deviation from target distance has been accounted as 1.5 cm.

Key words: seed drill, accuracy, GNSS receiver

INTRODUCTION

Seeds in agricultural field operation are sown by seed drills. The drills meter by volume with toothed wheels which is common for cereals or by singling devices, selecting single seeds and allocating the seeds with fixed distances in a row. Different crops are sawn by precision seeders, e.g. sugar beets in Europe on an area of 1.54 Mio ha (WVZ; 2016), corn in Europe (EU 27) on an area of 15 Mio ha (DMK, 2016) and in other regions of the world cotton and soya beans are sawn by this type of seed drill as well.

Current cropping systems are applicable for field traffic in longitudinal direction. In case of weeding by herbicides the space between the rows are used for sprayer paths. Mechanical weeding requires satisfactory space between the rows which is treated by haws with cutting tools. The space between the plants in the rows is left untreated and reduces the mechanical weeding efficiency.

Generating geometric regular plant formations means to position the seeds in predefined arrangements. The formation can be optimized to give the plants the maximum space as related to the neighboring plants (e.g. triangle formation). Optimization of plant`s space is a traditional request of cultivating crops to utilize the yield potential.

Another feature is to place the seeds on predefined coordinates in the field resulting in a geometric formation of plants to allow more independent field traffic. These cropping systems can be called machine traffic conform. The crop stand can be treated by mechanical weeding in two orthogonal directions or longitudinal and diagonal in case of a triangle formation. The space between the plants in a row can be treated by regular machines haws. By bi-directional machine hawing in sugar beet stands 95 % of the cropping area can be weeded (Kam, et al, 2010).

Finally the seed coordinates characterize the position of an individual plant. For later operations the plants need not to be detected by machine vision, even no weed scouting is necessary as the position can be retrieved and used for precise hawing or precise fertilizing and plant protection applications. The individual plant can be monitored by sensing tools to determine its health and nutrition status and to explore its potential yield in field scale.

Sawing adjustment

A similar approach has been attempted by Griepentrog et al. (2005). The mechanical precision seeder was equipped with a GPS-system, recording the seed positions when seeds dropped from the cell wheel trigged by a light bar. The method records the coordinates of the seed release but does not place the seeds actively in a formation. As the seeds are logged when they are released from the cell wheel, the coordinates do not present the true location in the soil as rolling or seed bouncing occur as well as seed trajectories vary with peripheral speed. This deviation was measured by the authors as distances between estimated seed drop position and sugar beet positions in the field after emergence. A crop plants was found in radius of 37.3 mm from its logged seeding coordinates (Norremark et al. 2007). Ehsani et al. used an air assisted precision seeder (vacuum planter), which was instrumented with an RTK-GPS for corn seed mapping. They found that on average the mapped seeds were within a distance of 34 mm of a germinated plant.

Yazgi et al. studied the spacing uniformity of vacuum type precision seeder. This type of seeder is globally more widely used than the seeder under this study.

MATERIAL AND METHODS

The coordinate controlled placement of seeds was enabled by the development of a system, which consists of two parts: (1) a multi-sensor system including a high precision GNSS receiver, an odometer and a gyroscope and a real-time processing unit to determine the absolute position of the vehicle for every time step, and (2) a modified seed drill, which is controlled by the trajectory coordinates and a desired seeding distance to some absolute reference row (Fig. 1).

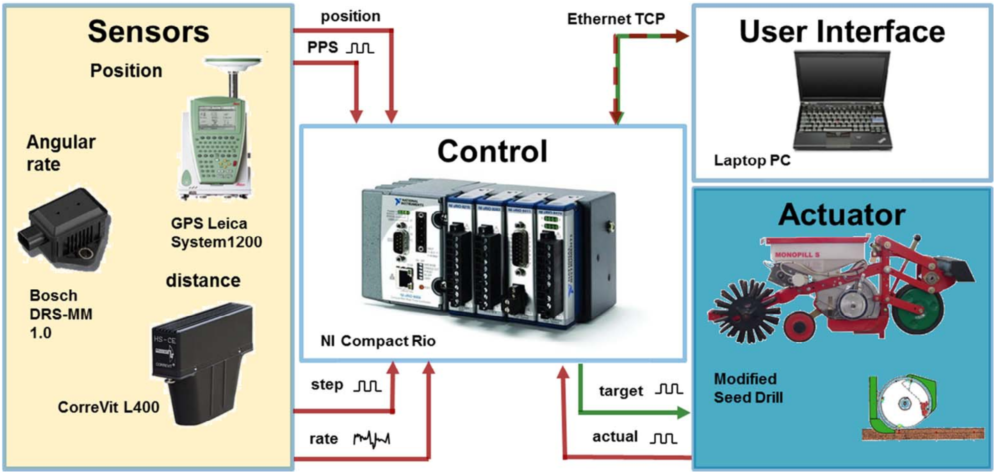

Figure 1: Setup of the developed multi-sensor system, which is used to generate precision coordinates in real-time

Multi-Sensor System for trajectory estimation

The sensor platform is equipped with a GPS-system, a travelled distance sensor (odometer), MEMS (Microelectromechanical systems) gyroscope (yaw rate sensor), a measurement controller and a laptop as a user interface.

GPS positions are available with a frequency of 10 Hz and with an accuracy of a few centimeters (Real-Time Kinematic GPS is used here). The odometer provides information about the traveled distance with a high rate and accuracy, the angular rate sensor provides the rotation rate around the vertical axis of the vehicle, also with a high rate and accuracy. Based on the gyroscopes and the odometer the position of the vehicle can be updated with a high frequency ('dead reckoning'), although leading to an unbound drift of the position error. To avoid this, the sensor data are fused with the GPS observations using a Kalman Filter approach, leading to high rate and high precision coordinates, available in real-time. These are the inputs to a number of parallel control loops, independently controlling the speed and the rotational position of each of the cell wheel of the seed drill. Details on the estimation algorithms and the control loops, as well as on the system implementation can be found in Kuhlmann (2012).

Seed drill design and instrumentation

An electronic precise control mechanism was integrated in a conventional precise seed drill for single seeding (Kverneland, Accord Monopill S). Each seeding unit (cell wheel or cell disc) was adjustable independently. The mechanical chain drive of the precision seeder was replaced by a toothed belt (Fig. 2). A stepper motor actuated the cell disc with a transmission ratio of 4:1. The control function was managed by an adjustable impulse generator. One motor step caused 1/4000 revolution of the disc and the distance between two seed depositions were 800 motor steps. For practical use every 3.75 mm an impulse was generated for a desired plant distance of 30 cm. In order to determine potential slip, an encoder was installed at the belt. The slip is caused by lost motor steps due to short-time overcharge when high accelerations occur. A microcontroller was employed to adjust the rotation of the disc according to the current slip by comparison of steering impulses and performed motor steps. Parallel to the cell disc a second wheel with marks for each cell was installed. Using a light-barrier each seed release and indirectly each position was determined. The seed drill was designed for driving velocities in a range from 1 to 3 m/s. The dynamics of the cell disc and the control unit depends on the tractors acceleration/deceleration and the expected variations of the seed depositions.

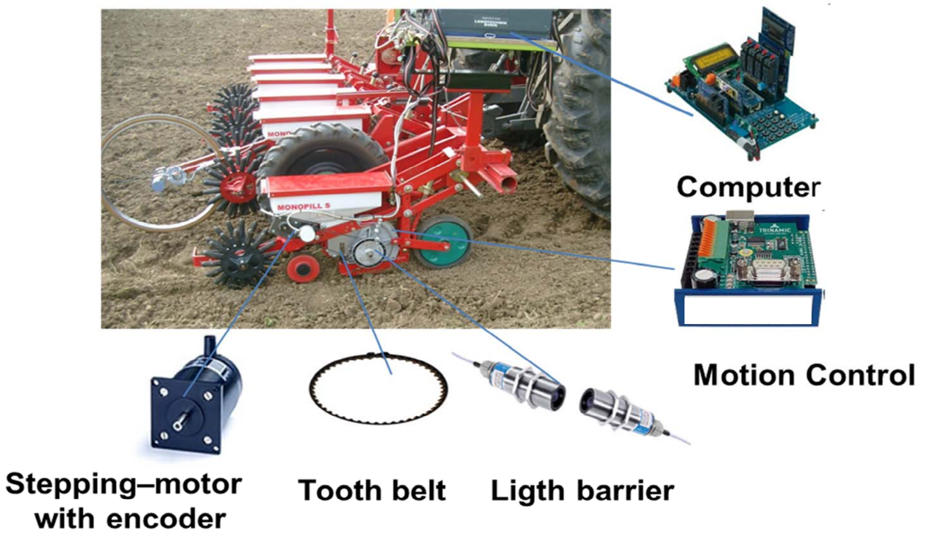

Figure 2: Seed drill with actuator to adjust the cell wheel revolutions

Seed placing errors

There are three major aspects affecting the accuracy of coordinate triggered sowing (Table. 1).

Table 1: Structure of accuracy for coordinate triggered positioning of seeds

Accurarcy of coordinate controlled seeding		
Accuracy of seed deposition	**Accuracy of field appereance/ position of plants in the field**	**Accuracy of machine**
- actuation - cell filling , misses, doubles - trajectories of pills	- pill rolling - erectophil emergence	- position of cell disc - machine coordinates

Coordinate accuracy: The position of the platform, determined by the multi-sensor system is the input for the loop controlling of the seed drill. Therefore its accuracy affects the accuracy of the seeding process. Errors sources here are the accuracy of the GPS observations, the accuracy of the knowledge about the temporal and the spatial relationship between all sensors and the seed drill (time synchronization and system calibration).

Seed deposition accuracy: Even when the trajectory of the drill is perfectly known at any point in time, the actual deposition of the seed by the seeder is prone to errors. The accuracy of deposition implies the actuation respectively the drive of the cell disc, which can be affected by slippage. This is mainly influenced by the precise seeder. The quality of the cell filling may lead to missing or double fillings. Furthermore, the quality of the seed deposition is affected by variations of the dropping point (release of seed pill) and the dropping trajectory, which varies due to rotational speed of the cell disc

Accuracy of field appereance: The accuracy of field appearance implies pill rolling when deposited in the tilled soil and the non erectophil growth. Both are influenced by the soil structure.

The trajectory of sugar beet pills while dropping from the cell disc vary due to rotational speed of the saw disc. Apart from deposition errors due to differences in trajectories the rolling effect of the seed pills can only be analysed in soil. Therefore one sowing unit was tested in a soil bin and the rolling displacements were determined by a high speed camera. The erectile growing of the sugar beet seedlings was analysed in pots with different soil conditions.

The total accuracy of the process can be determined by a precise determination of every plant after its emergence. This has been realized using a geodetic high precision total station.

RESULTS AND DISCUSSION

Coordinate accuracy

In a field experiment, the system has been configured to place the seeds in a way the they are placed in lines, which are perpendicular to the driving directions but parallel to a predefined reference line and a distance of multiples of 20 cm to the reference. When driving in parallel along parallel tracks, all seeds will be deposited on a perfect grid. Figure 3 (left) shows the trajectory of the vehicle and the seed depositions points for both seeders. On the left it can be seen, that desired structure has been achieved. Evaluations described in Kuhlmann (2012) show, that this deposition accuracy, defined as the deviation of the lateral position from the next multiple of the desired seed distance, is in the order of 1 cm, which is the expected accuracy of the RTK GPS observations.

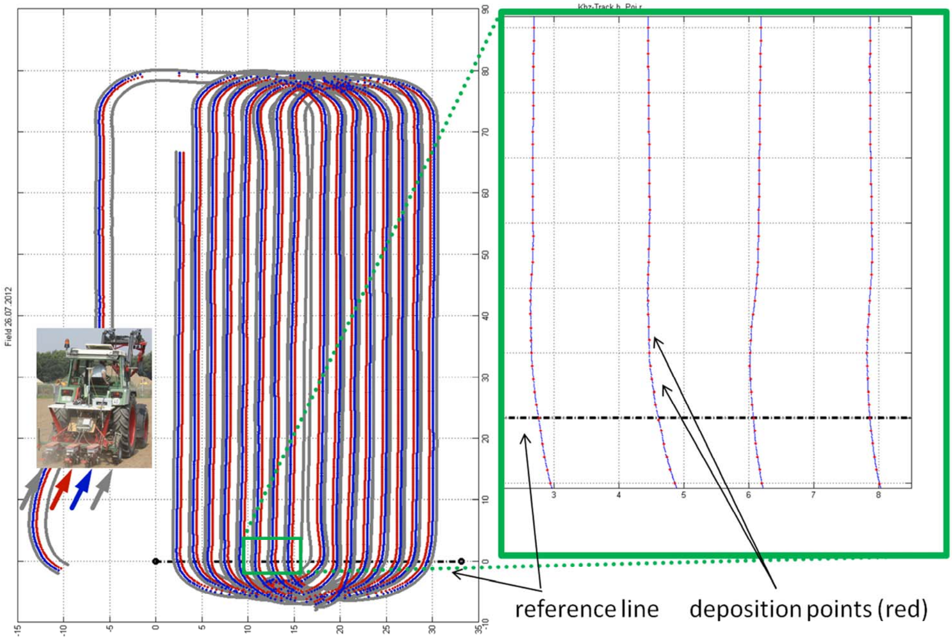

Figure 3: Left: Track of the vehicle during the placement of seeds. Right: Magnified part of the left figure

Accuracy of seed deposition as effected by the seed drill

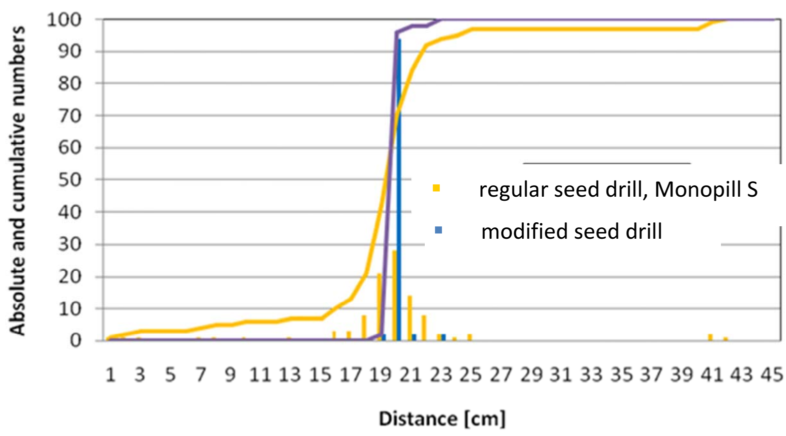

Figure 4: Comparison of regular/conventional and modified/precise sowing unit

The quality of seed deposition is influenced by variation of the dropping point (release of seed pill) and the dropping trajectory. The advancement of the developed drive system as compared to the conventional type, is described in figure 4. The comparison is made for a speed of 3 km h^{-1} and a spacing of 20 cm. In contrast to the conventional system the new system creates no double depositions, no missing depositions and about 95% of all depositions vary less than 1 cm (σ<5 mm). The accuracy of deposition of the new system is 97,5% in comparison to the regular unit 91,1% (Thelen, 1992).

Accuracy of field appereance

While the accuracy of deposition depends on technical effects, the accuracy of field appearance is influenced by biotic effects and soil conditions (Kam et al. 2010). This effect alone is difficult to measure in field conditions, therefore the total accuracy of the whole process has been determined by the field experiment described above. The position of all plants after emergence have been precisly determined using a total station with an accuracy of less than 2 mm. For all plants the deviations to the desired lateral row have been counted in the histogram in figure 5.

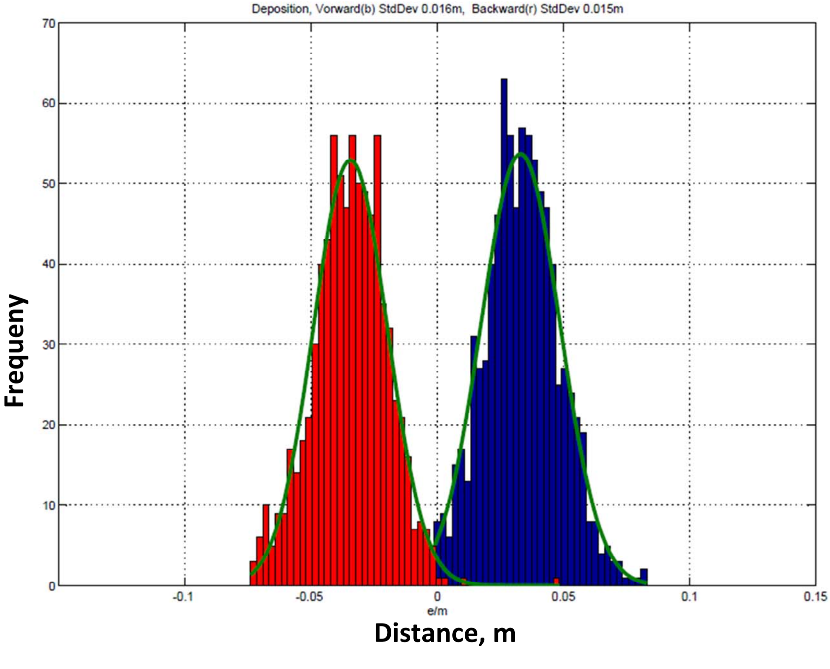

Figure 5: Histogram of the devitions from the target line of plants, separated for the two driving directions.

The histogram has two peaks, showing the deviations for two different driving directions on the field (forward: blue and backward: red). This clearly shows, that the system calibration, especially the distance between the GPS antenna and the seed drill has an error of about 3 cm, leading to the observed bias. Assuming, that this can be compensated by a proper calibration process, the accuracy of the whole seeding process can be determined to be 15 mm (standard deviation).

Given this accuracy (σ=15 mm), the deposition accuracy the sensor system (σ<10 mm) and the deposition accuracy of the drill (σ<5 mm) , the effect of the field emergence can be estimated to be in the order of 10 mm (standard deviation).

The results can be compared with a general field study of Ziegler et al. (2012). In this study 5 seed drills for sugar beet pills were tested in 3 years. Misses occured with a frequency of 5 %, doubles with 3% and the accuracy of position was described by 65 % of the plants were in a distance of 2.5 cm from the target position of the seed (σ=25 mm).

CONCLUSION

A system for coordinate controlled seeding of sugar beets has been developed and evaluated in the field. A multi-sensor systems, based on GPS, inertial sensors and an odometer enables the precise determination of the position of the vehicle with a high rate (1 kHz) and a high accuracy (σ<10 mm) in real time. Together with a seed drill, which has been modified to be controlled by the speed of vehicle and a desired seed position, the deposition of seeds is possible with an accuracy in the order of 10 mm. Experiments have shown, that about 95% of the sugar beet plant emerge within 30 mm distance to the desired position.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.052.9
Pregledni rad
Review paper

PRECISION GRASSLAND FARMING – STATE OF THE ART AND FUTURE RESEARCH TOPICS

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SUMMARY

Today Precision Farming Technology is a commonly used method on arable land. The technology is widely discussed, there are new developments nearly every month. Although there is a great potential for this technology, it is seldom used on machines for grassland. This work contains an overview of latest scientific research in precision farming for meadows. Next to an introduction in which different conceptions are explained, there is a description of the whole harvesting chain in grassland respectively precision farming given. Starting with modern technology in mowers, along different harvesting technologies, even up to rolling silage, developments are lighted and discussed. Giving a perspective for future main research options, the thesis will be closed.

There has to be concluded, that mainly machines, which are used on arable land and grassland as well, like choppers are highly technologized. Because of this, they show a high amount of precision farming applications. However, machines, which are solely used in grassland have seldom been provided with intelligent technique. If done so, these techniques were often just used for scientific purposes and seldom found their way into practice.

Key words: Precision Farming, grassland,

INTRODUCTION

During the last decades, the agricultural production processes took profit out of a huge amount of developments. Horses and oxen were common used in agriculture just 80 years ago. Today latest technology is obstructed in modern machinery, mostly fitted with fuel engines. Whilst in 1949 one farmer in Germany was able to feed 10 people, nowadays the number increased to 145 in 2013 (DBV). Modern machineries raised the productivity to a never known level. Progresses in information and electronic technology allow the farmers to ascertain data over the whole production line. A quality management system is able to trace food products from the origin up to the supermarket shelves.

Concerning the developments especially in information and electronic technology as well as some other advantages like in information technology a new age of farming was introduced, called "Precision Agriculture". Today there are different interpretations of the term "Precision Agriculture". Referring to Auernhammer (2002), Precision Agriculture is just an hypernym and can be divided into three major topics: "Precision Pasturing", "Precision Lifestock Farming" and "Precision (Crop) Farming". While Precision Pasturing focuses on methods for e.g. managing feed supply and stocking rates on pastures (Schellberg et al. 2008), Precision Lifestock Farming addresses all kind of systems which correspond with animals in husbandry. The last topic, Precision Farming, is defined as technology-supported cultivation of agriculturally used areas (Doluschitz et al. 2011).

Precision Farming did become a popular research field since the 1980s. Scientists and companies all over the world developed technologies to help the farmers raise crop yields and make agricultural production processes more efficient. Continuous new developments steadily contribute to a higher productivity and show that this technology is of critical importance. Electronic assistance systems, such as autonomous track guidance or section control are state of the art when investing in new machines on crop farms.

Automated data mining and -interpretation is becoming a focal point of agricultural industrial research, as was demonstrated at the Agritechnica trade show in 2015 (Horstmann 2016) and it is in demand by practitioners. Developments in agriculture which mine data and act almost autonomously on basis of these data can be summarized by the term "Agriculture 4.0" (Clasen 2016).

Precision Farming is often linked with arable or crop farming rather than grassland farming despite the fact that more than 3.44 bn ha of grassland existed worldwide in 2008 which is twice as much as arable land (Schellberg et al. 2008). In comparison to its widespread implementation on arable farms, Precision Farming in grassland is used rarely in practical farming. However, research concerning Precision Grassland Farming has been done in several universities and scientific institutes as well as in agricultural companies.

The aim of this study is to give an overview of existing research and furthermore to highlight special issues to be focused on in the future. For this purpose, grassland harvesting machines were contemplated.

PRECISION FARMING IN GRASSLAND DEVICES

Mowing

Dairy Farmers seek after high quality forage to get as much milk out of staple diet as possible. This is necessary to safe concentrated feed and thereby generate higher profit.

Several scientists dealt with technologies to get information about quality and quantity aspects of grass during its cutting. As Schellberg et al. (2008) already mentioned, one of the biggest problems of using Precision Farming applications in grasslands is the huge heterogeneity of meadows. This heterogeneity also changes during the vegetation period. Therefore, technology is needed which does not respond to heterogeneity. Suzuki et al. (2008) did scientific research to generate field maps of chemical composition of grassland using a hyperspectral imaging system. The sensor was attached at the rooftop of a tractor and scanned the windrow of a mowing device. Results showed that this technology could give reliable information about total digestible nutrients and crude protein content of mowed grass.

The mower is the first device which is in contact with the forage crop, no disintegration losses occurred and no further treatment which leads to spreading of the cutted grass (e.g. tedding) was done. Thus for creating a preferably precise yield map it is inevitable to quantify the biomass during the cutting process.

Several efforts have been made during the past decades to measure the quantity of harvested grass to, amongst other things generate yield maps. Demmel et al. in 2002 examined a weighing system in a conveyor belt, mounted at the rear part of a mower. Indeed, they got some results, however the accuracy of the system was with a standard deviation of 9 to 12 % too high. Great problems with this technology are that it only can be affixed on rear mounted mowers and that a conveyor belt is needed. This technique is not commonly used on every farm. So Kumhála et al. (2007) used methods to measure forage yield known from choppers or harvesters. They equipped a drum mower with a torque sensor and a curved impact plate (behind a mower conditioner) which was hit by the mowed grass. Results showed that measurements with the impact plate are not influenced by crop variety and maturity. With coefficients of determination of about 0.95 the results seem to be promising.

Against this backdrop, the efforts of Baldinger & Hofinger (2013) to electrify the mower conditioner are interesting. On one hand it may be possible to do measurements in the electric driven device easier. On the other hand, Baldinger & Hofinger mention that it would be possible to reduce disintegration losses in a range of 4,5 to 5 %. This electrified conditioner could save energy in that way that it can be controlled and adjusted to driving speed and mass of grass.

Other approaches like using a pulse radar system (Wild et al. 2003) have not proven a sufficient accuracy at the time.

Some small smart applications already found their way into practice like a torque sensor for warning the driver if the rotation of the mower and the rotation of tractors power take off (PTO) distinguish too much to give him assistance for an optimum velocity and motor speed (AGCO Feucht GmbH 2015).

Sometimes forgotten in consideration of grassland farming is the high number of killed animals during the mowing process. Whilst the first cut of grasslands in May the offspring of wild animals are already born and laying in high fields to be avoided from natural enemies. They often just lay down in case of unknown sounds and are killed or seriously injured by the blades of the mowing device. In 1976/77 there were 84.000 animals killed during harvesting just in West Germany (Wimmer et al. 2013). To avoid the offspring from such a fate there have been made several tests with sensors to detect them in high grass directly before the mowing process by a coalition of different scientific institutes. The "Wildretter Projektteam" ("Wild savior project group") (2012) came to the conclusion that mainly Unmanned Aerial Vehicles (UAV) carrying a thermal and a normal visual camera in combination are a proper method to tag and rescue animals. Devices attached at the tractor or the mower indeed showed bad results because the grass shielded the sensors radiation too much.

Tedders and Rakes

In German regions tedders are widely used. The cutted grass has to be dried quick to minimize disintegration and quality losses. Nevertheless, tedders, as well as rakes are responsible for the greatest part of disintegration losses which is said to be between 15 and 20 % in best case or even higher under bad conditions (Sauter et al. 2011). Sauter et al mention that about 60 % of the original protein can be left on the field. Because of the high mechanical stress of the forage crop, attributable for example to the tedders and rakes rotation speed, much leaves are pulled off and are left on the meadow. That is why Auernhammer & Neuhauser mentioned in 2001 that precision farming applications in especially this devices should be implemented, to reduce disintegration losses. While tedders show no real technology which is dedicated to precision farming, however rotor rakes do have at least some opportunities for this area. Alternative drivetrains are coming up in rotor rakes like hydraulic powered (company KUHN) which is already on the market or driven by electric power (company FENDT) which will be available in 2017. These technologies provide possibilities of using sensors for example to control the rotational speed of the rake.

Even though there has been not that much effort to implement information technology into these devices, there are attempts in reducing disintegration losses. The mergers for example, which pick up the forage and form it to a windrow with a conveyor belt attached to the rear of the Pick-up. This form of construction is said to be very indulgent to the forage crops.

Loading wagons, balers and choppers

Nowadays loading wagons are highly technologized machines in which the ISOBUS implementation is common used. Sensors in loading wagons are known for several years for example for automated filling and control of the scraper floor. Also automated sharpening systems are known and used to keep the needed power of the tractor on a low level and to guarantee a good cutting. First attempts to implement a yield measurement system in loading wagons are made by companies. The company Schuitemaker for example already sells a combined system in their wagons which measures the dry matter content of forage with a Near Infrared (NIR) Sensor in combination with a weighing system. The weight is measured by strain gauges in the undercarriage and in the drawbar (Schuitemaker 2015). First scientific research for this has been made by Wild & Auernhammer in 1999 in a baler.

Wild & Auernhammer were able to measure the weight of a bale very precisely in a baler which did not move (errors less than 1 %). While moving, there had been too much physical influences for a precise measuring. Kroulík et al. (2011) measured the mass of a bale by measuring the position of a tension roller of the circular belt in a baler with variable chamber. Good results were made for straw. For other kind of material further calibrations have to be done (Kroulík et al. 2011). For square balers there are already some commercial solutions existing to measure weight on the bale chute like Shinners et al. (2000) describe. First attempts for an ongoing measurement of the yield (for yield maps) are already done by Shinners et al. For specifying the quality of harvested forage, there is also a possibility needed to measure the moisture content and if possible the ingredients of forage. First Sensors are sold by companies to get the moisture content. New Holland for example uses the conductivity of crops to conclude to the moisture content.

Choppers are highly technologized. Due to their different possible applications, there are many different researches done in that machine. Moisture content and yield mapping is common used in newer machines and done by NIR Sensors and volume flow measurement. Because of their multiple possibilities of use (also in arable farming) and the broad scientific researches, the forage harvesters are not described in further details.

Silage heap

Due to rising effectiveness during the last years the compression of forage, either maize or grass became the weakest part of the harvesting chain. For gaining a high conservation quality it is absolutely necessary to reach a high compression. Because of short time slots when harvesting is possible, the amount of forage which is brought to a silage heap is quite high compared to the time. Therefore, the drivers on the heap are working under high pressure to compress the forage evenly and as fast as possible. In order to make this more efficient, some authors tested machines known from other purposes like vibration rollers (road construction). But also some suggestions with intelligent techniques were made. Hoffmann et al. for example worked in 2013 on a method to determine the compression of a silage heap via an online measuring system. The system based on a radiometric measurement method with caesium. Hoffmann et al developed an aluminum wheel in which the caesium was implemented. The wheel was drawn across the heap by a tractor. It was possible to measure the compression till 10 cm depth. Via DGPS a map of the heap was created and visualized to give the driver information about less compressed parts of the heap. The technology seemed to be promising, although a radiation source has to be used.

Future research options

Several developments from Precision Farming on arable land can be adapted to grasslands, like autonomous track guidance systems or sensor technologies. Using autonomous track guidance systems in grasslands is focus of scientific research at the University of Natural Resources and Life Sciences in Vienna (first results are presented at the XLV International Symposium "Actual Tasks on Agricultural Engineering" as well).

But also reducing disintegration losses should be a big topic of future research in precision grassland farming. Losses up to 20 % in best cases or even higher (Sauter et al. 2011) of protein material or in other words up to 800 liters of milk per cut and hectare (Pöllinger et al. 2013) are startling high numbers. Just small savings in this area may reduce the need of concentrate feed like soy significantly. Innovative propulsion systems shown by KUHN or FENDT promise new ways of using sensors in grassland machines and give the opportunity to reduce disintegration losses. Also, known communication interfaces like ISOBUS or other data interfaces can be used for that purpose.

CONCLUSION

Today, Precision Farming is not a science fiction technology. Since the beginning of the computer age it became possible to measure and interpret a big amount of data.

Nevertheless, precision farming is not common used in grassland or meadows. A review of agricultural machines with precision farming capabilities leads to the conclusion that this include mainly machines which are used on arable land as well as on grassland, like choppers. Such machines show a high amount of precision farming applications like track guidance systems, or near infrared sensors to capture the dry matter content of the harvested crop. However, machines, which are solely used in grassland have rarely been provided with intelligent sensor or steering technologies. Some authors mentioned poor profitability and a high number of different grassland harvesting machines as reasons for this (Schellberg et al. 2008; Shinners et al. 2000). However, there is a great potential for precision farming applications in this area. Mainly to avoid disintegration losses during the harvesting, especially by windrowing and tedding.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

APPLICATION OF GSM NETWORK FOR AUTOMATED SOIL MOISTURE INDEX (SMI) MONITORING

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ABSTRACT

A real-time SMI Monitoring System (SMIMS) was developed, laboratory-tested, calibrated and field tested in this study. The SMIMS was developed to monitor soil-water content and ultimately provide measures to prevent crops from stress, thereby increasing its productivity. Locally available electronic devices and soil moisture sensors were used. These devices were designed, modified and assembled based on the conceptual framework paradigm of the study. The signal was collected in the field and the data were processed in the microcontroller and sent through GSM in the form of short messaging system (SMS) into the Android phone. Simultaneously, the device sent information on the web or internet which displayed information through graphs and printable data for the current soil water content and soil moisture index (SMI) in the agricultural field.

Three locations of the study sites each in Bataan, Pampanga and Nueva Ecija (all in Central Luzon region, Philippines) were used for the laboratory and field testing. Soil samples were collected in BPSU Abucay Campus, Abucay, Bataan (N 14° 44.487′ and E 120° 27.098′), SRA, Floridablanca, Pampanga (N 14° 59.281′ and E 120° 31.886′) and WRMC Experiment Station, CLSU Science City of Muñoz, Nueva Ecija (N 15° 74.194′ and E 120° 94.460′) from each of the site identified. Laboratory and field calibrations were also done using the developed SMIMS prototype. The derived equations from the laboratory and field calibrations for SMIMS 1: Sensor -1 ($Y = -0.0008x + 0.6405$) and Sensor – 3 ($Y = = -0.0004x + 0.4769$); SMIMS 2: Sensor – 1 ($Y = -0.0004x + 0.3666$), Sensor – 2 ($Y = -0.0005x + 0.3769$) and Sensor – 3 ($Y = -0.0007x + 0.4174$); and SMIMS 3: Sensor - 2($Y = -0.0004x + 0.4405$) and Sensor - 3 ($Y = -0.0004x + 0.4293$) were installed in the SMIMS microcontroller for actual field testing.

Based from the SMIMS actual field performance and evaluation provided significant results thereby suggesting that this SMIMS may be introduced and used in most parts of the country particularly in agricultural areas. The system was found to favorably monitor real-time soil water content and SMI equivalent in the soil. This becomes useful in anticipating drought that will threaten crop productivity and farmer's income in some parts of the country.

Key words: Soil moisture index (SMI), SMI Monitoring System (SMIMS), Soil-water content, Global system messaging (GSM)

INTRODUCTION

The Philippines is presently facing the pressures of climate change in the agricultural system. Climate change is a real and urgent challenge that is already affecting people and the environment worldwide (United States Environmental Protection Agency, April 2010) [5]. Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable (Intergovernmental Panel on Climate Change, 2008) [3]. This will directly affect not only agricultural ecosystems but also human societies.

The great challenge for the coming decades is to increase food production with less water, particularly in countries with limited water and land resources. The effective and sustainable use of water for agriculture has become a global priority of vital importance, requiring urgent and immediate solutions in view of intensifying competition.

The importance of soil moisture has been neglected and more water resources are wasted. Knowing the exact soil moisture and SMI [6] status in the field could give better decision and plan on the use of more efficient water application thereby saving water and time. This process could lead to increased and intensified production which will ultimately improve agricultural productivity. The urgent need in this situation is to harness the existing resources that could favorably give advantage for sustainable agriculture production.

This study shall be able to provide advisory services to the farmers with the real-time soil moisture and SMI status of agricultural areas. The use of the automated system with the generated data shall be able to assist in mitigating potential crop production losses that will occur before the soil moisture reaches the minimum level that is favorable for plant growth.

The development of this technology aids in addressing the exact water needs of the soil for crop production in increasing agricultural products and farmers opportunities in the region in particular and in the whole country in general. This technology breakthrough is needed to mitigate and eliminate losses during farm production activities. To date, the cost of the imported soil moisture sensors and data logger is expensive for irrigation microcontroller. Further, our farmers have difficulty to avail after sales services for these imported products.

This study was focused on the development of automated system to identify the real-time soil moisture and soil moisture index (SMI) status in the field. It can provide farmers and farm managers the soil moisture information for drought monitoring that will be used for crop planning purposes, thus saving irrigation water, intensifying crops and enhancing production. Furthermore, this study is very significant in addressing the problems in real-time soil moisture and soil moisture index (SMI) status identification in agricultural areas and in monitoring the occurrence of moisture deficit in production areas covered by the study.

METHODOLOGY

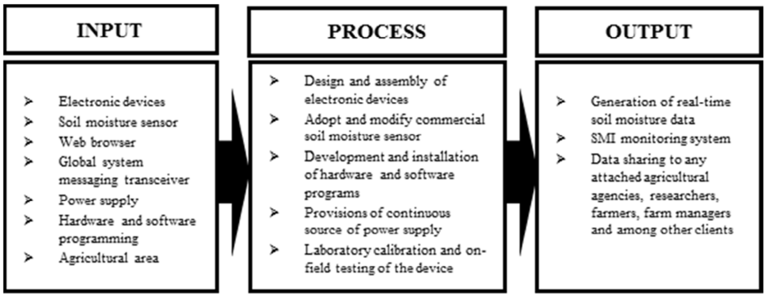

Figure 1. Conceptual framework of the study

The conceptual paradigm of the study is presented in Figure 1. The inputs were composed of electronic devices, soil moisture sensor, global system messaging (GSM) transceiver, web browser, solar panel, lead acid battery, hardware and software programming and agricultural areas. The process was to design and assemble the different electronic devices with the provisions of continuous source of power. The development and installation of hardware and software programs in the SMIMS that generates real-time soil moisture data and SMI value that will be viewed in the cloud computing.

Design concept

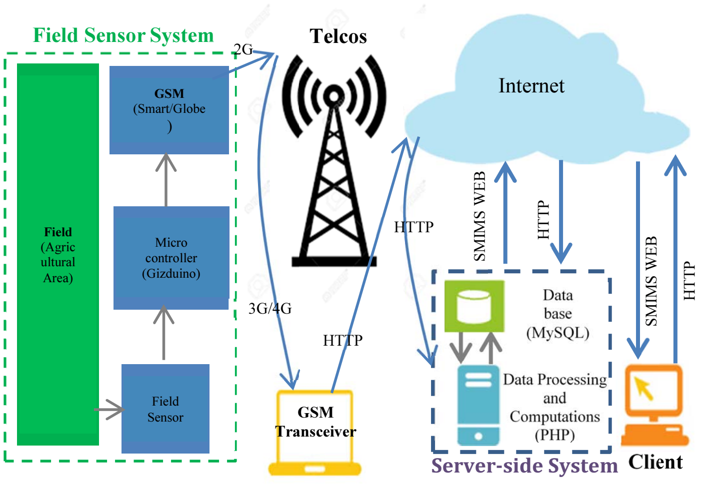

Figure 2. Schematic diagram of the SMIMS

The design concept was to quickly identify and monitor the real-time soil moisture in the field as presented in Figure 2. In this study, existing electronic devices[1] were utilized that was available in the local market. These electronic devices were assembled and modified to attain the concept designed. These field devices collected signals and converted them to equivalent soil moisture data. These soil moisture data will be transmitted to the GSM server (Android phone) and thrown into the dedicated web through the Telcos provider. The data collected in the database will be saved and processed for the client utilization. The client can browse the website in the real-time soil moisture and SMI status with graphical formats and printable data options.

Calculations

The following calculations were used to evaluate the data generated by the SMIMS to the actual soil moisture of the considered soil samples and the SMI computation that was encoded in the web program. The date and time of the data transmitted were also determined:

a) Gravimetric method

The gravimetric moisture content was calculated based on the weight of water per unit dry weight of soil:

$$w = m_{wet} - m_{dry} / m_{dry} \tag{1}$$

where: w - soil moisture content (g/cm3)
m_{wet} - mass of moist soil (g)
m_{dry} - mass of the dry soil (g)

b) Soil Moisture Index (SMI)

The equation for the SMI used was developed by Hunt (2009) [2]. The field capacity and the permanent wilting point identified location was considered and these values were used together with the calibrated readings to the actual soil moisture were as follows:

$$FAW = (AM - PWP) / (FC - PWP) \tag{2}$$

where: FAW - field available water
AM - available moisture
FC - field capacity
PWP - permanent wilting point

$$SMI = - 5 + (10 * FAW) \tag{3}$$

where: FAW - field available water
SMI - soil moisture index

RESULTS AND DISCUSSION

The SMIMS was designed to facilitate the collection, processing, and transmission of signal directly from the field to cloud computing which would provide real-time information of soil water content and soil moisture index (SMI). As shown in Figure 2, the components were composed of the Field Sensor System, the Telco, and the Server System.

Preliminary testing and evaluation

After the fabrication and assembly of the developed SMIMS prototype, the results of the preliminary testing of the different components were tested and evaluated. The power supply, consisting of a 12-V lead acid battery and a 20-W solar panel was inspected and tested if it automatically switches from solar to battery and vice versa. It was observed that when the panel was exposed to sunlight and produced more than 12V, the lead acid battery was charging and providing power to the device.

The solar panel was able to produce 18.3-W when the sun shines at high intensity between 11 AM to 2 PM. At the early and late part of the day the solar panel cannot charge the lead acid battery due to insufficient voltage generated. At this time, power was directly supplied by the battery. With these results, the developed power system for the device was assured of a continuous operation for soil moisture data collection in the field. Preliminary testing of the other components was also successful with regards to their respective functions in the system.

Calibration curves of the Soil Moisture Sensors

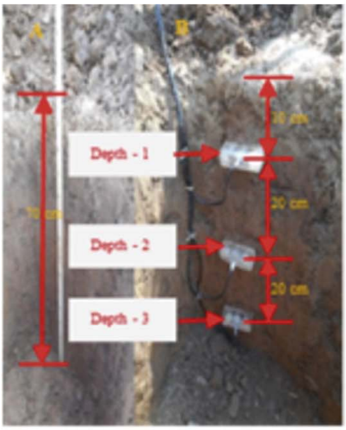

Figure 3. Location of the sensors from the soil profile

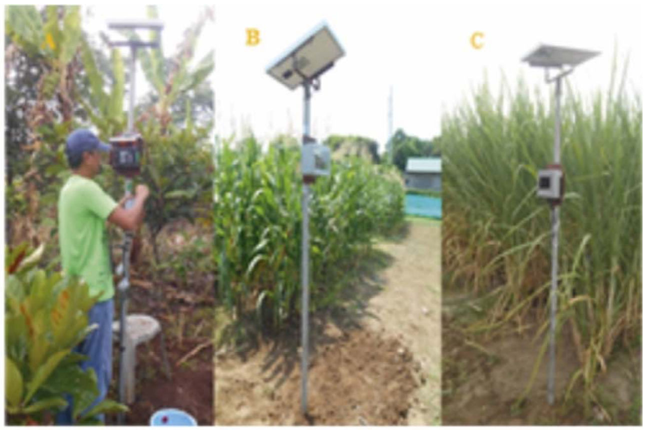

Figure 4. Installed RDSM device in the selected provinces in the Reagion 3 (Abucay, Bataan, WRMC, CLSU Nueva Ecija and Floridablanca, Pampanga)

The laboratory and field calibration data generated from the three station sites identified were analyzed using regression analysis and the calibration curves for each sensor were derived. The derived equation in the laboratory calibrations [4] for each sensor were used in the microcontroller program and tested for field calibration. The collected data were compared in the laboratory and field calibration and the resulting linear equation was the final adjustment factor for each sensor. Figure 3 and 4 are the actual locations of the installed soil moisture sensors at three different depths and SMIMS for every station sites.

Based on the laboratory and field calibration data of each sensor, an adjusted regression equation was determined (Table 1). This is the final regression equation inputted in the microcontroller program used in the actual monitoring of soil moisture in the field.

Table 1. Final regression equation generated for each sensor

SMIMS No.	Sensor No.	Regression equation	R^2	Remarks
SMIMS 1	Sensor 1	Y = -0.0008x +0.6405	1	None
	Sensor 2			Disconnected wires
	Sensor 3	Y = -0.0004x + 0.4769	1	None
SMIMS 2	Sensor 1	Y = -0.0004x + 0.3666	1	None
	Sensor 2	Y = -0.0005x + 0.3769	1	None
	Sensor 3	Y = -0.0007x + 0.4174	1	None
SMIMS 3	Sensor 1			Disconnected wires
	Sensor 2	Y = -0.0004x + 0.4405	1	None
	Sensor 3	Y = -0.0004x+ 0.4293	1	none

Y – adjusted SMI value; x – actual value generated by the sensor

Field Performance of the SMIMS

The real-time data collected from the field sensors and sent to the Android phone and to the database were tabulated and analyzed. This was done to determine the observed moisture contents and the computed soil moisture indices at an hourly time increment.

Observed moisture content at different depths

Actual data generated from SMIMS 1

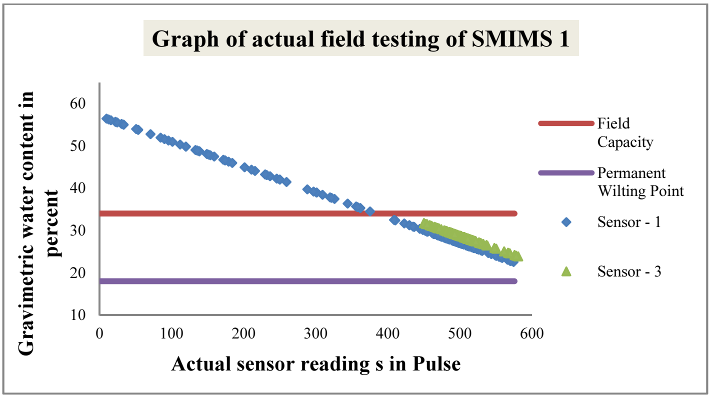

Figure 5. Actual data generated from SMIMS installed in BPSU Abucay, Abucay, Bataan

The graph of the actual data is presented in Figure 5. A total of 378 soil moisture data accumulated for 30 days period in the station sites was recorded. These data transmitted by the device were only about 54 % and the remaining percent was not transmitted due to the technical problems in the SMIMS encountered during the field testing where Sensor 2 was affected and failed to generate data.

At Depth 1, the Sensor 1 responded sensitively from the changes of soil moisture in the soil as evidently seen in the data collected and the soil moisture easily changes at this level.

However, at Depth 3 where Sensor 3 was located, the observed soil moisture in the soil was within the level of field capacity and permanent wilting. The soil moisture readings were observed to be stable.

Actual data generated from SMIMS 2

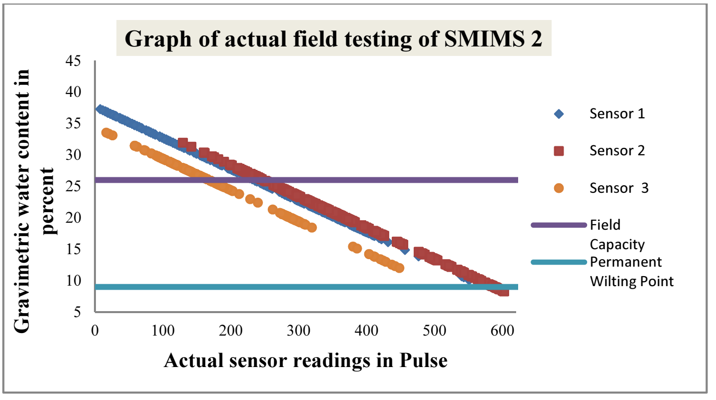

Figure 6. Actual data generated from SMIMS installed in SRA, Floridablanca, Pampanga

The SMIMS 2 was installed in SRA, Floridablanca, Pampanga. Figure 6 presents the results of data at Depth 1, 2 and 3. The generate graph for 30 days period was around 688 data points equivalent to 95.56 %. The high percentage of data transmitted was due to the proper component assembly. The observed readings were distributed and almost half of the results were recorded within the field capacity and permanent wilting point while the others were above the field capacity. However, some of the observed data collected at Sensor 2 are near the permanent wilting point indicating that crops at this level were within the critical level.

Actual data generated from SMIMS 3

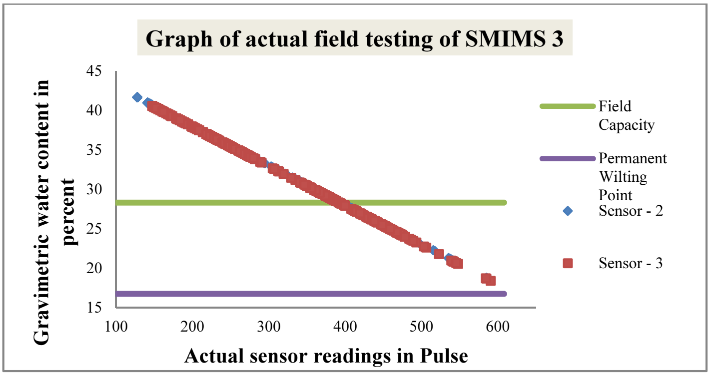

Figure 7. Actual data generated from SMIMS installed in WRMC, CLSU Science City of Muñoz, Nueva Ecija

The SMIMS 3 was installed at the WRMC, CLSU, Science City of Muñoz, Nueva Ecija (Figure 7). The graph presented the 538 data points generated for 37 days which was equivalent to 49.43 %. Almost half of the data were not transmitted due to power system problems while Sensor 1 at Depth 1 encountered wire connection problems during the installation process.

In the graph at Depth 2, most of the observed data were above the field capacity level while the remaining part was within the field capacity and permanent wilting point boundary while at Depth 3 most of the observed data were above the field capacity of the soil while the rest were within the boundary of field capacity and permanent wilting point.

Web-based Soil Moisture Indices

Web-based output of SMI generated by SMIMS 1

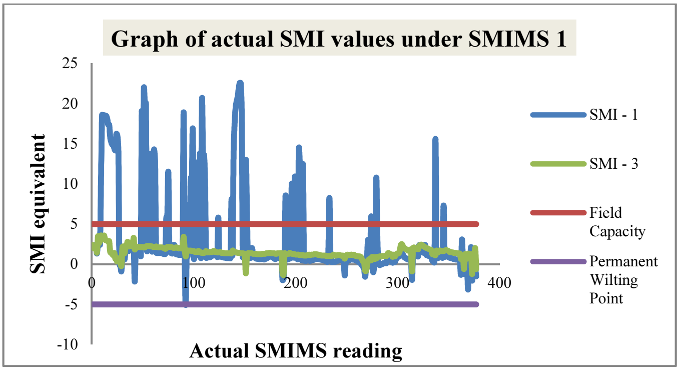

Figure 8. Actual SMI values generated from SMIMS 1 installed in BPSU Abucay, Abucay, Bataan

Figure 8 presents the graph of the corresponding SMI values for 30 days observation period. The SMI equivalents in Depth 1 were mostly above the +5 value indicating that there was excess soil water in the soil while other data nearing the zero value that it is within the range of MAD. It was also observed that there were few data below the zero value which suggested that the soil at this depth experienced water stress as indicated in the generated graph. The increased of the readings was caused by the water application that sensitively responded and detected by the sensors while the decrease were the changes of soil moisture due to the high drainage flow movement of soil moisture within this level. However, the abrupt decrease was observed before the stored energy in the battery was totally consumed. At this condition, the SMIMS responses was very low which recorded and plotted in the graph.

The SMI values generated at Depth 3 were mostly in between 0 and 5 which was in the range of MAD. This suggested that the soil water at this depth was favorable for crops and also at this depth, the soil moisture available was almost stable. However, there were data points in the observed graph that were below zero value indicating water stress at this level. The abrupt decrease in readings was observed before the SMIMS stops sending signals which indicate that the required energy to facilitate the processing of data was not sufficient to provide normal readings.

Web-based output of SMI generated by SMIMS 2

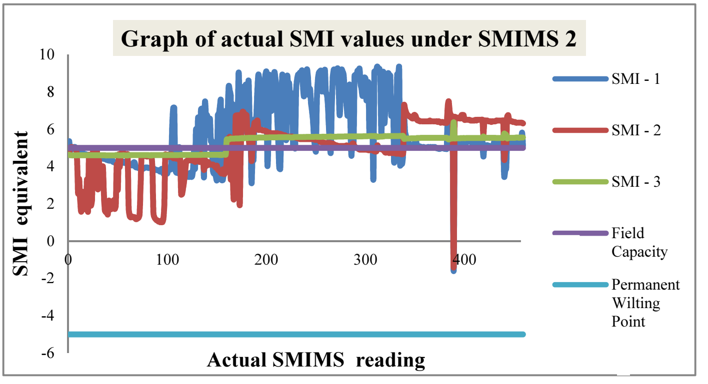

Figure 9. Actual SMI values generated from SMIMS 2 installed in SRA, Floridablanca, Pampanga

The computed SMI value at Depth 1 (Figure 9) was mostly above +5 value while the other data points were within the zero and positive five value which means that there was a sufficient soil water available for crops where the soil water content in the soil was high and favorable for the growing crops. However, it was observed that there were fluctuations in the recorded data due to the sudden increase of soil water in the field that was caused by water application in the area while the abrupt decrease was due to the fast soil water flows at this depth.

The equivalent SMI values at Depth 2 for Sensor 2 were fluctuating from the +5 to 0 value while some parts of the data points were above +5 value which suggested that there was sufficient soil water within this depth. Also, there were data recorded below zero value which was affected by the poor wire connection problem from the sensor to the SMIMS microcontroller during the actual field testing which resulted to the unstable and erratic data generation at this level as indicated in the graph.

The SMI values for Sensor 3 at Depth 3 were consistent and near the +5 value with limited fluctuations as presented in the graph. This indicated that the soil water condition was favorable for crops without soil water shortage at this depth. This was due to the soil structure condition where the subsoil was located and the changes in the soil water content was minimal.

The SMI equivalent for Sensor 2 is presented in Figure 10. The observed values were fluctuating during the early stage of the actual field evaluation due to the power source problem that was encountered in the SMIMS 3. The generated SMI values at this depth were mostly above the +5 value which suggested that there was excess soil water at this depth while the other was below +5 value which means that it was within the range of MAD that favors crop growth.

Web-based output of SMI generated by SMIMS 3

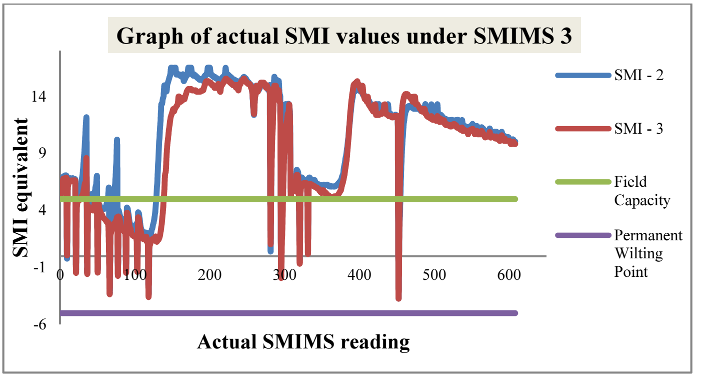

Figure 10. Actual SMI values generated from SMIMS 3 installed in WRMC, CLSU Science City of Muñoz, Nueva Ecija

The SMI equivalent generated at Depth 3 was above the +5 value except in the early part where the SMI drops below the +5 value. The fluctuation was similar to Sensor 2 due to the power system problem in the SMIMS. This indicated that the observed data was above the +5 which means that there was excess soil water available in the soil as observed in the data collected at this depth.

The abrupt decrease of the readings from the SMIMS in depth 2 and 3 as indicated in the generated graph. This instances occur before the SMIMS stops sending messages were the data was very low or way below the previous data. This technical problem from the SMMIS was observed in the power system were the excess energy produced by the solar panel during the daytime operation was not fully utilized in which during the absence of sunlight the energy stored in the battery was not sufficiently run the SMIMS system normally.

The wed-based SMI output

Figure 11 presents the sample of soil water content readings collected from the SMIMS located in the testing field area in SRA, Floridablanca, Pampanga. In the Android phone, every message received the device number and the sensor readings of every depth installed in the station site in which s1 (Sensor 1), s2 (Sensor 2) and s3 (Sensor 3) where the designated depths at 10 cm, 30 cm and 50 cm. The messages received by the Android phone with the values after the s1, s2 and s3 statement was the actual soil water content of the soil in that location. Also, the date and time were displayed below the messages. These messages were automatically sent into the dedicated website through the SMS Gateway application. The created password served as the firewall protection mechanism to accept and reject the message sender in which the SMIMS dedicated web program executed.

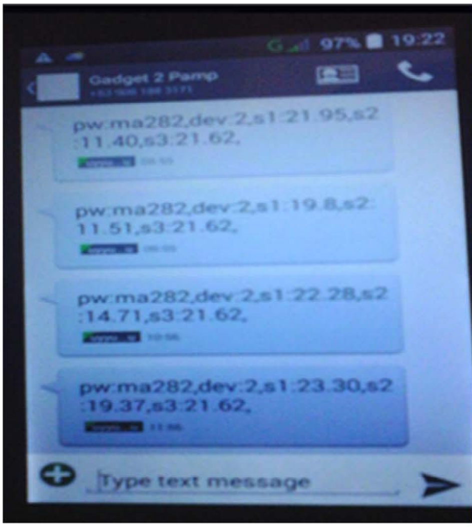

Figure 11. Sample soil moisture data messages from SMIMS 2 displayed in the Andriod Phone

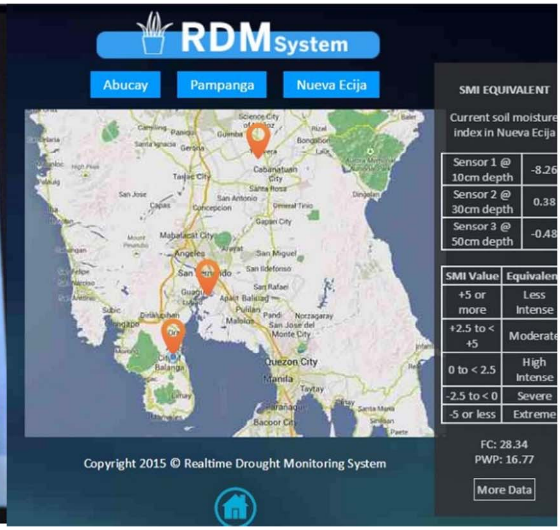

Figure 12. SMIMS web page displayed the SMI values at three different depths

The received messages were stored in the database and processed when needed during the cloud computing using the dedicated web browser www.agriculruresystem.tk. The real-time soil moisture and SMI values at the different depths of the sensors were displayed in the created webpage. Figure 12 presents the web page, data navigation shortcut menu that is available for browsing the needed information of the soil moisture content status in the area. Clicking the navigation button in the map where the installed SMIMS was located will automatically display the calculated current value of the SMI with the corresponding SMI equivalent. Clicking the name of the area at the top of the map in the webpage will display the daily generated data from field in graphical and printable data format and an option button that will navigate the previous data stored in the created database and will be presented in graphs, tabular form and printable option.

Observed data transmission of the SMIMS at different station site

The transmission time of the data from the SMIMS was dependent on the current Telcos signal in the area. The delay and recurrence of messages were affected by the strength of the signal in the Telcos system while the advance and late messages were created by the program in the SMIMS microcontroller.

CONCLUSION

Continuing water crisis affects crop productivity. Inefficient use of water during rainy season and lack of water resources during dry season are a common phenomenon in this country in general and in Central Luzon, where this study was conducted in particular. Recently, the country was hit by the El Nino phenomenon where most crops in the southern parts of the Philippines were greatly affected. With this, real-time SMIMS is necessary and has been developed and done in Central Luzon.

The development and installation of hardware programming based on the design platform of the system and software programming that facilitate the processing of data transmitted and viewed in the dedicated designed web browser that was shared in the cloud computing. Calibrations were carried out both in the laboratory and field for the SMIMS and the actual field testing and evaluation was done in Bataan, Pampanga and Nueva Ecija.

The Web-based SMI outputs of this study, through the device will generate information and will send signals to the Android phone stating the real-time soil water content from the area being covered while at the same time also being sent to the website which will show the soil water content at three different depths in the form of graphs, tables and SMI equivalent based on the information provided by the SMIMS. This information can be utilized by the target clienteles like: farmers, farm planners, researchers, student, technology experts, and policy-makers for monitoring and look into for suggestions and recommendations to mitigate the effect of soil water content and to sustain crop production and productivity.

ACKNOWLEDGEMENT

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Original scientific paper

ANALYSIS OF INFLUENCING FACTORS ON INFIELD LOGISTICS IN GERMANY

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SUMMARY

Future efficiency enhancements in agriculture will not only be achieved by higher engine powers or rising working widths but increasingly by process optimizations of agricultural production processes. Navigation not only to the fields but also within the fields will certainly contribute to make use of these efficiency reserves. Knowledge of potential influences on infield-logistics is a basic requirement to be able to navigate agricultural machinery in the fields effectively and process optimized individually or in process chains.

A view inside the agricultural landscape of Germany illustrates that farmers do not always implement the infield strategy suggested by a mathematical optimization tool. Thus, there must be influencing factors which are more important for farmers concerning their choice of infield patterns. Both farm managers and staff members act quite farm specifically as well as depending on technology or situation and furthermore often intuitive.

To analyze these “soft” influencing factors the examinations are based on expert interviews with the aid of aerial images. The study is intended to cover the entire range of German agriculture from rural mixed farms up to large agricultural cooperatives farming thousands of hectares.

First results show that farm managers using guidance systems increasingly attune their infield-logistics on direction giving obstacles. In consequence they can avoid inefficient boom flippings while doing plant protection. Livestock farmers rather focus on the application of organic manure with its specific requirements concerning road conditions, landscape terrain or field access points. Cultivation of sugar beets makes great demands on infield patterns because of its particularities such as the row crop system or high logistics demands.

Summing up the choice of specific infield strategies always is a compromise of many influences. Mostly it is not enough to consider one single working step but the entire production process. The obtained influencing factors can be afterwards integrated as decision criteria into an infield navigation tool. Thus process efficiency can be further increased.

Keywords: Infield logistics, process organization, route planning, vehicle navigation

INTRODUCTION

In future agriculture not only higher engine power or higher machinery working widths will contribute to enhancing efficiency but also optimized techniques of agricultural processes that are well organized and coordinated (Mederle et al. 2015). Infield logistics especially has to be considered when several machines are working together in one field. In this case optimal coordination of all equipment being part of the process is very important (Bochtis et al., 2007b).

The more machines are interacting in complex process chains, the higher is the optimization potential of the logistics behind it (Bochtis et al., 2007a). Badly organized process chains lead to higher shares of dead times during the process and result in rising costs per unit produced (Lin Li et al., 2013).

Some software solutions already help at planning and organizing of complicated agricultural processes (Bakhtiari et al., 2013). These analysis and optimizations often are conducted post-harvest and base on experience (Costa et al., 2014). Hence, they mostly are not really feasible for pre-planning of possible infield routing.

However, infield path planning will increasingly contribute to make agricultural production processes more efficient in future (Zhou et al., 2015). By now researches concerning logistics rather deal with navigation on public and field roads till the edge of the field which is useful for contractors or big farms with changing staff to help finding the fields to be worked (Götz et al., 2014). By contrast, infield logistics is known as area logistics. Farmers could choose an endless number of possible lanes to work their fields but only a certain part of them is realistic and practicable.

Although there has been done a lot of optimization concerning infield-logistics during the last years farmers still do not always implement these theoretical optimizations. The predicting calculations mostly base on field geometry and do not really take into account the reasons for certain farm-specific infield-strategies. There reasons why farmers do not work their fields as the optimization pretends partly differ from farm to farm and are often based on experience or intuition. Not every farmer decides the same way in a specific situation (Mederle et al., 2016).

The goal of this research is to find “soft” influences on infield logistics which are hardly researched scientifically. These decision criteria should be analyzed and considered in order to optimize route planning within the field.

METHODS

Main part of the research is a survey of farmers all over Germany in the shape of an expert interview. The advantage of direct conversation compared to a standardized questionnaire is that farm-specific information can clearly be registered which ends up in good data quality.

To cover as many different types of farms as possible is intended because variety of German agriculture is very broad. Arable farming in the north and east is rather large-scaled and farms are often organized as agricultural companies. By contrast, family farms with mainly smaller sizes dominate the structure in the south.

Every interview is clearly structured and starts with general questions on the particular farm. Next part covers general questions on infield strategies. Third section of the guideline deals with issues concerning headland, patches and tramlines. Further parts of the interview are about various operation steps as tillage, seeding, plant protection (fertilizing or spraying) or grain harvest. Livestock or biogas farmers are additionally asked about slurry or organic manure application affairs.

Table 1 shows 12 farmers of different parts in Germany with various agricultural preconditions that have already been interviewed in the first step of the study.

The participating farms have been clustered in 3 different categories depending on their amount of arable land in hectare. 3 of the participants farm less than 100 ha but all these 3 also do livestock farming for having more refinements per hectare. One of them cultivates sugar beets whereas no one uses GPS technology. Half of the already interviewed farmers belong to the second group of 100-500 ha arable land. Five of them grow sugar beets and two thirds use GPS assistance systems with RTK accuracy. 3 participants farm more than 500 ha. This range is from 640 to 1200 ha. All these 3 use RTK technology but only 2 cultivate sugar beets.

Table 1. Already interviewed farmers

Farm size	Total number	Livestock farming	Sugar beet cultivation	Use of GPS technology
< 100 ha	3	3	1	0
100-500 ha	6	0	5	4
> 500 ha	3	1	2	3
Total	12	4	8	7

RESULTS AND DISCUSSION

First results of the evaluation show that influences on infield logistics can be categorized in two different groups. There are so-called “hard” factors which are not or only hardly changeable, such as field shapes, field sizes or field access points. Of course, the geometry of a field strongly affects the working direction of this specific field. “Soft” factors can be changed quite easily because they strongly depend on organization and structure of a particular farm. Examples therefore are e.g. facilities with manpower or utilized mechanical equipment.

Figure 1 illustrates that different farm types take different influences into consideration when talking about infield strategies.

The field is surrounded by neighbor fields north and south as well as by field roads east and west. Arable farmers who are not reliant on the application of organic manure but do all their fertilization with mineral fertilizer choose the north-south lane (Scenario A) because they do not have to move that much amount of tons. Nevertheless, concerning sugar beet cultivation even non-livestock farmers answer to take the shorter east-west-lane in order to position the beet clamp along the field roads and so to ensure a smooth harvest removal by trucks.

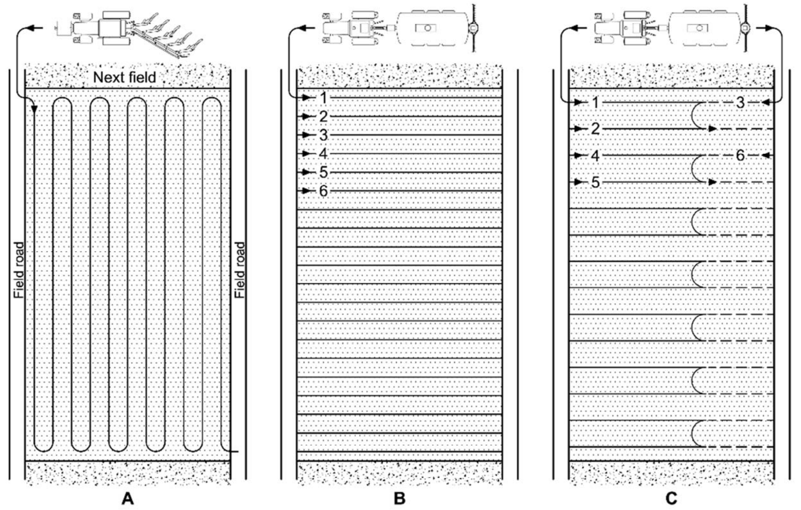

Figure 1: Different infield-strategies depending on various operations or farm types

Scenario B and C represent operations where supply-logistics is required, e. g. slurry application. Livestock farmers indicate to make use of the field roads for direct entrance and exit of the field without any unnecessary dead ways within the field. The agricultural public path network now surely has influence on the infield-strategy and farmers will also arrange the tramline system in east-west-direction. Tramline systems play a significant role in German arable farming because conventional agriculture mostly is practiced with high intensity. In these tramlines farmers go up to 5-8 times with the sprayer or fertilizer spreader for plant maintenance.

The difference between scenario B and C is the working width of the slurry tank. In B it is operated with a smaller width to be able to cover the whole west-east-distance. This scenario is fitting either for smaller-scaled farms with closer tramline pitches or even for bigger farms when spreading manure on the stubble field after harvest.

Scenario C is to illustrate slurry application in growing plant stocks with defined tramlines of up to 36 meters pitches. Particularly in case of bigger distances one manure tank is not enough for covering the whole field length. Reduction of the working width is no option because too many plants would be irreversibly damaged. To face this problem there are two possibilities: either reducing the application rate or to take three tanks for two tramlines (Scenario C).

As mentioned before sugar beet has very high influence concerning infield logistics. Two of the main issues are high mass yields per hectare as well as supply quota. Additionally the positioning of the beet clamp requires some considerations because removal logistics is mainly carried out by trucks which are not able to use field roads of bad quality. Further soft influencing issues are e.g. weather conditions which particularly affect the organization of the harvest process chain. Sugar beet harvest usually takes place in autumn from September until December with high probability of wet conditions that will inevitably result in soil compaction. Furthermore, farmers often are interested in late harvesting because otherwise the sugar content of the beets might be too little. This fact additionally intensifies the already mentioned problems of wet conditions and soil compaction. Thus some farmers prefer as little machines as possible in the field. This kind of harvesting system is called single-phase harvest and typical for smaller-structured agriculture. The sugar beet harvester does the work completely on its own without any additional unloading trailers.

Figure 2 shows a typical case for farmers dividing their fields for growing sugar beets. One reason for this measure is the farm-specific supply quota. No farm is allowed to deliver more than this contractually committed quantity of sugar beets. In the present example this amount is equal to the estimated yield of 13 to 14 ha cultivated sugar beets. If the farmer wants to grow sugar beets on this particular field of 27 ha in total, he has to separate it into several subunits for not exceeding the delivery volume. There would be two possibilities of separating, across or along the longer edge. Thus further influencing issues have to be considered. Several reasons suggest to cut the field the way shown in figure 2. As mentioned before the harvest system plays a significant role. This farmer explicitly wants to work without multiphase logistic systems in the field because of soil protection. Severing the field length ensures that the harvester does not have to cover more dead distances than unconditionally necessary with full beet tank. Therefore the farmer is willing to accept more time for turning and unloading while standing. Indeed this prolongs the whole harvesting process and makes it less efficient but on the other hand one single machine with one single operator can get the harvest done, so less machinery and less manpower is required. Other farmers rather focus on process times of the expensive harvest machine at the expense of more vehicles being in the field.

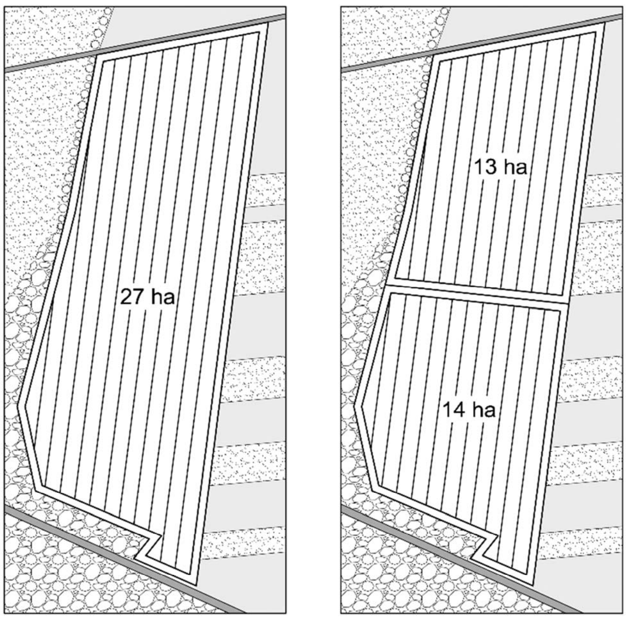

Figure 2: Field arrangement depending on sugar beet cultivation

Another issue is the beet clamp that should be positioned parallel along public roads or at least well developed field roads because removal logistics is completely carried out by trucks and lorries which cannot run on field roads of bad conditions. The main working direction of the field should be vertical to the beet clamp. Thus ineffective dead distances with full tanks and without harvesting can be kept low.

There are cases in which sugar beet cultivation strongly affects the way farmers arrange the tramline system of their fields because the decision-maker has to make compromises. On the one hand field lengths are wanted to be as long as possible to have both high process efficiency and less time needed for turnings. On the other hand dead distances with full bunker lead to soil compaction and decreasing yields. The positioning of the beet clamp, a major influence, additionally pretends the main working direction. Furthermore, the type of harvest organization, e.g. single-phase harvest, have to be adjusted and taken into consideration when planning infield strategies.

A feasible solution for field lengths being too long would be a special headland designing as shown in figure 3**.** The sugar beet harvester is not able to cover the whole distance from one edge of the field to the other and back (1400m in total) with one bunker. This is too much and would lead inevitably to dead distances. Thus the farmer decided to enlarge the headland at the eastern side of the field to reduce the distance of the main field to 520m. This adaption ensures that the harvester's tank size suffices for one working round which is now 1040m.

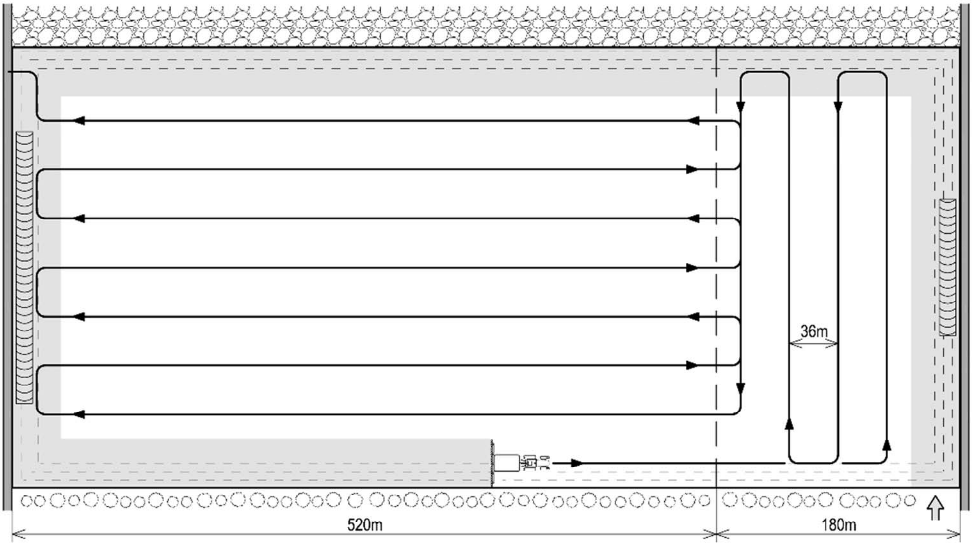

Figure 3: Influence of sugar beet cultivation on headland designing

For grain crops as barley, wheat or canola, it would not be necessary to arrange the tramlines this special way because there would be no problem to cover the whole distance with one grain tank of the combine harvester. Secondly, compared to sugar beet harvesters combines do not mandatorily have to take the same routes or working directions as the seeding machine pretends. Tramlines could be arranged as long as possible for high process efficiencies in plant protection measures with little turning times. This is definitely useful because in intensive conventional agriculture the mechanical equipment has to pass the plant stock up to 8 times for fertilizing or spraying whereas harvest could be done across the tramlines as far as necessary.

In the particular issue of working directions and tramlines sugar beet cultivation is a very special challenge because of its particular row crop system. To get the harvest done with good results of working quality the beet harvester has to take exactly the same working direction as the seeding machine. Furthermore it is not recommendable to make tramlines across the beet rows because of damaging beets. Thus the seeder already has to work the field exactly the same way the plant protection measures are carried out and finally the beet harvester should harvest it.

One of the major influences on infield logistics is the common agricultural structure the specific farm is located in. Figure 4 shows an example for that issue. This particular field has a size of 23 ha in total and is completely owned by one single farmer. According to Engelhardt (2004) in Eastern Germany the average field size is 49 ha and thus compared to the average a field of 23 ha is quite small anyway. Probably no farmer would even think about separating the field in different subdivisions because the general opinion is 'the bigger a field the more efficient work can be done'. Unnecessary subunits only would cause more time for avoidable turning or machine set-up. Quite the contrary, farmers even change fields and in consequence do not farm their own or their rented land in order to enlarge units. Looking to the southern part of Germany, e.g. Bavaria, the situation is completely different. The field shown in Figure 4 is in possession of a typical family farm with arable land of 65 ha in total. Thus this field is one third of the entire farm land.

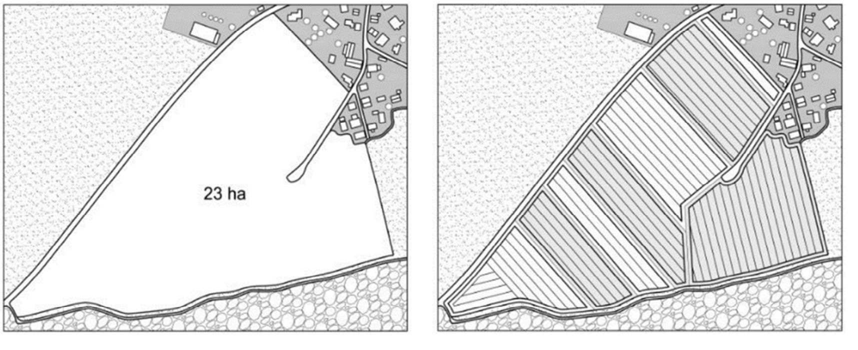

Figure 4: Influence of general agricultural structure on field subdivisions

For spreading the risk as well as for adapting this field to the structure of his other field sizes the farmer separates the field into different subunits of about 2-4 ha. A further reason for the subdivision is the cultivation of sugar beets once more. Only few farmers in Bavaria are in possession of supply quota that complies with 23 ha of acreage. Thus fields are subdivided and sugar beets only are cultivated on sites of good soil quality. Additionally removal logistics by trucks has to be considered and ensured.

Headland designing also is an issue that is dealing with the common agricultural structure and which is mentioned by farmers in the survey every now and then. Headland is an essential part of the field because every machine uses it quite frequently especially for turning. The worse the conditions during working in the field the higher is the danger of soil compaction and consequently decreasing yields in this part of the field. In addition headland is often used for temporary storage of harvest goods, mainly sugar beets, or fertilizers like manure or lime. All these influences require special measures as frequent deep tillage to keep the soil damage as low as possible.

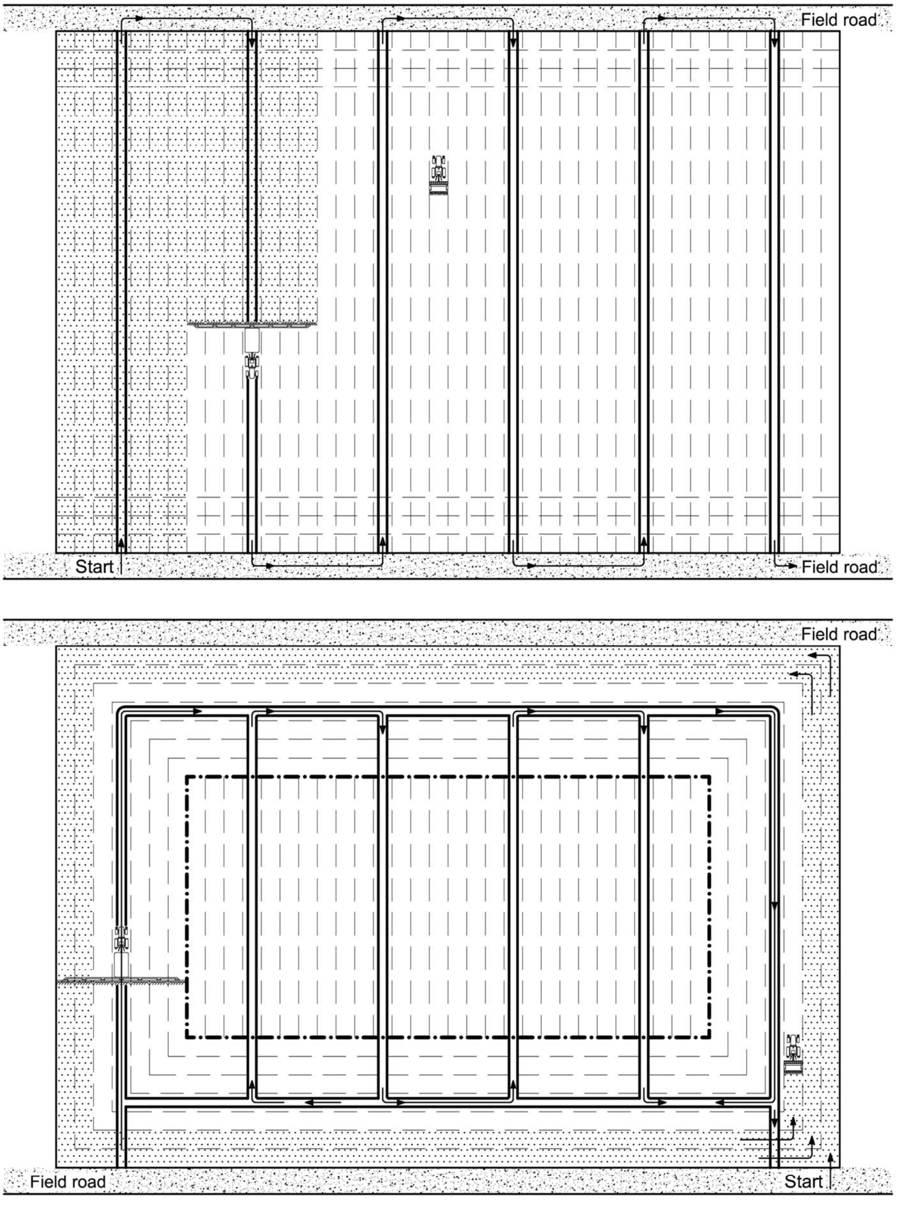

Figure 5: Different ways of headland designing in consideration of various influences

Because of all the reasons mentioned above farmers have particular interests concerning the headland designing which has to be considered individually for each field. Especially smaller-scaled farms tend to keep the headland as small as possible because otherwise the share of headland compared to the field in total would be even higher than anyway. Additionally, small fields usually do not have high field lengths, so these are not unnecessarily wanted to be even shortened. Furthermore small structured agricultural landscape usually provides a well-established and close network of field roads almost every field is directly connected to. In order to protect the headland from soil compaction farmers try to turn their machinery equipment off-site the field on a paved road or in an adjacent fortified area. Figure 5 shows these facts in its upper part.

By contrast farmers with more arable land and bigger machinery respectively prefer a tramline surrounding the whole field (shown in the lower part of figure 5) for not having to leave the farmland while working. Firstly this is due to bigger working widths of the implements. Specifically in case of spraying a boom of up to 36 m has to be flipped significant more often because of any obstacles, like trees or power poles, than a smaller one.

Another reason for this kind of headland designing is the usage of different machinery types.

Trailed or saddled implements for higher working widths at tillage or seeding require different ways of turning manoeuvers with the need of larger headlands. Mostly headland sizes are adjusted to the farm individual machinery that carries out the following work, e.g. the working width of the sprayer. Furthermore keeping machinery within the field helps the farmer to avoid dirty public or field roads and thus higher acceptance of the society. Finally in many cases there is no possibility at all to leave the field for turnings because it is surrounded by natural boundaries like hedges, woods or ditches.

CONCLUSIONS

Generally influencing factors on infield logistics can be categorized in "hard" and "soft" factors. Field geometry, the terrain of the landscape as well as the common structure of the particular rural area are some of the biggest influences which are hardly changeable. More difficult to detect are influences that are caused by farm specific organizational reasons or by technical issues.

Farms with differing orientations and focuses respectively consider an equal issue in different ways because of varying preferences. Arable farmers focus on high field lengths with high shares of process times whereas livestock farmers rather focus on the application of manure with the influencing network of roads and paths through the landscape. Furthermore the cultivation of sugar beets plays a significant role when thinking about infield strategies. Depending on the common agricultural structure and farm specific organization all influences might differ from farm to farm. In addition they always have to be considered field individually.

Summarizing infield logistics and the system due to which tramlines are arranged in a specific field strongly depend on common agricultural structures, on types of machinery equipment used on the examined farm as well as on the kind of production the farm is set up for. In the end agricultural infield route planning always represents a compromise of all sorts of influences being mentioned above.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 636.083.1:636.1
Stručni rad
Expert paper

PRELIMINARY COMPARISON RESULTS OF DIFFERENT BEDDING MATERIALS FOR HORSES

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ABSTRACT

Through the research, four different materials have been tested: two types of sawdust (one in bulk and second is packaged), straw in bulk and slice-dusted straw. During the survey the measuring and collecting the everyday observations to get the data about capacity of eliminated materials and time to clean the stalls were carried out. Results show different characteristics between the bedding materials. After the statistical analysis, the main conclusion of the paper going in the way to statistical significant correlation between characteristics of bedding material and weight of horses. Our predictions get in the way that findings in this paper can make a good contribution to economic analysis of using bedding material for (sport) horses.

Key words: Economic analysis, bedding materials, horses, stable

INTRODUCTION

The bedding material is one of the technological elements in stables. The main function of the bedding material is to absorb the moisture, so it is possible to maintain a dry ground and optimum microclimate parameters in the stables. The absorption properties of the bedding material are also important for the absorption of harmful gaseous impurities present in the stable air. Fresh, clean air in the stable is not only essential for the horses health, but also for their care takers (Kwiatkowska-Stenzel et al. 2016). The choice of good (or the best option) of bedding material is also decision making problem based on the right proportion between economic and technologic material assessment. The optimal costs of bedding materials could make a good contribution to reducing the total costs on the farm. According to Werhahn et al. (2010), Garlipp et al. (2011) and Kwiatkowska-Stenzel et al. (2016) we can found out that choosing of bedding material in horse stables have two important aspects i) on the behavior of horses, ii) on the air quality conditions. Both have the important consequences on the animal health status and further for reducing the veterinarian costs. However, chemical and physical properties of bedding materials have been usually analyzed while there is no information about the economic assessments of using different bedding material in equine breeding.

From this aspect, the aim of this study is to analyze four different bedding materials (two types of sawdust - one in bulk and second is packaged, straw and slice-dusted straw. The research based on collecting data about technical and cleaning characteristics of 4 different bedding materials on 8 warmblood horses.

MATERIAL AND METHODS

The experiment was carried out between 15th February and 6th March 2016 (during the winter the time of standing the horses is also during the day, otherwise it is not usually during summer time - pasture) and consists from collecting the everyday quantitative measurements (which one) to get the information about technical characteristics of bedding materials.

Stable characteristics

The measuring of technical characteristics of four bedding materials on eight warmblood horses with the body weight vary between 294 and 488 kg housed in single stalls were analyzed. For estimation of the horse body weight we used Adult horse weight calculator (The Horse 2016) (with previously measuring the horses heart girth and body length). The important fact was the equivalent values of stalls dimensions which were 270 x 270 cm. We were focused to provide the same conditions in all stalls (size, floor, inside temperature, etc. We were focused to choose the horses with comparable weight (±70 kg) and with the same behavior and breeding conditions (not aggressive pattern, 3 to 4 times of ridings per week and same feed ration – optimized by Prišenk et al. 2013) as much as possible.

Data collection setup

Four different bedding materials (Table 1) on 8 warmblood horses have been tested. We were focused to choose the horses with comparable weight (±70 kg) and with the same behavior and breeding conditions (not aggressive pattern, 3 to 4 times ridings per week and identical feed ration – optimized by Prišenk et al. 2013) as much as possible. We should note that we did not take into account observations of behavioral events of horses in stalls. Time of horses stayed in the stalls [h] and inside/outside temperatures [°C] were the same. Other observed units with abbreviations are listed below (a, b, c, d, e, and f) and will be used further in paper):

a) the exclusion of daily quantity of bedding material (bedding material+ manure) [kg],

b) the quantity of bedding material stayed in the stall [kg],

c) the quantity of new bedding material put into stall [kg],

d) time of cleaning stalls [h],

e) time of preparing the bedding material [h] and

f) time of putting the bedding material in stalls [h].

The cleaning procedure was carried by breeder with hands and pitchfork. Also, putting the bedding material was carried out by hand and hayfork. Manual work under e. contain the preparing materials such as, putting bedding material in wheelbarrow and transport the material from warehouse to stall.

The number of observations is one less compare to duration days because first day was preparing day for experiment (putting the same quantity of new bedding materials in stalls – 15 kg).

Table 1: Type of bedding materials with descriptions and their symbols

Type of bedding material	Short description	Symbol of bedding material
Squared harvest straw	It was transported directly from the local farms	I
Wood shavings	The wood shavings packaged in 20 kg	II
Sawdust in bulk	It was transported directly from local sawmill	III
Slice-dusted straw	Slice-dusted straw packaged in 25 kg.	IV

After collecting data, the statistical analysis was done. We used Bivariate Correlations approach in SPSS 21.0 statistical package and tested Pearson correlation coefficient for estimating the linear correlation between the observed data.

RESULTS AND DISCUSSION

In Table 2 are presented results of collected data from 2.2 subsection. In Table 3 are presented the statistical results. The most important result show statistical significant correlation between weight of horses and a.) the exclusion of daily quantity of bedding material (bedding material + manure) [kg], b.) the quantity of bedding material stayed in the stall [kg], c.) the quantity of new bedding material put into stall [kg], d.) time of cleaning stalls [h], e.) time of putting the bedding material in stalls [h]. From this point of view the statistical correlations confirm the importance of similar weight horses in research. The most powerful correlations (significant at the 0,01 level) are between the body weight and exclusion of daily quantity of bedding material and consequently also the quantity of new bedding material put into stall.

The aim of the further research activities is to give the clear directions which bedding material is the most suitable from the economic aspects of sport and recreative horses` breeding technology. First of all, we are going to estimate the life-long period of bedding materials on four warmblood horses with the most comparable weight. After that, the collected data from this paper from a) to f) and data about life-long period of bedding material will be used in Cost analyses calculation model. The main results of the feasibility analysis will be calculating net return for discuss and identify which type of bedding material is most suitable from economic aspect. Interesting results will be also the proportion between the bedding materials and labor costs in costs structure. According to that, the annual savings between bedding materials are going to be estimate and furthermore it will be transformed into full time equivalent (FTE) predictor.

Table 2: Measured observed data and their sum and average values

	Time of horses stayed in stalls [h]	The exclusion of daily quantity of bedding material (bedding material+ manure) [kg]	The quantity of bedding material stayed in the stall [kg]	The quantity of new bedding material put into stall [kg]	Time of cleaning stalls [h]	Time of preparing the bedding material [h]	Time of putting the bedding material in stalls [h]	Inside/outside temperature [°C]
The combination of bedding material symbol and horse	THE SUM OF OBSERVED DATA FROM 15th February to 6th March 2016							
I - CASPER	/	1048	31	153,95	2:01:30	0:20:00	0:22:15	/
I - KASCO	/	910	62,5	144	2:09:30	0:19:05	0:22:05	/
II - VASCO PAN	/	809	95,5	107	1:50:00	0:30:20	0:12:20	/
II - LUN	/	1134	92	112	2:01:20	0:28:10	0:12:10	/
III - SANDRO STAR	/	1202,5	562,5	280,5	3:14:45	0:38:20	0:12:50	/
III - MAXIM GEORGE	/	1293	547,5	294,5	3:02:25	0:44:15	0:13:45	/
IV- NAOMI	/	630	121	81,5	1:53:40	0:27:10	0:09:00	/
IV - CADORO	/	861	99,5	102,5	2:06:30	0:28:35	0:08:50	/
The combination of bedding material symbol and horses	THE AVERAGE VALUES OF OBSERVED DATA FROM 15th February to 6th March 2016							
I - CASPER	20:34:30	52,4	1,6	7,7	0:06:04	0:01:03	0:01:10	7,8 / 6,7
I - KASCO	20:34:30	45,5	3,1	7,2	0:06:29	0:01:00	0:01:10	7,8 / 6,7
II - VASCO PAN	20:34:30	40,5	4,8	5,4	0:05:30	0:01:36	0:00:39	7,8 / 6,7
II - LUN	20:34:30	56,7	4,6	5,6	0:06:04	0:01:29	0:00:38	7,8 / 6,7
III - SANDRO STAR	20:39:00	60,1	28,1	14,0	0:09:44	0:02:01	0:00:41	7,8 / 6,7
III – MAXIM	20:39:00	64,7	27,4	14,7	0:09:07	0:02:20	0:00:43	7,8 / 6,7
IV- NAOMI	20:39:00	31,5	6,1	4,1	0:05:41	0:01:26	0:00:28	7,8 / 6,7
IV - CADORO	20:39:00	43,1	4,97	5,1	0:06:19	0:01:30	0:00:28	7,8 / 6,7

Table 3: Statistical results of Bivariate Correlation analysis

Correlations								
		The exclusion of daily quantity of bedding material (bedding material+ manure) [kg]	The quantity of bedding material stayed in the stall [kg]	The quantity of new bedding material put into stall [kg]	Time of cleaning stalls [h]	Time of preparing the bedding material [h]	Time of putting the bedding material in stalls [h]	Body weight (kg)
The exclusion of daily quantity of bedding material (bedding material+ manure) [kg]	Pearson Correlation	1	,469**	,662**	,561**	,442**	,209**	,660**
	Sig. (2-tailed)		,000	,000	,000	,000	,010	,000
	N	160	160	152	160	152	152	160
The quantity of bedding material stayed in the stall [kg]	Pearson Correlation	,469**	1	,580**	,796**	,371**	-,158	,242**
	Sig. (2-tailed)	,000		,000	,000	,000	,052	,002
	N	160	163	155	160	152	152	163
The quantity of new bedding material put into stall [kg]	Pearson Correlation	,662**	,580**	1	,659**	,427**	,176*	,344**
	Sig. (2-tailed)	,000	,000		,000	,000	,030	,000
	N	152	155	160	152	152	152	160
Time of cleaning stalls [h]	Pearson Correlation	,561**	,796**	,659**	1	,304**	,126	,368**
	Sig. (2-tailed)	,000	,000	,000		,000	,120	,000
	N	160	160	152	160	152	152	160
Time of preparing the bedding material [h]	Pearson Correlation	,442**	,371**	,427**	,304**	1	-,016	,046
	Sig. (2-tailed)	,000	,000	,000	,000		,848	,570
	N	152	152	152	152	152	152	152
Time of putting the bedding material in stalls [h]	Pearson Correlation	,209**	-,158	,176*	,126	-,016	1	,247**
	Sig. (2-tailed)	,010	,052	,030	,120	,848		,002
	N	152	152	152	152	152	152	152
Body weight (kg)	Pearson Correlation	,660**	,242**	,344**	,368**	,046	,247**	1
	Sig. (2-tailed)	,000	,002	,000	,000	,570	,002	
	N	160	163	160	160	152	152	168

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

CONCLUSION

For the conclusion, we should give some restrictions and recommendations for improving and upgrading this experiment:

– It will be sense to evaluate the life-long period of bedding materials

– In according to assessing the life-long period of bedding materials some chemical and microbiological assessing approaches should be used

– Furthermore, with combination with results in this paper and life-long assessing results the suitable analysis approach could be analytical economic calculation approach

– As one of the criteria for assessing the life-long period should be also the ethology and behavior characteristics of the horses

– Developing the decision making program for assessing different types of bedding materials

These kind of recommendations gives clear directions for using multi-criteria decision modelling analysis and analytical hierarchical processes, such as decision expert systems and analytical hierarchical process used and described in Borec et al. (2013) and Prišenk et al. (2014).

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

CHARACTERIZATION OF CHICORY HERB (*Cichorium intybus*) OF SEPARATION PROCESS ON LENGTH OF FLAT VIBRATING SIEVES

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SUMMARY

The separation process of medicinal plants on sieves is a complex process and is influenced by many factors: charged of sieve, dimension of sieve, component of vegetal material, difference between the dimensions of plants fragments dimension and holes dimension through which they pass, cinematic regime of sieve, plants humidity and their content of bioactive substances, etc.

This paper presents experimental data on the separation process of chicory herb (*Cichorium intybus*) on the length of flat vibrating sieves depending on the flow rate and vibrations frequency for different dimension of sieve holes. For characterization of separation process of chicory herb on length of flat vibrating sieves it shows: separation intensity on the length of the sieve, cumulative separation on the length of the sieve and efficiency of the separation process.

The results are important for processing of medicinal plants for separating of chicory herb and for designers of machines for separating medicinal plants.

Keywords: herb, chicory, separation process; flat vibrating sieves

INTRODUCTION

Medicinal and aromatics plants have been used traditionally in folk medicine as well as to extend the shelf life of foods, showing inhibition against bacteria, fungi and yeasts. Biologically active compounds from natural sources have always been a great interest for scientists working on infectious disease (Nandagopal et al., 2007).

Cichorium intybus L., is a biennial or perennial herb and is a native of Europe and Asia (Tauseef et al., 2010), is a member of the family Asteraceae and is an erect perennial herb it is of different types depending on flowers which are bright blue, white or pink *Cichorium intybus* is about 80±90cm in height. It has a fleshy taproot up to 75 cm in length. Its habitants are roadsides, railroads and waste grounds, flowering period lasts from June to October (Zaman R. et al., 2013).

Recent studies have found some of the important constituents in chicory such as: flavonoids (Neha et. al., 2014) sesquiterpene lactones, caffeic acid derivatives, inulin, sugars, proteins, hydroxycoumarins, alkaloids, steroids, terpenoids, oils, volatile compounds, coumarins, vitamins (Al-Snafi A. E., 2016), saponins, tannins (Mehmood et al., 2012). Leaves of the plant contain salts such as sulphates and phosphates of sodium, magnesium and potassium as well as potassium nitrate. It also contains a bitter glycoside named cichorine (Zaman R. et al., 2013).

Many studies investigated the biochemical, phytochemical and antioxidant composition of root, stem, leaves and seeds of *Cichorium intybus* L., (Shad et al., 2013; Tauseef et al., 2010). Most of the pharmacological studies on this plant have been carried out on aqueous and/or alcoholic extracts (Chandra K. et al., 2016; Gospodinova et al., 2015).

In many parts of the world, *Cichorium intybus* has been used as vegetable (Munteanu et al, 2008) or as forage with good digestibility and curative effect (Shad et al., 2013; Wang et al., 2011).

The primary processing of medicinal plants comprises the technical operations by which the material is prepared, respectively the harvested vegetal material is stored, packed, labelled or subsequently processed. The primary processing supposes all the operations of conditioning, harvesting, drying, grinding by chopping (cutting), transport, sorting, performed by specialized equipment and through which the vegetal material is successively transformed, quantitative and qualitative, from the initial state S_0 to a state of finished product S_K. (Danciu et al., 2011; Oztekin et al., 2007).

In Romania, the technological flow of chicory herb processing to prepare food supplements includes the technological operations presented in Figure 1 (Păun G et al., 2011):

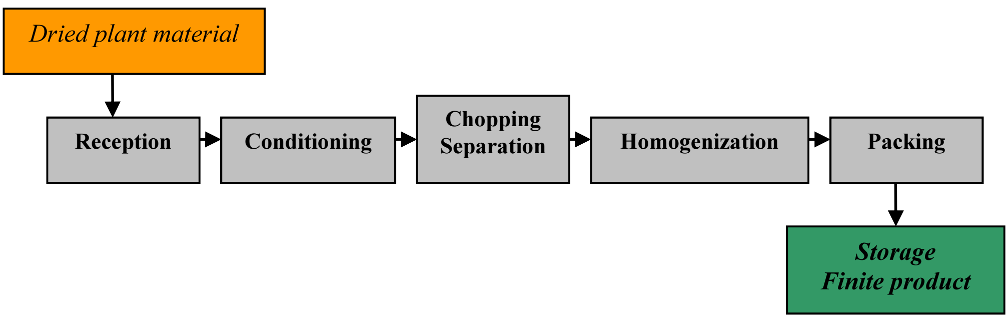


Figure 1 – Technological flow for chicory herb processing

The raw material is received in the manufacturing process in batches, depending on its origin and quality, based on the analysis report. Qualitative reception is done by checking the following parameters: plant authenticity; moisture; content in foreign organic and mineral bodies; impurities content. Next, the impurities are removed (parts of the same plant, other than herb), foreign organic and mineral bodies. At the end of the conditioning operation, samples are taken from the bulk product and the quality indices mentioned in the technical specification of the product are checked. The results are recorded in the analysis report and should be within the provided limits. The useless waste is destroyed according to current regulations.

The conditioned chicory herb passes through the chopper which is set for a fragment length of 8 mm, then is separated on sieves with different hole sizes, depending on their subsequent use (envelope tea, bulk tea, tinctures, vegetable extracts, etc.). During this operation, samples are taken from chopped and sieved vegetable product the correctness of performed operations is checked.

Material homogenization is done manually by repeated fallows. Packing involves the weighing in paper bags and proper labelling, with all data provided by the technical specification of the product. The finished product is stored in clean dry rooms, away from moisture and heat, well ventilated, and to it must be attached all the prepared analysis reports and the quality certificate of the accomplished batch.

The separations of solid particles by size represents the oldest separation technology and we find many studies about it. Many studies present the displacement or behavior of solid particles on a flat oscillating surface (Mosnegutu et al., 2014; Bontas O., 2013), these are important for optimizing the separation process. The paper (Simonyan et al., 2008) presented the effect of feed rate and of sieve oscillating frequency on the distribution of grain separated along the sieve length.

Another papers simulate the separating process using the discrete element method (DEM): (Chen et al, 2010; Xiao et al., 2013) investigated the relationship between vibration parameters and sieve efficiency; (Xiao and al, 2012) discussed about particle stratification and penetration of a linear vibrating screen, (Wang et al., 2011) submitted screening efficiency and screen length of a linear vibrating screen.

This paper presents the effect of sieve length on the separation efficiency of plant fragments, under various single parameter conditions including: vibration frequency, feed flow and aperture size of sieve for finding an optimal separating efficiency.

MATERIALS AND METHODS

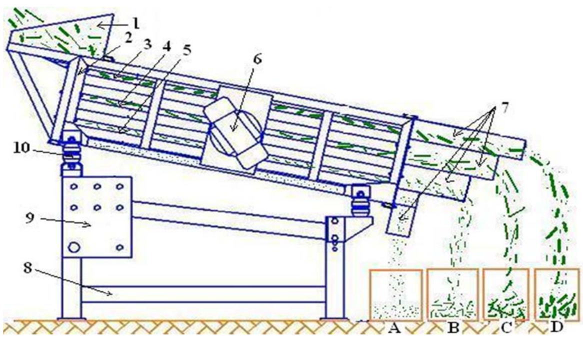
The plant material used in the experiments, chicory (*Cichorium intybus*) was harvested from the spontaneous flora of Romania and identified by morphological and biological characteristics (Chifu et al., 2002; Ciocârlan, 2000) of the species. The herb was dried naturally in the shade, until it reached the storage humidity (maximum 13%), cleaned of foreign bodies (inorganic materials or other plants, injured parties) under the provisions of (Romanian Pharmacopoeia, 1993; European Pharmacopoeia, 2005), and then was chopped in bulk using the TIMATIC grinder for medicinal plants, adjusted to the size of 8 mm.

The experimental researches were conducted on a dimensional sorting equipment for chopped plants, existing in operation within INMA Bucharest, whose design scheme is shown in Figure 2. This equipment is provided with 9 frames with sieves, having hole sizes ranging from 1.15-13.2 mm, used in sets of three, depending on the requirements. Sieve tilting can vary between 12-15^0 depending on plant type, and also on the removal of other unwanted parts of the plants.

The bedframe of the sieves (pos. 2) is supported on a frame made of welded laminated profiles (pos. 8) through rubber dampers (pos. 10). The drive of the equipment is made with two vibrating drives (pos. 6) mounted on symmetrically welded plates outside the bedframe.

The feeding of sorter with material is made using an inclined conveyor belt, which discharges the plant material in the center of the feeding hopper and hence on its upper sieve where the separation process takes place.

Three feed rates were used in the experiments (60 kg/h, 45 kg/h and 30 kg/h) and three vibration frequencies (50 Hz, 45 Hz and 40 Hz). The experiments were carried out on a sieve with square holes with dimensions of 8 mm and 10 mm, having a length of 1.395 m and a width of 0.6 m, confined on its constructive width by the width of the box.



1 – feeding hopper; 2 – bedframe; 3, 4, 5 – sieves with square holes of varying sizes (pos. 3 sieve with large holes, pos. 4 sieve with medium holes and pos.5 sieve with small holes); 6 – vibrating drive; 7 – outlets; 8 – frame; 9 – control panel; 10 – rubber dampers; A, B, C, D – collector boxes

Figure 2 – Scheme of the equipment for sieving medicinal plants

Adaptation and preparation of the equipment consisted in the removal of the lower sieves (pos. 4 and 5) and the replacement of the upper sieve, which was used in the experiments, with the chosen sizes of the holes. A box of metal sheets was made on the entire length of the sieve, divided into 7 equal compartments, each with a length of 0.195 m, as shown in Figure 3.

The working parameters chosen for the appreciation of separation efficiency of chopped chicory fragments on the length of plane vibrating sieves were: frequency of vibrations regulated by the frequency converter (f = 50Hz; 45 Hz; 40Hz) and feed rate (30 kg/h; 45 kg/h, 60 kg/h) for the sieve with hole sizes of 10 mm and the sieve with hole sizes of 8 mm.

Figure 3 – Aspects during the experimental research

The mass of feed rate of the sorter was adjusted by the speed of the conveyor belt. For each experiment, the plant fragments separated through the screen holes were collected in the box mounted below sieve C with large holes.

The amounts of chicory fragments collected in each compartment, noted by 1-7, starting from the feeding, were weighed with a Kern balance with accuracy of 0.01g, and the obtained values were rated in a Table to be easily recognized for processing and interpretation. The duration of an experiment was 30 seconds, and the tilting angle of the sieve was 13.33 degrees.

The steps of the experiments are presented synthetically next:

– the conveyor belt is filled with the sample of plant material;
– the box for collection of fragments on the length of the sieve is mounted under sieve's plane with hole sizes of 10 mm, respectively 8 mm;
– the sieve and the conveyor are driven for the proper feed rate;
– after 30 seconds (the duration of an experiment), the equipment and the conveyor are simultaneously stopped;
– the collecting box of plant fragments separated through the sieve holes is removed;
– the amount of plant material collected in each compartment of the box is weighed.

Interpretation of results was done for the collection box with seven compartments, by the representation of functions of several variables, in which case the dependent variable (total percentage amount of chicory fragments collected in the box) is simultaneously a function of several independent variables, x_1=Q respectively x_2=f, replaced for each opening of screen holes and resulting in polynomial functions of II[nd] degree with two variables, having the general form shown in equation (3), (Păunescu et al., 1999):

$$f_{(x_1,x_2)} = a_0 + a_1 \cdot x_1 + a_2 \cdot x_2 + a_3 \cdot x_1^2 + a_4 \cdot x_1 \cdot x_2 + a_5 \cdot x_2^2 \qquad (1)$$

For processing of the experimental data was used the structure of a split testing experimental program, for 12 experiments, in Mathcad, given by the values of the independent variables and the values of dependent variables from each experiment.

RESULTS AND DISCUSSION

Primary experimental data on the quantities of fragments separated on the length of the sieve, obtained from experiments, are reported in Tables 1 and 2.

The performances of a separation equipment can be evaluated by studying the separation efficiency along the screen, which is estimated by:

– *the intensity of separation along the sieve*, which is defined by the ratio of the amount of fragments separated in each compartment of the box and the total amount of fragments subjected to the separation process. It is of interest the intensity variation along the sieve depending on vibration frequency of the sieve and on its feed rate, and the sizes of screen holes.
– *the cumulative separation* along the sieve, defined as the percentage of the amount of fragments separated in the sieve's compartments of 0.195 m from the initial amount of fragments undergoing the separation.

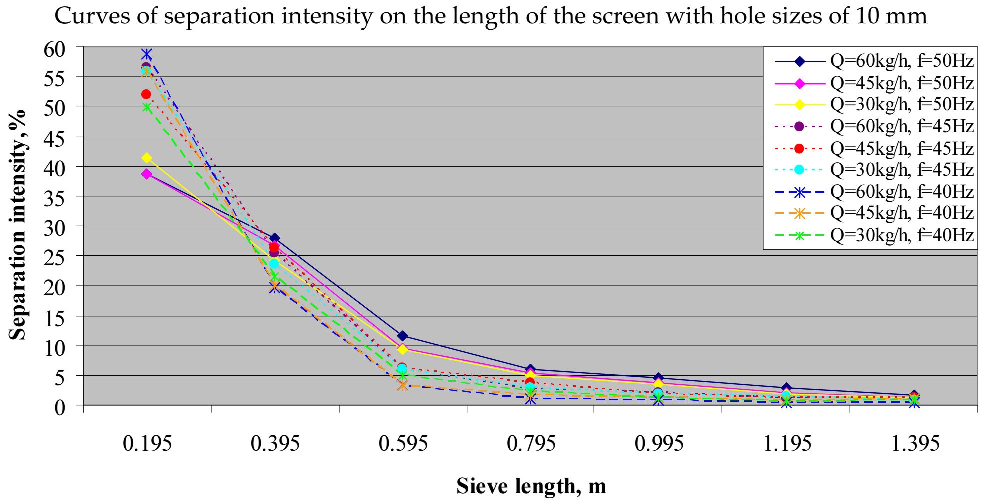
Table 1 - Primary data with masses of chicory fragments collected in the box compartments for different feed rates during the experiments on the sieve with hole sizes of 10 mm and the 3 vibration frequencies

Frequency [Hz]	Flow rate adjusted, [kg/h]	*Sieve length from which chicory fragments are collected, m*						
		0.195	*0.395*	*0.595*	*0.795*	*0.995*	*1.195*	*1.395*
		The mass of box, [kg]						
		1	2	3	4	5	6	7
50	60	0.1934	0.1394	0.0577	0.0303	0.0229	0.0143	0.0080
	45	0.1449	0.1003	0.0355	0.0200	0.0142	0.0079	0.0043
	30	0.1036	0.0605	0.0234	0.0126	0.0087	0.0045	0.0031
45	60	0.2827	0.1276	0.0297	0.0129	0.0100	0.0065	0.0054
	45	0.1949	0.0988	0.0230	0.0137	0.0073	0.0048	0.0049
	30	0.1396	0.0588	0.0150	0.0075	0.0045	0.0038	0.0019
40	60	0.2943	0.0987	0.0161	0.0051	0.0046	0.0025	0.0024
	45	0.2098	0.0751	0.0121	0.0061	0.0043	0.0029	0.0037
	30	0.1246	0.0541	0.0126	0.0055	0.0032	0.0015	0.0020

Table 2 - Primary data with masses of chicory fragments collected in the box compartments for different feed rates during the experiments on the sieve with hole sizes of 8 mm and the 3 vibration frequencies

Frequency [Hz]	Flow rate adjusted, [kg/h]	*Sieve length from which chicory fragments are collected, m*						
		0.195	*0.395*	*0.595*	*0.795*	*0.995*	*1.195*	*1.395*
		The mass of box, [kg]						
		1	2	3	4	5	6	7
50	60	0.1726	0.1180	0.0509	0.0307	0.0251	0.0140	0.0099
	45	0.1183	0.0844	0.0392	0.0244	0.0221	0.0086	0.0064
	30	0.0696	0.0480	0.0247	0.0170	0.0132	0.0079	0.0047
45	60	0.2106	0.1205	0.0410	0.0233	0.0175	0.0105	0.0081
	45	0.1506	0.0845	0.0324	0.0166	0.0128	0.0071	0.0047
	30	0.0829	0.0498	0.0208	0.0113	0.0098	0.0057	0.0048
40	60	0.2447	0.1016	0.0316	0.0150	0.0098	0.0075	0.0045
	45	0.1829	0.0828	0.0200	0.0066	0.0024	0.0019	0.0020
	30	0.1045	0.0531	0.0147	0.0078	0.0049	0.0035	0.0029

The results obtained from the separation of chicory fragments were transposed graphically in Figure 4 by plotting the variation curves of separation intensity, and in Figure 5 by representing the variation curves of cumulative separation, expressed as a percentage for each, depending on hole size of the chosen sieve.



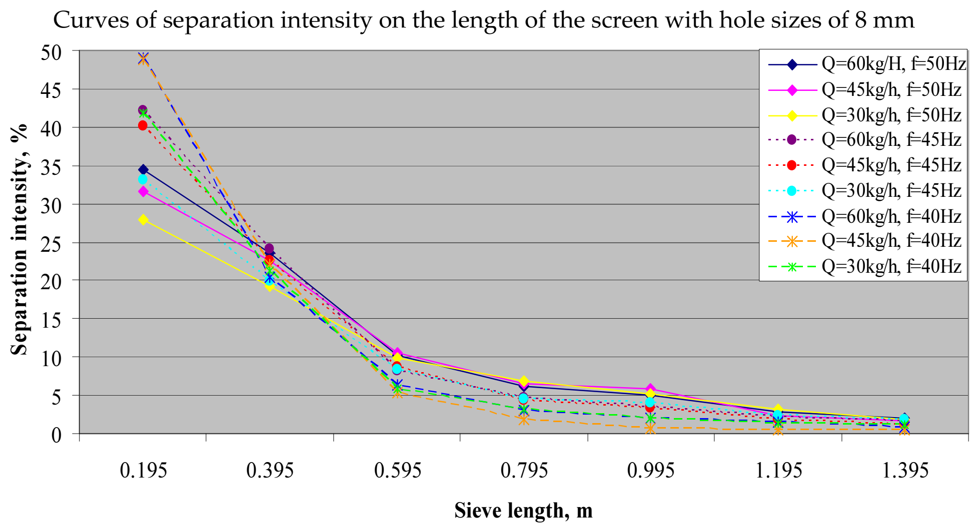
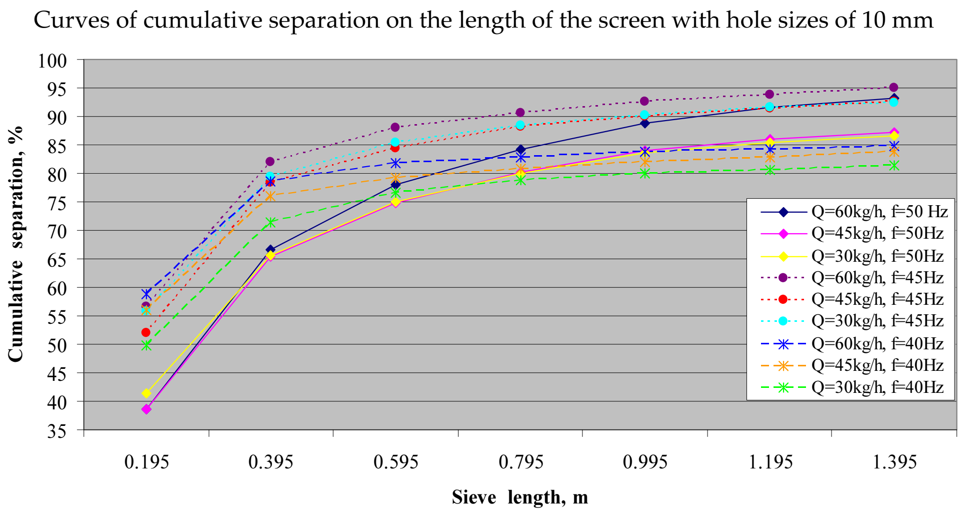


Figure 4 - Intensity variation of chicory fragments separation, on sieve length, for three flow rates and three vibration frequency

From Figure 4 it can be seen that the separation intensity decreases on the length of the sieve until it becomes insignificant at the end of the sieve. The separation intensity is maximum in the feeding area, to approx. 0.195 m on the length of the sieve, for all feed rates and vibration frequencies used in the experiments. Also, it was found an increase in separation intensity with the increase of feed rate.



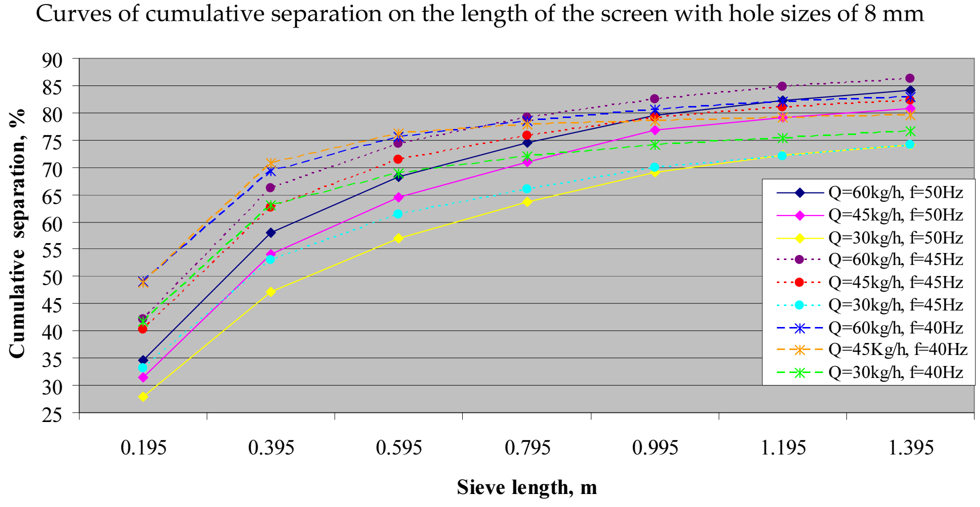


Figure 5 - Cumulative variation of chicory fragments separation, on length of flat vibrating sieves, with different aperture size (10 mm and 8 mm) and depending on two parameters (flow rates and vibration frequency)

From these figures, it can be observed that the cumulative separation increases with the increase of sieve length and varies for different values of the feed rate. Also, for the same length of the sieve, cumulative separation increases with increasing feed rate, for values of frequency from 40 to 50Hz. Separation efficiency decreases with increasing frequency and by keeping constant the feed rate.

Efficiency separation of plant fragments is expressed as a percentage (%) and is defined as the ratio between the amount of fragments separated into the 7 compartments of the collection box and the total amount of fragments that feed the sieve with different hole sizes. hopper with different hole sizes.

Using the percentage experimental data from the cumulative separation of chicory fragments, it was interpreted the separation efficiency by a polynomial function of degree two, depending on the feed rate ($x_1 = Q$) and the vibration frequency ($x_2 = f$) for each sieve.

For the sieve with hole sizes of 10 mm, separation efficiency is plotted in Figure 6, and in equation 2 are presented the function coefficients and the correlation coefficient **R^2 = 0.969**.

$$f_{(Q,f)} = -483{,}167 - 2{,}887 \cdot Q + 25{,}674 \cdot f + 0{,}065 \cdot Q^2 + 0{,}04 \cdot Q \cdot f - 0{,}284 \cdot f^2 \quad (2)$$

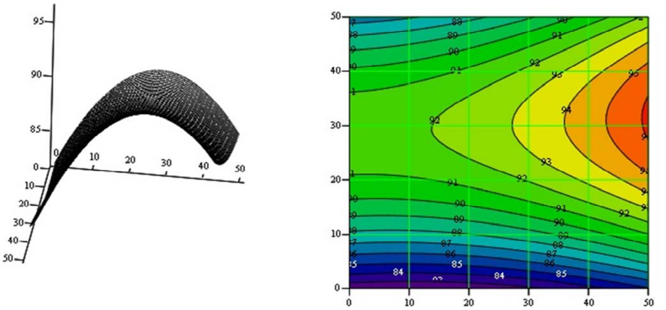


Figure 6 – Separation efficiency depending on the feed rate and on vibration frequency of the sieve with holes of 10 mm

For the sieve with hole sizes of 8 mm, separation efficiency is plotted in Figure 7, and in equation 3 are presented the function coefficients and the correlation coefficient **R^2 = 0.954**.

$$f_{(Q,f)} = 27{,}93 + 0{,}326 \cdot Q + 4{,}239 \cdot f - 6{,}406 \times 10^{-3} \cdot Q^2 + 0{,}013 \cdot Q \cdot f - 0{,}053 \cdot f^2 \quad (3)$$

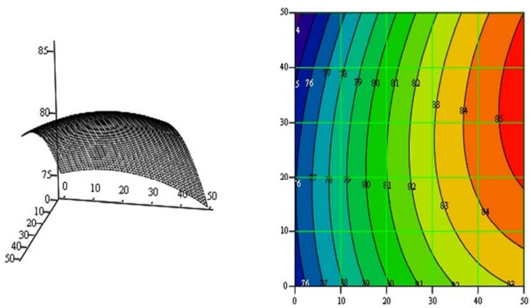


Figure 7 – Separation efficiency depending on the feed rate and on vibration frequency of the sieve with holes of 8 mm

In Figure 8 are presented by comparison the experimental and the calculated values of separation efficiency, for each experiment, depending on the studied parameters.

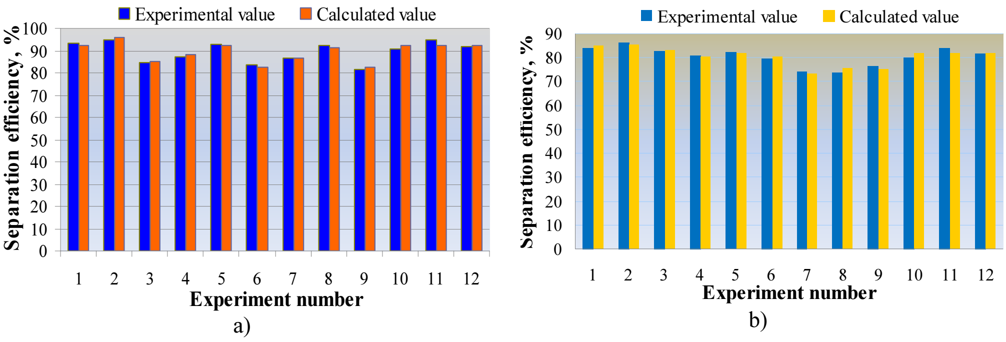


Figure 8 – Separation efficiency for chicory fragments for the experimental and theoretical values depending on the experimental feed rate and vibration frequency; a) on the sieve with holes of 10 mm; b) on the sieve with holes of 8 mm

Values of differences between the experimental and the calculated values obtained for the appreciation of separation efficiency, depending on the experimental feed rate and the oscillation frequency, indicate very small differences of 0.12%, respectively 0.18% for the average frequency of 45 Hz and average feed rate of 45 kg/h.

It can be seen that the applied polynomial equation correlates reasonably well with the values of experimental data, for both sieves being obtained large correlation coefficients R^2 = 0.969, respectively R^2 = 0.954.

CONCLUSIONS

To characterize the separation process of chicory herb on the lenght of vibrating flat sieves were used the results of own experimental research which showed:

- the analysis of the separation process development on vibrating flat sieves;
- presenting some basic factors that determine the working process on vibrating flat sieves;
- analysis of parameters that influence the quality and effectiveness of separation on flat sieves (material feed rate of the sieves, sieve length, sieve holes, sizes of the initial plant material, movement transmitted by the sieve to the plant mixture).

From the processing of own experimental data was appreciated the efficiency of separation of chopped plant material for choosing the appropriate working parameters related to the sieve and the material. For all three selected values of the feed rate, the maximum separation efficiency is reached at a frequency of 45 Hz, for both sizes of sieves holes. The separation efficiency of fragments decreases with reducing the size of the screen holes. The intensity of separation is evident in the first part of the screen and it becomes insignificant at the end of the sieve, resulting that the length of the screen is sufficient to achieve the separation process.

Optimal separation efficiency is obtained when the parameters are in their frequently used range, which has been proved by many researches and by practical application.

Capitalization of chopped medicinal plants through the separation process represents an important premise for processors of medicinal plants in order to obtain natural products.

ACKNOLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

NONDESTRUCTIVE EVALUATION OF SOLUBLE SOLIDS CONTENT IN PERSIMMON FRUIT CV. XICHU

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ABSTRACT

Consumer acceptance and satisfaction regarding the quality of product is an important issue in marketing. Soluble solids content, so-called SSC, is the most important quality parameter used to indicate sweetness of fresh and processed horticultural products.

Due to the increasing demand of internal quality assurance in the fresh product, industry has spurred the development of wide range of advanced, rapid, real time, reliable and non-invasive technologies for quality assessment. Near infrared (NIR) spectroscopy has shown significant potential to analyze postharvest quality parameters of several types of fruits and vegetables.

This paper presented an experimental research of the possibility of visible/near infrared (Vis/NIR) spectroscopy for monitoring internal quality of persimmon fruit. Calibration model relating Vis/NIR spectra (700-1100 nm) to SSC during de-astringency process was developed based on interactance mode of measurement. The developed calibration model was subsequently tested its accuracy by external validation set. The prediction performance was analyzed by using correlation coefficient of prediction (R_{pre}) between NIR model predicted values and measure values, standard error of prediction (SEP), root mean square errors of prediction (RMSEP), and bias, for preliminary estimation of the sweetness of persimmon fruit during de-astringency.

Key words: persimmon, soluble solids content, near infrared

INTRODUCTION

Premium persimmon fruits are commercialized in Thailand under 'The Royal Project Foundation' brand. This fruit has been introduced to Thailand in order to assisting highland people in northern area in engaging the agricultural production. As promoted fruit tree, astringent persimmon fruit has been mainly grown in area of the Royal Project Foundation (Krisanapook et al., 1997). Due to its well growing and delicious flavor, consumption of persimmon fruit has been increased consistently. Nowadays, there is a growing demand for quality on the agricultural product by consumers. Therefore, it is important to improve postharvest handling system for determine persimmon fruit quality prior to distribution. Convention quality analysis of postharvest quality are determined using destructive measures, and involve a considerable amount of manual work (Gómez et al., 2006)

Measurement of the optical properties of fruit and vegetable has been one of the most successful nondestructive techniques for assessing its quality property (Tian et al., 2007). From the later 1980s, near infrared (NIR) spectroscopy has gained a vast acceptance in quality assessment, due to its rapid and non-destructive technique which has potential to measurement of quality attributes of fruit and vegetable (Nicolaï et al., 2007). Compound identification by infrared spectroscopy is based on molecules property to absorb infrared light and experience a wide variety of vibrational motions characteristic of their composition (Shiroma and Rodriguez-Saona, 2009). Meanwhile, advanced multivariate statistical techniques, such as partial least squares regression, are then applied to extract the required information from the usually convoluted spectra (Nicolaï et al., 2007).

Soluble solids content being one of the major characteristics used for assessing fruit quality. Consequently, this non-invasive technique previously used to predict soluble solids content of a number of fruit and vegetables products including apple (Bobelyn et al., 2010), jujube (Wang et al., 2011) and passion fruit (Maniwara et al., 2014) with reliable accuracy by using different modes of measurement depending on the fruit and its characteristics. Therefore, this study aims to determine the prediction potential of vis/near infrared spectroscopy (Vis/NIRS) in measuring soluble solids content of intact persimmon fruit.

MATERIALS AND METHODS

Fruit sample

Fresh persimmon fruit cv. Xichu for this study were harvested in August 23, 2015 from cultivating sites of the Royal Project Development Center. A total of 100 persimmon fruit were used for calibration. Another 35 fruit were collected in late August in the same year as an external validation set. The equatorial diameter range of persimmon fruit was 60-70 mm, and all samples were stored in standard refrigeration (5 °C) for frequent sampling. After being taken out from cold storage accommodation, all samples were first allowed to equilibrate to 25 °C in a temperature-controlled chamber prior to NIRS analysis.

NIR measurements

Every sample was properly identified before spectroscopic measurements and traditional destructive tests. Interactance spectra of intact persimmon fruit were obtained by NIRSystem 6500 (Foss NIRSystems, Inc., Silver Spring, MD, USA) in the range of 700-1100 nm with a resolution of 2 nm. The light source was delivered by a fiber bundle equipped with a detector. In order to get rid of the characteristics of the light source itself, a Teflon plate (13 cm diameter, 20 cm thickness) was used as a standard reference and measured after every four fruit. Spectral measurements were performed and average from four equatorial positons at angles of 0°, 90°, 180° and 270° by using Vision software and Microsoft Excel®, respectively.

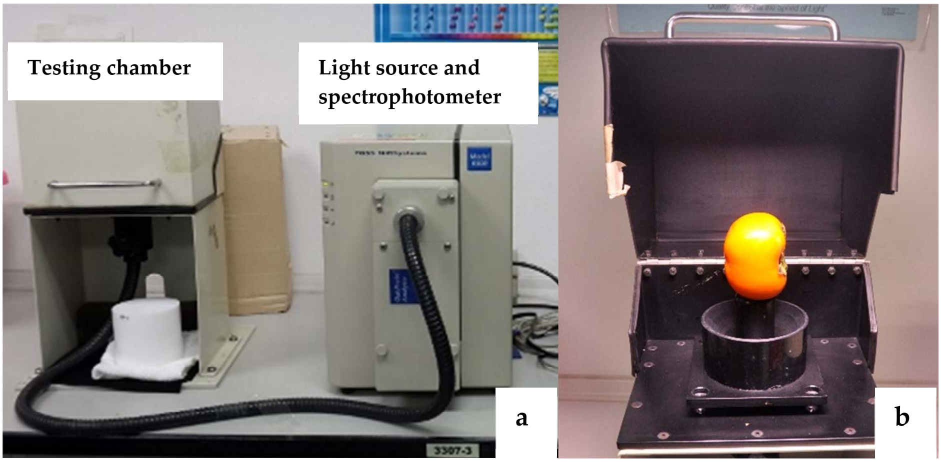


Figure 1 NIR interactance system (a) and collection of NIR spectra (b)

Soluble solids content

In order to access an actual quality of fruit at harvest time, soluble solids content (SSC) were determined using traditional destructive test. The fruit was peeled, homogenized and expressed by squeezing with 2-layered cheese cloth filtration. The juice sample was measured its SSC by using digital refractometer (Model PAL-1, Atago, Tokyo, Japan). The measurements were performed immediately after NIR acquisition.

Data analysis

All interactance spectra were obtained in the absorbance term (log(1/R)). The processed data were used together with the quality parameter during the statistics. The spectra were analyzed by means of The Unscrambler v.8 (CAMO Process AS, Oslo, Norway) software package for multivariate calibration. To test the influence of the spectrum data pre-processing on the prediction of the calibration model. Data preprocessing was used: First derivative and second derivative of the Savitzky-Golay algorithm, using a second order polynomial. Difference of five points (five points before and five point after) was used to calculate derivatives.

Subsequently, the pre-processed spectra were analyzed using partial least square (PLS) to obtain predictive model, which were analyzed in cross-validation. The 'best' preprocessing method was then selected based on its performance and prediction accuracy by using the correlation between model predicted values and actual values (R_{pre}). Moreover, in this study, the model's efficiency was determined by the following statistic values: R_{pre} standard error of prediction (SEP), root mean square errors of prediction (RMSEP) and Bias (predicted fault). The calculations of RMSECV, RMSEP, SEP and Bias are defined in the following equations:

$$\text{RMSECV} = \sqrt{\frac{\sum_{i=1}^{n_c}(x_i - y_i)^2}{n_c - p - 1}}$$

$$\text{RMSEP} = \sqrt{\frac{\sum_{i=1}^{n_p}(x_i - y_i)^2}{n_p - 1}}$$

$$\text{SEP} = \sqrt{\frac{\sum_{i=1}^{n_p}(x_i - y_i - \text{bias})^2}{n_p - 1}}$$

$$\text{Bias} = \frac{\sum_{i=1}^{n_p}(x_i - y_i)}{n_p}$$

where x_i is the predicted value of SSC from each observation; y_i the measured value; n_c the number of observations in the calibration set; p the number of factors used in calibration model development; n_p the number if observations used in validation set and SD_{pre} is the standard deviation of SSC values in validation set.

RESULTS AND DISCUSSION

Distribution of soluble solids content

Table 1 shows the statistic of persimmon fruits' SSC for both calibration and prediction sets. The SSC of persimmon fruit cv. Xichu varied between 12.75 and 20.5% (SD = 1.46) for the calibration set and between 15.25 and 18.90% for the prediction set. The range of SSC in prediction set was within a boundary of calibration ranges. Moreover, the standard deviation of calibration set was greater than the prediction set, which indicated the uniform distribution of samples (Williams and Norris, 2001). This purpose would enhance the applicability of the regression model.

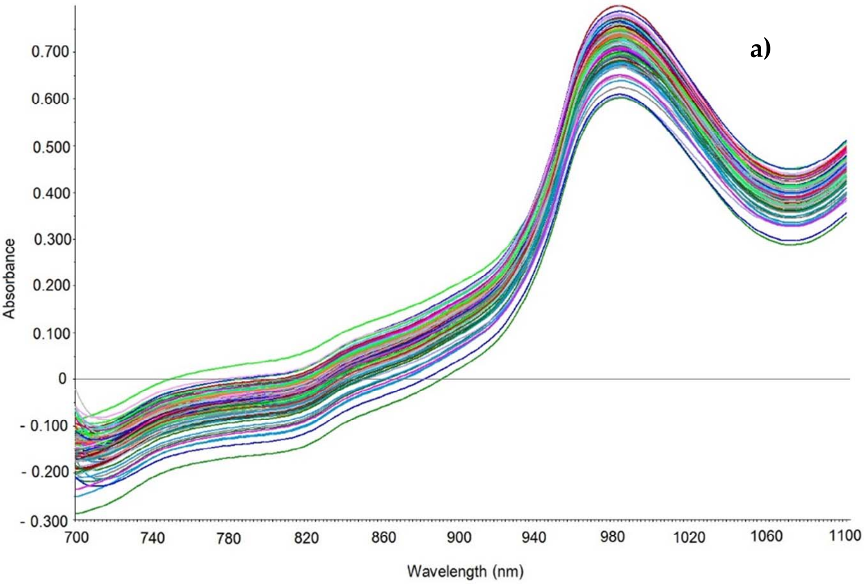
Table 1. Distributions of soluble solids content (%) of persimmon fruit in calibration and prediction sets

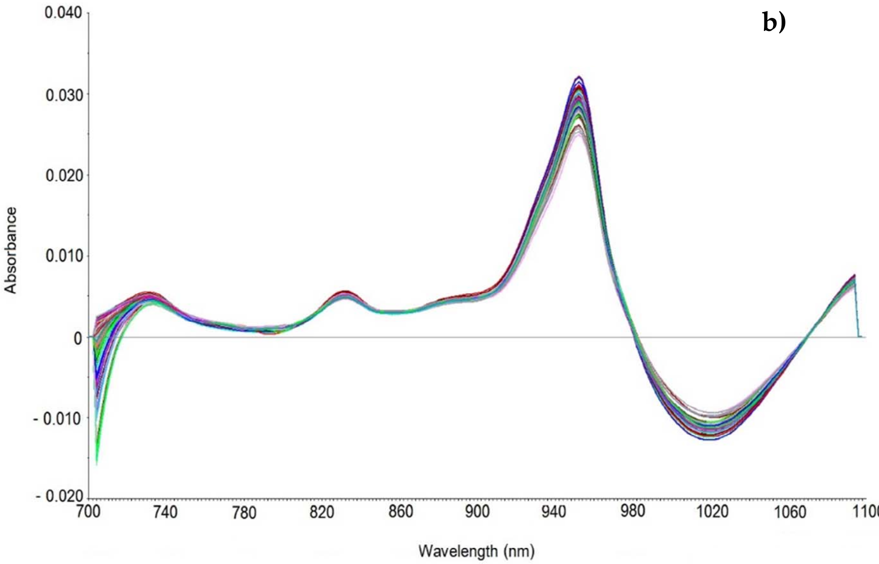
	Minimum value	Maximum value	Mean	S.D.[1/]	S.E.[2/]
Calibration set ($n^{3/}$ = 100)	12.75	20.5	16.85	1.46	0.15
Prediction set (n = 35)	15.25	18.90	17.00	0.86	0.15

[1/] SD abbreviated from standard deviation; [2/] SE abbreviated from standard error of mean; [3/]n means number of sample

Spectral characteristics

The typical NIR spectra for 135 intact persimmon fruit cv. Xichu are presented in Figure 2a. The spectra, in the wavelength range from 700-1100 nm, appear remarkably similar and all show broad absorption peaks around the 980 nm regions. This region (980 nm) coincide with the NIR absorbance bands of pure water and carbohydrate. A strong water absorption band can be expected to dominate since most fruit contain 80-90% of water (Beever and Hopkrik, 1990). The acquired spectra comprise scattering effect, which need pretreatments performed before model calibration stage. In this study, Savitzky-Golay first and second derivative (D_1 log(1/R), D_2 log1/R)), were attempted to improve the spectral signal.





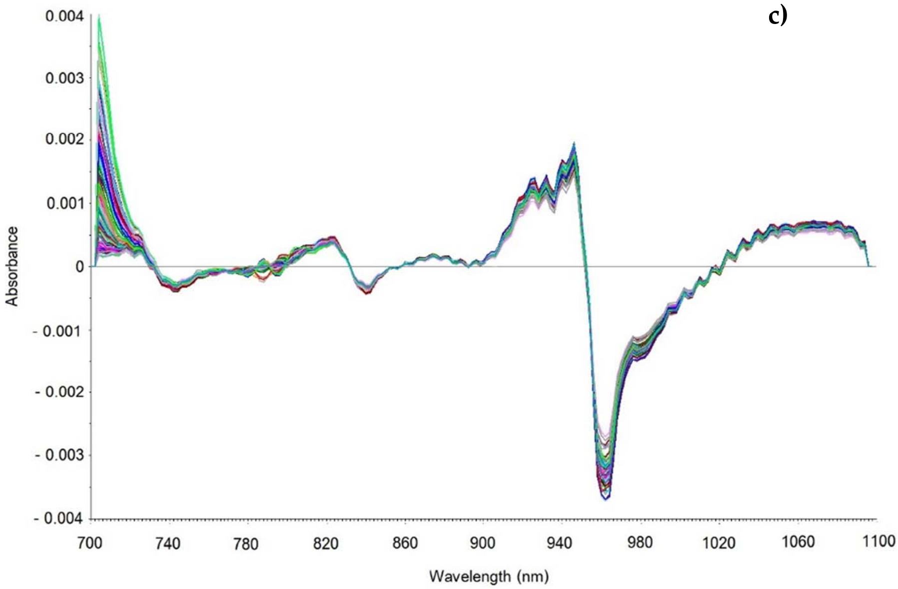


Figure 2. Original NIR absorption spectra (a) first derivative pre-processing (b) and second derivative pre-processing (c) NIR spectra intact persimmon fruit

Calibration and prediction results for soluble solids content

PLS prediction results for soluble solids content was presented in Table 2. It was clear that calibration model developed from original spectra had low coefficient of determination (r^2). The precision of calibration model was improved by using derivative. Many types of pre-processing methods have been described in the literature to reduce or eliminate the undesired variability in the spectra in order to further improve the robustness, of the calibration model (Nicolaï et al., 2007). Calculation of second derivative spectra with the Savitzky-Golay algorithm is one of the mostly used pre-processing technique due to its ability of baseline shift correction and peaks sharpener (Naes et al., 2004).

Table 2. Statistics for the regression model of SSC

Pre-processing	Latent variable	r^2	RMSEP
Original	7	0.37	1.16
First derivative	7	0.37	1.16
Second derivative	6	0.77	0.57

When the SSC regression model was used to predict the data for 35 persimmon fruit samples, prediction results of the validation model were fair, with r^2 = 0.62 and SEP = 0.53%. The results are worse than those obtained by Fan et al. (2009) in apples with r^2 = 0.95 and SEP = 0.38%. In the literature, typical SEP or SECV values for SSC around 0.5% have been reported, but in the few applications where external validation sets from different orchards or seasons were used to calculate the SEP it was considerably higher (1-1.5%) (Nicolaï et al., 2007).

In our study, the prediction result was not excellent, and the further research will be directed on parameters which increase model accuracy, as well as measurements setup. Scatter plots of SSC by refractometer versus SSC by NIRs for the prediction data sets were shown in Figure 3.

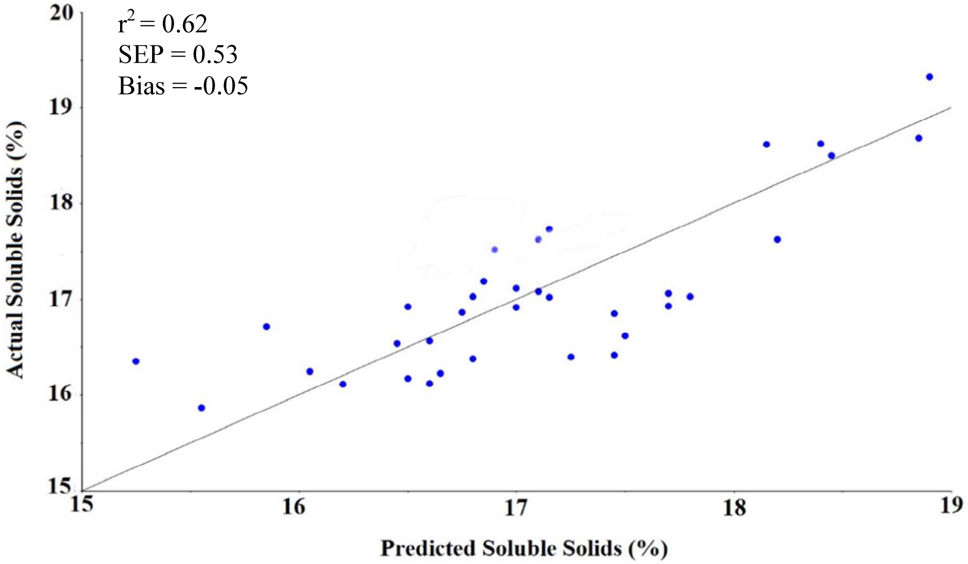


Figure 3. Scatter plot of prediction for soluble solids content in persimmon fruit

CONCLUSIONS

In this study, PLS calibration model was constructed to predict soluble solids content of persimmon fruit cv. Xichu based on NIR interactance spectra. The PLS model with second derivative was found to provide the best prediction for SSC of persimmon fruit. The results indicated that it is possible to develop the non-destructive technique for measuring persimmon fruit cv. Xichu by VIS/NIR spectroscopy.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

CONSIDERATIONS ABOUT THE SHEETING OF DOUGH PIECES TO OBTAIN BREAD

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ABSTRACT

Sheeting of dough pieces and other bakery products is an important operation of the modelling process, through which dough thins and turns on the dough sheet. Sheeting is usually carried out by a pair of sheeting rolls with rotation motion. Among other, the characteristics of the finished product depend on the way the operation is performed. The paper proposes a mathematical model to estimate forces and moments necessary to sheeting, leading to the assessment of energy consumption. Based on the mathematical model, the centre of pressure (point of maximum pressing of dough on rolls) is determined, usually being appreciated at 3/8 of the contact angle made by dough with rolls (neglecting elasticity of the dough after sheeting). Calculation software achieved in Mathcad estimates with sufficient precision the specified point, for a real sheeting machine with two steps.

Key words: wheat flour dough, sheeting, pressure centre position, mathematical model

INTRODUCTION. A SHORT REVIEW ABOUT DOUGH SHEETING

As known, behaviour at mechanical stress of wheat dough is similar to viscoelastic bodies and can be described rheologically through various constitutive mechanical models, approaching more or less to reality, (Burgers and Bergstrom-Boyce bodies), [2,9,11].

At large deformations, without breaking the links between particles, at stress removal, dough gets permanent deformations called improper „plastic”, which is due to leakage of the liquid phase from content of the dough structure, and are determined by its mechanical and chemical structure, [9].

In case of dough pieces modelling, to obtain the final form of bakery products, they are first subjected to sheeting to achieve a sheet of dough of a certain thickness, followed by rolling (winding) and lateral pressing in order to appropriately bond the sheet layers. Dough sheeting is a common method of processing dough, performed by means of a pair of rigid rolls, of the same diameter or of different diameters, with rotation motion. These pull the dough piece between them, bringing it at a thickness given by the distance between them, in the form of a sheet approximately elliptical, asymmetric. Due to dough particles movement in different directions, a part of gas phase is eliminated, bulk density increases and inner surface given by foam structure is further reduced, [9,15]. Performing this way, a deformation Φ of dough piece is obtained, by moving through rolls of a dough volume V_d, lower than its original volume, [1,5,9,10,15]. In order for permanent deformation to takes place is necessary that the force applied by roller on the piece of dough to achieve a state of higher tensions as bio-flow tension σ_c of dough, [9].

The relationship between the rolling force and thickness of the dough at output between sheeting rolls can be used to characterize the strength and elasticity of the dough, and also to evaluate the flour quality, knowing that it varies with humidity, [11]. The property that governs the return of dough at output from sheeting rolls is its elasticity.

Variation of relaxation time with dough humidity can provide unique information about the quality of flour and dough. Relaxation times, determined from parameters of constitutive anisotropic Bergstrom-Boyce model, with Mullins damage, have shown that dough elasticity and sheetability can be evaluated through analysis of the humidity effects on behaviour of dough at relaxation, [11]. It has been found that the humidity has a greater influence on the relaxation times of bread dough, compared with those of the noodle dough, that presents a higher strength to moisture changes. The numerical simulations of stretching dough subjected to sheeting showed a degree correlation R^2 over 0.9 between the measured values and those projected for thickness of the dough, but also for vertical and horizontal forces from rolls, for 18 samples of dough made from different flour, [11].

Also, prediction of final thickness of the dough sheet after sheeting can be done taking into account the initial, interim and final configuration of material, based on constitutive models properly established. Qi et al [12] have proposed for this a viscoelastic constitutive model containing also a deformation function, in which lateral extent and compressibility were ignored. Predictions of dough thickness after sheeting depending on the rotational speed and the rollers diameter, rollers gap and initial thickness of dough, showed a good correlation with experimental data achieved from unyeasted dough. Authors found that there are differences between different types of doughs, and that the final thickness of the dough is not necessarily in relation to the thickness with which leaves the sheeting rolls. Therefore, to predict the final thickness of the dough it takes a strong viscoelasticity, and a more complete knowledge of rheological data [12].

Forming of wheat dough sheets passing through two cylindrical rollers was studied also in [4], relating to stresses and deformations of dough. It has been observed, also, that the ratio between thickness of sheet at the entrance and gap between rolls had a strong influence on the deformation and tensions, while the rollers speed had a relatively minor influence. An approximate model for dough sheeting compared to the experimental data was developed. The model is able to predict the correct thickness at output, but not the final thickness of the sheet, most likely because the dough elastic recoil.

Therefore, most researchers agree that the consequences of exploring more complex rheological models presents a major interest, even if this requires a much greater mathematical effort, [2,4,8,12].

For developing some rheological models for dough appreciation is necessary to determine the actual rheological properties through compression and extension tests. Such a model, validated through finite element simulation of dough sheeting between two rolls, was developed in paper [2], by measuring forces from rolls and of sheet thickness during sheeting. Stretching tests have shown that dough is a non-linear material, that can undergo large deformations, but the elastic recovery is moderate. Also, freshly kneaded dough has additional complexities of anisotropy and Mullins softening, which must be taken into account in analysis based on constitutive models (authors studied the dough on the model Bergstrom-Boyce, which was amended to include anisotropy and Mullins softening).

Rheological measurements performed on bread dough showed that it possesses a shear stress behaviour which can be described very well by the model Herschel-Bulkley, [8]. Sheeting experiments were performed for different feeding thickness and rotation speeds. The output thickness and torque moments at dough sheeting rolls were measured and put into correlation. It has been found that the torque moments of the rolls substantially increase with speed of rolls and with initial thickness of dough samples. Bidimensional simulation with finite element based on the rolling geometry and sliding rheological characteristics can provide information about the flow of dough between rolls or at distribution of pressure and tension over the rolls. Simulation results were compliant with experimental values of torque moments, but thickness of sheets at the exit between rolls has been underestimated. Authors argue that the latter would be a consequence of viscoelasticity of bread dough, especially if it contains a certain volume of gas, which affects the compressibility.

Flow encountered during the sheeting process contains more a stretching component than a simple shear, [7]. Evaluation of extensional rheological properties of wheat flour dough is essential to better understand the process of sheeting and the final quality of the product. Results from [7] show that biaxial extensional viscosity curves, in relation to extensional deformation rate for different types of wheat dough, having a content of proteins of 7.81-18.09% and a moisture content of 32-40% can be distinguished. During a lubricated sheeting test (between two rolls with gap 6 mm), dough sheet showed a thickening extensional region, followed by a slight extensional thinning region, giving rise to a tension-strain curve S-shaped. Extensional thinning index was of 0.65-0.96, depending on the variety of wheat. Biaxial extensional viscosity in relation to the moisture content and the protein content could be described by relations of power type, [7].

Other papers that treats issues of rheological characteristics of bread dough are [3,13,14,16,17].

This paper proposes a mathematical model to determine the functional parameters of sheeting rolls which refers to forces and moments necessary to sheeting dough pieces, in order to estimate the rolls actuating power. Based on the proposed mathematical model was developed a calculation program in Mathcad which was tested on data corresponding to a real machine of dough sheeting, in two stages.

MATERIALS, METHODS AND PROCEDURES: THEORETICAL ASPECTS

Theoretical condition of dough drawing (of original size H and B) between two cylindrical rolls with radius R_1 and R_2 and with distance h between them (fig.1), each having the same coefficient of friction with the dough μ ($\mu = tg\ \varphi = 1.6$–1.73), is given by, [1,2,3,4]:

$$\alpha_{1,2} < \varphi \tag{1}$$

Clamping angles α_1 and α_2 (fig.1) are determined from geometric relationship between compression of dough between rolls (*H-h*) and their diameters. If the diameters of the two rollers are equal, assuming that clamping angles are equal ($\alpha_1 = \alpha_2 = \alpha$), then they can be determined from the equation of projection of the contour O_1ABO_2 on line of centres (fig.1):

$$\cos\alpha = 1 - \frac{H-h}{R_1 + R_2} \quad (2)$$

where H – thickness of the dough before sheeting.

To determine the distance of clamping H when the rolls have different diameters and both clamping angles are required to be equal ($\alpha_1 = \alpha_2 = \alpha$), when rolls are filled with dough (as in the case of dividing machine provided with feed rolls or for other similar cases), the following relationship can be used:

$$H = (R_1 + R_2)(1 - \cos\alpha) + h \quad (3)$$

in which clamping angle α is taken equal with φ (friction angle of dough with rolls), [2,4,5].

In reality, this relationship becomes:

$$H = R_1(1 - \cos\alpha_1) + R_2(1 - \cos\alpha_2) + h \quad (3')$$

if angles α_1 and α_2 are different.

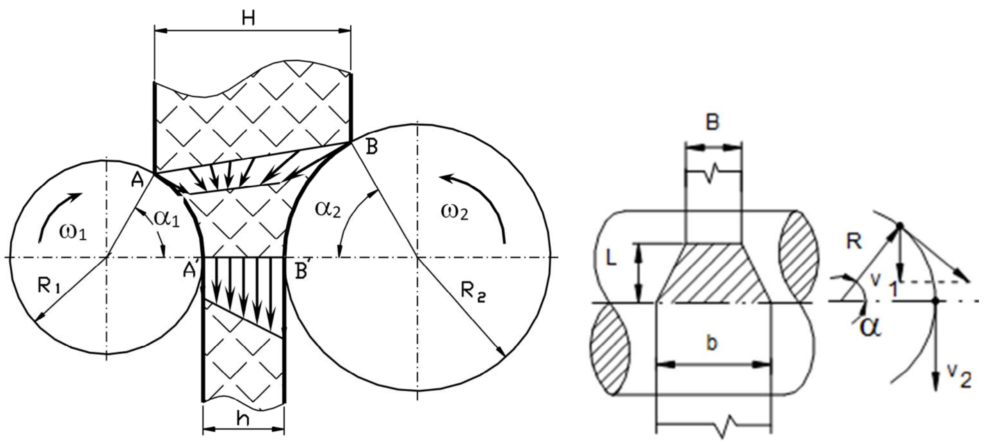

Fig.1. Scheme of dough drawing between rolls of different diameters

There are situations, in practice, in which dough feeding of sheeting rolls is tangential to one of the two rolls (often at larger diameter roll – see application from fig.3). In this case, clamping angle α_2, although it can be considered zero, in reality is present due to the relaxation of the dough after passing through first pair of rolls and / or because inclined plane of directing can not be brought to the point of tangency due to practical considerations. It must be practically measured and has the opening to the end of the inclined plane. However is considered that α_2=0, and angle α_1 is determined by the relation:

$$\cos\alpha_1 = 1 - \frac{H-h}{R_1} \quad (4)$$

In the process of sheeting a piece of dough which has initial width *B*, known, considering the dough incompressible, final width *b* of dough piece is deduced theoretically from volume flow continuity law in inlet and outlet points of the piece of dough:

$$b = \frac{H \cdot B}{h} \cdot \frac{\cos\alpha_1 + \cos\alpha_2}{2}, \tag{5}$$

Considering speed on drawing direction in the inlet section of the dough equal with $v_p \cdot \cos\alpha$ (v_P – peripheral speed of the roll – fig.1). In the real case of dough compressibility, from mass flow continuity law, relation (5) becomes:

$$b = \frac{H \cdot B \cdot \rho_i}{h \cdot \rho_e} \cdot \frac{\cos\alpha_1 + \cos\alpha_2}{2} \tag{5'}$$

where: ρ_i, ρ_e are volumetric masses of dough at input and output of the rolls.

Contact surfaces between dough piece and sheeting rolls depend on the clamping angles α_1 and α_2, rolls diameters and of gap between rolls, and can be approximated with:

$$S_{c1,2} = R_{1,2} \cdot \alpha_{1,2} \cdot \frac{B+b}{2} \tag{6}$$

Forces exerted by rolls on dough are determined by the action of the dough to deformation (fig.2,a), ie reactive pressures on contact surface:

$$F_{1,2} = S_{c1,2} \cdot p_{med} \tag{7}$$

where: p_{med} – dough mean pressure on roll.

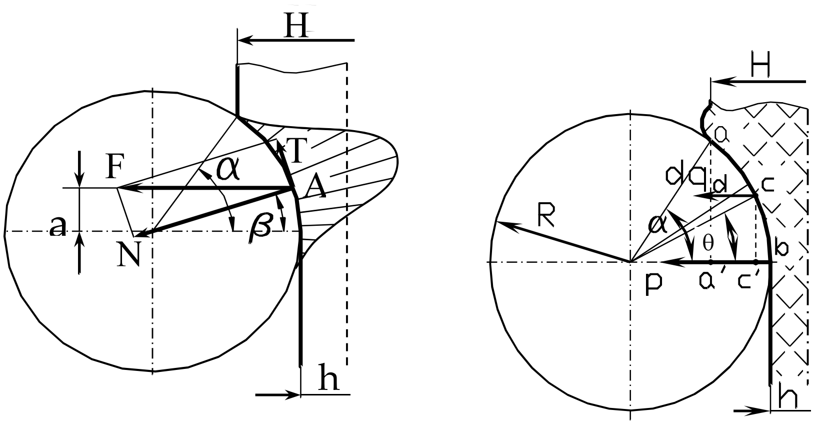

Fig.2. Distribution of unitary tensions at sheeting (a); scheme for calculating distance a (b)

Considering that dough passes between two rolls of the same diameter and that the normal reaction is applied in point A (fig.2,a), one can write:

$$T_{1,2} = N_{1,2} \cdot \tan\beta_{1,2} \tag{8}$$

where: T is the tangential component of the resultant forces, and β - angle of application point of this force, A.

The rotational resistant moment of that roll is:

$$M_{1,2} = a_{1,2} \cdot F_{1,2} = F_{1,2}.R_{1,2}.\sin \beta_{1,2} \tag{9}$$

where: a_1, a_2 are arms of resultant pressures.

Total rotational resistant moment, of the two rolls is given by sum of the two moments M_1 and M_2.

For determination of distance a it is accepted that rolls are rotating at the same angular speed, and normal tension along the deformation path is distributed considering Hooke elastic deformation of dough in all points. In this case, following fig.2,b, it results:

$$\frac{dq}{p} = \frac{\overline{dc}}{\overline{a'b}} \tag{10}$$

in which: dq is the pressure due to deformation to a certain point c, and p – maximum pressure corresponding to maximum deformation directed on to centre line.

Also, following fig.2,b one can be write:

$$\overline{a'b} = R \cdot (1 - \cos \alpha) = 2R \cdot \sin^2 \frac{\alpha}{2} \tag{11}$$

$$\overline{dc} = \overline{a'b} - \overline{c'b} = R(1 - \cos\alpha) - R(1 - \cos\theta)$$

ie:

$$\overline{dc} = 2R \cdot \left(\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2} \right) \tag{12}$$

Therefore:

$$\frac{dq}{p} = \frac{\sin^2 \frac{\alpha}{2} - \sin^2 \frac{\theta}{2}}{\sin^2 \frac{\alpha}{2}} \tag{13}$$

Knowing the pressure dq on elementary surface unit, in the vicinity of c point, one can determine the elemental force dF_l along roll on an elementary strip of length l and angle dθ. So:

$$dF_l = dq \cdot l \cdot R \cdot d\theta \tag{14}$$

If it is appreciated that the width l of dough piece between rolls varies linearly on contact angle α from width B at b, then this can be expressed by the equation:

$$l = b - \frac{b - B}{\alpha} \cdot \theta \tag{15}$$

Total force F on sheeting roll, acting on the arc **ab**, is obtained by integrating expression (14). Considering expression of dq from relation (1) and l from relation (15), considering in a first approximation l constant, after performing integration was obtained:

$$F = \int_0^{\alpha} dF_l = p \cdot l \cdot R \cdot \left(\alpha - \frac{\alpha - \sin\alpha}{2 \cdot \sin^2 \frac{\alpha}{2}} \right) \tag{16}$$

Rotational resistant moment of elementary force dF_l, is:

$$dM = dq \cdot l \cdot R \cdot \sin\theta \cdot d\theta \,; \tag{17}$$

Considering relation (13) by solving the integral, the rotational resistant moment M is obtained:

$$M = \int_0^{\alpha} dM = p.l.R^2 \cdot \sin^4 \frac{\alpha}{2} \tag{18}$$

Using relations (16) and (17), distance a is calculated:

$$a = \frac{M}{F} = \frac{2R \cdot \sin^4 \frac{\alpha}{2}}{(\sin\alpha - \alpha \cdot \cos\alpha)} \tag{19}$$

For angles $\alpha<20^o$, the error by replacing value of $sin(\alpha)$ with angle α is under 2.1%. In this case, distance a would be $a=0.25 \cdot R \cdot \alpha$.

For a more precise calculation, in expressions (14) and (17) l is replaced with relation (15) and it is envisaged that at $\alpha<20^o$ ($sin\alpha \approx \alpha$) and after computations in those integrals expressions, is obtained:

$$F = \frac{p \cdot R \cdot \alpha}{12} (5b + 3B) \tag{20}$$

$$M = \frac{p \cdot R^2 \cdot \alpha^2}{60} (7b + 8B) \tag{21}$$

$$a = \frac{M}{F} = R \cdot \frac{\alpha}{5} \cdot \frac{7b + 8B}{5b + 3B} \tag{22}$$

In the particular case $b=B$ (constant width of dough sheet on the contact perimeter with rolls) $a = (3/8) \cdot R \cdot \alpha$ is obtained. This value is used and recommended in literature, [1,2,4,5]. In first case ($a=0.25 \cdot R \cdot \alpha$) compared to last ($a=(3/8) \cdot R \cdot \alpha$) considered accepted one, error is 33.3%.

Pressure p_{med} depends of flour quality, of dough humidity, of value and duration of compression and rolls diameter. Literature recommends: for a deformation of 50%, pressure p_{med} varies between 0.3 – 0.6 daN/cm^2, and for a deformation of 90% pressure lies between 0.4 – 0.8 daN/cm^2, [1,5,9,10].

Due to the elasticity of the dough, it tends to return to the previous size of the sheeting process, and its thickness after sheeting h_e may be established with the relationship proposed by Levine and Drew (1990), presented in the paper [6]:

$$h_e = 0.06\, R^{0.58} h^{1/0.58} + h \tag{23}$$

or with the relationship proposed by Qi et al in 2008, [12]:

$$h_e = h \exp\left[0.23 + 0.275\left(\ln h_i/h - 0.23\right)\cdot \omega \frac{1-h_i/h}{\sin\alpha}\right] \quad (24)$$

where: α is clamping angle (at limit equal to the angle of friction); ω - the angular speed of the rolls; h*i* – thickness of dough at entry (equal with h+2Rcosα).

RESULTS AND DISCUSSION

Sheeting can take place in a single pass or in two successive passes. Peripheral speeds of the rolls from the two sheeting stages are, in general, different and, in order the sheet of dough to enter under the action of modelling strips (which follows) and to wrap, rolls from the second stage of sheeting have, in their turn, different peripheral speeds.

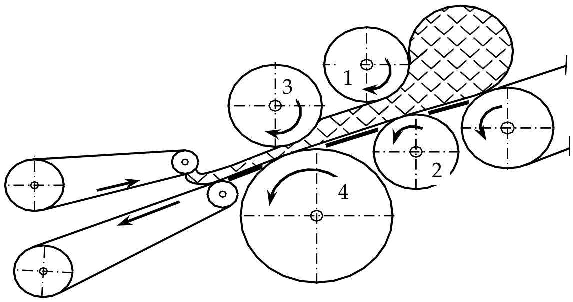

Fig.3 Functional scheme of a sheeting machine in two stages

Based on the theoretical elements presented in paper, a calculation program in Mathcad was conducted. The program has been validated for a sheeting machine with two pairs of rolls (fig.3): first two rolls of the same diameter ϕ35 mm at a gap h_1=5 mm between them, and the following with diameters ϕ38 mm and ϕ100 mm at a gap h_2=2 mm.

If shaping pieces of dough (spherical considered) with diameter 80 mm (for bread of 300 g, a dough piece of ~350 g is corresponding), then it can be considered that clamping angle of first pair is $\alpha_1 \approx \varphi \approx 60^o$, even if the thickness of dough piece at input between rolls exceeds the maximum thickness from theoretical condition. Thus, it results that at the input in action area of first rolls, distance *H*, determined from relation (3), is about 22.5 mm.

Considering that at the input between rolls the calculated width of dough piece is equal with his diameter (~80 mm), based on relation (5) results maximum width of dough piece at output between rolls of 180 mm. On this basis, relation (6) gives that the maximum contact surface of dough is 23.82 cm^2. Also, for a mean pressure of the dough on rolls of 0.5 daN/cm^2, total rotational resistant moment of first rolls pair is 1.52 N·m (rel. 7, 9 and 19).

From the analysis of data obtained in Mathcad (for relation 5) and of charts presented in fig.4, for smooth rolls, dough width can greatly increase in gap between rolls, particularly if this gap is small (under 8 mm), which requires a larger length of rolls. For this reason, sheeting rolls are provided with notches in order to increase the clamping angle (respective α_1 and α_2). More, given that in sheeting process a part of the accumulated gases is lost, the dough sheet width does not reach the dimensions given by relation (5), being necessary to determine the density of the dough before and after pass between rolls, for an exact calculus in other similar terms. For example, if in sheeting process, dough density increases from 1.25 to 1.41 kg/dm^3, then the width of the sheet may fall to 88% of the value given by the relation (5).

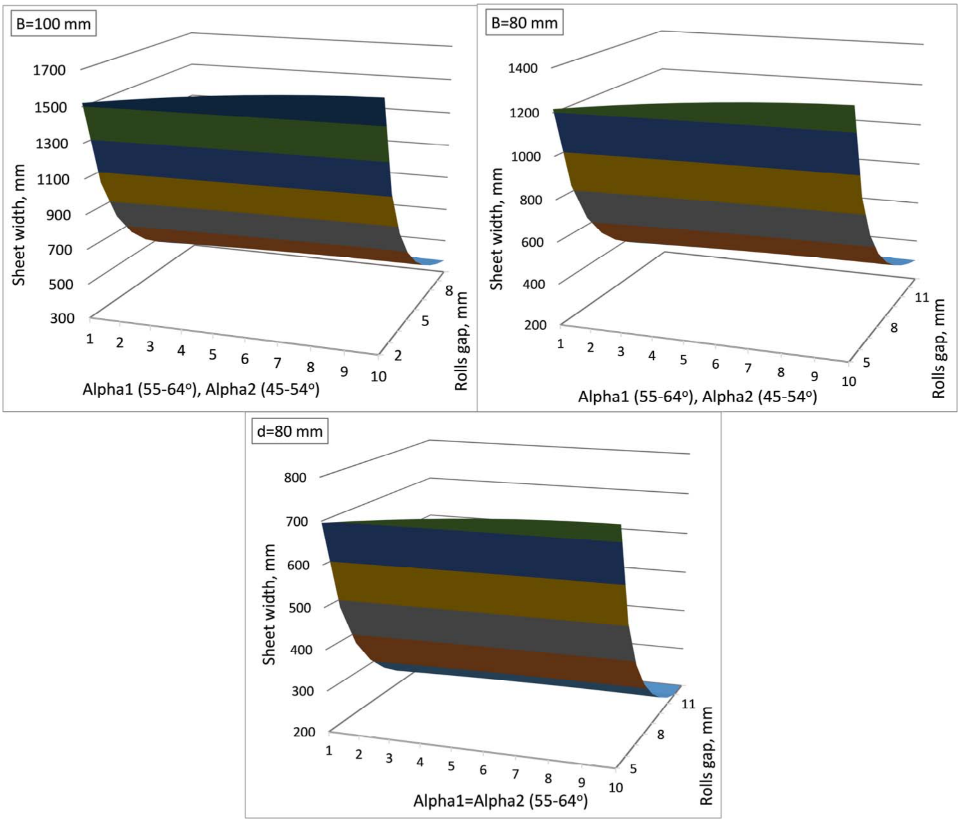

Fig.4. Variation of dough sheet width, for smooth rolls of different diameters (38 mm, 100 mm) and dough pieces with initial width B=100 mm, respectively B=80 mm, depending on the distance between rolls (eq.5) (a,b) also for rolls of equal diameter - 35 mm (c)

For rolls from the second stage of sheeting, starting at output thickness *b* of dough piece from the first sheeting stage and assuming (as shown fig.3) that input of dough piece is tangential to the large diameter roll, results a clamping angle α_3=32,63° (rel.4), while the clamping angle α_4 is about 30° (measured on scheme). Using relation (5), a maximum width of dough piece at output between rolls of 384.3 mm is obtained. From relations (6), respectively (7), assuming the same mean pressure of dough on rolls, is obtained a contact surface of rolls with dough of 30.54 cm^2, respectively 73.87 cm^2, while forces have values of 152.7 N, respectively 369.4 N.

In continuation, using relations (19) and (9), torque moments at each roll were determined, and values of about 0.61 N·m, respectively of 3.56 N·m were obtained.

CONCLUSIONS

There are cases, in practice, wherein the thickness of the dough pieces in the clamping area of sheeting rolls must be determined on the basis of the angle of friction between dough and rolls. On the other hand, after passing between the rolls, dough piece expands because of its elasticity, and because the thickness in the area of entry to the second sheeting stage is greater than the distance between the rolls of the first stage. Even if the feed of second stage is made tangentially, clamping angle of respective roll is different from zero. Determination of the rolls actuating power is made based on the value of their rotational resistant moment, which can be estimated as presented herein.

The mathematical model presented in the paper disregards the fact that the rolls of sheeting (mainly those from the first stage of sheeting) have the surface provided with flutes (of small depth) which enhances the effect of drawing. Still, rolls dimensions (especially diameter) affect the passage of the dough through the space between them and pressure on dough, especially if passing gap is reduced. Reaction of dough on rolls leads to a contact pressure with rolls whose centre is changing depending on the diameter of rolls and by rheological properties of the dough (humidity and viscosity).

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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VALORISATION OF WINERY WASTE BY USING GSP (*GRAPE SEED POWDER*) AS FLOUR SUBSTITUTION IN BAKERY INDUSTRY

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SUMMARY

The winemaking process involves the generation of a significant amount of waste and wastewater. These residues should be addressed for recycling or treatment before being returned to environment. Winemaking generates different residues characterized by high contents of biodegradable compounds and suspended solids. Grape seeds can be used to obtain anthocyanin colorants or oils, and catechin polymers, respectively. Antioxidant activity of polyphenols was reported. This paper studies the possibility to use GSP in bakery industry.

GSP (grape seed powder) were added at 5%, 10%, 15% flour substitution level for different bakery recipes. The final products after baking were analyzed taking in consideration: shape and volume of the product; color and appearance of the crust; degree of ripeness, state and core appearance; core porosity and pore structure; flavor (smell); taste and acidity. Results show the following values (max=6; min=0): shape and volume of the product: 4, 3, 2, 0; color and appearance of the crust:2, 2, 2, 2; degree of ripeness, state and core appearance: 6, 6, 4, 6; core porosity and pore structure: 4, 4, 4, 4; flavor (smell): 4, 4, 4, 3 ; taste and acidity: 6, 6, 4, 3 for control flour, 5%, 10%, and 15% flour substitution level, respectively.

In conclusion, addition of GSP at the level between 5...10% as flour substitution in bakery recipes has a big potential in functional food designing, taken in consideration many parameters, from technological to sensorial ones.

Key words: Grape seed flour, quality parameters, bread.

INTRODUCTION

As a by-product of winemaking industry, marc contains in average 3% crap bunches, 65% peel and 32% seeds. Grape seeds contain 9,9-17,9% oil, which varies depending on grape variety and climatic conditions. Varieties from southern areas contain more oil, and the air dried seeds contain 13.1-18.7 oil and 6.8-13.4% enotan. Red grape varieties have a higher oil content (17%) and enotan (11.1%), than white varieties. Depending on the variety of grape, the seed represent between 2-6% from the grape weight [1], [2].

The dried marc contains 40-65% seeds, which contain 12-22% oil. Grape seeds contain 44-57% cellulose, 30-40% water, 8-10% oils, 6-10% fats, 3-7% tannin and 1-2% mineral substances. [7] [10].

In Romania, from the about 1 million tons of grapes used in the wine industry, beside wine, there are obtained 120.000 tons of grape marc, without bunches and 400.000 hectoliters of yeast.

Due to the antioxidant properties of grape seeds from the oligomeric proanthocyanidins complex (OPC), the grape seed extract is recommended for many diseases. Research has shown efficacy of OPC from grape seed for damaged blood vessels or weak blood vessels, for the treatment of diabetic retinopathy, edema (fluid accumulation) in the arms and legs and high cholesterol and could prevent cognitive decline. Due to the proanthocyanidins component from grape seeds, they have an important role as a neuro-protectant in the hippocampus and in preventing cognitive loss that can occur with age.

Thus, flour from the seeds of grapes is a valuable element in strengthening bakery products. Notable results in rheological characterization of the dough with the addition of GSP were published. [6].

The study was to determine the effects of grape seed (GS) on the rheological and bread-making properties, antioxidant activity and phenolic composition of bread. Wheat flour was replaced with GS at levels of 2.5%, 5.0% and 7.5%. GS increased the dough development time at a level of 5.0% but did not change it at levels of 2.5% and 7.5%. The dough stability value increased from 6.4 to 12.3 min with the increase of GS content from 0% to 7.5%. Mixing tolerance index decreased from 41.1 to 6.4 Brabender Units Equivalent. Extensibility of dough containing GS was higher than that of the control dough. The antioxidant activities of the bread increased significantly with the increased GS substitution. Gallic acid and catechin content increased in the bread containing GS. It was concluded that GS could be added to the formulae to improve functionality of the bread.

MATERIAL AND METHODS

A common commercial wheat flour, ground (T 512) (moisture content (MC) = 13.50 %, ash = 0.55 %, gluten (GC) = 34.10 %, Falling number (FN) = 296s) provided by Carrefour Romania was used for the evaluation. Grape seeds were dried up to 2 to 4 % moisture and defatted by cold pressing to produce virgin grape seed oil as a main product. The defatted seeds were ground to a grape seed flour of particle size 100 to 150 μm required for dough preparation. GSP (grape seed powder) were added at 5%, 10%, 15% flour substitution level for different bakery recipes [12], [13].

Table 1. Recipe used for bakery products with grape seed flour substitution

Ingredients	Bread control (0% flour substitution)	Bread 5% flour substitution	Bread 10% flour substitution	Bread 15% flour substitution
Flour type 650	375.5 g	356.5 g	337.5 g	319.5
Yeast	8 g	8 g	8 g	8 g
Salt	6 g	6 g	6 g	6 g
Oil	2 g	2 g	2 g	2 g
Grape seed flour	-	19 g	38 g	56 g
Water	190 ml	190 ml	190 ml	190 ml

The final products after baking were analyzed taking in consideration: shape and volume of the product; color and appearance of the crust; degree of ripeness, state and core appearance; core porosity and pore structure; flavor (smell); taste and acidity. In Table 1 are presented the quantities of ingredients used for obtaining bread by the direct method [5], [8].

The standard program for bread baking lasts 3 hours and 8 minutes, and it consists of the following technological processes: first kneading (5 min), rest (5 min), second kneading (20 min), first leavening (39 min), 3rd kneading (10 seconds), second leavening (25 minutes and 50 seconds), 4th kneading (15 seconds), 3rd leavening (49 minutes and 45 seconds), and ripening (43 minutes).

For qualitative analysis of bakery products was used method of quality assessment scheme based on a standard of 30 points, evaluating the parameters presented in Table 2. [14], [15].

Table 2. Parameters checked for quality evaluation of bakery products [5], [8]

Organoleptic characteristics	Examination mode
Product form	It is estimated visually shape, volume proportional to mass and the presence of possible defects (deformed products, flat or raised, crushed, broken, etc.)
Crust	Observe the appearance, thickness, color and any cracks, wrinkles, seams, thick skin burned or blistered
- aspect	The cracks measure the length and width with a graded ruler and the results are expressed in millimeters.
- color	Examine the color of the visual surface and feature assortment considers whether it is analyzed.
Core - section aspect	Examine the visual core section (uniformity, smoothness and pore shape).
- color	Examine the color of flesh and visually observed if feature to the - analyzed assortment.
- consistency	Consistency is assessed by finger pressure, once in one place, on the core; if it returns to its original shape (do not takes finger shape). It is observed if the core is separated from the shell, ripe, dense, brittle, elastic, compact layers and traces of flour, sticky and breaking stretching thin silvery wires.

Table 2 - Continue

Smell	For assessing odor the product is cut, pressed a few times and immediately smelled. It appears it has sour, rancid, or musty smell or has another uncharacteristic smell.
Taste	A portion of the product is tasted (core and crust) and determine if whether the taste is characteristic and if there are some flaws as: foreign taste, sour, bitter, or too salty, impure minerals (sand, earth) by the appearance of a screech characteristic.
Ripeness, condition and appearance of core	The product is sufficiently baked so that at the impact on the crust the product sound seems muffled (not quite so pure) have less soft crust; pressing the middle finger slowly returns to its original state, the cutting blade core stays clean and does not crumble.
Core porosity and pore structure	The product has a uniform core porosity and fine pore structure (fluffy), with possibly max 2 goals up to 1x1 cm section and determined porosity is: - minimum 63% for black bread; - minimum 67% for semi-white bread; - minimum 76% for white bread.

RESULTS AND DISCUSSION

Applying the method of scoring ladder with 30 points, the score awarded to control product is 26 points. The product has met all requirements for sensory quality with less asymmetric shape and appearance of the crust was mat. According to Table 3, by evaluating the results we can say that the product is very good, exceptional quality characteristics, ideal.

The score given for bread with 5% added grape seed flour has 25 points. The bread obtained had mild defects of shape (asymmetry) and appearance of the crust was dull, rough with cracks. According to Table 2 examined by evaluating the results we can say that the product is really good, proper quality characteristics.

Bread with 10% added grape seed flour, achieved a score of 20 points using the same valuation methods. The obtained bread did not meet all the requirements, had defects on product shape, aroma and appearance of the crust.

By evaluating the examined results we can say that the product falls into the category of "acceptable product". By applying the scoring ladder with 30 points, the score given for bread with 15% added grape seed flour is 18 points. The obtained bread presents a lot of defects on the shape, appearance, aroma and taste. The product had an unsightly asymmetric shape. On the surface of the crust had appeared cracks, the aroma and the taste was sour, intensive, and characteristic of the addition. Product is satisfactory, with obvious quality defects.

Table 3. Parameters checked for quality evaluation of bakery products

	Product clues	Score				
		maximum	control	5%	10%	15%
1.	The shape and volume of the product	6	4	3	2	0
2.	The color and appearance of the crust	4	2	2	2	2
3.	Ripeness, condition and appearance of the crust	6	6	6	4	6
4.	Core porosity and pore structure	4	4	4	4	4
5.	Aroma (smell)	4	4	4	4	3
6.	Taste and acidity	6	6	6	4	3
	Total score	30	26	25	20	18

CONCLUSIONS

Different ingredients are included in bread formulations to improve nutritional and health benefits, organoleptic properties and shelf life. Grape seeds, a major component of grape pomace, are a waste product of the wine industry. Grape seed products (flour, oil, o/w emulsion etc.) belong to a group of additives with health benefits. A variety of nutraceutical and bioactive compounds, including procyanidins, phenolic compounds, tannins, dietary fibre, and resveratrol, a cancer chemopreventive agent, can be extracted from grape seeds. Antioxidants have also been found in cereals plant and seed oils, vegetables. Natural antioxidants including tocopherols and phenolic compounds may act to confer an effective defense system against free radical attack. Phenolic antioxidants have been viewed as an important class of food ingredients either as food additives or as novel ingre - to introduce extra health benefits to various food products.

According to the set methodology, the maximum recommended for replacement with grape seed flour is 5%, ensuring maximum functional compounds valuable in terms of minor technological changes and keeping quality conditions for the obtained products. Higher additions of grape seed flour (80 to 100 g/kg) were unacceptable on the part of assessors and final quality of bread, too. The dark color of the bread produced is a positive aspect, too (according to preference of consumers today).

The results will be applied on a large scale in a pilot production line in the bakery laboratory of Trasnilvania University of Brasov.

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RHEOLOGICAL INFLUENCE OF (1–3)(1–6) MUSHROOMS ß-GLUCAN, USED AS FLOUR SUBSTITUTION IN BAKERY INDUSTRY

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SUMMARY

Using of mushrooms waste as a source of valuable compounds is an important approach in sustainable development of human society. β-Glucan, as extract from mushrooms and mushrooms waste, is one of the most studied soluble dietary fibres, and is known for its positive effects on human health such as lowering glycemic responses and reducing serum cholesterol level, antitumor agent, and other important health benefits.

The paper shows a study about the effect of (1–3)(1–6) β-Glucan extracted from Pleurotus Ostreatus mushrooms, after addition in bread receipt, on the rheological characteristics of the dough bread.

Five levels of flour substitution level (0%, 1%, 2%, 3%, 4%) of (1–3)(1–6) β-Glucan extracted from Pleurotus Ostreatus mushrooms were used for the same bakery recipe. The dough was analysed by using MIXOLAB equipment, Chopin + protocol. Typical records were: water absorption, dough weight, tank temperature, mixing speed, torque, amplitude, dough stability.

The comparative study shows a good behaviour of the dough obtained by addition of mushrooms extract, opening new possibility to prepare new functional food products in the area of bakery industry. Future researches will take in consideration the influence of baking temperature on the main bio-compounds from the final product.

Key words: β-Glucan - rheological characteristics of bread dough

INTRODUCTION

Beta-glucans are a family of polysaccharides of D-glucose monomers connected via a beta-glycosidic linkages and differing molecular weight, density and three-dimensional structure. Biological activity of glucans is multidirectional and depends on many factors, primarily on the type and configuration of the connections between the constituent sugar residues, the degree of branching of the side chains of biopolymers, molecular weight of polysaccharides, and solubility in water. The most biologically active form of beta-glucan is the beta-1,3 / 1,6 glucan [5]. [5]

There are three ways to integrate the beta-(1-3),(1-6)-D-glucans among organisms; the first way is eating the foods that contain it, such as some types of fungus, the second way by eating like a drug dose, the third way, is the integration of beta-1,3 / 1,6 glucan in the food ingredients to get a functional food rich in beta-glucans, our research belongs to this type of study. This research comes as an initial step in this way, where we study the effect of addition of beta-1,3 / 1,6 glucan in rheological characteristics and the consistence of bread dough (we aim to produce a functional bread which contains B-G) [15]

MATERIALS AND METHOD

Method of extraction of beta-glucans from mushrooms

The objects of our study were aquaeous extracts of fruiting bodies of oyster mushroom Pleurotus ostreatus (Jacq.: Fr.) Kumm. Fruiting bodies were purchased from the local market in St. Petersburg. They were dried at 60°C, crumbled up and treated with 85% ethanol at 78 ° for 3 hours, twice, for extraction of lipids and low molecular substances and to increase permeability of mushroom cell walls. The remaining sediments were extracted twice by boiling water during 3 h. The resulted filtrates were evaporated and polysaccharide fractions were precipitated by 5 volumes of 96% ethanol and dried at 60°C.

Obtained extracts were powderized, stored at room temperature and were used for immunological studies and for fortification of bread. [1], [11], [15].

Immunological studies

For immunological studies fresh donor blood, Ficoll-Paque (density 1.078 kg m–3), Hank's salt solution (Biolot), luminol, phorbolmyristate acetate (PMA), formyl-peptide fMLP 1640, cow fetal serum, zymozane, agarose EEO, prodigiozan, concanavalin A (all "Sigma") were used.

Mononuclear and granulocyte cells were isolated from the donor blood stabilized with heparin solution (20 ME per 1 ml of blood) in Ficoll-Paque gradient using standard technique described by Boyum6. Blood plasma was layered on to Ficoll-Paque gradient and centrifuged for 40 min at 400 g. The mononuclear cells were collected from the interphase between plasma and Ficoll-Paque. The neutrophilic granulocytes were gathered from the precipitate after isolation of mononuclear cells by a hypotonic shock with distilled water during 30 seconds. [7], [14]

Mononuclear cell suspension (concentration of 5 × 106 ml–1) resuspended in RPMI 1640 medium including 10% fetal serum was placed in a 96-well flat-bottom microplates (Costar) by 0.1 ml in each hole. Simultaneously, the investigational preparations placed in appropriate solutions were added in the same holes. The Russian preparation of the natural lipopolysaccharide prodigiosan, a strong inducer of pro-inflammatory cytokines, was used as the positive control. The microplates were placed in the CO2-incubator for 24 h, after that the amount of cytokines in the culture medium was detected by an immunoenzymatic method 7. Test systems made by the company Cytokine (St. Petersburg, Russia) were used.

Determination of the extracts composition

The extracts were analysed for the total carbohydrate content by phenol-sulfuric acid method 9, and protein content was determined by Lowry's method 10.

Impact of beta glucans in rheological characteristics of bread dough

Five levels of flour substitution level (0%, 0.2%, 0.6%, 1%, 1.4%) of (1–3)(1–6) β-Glucan extracted from Pleurotus Ostreatus mushrooms were used for the same bakery recipe. [9] The dough was analysed by using MIXOLAB equipment, Chopin + protocol. Typical records were: water absorption, dough weight, tank temperature, mixing speed, torque, amplitude, dough stability.

RESULTS AND DISCUSSION

The yield of water-soluble fraction from mushroom fruiting bodies was 6.5 - 6.8 g per 100 g of dried mushroom powder. The content of polysaccharides in mushroom aqueous extracts was analysed and was estimated to be 73 ±2 % of dry matter. The protein content in the extracts was up to 23±1%.

Primary evaluation of biological activity of studied extracts was made by test analysis of the reactive oxygen species generated by cells of peripheral human blood by a method of luminal-dependent chemiluminescence. The test was selected on the basis of supposition about stimulating effect of extracts of Pleurotus ostreatus on the system of phagocytosis. When activating the phagocytes of the blood, a cascade of chain reactions is started accompanied by the increased oxygen consumption from the environment. The cells pass on hexose monophosphate path of respiration. The final products of the reaction contained the reactive oxygen species, which, being combined with luminol, caused luminescence registered at a wave-length of 425 nm.

The extracts from fruit bodies of Pleurotus ostreatus were studied at concentrations of 0.001–1.0 mg ml–1. Against the background of the whole blood and PMA as a positive control, tested samples of mushroom aqueous extracts have increased production of reactive oxygen species by neutrophils of peripheral human blood. The maximum effect was observed at a dose of 0.1 mg ml–1 [2], [3], [4].

The ability of obtained mushroom extracts to induce the synthesis of cytokines, immunoregulating proteins performed by human blood cells were studied. The preparations studied showed pronounced immunostimulating action involving almost various immunocompetent cells. The results obtained in the in-vitro experiments have indicated the potential for extracts of Pleurotus ostreatus to be used as a functional ingredient to develop functional food products [6], [10].

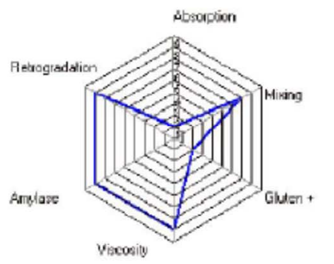
From rheological point of view, the researches show the stability values (min) respectively for 0, 2%, 0,6%, 1%, 1,4% level of substitution: 10,88; 10,43; 10,43; 9,42; 9,68; 9,92. Torque values (Nm) were: 1,07; 1,10, 1,11; 1,10, 1,08. α , β , γ coefficients were (Nm/min): -0.078, 0.386, 0.042; -0.080, 0.410, 0.056; -0.020, 0.370, -0.004; -0.032, 0.370, -0.002; -0.030, 0.342, -0.020.

In figure 1, 2, 3, 4, 5 are presented result of Chopin + protocol, for 0, 2%, 0,6%, 1%, 1,4% level of substitution at tank temperature 30 degrees C, mixing speed 80 rpm, dough weight: 75 g. [12]

The parameters shows have the following meaning: α is slope of curve between end of period at 30°C and C2 and represent the protein weakening speed under the effect of heat; **β**- slope of curve between C2 and C3and represent starch gelatinisation speed; γ - slope of curve between C3 and C4 and represent enzyme degradation speed.

Water Absorption (%) is the quantity of water required to obtain C1 = 1.1 Nm +/- 0.05. This quantity of water is absorbed by the flour in order to achieve a given consistency during the constant temperature phase. **Time for C1** (min) is the time required to obtain C1. The stronger the flour, the longer it takes. **Stability (min)** is the time during which torque is > C1 – 11% (constant T° phase) and is related with the dough resistance to kneading: the longer it takes the "stronger" the dough. **Amplitude (Nm)** is the curve width at C1, related to the dough elasticity: the higher the value, the greater the flour elasticity.

	Time (min)	Torque (Nm)	temp. Dough(°C) (Traduction	Amplitude (Nm)	Stability (min)
C1	7.62	1.07	32.1	0.07	10.88
C2	17.35	0.42	55.6		
C3	23.00	2.03	76.3		
C4	30.00	2.27	87.2		
C5	45.02	3.59	58.6		



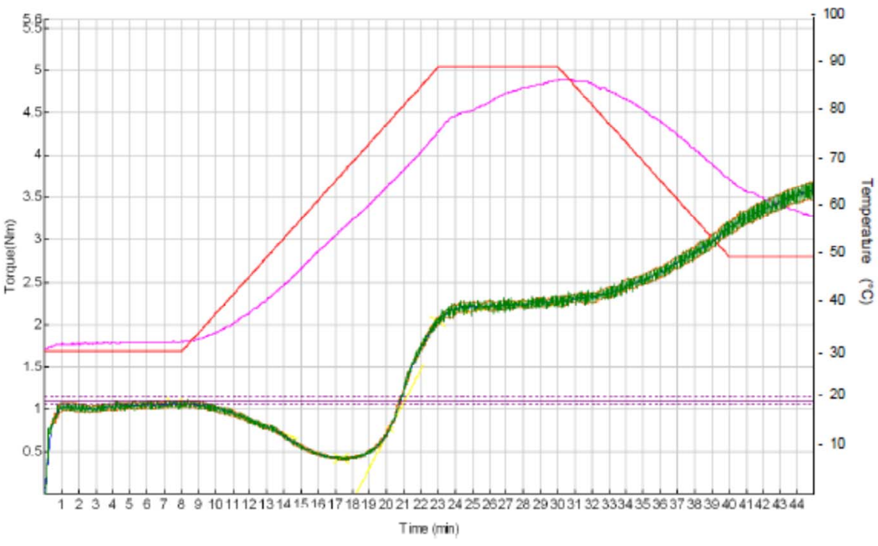
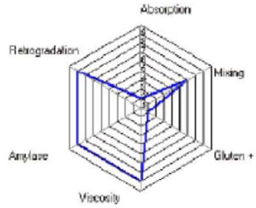


Figure 1. Results for the control flour 0% of β-glucan (k)

	Time (min)	Torque (Nm)	temp. Dough(°C) (Traduction	Amplitude (Nm)	Stability (min)
C1	1.25	1.10	31.8	0.09	10.43
C2	17.28	0.42	56.3		
C3	23.00	1.99	77.1		
C4	30.00	2.28	87.5		
C5	45.02	3.65	58.6		



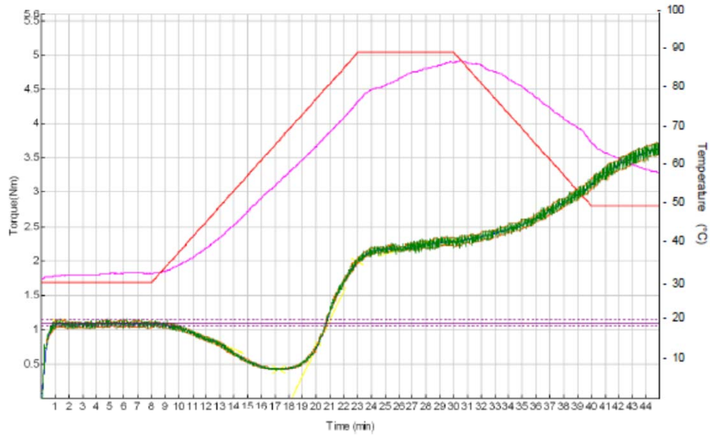
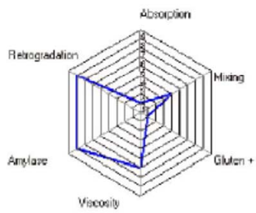


Figure 2. Results for the flour with concentration 0,2% of β-glucan (P2)

	Time (min)	Torque (Nm)	temp. Dough(°C) (Traduction	Amplitude (Nm)	Stability (min)
C1	1.10	1.11	31.6	0.10	9.42
C2	17.28	0.38	56.5		
C3	23.00	1.84	77.2		
C4	30.00	2.05	87.6		
C5	45.00	3.27	58.8		



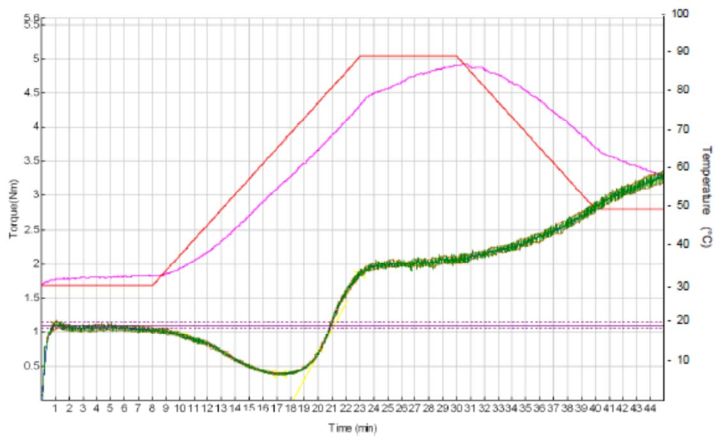
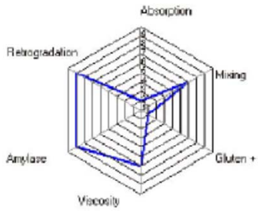


Figure 3. Results for the flour with concentration 0,6% of β-glucan (P3)

	Time (min)	Torque (Nm)	temp. Dough(°C) (Traduction	Amplitude (Nm)	Stability (min)
C1	4.00	1.10	32.8	0.08	9.68
C2	17.30	0.40	56.1		
C3	23.00	1.82	77.1		
C4	30.00	2.01	87.3		
C5	45.02	3.20	60.2		



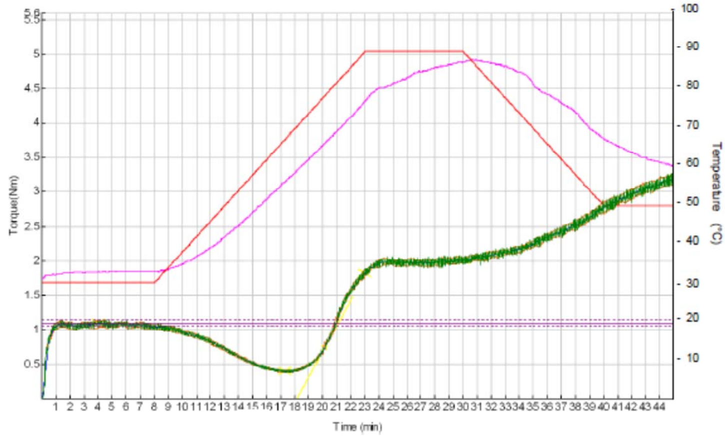
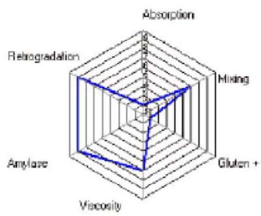


Figure 4. Results for the flour with concentration 1% of β-glucan (P4)

	Time (min)	Torque (Nm)	temp. Dough(°C) (Traduction	Amplitude (Nm)	Stability (min)
C1	5.52	1.08	32.8	0.07	9.92
C2	17.50	0.38	56.4		
C3	23.00	1.80	76.5		
C4	30.00	2.08	86.9		
C5	45.00	3.41	58.8		



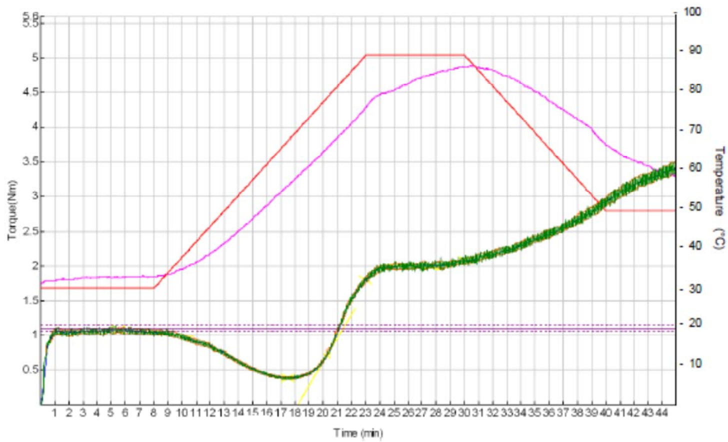


Figure 5. Results for the flour with concentration 1,4% of β-glucan (P5)

The point C1 it is used to determine water absorption at T1°C and time T1 (dough temperature and time corresponding to the occurrence of the various torques); C2-measures protein weakening as a function of mechanical work and temperature T2°C and T2; C3-measures starch gelatinisation at T3°C and T3; C4-measures hot gel stability at T4°C and time T4; C5-measures starch retrogradation in the cooling phase at T5°C and time T5. [8]

CONCLUSIONS

Using of mushrooms waste as a source of valuable compounds is an important approach in sustainable development of human society.

β-Glucan, as extract from mushrooms and mushrooms waste, is one of the most studied soluble dietary fibres, and is known for its positive effects on human health such as lowering glycemic responses and reducing serum cholesterol levels (Kinnari J. Shelat et al, 2011), antitumor agent, and many other important health benefits.

Five levels of flour substitution level (0%, 1%, 2%, 3%, 4%) of (1–3)(1–6) β-Glucan extracted from Pleurotus Ostreatus mushrooms were used for the same bakery recipe. The dough was analyzed by using MIXOLAB equipment, Chopin + protocol. Typical records were: water absorption, dough weight, tank temperature, mixing speed, torque, amplitude, dough stability.

The comparative study shows a good behavior of the dough obtained by addition of mushrooms extract, opening new possibility to prepare new functional food products in the area of bakery industry. Future researches will take in consideration the influence of baking temperature on the main bio-compounds from the final product.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.798:631.564:637.5’64
Prethodno priopćenje
Preliminary communication

STUDY OF TECHNICAL AND HUMAN INFLUENCE FACTORS ON THE EFFICIENT USING OF HOG CASINGS PROCESSING EQUIPMENT

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ABSTRACT

In the food market, there is a growing interest in traditional products. Thus, some sausage producers tend to industrialize the manufacturing of traditional sausages filled in natural hog casings. This requires the improvement of the technical industrial processing system geared toward both high productivity and greater guarantee of the hog casings quality. The paper presents a study on the factors that can positively influence the effective use of industrial equipment. Legal requirements for hog casings processing were identified and also the technical factors and the situations that cause rejections. As the determining factor is considered to be the training of operators shown in an experimental study on effective methods to ensure adequate workforce to obtain top quality products.

Key words: technical system, hog casings, factors, workforce, quality.

INTRODUCTION

Usually, the natural hog casings are processed in order to use them in sausage factories and are intended for human consumption. Sausage consumers prefer natural casings instead of artificial casings because the sausages taste and quality offered by natural casings are unique (Chawla, 2006). Any natural product has its disadvantages, and in this case we are talking about a higher price compared to the sausages produced in artificial casings (Fischer, 1988). In slaughterhouses all the sacrificed pigs must be checked by a veterinary and proven healthy. The natural hog casings processed in slaughterhouses are usually preserved by salting, curing and/or drying (Ockerman, 1988). The hog casings packed in dry salt may deteriorate in quality (Wijnker, 2006). However, salting also has advantages: it does not require special equipment and protects the product from the attack of micro-organisms. Pathogens like Salmonella spp. and Listeria monocytogenes occasionally survive in fermented sausages (Cowden, 1989; Leistner, 2000; Lelieveld, 1990). For more thorough research on these issues, firstly the products can be lyophilized (Mnerie, 2008).

For greater guarantee of the quality of sausages stuffed into natural hog casings, a series of technological and sanitary measures are set, most of them being standardized. All these aspects must be listed on the product label, according to the recommendations for nutrition labeling (Mnerie, 2015). In the context of continuous upgrades in the field, a more careful analysis of the factors which have directly influenced the quality of natural hog casings is required. Thus, the literature warns that factors such as the age of the animal and its diet influence the quality and properties of natural hog casings because the natural casings must be sufficiently strong to withstand the pressures exerted during filling, stuffing and processing (Bakker, 1999; Ockerman, 1988; Wijnker, 2006).

This paper addresses some constructive and functional aspects of the processing machines for hog casings. Typically, a line of hog casings processing mainly includes equipment for emptying, cleaning, washing and conservation. Currently, as their performance increases and they constantly improve, there are on the market competitive industrial producers of equipment for the food industry. This study intends to identify some constructive critical points that can affect the quality of the cleaned hog casings. The constructive conditions and how to exploit them are significant factors that influence the effectiveness of modern technical systems. Therefore, it is also included a study on the influence of the periodic professional trainings of operators on the high quality of the final products.

METHODS

The experimental study was conducted under industrial conditions in the casings department (owned by SC DARIMEX INTERNATIONAL S.R.L.) of the largest slaughterhouse in Romania, located in Timisoara (owned by Smithfield) [13].

In the **first phase,** the characteristic elements of work environment were identified, where approximately 5000 pigs are sacrificed daily (more than 600 pigs per hour). Because of the slaughtering rhythm, it was impossible to use the manual processing of the hog casings. Figure 1 shows the *Hog Casing Cleaning Line* used in the casings department for the cleaning of the hog casings.

Figure 1 - Hog Casing Cleaning Line (with 6 machines).

In the **second step**, the legal provisions under which the production activity is carried out were identified. It was found that the whole process is based on the following legislation:

– The Romanian Health Ministerial Order number 1225/2003 approving the methodology for the organization and certification of the professional training of staff on learning fundamental notions of hygiene;
– The Romanian Health Ministerial Order number 568/2004 for approving the guide concerning the thematic content of the modules for the training of the staff participating in vocational training courses on learning fundamental notions of hygiene;
– The Romanian Health Ministerial Order number 976/1998 approving the norms of hygiene, concerning production, processing, storage, preservation, transport and sale of food;
– Regulation number 178/2002 /EC stating the general principles and requirements of food law, establishing the European Food Safety Authority and establishing procedures in matters of food safety;
– Regulation number 852/2004 /EC on the hygiene of foodstuffs;
– Regulation number 882/2004 /EC on official controls performed to ensure the verification of compliance with feeding and food law, animal health and animal welfare rules;
– CODEX ALIMENTARIUS;
– Regulation number 1333/2008 /EC on food additives;
– Regulation number 98/83 /EC on the quality of water intended for human consumption;
– Romanian law number 296/2004 concerning consumption code, with subsequent amendments (Directive 98/37/EC).

In the **principal moment** of the study, it was observed that the situations causing the rejections fall into two categories:

A. Characteristics of the animals slaughtered: race, age, sex, diet, health

Among them were identified on stream:

– The presence of intestinal parasites (e.g. *Ascaris lumbricoides*)
– High intestinal content
– Weak and ill casings; and other

B. Processing conditions:
   1. Technical deficiencies of the system:
   - Damaged rollers, (Figure 2, a.)
   - Grease losses, (Figure 2, b.)
   - Overburdened gear motors, (Figure 2, c.)
   - Water temperature failure (37-45^{0}C, provided technological); and other
   2. Human mistakes: wrong actions on the equipment, failure of the equipment cleaning procedures, superficial cleaning of the hog casings etc.

a. b. c.

Figure 2 - Some technical deficiencies of the Hog Casing Cleaning Line.

After analyzing these comments together with 6 experts from the technical staff it was decided to continue the research by experimental study on the importance of regular training of operators, the professional level and responsible attitude of the operators being considered the main factor influencing the using with efficiency of the technical system for processing hog casings.

To check this hypothesis of the experts, in January 2016, the 53 operators working on the processing line were subject to an assessment. Each operator had to complete a questionnaire with 18 questions about the main issues of exploitation of the technological line for processing. Then a training was organized, which included instructions and rules of operation of the equipment for producing quality products, and regarding the technological process, qualitative and quantitative requirements and basic notions of hygiene, H.A.C.C.P. concepts, general requirements for food business objectives, rules of good hygiene practices in the food industry, cleaning and disinfection, as well as pest control.

In March, we repeated the questionnaire and we conducted training with new intervention procedures to avoid rejects due to maintenance and operation of machinery.

In May, it was performed the evaluation by means of questionnaire and trainings were also conducted, comprising some corrective elements of errors detected in the questionnaire.

RESULTS AND DISCUSSION

Because in this field qualified workers are very rare, we considered their evaluation absolutely necessary and all the operators were submitted to a written examination on paper, consisting of 18 questions, and they were given 60 minutes to answer the questions, then the papers were corrected by a specialist in this field and the results were centralized and presented in Table 1.

Table 1 - The situation of the results of the operator's evaluation

The average number of correct answers per operator		
January 2016	March 2016	May 2016
11.34	14.82	17.36

Quality controllers checked each set with water, and the sets that did not fit the technical specification of the product were subject to additional manual work (additional cost) named calibration, where the defects were eliminated and the remaining good sections of the sets were placed by categories of calibers.

At the end of each period, the refused sets of hog casings were inventoried and a substantial reduction in the number of refusals due to the work environment was observed (Table 2)

Table 2 - Situation of the evolution of the hog casings sets refused

Evaluation period	Number of hog casings sets processed	Number of sets refused	%	Comparative evolution
January - February 2016	178,636	8,632	4.83	1
March – April 2016	185,324	7,535	4.06	0.84
May-June 2016	188,582	6,389	3.39	0.70

The higher emphasis on the importance of professional training of workers was reflected in the increased maintenance work quality on mechanical drive systems. The interest of the operators for this experiment was financially rewarded. In Figure 3 it is shown the graphical representation of the effect of raising the level of professional training of operators on hog casings quality. By analyzing the experimental results, it can be noticed that with further training, after six months, the number of the hog casings sets refused decreased with about 30%.

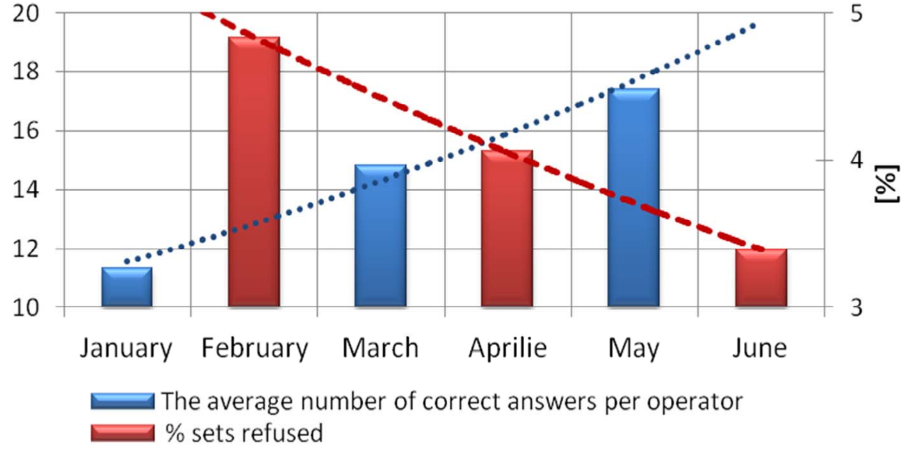

Figure 3 - The effect of raising the level of professional training of operators on hog casings quality

Because the human factor is very important, and in accordance with hygienic design principles, [12], [14] it is recommending to the top management of the company the publishing of some instructions for operators who work on the technical system for hog casings processing. For example: „*Cleaning is only allowed when all power is shut down. The emergency stop should be pressed, so it is sure that the power is shut down. At the end of the day the warm and cold water tanks should be emptied. With a high-pressure cleaner, max. 100 bar and maximum 50^{0}C hot water, to clean the machines and water tanks. It is forbidden to spray water directly on the rollers, in the motors and other electrical parts, switches and sensors. The rollers, switchers and sensors should be cleaned with brushes and hot water. But it is not allowed to do this with a high pressure cleaner because it is possible that the rollers, switches and sensors will be damaged. Only turn the rollers by hand. All turnable covers should be in the open position when they will be cleaned. Never use flammable cleanings fluids, just use a soft disinfecting cleaning fluid. Check if all cleaning fluids are removed before starting the machine again. Way of work: the pre-cleaning with high pressure cleaner. Spray the cleaning fluid on the machine and let it work in for about for 15 minutes. Then clean with high pressure cleaner with hot water 50^{0}C. After that spray a disinfecting cleaning fluid and let this work in for 10 minutes. Then on the cleaning machine use a high pressure cleaner, then spray with cold water. Make sure that all the cleaning fluids are removed.*” [12].

CONCLUSIONS

The results of this research prompted a change of the firm’s strategy, which until that moment had put greater emphasis on the technical equipment, not on the professional quality of the human resources. The company found itself in this situation also because there is a high personnel fluctuation in this area, caused by a difficult working environment and a low salary. Presently, the company acts more on keeping its current employees, allocating funds, both for higher salaries and for covering the costs of organizing trainings. Now there is a complex program of regular professional training for all staff involved in this area. It aims specifically at raising the level of consciousness and responsibility for the transformation of an animal by-product that is processed to become food. It was noted that staff training costs are insignificant in relation with the contribution to company profits, which can grow by reducing rejects and increasing customer confidence in the quality of the provided product.

Regular analysis of the effective functioning of the technical systems for various agro-food products highlights key issues always oriented toward food quality. The working environment for hog casings processing is not attractive for hiring operators, but ensuring a high level of training is a guarantee of the superior quality of the hog casings production, with costs as low as possible, a better chance for good quality of the sausage and safe food for consumers.

AKNOWLEDGEMENT

This paper contains results of studies realized in the frame of the doctoral study of PhD student Vasile Nagy with the title "*Optimization of the technical-functional parameters of line processing hog casings, through integrated approach.*"

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.767.2
Stručni rad
Expert paper

CARBON FOOTPRINT OF ELECTRICITY FROM BIOGAS WITH STEAM EXPLOSION PRETREATMENT

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ABSTRACT

In the absence of appropriate pretreatment, maize stover is a widely available but poorly fermentable agricultural residue. With stover pretreatment using the novel steam explosion (SE) technology, this study calculates the carbon footprint of 1 kWh electricity from maize stover biogas. The system includes a 500 kW_{el}-biogas plant with a combined heat-and-power (CHP) unit (50% external off-heat utilization), as well as substrate production and digestate management. Total GHG-emissions are 239 g CO_2-eq/kWh, with the most important contributors being methane slip in the CHP exhaust (133 g CO_2-eq/kWh), electricity for plant operation (43 g CO_2-eq/kWh) and construction materials (24 g CO_2-eq/kWh). Constructing and operating the SE unit contributes little (0.5 g CO_2-eq/kWh) if the heat requirements can be covered by off-heat from the CHP unit. Hence, SE pretreatment can allow the use of agricultural residues for biogas as a suitable alternative to the use of energy crops.

Key words: carbon footprint; life cycle assessment; agricultural residues; bioenergy, maize stover, steam explosion; pretreatment

INTRODUCTION

Electricity production from renewable sources is an important topic in Austria (BMLFUW (Bundesministerium für Land- und Forstwirtschaft 2010). Biogas production from agricultural residues such as maize stover allows substitution of dedicated energy crops. Agricultural residues as biogas substrates avoid competition for agricultural lands between food and energy crops in an economically efficient way (Agrinz Technologies GmbH 2012).

Pretreatment can enhance the digestibility and gas yield of lignocellulosic biogas substrates such as straw (Hendriks and Zeeman 2008). Steam Explosion (SE) is a pretreatment technology which exposes the substrate to steam under high temperature and pressure for a specific period of time, followed by a rapid pressure drop (Horn et al. 2011). During this procedure the fiber structure is destroyed, making the substrate more digestible for microbes and leading to higher fermentation rates (Menardo et al. 2012).

This technology is relatively new, and its environmental effects have rarely been studied in the context of biogas production. Environmental life-cycle assessment (LCA) is a method to estimate potential environmental impacts of products and services (Klöpffer and Grahl 2007) and it is used in this study to assess the effects of electricity (and heat) production from biogas with maize stover as the main input substrate under typical Austrian conditions. LCA results for the impact category global warming potential (GWP100), also known as the carbon footprint, are presented in this paper.

METHODS

To calculate the carbon footprint, the entire biogas plant setup is modelled. This encompasses the construction and operation of the biogas facility (including the SE unit), as well as substrate production and digestate management (Figure 1). The model of the biogas plant is based on Laaber (Laaber 2011) and described in more detail in Kral et al. (Kral et al. 2016). The biogas is produced in two fermenters with a volume of 2,701 m^3 each and afterwards combusted in a 500-kW combined heat and power module (CHP).

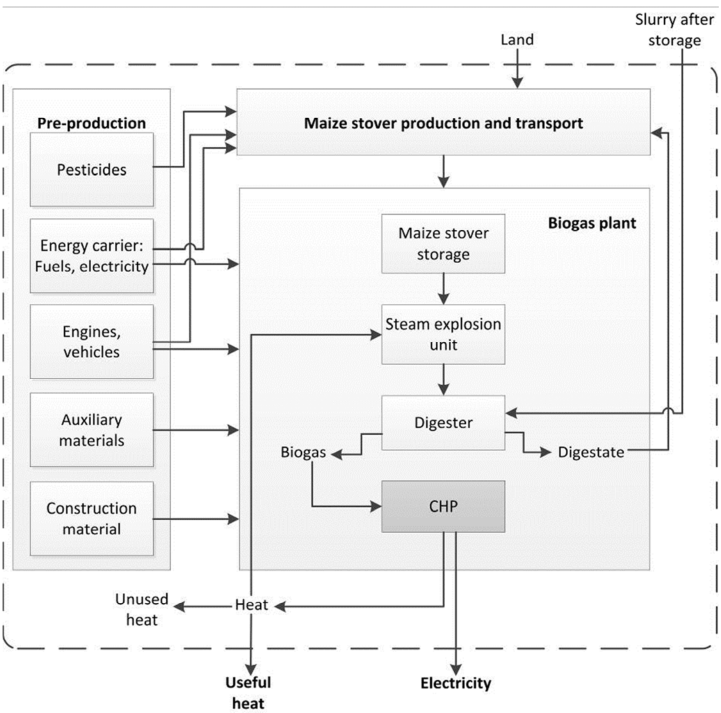

Figure 1 System overview (Kral et al. 2016)

The main input substrate for the fermentation process is maize stover (3215 t DM per year) which would otherwise be mulched into the soil. Operation of the 500-kW biogas plant requires 5.2 km^2 of croplands, with an annual yield of 5,043 t grain maize. Pig slurry (178 t DM per year) serves as a co-substrate whose greenhouse gas (GHG) emissions prior to entering the biogas fermenter are attributed entirely to the pig fattening process. Maize stover is stored at the biogas plant while slurry is immediately processed after delivery; hence no infrastructure or GHG emissions for slurry storage are calculated.

The process for stover production is modelled based on an adjusted Ecoinvent (Ecoinvent-Centre 2010) process that includes machinery usage for ploughing, sowing, hoeing, harrowing, digestate and pesticide applications, harvesting and transport. The following auxiliary processes are also included: seeds and pesticides production, energy generation and the production of machinery and infrastructure. Grain drying was omitted from the system as it can be attributed to grain production only. The pesticide mix was adjusted to reflect pesticides commonly used in Austria and the fertilizer input was replaced by 15,365 t a^{-1} digestate from the fermentation process. A rough calculation comparing the nutrient content of the digestate (Döhler and Achilles 2013) with the demands for maize production (Lebensministerium 2006) shows that nutrient flows are approximately balanced. The harvest ratio for grain maize: maize stover is 1.3 : 1 (Döhler et al. 2009). To attribute the environmental burden of maize cultivation between grain and stover, economic allocation factors of 0.75 and 0.25 were calculated using market prices for grain maize at field and maize stover at field (Agrinz Technologies GmbH 2012; Chamber of Agriculture 2012; Schindler 2014). Thus, 25% of emissions caused during maize cultivation are attributed to the stover portion, and the remaining 75% to grain maize.

The pretreatment unit is modelled using the following amounts of materials: 1.9 t of steel, 37.24 of kg polystyrene and 32.78 t of concrete for the foundation (authors' estimates based on information from a SE-unit manufacturer). The rest of the construction of the biogas plant and the CHP unit is modelled as described in Kral et al. (Kral et al. 2016).

The heat required to operate the SE module is supplied by the CHP unit via a steam boiler. 12.3% or 488,574 kWh of the total heat output at the CHP unit are used for pretreatment assuming heating and pumping losses of 10% of the total heat used (own estimate) and a boiler efficiency of 64% (Panther et al. 2004). Temperature, duration, and pressure of the SE pretreatment process are based on Bauer et al (Bauer et al. 2014).

The CHP unit was chosen to produce 500 kW electrical power and 534 kW thermal power. To reflect common practice in Austria, 100% of the produced electricity are fed into the national power grid while the 498,000 kWh annual electricity requirement for biogas plant operations (CHP unit manufacturer, pers. comm.) is not supplied directly by the CHP but taken from the national grid. Hence the use of electrical grid energy is modelled, applying an average production mix for Austria from the Ecoinvent database (Ecoinvent-Centre 2010). Further energy for fermenter heating is not necessary as the substrate is warm enough after pretreatment to run the fermenters at a mesophilic level. A share of 50% of the produced energy goes to external uses such as district heating, 12% are used for the SE unit and the rest remains unused.

The functional unit of this carbon footprint study is 1 kWh electrical energy going to the power grid. Emission factors to calculate GHG emissions are taken from the LCA method ReCiPe (H) (Goedkoop et al. 2008) over a 100 year time horizon. For methane emissions the original factors are replaced by those published in the latest IPCC report (Intergovernmental Panel on Climate Change 2013).

RESULTS AND DISCUSSION

Figure 2 shows the contributing processes to overall GHG emissions as GWP100 expressed in CO_2-equivalents per kWh of electrical energy produced at the CHP unit.

The biggest portion of CO_2-eq emissions (133 g CO_2-eq/kWh or 56% of total emissions) occurs in form of unburnt methane called methane slip from the CHP module that emits into the atmosphere. These emissions can be partially avoided by keeping the machine in good condition through regular engine maintenance.

Provision of grid electricity for plant operations is the second largest emitter, with 43 g CO_2-eq/kWh or 18% (including electricity requirements of the SE unit with 0.1 g CO_2-eq/kWh). This source of GHG emissions can be influenced by the choice of the electricity mix (Kral et al. 2016). Using electricity from renewable sources would clearly reduce these GHG emissions as this mix would be "cleaner" than the Austrian average.

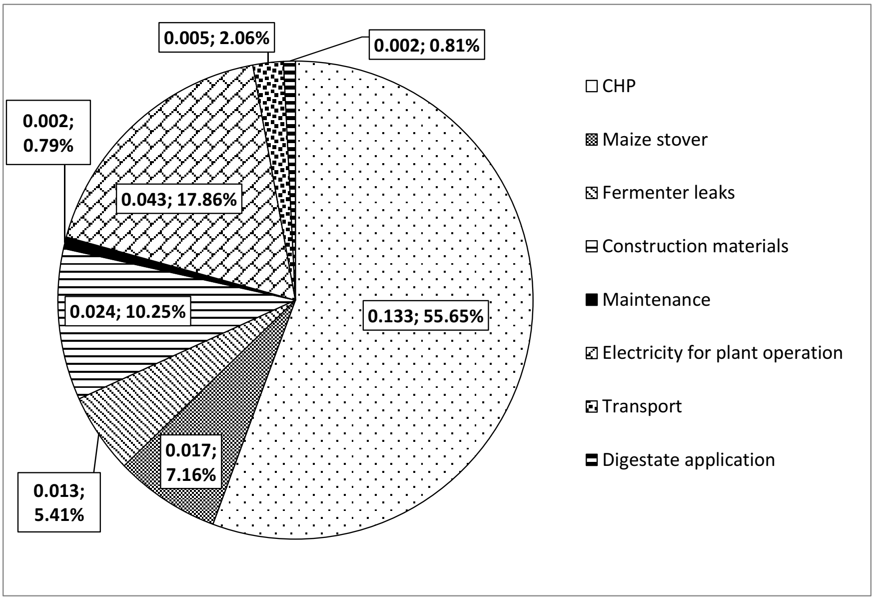

Figure 2 Contributing processes to overall GHG emissions from electricity production from biogas in kg CO_2-eq and percent, both per kWh electrical energy output from the CHP unit.

Mastic asphalt and concrete causing 10 g CO_2-eq/kWh each are the two most important construction materials considering GHG emissions followed by gravel with 1.4 g CO_2-eq/kWh. The remaining construction materials (more than 20) cause in sum less than 3 g CO_2-eq/kWh. In total an amount of 24 g CO_2-eq/kWh (10%) is emitted due to construction materials. Transport of the materials is excluded as it is expressed separately. Emissions referring to the construction of the SE unit sum up to a total of 0.4 g CO_2-eq/kWh.

Maize stover, the main input substrate for biogas production, causes 17 g CO_2-eq/kWh (7%) based on the economic allocation method applied here. The most important emitters are the

harvesting process (approx. 6 g CO_2-eq/kWh) and ploughing (approx. 4 g CO_2-eq/kWh). Digestate application could also be considered as part of substrate production but is shown separately here in order to indicate its contribution. It causes 2 g CO_2-eq/kWh or less than 1% of overall emissions.
Methane emissions from leaks in the fermenters sum up to 13 g CO_2-eq/kWh (5%). This is quite low compared to other studies (Bachmaier 2012) but it is assumed that most of the emissions are eliminated by a gas torch.
Transports and biogas plant maintenance are of minor importance, emitting 2 g CO_2-eq/kWh each which is less than 1%.

CONCLUSIONS

The main contribution to GHG-emissions from electricity production from biogas comes from unburned methane emitted at the CHP unit, with 133 g CO_2-eq/kWh or 56% of total emissions. These emissions can be reduced by proper CHP maintenance.

The additional emissions caused by the construction and operation of the SE pretreatment unit are of minor importance (0.5 g CO_2-eq/kWh) if the heat requirements can be covered by off-heat from the CHP unit. Hence, from a carbon footprint perspective, the use of agricultural residues as biogas substrates after pretreatment can be a suitable alternative to the use of energy crops, provided that the necessary extra heat is not required elsewhere to supply external heat users.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.767.2
Izvorni znanstveni rad
Original scientific paper

BIOGAS PRODUCTION FROM MAIZE STRAW AFTER PRETREATMENT WITH STEAM EXPLOSION

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SUMMARY

The production of bioenergy from agricultural residues does not compete with food or feed production and represents a largely unused resource. One of the most widely available lignocellulosic residue is maize straw, which is a very promising raw material for biofuel production. However, proper bioconversion of this biomass requires a pretreatment step. Steam explosion has proven to be an effective pretreatment method for refractory lignocellulosic biomass. The aim of this study was to (1) determine the optimum pretreatment conditions (temperature and time) of maize straw for biogas production, (2) optimize the utilization of the steam-exploded maize straw in continuous anaerobic digestion (AD) systems. Different steam explosion conditions were tested (temperature and pretreatment time). The effect of the pretreatment on the methane yield was analyzed in eudiometer batch digesters of 0.25 l capacity. The results of the batch tests showed that methane production raised with pretreatment at 160 °C for 30 min, obtaining an increase in the yields of around 33% in comparison to the untreated biomass. Methane yields decreased slightly with pretreatment intensities extending beyond this point. The continuous digestion tests were carried out in two fermenters with a capacity of 150 L at mesophilic temperature (40 °C). Two different organic loading rates (OLR) of 1 and 2.5 kg VS m^{-3} d^{-1} were tested and some parameters such as dry matter (DM), volatile solids (VS), pH, ammonium nitrogen (NH_4-N), and residual methane potential were regularly measured. The results of the continuous tests showed that the utilization of steam exploded maize straw in a continuous system is feasible with an OLR of 2.5 kg VS m^{-3} d^{-1} with the use of no more additives than a nitrogen source (urea). The residual methane potential increased notably when the OLR was increased to 2.5 kg VS m^{-3} d^{-1} due to the decrease in the hydraulic retention time (HRT), entailed with an increment in the OLR.

Keywords: anaerobic digestion, maize straw, pretreatment, agricultural residues

INTRODUCTION

Agricultural residues do not compete with food or feed production and represent a largely unused resource. Their utilization for biofuel production is a fast growing market in many European countries (Schittenhelm S., 2008). One of the most widely available lignocellulosic residue is maize straw, which is a very promising raw material for biofuel production (Scarlat et al., 2010). Maize straw was estimated to be the second most abundant crop residue in the European Union with a total average production of 49 million tons of dry matter per year (Scarlat et al., 2010). Even using moderate rates of removal of around 40-50%, maize straw could provide in the EU27 between 19 and 24 million dry tones per year for its sustainable transformation into biogas.

However, proper conversion of this biomass requires a pretreatment step, as the lignocellulosic complex hinders the hydrolysis of polysaccharides into fermentable sugars. Steam explosion has been proven as an effective pretreatment method for strong lignocellulosic biomass (Lizasoain et al., 2016; Menardo et al., 2013; Vivekanand et al., 2013). This pretreatment involves heating the biomass at high temperature values, followed by a mechanical disruption of the biomass fibers through a rapid pressure drop. The process causes hemicellulose degradation and lignin transformation. In addition, it enhances the methane yields as well as the degradation speed. However, steam explosion pretreatment can induce the formation of degradation by-products (e.g. furan derivatives), which could have inhibitory effects on the microorganisms involved in the anaerobic digestion (AD) (Bauer et al., 2014; Hendriks et al., 2009). Therefore, optimal steam explosion conditions should be identified for each specific type of biomass in order to achieve an efficient anaerobic digestion processes.

Continuous stirred tank reactors (CSTR) are the most common type of bioreactors for anaerobic digestion. CSTR can be used in different sizes from small-size, used in decentralized and remote areas, to large-scale biogas plants. Despite there are many studies about steam explosion of lignocellulosic biomass for biogas production, no research results about steam exploded maize straw for biogas production in a CSTR system has been published

The current study aimed to (1) determine the optimum pretreatment conditions (temperature and time) of maize straw for biogas production, (2) optimize the utilization of the steam-exploded maize straw in continuous anaerobic digestion systems.

MATERIAL AND METHODS

Substrate and steam explosion pretreatment

The maize straw used in this study was harvested in autumn 2013 in the region of Burgenland (Austria). The straw was dried on the field, compressed in a round bale and transported to Parndorf (Austria), where the steam explosion unit is located. The maize straw was chopped to a maximum particle size of 5 cm using a straw mill. In the pretreatment unit, the chopped material is mixed with water and introduced into a preconditioning tank. Here, the mixture is preheated with water vapor and then it is transported along a conveyor screw, which also provides water vapor, until the straw reaches a feed tank. Then, this tank closes by means of automatic valves and the biomass in the tank is heated with water vapor until it reaches a temperature close to the final target. At this point the biomass is introduced into the hydrolysis tank, where the biomass is kept at the target pretreatment temperature using a heating jacket containing thermal oil, which is heated up with the exhaust gases from the CHP unit. During the stay in the hydrolysis tank, a homogeneous heat distribution in the biomass is ensured by an agitator, which also prevents the formation of coatings in the reactor. As a consequence of the temperature increase, the pressure inside the reactor increases. After the set holding time, the pressure is abruptly reduced to almost atmospheric pressure using a pressure diaphragm, whereby the water in the biomass immediately evaporates, which fosters the physical disruption of the biomass. This "explosion" takes place in an expansion tank and the pretreated biomass is transported to a blow tank, from where the pretreated straw is removed. In this study the target temperatures were 160 °C and 176 °C for the batch tests and 173 °C for the continuous tests. In both cases the pretreated material was filled into barrels and stored at 4 °C.

Substrate characterization

The dry matter (DM) content of the biomass was determined by drying samples at 105 °C until a constant weight could be measured (ASTM, 2008). Ash and volatile solid (VS) content was determined after dry oxidation at 550 °C in a muffle furnace according to Sluiter et al., (2004). In addition, the contents of cellulose, hemicellulose and lignin of the untreated and pretreated biomass were determined (data not shown). The ammonium nitrogen (NH_4-N) was determined in duplicates according to the using the SpeedDigester K-439 (Büchi, Switzerland) and a distillation unit type B-324 (Büchi, Switzerland).

Batch and continuous anaerobic digestion trials

Batch trials

The biogas and methane production from untreated and steam exploded maize straw were determined by randomized AD batch experiments carried out in triplicate, according to VDI 4630 (VDI, 2006). Eudiometer batch digesters with 250 cm^3 capacity were used to conduct this part of the procedure. The inoculum used was a mixture of inocula taken from a previous biomethane potential (BMP) test and inocula coming from two biogas plants (located in Parndorf and Margarethen, Austria), both using lignocellulosic material and manure as input material at the time of the collection. Inoculum was sieved and diluted to approximately 4% DM, the pH value was measured and no nutritional additives were used. After an inoculum starvation period of approximately two weeks, the fermenters were filled with 200 cm^3 of inoculum and the substrates were added to the fermenter in order to achieve an inoculum to substrate ratio of 3 based on VS content. The fermenters were maintained in water baths under mesophilic conditions (37.5 °C) and continuously stirred during the 63-day process and the production of biogas was monitored on a daily basis. In addition, microcrystalline cellulose was used as a control. All gas volumes are reported in norm liters (273 K and 1013 mbar) per kilogram of VS. The portable gas analyzer “Dräger X-am 7000” (Dräger, Lübeck, Germany) was used to simultaneously determine of methane concentrations (CH_4) and carbon dioxide (CO_2) content in the biogas.

Continuous trials

The test consisted of two fermenters with a capacity of 150 liters (L) each. Each fermenter had a stirrer placed vertically in the middle of the fermenter to ensure good mixing and to avoid the formation of swimming layers. The stirrer was operated automatically and it intercalated 10 minutes of mixing with 10 minutes of pause. At the start of the trial, inocula from two different biogas plants located in Ziersdorf (Austria) and Parndorf (Austria) were used. The plant in Ziersdorf was using maize silage and farm wastes as input material at the time inoculum was collected, and the plant located in Parndorf used steam exploded maize straw. The feeding material was daily filled in glass containers, which were placed above the fermenter. A vertical stirrer was installed in the glass containers to ensure material homogeneity during the feeding intervals. The feeding material was introduced into the fermenters through an electronically-controlled peristaltic pump. The feeding intervals were adjusted to one hour. A simple overflow system was used to maintain constant the 150 L volume and periodic sampling of the overflow contents were carried out to determine the residual methane potential.

The organic loading rates (OLR) 1 and 2.5 kg VS m^{-3} d^{-1} were tested in the study. The adaptation time to each OLR was fixed to around two times the hydraulic retention time (HRT). As maize straw has a C:N ratio of around 100:1, urea was weekly added to decrease the C:N ratio in the fermenter. An ammonium nitrogen (NH_4-N) content in the fermenters of 1.5 g L^{-1} was fixed as a target level.

The gas yields were measured continuously using the gas meter TG5 (Ritter, Germany). The measured gas volumes were converted into norm litters using a thermometer and an incorporated manometer, which measures the differential pressure at the inlet of the gas meter and the atmospheric pressure. The temperatures and pressures were read once per day and the calculation of the data was done according to VDI 4630 (VDI, 2006). The methane yields of the continuous trials are reported in liters per m^3 digester and day (L m^{-3} d^{-1}).

RESULTS AND DISCUSSION

BMP tests

Figure 1 shows the specific methane yields of the untreated and pretreated samples. Results revealed that steam explosion had a significant effect on the methane yield. While untreated maize straw had a specific methane yield of 252 L kg^{-1} VS, this value was improved with all the different pretreatments carried out in the study. The maximum methane yield reached 335 L kg^{-1} VS and was obtained after a pretreatment at 160 °C for 30 minutes. Nevertheless, similar methane yields were obtained after pretreatments at 160 °C for 60 minutes and 176 °C for 30 minutes, reaching 324 and 328 L kg^{-1} VS, respectively. Increasing the severity of the pretreatment up to 176 °C for 60 minutes resulted in significantly lower methane yields, which decreased to 288 L kg^{-1} VS. Similar steam explosion conditions applied to other lignocellulosic biomass, such as Salix (Horn et al., 2011) or hay (Bauer et al., 2014), revealed the formation of furfural and HMF during the pretreatment, which may have a negative effect on the microorganisms involved in the anaerobic digestion process (Hendriks et al., 2009; Kim et al., 2011). In addition, the range of pretreatment intensities used in the present study have been connected to the formation of pseudo-lignin, which has been reported to inhibit the enzymatic hydrolysis of cellulose (Hu et al., 2012). Both inhibitors and pseudo-lignin formation could be one cause of the lower methane yields observed after pretreatment at 176 °C for 60 min.

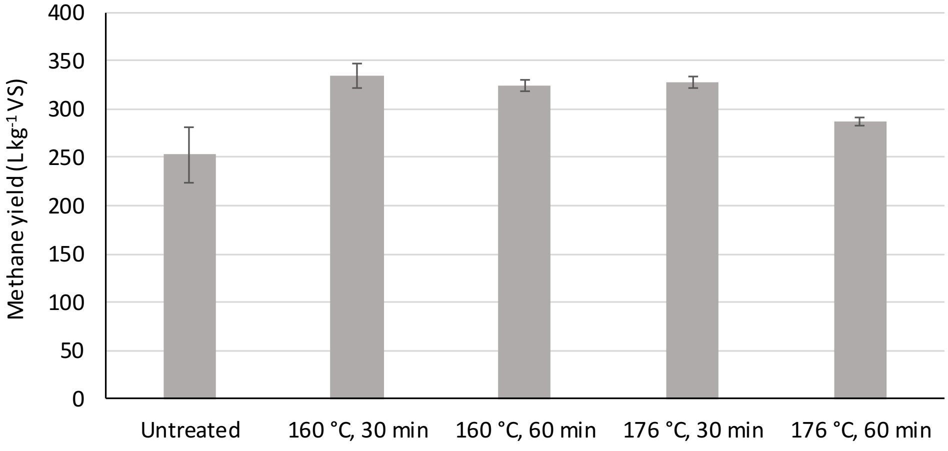

Figure 1 Specific methane yields of untreated and pretreated maize straw

Continuous anaerobic digestion tests

The results showed that the continuous system could handle an OLR of 2.5 kg VS m^{-3} d^{-1} maintaining stable pH conditions and methane productions. Higher OLR were not tested so far for this material. The first OLR tested, consisting of 1 kg VS m^{-3} d^{-1}, provided a methane production of 207 L m^{-3} d^{-1}. The methane production from the residue reached 12 L m^{-3} d^{-1}, which represents 5.4 % of the total methane production (considering as total the methane produced in the fermenter and the produced from the residue). The hydraulic retention time (HRT) was 68 days. Such high retention time allows achieving high bioconversion efficiency as the input material stays in the digester for a long period. When the OLR was increased to 2.5 kg VS m^{-3} d^{-1}, the produced methane reached 464 L m^{-3} d^{-1}. However, the methane production from the residue increased significantly to 42 L m^{-3} d^{-1}, which represents 8.2 % of the total methane production. The reduction in the hydraulic retention time (HRT) to 35 days decreased the bioconversion efficiency and hence increased the methane potential of the residue. Such low HRT were caused by the need of using pumpable liquid feedstock in the selected dosing pump. A change to a different feeding system that allow the use of a drier feedstock would be desirable in order to have higher HRT and thus, closer conditions to full-scale continuous biogas plants. Moreover, it is worth to mention that the increase in the OLR from 1 to 2.5 kg VS m^{-3} d^{-1} decreased the percentage of methane in the biogas from 61 % to 55 %.

Table 1. Results of the continuous anaerobic digestion trials

Parameter	OLR [kg VS m^{-3} d^{-1}]	Average	SD
Methane yield [L m^{-3} d^{-1}]	1	207	34.8
	2.5	464	96.4
Residual methane yield [L m^{-3} d^{-1}]	1	12	1.0
	2.5	42	3.3
HRT [days]	1	68	-
	2.5	35	-
CH_4 [%]	1	61	-
	2.5	55	-

In the present study, the specific methane yield (L kg VS^{-1}, data not shown) decreased with increasing the OLR. Despite the biomass was pretreated, fractions of relatively difficult degradable components were still present in the input material. The results of the main structural compounds (data not shown) revealed a concentration of lignin of around 35%. With these circumstances, the hydrolysis stage of the anaerobic digestion process will require longer time than the subsequent stages. Then, a reduction of the HRT would have a counterproductive effect on the efficiency of the process as the amount of remaining organic material in the reactor increases, and thus also increases the residual gas potential of the fermentation residue.

CONCLUSION

Steam explosion provides a significant increase in the methane yields and digestibility of maize straw. The batch tests showed that initial methane production raised 33% after pretreatment with steam explosion at 160 °C for 30 minutes. Methane yields decreased with pretreatment temperatures extending beyond this point, probably due to the formation of pseudo-lignin and inhibitors. In addition, steam explosion showed to speed up the bioconversion of biomass into methane. Moreover, the utilization of steam-exploded maize straw in a continuous system is feasible with an OLR of 2.5 kg VS L m^{-3} d^{-1} with the use of no more additives than a nitrogen source (urea). The residual methane potential increased notably when using higher OLR. This residual potential could be reduced by increasing the dry matter of the substrate, which would increase the HRT. The integration of steam exploded maize straw in biogas production strategies based on the co-digestion with nitrogen-rich wastes could allow the utilization of inexpensive co-substrates while improving the whole environmental sustainability will be improved.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.767.2
Prethodno priopćenje
Preliminary communication

SUSTAINABILITY OF BIOGAS PRODUCTION AND UTILISATION – CASE STUDIES

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SUMMARY

Sustainability of renewables production and utilisation, expressed as greenhouse gases (GHG) emission savings in comparison with fossil fuels, plays important role nowadays. This is stated, for biofuels and bio liquids in Renewable Energy Directive (RED) and other EU documents. The savings have to be at least 60 %. Same or similar criteria are expected to be introduced for other renewables, including gaseous biomass – biogas. Study of GHG emission saving for two biogas plants in Serbia was performed, whereby method described in EU documents was used and contemporary tools for Life Cycle Assessment (LCA). Analyses were performed based on input data collected from the biogas plants. Final results are obtained, and GHG emission savings are 90 and 84 %, in comparison to fossil fuels electricity generation, which is 186.0 gCO_{2eq}/MJ. Some weaknesses, related to data the used method, were identified.

Keywords: biogas, sustainability, GHG emission savings, LCA.

INTRODUCTION

Global challenges such as climate changes – global warming, caused by emissions of greenhouse gases (GHG) and the depletion of fossil fuels reserves, initiated a number of measures at the global level for promotion and encouragement of use of renewable energy sources (RES), and energy efficiency. By Directive 2009/28/EC (Anonymous, 2009a), (named Renewable Energy Directive – RED), EU has defined goals concerning utilisation of RES, but also several sustainability criteria applicable for RES. The sustainability criterion *GHG emission saving* is officially recognized at the EU level for production of biofuels for transport and bioliquids (biofuels used for electricity or heating and cooling). It introduces the following requirements (Anonymous, 2009a; Anonymous, 2015): *The greenhouse gas emission saving from the use of biofuels and bioliquids shall be at least 60 % for biofuels and bioliquids produced in installations starting operation after 5 October 2015.* In order to determine the GHG emission savings for biofuels, emissions are compared with fossil fuel comparator (FFC) whose GHG emission is 83.8 gCO_{2eq}/MJ, and this should be applied if biogas plants produce biomethane, to be used as a fuel in Compressed Natural Gas (CNG) engines. The same or similar criterion could be expected for other RES, including biogas which is used for generating electricity and heat energy (Giuntoli *et al.*, 2015).

Biogas plants, in addition to the expected economic benefits and positive social effects, such as job creation, have positive effects in terms of environmental protection. This is actually main reason why production of biogas is subsidized. That claim is supported by numerous studies based on the principles of a Life Cycle Assessment (Bachmaier *et al.*, 2010; Poeschl *et al.*, 2012; Fuchsz and Kohlheb, 2015; Kral *et al.*, 2015).

Life Cycle Assessment (LCA) is a standardized analytical tool for determination of environmental impacts that takes into account an entire life cycle of products or services (Anonymous, 2008; Anonymous, 2009b). It comprises four mandatory steps: goal and scope definition, life cycle inventory, life cycle impact assessment and interpretation. In principle, LCA considers all relevant material inputs, energy inputs and emissions during analyzed life cycle, process data about them, and determines impact on a relevant impact category.

Principles of LCA are fully integrated in a method necessary to be applied for calculation of GHG emission savings, defined by RED directive and other documents of EU (Anonymous, 2010; Anonymous, 2014). Determination of GHG emission savings for utilisation of biogas for electricity was the aim of several publications which in focus had hypothetical life cycles of biogas (Giuntoli *et al.*, 2015), or actual biogas plants (Rana *et al.*, 2015) with different conclusions about sustainability of analysed biogas life cycles. Reason why it is difficult to give the general value for GHG emission saving in case of biogas utilisation for electricity is due to different properties that can greatly affect GHG balance: the existence of cover above digestate storage reservoir, value of methane fugitive emissions from the reactor and gas installations, digestate transport distance, type of biogas utilisation equipment, heat utilisation, size of analysed biogas plant, *etc*.

The main objective of the investigation was to define GHG emissions savings for two selected biogas plants in Serbia, using method defined in RED based on principles of LCA, and to identify problems of the method application.

MATERIALS AND METHODS

Materials

Two plants operating in Serbia were selected for case studies: *Global Seed* biogas plant (GSBP) and *Mirotin Energo* biogas plant (MEBP).

GSBP annually uses 6,200 t of manure, app. 20,000 t of slurry and 3,600 t of soya oil residues as the biogas substrates. All substrates are considered as waste materials, so none of the emissions from the milk and oil production processes aren't associated to these wastes. Boundaries of the analysed system included only transport of the soya oil residues by a truck (22 t load capacity) from 40 km remote site. The other considered material and energy inputs are own electricity consumption and chemical compounds for desulfurization. Own electricity consumption is 4 % of produced and it is taken from the public grid. Consumption of iron(III)chloride is app. 15 tons annually. Other material inputs are negligible, and were not considered. Produced biogas, app. 2 million Nm^3, with methane content of 59 % is used for generating of some 5 GWh of electricity annually with 42 % electrical efficiency. Produced digestate is separated to liquid and solid fraction and some 25,000 and 3,000 tons are generated on yearly basis. Since the reservoirs for digestate storage are not covered, residual biogas emissions are released to atmosphere.

MEBP has 1,750 kW_e total installed capacity of combined heat and power (CHP) units. Biogas production is officially divided between two biogas units, where the first is commissioned for 1,000 kW_e CHP unit. Within this study, LCA is performed only for this first unit.

As the substrates are annually used: app. 9,000 tons of manure, 12,000 tons of slurry, 10,000 tons of corn silage and periodically, during campaign, sugar beet residues (root fragments), 6,000 tons. Manure and slurry are waste materials generated at the farm where biogas plant is constructed, so none of emissions associated to the milk production are assigned to them. Sugar beet residues are transported from a sugar mill which is located some 5 km from the biogas plant and this transport is included in to analysis. Corn silage is produced on company owned agricultural land by application of common agricultural practice including usage of both mineral fertilizers and digestate. Annually, around 3.5 million m^3 of biogas with methane content of app. 53 %, are produced and used in the CHP unit to generate some 7.9 GWh. The electrical efficiency is app. 42 %. Quantity of the digestate liquid fraction corresponds to 78 % of input mass of the substrates, while 15 % represents the solid fraction. Current practice at the MEBP is to store liquid fraction in uncovered digestate tank (concrete lagoon), so the residual biogas is emitted in to the atmosphere.

Methods

Calculation of GHG emission savings, is performed using the method defined by RED directive (Annex V) and documents COM(2010)11 and SWD(2014)259 which are based on the principles of LCA. According to the method, electricity is considered as a final energy product, and all calculated emissions should be specified to MJ of electricity. In principle, method is based on several steps. It requires that for each substrate separately, emissions during entire life cycle phases, *i.e.* cultivation, transport, distribution, production of biogas, use of biogas, are determined and expressed in gCO_{2eq}/MJ of produced biogas. Further, obtained values are used in series of equations after which total GHG emissions in producing electricity, EC_{el}, is obtained and expressed in gCO_{2eq}/MJ of electricity. Last step requires that GHG emission in producing electricity is compared with FFC emission E_F, that for electricity production is 186 gCO_{2eq}/MJ, in order to obtain GHG emission saving value:

$$\text{saving}=\frac{E_F-EC_{el}}{E_F}$$

This method allows that specificity of biogas production, *i.e.* co-digestion of different substrates, different biogas yields, different characteristics of substrates *etc*., can be included in calculation. For detail explanation of the method see Anonymous, (2010 and 2014).

For both biogas plants, data about relevant material and energy inputs and outputs which were used as a primary data for LCA were collected by interviews with biogas plants' operators. LCA was performed using the software *GaBi* and alongside the primary data, databases *Ecoinvent v3.1* and *Thinkstep Professional* database were used as a source for secondary data *i.e.* electricity production, corn silage production, diesel production, transport operations, desulfurization material production, biogas combustion.

Laboratory analyses were performed for determination of residual biogas potentials from digestate.

In order to obtain values of GHG emission, boundaries of the analysed biogas plants included emissions from the cultivation of raw materials (substrates), emissions from transport, emissions from production of biogas, and emissions from combustion of biogas. Digestate application was only included in the case of MEBP because it was used partially as a fertiliser for cultivation of the corn silage. Emissions generated by the equipment manufacturing were not included. Emission credits for improved manure and slurry management are calculated in accordance to generally accepted TIER 2 method of IPCC (International panel for climate change) (IPCC, 2006).

In accordance to the method, functional unit for this stage of evaluation was 1 MJ of produced biogas, and all emissions were specified to it. Only three GHG were of interest, carbon dioxide, methane and nitrous oxide, so only emissions of these gases were considered. For the purpose of calculating CO_2 equivalence, these gases were valued by using following characterization factors – carbon dioxide: 1; methane: 23; nitrous oxide: 296 (Anonymous, 2009a).

Yield of residual biogas is experimentally measured in accordance to method described in VDI 4630 (Anonymous, 2006). Since the applied method for GHG emission saving calculation requests that each substrate is analysed independently, problem was that each substrate should be associated with appropriate amount of residual biogas, since it was possible to analyse only digestate which represents residue for entire substrate mixture digestion. Based on the substrates and digestate quantities and characteristics (*e.g.* ODM contents which were used to assume degradation rate for each substrate) certain amount of residual biogas was seen as consequence of not digested substrate. Nitrous oxide emissions were not considered due to insufficient data about the nitrogen content of liquid digestate. Properties of digestate are stated in Table 1. Other relevant emissions which are considered are: fugitive emission of methane from gas installations for which is adopted value of 0.5 % of total produced methane (Liebetrau *et al.*, 2010); emissions from the gas engine – not combusted methane and generated nitrous oxide.

Table 1 Properties of substrates and digestate

Biogas plant	Substrate/diges.	DM, %	ODM, %	Biogas yield, Nm^3/tFM	Methane content, %
GSBP	Manure	18	14	49	57
	Slurry	5	4	12	55
	Soya oil residue	76	63	429	60
	Digestate*	8	5	4	59
MEBP	Manure	25	21	100	55
	Slurry	10	8	30	55
	Corn silage	33	31	200	52
	Sugar beet resid.	13	11	67	52
	Digestate*	6	4	3	62

DM – dry matter, ODM – organic dry matter, FM – fresh matter, *before separation

Biogas is the energy carrier for which emissions are calculated and digestate is a co-product. GHG emissions should be allocated between the energy carrier and its intermediate product, in this case digestate, in proportion to their energy content (Anonymous, 2010). Allocation of emissions is made between produced biogas and digestate in ratio 80/20, following explanations in (Adams *et al.*, 2015; Giuntolli *et al.*, 2015).

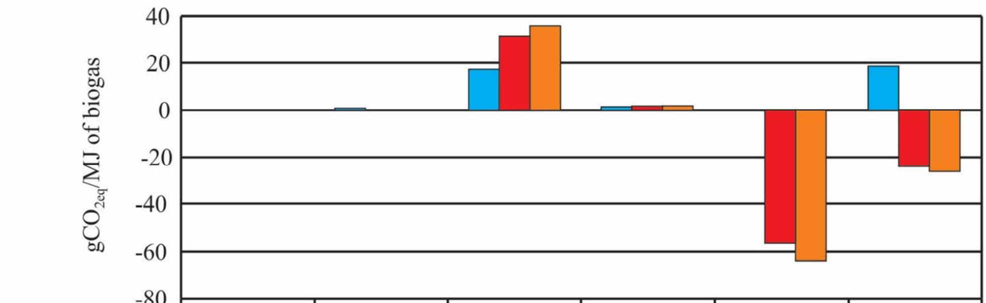
RESULTS AND DISCUSSION

In Table 2 are given selected results of material and energy inputs into analysed systems.

Table 2 Selected material and energy inputs for biogas plants per 1 MJ of produced biogas – GSBP

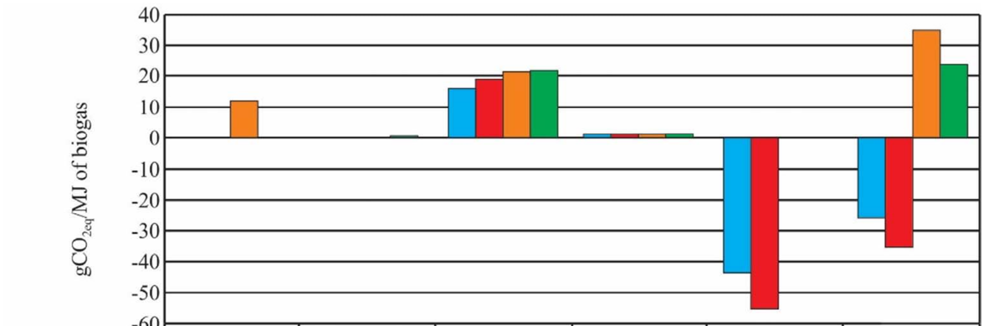
GSBP			MEBP		
Inputs	Unit	Quantity	Inputs	Unit	Quantity
Substrates			Substrates		
Manure	kg	1.63E-01	Manure	kg	1.34E-01
Slurry	kg	5.28E-01	Slurry	kg	1.78E-01
Soya oil residues	kg	9.57E-02	Corn silage	kg	1.49E-01
Trans/distr.			Sugar beet res.	kg	0.89E-01
Truck - cargo	kg	9.57E-02	Trans/distr.		
Diesel	kg	5.06E-05	Tractor	tkm	4.46E-04
Production			Diesel	kg	1.61E-05
Electricity	MJ	1.86E-02	Production		
Iron(III)chloride	kg	4.26E-04	Electricity	MJ	0.46E-01
Biogas	m^3	4.99E-02	Biogas	m^3	0.53E-01
Credits			Credits		
Methane	kg	-3.20E-03	Methane	kg	3.76E-03
Nitrous oxide	kg	-2.06E-05	Nitrous oxide	kg	5.60E-05

Results of the assessment have shown that, for both biogas plants, major source of the GHG emissions is the phase of *processing*. Emissions associated to this phase are from: residual biogas (methane) emissions and fugitive methane emissions, used electricity and material consumption. Quantity of residual biogas emissions represents app. 5 % and 2.5 % of totally produced biogas respectively for GSBP and MEBP, and they are main source of impact, followed by emissions from electricity use and fugitive methane emissions. Phase of *cultivation* contributes to the emission balance only in the case of corn silage. Dominantly, emissions in this phase are consequence of nitrogen fertilisers use, *i.e.* nitrous oxide emissions. Methane slip and nitrous oxide emissions in the *use* phase and diesel production and combustion within the *transport* phase are minor contributors to the total GHG balance. Emission credits associated to improvement of manure and slurry treatment have huge influence on total emissions of analysed biogas plants. They are originating from avoided emissions of methane and nitrous oxide. In Figures 1 and 2, are given the results of emissions classify per phases for both analysed biogas plants. Emissions are expressed in gCO_{2eq}/MJ of produced biogas, *i.e.* before conversion into electricity.



	Cultivation	Transport & Distribution	Processing	Use	Credits	Total
Soya oil residue	0	0.2	17.4	1.3	0	18.9
Manure	0	0	31.4	1.3	-56.7	-24.0
Slurry	0	0	36.2	1.3	-63.8	-26.3

Figure 1 GHG emissions in the different phases within life cycle of substrates used in GSBP



	Cultivation	Transport & Distribution	Processing	Use	Credits	Total
Manure	0	0	15.9	1.5	-48.4	-26.1
Slurry	0	0	18.9	1.5	-55.5	-35.1
Corn sillage	12.1	0	21.5	1.5	0	35.1
Sugar beet res.	0	0.5	22.0	1.5	0	24.0

Figure 2 GHG emissions in the different phases within life cycle of substrates used in MEBP

Based on values for total emissions obtained for each substrate resulted with GHG emissions of entire biogas plants. For GSBP, quantity of GHG is 18.3 gCO_{2eq}/MJ of electricity. The same value for MEBP is 29.8 gCO_{2eq}/MJ of electricity. Based on these values it is determined that GSBP has 90 % GHG emission saving in comparison to fossil fuel comparator, while MEBP has 84 % GHG emission saving.

These values of the GHG emissions saving satisfy limit of 60 % saving. This means that both biogas plants generate electricity in sustainable manner in terms of GHG emissions.

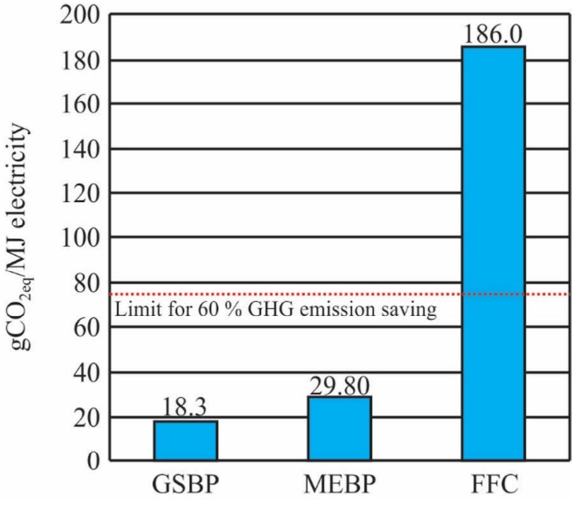


Figure 3 Total GHG emissions in producing electricity for *Global Seed* and *Mirotin Energo* biogas plants

CONCLUSIONS

LCA of two biogas plants in Serbia, performed in accordance to the method for determination of the GHG emission savings, confirmed that these two examples of biogas production and utilisation for generating electricity can be declared as sustainable. From environmental point of view and especially global warming aspect, incentive measures for these biogas plants are justified.

Introduction of the GHG emission saving in current form, 60 % saving in comparison to the FFC, as the obligatory sustainability criterion for generating electricity from biogas, could potentially increase utilisation of waste materials for biogas production. Use of waste materials is much better in terms of GHG emissions in comparison to energy crops as it was shown in presented case studies. Further, it can also initiate improvement of the biogas utilisation efficiency due to initiation of a cover construction above reservoirs for digestate and placement of surplus heat energy.

The method used for determination of GHG emission saving should be further adapted to specific case of biogas utilisation. Consideration of manure and slurry emission credits, type of allocation between produced biogas and digestate, impacts of energy crops production (or crop residues collection) on agricultural soil are insufficiently described by the method and could potentially create doubts during its use. GHG emissions could also be calculated for mixture of substrates and not for each substrate individually, which is commonly practiced in LCA of biogas plants in scientific community. In this way some specific data characteristic for analysed biogas plant could be easily applied, *e.g.* residual biogas emissions. Special attention should be given to the usage of appropriate correction factors for GHG in line with latest scientific trends *i.e.* latest values described in IPCC (2013).

Understanding mechanisms about some emissions should be further improved by scientific community, *e.g.* nitrous oxide emissions from digestate, or fugitive methane emissions from gas installations. Improvement of existing databases with geographically specific data is also very important, especially in the case of Serbia.

Improvement of data quality, inclusion of their uncertainty, expansion of the data collection scope, expansion of survey to another biogas plants, it all can contribute to better understanding of the GHG emissions and emission saving. It can secure that, if this criterion would be introduced worldwide, in EU and Serbia, companies that operate biogas plant have no problem to produce and utilize biogas in a sustainable way.

The overall analyses should include also other aspects, like impact on soil fertility preservation, utilisation of heat energy, digestate utilisation, *etc*.

The society expects new solutions with maximised reduction of GHG emission, reduction of food-feed utilisation, and preservation of soil fertilisation related to crop residues utilisation.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95(497.11)
Prethodno priopćenje
Preliminary communication

CORN COB PELLETS AS A FUEL IN SERBIA: OPPORTUNITIES AND CONSTRAINTS

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SUMMARY

Corn cobs have the largest potential among other crop residues in Serbia. This potential rates 1.2 million of tons (430 ktoe), or approximately 1/3 of all crop residues. So far, corn cobs are utilized mostly as fuel in traditional stoves in Serbia. Like other crop residues, corn cobs have unfavorable properties as a fuel, which cause technical and environmental problems during combustion. Therefore, the objective of this study was to investigate possibilities to improve properties of corn cobs by making pellets, as well as to define opportunities and constraints for its commercialization. Investigated were mechanical properties: bulk density and mechanical durability, as well as chemical properties: net heating value, ash content and ash melting behavior. Additionally, fuel and energy costs were calculated and compared with natural gas. The obtained results of bulk density and mechanical durability prove that corn cob pellets can fulfill defined quality criteria, which rate 600 kg/m^3 and 97.5 %, respectively. Considering chemical properties, the ash content of corn cobs rates around 2.5 %, and even higher if slagging inhibitors are added. Net heating value of dry corn cob pellets is 16.1 MJ/kg. Slagging inhibitors can significantly increase ash melting temperatures up to 1,400 °C, which would allow technically reliable combustion. It was concluded that unfavorable properties of corn cobs could be improved, if pellets are produced and used. Energy costs of corn cob pellets are significantly higher than of unprocessed corn cobs, but still slightly lower than natural gas. Therefore, corn cob pellets have perspective to be commercialized, but first if the costs of natural gas would increase, what is expected in the future. For the future investigation, combustion trials of corn cob pellets should be performed to determine technical and environmental effects and need for improvement of heat generators.

Keywords: corn cobs, fuel, combustion, properties, improvement, pellets

INTRODUCTION

Definition, potentials and availability of corn cobs in Serbia

Corn (*Zea mays* L.) is one of the most important field crops Worldwide, with the average annual production of over 800 million of tones. In Serbia, corn is the major field crop covering about 40 % of arable land, whereby in agricultural regions like Autonomous Province of Vojvodina this share is even higher. Thus, corn harvest residues, or so called corn stover, have the largest potentials among other agricultural biomass, *i.e.* crop residues. Corn stover is defined as entire aboveground biomass, mostly except at least the lowest 0.2 m of stalks that is treated as unusable part of plant and not harvested, due to high moisture and ash contents. It subsumes following plant fractions shown in Figure 1: 1) stalk and leaves (including tassels); 2) cobs; and 3) husks.

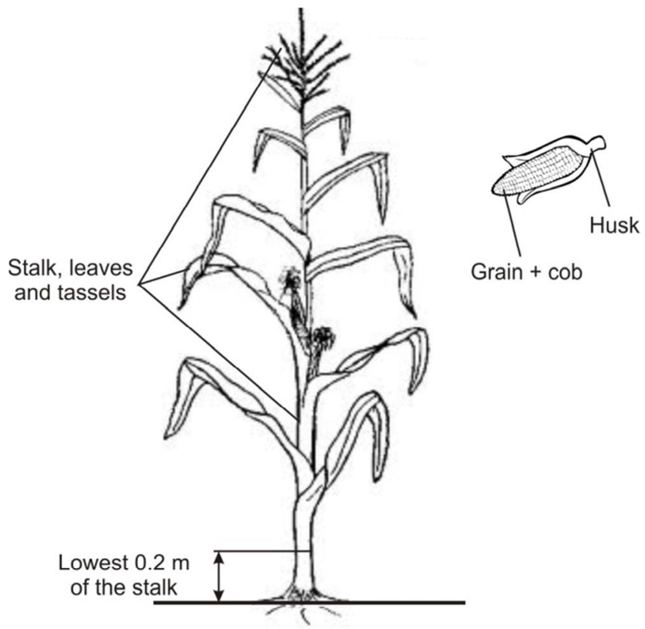

Figure 1 Corn plant fractions

In Serbia are practiced two different corn harvest technologies and postharvest processing:

1. Harvest with combine harvester, snapping of ears and threshing. Result of harvest is grain. Entire corn stover, including corn cobs, remains on the field available for collecting. This technology is practiced by big and some medium sized farms.
2. Harvest of ears by using picker-sheller (husker). Results of harvest are ears without husks (corn cob and grain). Ears are stored in traditional or contemporary drying bins (cribs) and there is performed natural drying. Threshing is performed after reaching equilibrium moisture content of grains. Therefore, dry corn cobs remain on the farmer's yard, which

mass is 18 to 20 % of grain mass of same moisture content. This technology is practiced predominantly on S&M sized farms.

The largest share of corn in Serbia is cultivated on S&M farms, where the second mentioned harvest technology is dominant, corn cobs are, after threshing, locally available at farms. This potential of corn cobs in Serbian rural areas is assessed to be about 1.2 million tons (moisture content about 15 %), or about 430 ktoe (Martinov and Tesic, 2008). Thereby, corn cobs potential rate around 30 % of total potentials of crop residues for energy generation. These potentials are determined by considering farm sizes, applied harvest technologies, losses, need for soil fertility preservation and other utilization pathways.

State of the art of corn cobs utilization in Serbia

Corn cobs are typically, prior to utilization, stored mostly in hovels. This significant potential of corn cobs is almost completely utilized, primarily in the form of non-processed fuel for heating of households in rural areas, but unfortunately in inefficient or inappropriate way. Used heat generators, *i.e.* small boilers and stoves, are almost exclusively simple and without equipment for controlling the combustion process. Therefore, the utilization is at low technological level followed by low efficiencies and high emissions of pollutants.

Pellets as an improved fuel

Generally, biomass is processed in the form of pellets mostly to generate energy (Döring, 2013), but for other purposes as biofuels production and chemical industry as well. Pellets show improved properties compared to non-processed biomass. The particular advantage is increased density, to make transport, manipulation and storage much more advantageous. Additionally, dust generation is significantly reduced, what minimizes risks and negative impacts during handling and utilization, and fuel composition is homogeneous. Therefore, the most important mechanical properties of pellets are bulk density and mechanical durability. Bulk density is relevant for logistic issues. Mechanical durability describes capability of pellets to remain form and mass under mechanical stress.

Fuel pellets enable automation of firing process and conversion efficiency of heat generators run on pellets is mostly higher. Pressed biomass has an advantage that creation of volatiles is reduced and therewith better control of combustion process could be achieved, what omits energy loses. Comparing with other biomass forms, emissions of pollutants during combustion of pellets are expected to be lower (Lenz *et al.*, 2014).

While pelletizing biomass, it is possible to blend it with other fuels or apply additives to improve chemical properties, mostly related to ash. Firstly, the content of ash content could be influenced and it describes presence of mineral compounds that reduce energy content. Increased ash content causes increased emissions of particulate matter and increased effort and costs for ash disposal. Well known is that crop residues have low ash melting point, followed by higher emission of pollutants. To predict ash melting and slagging, what cause technical problems or even damages in generators, the parameter ash melting behaviour is used. It is determined by the four characteristic temperatures: shrinkage starting temperature (SST); deformation (DT); hemisphere (HT); and flow temperature (FT). Shrinkage starting temperature is used as relevant temperature to indicate ash melting occurrence.

Although pellets have important advantages as a fuel, the disadvantage is additional energy demand, used mainly for grinding, pressing and drying. All these, including purchase of equipment for pelletizing, increase the fuel price and result with negative environmental impact.

Objectives

The objective of this study is to investigate properties of corn cobs as a fuel for combustion and to define possibilities for their improvement in the form of pellets. Thereby, utilization in small heat generators in Serbian rural areas is considered. The wider objective is to define techno-economic opportunities and constraints for commercialization of this fuel in Serbia.

MATERIALS AND METHODS

Samples

Samples of corn cobs of hybrid ZP 677 (FAO 600), from the agricultural farm in Vrbas, were used. Corn cobs in the bulk bag were transported to Hamburg University of Technology, Institute of Environmental Technology and Energy Economics (IUE), where the experiment was performed. Prior to the experiment, the cutting mills Hellweg MDS 410-200 and Retsch SM 300, with 6 and 4 mm sieve openings, respectively, were used.

Setting-up of pelletizing experiment

The flat horizontal die pellet press Kahl 14-175 (Amandus Kahl) was used. The following parameters were varied to investigate the influence the properties of corn cob pellets:

- – raw material moisture content;
- – raw material particle size;
- – die extrusion ratio;
- – slagging inhibitor type.

In preliminary experiments, it was found out that pelletizing of raw material with moisture content lower than 15 % and higher than 19 % mostly was not possible, and therefore this range was selected. Particle size of raw material is varied by selecting the sieve openings in grinding step. It was selected to be 6 and 4 mm, to investigate the effect of pelletizing the raw material with particles of the same size as die openings diameter and somewhat smaller. In order to simulate different extrusion ratios, dies with two different thicknesses of 20 and 24 mm were used. The following slagging inhibitors were used to try to improve chemical properties: magnesium-oxide (MgO); kaolin ($Si_4Al_4O_{10}(OH)_8$); and aluminium-oxide (Al_2O_3). Shares of 1 % related to dry biomass were applied, which were supposed that could improve combustion properties, but do not increase production costs significantly. The produced pellet samples were left for the next 24 h to fully cool down and harden prior to determination of their properties.

Investigation of pellet properties

In Table 1 are presented properties of corn cob pellets that were investigated within this study and used standardized procedures listed. The first two properties represent mechanical, while the last three chemical properties of corn cob pellets. In the results, presented are average values from three measurements, including standard deviation only in the positive direction. The exception is parameter ash melting behaviour, for which the presented temperatures are average values of two measurements and deviation is maximum value.

Table 1 Investigated properties of corn cob pellets

No.	Property	Unit	Standard
1	Bulk density	kg/m^3	EN 15103
2	Mechanical durability	% (*w.b.*)	EN 15210-1
3	Ash content	% (*d.b.*)	EN 14775
4	Net heating value	MJ/kg	EN 14918
5	Ash melting behaviour	°C	CEN/TS 15370-1

Calculation of energy costs

In this study, fuel costs and two types of energy costs are considered and calculated. The primary energy represents the energy contained in the fuel, before conversion. Therefore, this cost is for energy of purchased fuel. The final energy, after the conversion, depends on applied combustion facility and is relevant to assess the cost of utilized energy. The fuel costs for unprocessed corn cobs, pellets and natural gas were collected in Serbia in autumn 2016. Although there is no market for corn cobs in Serbia yet, this fuel is traded in rural areas between farmers that have surplus quantities and buyers who need it for heating. The following assumptions for calculation of energy costs are stated. Moisture content of unprocessed corn cobs is 15 % and of pellets 12 %. Result of net heating value of corn cob pellets is presented in the section 3.2 and net heating value of natural gas is 33.4 MJ/Stm^3. Annual energy conversion efficiency of stove for unprocessed corn cobs is 50 %, of pellet boiler 75 % and of natural gas boiler 85 %. The stove for unprocessed corn cobs is traditional way of combustion with the lowest conversion efficiency.

RESULTS AND DISCUSSION

Mechanical properties of corn cob pellets

In Figure 2 are presented results of bulk density and mechanical durability of produced corn cob pellets. Both properties are presented for two different extrusion ratios (abbreviated ER 3.5 and 4.0), two different particle sizes of raw material (abbreviated PS 4 and 6 mm) and three different raw material moisture contents (15, 17 and 19 %).

With an increase of raw material particle size, bulk density of pellets is increased as well, due to lower mass rate and therewith longer retention time of raw material leading to more intensive pressing. Increase of particle size leaded mostly to slight improvement of mechanical durability. This was expected, since larger particles enable more intensive wrapping of raw material in pellets, leading to higher mechanical durability. Both mechanical properties are improved if die of higher extrusion ratio is to be applied, due to increased friction in the die and therewith more intensive pressing. Concerning the influence of raw material moisture content, generally, both mechanical properties are worsening with its increase. Presumably, the reason is saturation by water, which acts as lubricant and reduces the pressing intensity.

According to the standard that describes quality requirements for non-woody pellets (Anonymous, 2014b), bulk density should be at least 600 kg/m^3 and mechanical durability at least 97.5 % or 96.0 %, considering two quality classes. Neither bulk density nor mechanical durability could reach threshold values if lower extrusion ratios are applied, as well as particle size of raw material that is much smaller than die opening.

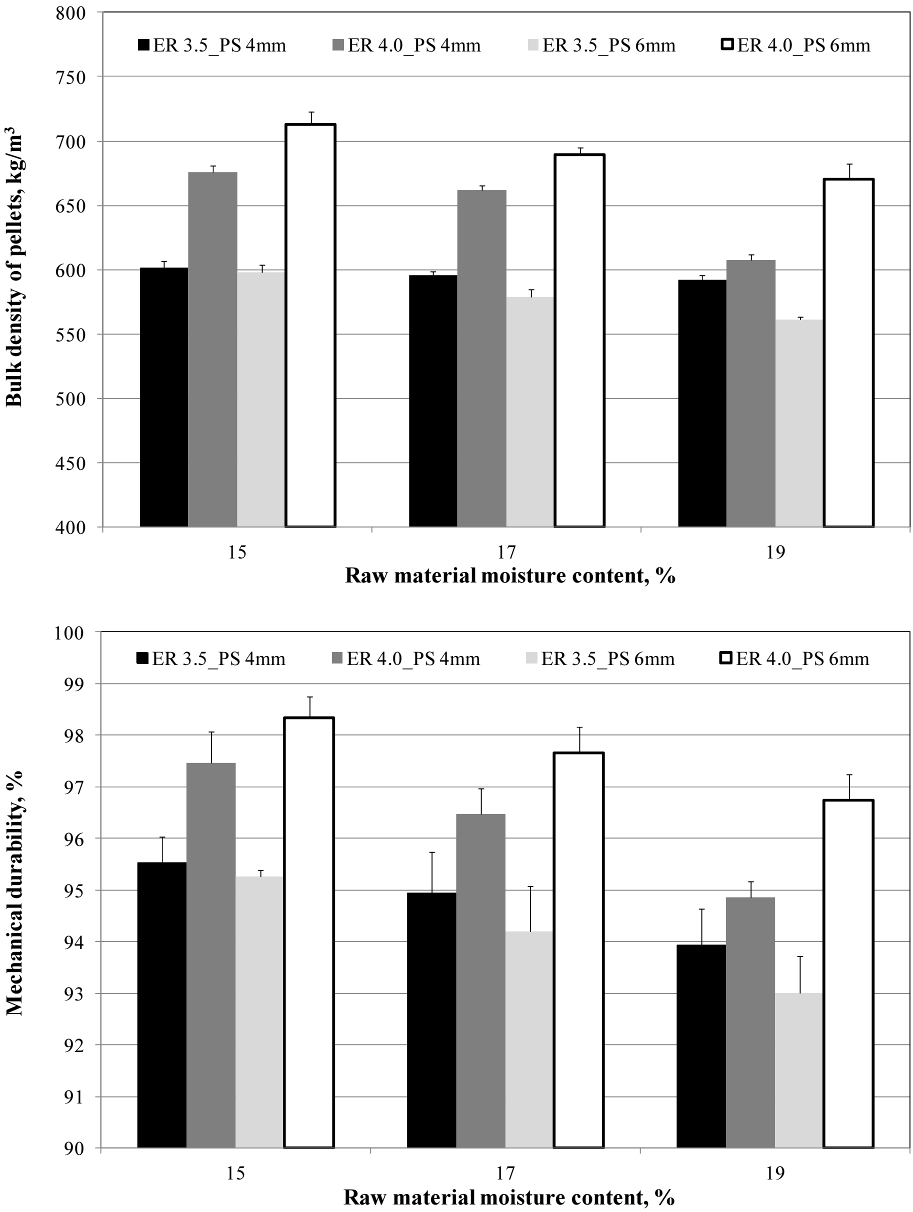

Figure 2 Bulk density and mechanical durability of corn cob pellets – influence of moisture content, particle size and extrusion ratio (*ER: extrusion ratio; PS: particle size*)

Chemical properties of corn cob pellets

The ash content of analyzed pellet samples is presented in Figure 3. The comparison is given between pellets produced from pure corn cobs and pellets containing 1 % of three different slagging inhibitors. The ash content of pure corn cob pellets is around 2.6 %. Comparing obtained values with wooden biomass, which is considered as convenient solid biomass fuel and has ash content between 0.5 and 2.0 % (Kaltschmitt *et al.*, 2009), requirements for ash disposal and potentials for emission formation after combustion of corn cobs are significantly higher. On the other hand, corn cobs have significantly lower ash content than other crop residues (at least 5 %), without soiling effect which increases it additionally. The three slagging inhibitors were added in the same ratio. Still, the resulting ash contents are not the same, although the expected value was around 3.6 %. This indicates that certain chemical reaction occurs during combustion between slagging inhibitor and mineral compounds in the ash. This is the most obvious in the case of aluminium-oxide application.

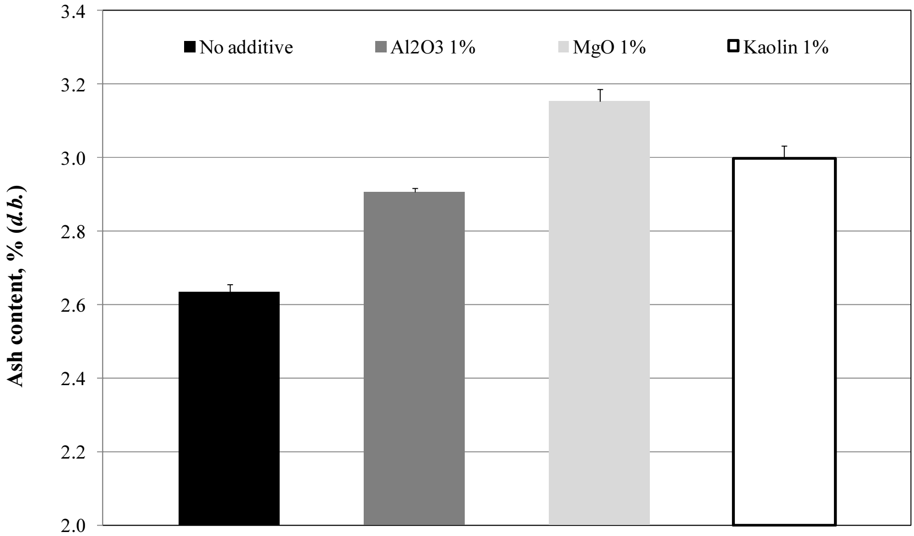

Figure 3 Ash content of corn cob pellets

Net heating value of dry corn cob pellets was 16.1 MJ/kg. Comparing this with wood which rate more than 18 MJ/kg (Kaltschmitt *et al.*, 2009), net heating value of corn cob pellets is lower, mainly due to increased ash content.

In Figure 4 are presented results of ash melting behaviour of pure corn cob pellets and again when the three slagging inhibitors are used. The pure corn cob pellets have low ash melting temperature, whereof the shrinkage starting temperature is below 1,000 °C. Even if only 1 % of slagging inhibitor is added, the ash melting temperature increases significantly. If magnesium-oxide is applied, although has the smallest influence, increased the shrinkage starting temperature to be higher than 1,200 °C. Using kaolin and aluminium-oxide, the shrinkage starting temperature reached even around 1,400 °C. Expecting temperatures in combustion chamber to be up to 1,200 °C, these two slagging inhibitors could be used to omit slagging. If these results are compared with those in Figure 3, it can be assumed that aluminium-oxide chemically reacts with the mineral compounds in the ash and that have low melting temperatures, after which they evaporate. Although this has positive influence on ash melting, possible negative influence are increased emissions of pollutants. Considering purchase price of applied additives, kaolin could be more promising option.

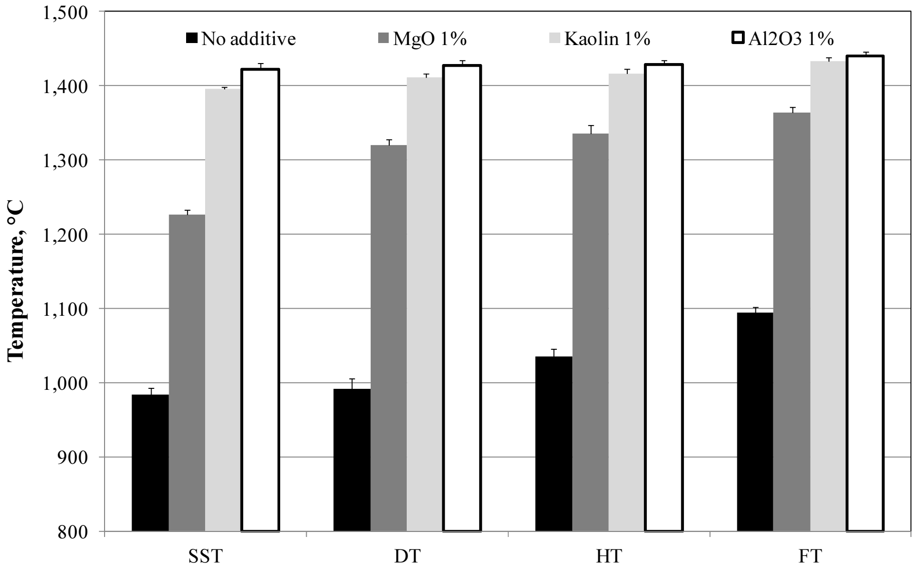

Figure 4 Ash melting behaviour of corn cob pellets without and with slagging inhibitors (SST: Shrinkage starting temperature; DT: Deformation temperature; HT: Hemisphere temperature; FT: Flow temperature)

Energy costs

In Table 2 is given the overview of fuel and energy costs of corn cobs, in the form of unprocessed corn cobs and pellets and compared with natural gas. It is obvious that fuel and energy costs of unprocessed corn cobs are several times lower than of corn cob pellets. The final energy costs of pellets are slightly lower than for natural gas. However, final energy cost of pellets becomes higher due to lower conversion efficiency of pellet boilers comparing with efficiency of gas boilers. However, it should be taken into account that boilers for natural gas have multiple lower purchasing prices, which has additional influence on feasibility of investment in biomass heat generators. However, used price of natural gas is extremely low and in the future only its increase could be expected.

Table 2 Fuel and energy costs of corn cobs

Fuel	Fuel cost, €/t	Primary energy cost, €c/kWh	Final energy cost, €c/kWh
Corn cobs (bulk)	30	0.87	1.75
Corn cobs (pellets)	100	2.74	3.66
Natural gas	0.3[1]	3.24	3.81

[1] €/Stm^3; Stm^3: standard cubic meter.

CONCLUSIONS

In this study, the improvement of fuel properties of corn cobs in the form of pellets was attempted. Based on results, opportunities and constraints were defined to commercialize this fuel. The obtained results showed that investigated mechanical properties, bulk density and mechanical durability, by appropriate combination of varied parameters of pelletizing process, could satisfy defined quality requirements, 600 kg/m^3 and 97.5 %, respectively. Therewith, technically reliable and economically feasible transport, manipulation and storage of corn cob pellets could be achieved. Ash content of corn cobs is higher than of wood, but still lower than of other crop residues. Therefore, corn cobs provide an opportunity to improve unfavorable combustion properties more easily. Accordingly, only by adding 1 % of slagging inhibitors, ash melting temperature was increased up to 1,400 °C, that allow reliable combustion process. However, a constraint to successfully commercialize corn cob pellets in Serbia are high costs of fuel and generated energy, that are only slightly lower than of natural gas. To enable appropriate commercialization of this type of fuel on the market, energy cost from corn cob pellets and natural gas should differ more significantly, in order to compensate increased labor need and higher investment costs for biomass heat generators. Since fuel properties of corn cob pellets are improved within activities in this study, the next step would be to define and improve properties of heat generators. Therefore, future investigation should focus on combustion trials with corn cob pellets to determine shortcomings. Thereafter, heat generators can be adapted and improved to satisfy technical and environmental requirements.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.544.4.:662.767.2
Izvorni znanstveni rad
Original scientific paper

CALCULATING GREENHOUSE GAS MITIGATION FROM THE UTILIZATION OF BIOGAS FOR COMBINED HEAT-AND-POWER PRODUCTION

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SUMMARY

Resource strategy concerns and the need for the mitigation of greenhouse gas emissions (GHG) associated with energy generation from fossil fuels have increased the deployment of renewable energy carriers such as biogas. Biogas can be utilized to produce electricity and heat or as vehicle fuel. This paper presents results for the GHG balance of combined heat-and-power production from biogas for a selection of experimental farms in Bavaria. The specific CO_2 equivalent emissions of utilized energy from biogas are evaluated using the methods of exergetic allocation and substitution / system extension. On the background of German grid emissions we discuss the potential of agricultural biogas systems to mitigate GHG emissions and measures to improve this.

Key words: biogas; greenhouse gases; life cycle assessment; mitigation

INTRODUCTION

During the first decade of the 21st century, the utilization of renewable energy sources (RES) in Germany exhibited average annual growth rates of between 1.4 % for solid biomass and up to 40.2 % for photovoltaic. In the industrial-scale deployment of biogas technology, Germany has become world leader 1.

Anaerobic digestion in biogas plants has beneficial environmental effects such as energy recovery from waste and residues, reduction of pathogens and – in the case of agricultural applications – odor reduction as well as improved flow and fertilizing properties of digested compared to raw animal manure. The environmental impacts from biogas systems are dependent on a number of factors such as the sourcing of input materials, the technical configuration of the biogas plant, and the actual utilization pathways for biogas and digestate. Currently, biogas is utilized mainly for combined heat-and-power (CHP) production and also as vehicle fuel. In this way, GHGs from the utilization of fossil energy carriers and conventional open storage of animal manure can be mitigated. The objective of this paper is to illustrate the evaluation of greenhouse gas mitigation by the utilization of biogas and how this is influenced by methodological choices.

MATERIALS AND METHODS

Description of biogas systems in general

A biogas (energy) system consists of various biological, procedural, and energy conversion steps. For the purpose of analysis, biogas systems may be divided into four stages: Feedstock supply, biogas production, digestate utilization and biogas utilization (

Fig. 1).

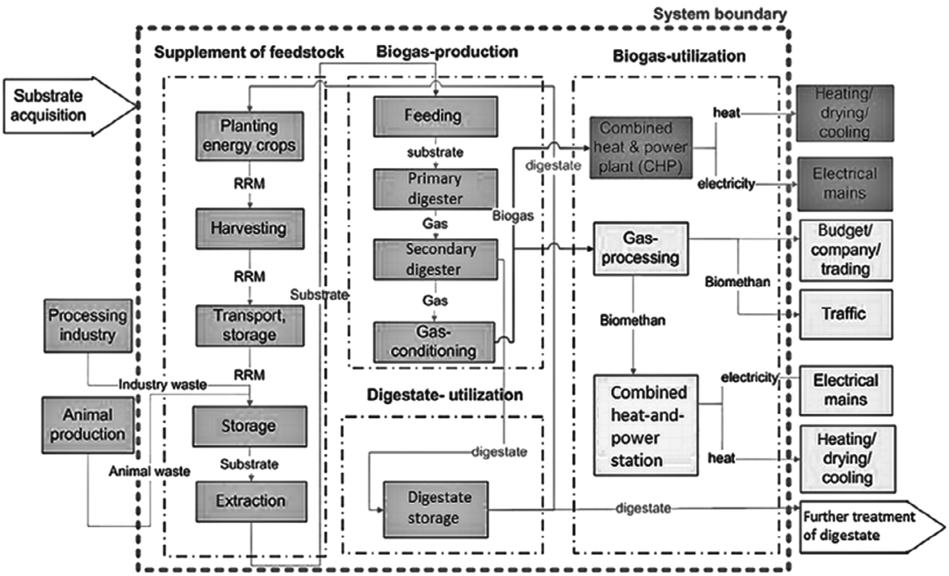

Fig. 1. Schematic of biogas energy systems. RRM: renewable raw materials (Source: 2)

The substrate is the output from the first stage (Feedstock supply) which is then used in the second stage (biogas production) to produce biogas and digested residue (digestate). Digestate as organic fertilizer is redirected to the stage of feedstock supply to produce energy crops. Finally biogas is utilized for CHP generation or as vehicle fuel.

The digester/s is/are fed with the feedstock directly and/or from a collection tank. Inside the digester, the anaerobic digestion (AD) of the feedstock is carried out by a network of a large variety of microorganisms (bacteria and methanogenic archaea) to produce biogas. Typically, the AD process is modeled in four phases: Hydrolysis, acidogenesis, acetogenesis / secondary fermentation, and methanogenesis 1. Based on the temperature in the digester(s), AD processes are commonly classified as thermophilic (45 - 55 °C), mesophilic (35 - 44 °C), or psychrophilic (below 35 °C). The main components of biogas are CH_4 and CO_2, besides residual gases such as ammonia (NH_3), hydrogen sulfide (H_2S) and water vapor 3.

Biogas systems can utilize a large variety of feedstocks such as municipal and industrial organic waste, sewage, animal waste, agricultural by-products or renewable raw materials (RRM) / energy crops.

Description of experimental farms analyzed for this publication

In order to illustrate some of the variability of GHG mitigation in real biogas systems, five experimental farms were analyzed. These farms are located in three different "pedological-climatic-regions" 4 within Bavaria. Input materials for biogas production are animal manure, maize silage, grass silage, and other energy crops. In all cases, the biogas is utilized for combined heat-and-power production on site. More information on the five experimental farms can be found in

Table .

Table 1. Characterization of the biogas farms analysed for this paper

ID	Feedstock*, % (m/m)	Nominal electrical power output of CHP unit, kW	Proportionate electricity demand of biogas plant§, %	Proportional heat sales$, %
1	MS: 61, GS: , WCS: 10, CCM: 2, CM: 2	630	7.7	81
2	KG: 61, WCS: 3, CM: 33, MS: 3	440	10.2	56
3	MS: 36, GS: 18, WCS: 15, PM: 12, CM: 4, GK: 4	990	6.2	57
4	GS: 55, CM: 45	100	17.6	92
5	MS: 52, PM: 36, WCS: 8, CCM: 4	207	10.0	70

*) CCM: Corn-Cob-Mix, CG: Clover grass, CM: Cattle manure, GK: Grain kernels, GS: Grass silage, MS: Maize silage, PM: Pig manure, WCS: Whole cereal crop silage; §) With respect to electricity output; $) With respect to surplus heat after satisfying digester heat demand.

Calculation of specific GHG emissions for biogas systems

In order to calculate specific GHG emissions of electricity and heat generation from biogas, we followed the standardized methodology of life cycle assessment (LCA), using the GaBi® 6.0 tool (thinkstep AG, Germany). The goal of this study was to present the specific impacts on global warming / greenhouse gas mitigation of producing and utilizing biogas as an energy source. Therefore, useful energy was used as functional unit. Other environmental impacts were also assessed but the results are not presented in this publication. The system boundaries are illustrated in

Fig. 1. For the biogas systems, the life cycle inventory (LCI) was compiled from primary data collected from the farms and supplementary data from literature. For characterizing the impact of the biogas systems on global warming, the main GHGs carbon dioxide (CO_2), CH_4 and N_2O were taken into account, using CO_2 equivalence factors (mass basis) for a 100 year time horizon of 298 for N_2O (without considering climate-carbon cycle feedback) and of 25 for CH_4 5.

Determination of specific GHG emissions with respect to heat and power output

Allocation method

Allocation of the total system GHG emissions between heat and power output has been a subject for never ending discussion. Several thermodynamic and economic methods are available to perform this allocation. For our study, we chose the exergetic allocation method, whereby exergy is defined as that part of a system's energy content which can be converted into mechanical work 6. Electricity is 100 % exergy, therefore if exergetic allocation is performed, electricity shall bear the main part of the system's GHG emissions whereas the emission share allocated to heat will remain small (see Equations 1 to 3 after 7).

$$E_Q = \left(1 - \frac{T_U}{T_Q}\right) \tag{1}$$

$$AF_{Power} = \frac{W_{el}}{W_{el} + E_Q} \tag{2}$$

$$AF_{Heat} = 1 - AF_{Power} \tag{3}$$

AF_{Power} = Allocation factor for power, 1
AF_{Heat} = Allocation factor for heat, 1
W_{el} = Generated electrical power, MJ
E_Q = Exergy of heat, MJ
Q = Lower heating value of biogas, MJ
T_U = Ambient temperature, K (Reference temperature = 288 K)
T_Q = Temperature of heat output, K

System extension / substitution method

Using the substitution method, credits are derived from extending the system for additional effects of electricity production from biogas. In our case we calculated credits for heat supply, manure digestion, and the use of digestate as fertilizer. For the heat produced from biogas, it was assumed that this heat was utilized to substitute the average heat supply in Bavaria with specific GHG emissions of 0,075 kg CO_2-eq according to Wolf et al. (2016). For the digestion of manure, a credit was calculated based on the GHG emissions in the form of methane (CH_4) and nitrous oxide (N_2O) which would have occurred during open storage of manure. It was assumed that 25 % of the potential methane yield from pig manure and 17 % from cattle manure were mitigated in this way. For N_2O, a mitigation factor of 0.004 kg N_2O-N per kg of nitrogen content was used for both pig and cattle manure 8. A credit for the substitution of mineral fertilizer by delivering digestate to other farms was calculated on the basis of a mineral fertilizer equivalent of 50 % for nitrogen, and 100 % for phosphorous and potassium.

RESULTS AND DISCUSSION

In the following, we present specific GHG emissions of electricity production from biogas for the individual experimental farms, evaluated by different methods. Furthermore, we discuss the possibilities for maximizing the mitigation of GHGs in biogas systems.

Experimental farm 1

Fig. 2 shows the specific CO_2 equivalent emissions for electricity production from biogas for experimental farm 1, using the methods of substitution (left column) and exergetic allocation (right column). The calculated specific CO_2 equivalent emissions allocated to electricity output are 68 g MJ^{-1}. If broken down into the different sections of the biogas system, the feedstock supply has a share in CO_2 equivalent emissions of approx. 56 %, while biogas production and biogas utilization have a combined share of approx. 36 %. The share of GHG emissions from constructing the biogas plant is 10 %, only. As the plant is run by diverting electricity from own production, the GHG footprint of its own electricity does not show up in the inventory.

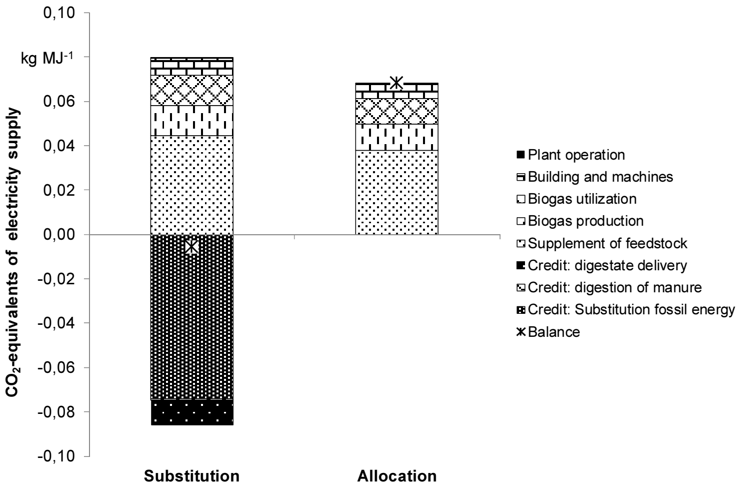

Fig. 2. Specific GHG emissions for electricity production from biogas for experimental farm 1, using allocation or substitution

Since most of the surplus heat was utilized to substitute natural gas for heating, a credit was calculated that compensates a large part of the CO_2 equivalent emissions from the biogas chain. The credit for the small amount of manure input is negligible (

Fig. 2). In total, the substitution method calculates sspecific CO_2 equivalent emissions for electricity production from biogas of -6 g MJ^{-1}.

Experimental farm 2

The calculated specific CO_2 equivalent emissions allocated to electricity output are 86 g MJ^{-1} (Fig.). This plant uses grid electricity (German grid mix CO_{2eq} emissions, kg MJ^{-1} = 0,178) which takes up a share of approx. 20 % of the total CO_2 equivalent emissions for this biogas system.

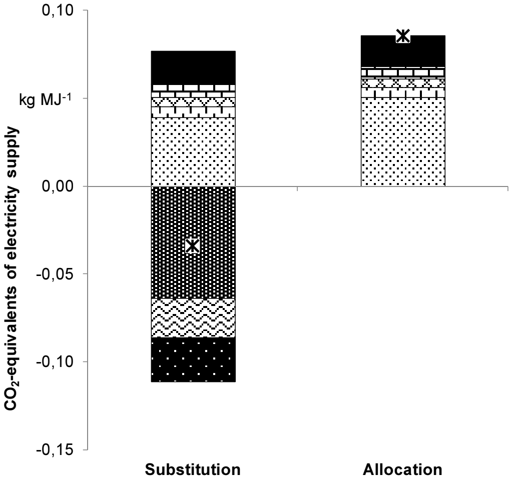

Fig. 3. Specific GHG emissions for experimental farm 2

Another main difference of farm 2 compared to farm 1 is the use of a fairly high share of cattle manure as input material (Table 1), resulting in a CO_{2eq} credit of 22 g MJ^{-1}. Together with the credit for heat supply of 64 g MJ^{-1} and digestate delivery of 25 g MJ^{-1}, the GHG emissions of the biogas chain are overcompensated in the extended system (Fig.).

Experimental farm 3

The calculated specific CO_2 equivalent emissions allocated to electricity output are 82 g MJ^{-1} which is similar to the value calculated for farm 2. Farm 3 uses 12 % pig manure in the input resulting in avoided specific CO_{2eq} emissions of 21 g MJ^{-1}. Again, with the credit for heat supply of 52 g MJ^{-1} and digestate delivery of 25 g MJ^{-1}, the GHG emissions of the biogas chain are overcompensated in the extended system (Fig.).

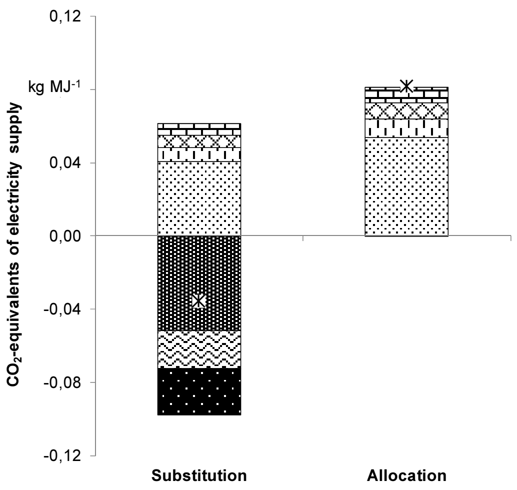

Fig. 4. Specific GHG emissions for experimental farm 3

Experimental farm 4

Experimental farm 4 is different from the others as it uses grass silage from grassland as the main input, combined with liquid cattle manure supplied from neighboring farms (*Table*). The total specific CO_2 equivalent emissions allocated to electricity are 142 g MJ^{-1}. This is comparably high due to two reasons: The large CO_{2eq} footprint of the intensive grassland and the very high demand of the biogas plant for grid electricity, which can be attributed to the difficult handling of the grass harvested with a loading trolley. In this case the credits cannot fully compensate the biogas chain emission (Fig).

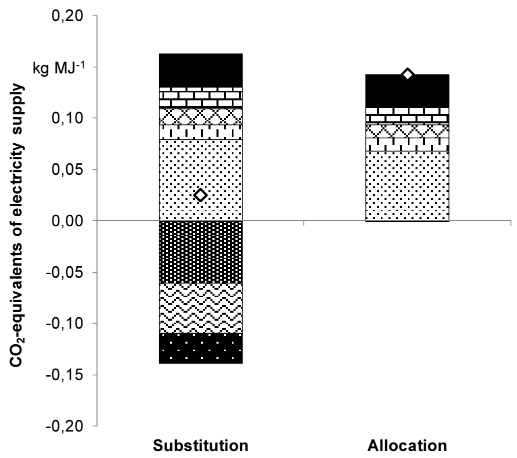

Fig 5. Specific GHG emissions for experimental farm 4

Experimental farm 5

The calculated specific CO_2 equivalent emissions allocated to electricity output are 91 g MJ^{-1} which is a bit higher than for farm 3 with similar prerequisites. Compared to the latter, farm 5 uses about double the share of pig manure in the input. System extension retrieves an almost net zero CO_{2eq} balance for electricity production of 5 g MJ^{-1} (*Fig.*).

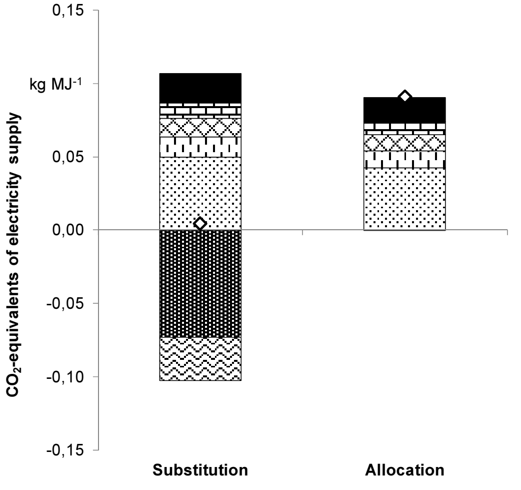

Fig. 6. Specific GHG emissions for experimental farm 5

If the electricity supply from the five biogas plants is compared with the reference system of the German grid mix, the specific CO_{2eq} mitigation amounts to between 86 and 120 %. If exergetic allocation is applied, the specific CO_{2eq} emissions of electricity supply are 20 to 62 % lower for the biogas systems in comparison with the German grid mix. In all five cases, the largest share of GHG emissions from the biogas systems is due to the supply of renewable raw materials as input.

CONCLUSIONS AND OUTLOOK

Within the current energy supply system in Germany, utilizing biogas produced from agricultural input materials to supply combined heat and power can make substantial contributions to the mitigation of GHG emissions. However, the cultivation and harvesting of renewable raw materials for biogas production is responsible for a lion's share of the total GHG footprint of the evaluated farm biogas systems. In this respect, the use of animal manure as input material is unequivocal, since avoided emissions from the reference system of conventional manure management can compensate for a significant share of the CO_{2eq} emissions from agricultural production. Key factors for the reduction of GHG emissions of agricultural biogas chains are "good professional practice" in cultivation, efficient use of synthetic and organic fertilizers, as well as minimization of fuel consumption and the use of regenerative fuels. The specific CO_{2eq} emissions of the feedstock can be reduced by selecting energy crops with a high yield of organic dry matter per unit area. Any losses of biomass that occur along the supply chain will increase the specific impacts of the biogas system on the environment.

Regardless of the selection of feedstock, the following measures are necessary – if not legally required, anyway – to minimize the impacts of biogas systems on global warming: Installing a flare to avoid discharge of biogas to the atmosphere during outages of the combined heat-and-power unit; minimizing the loss of biogas by means of regular leakage control; covering the storage tank for digested residues and collecting the residual biogas production; minimizing the parasitic electricity demand of the biogas plant and supplying it from low-emission sources; utilizing as much heat output from the CHPU as possible to substitute fossil energy carriers; and employing a high-efficiency CHPU, possibly with additional exhaust gas treatment.

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:631.12:661.9
Prethodno priopćenje
Preliminary communication

MOŽNOSTI ZA UVAJANJE NOVIH BIOPLINSKIH TEHNOLOGIJ NA DRUŽINSKIH KMETIJAH

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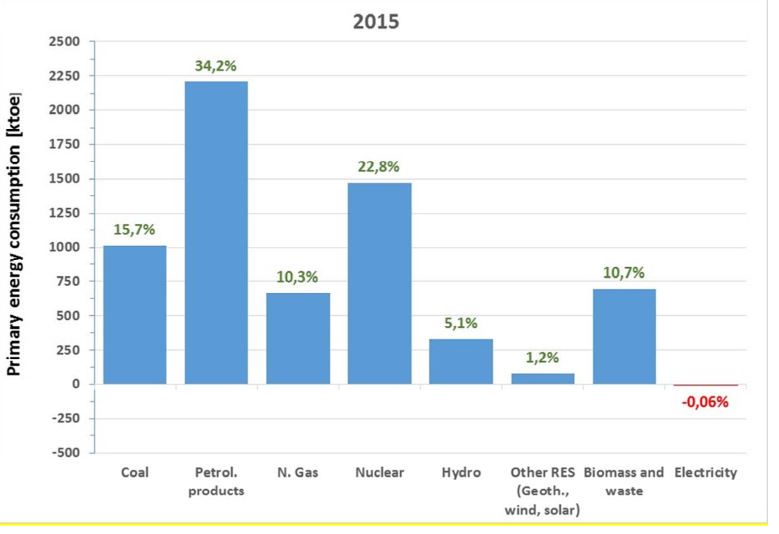
POVZETEK

Trenutno se v Sloveniji, bioplin na vseh kmetijskih bioplinskih napravah uporablja na kogeneracijskih enotah za proizvodnjo električne in toplotne energije, samo zelo majhno število bioplinskih naprav oddaja toploto drugim odjemnikom (zaradi tehničnih in ekonomskih ovir), zato je izkoristek večine bioplinskih naprav nizek. Za domače kmetijstvo in druga področja uporabe obstaja neizkoriščeni potencial na področju mikro bioplinskih naprav modularne izvedbe ter skupinskih bioplinskih naprav. Bioplin ponuja tudi drugo možnost, z njegovim čiščenjem in nadgradnjo do faze biometana. Z vbrizgavanjem biometana v prihodnosti bo mogoče izkoristiti omrežje zemeljskega plina in ga transportirati tudi na večje razdalje. Z uporabo omrežja zemeljskega plina se tudi povečuje število potencialnih odjemnikov biometana. Podani so scenariji za proizvodnjo bioplina in biometana na družinskih kmetijah usmerjenih v živinorejsko ali mešano pridelavo ter pregled nekaterih tehnologij, ki bodo omogočile višje izkoristke v proizvodnji bioplina v prihodnosti, njegovo nadgradnjo v biometan ter uporabo biometana za pogon traktorjev, delovnih strojev in drugih vozil.

Ključne besede: Bioplin, mikro bioplinske naprave, biometan, biometan za pogon vozil

UVOD

Zemeljski plin danes predstavlja več kot 21 % globalnih potreb po primarni energiji. Globalne potrebe po zemeljskem plinu se vsako leto povečajo za 2,8 %. Zaloge zemeljskega plina v EU upadajo in po ugotovitvah Eurogasa [1] bo leta 2020, EU pokrivala 32 % svojih potreb z lastnim zemeljskim plinom in samo še 26 % v letu 2030. Celotna poraba primarne energije v Sloveniji v letu 2015 je bila 6455,1 kt_{oe}. Delež zemeljskega plina v oskrbi Slovenije s primarno energije je 10,3 % (664 kt_{oe}). Največji delež v porabi primarne energije imajo naftni derivati, sledi nuklearna energija in premog [2]. Delež fosilnega goriva v energetski bilanci presega 60 % celotne rabe primarne energije. Delež obnovljivih virov energije (vključno z odpadki) predstavlja 17 % in delež nuklearne energije je okoli 23 %. Slovenija je tudi neto izvoznica električne energije. Struktura rabe primarne energije v Sloveniji je prikazana na sliki 1.



Slika 1: Struktura rabe primarne energije v Sloveniji v letu 2015
Figure 1: Structure of primary energy consumption in Slovenia for year 2015

V Sloveniji zemeljski plin uvažamo iz tujine, letna poraba zemeljskega plina v Sloveniji je v letu 2015 znašala 813 M Sm^3 [2]. Ena od možnih rešitev za zmanjševanje odvisnosti od uvoženega zemeljskega plina je tudi uporaba bioplina, ki postaja v zadnjem obdobju vse pomembnejši na področju izkoriščanja alternativnih virov energije v EU in pri nas. Velika prednost bioplina oziroma biometana v primerjavi z nekaterimi drugimi obnovljivimi viri energije je možnost njegovega skladiščenja in porabe glede potrebe po energiji (na poljubnem mestu in ob poljubnem času). Z njegovim skladiščenjem in uporabo lahko kompenziramo fluktuacije pri ostalih obnovljivih virih energije, kot so npr. vodna, vetrna in solarna energija. Po podatkih Javne Agencije Republike Slovenije za energijo in nam dostopnih informacijah je v Sloveniji bilo šestindvajset bioplinskih naprav (podatek za leto 2015) z deklaracijami in s skupno nazivno električno močjo 28,2 MW_e [4].

Sodoben način pridelave hrane je v veliki meri odvisen od energije fosilnih goriv. Energija predstavlja velik strošek v kmetijski pridelavi in predelavi, ki finančno in okoljsko, bremeni končne produkte kmetijstva. Z uporabo bioplina/biometana za energetske namene lahko zmanjšamo emisije metana (močan toplogredni plin) ter odvisnost kmetijstva od uvoženih fosilnih goriv. Stranski produkt npr. živinorejske kmetije je gnoj ali gnojevka, ki pri skladiščenju sprošča toplogredne pline in emisije smradu. Na kmetijah usmerjenih v mešano pridelavo in kmetijah usmerjenih samo v rastlinsko pridelavo pa nastaja tudi druga kmetijska biomasa, kot so npr. različni rastlinski ostanki in organski odpadki pri predelavi kmetijskih pridelkov v končne produkte itn., ki pri dolgotrajnem skladiščenju ustvarjajo zaradi svojega razkroja emisije toplogrednih plinov. Pri skladiščenju ali končnem deponiranju organskega odpada pa so zahteve po prostoru, poleg tega se ustvarjajo dodatne emisije toplogrednih plinov zaradi transporta organskega odpada. Vse prej omenjeno je povezano tudi z dodatnimi transportnimi stroški in povezanimi emisijami toplogrednih plinov, obremenjevanjem prometnic, itn. Sodobno kmetijstvo je v veliki meri odvisno od uvoženih mineralnih gnojil, ki so okolju neprijazna in predstavljajo velik strošek v kmetijski pridelavi, poleg tega se za proizvodnjo mineralnih gnojil porabijo tudi velike količine energije in surovin, kar pomeni dodatno obremenitev okolja z emisijami toplogrednih plinov. Izhodni digestat iz bioplinske naprave se lahko uporabi za direktno gnojenje (po opravljenih analizah glede primernosti za uporabo na kmetijskih površinah) oziroma proizvodnjo organskih gnojil, npr. v obliki peletov, briketov, itn.

PRIHODNOST PROIZVODNJE BIOPLINA IN BIOMETANA

Bioplinske naprave so pri nas trenutno najbolj zanimive za živinorejske kmetije, ker se kmetje na njih vsakodnevno soočajo z veliko količino gnojevke in gnoja, ki lahko predstavlja okoljski problem, poleg tega pa morajo omenjeni material po uredbi začasno skladiščiti do 6 mesecev. Kmetije z več kot 100 GVŽ predstavljajo skupino z največjim potencialom za izgradnjo novih bioplinskih naprav. Na omenjenih kmetijah bi teoretično lahko pridobili 8,97 M Sm^3 metana letno. Kmetije od 50 do 100 GVŽ, imajo teoretični potencial pridobivanja 10,94 M Sm^3 metana letno. Število živine v velikostnih razredih od 5 do 20 GVŽ in nad 20 do 50 GVŽ nam da podatek o teoretičnem potencialu pridobivanja še dodatnih 64 M Sm^3 metana letno (vidno je, da je na teh kmetijah največji teoretični potencial metana). Omenjene teoretične vrednosti za potencial metana so seveda nižje zaradi tehničnega in ekonomskega potenciala bioplina oziroma biometana. Tehnični potencial znaša približno 80 % od teoretičnega potenciala, za ekonomski potencial se ocenjuje da bi znašal 40 do 50 % od omenjenega teoretičnega potenciala biometana. Na pretežnem delu kmetij pa obstaja možnost tudi uporabe dodatnega substrata iz odpadne kmetijske biomase, ostankov iz predelave hrane, uporabe četrtega odkosa itn. Obstaja tudi možnost uporabe različnih organskih odpadkov iz gospodinjstev, javnih objektov, komunalnih aktivnosti (pokošena trava iz vzdrževanja zelenic, igrišč, športnih objektov itn.), živilsko predelovalne industrije itn.

Mikro bioplinske naprave modularne izvedbe z močjo 20 do 50 kW_e

Mikro bioplinske naprave v modularni izvedbi so lahko razpršeno postavljene po celotnem teritoriju države. V okolju, kjer bivamo, omenjene naprave lahko lokalno prispevajo k zmanjševanju problemov z odpadno biomaso ter emisijami metana. Z njihovim uvajanjem v večjem obsegu bo v prihodnosti omogočeno ustvarjanje novih delovnih mest, večja energetska varnost kmetij, ustvarjanje različnih sinergij (npr. kmetijstvo in energetski sektor). Zaradi decentraliziranosti in regionalne strukture naložb lahko znatno prispevajo k trajnostnemu razvoju podeželja in zagotovijo družinskim kmetijam nove možnosti dohodka. Pomembno pa lahko prispevajo razvoju in ohranjanju kmetij, ki se nahajajo na območjih z omejenimi dejavniki za kmetovanje, ker dodatno lahko prispeva k ohranjanju kmetijske proizvodnje, ki je lahko ogrožena zaradi višjih stroškov pridelave. Kmetija postane energetsko manj odvisna ali v celoti neodvisna (izboljšava energetske bilance), kar je velikega pomena tudi v primeru naravnih nesreč. Izboljšuje se tudi dohodkovna plat kmetije ter izboljšuje energetska bilanca države. Bioplin se sedaj največ uporablja v kogeneratorskih enotah (sočasna proizvodnja električne in toplotne energije). Za razvoj bioplinske tehnologije v prihodnosti bo pomembno vlogo igralo dvigovanje izkoristka procesov na bioplinskih napravah. Ena možnost je uporaba novih tehnologij, ki omogočajo večjo proizvodnjo bioplina z izboljšavo procesov priprave vhodnega substrata. Druga možnost je večja proizvodnja bioplina iz substratov, ki se do sedaj niso uporabljali – npr. lignocelulozni materiali, ki bodo imeli večjo vlogo v prihodnosti. Tehnologija, ki je zelo obetajoča in bo v prihodnosti vse bolj razširjena je tudi tehnologija čiščenja in nadgradnje bioplina do faze biometana. Plin, ki je očiščen in nadgrajen do faze biometana, je možno vbrizgavati v omrežje zemeljskega plina oziroma ga skladiščiti in uporabljati ob poljubnem času in mestu za pogon vozil in druge energetske namene.

Sedanji način gradnje bioplinskih naprav manjše moči je časovno in finančno potraten, ker se opravljajo gradbena in druga tehnična dela večjih obsegov, vsak objekt potrebuje veliko projektne dokumentacije, ki se pripravlja posamično. Razvoj in uvajanje tipiziranih modularnih izvedb mikro bioplinskih naprav (iz večjega števila standardiziranih modulov) lahko poenostavi, pospeši in značilno poceni način postavitve tovrstnih objektov ter posledično motivira kmetije da se v prihodnosti odločijo za tovrstno tehnologijo.

Slika 2: Mikro bioplinska naprava modularne izvedbe (skupni razvoj MIBP, Omega air – Kmetijski inštitut Slovenije), 1 – reaktor (digester), 2 – strojnica s čiščenjem plina, kogeneratorsko enoto in zalogovnikom toplotne energije, 3 – predpriprava trdnega substrata (mletje in dozacija), 4 – zalogovnik bioplina, 5 – predpriprava tekočega substrata – hidroliza (vir: Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko in energetiko)
Figure 2: Micro biogas plant modular type (collaboration development MIBP Omega air – Agricultural Institute of Slovenia), 1 – digester, 2 – container unit with cleaning of biogas, cogeneration unit and storage of thermal energy, 3 – pretreatment of solid substrate (milling and dosing), 4 biogas storage, 5 - pretreatment of liquid substrate - hydrolysis tank (source: Agricultural Institute of Slovenia, Department of Agricultural Engineering and Energy)

Možnosti uporabe bioplina iz kmetijskih mikro bioplinskih naprav:

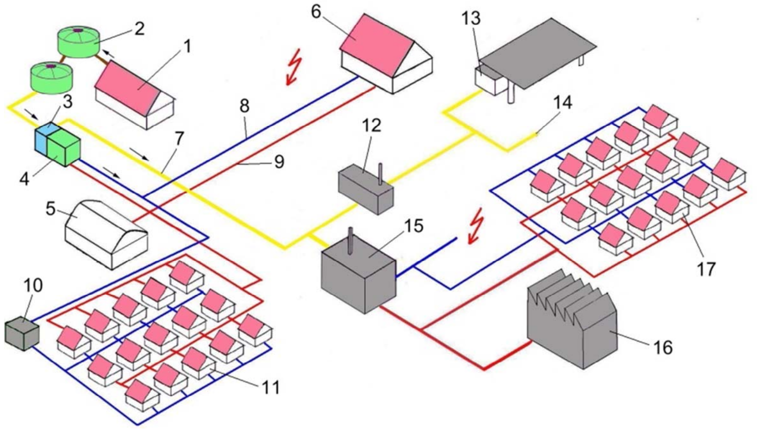
- za kogeneracijo (istočasna proizvodnja električne in toplotne energije)
- za sežiganje za proizvodnjo toplotne energije
- za čiščenje in nadgradnjo do faze biometana (za pogon traktorjev, delovnih strojev in drugih vozil)

Električna moč kogeneratorskih enot na mikro bioplinskih napravah je v razponu 10 – 50 kW_e., toplotna moč pa v razponu od 15 – 80 kW_t. Električna energija se lahko oddaja v javno električno omrežje oziroma je namenjena kmetiji za različne električne porabnike, toplotna energija se lahko uporablja za različne procesne potrebe kmetije (presežke toplotne energije se lahko uporabi tudi za daljinsko ogrevanje).

Dodatna prednost modularne izvedbe bioplinske naprave je da se osnovna mikro bioplinska naprava nadgradi glede energetskih potreb ter finančnih možnosti uporabnika z dodatnimi procesnimi moduli, ki maksimalno izkoriščajo toplotno energijo iz kogeneracijske enote. To so lahko moduli za proizvodnjo organskih gnojil (v obliki peletov ali briketov); za dosuševanje različnih pridelkov, zelišč, sekancev ali lesa; za čiščenje in nadgradnjo bioplina do faze biometana za gorivo za pogon delovnih strojev in vozil itn. Mikro bioplinsko napravo modularne izvedbe bo mogoče tudi povezovati z ostalimi sistemi za izkoriščanje obnovljivih virov energije (vetrna energija, sončna energija, fotovoltaika itn.). Mikro bioplinska naprava je v osnovi namenjena uporabi v kmetijstvu, lahko pa se uporablja tudi za predelavo organskega odpada živilsko predelovalne industrije, organskega odpada iz gospodinjstev, komunalne dejavnosti itn. Mikro bioplinske naprave se lahko uporabljajo tudi kot skupinske, npr. za nekaj kmetij ali večje število kmetij, vas, naselje itn. Letna teoretična proizvodnja električne energije na mikrobioplinskih napravah se lahko giblje od 80.000 kWh do 400.000 kWh (odvisno od vrste in razpoložljivih količin substrata). Električna in toplotna energija (procesne potrebe) se lahko v celoti porabi na kmetiji. Viški električne energije se lahko oddajo v električno omrežje, za toplotno energijo pa obstaja možnost odjema za daljinsko ogrevanje različnih objektov. Slaba stran mikro bioplinskih naprav je visoka investicija v napravo, ki se giblje od 8.000 do 9.000 EUR/kW_e, ter vpliva na njihovo uvajanje v večjem obsegu v EU in pri nas (strošek se lahko zniža v primeru, da bi bioplinska naprava npr. proizvajala samo bioplin za uporabo na drugih lokacijah, v tem primeru ni potrebe po kogeneracijski enoti, odpadejo pa tudi stroški za transformatorsko postajo itn.).

Za potrebe raziskovalno razvojnih aktivnosti smo na Kmetijskem inštitutu Slovenije; Oddelku za kmetijsko tehniko in energetiko postavili pilotno mikro bioplinsko napravo modularne izvedbe (skupni razvojni projekt podjetja Omega air, Ljubljana in Kmetijskega inštituta Slovenije). Pilotna naprava obratuje intenzivno od leta 2015, trenutno ima en horizontalni reaktor s horizontalnim mešanjem substrata, v prihodnosti pa je predvidena razširitev z enim do dvema novima reaktorjema, posodo za mešanje gnoja s povratnim tokom tekoče faze iz predvidene separacije digestata, separatorjem za digestat (ločevanje trdne in tekoče faze), itn. Vhodni substrat na bioplinski napravi je goveja gnojevka od 100 GVŽ s povprečno 83g/kg suhe snovi ter trdna kmetijska biomasa (ostanek od procesiranja semena žit). Trdna kmetijska biomasa (50 kg/dan) se dodaja v hidrolizno posodo, kjer se meša z govejo gnojevko. Proizvodnja bioplina znaša povprečno 9000 Sm^3/leto. Proizvedeni bioplin se v celoti porabi na kogeneratorski enoti, moči 7 kW_e in 15 kW_t. Električna energija se večinoma uporablja za lastne potrebe živinorejskih objektov (mlečna pridelava), odvečni del električne energije pa se pošilja v javno električno omrežje. Delovanje bioplinske naprave je popolnoma avtomatično tako da uporabnik nima posebnega dodatnega dela. Na bioplinski napravi se opravljajo različne razvojno raziskovalne aktivnosti glede možnosti uporabe različnih substratov, spremljanja proizvodnje električne in toplotne energije, zmanjševanja emisij toplogrednih plinov, vpliva substrata na kaljivost semen različnih plevelov in tujih invazivnih vrst rastlin, itn.

Scenariji za uporabo bioplina v prihodnosti



Slika 3: Možnosti povezovanja kmetijskih bioplinskih naprav z uporabniki bioplina, 1 – živinorejska ali mešana kmetija, 2 – bioplinski digestor, 3 – grobo čiščenje bioplina, 4 – kogeneratorska enota, 5 – rastlinjak, 6 – gospodinjski objekt na kmetiji, 7 – plinovod za grobo očiščeni bioplin, 8 – električna energija, 9 – toplotna energija, 10 – transformatorska postaja, 11 – gospodinjski odjemniki električne in toplotne energije, 12 – enota za čiščenje in nadgradnjo bioplina do faze biometana, 13 – postaja za biometan za delovne stroje in druga vozila, 14 – biometan, 15 – enota za kogeneracijo na bioplin povezana z lokalnim plinovodom za bioplin, 16 – industrijski odjemnik toplotne energije, 17 – gospodinjski odjemniki toplotne in električne energije (vir: Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko in energetiko)

Figure 3: The connectivity options of agricultural biogas plants with end users of biogas 1 – livestock or mixed type farm, 2 – biogas digester, 3 – raw biogas cleaning, 4 - cogeneration unit 5 - greenhouse 6 - household object on farm 7 - pipeline for roughly cleaned biogas, 8 - electricity, 9 – heat, 10 - transformer station, 11 – households users of electricity and heat, 12 - unit for cleaning and upgrading biogas to biomethane phase, 13 - station for biomethane for working machines and other vehicles, 14 – biomethane, 15 - cogeneration plant using biogas connected with local pipeline for biogas, 16 - industrial user of heat, 17 – households users of heat and electricity (source: Agricultural Institute of Slovenia, Department of Agricultural Engineering and Energy)

Trenutno na manjših kmetijah do 50 GVŽ ni ekonomsko opravičeno postavljati bioplinskih naprav (v prihodnosti bo pomembno vlogo igral tudi ekološki prispevek naprave). Za omenjene manjše kmetije je potrebno ubrati nove rešitve v smeri povezovanje mikro bioplinskih naprav, ki delujejo na posameznih kmetijah. Združevanje kmetij z namenom pridobivanja bioplina bi lahko potekalo znotraj nekaj različnih scenarijev izvedljivosti glede velikosti kmetij. Zelo majhne kmetije (razreda do 5 GVŽ in nad 5 do 20 GVŽ) bi morale substrat transportirati na skupno bioplinsko napravo. Transport bi lahko potekal s traktorji agregatiranimi s cisternami za prevoz gnojevke ali pri nekaterih primernih lokacijah tudi s pomočjo krajših cevovodov za gnojevko oziroma tekoči substrat (na ta način se razbremenijo prometnice). Drug scenarij, ki izključuje transportne aktivnosti na prometnicah in ne zahteva veliko angažiranje človeškega dela, predvideva združeno proizvodnjo bioplina iz več bioplinskih naprav, ki so povezane v mrežo lokalnih plinovodov za bioplin (omenjena tehnologija pride v poštev predvsem za manjše transportne razdalje). V prihodnosti bi v ta scenarij lahko uvrstili kmetije s številom živine od 20 do 50 GVŽ, v nekaterih primerih tudi nad 50 do 80 GVŽ. Proizvedeni bioplin (lahko grobo očiščen od primesi) bi transportirali preko nizkotlačnih plinovodov do skupnih čistilnih ali kogeneracijskih enot, ki bi se nahajale v bližini večjih naselij zaradi lažje izvedbe daljinskega ogrevanja objektov z odvečno toplotno energijo. V tretjem scenariju pa odpadejo potrebe po plinovodih (izgradnja plinovodov je povezana s stroški). V omenjenem scenariju se lahko uporabljajo posebna vozila za prevzem bioplina, delno čiščenje in odvoz bioplina na centralno enoto za končno čiščenje in nadgradnjo bioplina do faze biometana. Ta scenarij je zanimiv tudi za bioplinske naprave, ki proizvajajo bioplin ter ga same očistijo in nadgradijo do faze biometana.

V primeru, da je proizvodnja plina pod 70 Nm^3/h, začnejo zelo naraščati stroški čiščenja in nadgradnje plina, zato se s trenutno na trgu dosegljivimi tehnologijami ne more opravljati ekonomičen postopek čiščenja in nadgradnje bioplina do faze biometana [3]. Zato se v prihodnosti predvideva uporaba načinov čiščenja in nadgradnje bioplina, ki bo temeljila na kooperaciji. Kmetija bo lahko razpolagala samo z mikro (ali malo) bioplinsko napravo, opremljeno z reaktorjema (digestorjema) in enoto za skladiščenje plina (plinohram). Enota za skladiščenje mora imeti zadostne kapacitete za skladiščenje bioplina (vsaj za nekaj dni). S tem na sami bioplinski napravi odpadejo tudi stroški za kogeneratorsko enoto in dodatno transformatorsko postajo (v nekaterih primerih je potrebno dodatno postavljati transformatorske postaje). Delno čiščenje plina se opravi že med transportom, na samih vozilih za prevzem in odvoz bioplina, dokončno čiščenje bioplina in njegova nadgradnja do faze biometana pa na centralni enoti za obdelavo bioplina v biometan. Na omenjeni centralni enoti za obdelavo bioplina, se bi lahko bioplin mešal tudi z metanom (možnost vbrizgavanja biometana v javno omrežje zemeljskega plina). Plin, ki je očiščen in nadgrajen do faze biometana, je možno vbrizgavati v omrežje zemeljskega plina oziroma ga skladiščiti dalj časa in uporabljati ob poljubnem času in mestu za pogon različnih vozil in druge energetske namene. Za transport biometana z večjega števila manjših bioplinskih naprav bi se lahko uporabile nekatere tehnologije, ki že obstajajo za transport zemeljskega plina. V nekaterih delih sveta že uporabljajo posebne modularne izvedbe rezervoarjev – kontejnerjev, ki so namenjeni za cestni, železniški ali vodni transport plina v komprimiranem ali tekočem stanju (stisnjeni plin je stisnjen pod tlakom 220 - 250 bar, utekočinjen pa je potrebno prevažati ohlajen v izoliranih posodah). Prednost omenjene tehnologije je, da se plin v tipiziranem kontejnerju pripelje na mesto uporabe, kontejner se hitro in enostavno spoji s postajo za zniževanje tlaka plina in plin se dobavlja v lokalno omrežje ali pa za pogon vozil [5].


a


b

Slika 4: a - enota za čiščenje in nadgradnjo bioplina do faze biometana na manjši bioplinski kmetijski napravi (proizvodnja bioplina iz gnojevke in travne silaže), čiščenje bioplina se opravlja s postopkom adsorpcije pod povišanim tlakom, enota zavzame zelo malo prostora; b - enota za komprimiranje biometana, en del biometana se vbrizgava v plinsko omrežje, drugi del biometana se uporablja za pogon osebnih vozil (vir: Viktor Jejčič, posneto na bioplinski napravi Graskraft anlage, Avstrija)
Figure 4: a - the unit for cleaning and upgrading biogas to biomethane phase on smaller agricultural biogas plant (biogas production from slurry and grass silage), biogas cleaning is carried out by adsorption process under increased pressure (pressure swing adsorption), the unit takes up very little space; b - unit for compressing the biomethane, one part of biomethane is injected into the gas grid, the second part of the biomethane is used to power vehicles (source: Viktor Jejčič, recorded in a biogas plant Graskraft Anlage, Austria)

Bioplin po čiščenju in nadgradnji do faze biometana postane primeren za vbrizgavanje v javno plinovodno omrežje, kjer se meša z zemeljskim plinom (vbrizgan delež pa se prodaja kot obnovljiv vir energije). Prednost vbrizgavanja biometana v omrežje zemeljskega plina pride do izraza na bioplinskih napravah, ki so odmaknjene od večjih naselij ali mest. Plinovodno omrežje je v Sloveniji dobro razvito, priključitev bioplinskih naprav, ki proizvajajo biometan na plinovodna omrežja pa bo izvedljiva, ko bo obstajala pravna in tehnična zakonodaja za vbrizgavanje biometana v plinsko omrežje ter zagotovljene odkupne cene za biometan.

Uporaba biometana za pogon motorjev traktorjev in delovnih strojev

Nekateri proizvajalci traktorjev, tovornih vozil in delovnih strojev v EU in svetu so v zadnjem obdobju začeli razvijati nadgradnje za dizelske motorje, ki omogočajo uporabo biometana. Za pogon posebnih izvedb traktorskih motorjev (predelane izvedbe, ki so jih v eksperimentalne namene razvili nekateri proizvajalci traktorjev) je mogoče uporabljati zemeljski plin in biometan. Na traktorskih motorjih se poleg stisnjenega zemeljskega plina CNG ter utekočinjenega zemeljskega plina (angl. LNG - Liquefied Natural Gas), lahko uporablja stisnjeni biometan - CBM in utekočinjeni biometan (angl. LBM – Liquefied Biomethane). Poleg tega je možno uporabiti tudi mešanice goriv, kot je zemeljski plin in biometan (angl. LNG/LBM - Liquefied Natural Gas/ Liquefied Biomethane). Možne so tudi druge kombinacije. V Veliki Britaniji npr. podjetje Gasrec ponuja za pogon vozil s plinskimi motorji, 25 % mešanico utekočinjenega biometana s 75 % utekočinjenim zemeljskim plinom. Omenjeno mešanico dveh goriv na trgu ponujajo že nekaj let, imenovali pa so jo Bio LNG.

Za uporabo biometana obstajata dva tipa motorjev z notranjim zgorevanjem, na eno ali dve vrsti goriv. V primeru uporabe enega goriva se uporablja plinski motor. Pri drugem tipu motorja, ki ga vse bolj zagovarjajo proizvajalci vozil se uporablja istočasno dve vrsti goriv (angl. Dual Fuel Engines), biometan in dizelsko gorivo (mineralno dizelsko gorivo, biodizel B 100, rastlinsko olje PPO, mešanice dizelskih goriv v različnih razmerjih). Dizelsko gorivo predstavlja vir za vžiganje biometana v motorjih na dve vrsti goriv. Biometan se ne more vžgati, kot dizelsko gorivo, ki se vžge v fazi kompresije na segretem zraku v motorju, zato funkcijo vžiga biometana opravi dizelsko gorivo, ki ima nižjo točko vžiga v primerjavi z biometanom. Motor, ki uporablja dve vrsti goriv ima tudi boljši izkoristek v primerjavi s plinskim motorjem, ki uporablja samo biometan.

ZAKLJUČEK

Z uvajanjem uporabe bioplina (biometana) se lahko zmanjša energetska odvisnost kmetijstva od fosilnih goriv ter značilno znižajo emisije toplogrednih plinov, kar pomeni da tudi končni produkti pridelave (hrana, surovine, goriva iz biomase itn.) imajo nižji CO_2 odtis. Z uporabo lastnega energetskega vira lahko pomembno prispevamo k ekonomičnosti kmetijske pridelave in večji konkurenčnosti končnih kmetijskih produktov na trgu. Kmetije z več kot 100 GVŽ v Sloveniji predstavljajo skupino z največjim potencialom za izgradnjo novih bioplinskih naprav (velik potencial imajo mikro bioplinske naprave v modularni izvedbi). Tehnologija, ki je zelo obetajoča in bo v prihodnosti vse bolj razširjena je tudi tehnologija čiščenja in nadgradnje bioplina do faze biometana. Plin, ki je očiščen in nadgrajen do faze biometana, je možno vbrizgavati v omrežje zemeljskega plina oziroma ga skladiščiti in uporabljati ob poljubnem času in mestu za pogon vozil in druge energetske namene. Z vbrizgavanjem biometana v javno omrežje z zemeljskim plinom lahko dobavljamo energijo iz obnovljivih virov do vseh uporabnikov omrežja. Proizvedeni biometan iz kmetijskih, skupinskih in drugih bioplinskih naprav bi se lahko vbrizgaval v lokalno ali v javno plinsko omrežje (v zimskih mesecih se lahko vbrizgava v lokalna plinska omrežja, v poletnih, ko ni večjih potreb po plinu pa v javno plinsko omrežje), ki je dobro razvito v Sloveniji. Za nadgradnjo bioplina do faze biometana, njegov transport in uporabo, bi se lahko v prihodnosti uporabile tudi nekatere nove tehnologije, ki jih že uporabljajo ali razvijajo v EU in svetu.

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OPTIONS FOR THE INTRODUCTION OF NEW BIOGAS TECHNOLOGY ON FAMILY FARMS

ABSTRACT

Currently in Slovenia, all biogas on agricultural biogas plants is used in cogeneration units for the production of electricity and heat, only a small number of biogas plants distribute heat energy to other end users (due to technical and economic barriers), so the efficiency of the majority of biogas plants is low. For domestic agriculture and other areas of application, there is untapped potential in the field of micro biogas plants of modular construction and collective biogas plants. Biogas also offers another option with his cleaning and upgrading to biomethane phase. With the injection of biomethane in the future it will be possible to take advantage of the natural gas network and also transporting it over long distances. By using natural gas network also increases the number of potential end users of biomethane. Presented are scenarios for the production of biogas and biomethane on family livestock or mixed oriented farms and a review of some of the technologies that will enable higher efficiency in the production of biogas in the future, its upgrading to biomethane and use of biomethane to power tractors, working machines and other vehicles.

Keywords: biogas, micro biogas plants, biomethane, biomethane for vehicles

45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PEAT PELLETS PRODUCTION AND USAGE AS ENVIRONMENTALLY-FRIENDLY LOCAL FUEL

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ABSTRACT

Laboratory trials with peat preparation and usage for energy purposes were carried out in Aleksandras Stulginskis University and Lithuanian Energy Institute. Peat suitability for solid fuel production in Lithuania was investigated and peat pellets biometrical and physical-mechanical properties were performed; energy productivity as well as impact to the environment during burning process was investigated. Crumbly peat was dried, milled and granulated by a small capacity (100-120 kg h^{-1}) granulator with a horizontal granulator matrix. After pellets cooling, their biometrical parameters were determined: dimensions, moisture content, volume and density. Investigated peat pellets average moisture content was of 11.6±0.7 %; pellets density was very high and reached 1067.1±30.9 kg m^{-3} DM (dry mass). After burning of peat pellets, comparatively high ash content was determined – 7.16±0.23% and very high net calorific value of peat pellets dry mass – 20.10±0.49 KJ kg^{-1}. After determination of harmful substances emissions into the atmosphere when burning of peat pellets, it has been concluded that this investigated fuel can be used as environmentally-friendly local fuel because it slightly pollutes the environment and harmful emissions are within the permissible values.

Key words: peat, pellets, fuel, properties, calorific value, harmful emissions.

INTRODUCTION

Wood biofuel is the most widely used sort of fuel in Lithuania. Apart from this sort of fuel, other local resources can be used for energy purposes: straw, waste products of agriculture, peat. The Danish farmers use about 40 % of straw for burning, and if we use this quantity in Lithuania for fuel, we would receive about 1.2 million tons of biofuel; it is about 440 thousand tons of oil equivalent (Raslavicius et al., 2013). According to the future plans for the years 2020-2025, the accumulated quantity of waste products in Lithuania would reach about 1.4 million tons. According to the forecasts, Lithuania shall develop both primary (performed by citizens) and secondary (performed centralised in special companies) sorting; thus, about 730 thousand tons of sorted waste should be obtained in Lithuania. It shall make about 200 thousand tons of oil equivalent (Biofuel potential, 2013).

According to the sources of information, peat is not considered renewable resource and biofuel. However, in Lithuania it is a local resource of fuel and there are some peat-bogs where light and dark peat is excavated. Light peat is usually sold as a raw-material for plant-growing and flower-growing. Meanwhile, dark peat, which could be used as fuel, is simply left in peat-bogs. Presently, peat is considered as little used fuel in Lithuania – only 80 thousand tons are used in the country. According to evaluation of scientists of Kaunas University of Technology, presently in the exploited peat-bogs of Lithuania about 17 million tons of dark peat is accumulated. Scientists offer using about 350 thousand tons of peat annually for energy production (Biofuel potential, 2013).

Lithuanian peat resources are presented in Table 1 (Sudintas, 2013).

Table 1. Lithuanian peat resources

Unused peat-bogs	Amount, mln., t
Bodies in the forest, in urbanized areas	14.9
Protected areas (reservations, sanctuaries)	70.4
Bogs, forest	8.9
Can be used, necessary for analysis	12.2
Total:	106.4

After analysis of the data presented in Table 1, we may state that peat resources in Lithuania are relatively high, so their use for energy needs of the country are especially relevant. However, wider use of peat requires new technological solutions, since peat fuel has high ash content, and by substantial combustion process produces some harmful emissions.

After peat extraction, volume potential analysis (Sudintas, 2013; Due to local fuel, 2014) was presented; the data of the analysis provide forecasts of energy potential of unused peat resources (Fig.1).

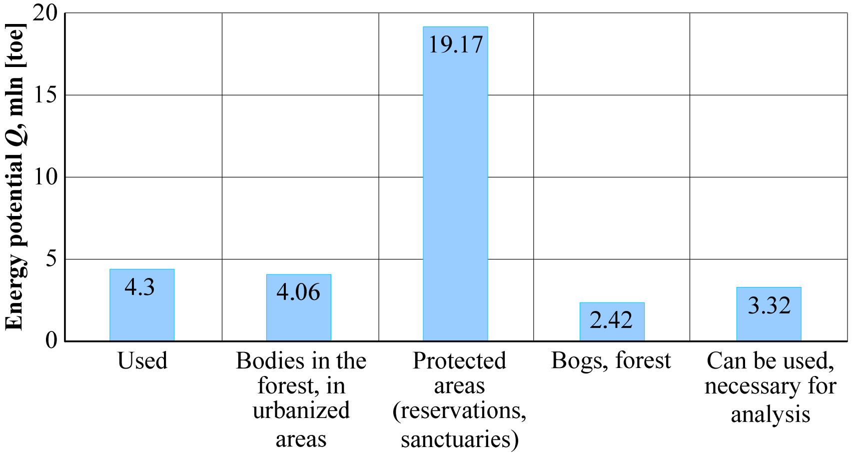

Fig. 1. Energy potential of Lithuanian peat bog usage for peat fuel

The greatest energy potential is in protected areas, *i.e.* 19.17 million ton oil equivalent [Toe], and the smallest is in the bogs, forests – 2.42 million [Toe]. The content of the used peat resources of 4.30 million [Toe] is equivalent to 50 TWh. Therefore, every year from peat fuel we can get 0.9-1.1 TWh, and peat energy resources would be sufficient for 50 years.

Peat fuel is attractive since it is less expensive than many other types of fuel. According to the literature sources, the main characteristics of peat fuel vary quite a wide range; their average values are presented in Table 2 (Vares et al., 2007). It should be noted that reliable data of peat fuel emissions and environmental impact was not found in the literature sources.

Table 2. Peat technical parameters

Parameter	Unit of measurement
Moisture content	40-45 %
Ash content	5-8 %
Density	700-850 kg m^{-3}
Lower calorific value of dry mass	15-20 MJ kg^{-1}

Talking about processed peat fuel, the most wide-spread forms is briquettes and granules produced from crumbly peat; chunk peat is used more rarely. Peat pressing to granules or briquettes is a rather energy consuming process; it increases prime-costs of obtained fuel (Sudintas, 2013; Due to local fuel, 2014). Limited usage of crumbly peat for biofuel depends on high quantity of ash (4-6 %) and sufficiently high quantity of harmful emissions (Vares et al., 2007; Sirvydis and Dravininkas, 2005; Wood and peat mixtures, 2016). Aiming to expand peat usage for fuel volumes, it is purposeful to investigate peat pelleting means and pellet main properties, which have the influence to the peat pellet storage, transportation and burning, and to determine harmful emissions while peat burning.

The aim of research work – to investigate technical means of peat preparation and utilization for fuel, to assess quality indicators of peat milling and pelleting, to determine main pellet properties: density, elemental composition, ash content, calorific value and harmful emissions while peat burning.

MATERIALS AND METHODS

The experimental research investigations were performed in research basis of Aleksandras Stulginskis University (ASU), joint stock company (JSC) *Klasmann-Deilmann Ežerėlis* and laboratories of Lithuanian Energy Institute. For research investigations was used crumbly peat produced by JSC *Klasmann-Deilmann Ežerėlis* in Kaunas district, samples were taken from different four places, of various moisture contents.

Moisture content of crumbly peat and pellet was determined in ASU laboratory: five samples were taken, they were weighted and dried in cabinet drier for 24 hrs, in the temperature 105 °C. Dried samples were weighted by a scale METTLER TOLEDO SB 16001, with precision 0.01 g.

Filled density was determined after filling crumbly peat and pellet to a cylindrical plate of the measured volume (V) of which was equal 5 dm^3 and not pressing weighted by scale METTLER TOLEDO SB 16001 to determine their mass (m), filled density was calculated by formula: $\rho = m/V$ (Solid biofuels. 2005).

Fractional composition of crumbly peat mill was determined using a set of 200 mm diameter sieves with the different diameter holes: 0 mm, 0.25 mm, 05 mm, 0.63 mm, 1 mm and 2 mm. The mass remaining on the sieves was weighed, and the sample fraction percentages were calculated. Each test was repeated 5 times (DD CEN/TS 15149-1:2006).

A stand produced in Agriculture Engineering and Safety Institute is used to determine ***fly angles***. Natural slope angle α_n and fall angle α_{gr} were determined by the special stand (Siaudinis et al., 2015).

The milled crumbly peat was granulated by a small capacity (100-120 kg h^{-1}) granulator with a horizontal granulator matrix. The diameter of the pellets was 6 mm. When the pellets were cooled, their ***biometric parameters*** were evaluated: ***dimensions, humidity, volume and density***. The peat pellet parameters were determined by measuring their height and diameter (accurate to 0.05 mm). Pellets weight was assessed by KERN ABJ scales (accurate to 0.001 g). Pellets moisture content was determined in a laboratory drying chamber oven according to the standard method (Jasinskas, 2007).

Pellet density and filled density. The peat pellet volume was calculated using the pellet size (diameter and length). After determination of pellet mass and volume there are calculated their density. It also has been determined the filled density of pellet, which were poured into 3 dm^3 container, weighing and calculating the filled density (Niedziołka et al., 2015).

Pellets elementary composition, ash content and calorific value were determined at the Lithuanian Energy Institute (LEI) Thermal equipment research and testing laboratory in accordance with the valid Lithuania and EU countries standard methodology:

– using the basic elements analyser Flash 2000, Nr. 2011 F0055;

– according to LST EN 14775:2010 standard, in ash content test rig Nr. 8B/5.

Calorific value (KJ kg^{-1}) of the peat pellet was determined by a C 2000 calorimeter (IKA, Germany) by the standard methodology (BS EN 14918:2009).

Peat pellet burning and determination of harmful emissions to the environment were fulfilled at the Lithuanian Energy Institute (LEI) in accordance with the valid Lithuania standard methodology (Jasinskas et. al., 2012; Sateikis and Lynikiene, 2007). Harmful emissions to the environment were determined, and they were compared while burning of granulated biofuel of various sorts. Five samples of granulated peat (5 kg each) were presented to the research laboratory where burning and emission research was performed. Burning period of each sample was 10 min.

When burning granules made of crumbly peat were determined emissions of oxygen O_2 (ZrO_2), and harmful emissions of: carbon dioxide CO_2, carbon monoxide CO, sulphur dioxide SO_2, nitrogen oxide NO_x and unburned hydrocarbons C_xH_y.

RESULTS AND DISCUSSION

Crumbly peat physical-mechanical properties. At the beginning of experiments there were determined crumbly peat moisture content, filled density and flow angles – natural slope and fall angles (Table 3). Moisture content of peat samples, which were got from various places of Ezerelis peat-bog, varied from 19.9±0.9 % to 41.7±1.0 %, average determined moisture content was 30.7±0.8 %. Upper limits of sample moisture correspond to moistures of crumbly peat supplied to boilers which are used in practice.

From the results presented in Table 1, it may be stated that if moisture of crumbly peat increases from 19.9 % to 41.7 %, their filled density also increases from 297.2±0.8 kg m^{-3} to 340.9±0.4 kg m^{-3}, and corresponds to 12-13 %.

Table 3. Crumbly peat moisture content, density, fall and natural slope angles

Samples	Moisture content w, %	Filled density ρ, kg m^{-3}	Natural slope angle α_n, degrees	Fall angle α_{gr},, degrees
Crumbly peat	19.9±0.9	297.2±0.8	37.1±1.0	71.0±0.6
Crumbly peat	29.7±1.0	299.7±1.1	36.7±1.1	73.0±1.0
Crumbly peat	31.5±0.3	309.4±0.7	36.8±1.1	77.0±0.8
Crumbly peat	41.7±1.0	340.9±0.4	36.7±0.6	90.3±0.6
Average:	*30.7±0.8*	*311.8±0.7*	*36.8±1.0*	*77.7±0.7*

Fall angles of crumbly peat have been determined and are presented in Table 3. Research results show that moisture has significant impact on peat fall angle, which varied from 71.0±0.6 to 90.3±0.6 degrees. Considering fall angles, constructive parameters of storages (bunkers), walls of transporters and various mechanisms of supply to boilers are set (leaning angles of walls should be higher than the determined).

There were determined natural slope angles of different moisture content crumbly peat show, that moisture content did not have significant influence on natural slope angles. Natural slope angle of peat with increase of moisture content varied insignificantly in the error limits (from 36.7±0.6 to 37.1±1.0 degrees). By using of these results, it is possible to calculate sizes of spreading areas of crumbly peat in the stores before milling and pelleting.

Crumbly peat fractional composition has been determined by results to ground qualitative preparation of peat for pelleting. As it may be seen from the research results, the big part of peat (about 30 %) is of 1-2 mm fraction. But the biggest fraction of peat (more than 50 %) exceeded the size of 3-4 mm, and it was too coarse fraction for high quality pellet production.

As a result, a hammer mill was used in order to more chopped peat mill preparation. After crumbly peat milling was got the sufficient small fraction of peat – the biggest mill fraction was of 1-2 mm – 60-70 %, and was sufficient for pellet production. Moisture content is not influenced the mill fractional composition.

The milled crumbly peat was granulated by a small capacity (120 kg h^{-1}) granulator, the diameter of produced pellets was 6 mm. There were investigated main properties of produced pellets.

Peat pellet biometrical and physical-mechanical properties. Very important parameter of qualitative pellet production is the moisture content, which has a great influence on fuel energetic indicators, pellet combustion efficiency and calorific value. Therefore, it is important to estimate biofuel's humidity. The obtained moisture content of peat pellets is shown in Table 4. According to the shown in table data it may be stated that the average moisture content is in allowed values – 11.6 %. The recommended humidity of pellets used for fuel should not exceed 12 % (Jasinskas et al., 2014).

Weight of peat pellets has also been determined, and the pellets' volume, filled density and dry matter content were calculated. The values of these peat pellets parameters and fall angles of pellets are presented in Table 4. Determined peat pellet filled density in the vessel was sufficient high and reached 587.2±4.4 kg m^{-3} DM (dry matter). Differently than crumbly peat, natural slope and fall angles of peat pellets were similar and varied in the limits from 32 to 40 degrees.

Table 4. Peat pellet physical-mechanical properties

Pellet sort and moisture content, %	Test No	Pellet parameters			Flow angles	
		Weight of pellets in the vessel, g	Volume of vessel, m^3	Filled density in the vessel, kg m^{-3}	Natural slope angle α_n, degrees	Fall angle α_{gr},, degrees
Peat pellets, w = 11.6 %	1	332.2	$0.5 \cdot 10^{-3}$	664.4	32	39
	2	333.5	$0.5 \cdot 10^{-3}$	667.0	33	38
	3	330.8	$0.5 \cdot 10^{-3}$	661.6	34	40
	Average mean with deviation	x	x	664.3 ± 5.0 **587.2 ± 4.4 DM**	33 ± 1.8	39 ± 1.8

Peat pellet biometrical parameters and density are presented in Table 5.

Table 5. Peat pellet biometrical parameters and density

Pellet sort and moisture content, %	Test No	Pellet parameters			
		Length *l* and diameter *φ*, mm	Volume, m^3	Mass, g	Density, kg m^{-3}
Peat pellets, w = 11.6 %	1	25.35; 5.95	$7.05 \cdot 10^{-7}$	0.84	1192.3
	2	22.50; 5.95	$6.25 \cdot 10^{-7}$	0.76	1215.4
	3	24.05; 6.05	$6.91 \cdot 10^{-7}$	0.86	1244.5
	4	23.45; 5.95	$6.52 \cdot 10^{-7}$	0.76	1166.2
	5	24.80; 5.95	$6.89 \cdot 10^{-7}$	0.77	1117.2
	6	24.25; 5.95	$6.74 \cdot 10^{-7}$	0.81	1201.9
	7	25.65; 5.80	$6.77 \cdot 10^{-7}$	0.85	1254.9
	8	21.75; 5.75	$5.65 \cdot 10^{-7}$	0.67	1186.9
	9	21.75; 5.80	$5.74 \cdot 10^{-7}$	0.72	1253.6
	10	23.25; 5.80	$6.14 \cdot 10^{-7}$	0.76	1237.8
	Average mean with deviation	x	x	x	1207.1 ± 30.9 **1067.1 ± 30.9 DM**

After investigations of pellet density it was determined, that the average density of peat pellets was sufficient high and reached 1067.1±30.9 DM. Determined so high density of produced fuel pellets satisfy the requirements in many European countries where the fuel pellet density should be higher than 1000 kg m^{-3} DM (Vares et al., 2007; Jasinskas et al., 2014).

Peat pellet elemental composition, ash content and calorific value. The peat pellet elemental composition analysis showed a high C (carbon) content of 52.58±1.10 (grassy and woody energy plant C content is 45-48 %) (Siaudinis et al., 2015), H (hydrogen) content of more than 5 %, and other chemicals composition of N (nitrogen) and S (sulphur) small in volume % (Table 6).

Table 6. Peat pellet elemental composition, ash content and calorific value

Parameters	Value	Deviation, ± %
Peat pellets		
C (carbon) content, %	52.58	1.10
H (hydrogen) content, %	5.09	0.44
N (nitrogen) content, %	1.38	0.31
S (sulphur) content, %	0.16	0.27
O (oxygen) content, %	33.63	-
Ash content, %	7.16	0.23
Moisture content, %	6.38	0.07
Dry fuel upper calorific value, MJ kg^{-1}	21.15	0.46
Dry fuel lower calorific value, MJ kg^{-1}	20.10	0.49
Wet fuel upper calorific value, MJ kg^{-1}	19.80	0.46
Wet fuel lower calorific value, MJ kg^{-1}	18.68	0.50

Determined ash content of peat pellets was high and it amounted to 7.16 ± 0.23 %, which was similar to that of traditional herbal plants and straw ash content (Siaudinis et al., 2012). The high ash content show that peat pellets insufficiently burned. But if compared with other investigated short rotation and non-conventional energy plants (their lower calorific value reached 17.5-18.3 MJ kg^{-1} DM) (Siaudinis et al., 2015), peat pellets lower calorific value was very high and reached 20.10 ± 0.49 MJ kg^{-1} DM. So high calorific value of peat pellets show, that according to the thermal properties this fuel is equivalent to the high quality wood fuel (Jasinskas et al., 2008).

Peat pellet burning and evaluation of harmful emissions to the environment. There were evaluated the harmful emissions to the environment while burning of granulated peat.

When burning produced peat pellets were fixed smoke temperature and emissions to the surrounding environment – oxygen O_2, carbon dioxide CO_2, carbon monoxide CO, sulphur dioxide SO_2, nitrogen oxide NO_x and unburned hydrocarbons C_xH_y. Research results of determined harmful emissions and their variations are presented in the charts of Fig.2 – Fig. 5.

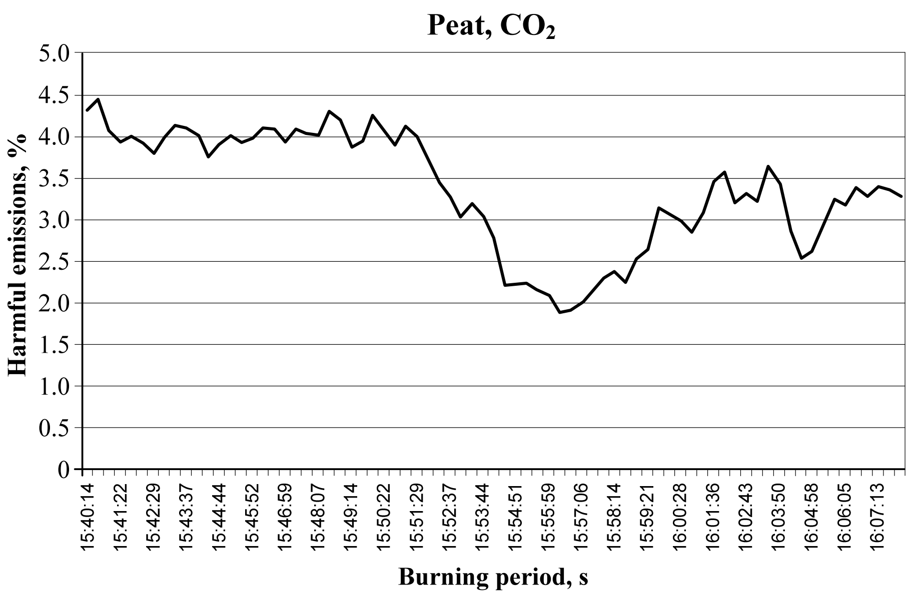

Fig. 2. Carbon dioxide CO_2 emissions to the environment while burning of peat pellets

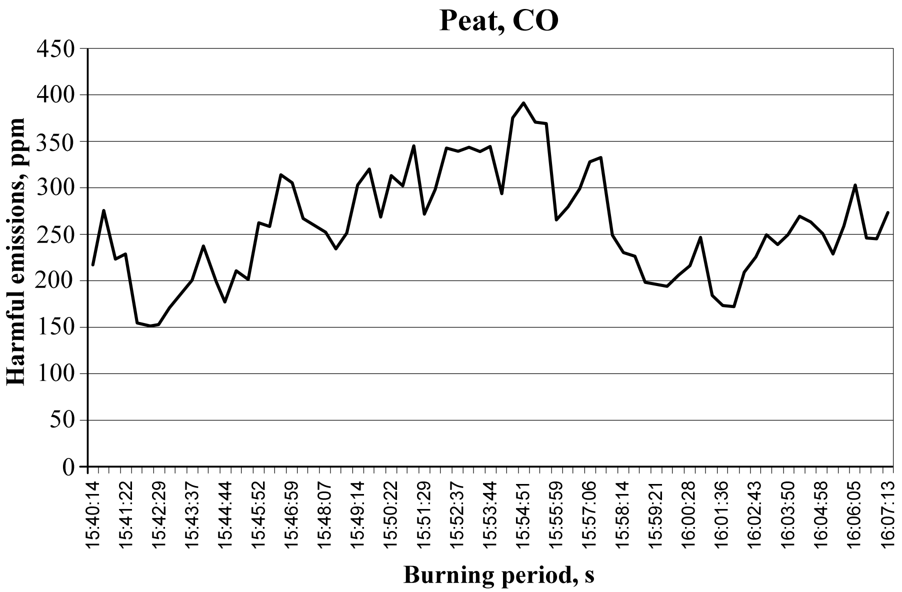

Fig. 3. Carbon monoxide CO emissions to the environment while burning of peat pellets

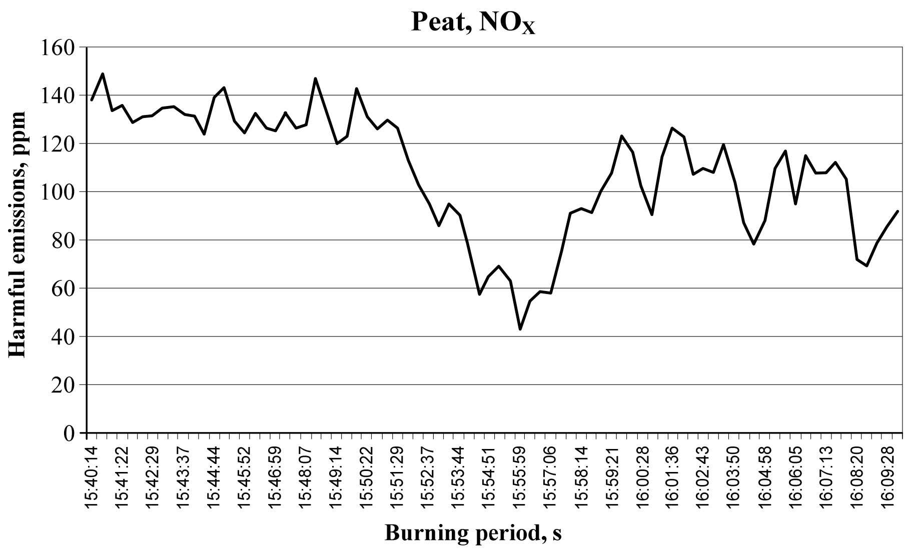

Fig. 4. Nitrogen oxide NO_x emissions to the environment while burning of peat pellets

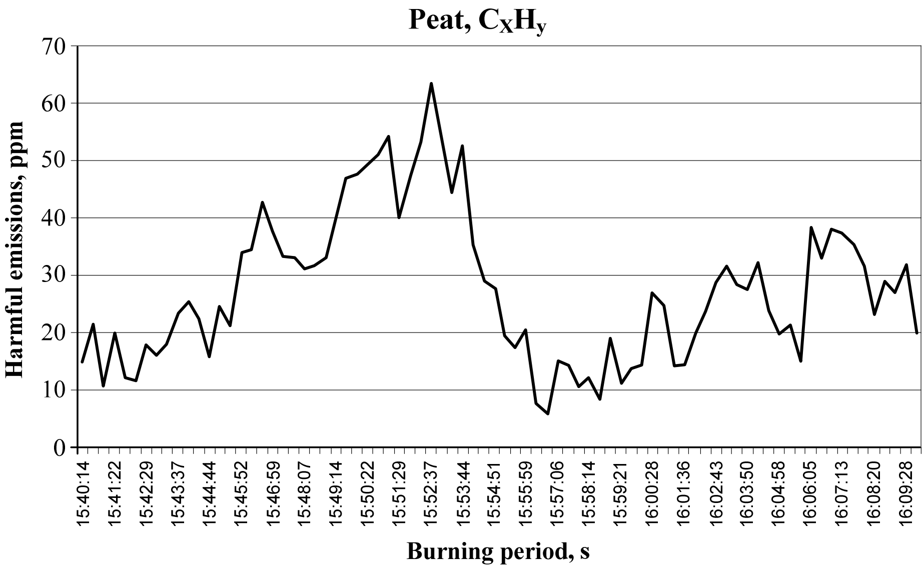

Fig. 5. Hydrocarbons C_xH_y emissions to the environment while burning of peat pellets

In the presented charts can be seen, that burning process and released harmful emissions was a sufficiently even and stable. Estimated the average emission values were as follows: carbon dioxide CO_2 – 3.3 %; carbon monoxide CO – 262.3 ppm; nitrogen oxide NO_x – 108.2 ppm and unburned hydrocarbons C_xH_y – 27.6 ppm. Emissions of sulphur dioxide SO_2 were not detected. After evaluation of harmful emissions into the atmosphere when burning of peat pellets, it has been concluded that this investigated sort of fuel can be used as environmentally-friendly local fuel because determined harmful emissions are within the permissible values.

Presented research results suggest that investigated peat pellets can be used as a solid fuel, because its main parameters satisfy the requirements for solid fuels.

CONCLUSIONS

1. There were investigated peat pellet biometrical, physical-mechanical, thermal and impact to the environment while burning peat pellets, also was evaluated the peat suitability for fuel production.
2. Determined row material of crumbly peat moisture content increases from 19.9 % to 41.7 %, their filled density also increases from 297.2±0.8 kg m^{-3} to 340.9±0.4 kg m^{-3}, and corresponds to 12-13 %.
3. The milled crumbly peat was granulated to the 6 mm diameter pellets by a small capacity granulator and there were evaluated pellets biometric parameters: dimensions, moisture content, volume, density.
4. The obtained average moisture content of peat pellets was in allowed values – 11.6 % (the recommended humidity of fuel pellets should not exceed 12 %), pellets density was very high and reached 1067.1±30.9 kg m^{-3} DM (dry mass).

5. The peat pellet elemental composition analysis showed a high C (carbon) content of 52.58±1.10, H (hydrogen) content was of more than 5 %, and other chemicals composition was small in volume %. S (sulphur) was not detected. Determined ash content of peat pellets was sufficiently high and it amounted to 7.16±0.23 %.
6. Peat pellets lower calorific value was very high and reached 20.10±0.49 MJ kg^{-1} DM. So high calorific value of peat pellets show, that according to the thermal properties this fuel is equivalent to the high quality wood fuel.
7. After evaluation of harmful substances emissions into the atmosphere when burning of peat pellets, it has been concluded that this investigated sort of fuel can be used as environmentally-friendly local fuel because determined harmful emissions are within the permissible values

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ESTIMATING THE CALORIFIC VALUE OF PELLETS FROM DIFFERENT BLENDS OF BIOMASS

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SUMMARY

As wood is a popular fuel, the dry mass net calorific values for different species were established, as well as the concentration of different chemical elements present in the dry mass. The calorific value and concentration of chemical elements were also determined for other energetic plants. In this article, we consider popular types of biomass available in Western Romania (spruce, beech, poplar, willow, rape), for which the amounts of C, H, S and O as well as the calorific value are known. On this basis, we determine a equation linking the amounts of C, H, S and O of each species to their calorific value, which is better than the Mendeleev equation. Also, we determine the expected calorific value of mixes of 2 primary components at different mass ratios.

Key words: energy crops, calorific value, pellets, high calorific blends

INTRODUCTION

The high demand for new and more efficient sources of energy bring into attention solid biofuels. The price of energy obtained using renewable biofuels is lower than the price of energy obtained through other methods. Romania already exceeded the target of 22% of renewables in total heating and cooling supply assumed for 2020 (REN21).

Often, the concepts of "renewable energy" and "energy recycle" overlap, as shown by Lela et al (2016) which studied the mechanical and thermal characteristics of cardboard sawdust briquettes and for which they obtained a higher heating value (calorific value) of 16.06 MJ/kg. However, this mixture is not a highly calorific one, since its calorific value does not exceed the one of triticale or wheat-straw.

The perspective of the renewable solid biofuels is mainly influenced by the world market price of crops and mineral energy resources, international food market regulations and environmental restrictions for agricultural technologies (Tucu and Mnerie, 2010). The market price of crops is determined of the offer and demand, and this can be adjusted if an initial agreement between the farmers (crop producers) and the pellets and briquettes producers is achieved. In this way, farmers are sure of the existence of a market for their future crops and even of a guaranteed price and pellets producers are sure of the existence of raw materials at a stable price for the next period of time.

All these considered, it is advantageous to determine a priori the highest yielding mixtures of solid biofuels for pellets and briquettes, in order to achieve better prices for the raw materials and thus, better price for the finite product.

For our purposes, we selected the most common type of biomass in western Romania, namely bark, beech, miscanthus, poplar, rape-cake, spruce, triticale, wheat-straw and willow.

METHODS

One of the empirical, approximate equations linking the net calorific value (in MJ/kg) of a specific solid biofuel to its weight content was deduced by Mendeleev and is presented by Hardy (2011):

$$c = 0.339\,C + 1.029\,H + 0.109\,S - 0.109\,O$$

where C, H, S, O represent respectively the weight content of carbon, hydrogen, sulphur and oxygen in the dry mass of wood.

Table 1. Net calorific value of different types of solid biofuel for dry matter (source: Hartmann (2013), Krajnc (2015))

Biofuel	C	H	O	N	K	S	Cl	Calorific value
unit	(%,wt. cont.)	(%,wt. cont.)	(%,wt. cont.)	(%,wt. cont.)	(%,wt. cont.)	(%,wt. cont.)	(%,wt. cont.)	(MJ/kg)
Bark	51.400	5.700	38.700	0.480	0.240	0.085	0.019	19.200
Beech	47.900	6.200	43.300	0.220	0.220	0.015	0.006	18.400
Miscanthus	47.500	6.200	41.700	0.730	0.700	0.150	0.220	17.600
Poplar	47.500	6.200	44.100	0.420	0.350	0.031	0.004	18.500
Rape-cake	51.500	7.380	30.100	4.970	1.600	0.550	0.019	26.500
Spruce	49.800	6.300	43.200	0.130	0.130	0.015	0.005	18.800
Triticale	43.500	6.400	46.400	1.680	0.600	0.110	0.070	17.100
Wheat-straw	45.600	5.800	42.700	0.480	1.000	0.082	0.190	17.200
Willow	47.100	6.100	44.200	0.540	0.260	0.045	0.004	18.400

Based on the data presented above, a new equation was developed linking the calorific value of dry wood on its chemical contents. This equation obtained in Statgraphics Centurion XVI, represents a multiple regression which uses ordinary least squares and a constant in the model. In order to evaluate the precision of the model, the P-value was computed, as well as the R-squared statistic and the Durbin-Watson statistic test. It should be mentioned that the regression model is meant to improve the Mendeleev equation and thus, all the four independent variables present in the Mendeleev equation are present in our equation, even if the model could be simplified.

Using the Mendeleev equation for calorific values but also the equation we proposed, the calorific values for different mixtures of the considered types of biomass were also computed. For two masses of biofuel, m_1 and m_2, having the mass concentrations of a certain chemical element $C\%_1$ and $C\%_2$, the total concentration of that element in the final mixture will be:

$$C\%_{tot} = \frac{m_1 C\%_1 + m_2 C\%_2}{m_1 + m_2}$$

Thus, knowing the mass concentration for the chemical elements in the final mixture, the calorific value can be computed. For our purposes, 1:1 and 2:1 mixtures of solid biofuels were considered.

RESULTS AND DISCUSSION

The regression best fitting the input data in Table 1 is

$$c = 26.2661 + 3.6154\,H - 0.0602\,C - 0.6217\,O - 8.7015\,S$$

Table 2. Coefficients of the model and their P-values

Parameter	Estimate	Error	Statistic	P-Value
Const.	26.2661	32.5471	0.8070	0.4649
H	3.6154	1.4492	2.4948	0.0671
C	-0.0602	0.3894	-0.1546	0.8846
O	-0.6217	0.4557	-1.3643	0.2442
S	-8.7015	12.1168	-0.7181	0.5124

Since the P-value computed for this model is 0.0027 (hence less than 0.05), one can conclude that there is a statistically significant relationship between the variables at the 95.0% confidence level.

This model explains 96.9599% of the variability in *c*, as indicated by the R-squared statistic. The standard deviation of the residuals is 0.70855 and the mean absolute error is 0.362919.

Analyzing the P-values for each coefficient, one can conclude that the term referring to the carbon concentration is not statistically significant at the 95.0% or higher confidence level and hence it should be removed. This leads to a equation for which the overall P-value is 0.0003.

$$c = 21.3331 + 3.4587\,H - 0.5539\,O - 6.9929\,S$$

This equation explains 96.9417% of the variability in *c*, but the term containing the sulphur mass concentration is not statistically significant at the 95.0% or higher confidence level. Removing the sulphur term, we finally obtain a equation

$$c = 21.2638 + 2.3579\,H - 0.4070\,O$$

in which all the terms are statistically significant (the overall P-value is 0.0001), but which explains only 95.4369% of the variability in *c*.

However, the equation we used in our computations was the equation linking the concentrations of all the four chemical elements to the calorific value, since it uses the same inputs as the Mendeleev equation and comparisons can be made. A comparison between the values obtained by our equation, the values obtained using the Mendeleev equation and the real values (as listed by Krajnc, 2015) is given below, in Table 3.

Table 3. Comparison between different equations for calorific values

Biofuel	Calorific value (MJ/kg)		
	Real value (Krajnc, 2015)	Computed value (our equation)	Mendeleev equation
Bark	19.200	18.982	19.081
Beech	18.400	18.749	17.900
Miscanthus	17.600	18.593	17.953
Poplar	18.500	18.137	17.679
Rape-cake	26.500	26.349	21.832
Spruce	18.800	19.059	18.658
Triticale	17.100	16.984	16.287
Wheat-straw	17.200	17.232	16.781
Willow	18.400	17.615	17.431

In the following, we will present 1:1 and 2:1 biofuels mixtures and their properties. From a total of 28 possible mixtures, we will only list the mixtures for which the calorific value computed by us is over 20 MJ/kg.

According to the Mendeleev equation, the mixtures have lower calorific values than the values computed with our equation, but the overall ranking of the mixtures with the highest calorific values is mostly unchanged.

Table 4. 1:1 biofuel mixtures and their qualities

Mixture	C (%,wt. cont.)	H (%,wt. cont.)	O (%,wt. cont.)	S (%,wt. cont.)	Calorific value (MJ/kg)	
					Mendeleev equation	Our equation
Rape-cake and Spruce	50.650	6.840	36.650	0.283	20.245	22.704
Beech and Rape-cake	49.700	6.790	36.700	0.283	19.866	22.549
Miscanthus and Rape-cake	49.500	6.790	35.900	0.350	19.892	22.471
Poplar and Rape-cake	49.500	6.790	37.100	0.291	19.755	22.243
Rape-cake and Willow	49.300	6.740	37.150	0.298	19.631	21.982
Rape-cake and Wheat-straw	48.550	6.590	36.400	0.316	19.631	21.791
Rape-cake and Triticale	47.500	6.890	38.250	0.330	19.059	21.667

One should also note that the highest yielding mixtures contain rape-cake. The highest calorific value computed for a 1:1 mixture that does not contain rape-cake is 18.904 MJ/kg, for 1:1 mixture of Beech and Spruce.

Table 5. 2:1 biofuel mixtures and their qualities

Mixture	C (%,wt. cont.)	H (%,wt. cont.)	O (%,wt. cont.)	S (%,wt. cont.)	Calorific value (MJ/kg) Mendeleev equation	Calorific value (MJ/kg) Our equation
Rape-cake and Spruce	50.933	7.020	34.467	0.372	20.774	23.919
Rape-cake and Bark	51.467	6.820	32.967	0.395	20.915	23.894
Rape-cake and Beech	50.300	6.987	34.500	0.372	20.521	23.816
Rape-cake and Miscanthus	50.167	6.987	33.967	0.417	20.539	23.764
Rape-cake and Poplar	50.167	6.987	34.767	0.377	20.447	23.612
Rape-cake and Willow	50.033	6.953	34.800	0.382	20.365	23.438
Rape-cake and Wheat-straw	49.533	6.853	34.300	0.394	20.148	23.310
Rape-cake and Triticale	48.833	7.053	35.533	0.403	19.983	23.228
Spruce and Rape-cake	50.367	6.660	38.833	0.193	19.716	21.489
Bark and Rape-cake	51.433	6.260	35.833	0.240	19.998	21.438
Beech and Rape-cake	49.100	6.593	38.900	0.193	19.210	21.282
Miscanthus and Rape-cake	48.833	6.593	37.833	0.283	19.246	21.179
Poplar and Rape-cake	48.833	6.593	39.433	0.204	19.063	20.874
Willow and Rape-cake	48.567	6.527	39.500	0.213	18.898	20.527
Wheat-straw and Rape-cake	47.567	6.327	38.500	0.238	18.465	20.271
Triticale and Rape-cake	46.167	6.727	40.967	0.257	18.135	20.106

Again, the highest yielding mixtures contain rape-cake. The highest calorific value computed for a 2:1 mixture that does not contain rape-cake is 19.033 MJ/kg, for the 2:1 mixture of Spruce and Bark, the 2:1 mixture of Bark and Spruce having a computed calorific value of 19.007 MJ/kg.

As shown in the literature (for instance, Lunguleasa et al. 2015), through torrefaction or usage of additives (binders), the calorific values of the final products increase. Since the increase depends on the initial calorific value, the determination of the calorific value of a certain mixture in absence of torrefaction and binders still presents interest. Thus, one can choose higher yielding mixtures for torrefaction (when applicable) or for the usage of additives and hence obtain higher calorific mixtures.

CONCLUSIONS

This paper investigated the potential calorific value for various mixtures of biomass available in western Romania. To this aim, we computed a new equation for the calorific value, which explained 96.9599% of the variability for the calorific value and is more accurate than the Mendeleev equation for the selected biomass. This new equation was used to compute the expected calorific values for different mixtures of biomass (1:1 and 2:1 mixtures). The highest yielding mixtures were presented in this paper.

As a further development, the economic efficiency of producing fire pellets out of the mixtures presented above will be considered. Torrefaction and usage of non-polluting additives (binders) will be also considered (from a physical and economical point of view), as methods to improve the quality of the new products.

Finally, this will lead to the selection of the best product recipes, with better quality/price ratio that the existent quality/price ratios.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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DECREASING POLLUTANTS EMISSION OF STOVES WITH HIGH ENERGY STORAGE CAPACITY

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ABSTRACT

Stoves are very common heating devices for rural households in North-Europe. Year by year there are stricter requirements for emissions. The main cause for an increase of harmful emissions from stoves is incomplete combustion. In this case, the flue gases also contain a significant amount of particulate matter. This occurs when the mixed air (incl. oxygen) is not inside the stove between the burning material for a sufficient dwell time. Stoves with low heat storage capacity are well studied in Europe, but this is not evident for stoves with high energy storage capacity. High energy storage capacity means that the stove can store energy for a 12-24 h heating period. The scientific hypothesis of the paper asserts that high quality and low emission combustion process needs the following conditions: a sufficient time for the air mixture to stay inside the stove, high enough temperature in the core of the combustion chamber and an optimal air mixture. Experiments show that omitting the fire grate, moving air openings to the sides of the combustion chamber and the use of proper materials for the combustion chamber enable to lower emissions several times. This allows better combustion process and decreases air pollution by chemical compounds and small particles. The flue gas analysis and small particle analysis was conducted in a boiler laboratory with Testo 350 and 380 devices.

Keywords: reduction of pollutants, emissions, stove, energy storage capacity

INTRODUCTION

Estonia is a Nordic country with a heating season of 220 days or more. In winter, the temperature has often reached below –25 ˚C. When planning and designing buildings, the average temperature of –22 °C has to be considered. The traditions of building wood-heated stoves date back for centuries and follow the traditions in Central Europe, mainly German masters. After the 1960s, district and central heating was introduced to Estonia, as cheap gas and fuel oil was provided from Russia. Since 1991 that source for cheap heating could not be used any more. We were facing the need to use domestic resources for heating. In Estonia it is either firewood or oil shale. Oil shale is not used as fuel for stoves, it is only used district heating. Estonia uses wood, which is the main heating resource for 80% of the population in rural regions. More than 50% of the territory of Estonia is covered with forests and wood is used for heating stoves. The traditional craft of a potter or over-craftsman did not disappear, fortunately, as 2.1 million stove tiles were produced annually in Estonia, back in 1959. Therefore the calculations show that about 500 stove craftsmen built up to 10 000 middle-sized stoves. Our typical stove has a base area of 1m x 1m and a height of 2.2–2.5m. A typical stove weighs about 3000 kg, the nominal power output being 4.5 kW. For older houses the estimated need for heating would be 100–250 W/m^2, in newer and renovated buildings 80 W/m^2. At the end of the previous century stoves built of bricks (masonry stoves) became more popular in Estonia. Craftsmen from Finland taught the construction of brick stoves used mainly in Russia. This type of stove is cheaper and can be built about 3 times faster, but the heating capacity is about two times lower. The prevailing opinion was that an aesthetic exterior of a stove is more relevant than its efficiency and thermal power, as the last parameters were not measured. Since 1999 studies and standards for firewood-heated devices - stoves, stoves and fireplaces - were published in Austria. European standards were introduced almost 10 years later. Standards, however, are recommendations until now, but in 2022 an European Directive on stove heating will be enforced and that is of mandatory character. In Estonia the stove craftsmen trainings has initiated contacts with companies in Austria and their craftsmen's organizations, which enabled to exchange know-how and the measuring methodology. Based on the know-how we could assess the technical parameters of our wider spread heating devices, also the basic building principles of contemporary heating stoves started to spread. Today the situation has changed and the client checks the licenses of the craftsman for doing the job. Unfortunately the technical parameters of heating devices cannot be carried out yet, as the measuring system is being developed and not ready yet.

Boiler units for central heating are widely used in Estonia. In 2012 the amount of central and space heating was 6.5 TWh, which was 40% of the total heat energy usage (Vali 2013). By 2030 the proportion of local heating is expected to rise to 60%. Hence it is estimated that the saved energy due to transition to local heating (105–240 GWh) enables to save about 5.1–11.7·10^6 Euros (Vali 2013, Eesti Arengufond 2014). Therefore local boiler units, both new facilities and more efficient usage and maintenance of the existing ones, still have and will have an important role in fulfilling the aims concerning renewable energy and energy efficiency (Hovi et al., 2014).

For centuries, wood-heated stoves have been indispensable both for preparing food and for heating rooms. Gas and electricity have changed the situation, but not replaced firewood as heating resource. However, the components and amount of flue gas emissions due to wood heated stoves and stoves has become problematic. The European Union has implemented more strict standards for the composition of gas produced by burning wood in stoves, stoves and fireplaces. Requirements and test methods The European Union requirement is that burning wood should result in as little carbon monoxide CO, nitrogen oxide NO, unburnt organic substances, fly-ash as possible and the efficiency level should be according to the standards.

To achieve this, the temperature of flue gases in the heating appliance has to be high. The ignition point for air-dried wood is between 240 – 400 °C (Pfestorf, 2011). The combustion rate of wood depends on its density (porosity), and wood of lower density has a lower ignition point. To get higher temperatures, the wood gases (flying particles) in the combustion chamber and air oxygen should mix well, which requires a sufficient residence time (Schmidl et al, 2011). It is reasonable to split combustion into primary and secondary zones, in primary is performed gasification and in secondary combustion of gases. This is the time required for the flow, mixing and burning of gases in the combustion chamber of the heating device. The higher the temperature in the combustion chamber and the better the mixing of gases, the shorter the residence time of gases required for combustion quality. A spacious combustion chamber enables the mixed gases to burn fully. Split firewood burns with long flames, unlike turf or coal, for example. High temperatures for ignition (at least 600 degrees) in the combustion chamber are needed for full combustion. The optimum is considered to be between 850 – 1000 °C (Ebert 2006). Ignition of gases from wood takes place at relatively high temperatures: hydrogen H_2 ca 560°C, carbon C ca 700 °C, carbon monoxide CO ca 605 °C (Hovi et al, 2015; Herrmann, 2011).

The main aim of this study is to find conditions to lower pollutants emissions existing stoves. The core task is to perform experiments and calculations to set parameters for achieving decrease of pollutants emissions and keep required efficiency.

MATERIALS AND METHODS

Local heating systems can be classified as central and space heating. Central heating can provide heat to a building with a heating system from one device, space heating provides heat to a part of a residential home or a bigger building. Statistics for heating fuels and heat generators used in central heating systems is not collected systematically - information can be obtained from separate studies based on surveys and questionnaires. There are two recent studies available:

– Energy-efficient behaviour in the population (Turu-uuringud, 2012) ;
– Energy consumption in households (Eesti Statistikaamet, 2013).

Main types of heating appliances are ovens, stoves and fireplaces. Also, for central heating mainly wood is used (firewood, waste wood, wood briquettes etc.) (EVS-EN 12815 2001; Pfestorf, 2002). An overview is of high heat recovery capacity stoves as one of the most widely spread space heating appliance in Estonia is given in the next sections.

Central heating and regulations

In 2009 the EU confirmed the regulations for stove craftsmen, who build heating appliances that use solid fuel (e.g. firewood). The present standard EN 15544 was enforced January 1, 2010 and defined the limits for CO, NO, fly ash and unburnt organic substances in stove masonry stoves. At the same time there is the standard EN 15250, which determines the requirements for heating devices and testing. Standards are recommendations as a rule, however, recently a corresponding EU directive has been discussed. A directive is mandatory to all EU member states, regardless of their own norms and regulations. The plan is to first work out a directive for industrially produced stoves that are heated with firewood or wood briquettes. Presumably the craftsmen-built stoves will be imposed regulations on soon as well.

Estonian traditional stoves and stoves

In 2013 the Estonian Ministry of the Environment ordered a study from (EKUK, 2013) the Estonian Environmental Research Centre (EKUK) on the parameters of smoke gases and fly ash from the typical Estonian stoves and stoves. The results (Table 1) show what the conditions for these heating appliances are and should give an overview of the current situation of Estonian stoves and stoves.

Table 1. Comparison of EN-15544 and EKUK measurements (EKUK, 2013)

Parameter	EN 15544 norm 1.01.2010.	Measuring results - oven	Measuring results - stove
Carbon monoxide CO mg/MJ	1000	3300	3552
NO_x mg/MJ	150	245	230
Unburnt organic matter mg/MJ	80	44	107
Fly ash (dust) mg/MJ	60	275	257

The standard EN 15544 sets the minimum average efficiency as 78%. The Estonian Environmental Research Centre did not measure efficiency, though, but measurements carried out previously have shown that the parameters of Estonian stoves are considerably below the norm. The similar situation was described by Jing Wang et al. in China Shanxi Province. The emissions problems were solved by stove design and using of combined coal and biomass fuel briquettes. (Wang et al., 2015)

Basics of stove-building today

The combustion chamber of a stove (heating appliance) has to be big enough to enable burning with maximum amount of firewood. The air flow to wood has to be dispersed as much as possible, but not under the wood thorough a grid (UmweltPlus, 2011). Then burning is intensive enough and the temperature in the fireplace high enough, which is one of the pre-conditions for getting high thermal efficiency. Our stoves fireplaces tend to be too small, especially in height.

The smoke flues from the combustion chamber have to be long enough to enable the smoke gases to transmit heat to the stove. Smoke flue cross-sections have to be suitable for the amount of smoke gases and each following flue has to be a bit narrower, as smoke gases shrink and the heat transmit to the walls of the flue walls is reduced. The height of the chimney is relevant. It has to be higher than the total length of the smoke flues. It could be problematic with lower houses (garden houses).

As a sample, we will take a closer look at a stove that has to heat up to 50 m^2, at ambient temperatures about –22 °C, with the heat emitting time of 12 hours. The capacity of such an stove should be at least 5 kW. The combustion chamber floor area should be 2,000 cm^2, the inner walls total area at least about 18,000 cm^2. The height of the combustion chamber is 65 cm. The area of the first smoke flue is 800 cm^2, the last one is 400 cm^2. Total length of the smoke flue is at least 5.8 m, usually comprised of 5 flues. Total length of flues is measured along the imaginary centre line. Each 90 degree bend in the flue adds 0.3 m to the flue length. If the stove is built with more or less the parameters described above, then 78% efficiency should be provided and no problems with smoke gases. The temperature of smoke gases output from the stove should not be more than 240 degrees C. It should be added that the firewood has to be dry (20 % moisture content) and split well. The circumference of a split log may be maximum 20 cm.

Preserving the existing stoves

Owners of traditional combined barn houses with barn stoves (Estonian "*reheahi*") would like to keep these in order to preserve the essence of a barn house. To assess the efficiency of a barn stove, its heating and cooling process have to be examined. In addition, its construction and efficiency rate have to be calculated. One of the recent studies on Estonian traditional barn stoves was compiled for „The Barn Stove Handbook", published with the support from the Land Architecture Centre of The Estonian Open Air Museum.

To determine the thermal efficiency of barn stoves, the firewood was weighed and the humidity measured. Then temperature sensors were placed on the surface of the stove, as evenly spaced as possible, also an attempt was made to take the temperature on the natural stone heater and smoke gases flowing to the chimney. When the sensors were fixed, the heating process was started. Later data processing was carried out and the difference of surface temperature and room temperature was used to calculate the thermal capacity from the surface of the stove. Thermal efficiency of firewood is calculated via their mass and humidity. Then direct method is used to find the efficiency level.

The calculations done for the stove in Kurgja set the efficiency level at 56.2%, even though the number is probably a bit higher, as the energy contained in the stove did not reach the room before the next heating. The figure also shows that the results can differ remarkably with approximately similar loads of firewood. The biggest amount of firewood may produce the lowest temperature, if the smoke flues are not closed in time.

RESULTS AND DISCUSSION

A heating experiment of a stove made from the composite stone mass by the Ahja stove company took place on April 15, 2014. The calculations were made to find the direct efficiency of the stove. Surface temperatures were taken from 35 sensors until the next morning. The difference between the average surface temperature and room temperature caused by further cooling was derived by the exponent equation (1), where τ is the time in seconds. On the graph it is seen as a slight spike.

$$\Delta t = 22.056 \cdot e^{15.65 \cdot 10^{-6} \cdot \tau} \tag{1}$$

The stove surface heat output is calculated with the formula (2), the so-called Wagener formula. The formula has been restored according to the written source (Ebert, 2001).", 3,07 m and 2.38 m are the circumference and the height of the active part of the stove, accordingly.

$$\Phi = (0.0564 \cdot \Delta t^2 + 8.2624 \cdot \Delta t - 19.632) \cdot 3.07 \cdot 2.38 \tag{2}$$

Considering the following, the amount of warmth from the surface of the stove could be 106.39 MJ. The solid residue after heating (in the combustion chamber and ash chamber) contained 69.1 g of ash and about 300 grams of charcoal bits, used for mechanically determining incomplete burning heat loss with the formula (3).

$$\Phi_4 = 0.3 \cdot 34 = 10.2 \text{ MJ} \tag{3}$$

Determining the efficiency level with indirect methods failed due to high levels of fume in flue gases. Considering the extremely low temperature of gases during the test heating, great loss due to chemically incomplete burning most probably took place, which was also indicated by the gas analyser recurrent switch-off during the test and black smoke from the chimney. Random measurements of CO in the gases resulted in up to 25949 ppm. However, the first heating of the stove could be considered a start-up procedure, which accumulated in the accumulating mass of the stove (ca 3000 kg) Δt = 20 °C and calorific receptivity 1 kJ/kg/K 60 MJ; about 5 kg of heating material accordingly.

A gas analyser with the capability of diluting the test sample would be advisable in such cases. Measuring accuracy might be compromised, but data would be available for the whole test period.

If the average temperature of the stove door in 6 hours since the beginning of heating is calculated as 300 °C, the emission heat from the door can be found, since it was not measured with the stove surface sensors, using formulae (4) presuming the emissivity factor is ε = 0.75 and the area is 0.16 m².

$$\Phi_u = A \cdot c_0 \cdot \varepsilon \cdot \left[\left(\frac{T_u}{100} \right)^4 - \left(\frac{T_s}{100} \right)^4 \right] = 0.16 \cdot 5.67 \cdot 0{,}75 \cdot \left[\left(\frac{573}{100} \right)^4 - \left(\frac{293}{100} \right)^4 \right] = 6833 W \tag{4}$$

Therefore, the heat output is 683,3W · 6h · 3600s = 14.76 MJ, which is added to the heat output of the stove door. The result can be adjusted later, when the data are more precise.

The firewood used was 11.83 kg of aspen and black alder (15 split logs) with average moisture content of 15% to the total mass. Therefore the lower calorific value is 15.5 MJ/kg. Hence the input energy of the first heating was 183.3 MJ.

For the direct method of finding the efficiency level we consider the energy of the heat produced and fuel that is consumed and calculate the ratio, expressed as per cent. With indirect method the efficiency level is found, based on the temperature and composition of burning gases. Mostly the content of oxygen and carbon monoxide is measured. Depending on the composition of the fuel, the carbon dioxide percentage by volume is calculated.

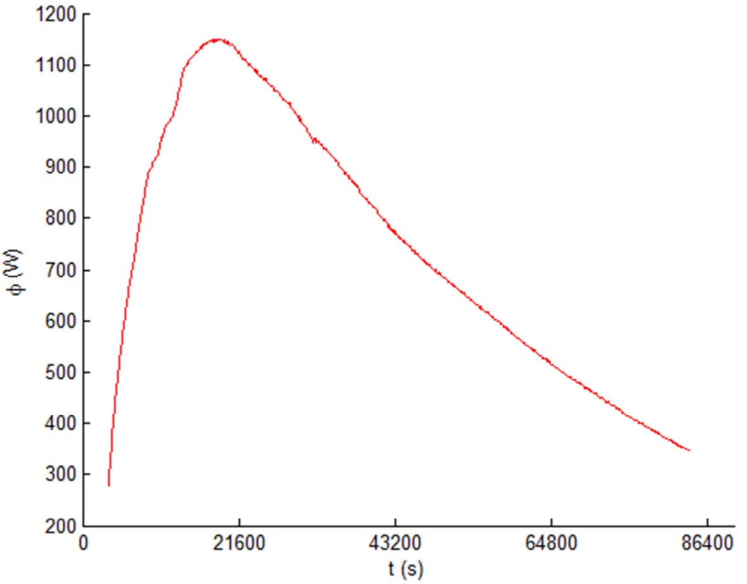

Figure 1. The third heating, April 15, 2014 - stove output capacity in watts.

The thermal energy generated is estimated to be about 121 MJ (calculated from the stove surface temperature and stove door temperature), and considering the 10.2 MJ charcoal pieces of mechanically incomplete burning loss that can be used as a starter for the next heating, the efficiency of the stove can be calculated by the direct method according to the formula (5).

$$\eta = \frac{\Phi_1 + \Phi_4 + \Phi_{1u}}{B \cdot Q_a^t} \cdot 100\% = \frac{106.39 + 14.76 + 10.2}{11.83 \cdot 15.5} \cdot 100\% = 71.64\% \tag{5}$$

Another main indicator to show high burning efficiency and a clean burning process is a low CO concentration in the flue gas. Previous experiments with a stove (Hovi et all 2013) have shown that the emissions are in accordance with the regulations, the average is 819 ppm (496 mg/MJ). It can be concluded that the analysed oven design has a high efficiency and low emissions. Further research will concentrate on data collection from more heating cycles and from more measuring points to analyse processes in ovens more in detail.

CONCLUSIONS

Stove combustion chamber is commonly surrounded by six sides, half of which are cooling metal surfaces (air grid, stove door), but these stoves were built without a grid in the combustion chamber. In the experiment described in the paper the surfaces of the combustion chamber are covered with ceramic tiles and the inner surface of the combustion chamber door was covered with heat insulating material. This is needed to ensure a sufficiently high temperature. To get air into the combustion chamber, slots were built to the back of the combustion chamber, which guarantees sufficient input of oxygen for the burning quality, with a proper system of flues and chimney draft. Laboratory testing proved that stoves built accordingly burn wood on high temperature and the process is clean. One of the main indicators to show high burning efficiency and a clean burning process is a low CO concentration in the flue gas. The CO emissions were in the testings approximately 496 mg/MJ and the efficiency was 71.64 %. At first there were problems with the required calorific power, indicated by the unburnt charcoal during the tests, but concentration of carbon monoxide was for the whole testing many times lower than the emissions from a traditional grid combustion chamber, where the fire in the combustion chamber is in direct contact with the walls of the combustion chamber.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

USE OF BIOMASS IN COAL STEAM BOILERS

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SUMMARY

Rural areas in Romania have a significant and unexploited potential in biomass that can be used as solid biofuels in boiler cogeneration plants. In addition to the renewable character of solid biofuel, its price is lower than the price of conventional fuels. Thus, using solid biofuels derived from energetic crops is becoming increasingly appealing. This paper presents a proposal to exploit the potential of biomass energy by increasing its calorific value. The increase in calorific value will be achieved by torrefaction and combination of different types of biomass with coal dust. The recipes for pellets and briquettes and their usage in big industrial coal boilers will be further discussed, as well as their applicability.

Keywords: torrefaction, agricultural biomass resource, renewable energy, wood, agricultural waste, cogeneration

INTRODUCTION

One of the options for replacing fossil fuels in Romania and worldwide, with great prospects for future development, is the usage of renewable energy resources. According to estimates RES-SEC (2008) in Romania is projected energy consumption of 34.9 MTOE (million tons of oil equivalent) by 2020. According to the same study finds that biomass covers more than 60% of Renewable Energy Sources (RES), i.e. 190-200 PJ / year [1].

Thus, biomass (including biofuels used for transport) is expected to become the main contributor to RES - more than 65% of the total, i.e. approx. 4.69 MTOE / year.

Energy potential technical or economical biomass is shown in Table1 [3]. As the data shows, harnessing the biomass potential to its full extent, would be sufficient to meet renewable energy target for 2020.

Table1.Biomass potential

Biomass type (potential)	UM	Technical potential	Economical potential
Vegetal biomass (forestry and agriculture)	TJ/year	471 000	289 500
	1000 MTOE/year	11 249	6 915
Biogas	TJ/year	24 600	14 800
	1000 MTOE/year	587	353
Urban waste	TJ/year	22 800	13 700
	1000 MTOE/year	544	327
Total	TJ/year	518 400	318 000
	1000 MTOE/year	12 382	7 595

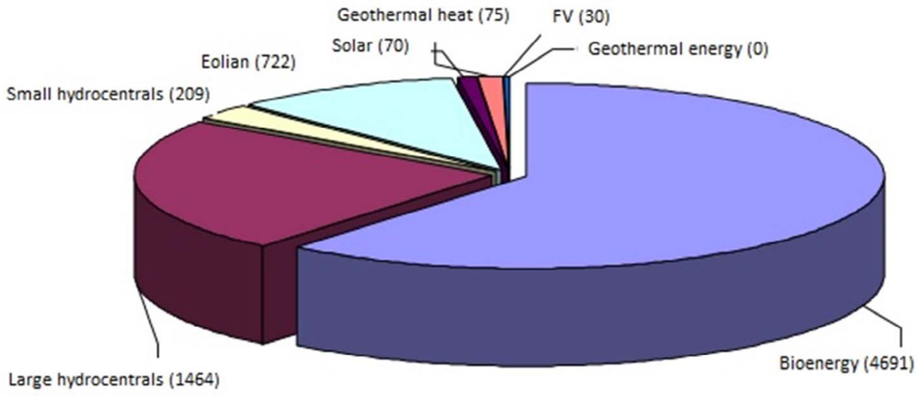

Figure1.Scenario for contribution of RES 2020 (thousands Step) [2]

Tables 2 and 3 show the Romanian counties with the largest forestry and agricultural resources. As the north of Romania and the mountain-area counties are richer in forestry resources, the plain-area counties are richer in agricultural resources.

Table 2. Richest Romanian counties in forestry resources

County	Forestry resource [thousand tones]
Suceava	647
Harghita	206.5
Neamţ	175
Bacău	132
Constanţa	10.4
Teleorman	10.4
Galaţi	10.4

Table 3. Richest Romanian counties in agricultural resources

County	Agricultural resource [thousand tones]
Timiş	1 432
Călăraşi	934
Brăila	917

One of the main current strategic directions that must be undertaken by Romania is to mobilize all efforts to develop and implement RES.

Using waste biomass combustion processes for the production of electricity and heat produced could increase the amount of energy and reducing carbon dioxide emissions [4].

Our paper presents the current situation, discussing the role of torrefaction in enhancing the biomass calorific value and presents two solutions for using the biomass along with coal in coal steam boilers.

MATERIALS AND METHODS

Current situation

At a national level, cogeneration of heat and electricity – CHP (Combined Heat and Power) using biomass could lead to significant socio-economic benefit. While wood represents the most important resource of biomass, it is highly desirable to use biomass residues from wood industry, horticulture and debris (twigs, shrubs etc.). Other biomass, such as agricultural residues (wheat straw, corn stovers, energy plants etc.) can also be used as fuel. In our country, in rural areas, woody biomass still represents a significant potential for households heating and cooking. The importance of using woody biomass illustrated by the fact that it is a renewable source of energy is neutral in terms of CO_2 emissions in nature and is found in large quantities in nature in various forms. All combustible materials derived from plant biomass are sustainable.

Many researchers believe that, contrary to classical fossil fuels, biofuels contribute to lower harmful emissions of gases into the atmosphere.

An attractive alternative to classical wood biomass energy production is represented by wood pellets and briquettes. In addition to biogas obtained by breakdown of the organic matter (including wood waste) in absence of oxygen, wood pellets and briquettes represent the best energy sources derived from wood biomass.

The regulations contained in EU law require the usage of a waste recovery technology from woody material to an effective valorization. This technology (the process of pelletization) is shown schematically in Figure 2A. To increase energy efficiency, the raw material used to make pellets and briquettes should be heat treated (torrefied) – as shown in Figure 2B.

Role of torrefaction in enhancing biomass calorific value

The torrefaction process is a modern method of mild pyrolysis of biomass. Through torrefaction, solid fuel from biomass achieve better properties similar to those of fossil fuels, achieving calorific values closer to coal than to raw wood. Torrefaction is a process similar to pyrolysis, the difference being a shorter duration of treatment and lower temperatures (typically 200-300°C).

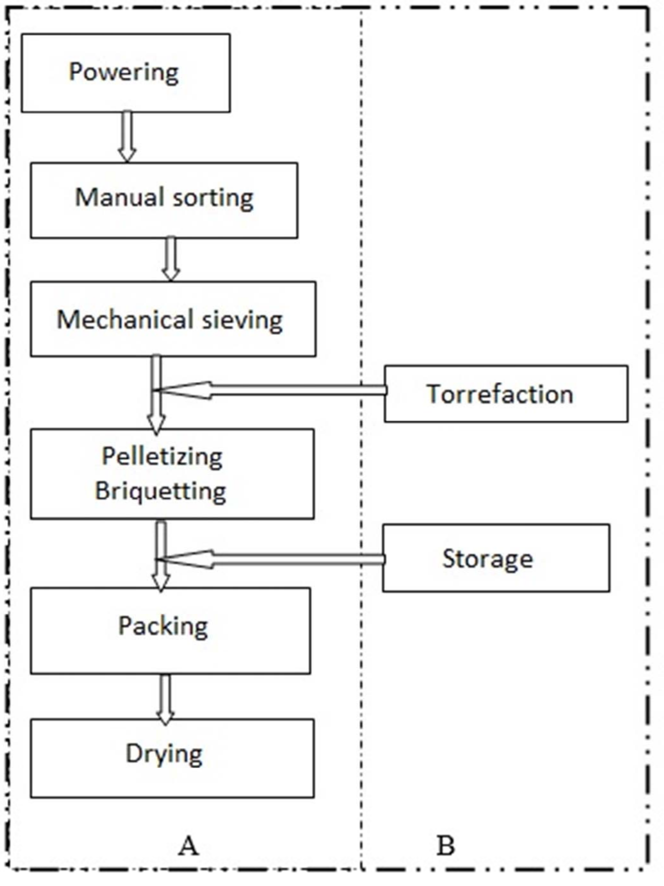

Figure 2. Technology for recycling wood waste: A - standard B - to increase the calorific value of the material

The process of torrefaction has three effects:

- Lowers the moisture content of the material;
- Increase the calorific value of the material;
- Obtain a hydrophobic fuel, i.e. it reabsorbs moisture content only in a small measure [5].

RESULTS

Proposed solutions

The first solution is to feed the boiler with a mixture of biomass and coal, as shown in Figure 3. Thus, the shredded biomass that loaded on a conveyor belt along with coal. The mixture is passed through ADM and overband in order to extract any trace of metal still present and is further fed in the bunker boiler. Inside the bunker, the mixture is further dried and shredded through a hammer mill, before being loaded into the boiler. The combustion inside the boiler is powered by methane burners. As the temperature of the gases inside the boiler is about 700 °C, and thus superior to the wood pyrolysis temperature, there cannot be used large amounts of biomass; otherwise, there is a risk that biomass self-ignites, leading to the ignition of coal and release of volatile gases, resulting in a violent combustion. This is why the ratio between biomass and coal is kept at a low amount of 5-10%.

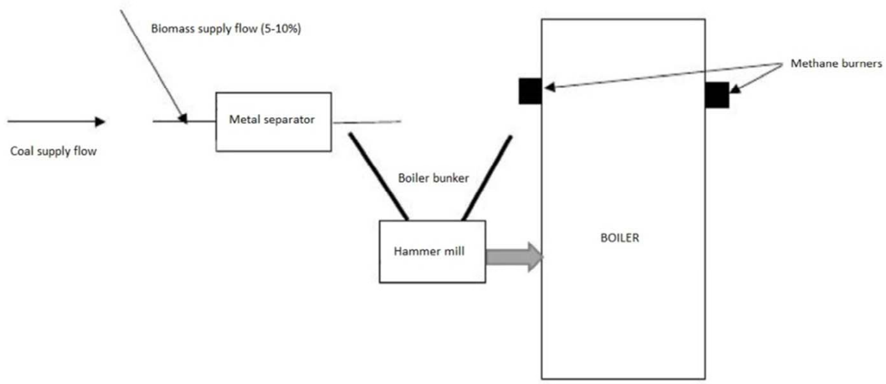

Figure 3. Scheme for a boiler fed by a mixture of biomass and coal, using methane burners

A second solution is to fed the boiler separately with coal and pellets. Coal will be supplied using a conveyor belt, passing through a metal separator and a hammer mill inside the boiler bunker. Separately, pellets are fed into the boiler from another bunker. The pellets are burned using a special pellet burner, mounted inside the boiler near the methane burners currently used for initiation and maintenance of coal combustion. In order to implement this solution, whose scheme is presented in Figure 4, tone should replace gas burners with pellet burners.

In order to achieve this solution biomass must be transformed into pellets according to the scheme shown in Figure 2.

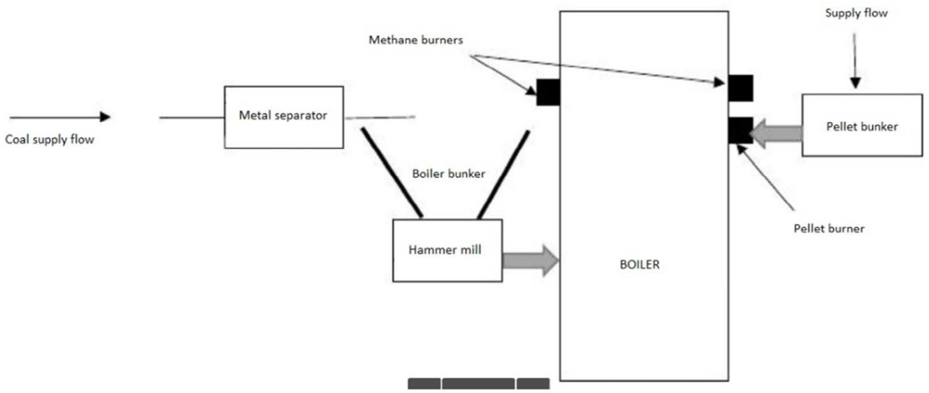

Figure 4. Scheme for a boiler fed separately by coal and biomass pellets, using methane burners

CONCLUSIONS

1. The main advantage of biomass is the impact on the environment, which is practically insignificant compared to the impact of classical fuels. Biomass is an important component in the carbon cycle. Carbon from the atmosphere is converted into biological matter (biomass) through the process of photosynthesis. By death or combustion plant material, the carbon goes back into the atmosphere as carbon dioxide.
2. In our country quantities of biomass waste resulting from industrial processes, forestry and agriculture are very high, their on-site price is very low (not considering the logistic costs). The main drawback is their transport to storage sites/processing.
3. Possibilities of using biomass processed or transformed into pellets and briquettes, syngas, biofuels are very diverse, so they can be used in industrial, agricultural and household.
4. The price per MJ produced using biomass is about 30% lower than with natural gas.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

CFD VALIDATION OF A NOVEL HEAT GENERATION EQUIPMENT FOR GREENHOUSES AND HOTHOUSES

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SUMMARY

The performance of a novel equipment including a top lit updraft (TLUD) gasifier will be investigated. In order to increase the energy independence of small hothouses and greenhouses, the proposed system harnesses the bioenergy potential of agricultural residues for heat generation.

TLUD gasifiers are mainly used to produce biochar through biomass pyrolysis. Biochar is a carbon rich porous product that can be used as soil amendment. As a positive side effect, the carbon in biochar is sequestrated into the soil for a very long time leading to a negative balance of CO_2, thus biochar being considered an important tool in fighting against climate change. Other biochar uses are for water purification or for toxin filtration.

The proposed TLUD based system, generates heat for greenhouses due to the pyrolysis of agricultural residues. It also produces up to 15% high quality biochar as a byproduct that can be subsequently used as fertilizer in the same greenhouse or hothouse. The paper presents a preliminary Computational Fluid Dynamics (CFD) analysis for the proposed TLUD based equipment, in order to validate its performance and to find its weak points before being manufactured and tested. The TLUD module uses biomass dried naturally at a relative humidity of 10% - 20%, and chopped at 10 to 50 mm. Combustible gases resulting from gasification processes are burned with hot air flow and resulting hot flue gas. An air-to-air heat exchanger transfers heat from the flue gases towards a fresh air flow. The subsequent step consists of mixing the hot fresh air from the outlet of the system with fresh cold air, until the necessary temperature for greenhouse heating is achieved. The ratio between the hot and cold fresh air flows depends on the temperatures of both streams of air. Thus, the main purpose of the CFD analysis aims to evaluate the temperature and flow of the heated fresh air to the outlet of the system. Finally, results are discussed and solutions to optimize the design of the equipment are proposed.

Keywords: TLUD, agricultural residues, pyrolysis, greenhouse, CFD

INTRODUCTION

According to Directive 2009/28/EC on the promotion of energy from renewable sources, exploitation of the full potential of biomass is a strategic aspect in the EU renewable energy policy (EUParliament 2009). From this point of view, an environmentally and economically convenient resource is the lignocellulosic residual biomass which is generated by agricultural and forestry related activities. In terms of abundancy, GHG (greenhouse gas) emissions, and land competition with food crops, residual biomass is more advantageous than traditional biomass resources such as dedicated crops (Paiano and Lagioia 2016) (Ayhan 2008). Furthermore, when compared to solar or wind energy, biomass can be constantly supplied independent of climatic conditions, when and as required.

In the framework of the same EU Directive, an important part of the strategy on using biomass is to establish the most efficient technology paths and supply chains, in order to contribute to the achievement of 20% improvement in energy production and 20% GHG savings.

In accordance with this legislative context, the scientific community increased its efforts to achieve these targets and to overcome the current limitations and technical and economical hurdles towards a strategical implementation of effective biomass based energy solutions. However, the share of collection and transportation costs per unit of energy produced from residual biomass is significant, due to biomass dispersion over territory, water content, low bulk density, as well as its low energy density when compared to fossil fuels. When used in rural areas for heat production, small scale solutions that harness the potential of locally available biomass resources are viable options, thus reducing or entirely eliminating transportation costs. However, simple burning of biomass should be avoided due to lower efficiency and to air quality related problems, such as emissions of greenhouse gasses (CH_4 and N_2O), particulate matter (PM) and polycyclic aromatic hydrocarbons (PAH) that lead to serious health issues (Devesa-Rey, et al. 2011) (Maican, et al. 2016). A higher efficiency alternative consists of thermo-chemical biomass conversion through gasification. Apart from many benefits, each of them specific to certain types of gasification reactors (such as low tar production, ability to scale-up, or high carbon conversion), disadvantages like complexity, sensitivity to biofuel moisture, low production of CO and H_2, resilience of system components, or maintenance costs, are still a concern (Molino, Chianese and Musmarra 2016), (Higman and Van der Burgt 2008), (Iovane, Donatelli and Molino 2013). Moreover, during long term operation, adverse phenomena like ash deposition on the reactor walls can lead to bed sintering and non-fluidisation, with a negative impact on the gasification process (Wang, et al. 2008) (Mikulandrić, et al. 2016).

In recent years, many studies on the use of biochar product from gasification as soil amendment were conducted, in order to improve the sustainability of the gasification process. From biochar 50 – 80% of its composition is unreacted carbon. Research results demonstrated positive contributions in terms of increased capacity to hold water, improvement of soil fertility, reduction of soil acidity, and reducing leaching of pesticides to groundwater (Fowles 2008), (Patuzzi, et al. 2016). However, further research show that gasification char, also called biochar, can also contain contaminants like heavy metals, PAH, furans or dioxins. On the contrary, it was also demonstrated that at higher pyrolysis time and temperature, PAH concentrations decrease well below existing environmental quality standards for soils (Hale, et al. 2012). Due to its porous structure, biochar can also be used as adsorbent, to adsorb organic pollutants or heavy metals in various filtering processes (Shen 2015), (Acharya, et al. 2013).

As opposed to regular types of gasification, the Top-Lit-UpDraft (TLUD) gasification process, has many advantages. TLUD reactors, also known as inverted downdraft gasifiers, benefit of very simple and durable designs, which positively influence the initial investment cost, as well as the maintenance costs. The gasification process is auto-adaptive and tolerant to biomass size and moisture, good operation being demonstrated for fuels with up to 30% moisture content (Reed, Anselmo and Kirker 2000). With very low emissions of PM and CO when the primary air and preheated secondary air flow are and properly adjusted, TLUD systems are also environmentally friendly. Depending on the used fuel, efficiencies of up to 93% for full gasified biomass were demonstrated on a forced draft equipment (Mukunda, et al. 2010). Moreover, the resulting biochar has a very good quality. Having a microporous structure, it demonstrated superior performance for complex wastewater treatment and nutrient recovery due to higher overall adsorption capacity, being also recommended as a very efficient soil amendment (Huggins, et al. 2016).

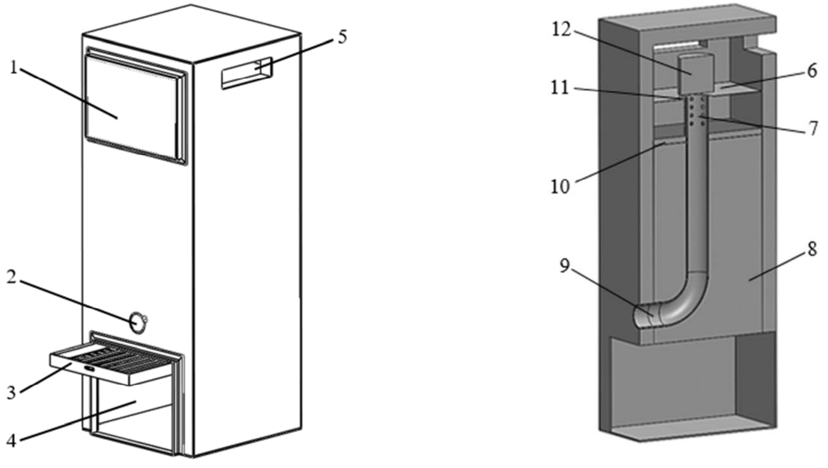
METHODS

Taking the affordability and the advantages of design and maintenance simplicity as primary objectives, a system using TLUD principle is proposed to heat small greenhouses and hothouses during cold weather. As described and analyzed in a previous work (Maican, et al. 2016), a proposed novel TLUD module can use chopped residual biomass (10 … 50 mm) from local agricultural activities, such as vines, branches, and any other lignocellulosic debris. For optimum performance, biomass should be naturally dried at 10% to 20% relative humidity. In these conditions, the reactor will produce up to 15% high quality biochar to be further used as soil amendment in the same greenhouse or hothouse. The reactor also fulfils other requirements such as durability, low emission levels, and adaptability to various biomass particle sizes. The superficial velocities of gases from gasification were determined to range between 0.03 m/s and 0.04 m/s, which is well below the limit of 0.08 m/s where $PM_{2.5}$ concentration increases above 2.4 mg/MJ. To achieve maximum operating time between charges and maximum energy efficiency, flow rate from the gasification module is controlled by means of an exhaust low pressure fan placed on the chimney. In case of an environmental temperature of 5°C, the flowrate ratio (ratio of the secondary air to primary air) was 2.6. The thermally insulated reactor delivered gasses at each of the three outlets with average temperatures between 675°C and 700°C, at a total flow of 0.007 m^3/s.

In this paper, the above described module is used as part of a heating system that aims to deliver air with temperatures between 22°C and 28°C for greenhouse or hothouse heating. Figure 1 presents the TLUD module, as described in (Maican, et al. 2016), while Figure 2 shows the heating equipment proposed in this paper, that uses the hot gases delivered by the module to heat fresh air that will be sent inside the greenhouse.

The TLUD process is autothermal and uses two air flows: the primary air for biomass gasification, and the secondary air for combustion of combustible gas. The process starts with the ignition of the top layer of biomass. In turn, heat radiation initiates the pyrolysis process in the proximity hot layer. Primary air is supplied in limited amount through the bottom of the bed in order to maintain the pyrolysis migratory front through partial oxidation of biomass. This migratory front starts to move downward through the bed. The combustible gas with up to 4.5 MJ/Nm^3 lower heating value (LHV), also called syngas, is turbulently mixed with preheated secondary air and burns, releasing heat. Because they slowly pass through the high temperature incandescent carbon layer, tars are cracked and reduced. After gasification, about 10%-15% charcoal and some incorporated ash remains. Previous calculations (Murad, et al. 2015) demonstrated that a TLUD system that uses 13.4

t/year biomass generates 1.78 t of biochar. If incorporated into the soil, the negative equivalent balance of CO_2 is -6.2 t/year. In the simplified model that was previously used for CFD simulation (Figure 1 *b*), the upper door was replaced by the front wall, taking into consideration that the door is closed during operation.



a *b*

Figure 1 TLUD module: (*a*) isometric view; (*b*) section view (simplified, used for CFD simulation); 1 – feed door; 2 – cover for adjusting secondary air flow; 3 – grate; 4 –primary air inlet and biochar evacuation chamber; 5 – lateral exhaust outlet; 6 – removable plate; 7, 11 – mixing system for primary and secondary air (7 – holes; 11 – annular gap); 8 –biomass bed; 9 – pipe for secondary air; 10 – layer of biochar and pyrolysis front; 12 – flame space.

a *b*

Figure 2 Greenhouse heating equipment (lateral wall removed): (*a*) isometric view; (*b*) simplified view, for CFD simulation; 1 – steel frame; 2 – TLUD module; 3 – heat exchanger; 4 – insulated exterior wall; 5 – flue gas evacuation; 6 – hot air pipe.

The TLUD module is the heat generator for small greenhouses or hothouses heating equipment presented in Figure 2. The aim of this research was to perform a preliminary CFD analysis in order to validate the performance and to find the potential weak points of this equipment, before being manufactured and tested. In order to make it simple to transport, assemble, and maintain, the entire construction is modular. The TLUD module *2*, air-to-air heat exchanger *3*, and piping *5* and *6*, are mounted on a rigid, compact, and light steel frame *1* made of square pipe. Fans for exhaust gases and for hot air are not represented here, but will be considered during the CFD analysis. The exterior walls *4* of the assembly are all insulated with 50 mm thick stone wool resistant to 950°C. Removal of any wall is simple and allows full access for maintenance. For the same purpose of simple cleaning of its exterior faces, the heat exchanger is made of flat sheet of metal.

During operation, hot gases exit through the exhaust outlets of the TLUD module *2*, in the interior space delimited by the exterior walls *4*. They will flow downwards, from the upper part of the equipment to the evacuation pipe *5*, being permanently in contact with the exterior of the heat exchanger, and thus transferring heat to the fresh air that flows inside the exchanger. Hot fresh air is evacuated through pipe *6* and will be subsequently mixed with colder air in order to achieve a final temperature of 22°C … 28°C. These values are chosen according to the crops inside the greenhouse, and they depend on the temperatures and flows of hot and cold streams of air. Because this research aims to evaluate the temperature and flow of the heated fresh air to the outlet of the system, the mixing process is not one of the CFD analysis objectives.

The CFD analysis will be performed in the conditions described earlier for the TLUD module. Furthermore, the option of heat conduction in solids was activated in order to asses: (i) – the efficiency of heat exchanger; (ii) – preheating of primary air from the hot gases from the exterior of the reactor, due to heat transfer through the reactor walls; (iii) – heat losses through the exterior walls of the equipment. The model also considers buoyancy effects.

The effective wall length, the Reynolds number, and the equivalent hydraulic diameter ($D = 4A/P$, where P is the perimeter of the opening, and A is the area), are extracted from the model by the simulation software, and are used to calculate the default boundary layer thickness. At the inlets, turbulence intensity was established at 5%. This value corresponds to a medium turbulence, which is found in ventilation flows, flows at low speeds, or in large pipes. Usually, it is problematic to predetermine the inlet turbulence length. Therefore, the default value Lt=0.01 m suggested by the CFD software was used. The biomass bed was considered an isotropic porous media (with permeability independent of flow direction). Its effective porosity was set to 70% which, according to (Karaj, et al. 2011), corresponds to biomass chopped at 40-50 mm. The hydraulic resistance was calculated as presented in (Maican, et al. 2016). Thus, the variation of the pressure gradient depends on the air speed in accordance with the following quadratic regression formula obtained in current simulation conditions:

$$\nabla P = 2495.9v^2 + 159.43v$$

Initial mesh was locally refined in areas where high flow and temperature gradients are expected. For higher accuracy, the average global mesh size was selected based on three runs that led to grid independent results.

RESULTS AND DISCUSSION

The CFD simulation was performed in case of four different flowrate ratios between the fresh air flow through heat exchanger, and flue gas flow:

$$\frac{Q_{fg}}{Q_{fa}} = \{1; 0.5; 0.33; 0.25\}$$

where Q_{fa} is the fresh air flow, and Q_{fg} is the flue gas flow, which has a constant value of 0.007 m^3/s. Thus, the fresh air flow has the following values, for each of them a different analysis being performed:

$$Q_{fa} = \{0.007; 0.014; 0.021; 0.028\}\left(\frac{m^3}{s}\right)$$

Temperatures of air and gas streams at model outlets were recorded and are presented in Table 1. Details on the calculus of heat exchanger efficiency are presented below.

Table 1 Values of the main parameters of fresh air and flue gas at the model outlets

Simulation no.	Fresh air parameters at outlet			Flue gas temperature at outlet [°C]	Heat exchanger efficiency, ε
	Flow [m³/s]	Speed [m/s]	Temperature [°C]		
1	0.007	0.62	243	244	0.35
2	0.014	1.24	172	208	0.24
3	0.021	1.86	99.3	141	0.14
4	0.028	2.48	78	130	0.11

Data from Table 1 is plotted in Figure 3, thus emphasizing the temperature variation of fresh air and flue gas at model outlets, both of them in relation to fresh air flow.

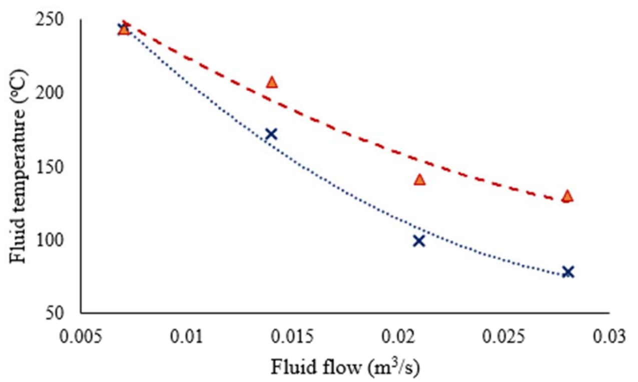


Figure 3 Variation of fresh air and flue gas temperatures with fresh air flow, at the outlets of the CFD model: △ (- - -) flue gas temperature; ☒ (…..) fresh air temperature.

As expected, the fresh air temperature drops significantly down to 78°C, when the flowrate ratio Q_{fg}/Q_{fa} decreases from 1 to 0.25. The first objective is to assess the performance of the proposed heat exchanger by means of its efficiency ε. However, due to heat losses of flue gas through the equipment walls, efficiency will be calculated based on temperature change of the fresh air, using the following equation (Holman 1997):

$$\varepsilon = \frac{t_{fa}^{out} - t_{fa}^{in}}{t_{fg}^{in} - t_{fa}^{in}}$$

where t_{fa}^{out} is the temperature of fresh air at the heat exchanger outlet (in °C), t_{fa}^{in} is the temperature of of fresh air at the inlet (5°C), and t_{fg}^{in} is the average temperature of flue gases when they exit the TLUD module (694°C).

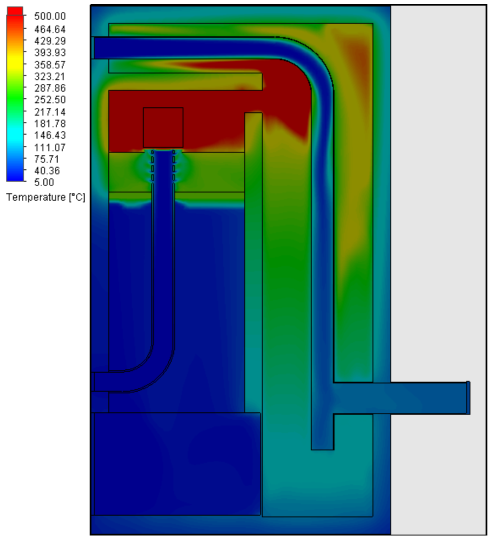


Figure 4 Distribution of temperatures

Even if the efficiency is low at high flows of fresh air, it is preferable to choose the version corresponding to the lowest temperature of flue gases at outlet, respectively a high value for fresh air flow and a low value for the flow of flue gas.

In order to better show variations of temperatures through the walls, the temperature range in Figure 4 was set to 500°C. One can notice that heat losses through the top and rear walls are significant. The temperature of the exterior side of top wall can reach about 125°C, while the rear wall can reach almost 134°C to the upper side, and 54°C towards its lower side. The highest temperature of the exterior side of the front wall is about 198°C in the area corresponding to the biomass feed door.

Otherwise, this wall is cold. Even if the interior walls of the TLUD module are thermally insulated, significant temperatures are recorded to the interior upper side of the rear wall, thus drying biomass from the vicinity and preheating the primary air before it enters the pyrolysis layer.

CONCLUSIONS

A simple design for heat exchanger was chosen in order to ease the maintenance procedure. Its exterior surfaces are in contact with flue gases but, because they are flat, they are accessible and easy to clean. However, this analysis revealed some efficiency issues. In order to improve its effectiveness, some simple but efficient design changes can be made. As seen from figure 4, the top wall of the TLUD module prevents hot gases to reach the top, horizontal section of the heat exchanger. In this respect, an additional array of small-size outlets can be drilled into the top wall of the TLUD module, to allow gases to reach the horizontal section of the exchanger. However, this design will also allow flames to reach the exchanger surface, therefore being necessary to use a thicker sheet of steel for the upper section, or to protect it with a thin layer of refractory material.

It is also evident that the thick refractory layer from the top wall of the TLUD module can be substantially thinned out, as it has only a protective role against flames. The same measure can be taken for the rear and lateral walls of the TLUD module, thus adding the advantage of a better heat transfer towards the biomass bed and primary air. Also, due to the high temperature recorded to the exterior of the frontal feed door of the TLUD module, it should be further insulated with a second layer of heat resistant reflective material.

A mandatory improvement consists in changing the design of the pipe for secondary air. In order to significantly simplify the overall design and to increase the temperature of secondary stream of air, pipe *9* (Figure 1) should be horizontal, entering the space between biomass bed and removable plate *6* from one of the lateral sides. Thus, it will cross the upper hot space inside the equipment, where temperatures reach about 300°C.

For high values of fresh air flow, flue gasses exit the equipment at about 130°C…140°C, thus loosing important amounts of heat. In this respect, a second more performant counter-current air-to-air heat exchanger should be fitted outside the equipment, where the inner tube of the exchanger is the flue gas evacuation tube *5* (Figure 2). A fresh air stream will pass through this second heat exchanger, then will be mixed with hot air from pipe *6* and used to heat the greenhouse. The flow of this stream should be automatically regulated in order to achieve a temperature of 22°C…28°C, depending on the crop.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RAZLIČNI NAČINI OBDELAVE TAL IN OKOLJSKI ODTIS PRI PRIDELAVI OLJNE OGRŠČICE

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POVZETEK

V raziskavi smo vrednotili, kako vplivajo različni načini obdelave oljne ogrščice na okolje. Izračunali smo okoljski odtis (SPI), izpust ogljikovega dioksida in potencial globalnega segrevanja (GWP). Pri raziskovanju smo primerjali tri načine obdelave tal: konvencionalno obdelavo, konzervirajočo obdelavo in direktno setev z namenom ovrednotiti, kateri način obdelave tal pri pridelavi oljne ogrščice je najprimernejši z okoljskega vidika. Rezultati kažejo, da je največjo obremenitev za okolje prinesla konvencionalna obdelava, z okoljskim odtisom 41,7 gha, sledita ji konzervirajoča obdelava s 37,6 gha in direktna setev s 36,6 gha, ki je bila za okolje najmanj obremenjujoča. Pri primerjavi količine izpustov CO_2 na enoto pridelka smo ugotovili, da je bil ta enak pri konvencionalni obdelavi in direktni setvi (0,46 kg/enoto) ter manjši pri konzervirajoči obdelavi (0,34 kg/enoto). Pri primerjavi obremenitve GWP na enoto proizvoda oljne ogrščice smo ugotovili, da je bila ta največja pri konvencionalni obdelavi tal (4,17 kg/enoto), manjša pri direktni setvi (1,94 kg/enoto) ter najmanjša pri konzervirajoči obdelavi tal (1,59 kg/enoto). Primerjava SPI na enoto pridelka pa je pokazala, da je ta največji pri direktni setvi (133,56 m^2/enoto), nekoliko manjši pri konvencionalni obdelavi tal (126 m^2/enoto) ter najmanjši pri konzervirajoči obdelavi tal (97,58 m^2/enoto). Zaključujemo, da se je v tem poskusu konzervirajoč način obdelave tal izkazal za najprimernejšega.

Ključne besede: okoljski odtis, oljna ogrščica, konvencionalna obdelava, konzervirajoča obdelava, direktna setev

UVOD

Oljna ogrščica (*Brassica napus L. var. napus*) je najpomembnejša oljnica iz družine križnic. Industrijsko pridobivanje olja iz semen ogrščice se je začelo šele v šestdesetih letih 20. stoletja, ko so uvedli sorte z malo ali brez za zdravje ljudi in domačih živali škodljivih eruka maščobnih kislin v olju in glukozinolatov v tropinah (Kocjan Ačko 2015). V svoji rastni dobi oblikuje oljna ogrščica od 10 do 13 ton suhe snovi na hektar površine. Zato jo na obratih, kjer nimajo dovolj živine ali pa so sploh povsem brez nje, uspešno uporabljajo kot podorino. Sama ali v posevku z nekaterimi drugimi poljščinami je primerna tudi kot strniščni dosevek. Glavni gospodarski pomen ogrščice je, da z njo pridelamo sorazmerno veliko semen, ki imajo visoko vsebnost olja. Navadno znaša pridelek semen od 2 do 3,5 tone na hektar, v izjemno ugodnih razmerah celo več kot 5 ton na hektar. Ker semena vsebujejo od 42 do 45 % olja, dobimo na hektar okrog 1100 ali celo do 1350 kg olja. Tako donosna ni nobena oljnica v zmerno toplem pasu (Tajnšek 1987).

Okoljski vplivi pridelave oljne ogrščice so odvisni od več dejavnikov. Med njimi so tako lokalne razmere (tla in podnebje), način obdelave tal, uporaba gnojil in pesticidov, pridelek in sprememba rabe zemljišč (Queirós in sod. 2015). Okoljski odtis sta leta 1996 razvila Wackernagel in Rees. Z njim predpostavljata, da ima vsak posameznik, proces, aktivnost in področje vpliv na planet in sicer skozi rabo naravnih virov, nastajanjem odpadkov in uporabo naravnih procesov. Ti vplivi se lahko pretvorijo v biološko produktivne površine (kot so zemljišča, na katerih poteka fotosinteza in proizvodnja biomase). Okoljski odtis izračunamo tako, da primerjamo biokapaciteto neobdelanih površin z vplivi človeka na naravo. Biokapaciteto predstavljajo biološko aktivne površine, kot so gozdovi, pašniki, polja in vodne površine. Največjo biokapaciteto imajo površine, ki jih pustimo neobdelane, saj te povečujejo svoj pozitiven vpliv. Te površine lahko predelajo veliko količino »odpadkov« in znatno znižajo emisije ogljikovega dioksida. Biokapaciteto nato primerjamo z vplivi človeštva na naravo. Tako pridobimo podatek o okoljskem odtisu. Ta zahteva produktivno območje, ki je potrebno za zagotavljanje zadostnih količin virov in območij, ki bodo predelali odpadke. Z merjenjem okoljskega odtisa lahko ocenimo naš pritisk na planet. Ta ocena pomaga bolj smotrno upravljavljati z naravnimi viri (Global Footprint Network 2016).

Skozi leta so se načini obdelave tal spreminjali, saj so se pojavljale vedno nove tehnologije obdelave, ki pa so hkrati povečale stroške goriva in dela. Z uvajanjem manj intenzivnih načinov obdelave so mnogi pridelovalci spoznali negativne učinke konvencionalne obdelave in opazili koristi ohranjanja ostankov na površini tal. Sistemi pridelave brez obdelave tal pustijo na površini največ ostankov, kar se mnogokrat izkaže kot najdonosnejši način pridelave (CropWatch 2016). V splošnem poznamo konvencionalno obdelavo, konzervirajočo obdelavo in direktno oziroma neposredno setev brez obdelave.

Za konvencionalno obdelavo tal je značilno vsakoletno oranje. Plug obrne brazdo, zrahlja zemljo celotnega obdelanega sloja, v celoti prekrije žetvene ostanke, gnoj in plevel. Sledi predsetvena obdelava, s katero poravnamo površino, zdrobimo grude, po potrebi pa se zgosti tudi setveni sloj tal. Nato sledi setev, po žetvi pa strniščna obdelava. Za predsetveno obdelavo so na voljo številni stroji s pasivnimi ali aktivnimi delovnimi organi. Pri tej vrsti obdelave tal imamo opravka s številnimi prehodi po obdelovalni površini (Klemenčič in Rihtarič 1998).

Konzervirajoča obdelava tal je vsaka metoda obdelave tal, ki pusti na površini rastlinske ostanke prejšnjega posevka (kot so na primer koruzna stebla ali pšenična slama) pred in po setvi naslednjega posevka, z namenom zmanjšanja erozije tal in odnašanja zemlje. V ta namen mora ostati prekrito z ostanki pred setvijo najmanj 30 % površine tal. Nekatere konzervirajoče obdelave tal se popolnoma odrečejo tradicionalni obdelavi in pustijo sedemdeset in celo več odstotkov ostankov rastlin. Konzervirajoča obdelava tal je še posebej primerna za tla, ki so izpostavljena eroziji. Na nekaterih kmetijskih območjih je konzervirajoča obdelava že pogostejša od konvencionalne obdelave z oranjem (MDA 2016).

Direktna setev je ukrep proti eroziji na nagnjenih zemljiščih in ukrep za preprečevanje izpiranja nitratov na ravninskih območjih. Rastlinski ostanki na površini ščitijo pred izhlapevanjem vlage iz tal in povečujejo biološko aktivnost ter tvorbo humusa. Za direktno setev se lahko odločimo le na globokih, lahkih, toplih, humusnih, s hranili bogatih in na nezapleveljenih tleh ali tam, kjer so predhodne kulture s koreninskim sistemom dobro drenirale in zrahljale tla. Pomembno je, da dva do tri tedne pred setvijo poškropimo njivo s herbicidom na osnovi glifosata. Počakamo, da se posevek in pleveli posušijo in da se zemlja dovolj ogreje (Flisar Novak 2014).

Cilj raziskave je, da na podlagi podatkov, pridobljenih v poljskem poskusu in s pomočjo spletnega programa SPIonWeb pridobimo podatke o okoljskem odtisu različnih načinov pridelave. Z rezultati okoljskega odtisa želimo ugotoviti, kateri način obdelave tal je pri pridelovanju oljne ogrščice ekološko (naj)prijaznejši, oziroma, s katerim načinom izpustimo čim manj emisij CO_2 v okolje.

METODE DELA

Lokacija poskusa in oljna ogrščica

Poskus smo izvajali v letih 2013 in 2014 v kraju Podova (slika 1). Koordinate njive so 46°25'52''N in 15°42'47''E. Domače ime njive je Podova. Celotna površina njive je 10,7 hektarja, povprečna nadmorska višina pa 250 m. Tla so peščeno rjava oziroma lahka distrična. Njiva je bila za namene poskusa razdeljena na tri dele.

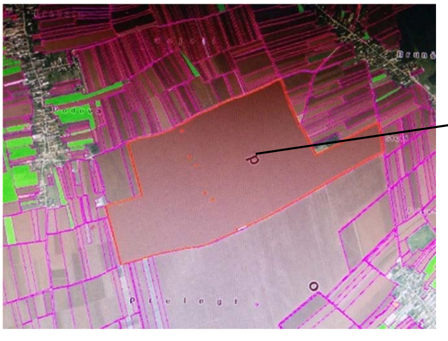


Figure 1: Location of the experiment - Podovo (Gerk viewer)

V našem poskusu smo sejali hibrid oljne ogrščice PR46W26. Hibrid oljne ogrščice PR46W26 se je v obdobju več zaporednih let dokazal z visokim pridelkom semena in veliko vsebnostjo olja. PR46W26 je srednje zgodnji hibrid, ki dobro prezimi in je dobro odporen na poleganje. Z visokim pridelkom in veliko vsebnostjo olja je zelo dobičkonosen. Upoštevati pa moramo tudi, da je občutljiv na škodljivce in bolezni. V letu 2013 je bil eden izmed najdonosnejših hibridov (LELF 2015).

SPIonWeb – spletni program za izračunavanje okoljskega odtisa

Za izračun okoljskega odtisa smo uporabili program SPIonWeb, ki je naslednik programa SPI, ki sta ga leta 1995 razvila Krotscheck in Narodoslawsky. V program smo vnesli podatke o uporabljenem repromateralu v poskusu in uporabljeni mehanizaciji za tri načine obdelave tal pri pridelavi oljne ogrščice.

SPIonWeb je brezplačen program, ki izračuna ekološke vplive tehničnih postopkov na okolje skozi cel življenjski cikel, vključno s surovinami in z vsemi emisijami ter odpadki. Izračun vpliva na okoljski odtis po metodi Sustainable Process Index (SPI), vključujoč emisije ogljikovega dioksida in potencial globalnega segrevanja (GWP) (SPIonWeb 2016).

Mehanizacija pri pridelavi oljne ogrščice za tri načine obdelave tal

V poskusu smo sejali oljno ogrščico v treh načinih obdelave tal (konvencionalna obdelava, konzervirajoča obdelava tal in direktna setev). V preglednici 1 je prikazana mehanizacija, ki smo jo uporabili v poskusu za izračun okolskega odtisa pri pridelavi oljne ogrščice.

Table 1: Machines used in the experiment

Work task	Tractor	Machine	Working efficiency (ha/h)	Fuel consumption (l/h)
		Conventional tillage		
Basic tillage	Fendt 818	Plough Regent 4B	0,5	13
Pre-sowing treatment	Fendt 818	Harrow Kverneland 4 m	10	11
		Conservation tillage		
Basic tillage	Challenger MT 875B	Väderstadt Top Down 6 m	5	57
Spraying	Fendt 309	RAU 24 m	14	7
Fertilizing	Fendt 309	Amazone ZA-M 24 m	14	7
Sowing	Fendt 930	Amazone	5	20
Harvest	Harvester Tucano 340		2	18

Pri konvencionalni obdelavi smo za oranje in predsetveno obdelavo uporabili traktor Fendt 818. Motor traktorja ima 6,1 l prostornine, 138 kW moči in 803 Nm navora pri 1450 obratih motorja. Masa traktorja znaša 7021 kg in ima skupno nosilnost 12499 kg. Traktor ima nameščen brezstopenjski hidromehanski menjalnik. Za škropljenje in gnojenje smo uporabili traktor Fendt 309. Motor traktorja ima 4,2 l prostornine, 70,8 kW moči in 375 Nm navora pri 1500 obratih. Pri konvencionalni obdelavi tal smo za osnovno obdelavo uporabili štiribrazdni obračalni plug Regent (slika 2, levo) in krožno brano Kverneland, delovne širine 4 m.

Za konzervirajočo obdelavo tal smo uporabili traktor goseničar Challenger MT875B. Traktor ima 18,1 l prostornine in razvije 570 hp moči pri 2100 obratih. V traktor je vgrajen menjalnik Cat 16FX4R powershift. Za konzervirajočo obdelavo smo uporabili priključek Väderstad Top Down 600. Delovna širina priključka je 5,75 m, transportna širina 3 m, transportna višina 3,6 m in masa priključka 9100 kg. Priporočena delovna hitrost je med 8 in 12 km/h.

Pri poskusu smo vedno uporabili sejalno kombinacijo Amazone in škropili s škropilnico RAU. Za spravilo pridelka smo pri vseh treh načinih obdelave uporabili kombajn Claas Tucano 340. Direktno setev smo izvedli s pnevmatsko sejalnico vaderstad (slika 2, desno).

Figure 2: Plough Regent (left) and pneumatic seed drill Vaderstad (right)

V poskusu uporabljeni agrotehnični ukrepi

Spodnja preglednica prikazuje agrotehnične ukrepe in uporabljen repromaterial pri vseh treh načinih pridelave oljne ogrščice.

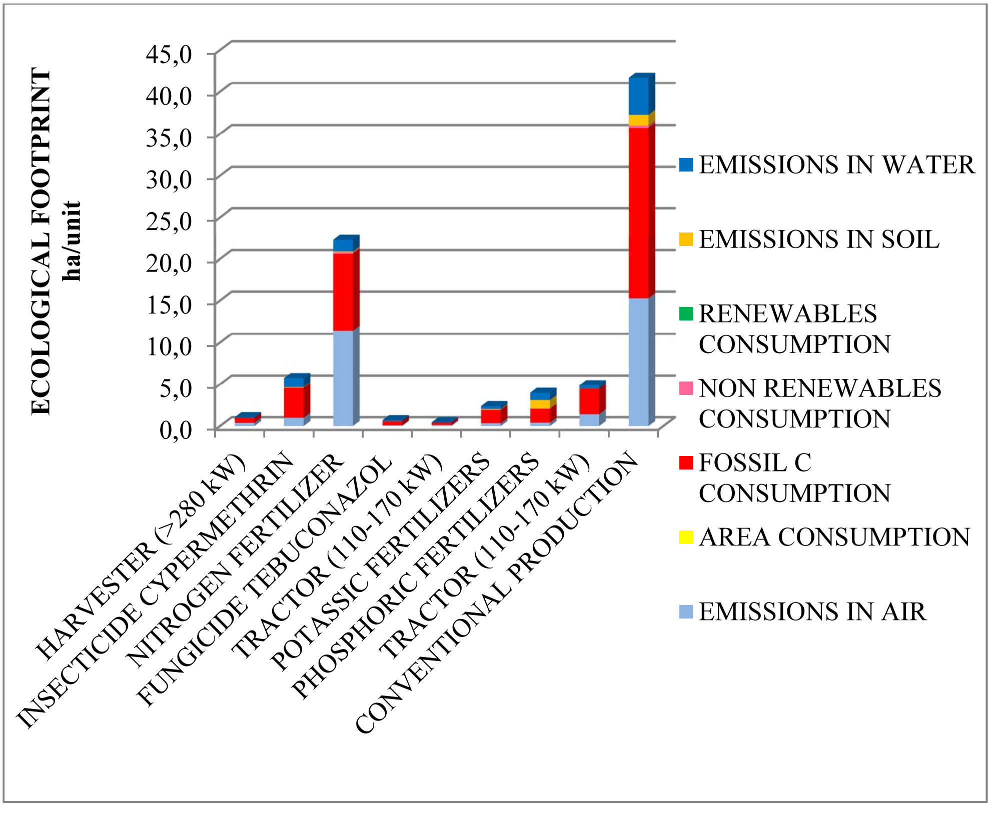
Table 2: Agro-technical measures used in experiment

Fertilizing	Quantity (kg/ha)	Spraying	Quantity (l/ha)
Basic: NPK 6:12:24	400	1. spraying fungicide Folicur insecticide Cypermethrin	0,7 2
1. fertilizing: KAN 27 %	280	2. spraying fungicide Folicur insecticide Cypermethrin	0,7 1
2. fertilizing: N-GOO 32 %	250		
Foliar fertilizing: FOLIBOR	2 (l/ha)		
Foliar fertilizing: LABI FITO	2 (l/ha)		

REZULTATI Z RAPRAVO

Konvencionalna obdelava tal pri pridelavi oljne ogrščice

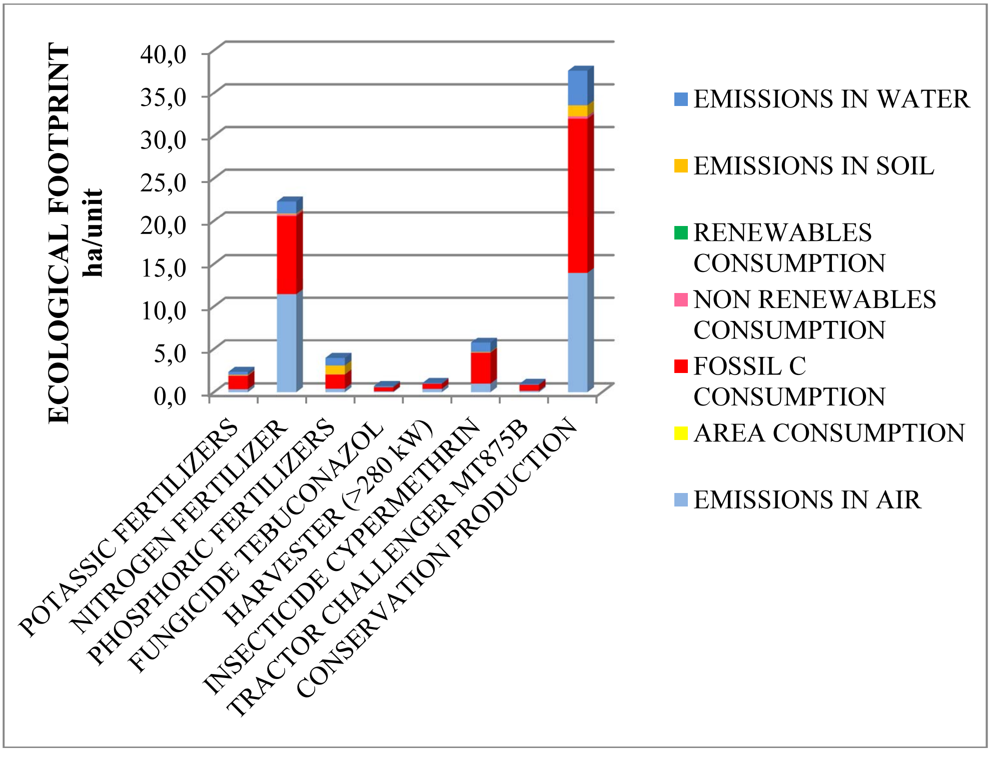
Pridelek olje ogrščice pri konvencionalni pridelavi je bil 3245 kg/ha. Na grafikonu 1 so predstavljeni rezultati obdelave tal s konvencionalno metodo. Opazimo, da je imela največji okoljski odtis uporaba dušikovih gnojil, ki je znašala 22,3 gha (53,5 %). Sledil je vpliv uporabe insekticida Cypermetrina, ki je znašal 5,8 gha (13,8 %), obdelava s traktorjem v velikosti 4,9 gha (11,7 %), uporaba fosfatnih gnojil z vrednostjo 4 gha (9,5 %) in uporaba kalijevih gnojil, ki je pustila odtis v velikosti 2,4 gha (5,7 %). Ostali dejavniki so skupno zaslužni za 5,8 % celotnega vpliva.



Graph 1: The ecological footprint of conventional rapeseed production

Konzervirajoča obdelava tal pri pridelavi oljne ogrščice

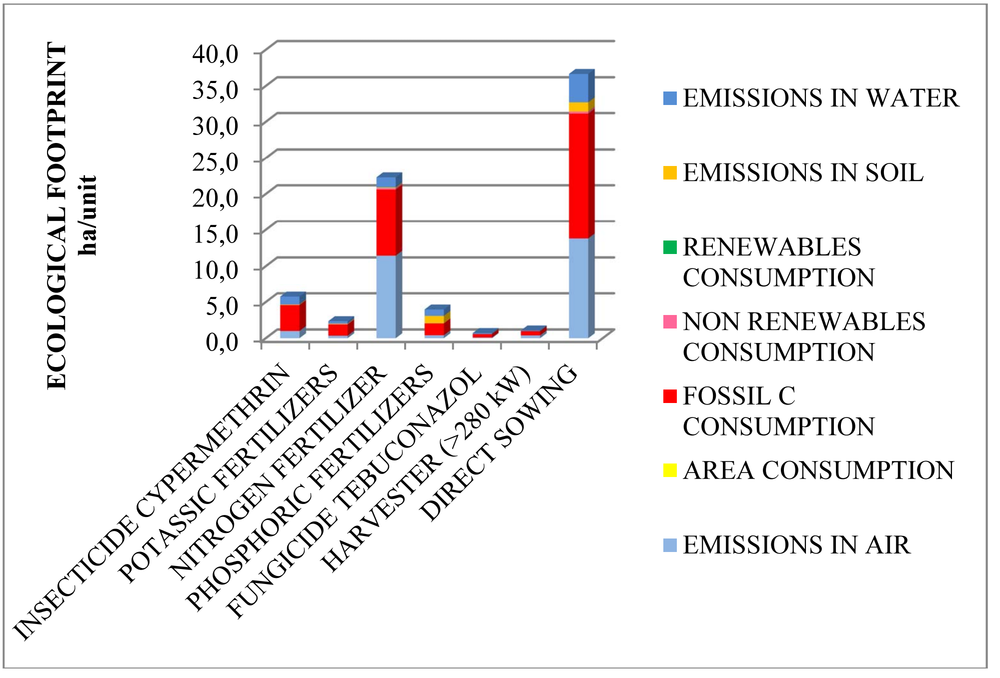
Pridelek olje ogrščice pri konzervirajoči pridelavi je bil 3856 kg/ha. Grafikon 2 predstavlja rezultate konzervirajoče obdelave tal. Opazimo, da je imela največji okoljski odtis uporaba dušikovih gnojil, ki je znašala 22,3 gha (59,3 %). Sledil je okoljski odtis pri uporabi insekticida Cypermethrin, ki je znašal 5,8 gha (15,3 %), nato uporaba fosfornih gnojil, z odtisom 4 gha (10,6 %) in uporaba kalijevih gnojil z 2,4 gha (6,3 %). Uporaba kombajna je prispevala odtis v višini 1,1 gha (2,8 %), ostali dejavniki pa so imeli skupaj 5,8 % vpliv.



Graph 2: The ecological footprint of conservation rapeseed production

Direktna setev

Pridelek olje ogrščice pri direktni setvi je bil 2745 kg/ha. Tudi pri direktni setvi prevladuje okoljski odtis gnojil in pesticidov. Edina razlika je v okoljskem odtisu strojev, ki je pri direktni setvi razumljivo najmanjši. Grafikon 3 prikazuje vplive posameznih dejavnikov pri direktni setvi. Največji okoljski odtis v višini 22,3 gha (60,8 %) je imela uporaba dušikovih gnojil, sledila je uporaba insekticida Cypermethrin z okoljskim odtisom 5,8 gha (15,7 %), nato uporaba fosfatnih gnojil v višini 4 gha (10,8 %) in uporaba kalijevih gnojil z okoljskim odtisom v višini 2,4 gha (6,4 %). Uporaba kombajna je bila zaslužna za odtis v višini 1,1 gha oziroma 2,9 %, ostali dejavniki pa so imeli 3,3 % vpliv.



Graph 3: The ecological footprint of direct sowing rapeseed production

Vrednosti vplivov na okolje

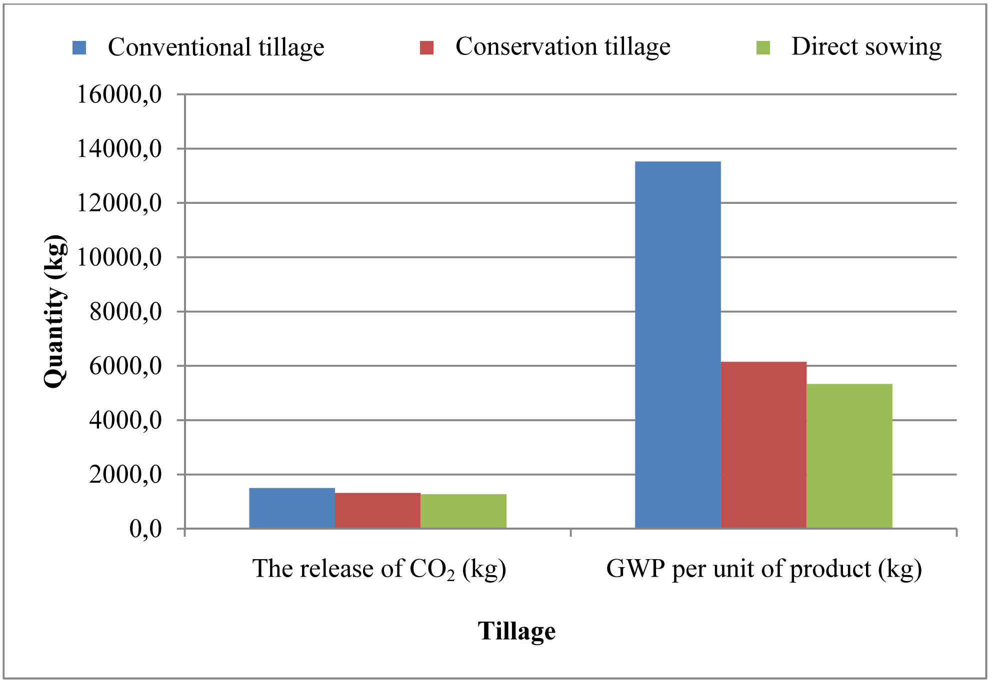
Konvencionalna obdelava tal ima največji okoljski odtis v vrednosti 41,7 gha, sledi ji konzervirajoča obdelava tal s 37,6 gha in direktna setev s 36,7 gha.

Najvišji izpust ogljikovega dioksida v ozračje imajo procesi konvencionalne obdelave tal in sicer kar 1500 kg na hektar površine. Procesi konzervirajoče obdelave izpustijo v zrak 1322 kg ogljikovega dioksida in procesi neposredne setve 1270 kg. Obremenitev s potencialom globalnega segrevanja je največja pri konvencionalni obdelavi in znaša 13526 kg. Obremenitev pri konzervirajoči obdelavi znaša 6148 kg in pri načinu obdelave z direktno setvijo 5337 kg. Pridobljene rezultate povezujemo s količino uporabe mehanizacije (strojnih ur), ki je potrebna za obdelavo tal, deležem procesov, ki so bili potrebni za izdelavo posameznih traktorjev in strojev ter neposredno porabljenih sredstev, potrebnih za rast in razvoj. Pri konvencionalni obdelavi tal je potrebnih največ delovnih faz oziroma porabimo največ delovnih ur, medtem ko je delovnih faz pri konzervirajoči obdelavi tal manj. Pri direktni setvi pa izvedemo samo setev.

Vrednosti vplivov na okolje glede na enoto pridelka

V grafikonu 4 je prikazana primerjava količine izpusta ogljikovega dioksida in obremenitveni potencial globalnega segrevanja na okolje GWP na enoto proizvoda pri vseh treh načinih obdelave. Opazimo, da je količina izpusta ogljikovega dioksida enaka pri konvencionalni obdelavi in direktni setvi ter nekoliko manjša pri konzervirajoči obdelavi.

Obremenitveni potencial globalnega ogrevanja na okolje je največji pri konvencionalni obdelavi tal, manjši pri direktni setvi ter najmanjši pri konzervirajoči obdelavi tal.



Graph 4: Comparison of the release of carbon dioxide and GWP per unit of product according to the tillage

Kilogram pridelanega semena oljne ogrščice ima pri konvencionalni obdelavi tal ekološki odtis 129 m^2. Ta znaša najmanj pri konzervirajoči obdelavi, in sicer 98 m^2. Pri direktni setvi pa je z vrednostjo 134 m^2 ekološki odtis največji.

Kilogram oljne ogrščice prispeva k največji obremenitvi s potencialom globalnega segrevanja, ki znaša 4,2 kg. Neposredna setev prispeva 1,9 kg GWP. Najmanj pa k obremenitvi z GWP- jem prispeva konzervirajoča obdelava, in sicer 1,6 kg.

Kilogram oljne ogrščice prispeva enako vrednost izpusta ogljikovega dioksida pri konvencionalni obdelavi tal in neposredni setvi, izpust je 0,47 kg na kilogram pridelka. Najmanjši izpust CO_2 ima konzervirajoča obdelava, in sicer 0,34 kg.

ZAKLJUČEK

V raziskavi smo vrednotili, kako vplivajo različni načini obdelave oljne ogrščice na okolje. Izračunali smo ekološki odtis, izpust ogljikovega dioksida in GWP. Primerjali smo konvencionalno in konzervirajočo obdelavo ter direktno setev brez obdelave tal.

Z opravljenim poskusom smo ugotovili, da je za prakso najprimernejša konzervirajoča obdelava tal pri pridelavi oljne ogrščice, saj povzroča najmanjši ekološki odtis glede na enoto proizvoda in s tem najmanj vpliva na okolje. Pri tem smo upoštevali količino pridelane oljne ogrščice.

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DIFFERENT SOIL TILLAGE AND ECOLOGICAL FOOTPRINT IN RAPE PRODUCTION

PETER VINDIŠ, DENIS STAJNKO, MIRAN LAKOTA

ABSTRACT

We researched the impact of different soil tillage of rapeseed production on the environment. Our main goals were to determine the ecological footprint (SPI), emissions of carbon dioxide and amount of global warming potential (GWP) in the comparison of three different types of tillage: conventional, conservational and direct sowing. The purpose of the research was to determine which method of rapeseed production is the most appropriate from environmental and from economic aspect. We determined that conventional tillage has a maximum footprint of 41.7 gha, followed by conversational tillage with 37.6 gha. Direct sowing with footprint of 36.6 gha brought the least burden on the environment. Comparison of the emissions of carbon dioxide per one unit of yield showed that the amount is the same in conventional tillage and direct sowing (0.46 kg/unit), and smaller in the conversational tillage (0.34 kg/unit). When we compared GWP per unit of produced rapeseed we determined that conventional tillage had the biggest value (4.17 kg/unit), followed by direct sowing (1.94 kg/unit) and conversational tillage (1.59 kg/unit). Comparison of SPI showed that the biggest amount comes when using direct sowing (133.56 m^2/unit), followed by a bit smaller SPI in conventional tillage (126 m^2/unit) and with the conversation tillage (97.58 m^2/unit) at the end. We conclude that the conversational tillage is the most appropriate in rape production.

Key words: Ecological footprint, oilseed rape, conventional tillage, conservation tillage, direct sowing

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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DISCOLORATION OF SYNTHETIC TEXTILE DYES BY LACCASE-PRODUCING FUNGAL BIOMASS

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SUMMARY

The ability of fungi to decolorize textile industry wastewaters by bioaccumulation/biosorption or laccase production mechanisms represents an eco-friendly method that offers many advantages over traditional approaches. The present study demonstrates the potential of some fungal strains to act on three synthetic textile colouring solutions based on Foron azo-dyes (Foron yellow brown S-2 RFL, Foron blue RD-S and Foron rubin RD-GFL). The experiments were carried out on solid and liquid media, using four microbial strains namely *Aspergillus niger* ATCC 20107, *Fusarium oxysporum* MUCL 791, *Cunninghamella echinulata* and *Polyporus squamosus*. These molds were analyzed in terms of laccase production by a screening method on solid medium containing guaiacol as substrate. The fungal potential for degradation of textile dyes was studied on Czapek Dox broth medium containing Foron dye, on an orbital shaker, at 150 rpm, 30 °C, for 5 days, in Erlenmeyer flasks. The absorbance of culture filtrates was measured by UV-Vis spectroscopy at the characteristic wavelength for each Foron dye. The decrease of absorbance in all samples has been assessed, showing remarkable values in the culture of *Aspergillus niger* ATCC 20107, where the percent of discoloration was more than 90%. This study demonstrates the capacity of fungal biomass to degrade the textile azo-dyes into non-colored intermediates and can be considered promising alternative to conventional technologies.

Key words: discoloration, textile dyes, laccase, fungi

INTRODUCTION

Textile industry is one of the leading promoters of global pollution, resulting in a textile finishing processes wastewater quantities exceeding 200,000 tons annually (Ogugbue et al., 2011). In addition, the industry is supported by an auxiliary industry that produces over 10,000 types of dyes from which over 700,000 tons of synthetic dyes (Robinson et al., 2001, Ogugbue et al., 2011). The increasing demand of textile materials resulted in increasingly water consumption in specific processes of dyeing and finishing (Przystaś et al., 2012).

Effluent treatment processes in the textile industry are presently achieved by various techniques including methods of sedimentation, filtration, flotation, coagulation, osmosis, solvent extraction, adsorption, incineration, etc (Archna, Lokesh et al., 2012). The treatment done solely by one of these methods proved to be insufficient leading to the need for their combination.

Biological treatments of wastewater from textile industry could be less expensive alternative techniques compared to the physical and chemical methods. These methods are based on treatment processes of polluting agents by biosorption, bioaccumulation or by enzyme biotransformation. Different species of fungi have been successfully used in bioremediation of effluents coming from the textile industry (Kaushik et al., 2009), which are capable of producing various iso-forms of extracellular oxidases including laccase, lignin peroxidase (LiP) and Mn peroxidase, enzymes involved in lignin degradation and various xenobiotic compounds including textile dyes (Wesenberget et al., 2003). Different species of *Aspergillus, Trametes* (Ramírez-Montoya et al., 2015) and *Phanerochaete chrysosporium* (Espinosa-Ortiz et al., 2015) were tested in the biodegradation processes of industrial effluents.

Due to relatively low degrees of fixing dyes on textile fibres, textile effluents present significant degrees of dye loading. The presence of dyes in textile industry wastewaters, even in concentrations of less than 1 mg/L, significantly affects the aesthetic properties and the transparency degree of public water effluents with direct environmental repercussions (Ibrahim et al., 1996).

Azo dyes group is one of the most important classes of synthetic dyes used in the textile industry, representing more than 60-70% of dyes used in the industry (Khehra et al., 2005). During the dyeing textiles processes, the amount of dye that is not retained on the fibre varies depending on its nature, ranging between 2% and 50% (Sheth et al., 2009; Watanapokasin et al., 2008).

The presence of dyes in water effluents reduces the sunlight passing through water, reaching with difficulty in lower volumes; it affects the photosynthesis activities of aquatic flora, lowering the concentration of dissolved oxygen, with negative effects on aquatic flora and fauna (Nilsson et al., 2006). Toxic effect of azo dyes may be a result of its direct action or of the amine derivatives resulted from biotransformation of azo groups (Rajaguru et al., 1999); ingested azo dyes can be metabolized to aromatic amines by azo reductases of microorganisms that inhabit the gastrointestinal tract.

Laccases (benzenediol: oxygen oxidoreductases; EC 1.10.3.2) are copper-containing enzymes belonging to the group of blue copper oxidases. These enzymes are responsible for the oxidation of a variety of phenolic compounds as well as aromatic amines with the reduction of molecular oxygen to water. In addition, in the presence of small molecular-weight compounds named redox mediators, laccases are able to oxidize non-phenolic structures (Sheikhi et al., 2012). Laccase and laccase-producing microorganisms play an important role in bioremediation of aromatic substances from contaminated soils, industrial pollutants and xenobiotics. The most extensively studied applications of laccases include denim finishing, pulp delignification, textile dye bleaching, wastewater detoxification and transformation of antibiotics and steroids. Laccases are generally found in plants and fungi from the genera *Aspergillus, Fusarium, Penicillium, Agaricus, Pleurotus, Phanerochaete* and others (Viswanath et al., 2008; Jebapriya et al., 2014).

The aim of this study was to evaluate the laccase production of four fungal strains and the discoloration of synthetic textile dyes by fungal biomass.

METHODS

Fungal strains and screening for laccase activity

The discoloration of textile azo dyes was assayed for four fungal strains: *Aspergillus niger* ATCC 20107, *Fusarium oxysporum* MUCL 791, *Cunninghamella echinulata* and *Polyporus squamosus* from the culture collection of Microbiology Laboratory, Faculty of Biotechnical Systems Engineering.

The fungal strains were cultivated on Potato Dextrose Agar (potato extract 4.0 g/L, glucose 20.0 g/L, agar 15.0 g/L) supplemented with 0.02% guaiacol (≥98.0%, SIGMA) for the assessment of laccase production. The fungal submerged cultures were cultivated in Czapek Dox broth (sucrose 30.0 g/L, $NaNO_3$ 3.0 g/L, K_2HPO_4 1.0 g/L, $MgSO_4$ 0.5 g/L, KCl 0.5 g/L, FeSO4 0.01 g/L, final pH 7.3).

The discoloration activity of the fungal biomass was assessed using three textile azo dyes:

1. FORON Yellow brown S-2RFL (Clariant) known as Disperse Orange 30 (molecular structure - single azo class, Molecular formula $C_{19}H_{17}Cl_2N_5O_4$, Molecular weight 450.27 g/mol);
2. FORON Blue RD-S (Clariant), commercial name Disperse Blue 79 (molecular structure - single azo class, Molecular formula $C_{24}H_{27}BrN_6O_{10}$, Molecular weight 639.41 g/mol);
3. FORON Rubin RD-GFL (Clariant) commercial name Disperse Red 73 (molecular structure - single azo class, Molecular formula $C_{18}H_{16}N_6O_2$, Molecular weight 348.36 g/mol).

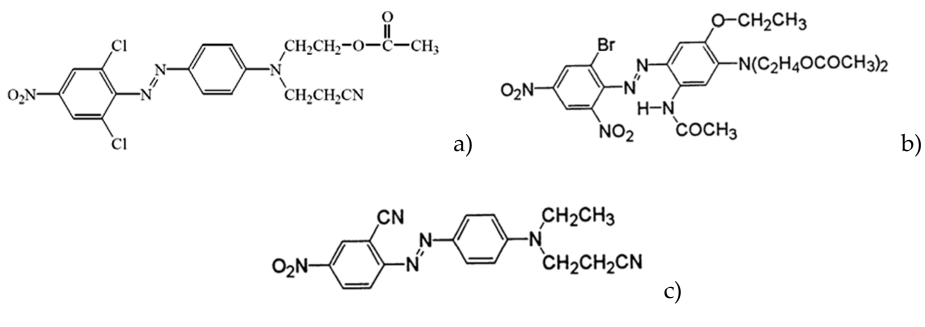

Fig.1 Structural formulas of
a) FORON yellow brown S-2RFL; b) FORON Blue RD-S; c) FORON Rubin RD-GFL

The absorption spectra in VIS domain were recorded for all three azo dyes and the wavelength for maximum absorbance (λ_{max}) was measured. A calibration curve (absorbance at λ_{max} against known concentration) was plotted to determine the concentration of each dye in samples.

Assay of dyes discoloration

Quantitative discoloration studies were carried out using the fungal cultures grown in 500 mL Erlenmeyer flasks containing 200 mL of Czapek Dox medium, on a rotary shaker at 150 rpm, 30 °C. The flasks were inoculated with 10 mL of 72 h old culture in Czapek Dox medium for each fungal strain.

After 3 days of incubation the synthetic azo dyes were added in the cultures as single dye solution. The specific absorbance of each sample was determined using a UV-VIS spectrophotometer (T92+, PG Instruments) at different time intervals. The percentage of discoloration was calculated using the following formula:

$$Discoloration\ (\%) = \frac{Ai - Af}{Ai} \times 100$$

where Ai is the initial absorbance, after adding the dye and Af is the final absorbance.

The final values of pH and total dry biomass were determined in the fungal cultures. After 8 days of incubation (5 days with the azo dye) the filtered wet biomass was weighed and the percent of dry matter was determined at 103 ^{O}C using a thermobalance (Kern RH 120-3).

All assays were carried out in triplicate.

RESULTS AND DISCUSSION

Four fungal strains were selected after the assessment of laccase production using the method with guaiacol. It was observed that the laccase-producing strains developed brown color in Potato Dextrose Agar supplemented with 0.02% guaiacol after 5 days, at 30 °C. The selected strains were *Aspergillus niger* ATCC 20107, *Fusarium oxisporum* MUCL 791, *Polyporus squamosus* and *Cunninghamella echinulata* that developed brown colour around the margin of the colonies. The absorption spectra of the textile dyes were recorded and the characteristic wavelengths for maximum absorbance were determined: 461nm for FORON yellow S-2RFL, 579 nm for FORON blue RD-S and 574 nm (secondary maximum at 615 nm) for FORON rubin RD-GFL. The concentrations of residual dyes were determined using the calibration curves shown in figure 2.

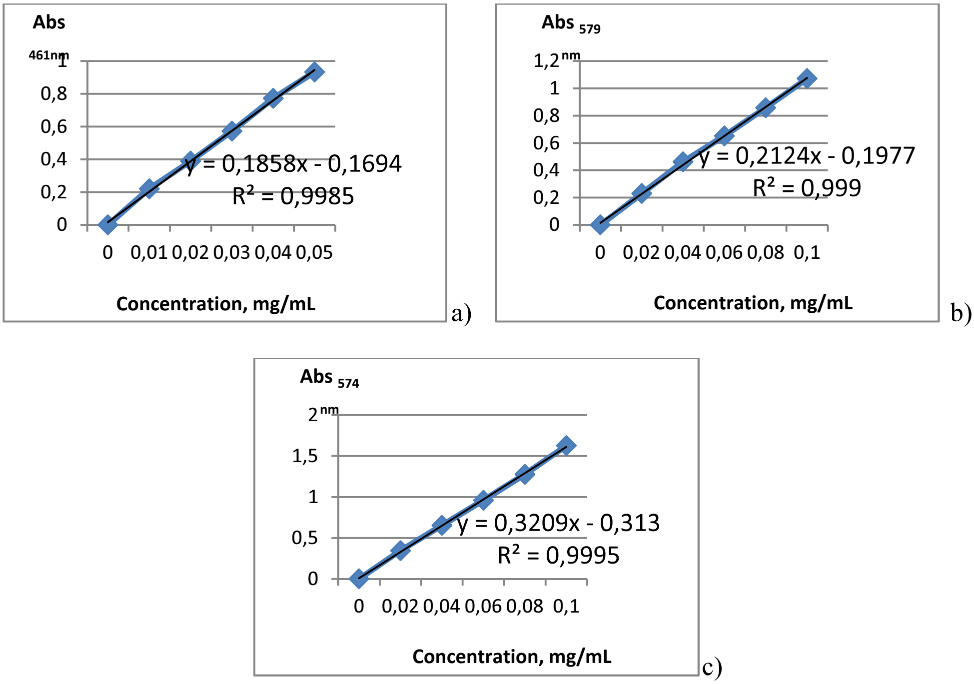

Fig.2. Calibration curves for
a) FORON yellow brown S-2RFL b) FORON blue RD-S c) FORON rubin RD-GFL

After 72 hours of incubation at 30 °C, 150 rpm, in the fungal cultures *of F. oxysporum, P. squamosus* and *C. echinulata* biomass was accumulated as filamentous structures while in the culture of *A. niger* the fungal growth in the form of pellets was observed.

In order to assess the discolouring activity of the four fungal strain, in the 3-days old cultures on orbital shaker the textile azo dyes have been added in the following concentrations: 0.05 mg/mL FORON yellow, 0.10 mg/mL FORON blue and 0.10 mg/mL FORON rubin, in order to obtain initial absorbance values in the domain of linearity of standard curve and to avoid dilution errors. The characteristic dye absorbance for each dye was determined at different intervals (4, 8, 24, 48, 72, 96, 120 hours) in the culture filtrate. The results are shown in figure 3 a, b, and c and demonstrate that even after the first 4 hours of incubation the absorbance decreased considerably in all samples.

The obtained results demonstrate that all azo dyes undergone a partial or quite total biodegradation in the fungal cultures, after 5 days. The specific absorbance decreases suddenly in the first 24 hours but slowly in the next time interval. This discoloration of textile dyes is due to the laccase action, but the absorption of pigments on the fungal biomass was also possible.

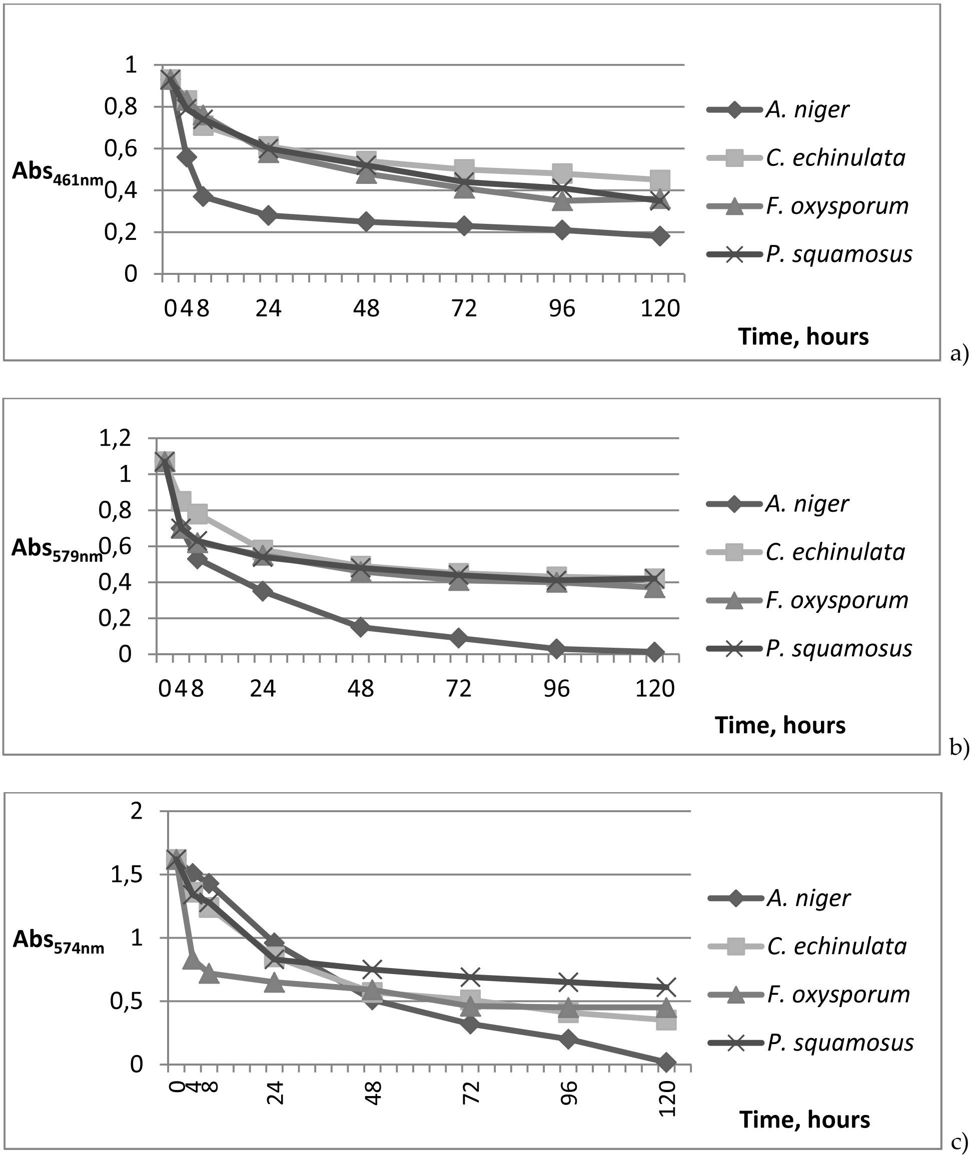

Fig.3 Absorbance values in fungal cultures containing
a) FORON yellow brown S-2RFL b) FORON blue RD-S c) FORON rubin RD-GFL

The greatest degree of biodegradation for all dyes has been observed in the cultures of *Aspergillus niger* ATCC 20107. For example, the concentrations of FORON blue and FORON rubin decrease from 0.1 mg/mL to about 0.001 mg/mL. In the samples of FORON yellow, the concentration has varied from 0.05 mg/mL to 0.009 mg/mL after 5 days. In the cultures of *F. oxysporum, C. echinulata* and *P. squamosus* the decrease of dyes' concentration was not so great, but higher than 50%. The weakest degradation activity was shown in the cultures of *P. squamosus* for all the dyes, although the biomass concentration was the highest (figure 4).

The percentage of discoloration for all fungal cultures after 5 days is illustrated in figure 4. The discoloration depends on the fungal strain and type of textile azo dye. After 5 days of incubation the discoloration ranges between 52% and 80% for FORON yellow, 58% and 98% for FORON blue, 62% and 98% for FORON rubin, the greatest values being determined in the cultures of *Aspergillus*.

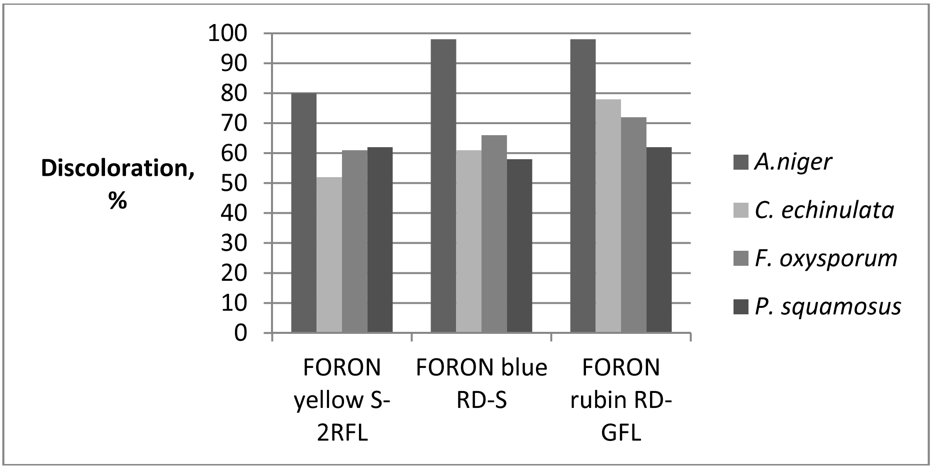

Fig. 4 Discoloration percents of azo dyes in the cultures of *A. niger* ATCC 20107, *F. oxysporum* MUCL 791, *C. echinulata* and *P. squamosus*

The obtained results are in accordance with other studies regarding the ability of fungi to produce laccase and to degrade azo dyes. Laccase activity in fungi has been detected for *Phanerochaete chrysosporium, Chaetomium globosum, Sterea ostreatus* and other fungi that produce laccase in different liquid media (Viswanath et al., 2008). In 2014 Jebapriya and Gnanadoss reported a percentage of discoloration of brilliant green, bromophenol blue, congo red, methyl red and phenol red between 33% and 98% using twenty two white rot fungi, after 15 days of incubation. A consortium containing *Bacillus cereus*, *Pseudomonas putida*, *Pseudomonas fluorescencens* and *Stenotrophomonas acidaminiphila* was able to decolorize Acid Red azo dyes in percentage between 78% and 99% (Khehra et.al, 2005). In 2012 Archna Lokesh and Siva Kiran described the use of a microbiological method for dye degradation using bacterial strains (*Bacillus, Pseudomonas*) and fungal strains (*Aspergillus, Pleurotus, Trichoderma*) with the ability to produce laccase.

In table 1 the final values of pH and biomass are presented. The different values of final pH (initial pH 6.3 in Czapek Dox broth) are probably due not to the added dye, but to the specific metabolites of utilized fungi. The amount of biomass seems to have less influence on the discoloration, as is shown in the case of *Polyporus* culture that has a maximum production of biomass but lower percentage of discoloration.

The obtained results demonstrated that the selected, high producing laccase microorganisms can successfully be used in the textile wastewater treatment. Biotechnological methods should successfully replace chemical and physical methods or can be combined.

Table 1 PH and dry biomass in fungal cultures after 5 days of incubation with azo dyes

Fungal strain	Final pH			Dry biomass (g/L)		
	FORON yellow S-2RFL	FORON blue RD-S	FORON rubin RD-GFL	FORON yellow S-2RFL	FORON blue RD-S	FORON rubin RD-GFL
A. niger	5.58	4.42	4.53	3.1	3.2	2.9
C. echinulata	9.01	8.37	8.23	4.7	4.3	4.6
F. oxysporum	7.63	7.49	7.62	3.9	4.2	4.5
P. squamosus	8.14	7.93	8.02	6.3	6.5	6.6

CONCLUSIONS

An interesting future perspective regarding biological methods for textile wastewater treatment is the use of oxidative breakdown potential of laccases produced by microbial strains.

Four fungal strains namely *Aspergillus niger* ATCC 20107, *Fusarium oxysporum* MUCL 791, *Cunninghamella echinulata* and *Polyporus squamosus* were selected on the basis of laccase production ability and cultivated in Czapek Dox broth supplemented with textile azo dyes after 120 hours of cultivation. The assessment of discoloration percentage demonstrated that all fungi were able to biodegrade textile azo dyes to some extent after 5 days of incubation at 30 °C in submerged, shaken cultures.

The degree of discoloration depends on the fungal strain and the structure of azo dye. The discoloration ranged between 52% and 80% for FORON yellow, 58% and 98% for FORON blue, 62% and 98% for FORON rubin, the greatest values being determined in the cultures of *Aspergillus niger* ATCC 20107.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC
631.35
Prethodno priopćenje
Preliminary communication

COMPARING THE EFFICIENCY OF AUTOMATED VERSUS MANUAL STEERING DURING GRASSLAND HARVEST OPERATIONS IN WESTERN AUSTRIA

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SUMMARY

In recent years, there has been a growing interest in GPS-based steering systems for agricultural processes. The objective of this study was to investigate differences between manual steering (mL) and automated steering (aL) with regard to operating time, fuel consumption, and working width during the operations mowing, tedding and swathing on intensively managed grassland in western Austria. Of six equal plots (0.79 ha each) on a five-cut grassland in western Austria, three plots were harvested using tractors with aL during straight driving and three were harvested with manually steered tractors. The largest difference between mL and aL steering was observed with the on-field operations time. On average, mowing time per plot was only 10.72 minutes with manual steering, but 15.28 minutes with automated steering, mainly because of difficulties with aL steering finding the straight track when exiting headland turns. Also, the manual steering paths for mowing proved to be more efficient. Single-section (straight section and headland turns) data for mowing operations support this interpretation. With swathing, the results show the opposite: The aL plots were completed in a 15.55% shorter time than the mL plots. This may in part be explained with frequent reversals during mL headland turns, while the aL turns skipped swathing lanes. Fuel consumption per plot was slightly, but not significantly lower during aL swathing. The aL tracks used 5.47% more of the single-track working width during mowing, and 4.45% more during swathing. Potential improvements of aL results may be realized by optimizing the automated steering path, particularly with wider implements, and by reliable track-finding during automatic steering.

Keywords: automated steering; GPS; precision farming; grassland; mowing; tedding; swathing; efficiency; operating time; fuel consumption

INTRODUCTION

In recent years, there has been a strong movement in agricultural engineering towards integrating precision farming technologies into agricultural processes. GPS-based automated steering systems can make an important contribution to more efficient cultivation and harvest operations (Holpp 2006). Their accuracy and thus relevance to agricultural practice has been drastically improved by a variety of correction systems that compare the known position of a ground-based station with its GPS-calculated position and use this information to generate a correction signal for a nearby mobile GPS receiver on a tractor or other machine (Treiber-Niemann et al. 2013). One such system is the RTK (real-time kinematics) automated steering system that can achieve a track-to-track accuracy of 1cm to 5cm (Demmel 2006). Automated steering systems make use of RTK-enhanced geopositioning by controlling a vehicle's steering hydraulics through a NAV controller.

A number of studies have compared the performance of automated steering systems to that of manual steering systems. Qualitative advantages of automated systems include the ability to work under conditions of poor visibility, consistent track following even during long working hours, and increased working speed (Demmel 2008, Treiber-Niemann et al. 2013, Moitzi et al. 2006). Landerl (2009) compared manual steering and automated systems on cropland in Austria. Automated steering was superior with regard to effective working widths (i.e., lateral overlap between implement tracks), fuel consumption, and labour requirements, but a return on investment was only observed with cultivated areas of 268 ha or larger. Most studies on the effects of automated steering, though, have been conducted in arable farming, and comparatively little is known on the effects of automated steering in grassland operations.

Therefore, the present study focuses on grassland harvesting operations, and its objective is the differentiation between manual steering (mL) and automated steering (aL) with regard to operating time, fuel consumption, and working width during the operations mowing, tedding and swathing on intensively managed grassland in western Austria.

METHODS

Grassland harvesting operations were conducted on an intensively managed, five-cut grassland site in western Austria that is part of a dairy cattle farm. The site was subdivided into six equal-sized, rectangular plots of 0.79 ha each (Figure 1). Three randomly selected plots (P1, P3, P6) were harvested using tractors with aL during straight driving and the three remaining plots (P2, P4, P5) were harvested with manually steered tractors during the 2015 grassland season. Data were recorded for the harvesting operations of mowing, tedding and swathing during the fourth cut in September 2015.

Mowing operations were conducted with a 96-kW Steyr tractor (model "4130 Profi" with continuously variable transmission; Steyr CNH, St. Valentin, Austria), equipped with an S-Guide RTK (Steyr CNH, St. Valentin, Austria) automated steering system. The mower was a EUROCAT 316F Classic front-mounted drum mower, combined with a NOVACAT 302 rear-mounted disc mower (both by Poettinger, Grieskirchen, Austria). Tedding and swathing were conducted with a smaller 84-kW Steyr tractor (model "4115 Multi" with manual transmission; Steyr CNH, St. Valentin, Austria), equipped with an XCN 2050 RTK (Trimble Inc., Sunnyvale, U.S.A.) automated steering system. Both steering systems used allow for pre-programmed straight driving, but the headland turns have to be completed with manual steering. The implements were a six-rotor "Euro-Hit 80 NZ" tedder, and a single-rotor "Euro TOP 421 N" swather (both by Poettinger, Grieskirchen, Austria).

Figure 1 Experimental site in Western Austria. Six plots at 95 x 84 meters (0.79 ha) each. Plots P1, P3, P6 = automated steering; plots P2, P4, P5 = manual steering (Mauch 2016).

On the mL plots P2, P4 and P5, the driver chose the working paths according to his own preferences and depending on the operation; the chosen path was the same on all three mL plots. For aL operations on plots P1, P3 and P6, the straight path tracks were pre-programmed in advance using the Farm Works software (Farm Works Information Management, Hamilton, U.S.A.). This was done prior to the field experiment, by defining a suitable set of parallel, straight "multi-swath" tracks with adjustable between-track distances for each plot. Pre-programmed working widths (automated steering) were maximized so as to still ensure complete coverage of the area, accounting in particular for lateral acceleration of the implements when transitioning at speed from a headland turn into the straight track. For mowing with the asymmetric front-rear mower assembly, pre-programmed paths also accounted for the mower's asymmetry by offsetting the planned tracks laterally by an appropriate distance. This resulted in unequal distances between tracks during mowing. Swathing tracks were equidistant for double swathing.

Data during harvest operations were obtained from the tractors' CAN-Bus System through their diagnostics interface, using a Vector GL-3000 data logger (Vector Informatik GmbH, Stuttgart, Germany). The data included the RTK-corrected GPS position (2,5 cm track-to-track accuracy), a timing signal generated by the logger, and the momentary fuel consumption, as well as other data related to the tractor operation. An additional, uncorrected backup GPS position (Garmin GPS18xLVC; 3 m accuracy) was also recorded.

10-Hz Signals were assumed to be evenly spread between consecutive 1-Hz data logger time signals. As the main indicators of operational efficiency, the on-field operation time and the average fuel consumption were calculated. The rear hitch sensor signal was used to differentiate between path sections, that is, between the straight-driven tracks and the headland turns. The effective working width for each operation was also calculated for mowing and swathing operations, by dividing the width of the area covered in a plot by the number of tracks, thus accounting for overlaps between tracks.

Data analysis was performed with Excel v. 15.0 (Microsoft Co., Redmond, U.S.A.) and Matlab v.5 (The MathWorks GmbH, Ismaning) software. Statistical analyses were performed using the SAS statistics software (SAS Institute Inc., Cary, U.S.A.), for a one-factor ANOVA, followed by a Student-Newman-Keuls post-hoc tests, and for a one-sided t-test with unequal variances for significant differences between plot results. For all tests, a significance level of $p=0.05$ was chosen.

RESULTS AND DISCUSSION

Whole-plot efficiency

The efficiency of harvest operations was measured through the on-field operating time and the average fuel consumption for each plot. The operating time, averaged over the three aL plots, was much longer during mowing operations than for the three mL plots - 15.28 minutes compared to 10.72 minutes on average (Table 1). However, the difference between aL and mL was not quite significant ($p=0.06$), due to large differences of operating times among the three aL plots. Plot-averaged diesel fuel consumption was significantly higher for automated mowing operations (by 20%), despite lower aL diesel consumption when single tracks were considered. The higher consumption for aL plots is in marked contrast to Landerl (2009), who found that aL steering saved 8.5% and 9% percent, respectively, of operating time and diesel consumption relative to the manually-steered operation of a short-disc harrow on cropland.

The unfavourable operating time and diesel consumption results for aL mowing can be explained to some degree by occasional track-finding problems when exiting headland turns. This required reversing the tractor, lost time and consumed fuel. Also, during mL mowing, the driver chose a relatively complex, but efficient driving path (Figure 2). The path consisted of two inward-propagating elongated spirals, thus avoiding narrow headland turns, with faster turns and fewer passes to clear the headlands.

For tedding operations, data were only recorded on two aL and two mL plots. As with mowing, tedding operations took longer for aL plots (11.14 minutes versus 8.75 minutes for mL plots), with a significance level of $p=0.03$. Again, problems occurred with finding the track after a headland turn. A second, more generic reason for the advantage of manual steering during tedding may be that the machine was wide enough to allow wide and fast headland turns, even without skipping a track. In contrast, the automated paths were designed to ted every other track, requiring longer headland turning times than with mL tedding. Fuel consumption averages were also lower on the two mL plots, but the difference was not significant ($p= 0.07$).

Table 1 Averages of three steered (mL) and automatically steered (aL) whole-plot operating times and fuel consumption averages. For a given operation, equal superscripts denote no significant difference between aL and mL averages (p = 0.05; n=3 for mowing and swathing, n=2 for tedding).

	Mowing		Tedding		Swathing	
	aL	mL	aL	mL	aL	mL
Average operating time [min]	15.28±3.01[a]	10.72±0.41[a]	11.14±0.73[a]	8.57±0.50[b]	22.60±2.23[a]	26.76±1.26[b]
Average fuel consumption [l/hr]	4.32±0.41[a]	3.61±0.23[b]	1.15±0.04[a]	0.96±0.08[a]	2.46±0.23[a]	2.63±0.03[a]

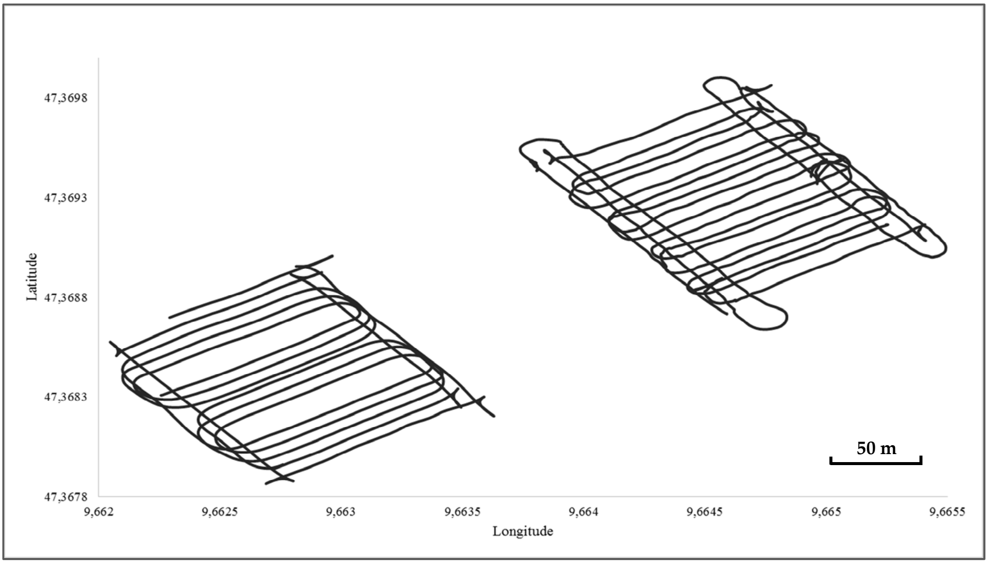

Figure 2 Driving paths during mowing operations. Manually steered path (as chosen by driver) is shown on the lower left, automated mowing path is shown on the upper right. The aL path on the upper right is based on relatively inaccurate uncorrected GPS data.

In contrast to mowing and tedding, automated swathing operations required 15.55% less time than manual swathing (22.60 minutes per aL plot, 26.76 minutes per mL plots), saving 15.55% time. Demmel (2006) reported 35% time savings for headland turns when reversing was avoided with automated seeding of sugar beets. Manual swathing turns were more time-consuming because the narrow working width (3.3 m) of the swather required reversing headland turns for side-by-side manual swathing tracks. This is in contrast to the automated tracks which skipped every other track with faster, non-reversing headland turns in between. The average diesel fuel consumption was also lower for the aL plots, but the difference was not significant due to large variability between aL plots (Table 1).

Single-track efficiency

For mowing, single-track data (headland turns and straight sections) of pooled aL and mL plots were compared with respect to operating time and average fuel consumption. Manual headland turns took significantly less time than aL turns (Figure 3), with a significantly higher average speed (data not shown) during mL turns. This can be explained by the aL track-finding problem mentioned above, missing the beginning of the straight track sections. The time required for the straight track sections was similar between mL and aL: Mowing of the headland shortened the aL straight sections, but this was compensated during mL mowing by higher average driving speeds made possible by faster turns in the mL path (Figure 2).

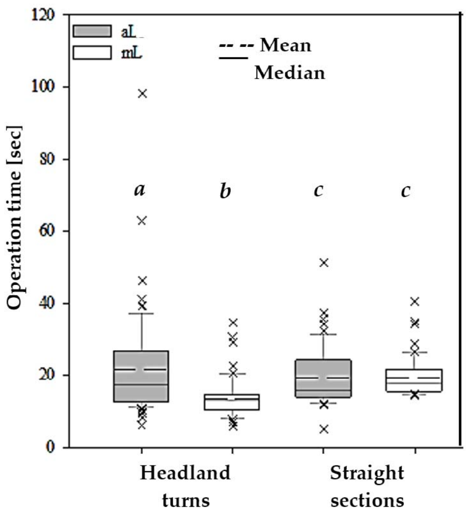

Figure 3 Operating time per mowing track section (headland turns and straight sections), all plots combined. Cursive letters indicate significant differences between aL and mL sections (one-factor ANOVA, p = 0.05).

When the average fuel consumption per single-track section was compared, automated steering was significantly more fuel efficient than manual steering both in the headland turns and in the straight sections (Figure 4). Conceivably the automated steering pattern (Figure 2) led to sharper headland turns and somewhat shorter straight sections (due to extra headland passes), which in turn resulted in lower aL average speeds and in a lower average fuel consumption.

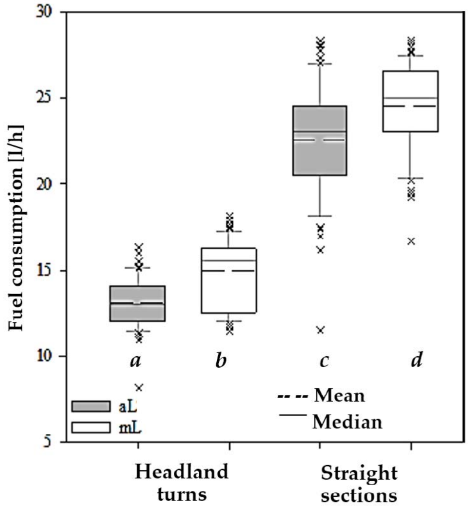

Figure 4 Average fuel consumption per mowing track section (headland turns and straight sections), all plots combined. Cursive letters indicate significant differences between aL and mL sections (one-factor ANOVA, p = 0.05).

Effective working width – manual versus automated steering

Single-track working widths measured prior to the experiments were compared to effective (i.e. track-to-track) working widths as determined during mowing and swathing (Table 2).

Table 2 Comparison of working widths. Nominal working widths as per manufacturers' specifications. Single-track working width was determined on site prior to field operations, effective (track-to-track) working width measured on-site.

	Mowing		Swathing	
	aL	mL	aL	mL
Nominal working width [m]	6.09		4.20	
Single-track working width [m]	5.70		3.30	
Effective working width [m]	5.52	5.21	3.30	3.15
Utilization [1] [%]	96.80	91.33	100	95.55

[1)] utilization = effective working width as a percentage of the single-track working width.

To illustrate how effectively the single-track working width was utilized during actual on-field operations, the effective working width is given as a percentage of the single-track working width. For comparison, nominal working widths as per manufacturer's specifications are also shown. During mowing, manual steering utilized less of the single-track working width than automated steering. This result matches literature findings: Holpp (2006) reports that automated steering increased the effective working widths and thus decreased labour requirements in grassland by one to two percent. Shinners et al. (2010) found that a working width loss due to overlap was reduced from 5.03% with manual steering to 2.34% with automated steering in grassland.

During swathing more of the single-track working width was utilized than during mowing, both for manual and automated steering. This may be explained in part by slower speeds during swathing that allow more accurate driving and less overlap between tracks. Another explanation may be that less lateral movement was caused by the lighter and more symmetric single-rotor swather when transitioning from the headland turn into the straight path section, in contrast to the wider and asymmetric rear mower implement.

CONCLUSIONS

Automated mowing operations (only straight tracks automated; headland turns executed manually) on small grassland plots were less efficient than manual steering, as measured by plot totals of working time and average fuel consumption. Mowing a plot manually took an average of 10.72 minutes, while automated mowing took 15.28 minutes on average, and the average fuel consumption was 20% higher on aL plots. Reasons for less efficient aL mowing include problems with finding the track when exiting a headland turn, and a more efficient manual driving pattern that allowed for faster headland turns. This pattern also compensated for the lower fuel consumption of single automated tracks, resulting in a lower overall fuel consumption for manually mowed plots.

Automated tedding operations also were less efficient than manual operations in terms of operating time (11.14 minutes per plot versus 8.75 minutes), with non-significant differences in fuel consumption. Reasons were similar to mowing – track-finding problems and an efficient manual tedding path.

In contrast to mowing and tedding, automated swathing was 15.55% more efficient than manual swathing, with 22.60 minutes spent on average per aL plot versus 26.76 minutes per mL plot; fuel consumption differences were non-significant. This was due to the narrow implement width of the swather used, which required reversing headland turns during manual swathing of adjacent tracks. Automated swathing paths skipped every other track, which allowed for faster headland turns.

Working width utilization was higher for pre-planned, automated steering paths, particularly during mowing operations (by 5.47% more for aL paths, relative to single-track widths), but also for swathing (4.45% more with aL paths).

Overall, the field experiment provided data from a first experiment comparing automated and manual steering efficiency in grassland harvesting. Results demonstrate the importance of optimizing the automated steering path, particularly with wider implements, and of reliably finding the straight track when exiting the headland turns, regardless of operations.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Izvorni znanstveni rad
Original scientific paper

NAVIGATION AND PERSONAL PROTECTION IN AUTOMATIC FEEDING SYSTEMS

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SUMMARY

Market prices for agricultural products are increasingly volatile within the 21st century. Dairy farmers are forced to rationalize their production and improve efficiency. One way is to automatize routine work, like heat control, milking and walkway cleaning or pushing feed with self-propelled robots. Currently most common setups in practice are systems with static implements like feed belts/chains or rail-mounted feed distributors fed by reservoirs and stationary mixers (Nydegger and Grothmann, 2009). For all these systems additional external installations are needed. For young cattle housed in old buildings additional mechanization like a manual feed mixer is needed. The Siloking Truckline© is a combination of an automatic, driverless feed mixer and a manually useable, electric feed mixer. It can easily be trained to various stables. Therefor a concept for navigation and personal protection was designed and tested in preliminary experiments.

Keywords: automatic feeding, cattle

INTRODUCTION

Worldwide trading of agricultural products promises a variety of selling opportunities. Consequently the influence of global price levels, production standards and production volumes increases. Trade embargoes, interest rate policies and crop losses are clearly reflected in prices for agricultural products and generate strong volatility. This was particularly evident in milk and milk products after the end of the EU milk quota in April 2015. The liquidity and stability of many agricultural holdings is thus seriously endangered and compel farmers to rationalization and efficiency enhancement. The automation of work routines is already used in many areas, such as milking, bedding, manure removal, feeding or heat control. With the second highest required daily working time after milking, feeding offers a high potential for optimizing that until now only little is used by automation. With automatic feeding systems, working time can be made more flexible and saved, and the performance potential of dairy cattle herds can be better utilized. The aim of the joint research project, the Technical University of Munich (TUM) and the University of Applied Sciences Weihenstephan-Triesdorf (HSWT) in collaboration with the Mayer Maschinenbaugesellschaft mBH (Siloking), is the development and construction of an electrically driven self-propelled feed mixer, which can automatically feed forage.

METHODS

For the automatic feeding system Truckline© a functional and a design concept was first developed. In order to ensure maximum flexibility for the farmer, the approach of a self-propelled feed mixer was chosen. Mixing, transporting and tabling can be done manually by a driver or autonomously over several times a day. Rear-wheel steering at a length/width/height of 6,350/2,280/2,250 mm makes the compact vehicle very agile. This flexibility allows accomplishing various tasks, e.g. tabling feed automatically in new stables, feeding of young stock in old cowsheds manually or dosing in biogas plants automatically. The Truckline© thus corresponds to the automation level 1 „Automated Feed Dispensation“, according to Haidn et al. (2014). To keep the construction expenditure low and the silage secure of reheating the intermediate storage was intentionally renounced. Furthermore use cases were defined from which three operating modes were derived:

1. **Manual Mode** (*Standard*): The machine is operated and driven by a person.
2. **Stable Automatic** (*Optional*): The machine has been loaded and parked on the feed table by a person. The machine moves through the stable according to defined specifications and tables/pushes the feed to predetermined groups.
3. **Follow Me or Silo Transportation** (*Optional*): *Variant 1* The machine follows a guidance vehicle (electronically controlled towing bar). *Variant* 2 The machine goes to the silos (predefined filling points) on call (via radio, WLAN, etc.), can be filled and travels back to the parking station independently for mixing.

A safety concept was discussed and drafted in close consultation with the (Sozialversicherung für Landwirtschaft, Forsten und Gartenbau), the German social insurance institution for agriculture, forestry and horticulture. Foremost the DIN EN 1525-1997 standard influences this personal protection concept, as it did in previous automatic feeding systems. Furthermore reasonable additions from other standards are considered (such as VDI 2510-2012, ISO 26262-2011 or Machinery Directive 2006/42/EC). A risk assessment according to 2006/42/EC is still to be considered as the next step. The hazardous situations recorded there serve as a guideline for the definition of safety requirements.

In the navigation and personal protection concept, the environmental conditions that the automated machine expects in the agricultural environment are particularly important. From outdoor weather conditions to floor coverings and emissions especially in dairy cows. Navigation and safety technology must be able to handle these requirements reliably. State of the art solutions, such as laser scanners, cannot guarantee functionality due to their characteristics as optical system under very adverse conditions (Adeili et al., 2015). The radar technology, known from the automotive industry, is hardly affected by such weather conditions. It is insensitive to rain, fog, snow, dust contamination and has no requirements on light conditions (Cacilo et al., 2015). For navigation, the radar sensor maps its surroundings as precisely as possible, similar to a laser scanner. This was hitherto been limited due to poor angular resolution as well as poor distance resolving power. By now developments in radar technology took place to meet the requirements of such navigation tasks.

From the functional, design, navigation and safety concepts a specification has been formulated that summarizes the requirements for the machine. Preliminary test show the basic suitability of radar as a technology for navigation and for personal protection.

The preliminary experiment 1 was carried out by Innok Robotics Ltd. with a radar evaluation board. The aim was to determine performance parameters. In a closed room, the evaluation board was aligned at a height of 0.6 m on three different radar reflectors. One person (no metal objects on the body) stood at different positions between sensor and reflectors. The person in front of the reflectors fully covered the sensors radar lobe. The distance resolution of the radar was 2 cm.

In preliminary experiment 2, distance measurements were carried out with a laser scanner and a radar evaluation board under the difficulties of artificial generated mists. These tests took place in a closed machine hall on the testing farm Dürnast (TUM). In the static test set-up an LMS100 outdoor laser scanner from SICK and a radar evaluation board were used. During the tests the LMS100 was operated exclusively with the fog and particle filter activated. The sensors were aligned vertical to a target object (400 by 400 mm) with a thickness of only 5 mm (Fig. 1). Both sensor and the target object were located at about 2.40 m height, each mounted on a mobile scaffold or on strings. The reason for the attachment was the characteristic of the radar technology with a lobe shaped propagation and blurring boundaries. The strings consisted of polypropylene (PP) with a diameter of 3 mm. The distances were varied between 0.5 m and 12 m in different test runs. In 0.5 m- and 1 m-steps flat-beam plant protection nozzles (Lechler, Germany) were installed between sensors and target object, which formed a mist curtain vertical to the detection direction (Fig. 2). They could be controlled individually or simultaneously in any order.

For preliminary experiment 3, the radar sensor system was used for the first time as a rotating scanner. For the first time contour was recorded and visualized from different rooms. The scanner worked with an updating rate of the measured data of 1 Hz with an angular resolution of 50 measurements per full (360°) rotation.

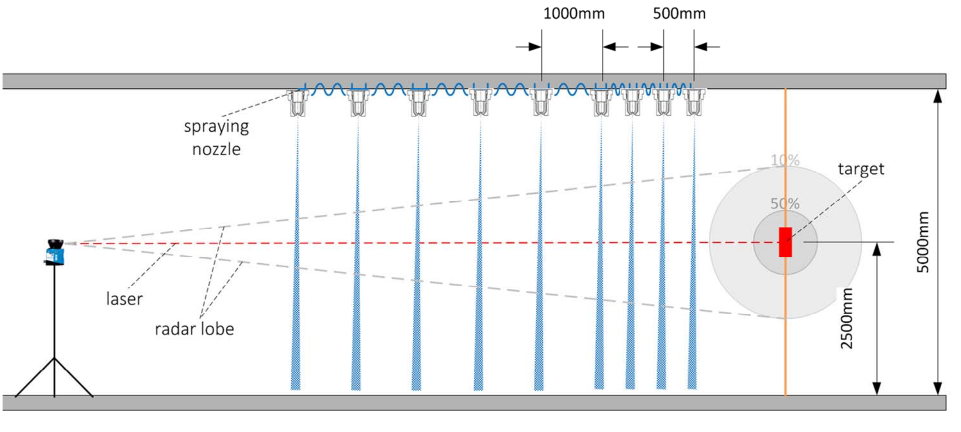

Fig. 1: The schematic structure of the static test set-up. You can see the sensor system (left) aligned to the target object (right) with up to nine fog slopes in between.

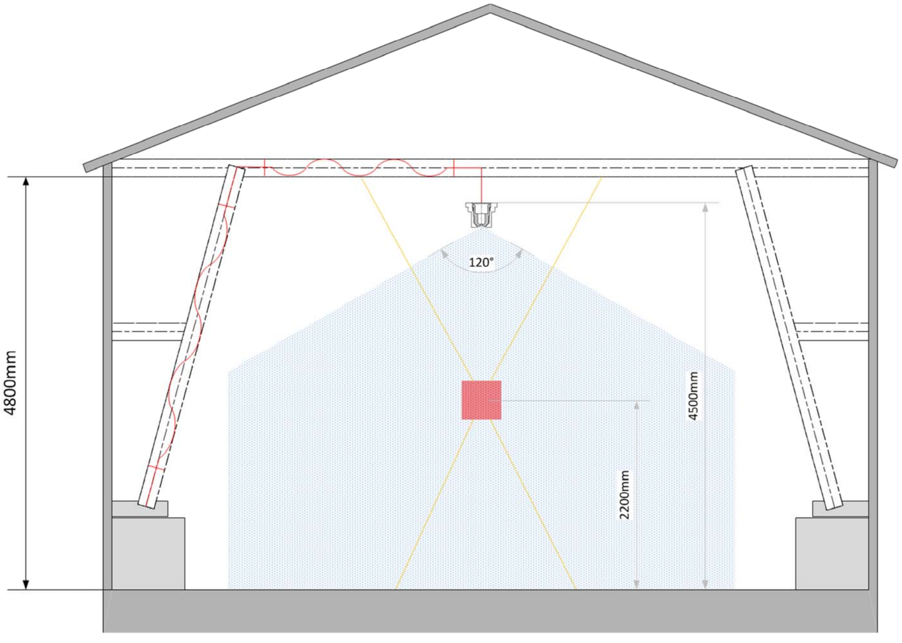

Fig. 2: The sensor's POV with the schematic nozzle setup.

RESULTS AND DISCUSSION

Preliminary test 1 was able to demonstrate the performance of the evaluation board by means of the parameters measurement accuracy, distance resolution and target separation capability. The measurement accuracy in the tests was better than 5 cm, sufficient for navigation tasks indoor and outdoor. The distance resolution was 2 cm which allows a very detailed perception/mapping of the environment. The target separation capability is directly dependent on the distance resolution. With a distance resolution of 2 cm objects can be distinguished at more than 4 cm space from each other. In Fig. 3 the three reflectors (number 1 to 3) and the person are clearly visible. Graph 3 shows that the person is also distinguishable from reflector 1 in the direct vicinity (10-15 cm). In addition, it was found that all reflectors could be clearly recognized even after the radar lobe had been covered by the person. The data obtained clearly stood out from the system noise that starts from about -75 dBVms downward.

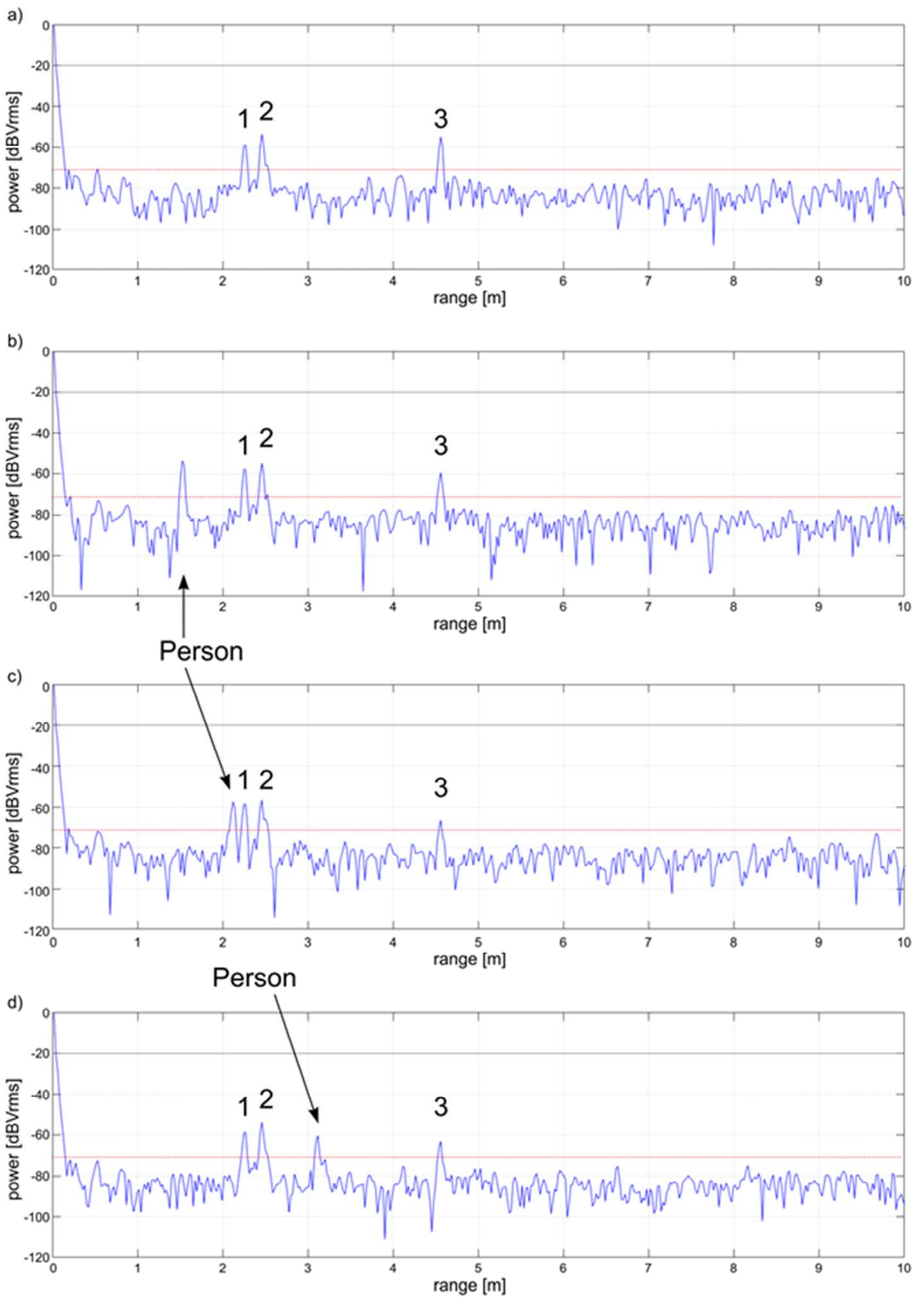

Fig. 3: The graphs show the reference measurements. In measurement (a) no person was involved, in graph (b) a person stood between the sensor system and reflectors 1 and 2. Graph (c) shows a person directly in front of reflector 1 and in Graph (d) the person stood between reflectors 2 and 3.

In preliminary experiment 2 it was shown that the artificially generated mist curtains strongly limited the laser scanner in its functional capability. On the other hand, radar technology was unaffected by these curtains. Fig. 4 shows the measurement of the target object at 3.6 m distance without artificial mists [1], with 1 mist curtain [2], with 2 mist curtains [3] and with 3 mist curtains [4]. In variant [1], the target object was clearly detected. As soon as mist curtain was generated 1 m in front of the target object a clear displacement of the measuring points could be observed. Adding a second and third mist curtain in shifts of half a meter towards the scanner also showed the displacement of the measuring points towards the sensor. In only a few cases the laser beam penetrated one mist curtain and hit the target object behind it. In case of two mists the laser beam could not detect the target object at any time. The finely atomized water particles in the air reflect the laser beam differently, whereby the measuring points fluctuate in a small area. The radar evaluation board had no problem detecting the target object through 9 mist curtains at a distance of 10 m. In the range of 10 to 12 m the target object was not visually separable from the system noise anymore.

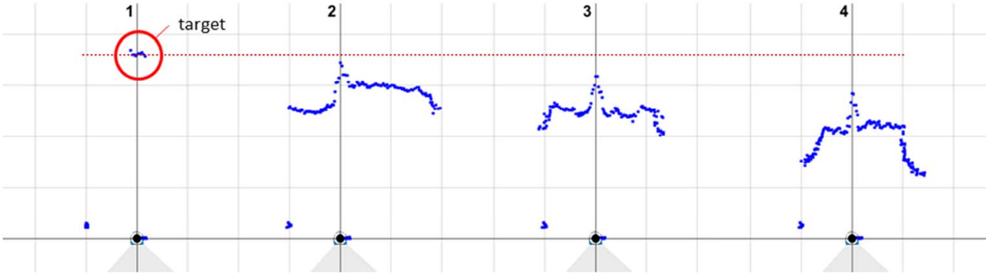

Fig. 4: The sensor's view in detail. Illustrated are the variations without fog [1], with 1 wall of fog [2], with 2 walls of fog [3] and with 3 walls of fog [4]. The graphic is based on an box grid with edge length of 1 m.

In Fig. 5 the visualization of the radar scanner data generated in preliminary experiment 3 is shown. The measuring range was limited to 3.5 mm in this experiment. Three walls, a table and a person could be recognized at this distance. The bright areas signal a high reflection intensity, which suggests objects. Especially the parts of the walls aligned vertically to the scanner are highly reflected because of the linear spreading characteristic of radio waves. Movements of persons can be traced in real time and the direction and speed of the movement could be determined in the data. Overall, angular resolution and updating rate of the measurements must be further increased in order to achieve better navigation and personal protection performances.

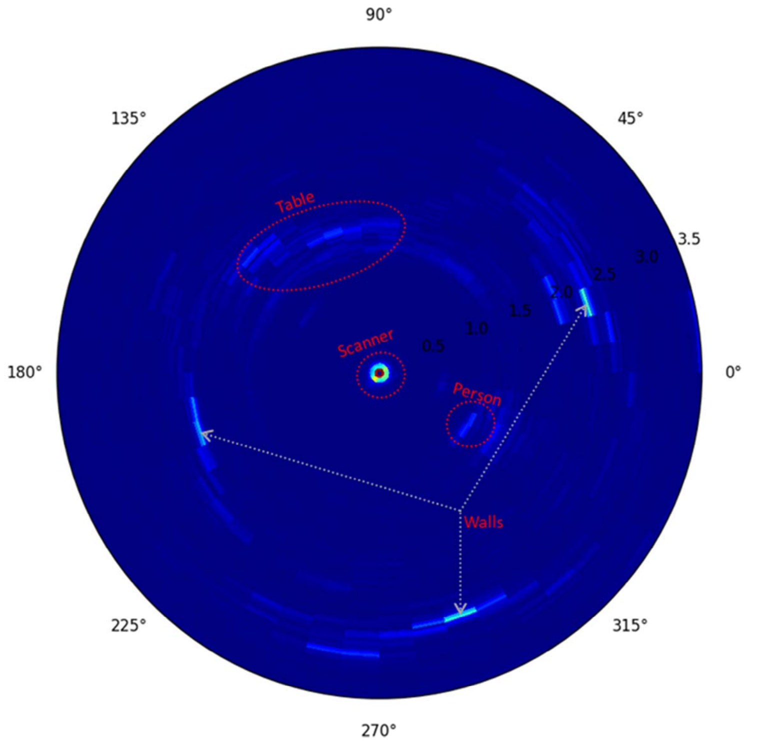

Fig. 5: Visualized data from the radar scanner placed in a room.

CONCLUSIONS

As expected, radar technology shows great potential for object detection under adverse conditions. First the advantages in adverse conditions against laser technology are due to the physical properties of the measurement methodology. The laser running time measurement takes place optically and comes to its limits quickly by means of reflecting surfaces. Radiation technology, on the other hand, uses electromagnetic waves that are reflected by electrically conductive bodies. If an object has poor electrical conductivity (such as plastics) the radio waves are only partially reflected and a predominant part penetrates the object. Second, the processing of the data obtained determines the performance of a sensor. Here, the laser scanner certainly has the potential to adapt to the adverse circumstances. The stock laser scanner with all additional data filters reaches its limits at the moment however with mists.

In order to be used for navigation and personal protection tasks, the radar scanner of the first generation has to be further improved in the measurement frequency and angle resolution. If the hardware hits the set targets, the radar scanner is a very good option for navigation and personal protection tasks. Which set-up is ultimately necessary must be clarified in the context of a risk assessment of the machine.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

POSSIBILITIES OF USING THE ROBOTS IN GREENHOUSES

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SUMMARY

Nowadays the presence of robots in greenhouses is useful and actually. The new intelligent greenhouses must be well equipped with integrated systems for water control, temperature control, humidity control, wind control, chemical and organic control by the mean of many other sensors etc. So, the „external conditions” are already prepared and monitored. The paper presents analyze based on some technical and economic aspects (considered the most important criteria), regarding the using of the robots in greenhouses in Romanian Banat area. It starts from most advantage criteria of using the robots (can help the high valued crops to be cheaper to produce, because the robots can work 24/7 without stop, and work faster in any climate conditions). The ranking of criteria for introduction of robotized solutions for greenhouses were made by using statistical processing and interpretation of 30 questionnaires distributed at peoples who have own greenhouses and gave us answers about specific criteria, agro-technical, and economical criteria regarding the use of robots in greenhouses. The resulted questionnaires served to compare with answers given by specialists. The results will be applied for establishing the rank of different technical solution and criteria package regarding using of the robots in greenhouses in rural area.

Keywords: robot, green houses, ranking, criteria

INTRODUCTION

Greenhouses are highly sophisticated structures, which aim at providing ideal conditions for satisfactory plant growth and production throughout the year. The growth factors “light, temperature, humidity and air composition” should be delivered and maintained at optimal levels. A well-designed greenhouse must provide the necessary climatic conditions for plant growth and production throughout the year and maintain the important climate factors as close as possible to specified optima. Thus, greenhouses are required to allow high light transmittance, low heat consumption, sufficient ventilation efficiency, adequate structural strength and good overall mechanical behavior, low construction and operating costs (Mistriotis et al., 2000a, 2000b)

Greenhouses are constructed in a large variety of shapes and sizes around the world. One of the latest technologies used in greenhouses are the hydroponic ones (for deep root system crops using soilless media or shallow root system immersed in water; water use, rain water, desalinization, recycling of water and nutrients). Smart greenhouse is another last minute technologies for greenhouses (can be controlled the temperature, humidity, wind, light and other factors who help the production).

According to Cuesta Roble Consulting statistics, total world greenhouse vegetable area is 473,466 hectares (http://www.cuestaroble.com/statistics.htm, September 2016), and in Europe are operating about 200.000 hectares of greenhouses, of which about 30% with permanent structures, and provided with acclimatization systems using fossil fuels. In Romania are cultivated over 7000hectares in farms of greenhouses, small greenhouses and plastic tunnels (Profitul Agricol no.26, 2016).

Use of the robots in greenhouses is a subject of actuality. Jesus R. J.et al. (2016), in their paper, "Heterogeneous Multi-Robot System for Mapping Environmental Variables of Greenhouses", underline the importance of the robots in greenhouses work. They highlight that "the productivity of greenhouses highly depends on the environmental conditions of crops, such as temperature and humidity. The control and monitoring might need large sensor networks, and as a consequence, mobile sensory systems might be a more suitable solution".

The robotics could help more in the future of sustainable horticulture. Actually the problem is the absence of sufficient intelligence in the current harvesting robots developed in (international) research projects, that determine no suitable harvesting robot for any crop (https://www.wur.nl/en/project/CROPS-Clever-robots-for-crops.htm, September 2016).

One example could be the European CROPS project which is focused „on the development of intelligent systems for the production and harvesting of high value crops, …, on harvesting peppers and thereby focuses on the development of intelligence for robots so they can be deployed in unstructured environments."

In the process of debating the economics, marketing and consumer research in horticulture, (Stegelin F. E., 2013), underlined the necessity of an organized agribusiness structure in order to provide economic gains in the area of horticulture.

The problem is to evaluate the necessity of robots for greenhouses, according to possibilities of farmers (almost small), and life cycle condition of production, as in other similar conditions (Tucu D., 2012).

This paper presents analysis on the use of robots in greenhouses from western Romania, based on some economical and technical aspects.

The objective of this paper was to analyze the level of using robots at greenhouses and how the greenhouses owners agree the use of robots in their work. On the other hand, another objective was to know more about the crops and how profitable are the greenhouses.

METHODS

In order to investigate the use of robots in greenhouses was created a specific questionnaire, containing 16 closed-ended questions. The questionnaire was distributed during August and September 2016 at 30 greenhouses owners in Timis County, Banat area, west of Romania. The selection of owners respects the principle of geographical distribution, according to the territorial repartition of Timis County.

The results of questionnaires were normalized and statistical processed, and the conclusions were carefully analyzed.

All the values from the graphics were presented in percent of the interviewed peoples.

RESULTS

The first question aimed to establish the type of exploitation owned by the respondents. It was established that 90% of the respondents use plastic tunnels and only 10% of the respondents use glass greenhouses (Figure1).

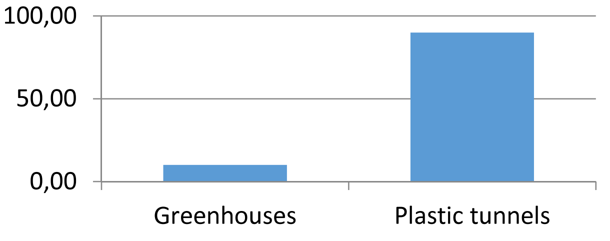

Figure 1 Type of exploitations

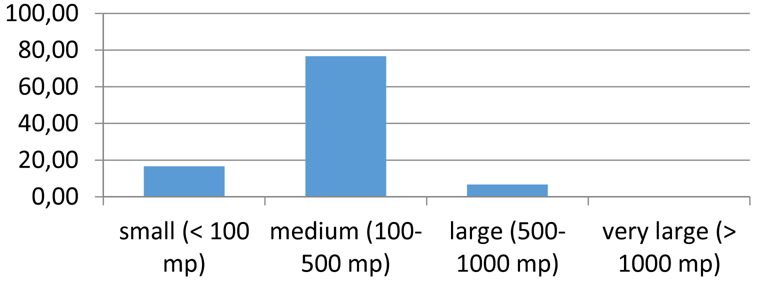

Figure 1 The dimension of the exploitations

Another question asked about the dimension of the exploitation. 16,66% of the respondents detain small exploitations (up to 100 mp), 76,67% of the respondents detain medium exploitations (between 100 and 500 mp) and 6,67% of the respondents detain large exploitations (between 500 and 1000 mp). No respondent detained very large exploitations, i.e. exploitations larger than 1000 mp (Figure 2).

None of the respondents interviewed use robots in the greenhouses or plastic tunnels they possess (Figure 3). So it suggests a higher amount of human work in order to harvest the crops.

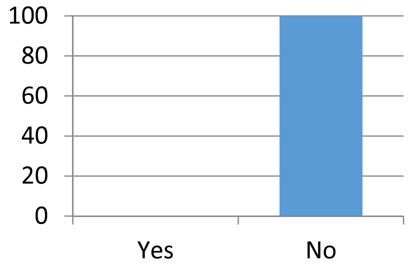

Figure 2 Utilization of the robots in the greenhouses and plastic tunnels (in the study)

Most of the respondents cultivate tomatoes, pepper, cucumbers, eggplants, lettuce and green onions during the year. Only half of the respondents are oriented to harvest other crops, like green beans or peas (Figure 4). This fact suggests market saturation for tomatoes, pepper, cucumbers, eggplants, lettuce and green onions, resulting a lower price for the final products and thus a lower income for the producers.

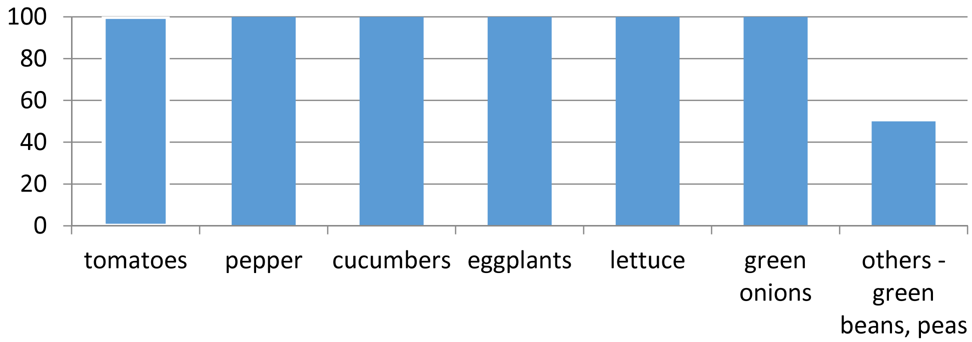

Figure 3 Crops

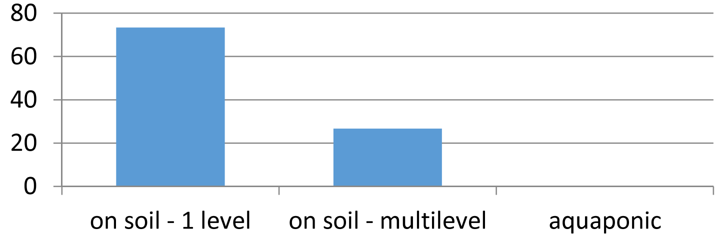

Figure 4 Agrotechnics

As Figure 5 shows, 73,33% of the respondents use an on-soil, one-level agrotechnics and 26,67% use an on-soil, multilevel. No respondent uses hydroponic (aquaponic) agrotechnics.

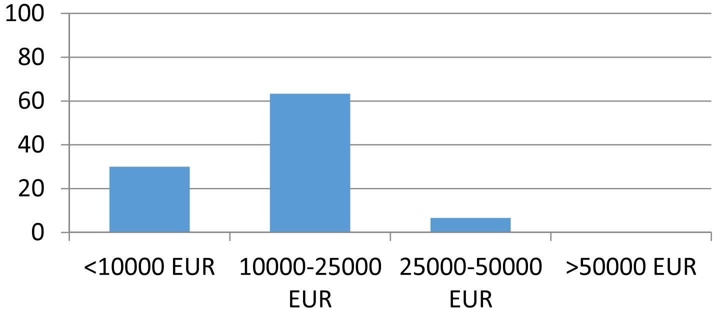

Figure 5 Estimated Investment Costs

The estimation of owners for "Investment Costs" in the greenhouses is shown in Figure 6. 30% of the respondents estimate that they invested less than 10000 EUR in their exploitation, 63,33% invested between 10000 and 25000 EUR and only 6,67% invested between 25000 and 50000 EUR. No respondent invested more than 50000 EUR in his exploitation.

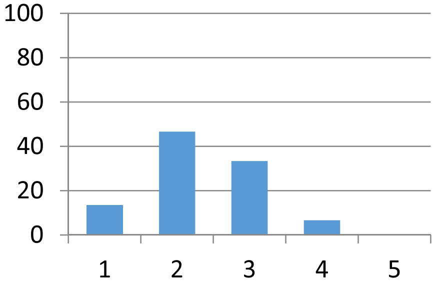

Figure 6 Information about the utilization of the robots in greenhouses

The next question asked the respondents to evaluate their knowledge on the use of robots in greenhouses, on a scale from 1 to 5, where 1 means no information and 5 means expert in the domain. 13,33% of the respondents have no information on the use of robots in greenhouse, 46,67% have little information, 33,33% have moderate information, 6,67% have extensive information on the use of robots in greenhouses and no one respondent is expert in the domain (Figure 7).

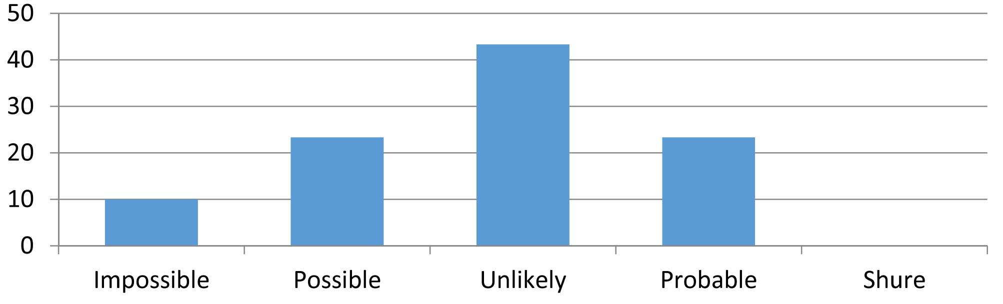

Figure 7 Opinion on the possibility of associating to robotize

Asked about the possibility of associating in order to buy some robots, 10% of the respondents found this impossible, 23,33% found it possible, 43,33% found it unlikely, 23,33% found the idea probable, but nobody found it sure (Figure 8).

About the profile of the respondents, 93,33% have rural residence and 6,67% urban residence; 86,67% are males and 13,33% females; 6,67% are under 25 years old, 23,33 between 26-35 years old, 13,33% between36-45years old, 23,33% between 46-55 years old, 30% between 56- 65years old, and 3,33% between 66-75 years old.

CONCLUSIONS

Analyzing the answers obtained while applying the questionnaire, the following ideas stand out:

- the greenhouses owners do not know the advantages of associating;
- the greenhouses owners do not know the advantages of using agricultural robots;
- a caravan in the areas with greenhouses could be useful in order to demonstrate the advantages of using robots and associating;
- a demonstrative greenhouse is needed in order to show the efficiency of robots and modern technologies in agriculture;
- agricultural robots are needed by the greenhouses owners.

Thus, can conclude that

- even if the respondents invested more in their exploitations, they still use brute human resources for work,
- they do not associate in order to avoid the market saturation,
- they do not use modern agrotechnics in their exploitations and,
- even they have some knowledge about the usage of robots in agriculture, they do not consider (at least not in the near future) the possibility of associating in order to buy an agricultural robot.

As a further work, the aim will be to create a demonstrative greenhouse using robots, in particular a robot for harvesting crops.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.42:631.563:636.085.52
Stručni rad
Expert paper

REFURBISHMENT PROJECT FOR COMMAND AND CONTROL OF A GRAIN TANK

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SUMMARY

PLC's (Programmable Logic Controllers) are today the most common technical solution applied to industrial command circuits, due to some obvious advantages like simplicity, flexibility, liability and no maintenance. This command and control solution is extremely used in industry, civil engineering and transportation, but still not very used in agriculture. This paper presents an original technical solution concerning that type of command used for all electrical equipment used on a classic 4 levels grain tank, based on a Möeller PS4 industrial PLC. The grain conveyor is simulated in the Power Apparatus Laboratory in Timisoara by using a dedicated stand made by ELWE. Hardware as well as software belonging to this application are shown, too inside the paper. The main conclusion is that PLC could be implemented as a modern and effective technical solution for command and control of agricultural processes. It could be easily applied for the refurbishment of existing grain tanks.

Key words: PLC, Command, Grain Tank

INTRODUCTION

Command and control of all industrial (and agricultural) processes is an important issue today. During the last few years we assist to an increased number of control equipment based on PLC's. PLC's (Programmable Logic Controllers) are today the most common technical solution applied to such systems due to some obvious advantages:

- the functional procedure of the whole equipment could be easily modified by changing only some program instructions;
- increased flexibility;

- safety in exploitation;
- improved liability;
- reduced volume;
- it not requires special and periodical maintenance;
- it could be easily programmed by any electrical engineer or technician;
- each control sequence could be virtually tested and verified without any costs or risks.

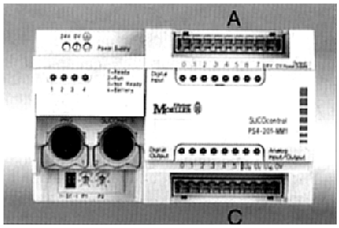

Figure 1: the PS 4-201 PLC basic type

When the price of all classic electrical equipment replaced is higher than PLC's price, this piece of equipment becomes even economically justified, being cheaper than the old electric parts changed [2].

In fact, a PLC is a small dedicated industrial computer (a sort of open embedded system) specialised in simultaneously treatment of both combinational and sequential logical instructions. It is a piece of equipment which allows connections between a large number of inputs and another large number of outputs, based on a set of established rules.

It simulates the classical physical electric wire structure by using logical ports disposed in a flexible and complex structure. Figure 1 shows us such a PLC type PS4-201 MM1 produced by the German manufacturer MOELLER, belonging to the Low Voltage Equipment Laboratory at the POLITEHNICA University in Timisoara [1]. This technical solution was applied to a farm near Timisoara, with a saving of around 30.000 Euros.

This piece of equipment has 6 digital inputs (marked with an A) and 8 digital outputs (marked with a C). All digital inputs and outputs are 24 V DC and maximum current of 100 mA. This current allows enough power to control a semiconductor device, relay or micro-contactor connected to that output [2], [3]. It also disposes of two analogical inputs and one analogical output all offering an array of 0 - 12 V DC at maximum 100 mA. This PLC disposes also of a serial RS 232 communication port which allows program downloading from an external program source (PC or panel). It also has a RS 485 serial communication connector used for PLC connections and an extension module connector for multiplying all the inputs and outputs needed. According to IEC 1131-3, it accepts all languages compatible with:

- **IL** (Instruction list);
- **LD** (Ladder Diagram);
- **FB** (Function Block).

METHODS

The process controlled by this programming sequence is a normal tank used for grain storage, located in each ceareal process areas. The most important aspect is the refurbishment of existing equipment, without any considerable modification of the electrical installtion allready on place [5].

Tank panel description

Figure 2 shows the main application panel for this tank command sequence. As we notice in Figure 2, this panel refers to agricultural tank both for filling and discharge sequence made of 4 different levels called **Level 1**, **Level 2**, **Level 3**, **Level 4**, progressive as volume, each of them having a level positioning sensor, called **S6**, **S7**, **S8** and **S9**. Filling of the tank is made throughout a **M1** pump and discharge is made by using an **Y1** electric valve. On the simulation panel there is a switch contact called **mode**, which switch between standard speeds of filling/discharge and manual set speeds.

When selecting **mode**, it switches all sequences from automatic to manual and reverse. Speeds in manual mode are preset by the two regulator switches called **M1-supply rate** and **Y1-discharge rate** located both on the right side of the control panel. All the other commands are the same, both manual and automatic; it only allows a different desired speed respecting the command logical sequence when manual.

All the equipment starts when selected a desired grain level and an operation (supply or discharge) and stops only when the desired cereal level is attended.

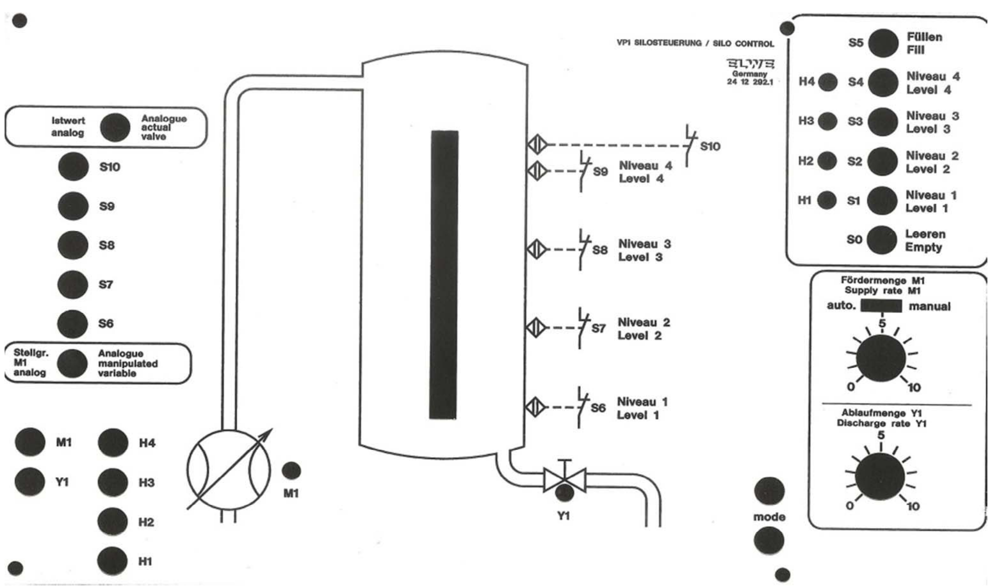

Figure 2: Grain Tank Simulation Panel

The cereal grains inside are simulated by a red LED column located in the center of the panel, continuously lighted, depending on the real level. **Maximum Level** sensor is given by the **S10** contact. The proper functioning of the 4 levels is shown by 4 LED's located on the right side command panel. On the up-left corner of the same panel, there is a button set used to activate all PLC inputs (process outputs). They are:

- **S6** is **Level 1** sensor;
- **S7** is **Level 2** sensor;
- **S8** is **Level 3** sensor;
- **S9** is **Level 4** sensor.
- S10 is Maximum Level sensor.
- **Y1 analog** is the input connection for analogue discharge in manual mode;
- **M1 analog** is the input connection for analogue supply in manual mode.

These are basically are PLC inputs coming from the process.

The whole process has other PLC inputs, coming from the main panel, as user commands. Those additional command inputs are (no matter manual or automatic mode):

- **S0** is the setting button for tank discharge;
- **S1** is the setting button for **Level 1**;
- **S2** is the setting button for **Level 2**;
- **S3** is the setting button for **Level 3**;
- **S4** is the setting button for **Level 4**;
- **S5** is the setting button for tank filling.

Due to the higher number of PLC inputs, we will use a separate extension module type EM 4-101 DD1, also made by Moeller and compatible with the PLC. This device has to be declared in the Project Configuration sequence of the software.

There are 4 other LED's located in the same area of the user control panel:

- the **H1** LED indicates the appropriate cereal stock position on **Level 1**, no matter manual or automatic mode;
- the **H2** LED indicates the appropriate cereal stock position on **Level 2**, no matter manual or automatic mode;
- the **H3** LED indicates the appropriate cereal stock position on **Level 3**, no matter manual or automatic mode;
- the **H4** LED indicates the appropriate cereal stock position on **Level 4**, no matter manual or automatic mode.

Tank control sequences

The control algorithm is, as follows:

- There are two major situations for the tank command and control sequence: *filling* and *discharging* the cereals from the storage facility. The filling operation is selected by pressing the **S5 Fill** button once. Discharging is made when pressing the **S0 Empty** button. When one of them is pressed, the other operation is cancelled. When selecting the manual **mode,** in connection with **Analog manipulated variable** and **Analogue actual valve**, the supply or discharge rate is given by the **M1** and **Y1** speed selectors.
- The cereal level is shown on the command panel by lighting the corresponding level LEDs **H1**, **H2**, **H3** or **H4** (depending on the cereal colon height 1,2,3 or 4 LEDs).

- The level is signalled to the PLC by the level sensors **S6**, **S7**, **S8**, **S9** and **S10**. The first sensors are related with cereal level LEDs described before. **S10** is activated only when the tank is full and charging has to be stopped.
- Starting and stopping the whole command panel (and tank command sequence) are made independently by simply turning power on or off, for the command panel, on a different selector.
- After selecting the filling or discharge procedure (**M1** or **Y1**) the tank manager has to select the desired level. The procedure works only if the desired level could be reached (it doesn't work, for example, if you want to fill the tank at a lower level then the real existing one or if you want to discharge the tank at an upper level). This procedure stops when the desired level is reached. Of course, the unnecessary LEDs of the discharged levels shut down as well as the new level LEDs of the filled areas are lighting up. Existing level LEDs are lighting without interruption on the command panel. Filling is stopped automatically when **S10** maximum level is reached and discharging is stopped automatically when **S6** minimum level is reached. Cereals are simulated by a continuously lighting column inside the tank facility.

RESULTS AND DISCUSSION - SOFTWARE APPENDIX

After describing all functional requirements for the conveyor band, the necessary control program write into the **Sucosoft S40** dedicated language, which does all those operations through the PLC, is shown below.

```
VAR (variable declaration section)
M1 AT %Q0.0.0.0.1 : BOOL ;
Y1 AT %Q0.0.0.0.0 : BOOL ;
K3 AT %Q0.0.0.0.3 : BOOL ;
S1 AT %I0.0.0.0.1 : BOOL ;
S2 AT %I0.0.0.0.2 : BOOL ;
S3 AT %I0.0.0.0.3 : BOOL ;
S0 AT %I0.0.0.0.0 : BOOL ;
S4 AT %I0.0.0.0.4 : BOOL ;
S5 AT %I0.0.0.0.5 : BOOL ;
S6 AT %I1.1.0.0.1 : BOOL ;
S7 AT %I1.1.0.0.2 : BOOL ;
S8 AT %I1.1.0.0.3 : BOOL ;
S9 AT %I1.1.0.0.0 : BOOL ;
S10 AT %I1.1.0.0.4 : BOOL ;
H1 AT %Q1.1.0.0.1 : BOOL ;
H2 AT %Q1.1.0.0.2 : BOOL ;
H3 AT %Q1.1.0.0.3 : BOOL ;
H4 AT %Q1.1.0.0.4 : BOOL ;
umplere : BOOL ;
golire : BOOL ;
END_VAR

Main program section

ld          S5
r           S0
s           umplere
r           Y1
ld          S0
r           S5
s           golire
r           M1
```

```
ld          S6
s           H1
ld          umplere
and         S2
andn        S7
s           M1
ld          S7
r           M1
s           H2
ld          umplere
and         S3
andn        S8
s           M1
ld          S8
r           M1
s           H3
ld          umplere
and         S4
andn        S9
s           M1
ld          S9
r           M1
s           H4
ld          umplere
andn        S10
and         S9
s           M1
ld          S10
r           M1
ld          golire
and         S10
and         S4
s           Y1
ld          S9
r           Y1
ld          golire
and         S9
and         S3
andn        S10
s           Y1
ld          S8
r           Y1
r           H4
ld          golire
and         S8
and         S2
andn        S9
s           Y1
ld          S7
r           Y1
r           H3
ld          golire
and         S7
and         S1
andn        S8
s           Y1
ld          S6
r           Y1
r           H2
```

CONCLUSIONS

PLC's are fully recommended for monitoring and control of such equipment located in agricultural areas (tanks, grain conveyors). A small program sequence introduced to a PLC could replace many electrical devices involved in a classic structure, reducing equipment costs. It could increase safety and reliability of all units involved at a lower maintenance cost, with interchanging possibilities. No major changes have to be made in the control scheme in order to apply this technical solution [4]. The program sequence could be easily verified virtually. It is totally suitable for agriculture equipment due to the simplicity of operation process too.

It could be applied without major changes to all existing equipment, as a refurbishment, with an updating and energy saving effect.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

ATMOSPHERIC PARAMETERS AND THEIR INFLUENCE OVER AERATION PROCESS FOR FODDER PRESERVATION

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SUMMARY

Conservation fodder plants in order to assure animal feed throughout the year, is a core activity for livestock farmers.

This paper addresses some theoretical and experimental aspects of the technological aeration process of fodder plants in conservation, storing and maintaining nutritional qualities. The experiments were performed with an installation of fodder drying by air venting in two consecutive years and the first period of the harvested.

During research was studied the influence of the parameters: plant moisture, temperature and humidity of aeration agent, environment characteristic, and the drying time over the aeration process of the fodder.

Key words: aeration, forage, drying technology, animals.

INTRODUCTION

Green fodder can be preserved and stored as silage or hay. Forage production is dominant in countries with intensive production systems and high productions of milk. (Voicu E. et al 2007). In 2010 in Romania the production of hay still prevails over that of silage (Frederiksen H. et al. 2010).

Hay quality depends on botanical composition, chemical composition and digestibility of organic matter expendability, all of which are subject to the natural environment they grew up plants, stage and method of harvesting, drying and storage technique.

The main objective of the technology of preparation and conservation forage as hay meadows and forage crops is to provide a final product with nutritional value as close to the original (harvesting) of green fodder, here is based from latter satisfies the conditions premise that a feed of high quality, both in terms of its botanical composition (balanced mix of perennial grasses with legumes), and in the epoch of harvest on (Hermenean I., Mocanu V. 2008)

On livestock farmers in hilly and mountainous area of meadows interest them as it operates to provide the necessary fodder for the entire calendar year. Problems occur with increasing altitude, there are frequent adverse weather conditions and the number of days required for the maintenance of animals indoors during winter is higher, so at altitudes above 900 m, indoors during the winter period is equal to the suburbs (Frederiksen H. et al. 2010).

There are numerous storage systems feed, keeping dry is now the system most widely used, regardless of destination, in these circumstances physiological processes resulting with the intensity very small microorganisms not exceed the terms of development and is therefore economically effective.

The conditions for drying the feed vary from species to species, depending on their further destination. These terms refer to the temperature of the drying humidity and duration of the drying process.

There is a correlation between the size of a complex form, which depends on a number of constructive and functional parameters of dryers or installations for drying feed; architecture drying chamber, the speed of the drying agent, the drying agent humidity. (Cioabla A. et al. 2010). As the temperature of the feed and the drying time (required for the extraction of moisture) can be adjusted by changing the value of the temperature of the drying, this means finding the best mode of the drying process.

Drying agents most commonly used are: air, gases, superheated steam and mixtures thereof, and ways of drying: the most common are natural drying, performed outdoors and artificial drying, performed with a drying agent heated (Cioabla A. et al. 2010).

Essentially, three factors determine the success of drying: air circulation, temperature control, humidity control.

METHODS

Conditions for using the active ventilation with atmospheric air are influenced as shown in Figure 1, by the moisture content of ambient air (grams of water per 1 kg of dry air) by temperature and relative humidity, these parameters give a clear view about the effectiveness of drying ventilation under atmospheric unheated air. For example, where atmospheric air ventilation with a moisture content of 40% and a temperature of 30°C to a moisture content equal to 10,32 g/kg.

Accordingly when air passes through a layer of moisture fodder subjected to drying up because it adds humidity and temperature taken from material decreases because part of the heat to the evaporation of water (Zaica A. et al. 2015).

Evidently drying time is inversely proportional to the amount of evaporated water per kg air to be admitted when a constant amount of air per hour. Therefore, drying time under adverse conditions will be approximately 5-20 times longer than favorable weather conditions, and in the case artificial drying increase energy consumption for drying and dryers productivity will decrease in inverse proportion.

During research was studied the influence of the following parameters: fodder moisture, temperature and humidity of aeration agent (typical of the environment) on the drying time of fodder through the aeration process using IVF ventilation system from INMA Bucharest (Nedelcu A., Popa L., Ciupercă R. 2014).

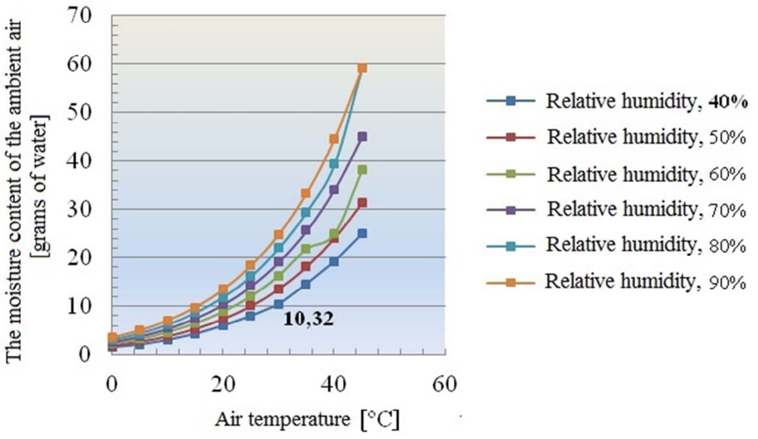

Fig. 1 The moisture content of the air in grams of water depending on the temperature and relative humidity

Experimental model of the fodder ventilation system uses atmospheric air as well as heated air drying being intended for completion venting cold air / warm of the fodder aeration process. For necessary air heating for fodder ventilation the system using solar radiation, which is converted into heat with the aid of solar panels and transported through the aluminium tubes (Fig. 2) (Nedelcu A., et al. 2014).

Fig. 2 Experimental model of installation for fodder aeration
1. Assembled solar panel; 2. Electrical installation; 3. Equipment for ventilation; 4. Ventilation tube placed in the fodder; 5. Hot air piping circuit; 6. Drying platform (uniformity room).

Material used in the experiments is represented by composition of fodder grass in natural meadows and pastures. In order to achieve this experimental evidence of the IVF installation, were harvested forage plants who spontaneously grown on experimental lot located inside the INMA Bucharest during two different periods for two consecutive years (Nedelcu A., Popa L., Ciupercă R. 2014), Table 1.

Table 1 Types of feed used in the tests of the experimental lot

Characteristics	UM	Fodder 1 (Period I)	Fodder 2 (Period II)	Observation
Type	-	hay from the meadow	hay from the meadow	herbaceous fodder plants
Harvest moisture	%	76	54,67	
Harvest time	-	June 2013	May 2014	
Drying period ground	days	approximate 1 day (18-20.06.2013)	approximate 1 day (27-28.05.2014)	They were carried out successive turns of furrows
The ground drying of the fodder	hours	32	24	

Technical equipment of the IVF installation allows monitoring of drying process through ventilation, thus:

– are measured meteorological parameters: temperature, humidity;
– the fodder temperature is measured by sensors;
– it monitors the temperature in the fodder mass.

In order to measure humidity during the aeration process fodder samples were taken from four different areas of the platform to monitor whether a uniform dry fodder (Fig.3, a).

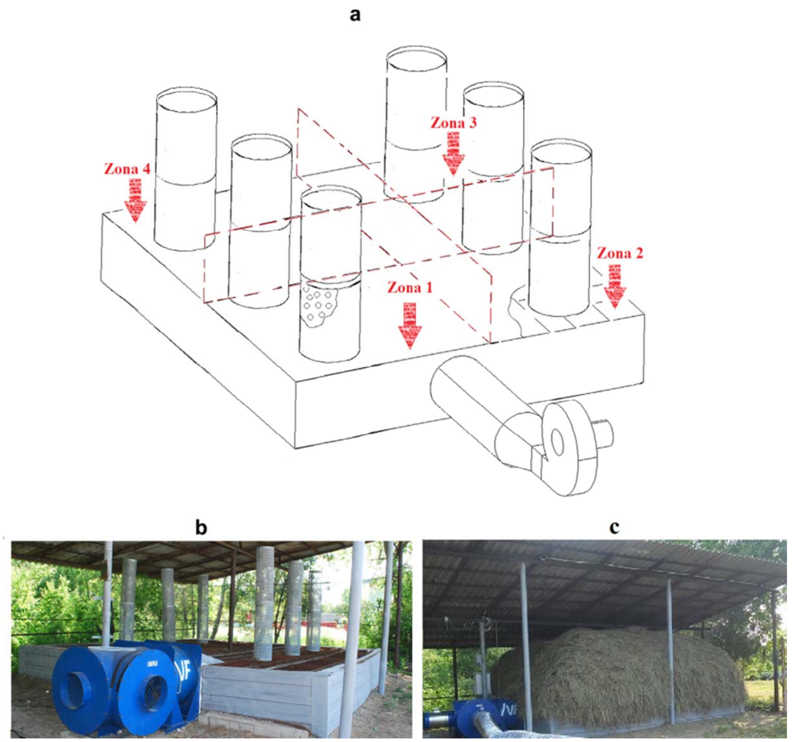

Fig. 3 Installation platform scheme with zones division (a), platform with highlighting ventilation tubes (b), loaded installation during experimental research (c).

Periods where there have been experiments they differed in certain particulars, as follows:

- **Period I** is characterized by high air temperature T [°C] and low air humidity, U [%], the material is subjected to an aeration process is was composed of a mixture of harvested hay fodder;
- **Period II** is characterized by low atmospheric temperatures caused by rainy weather and high air humidity, material to the aeration process it was composed of a mixture of forage harvested from the meadow and in greater quantity than the previous period.

RESULTS AND DISCUSSION

Interpretation of the results obtained during the first period of experimental research

Experimental research for the related analyzed period went over 7 days, for 21 totally effective hours of the ventilation process of the deposited material on platform installation.

Interpretation of results in graphical form shows the variation of temperature and atmospheric humidity used as a drying agent (Fig. 4 and 5).

Because in June 2013 do not were recorded any rainfall for analysis results were considered two times of day, 8 am and 14 o'clock in the afternoon.

In Figures 4 and 5 are presented the variation of atmospheric humidity and air temperature, used in the aeration study.

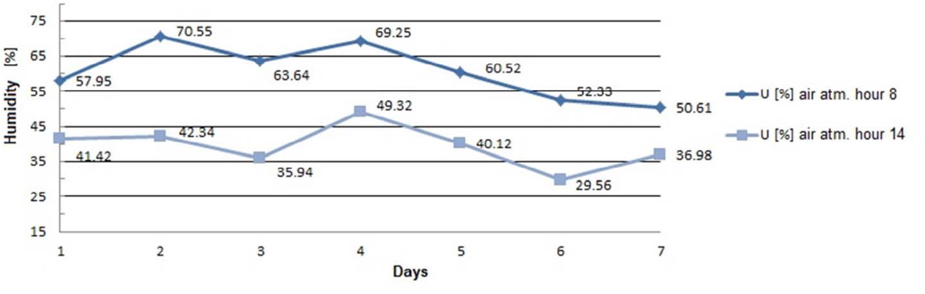

Fig. 4 Humidity variation of aeration agent used in ventilation process

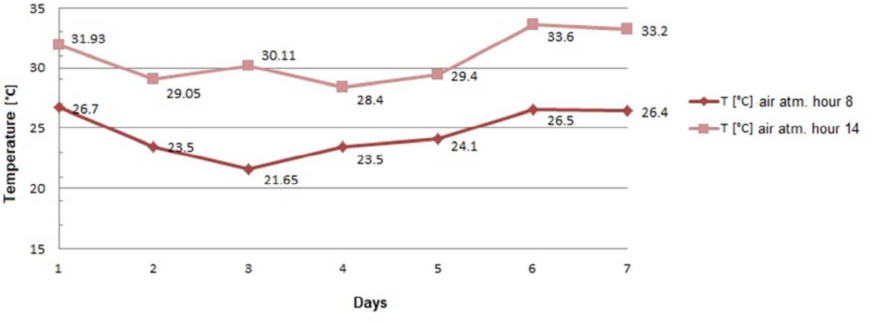

Fig. 5 Temperature variation of aeration agent used in ventilation process

Atmospheric parameters of drying agent used in process temperature directly influence developments in fodder causing the mass loss of moisture fodder on the 4 zones of the platform. In Figure 6 you can follow the temperature variation in the mass fodder and humidity from the fodder in Figure 7, the latter parameter is an objective in optimizing the aeration process.

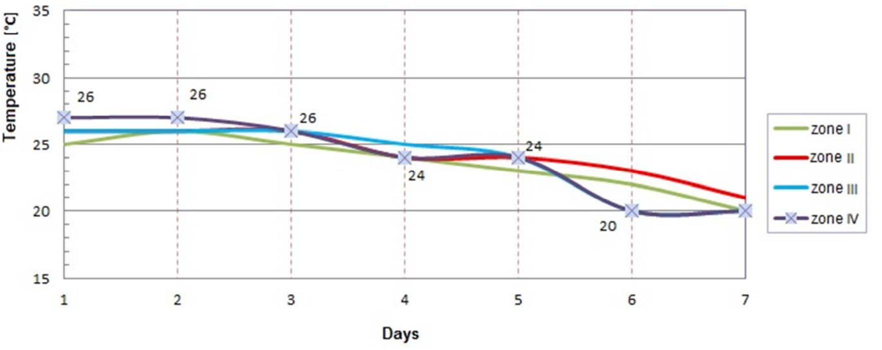

Fig. 6 Temperature variation in the fodder mass during the aeration process, in different parts of the platform

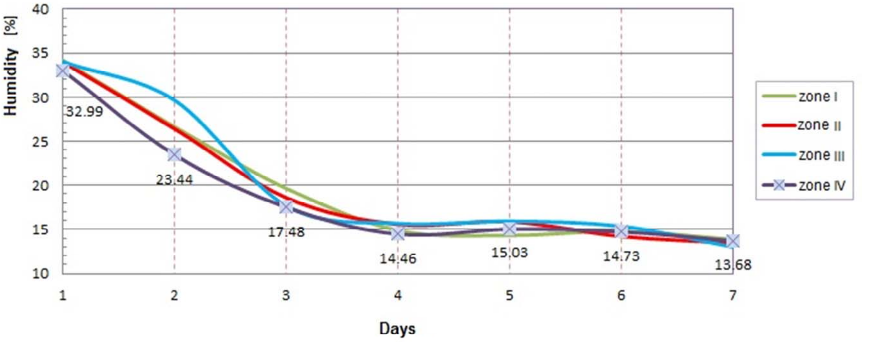

Fig. 7 Humidity variation in the fodder mass during the aeration process, in different parts of the platform

Analyzing the variation in parameters conduct atmospheric air during the drying process it is found that moisture ranged from 50.95-70.55% in the first part of the days, and atmospheric temperature varied between 22-27°C, these have a minor influence on the loss of humidity in the material subjected to drying, but had remained constant temperature in the fodder.

In the first four days are observed, maintaining constant temperature in the fodder of approx. 26°C and a humidity loss in the material from 32,99% to 14,46%. In the following period, until the completion of drying, the temperature dropped in the fodder with value of approximately 20°C and humidity in the fodder was maintained in the range 14.46-13.68%, while the atmospheric air temperature varied between 23-33°C and atmospheric humidity was between 69% and 37%.

Weather conditions, the time of completion of the drying phase, effective for 7 days, allowed duration of ventilation to be reduced to only 21 hours.

The uniformity of drying of the feed platform of ventilation was 97.5%, as shown in Figure 7, the humidity values are very close to all areas.

Interpretation of the results obtained during the second period of experimental research

In order to determine the characteristics influence aeration agent (free air), was applying the same methodology in conducted experimental research from May 2014, the period it was imposed by the optimal stage of harvesting for the plants.

During a day were made measurements every two hours, between 7.30 and 15.30, monitoring imposed by the daily rainfall.

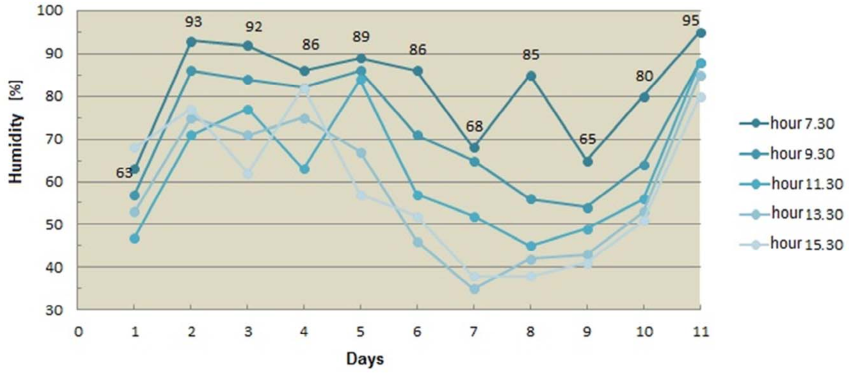

Fig. 8 The variation of the air humidity in the atmosphere during the process of aeration, at specific times of the day

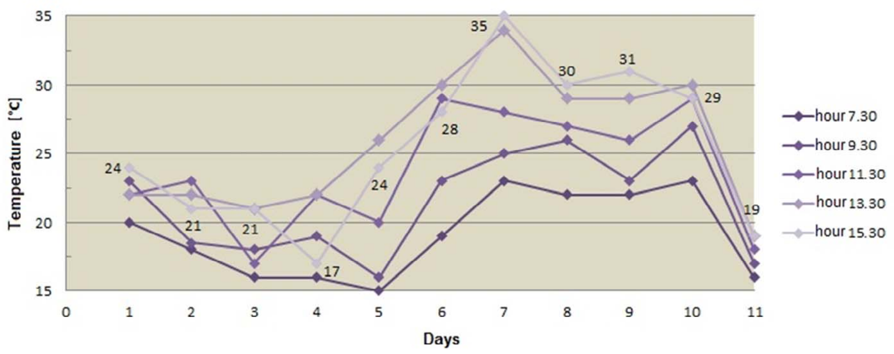

Fig. 9 The variation of atmospheric air temperature on the process of aeration, at established time intervals of the day

From the chart shows that humidity variation in the time interval 7.30...9.30 was recorded values between 63-80%, all the maximum amounts indicated in Figure 8 were recorded during or after rain. At that time, ventilation was only carried out for 30 minutes to avoid the temperature increase in the mass of the feed and degradation.

Comparing the variation of the two parameters, humidity and air temperature, it is found that their development is inversely proportional, so the humidity decreases when the temperature rises, and has been fluctuating from day to day. In these circumstances, according to the methodology was ventilated between the hours 13-16.

The fodder aeration conducting in the climatic conditions recorded in studied period have influenced during the aeration process, the fodder humidity decrees at 18%, recommended for conservation, was conducted in 50 hours of ventilation, namely 11 days, (Fig.10 and 11).

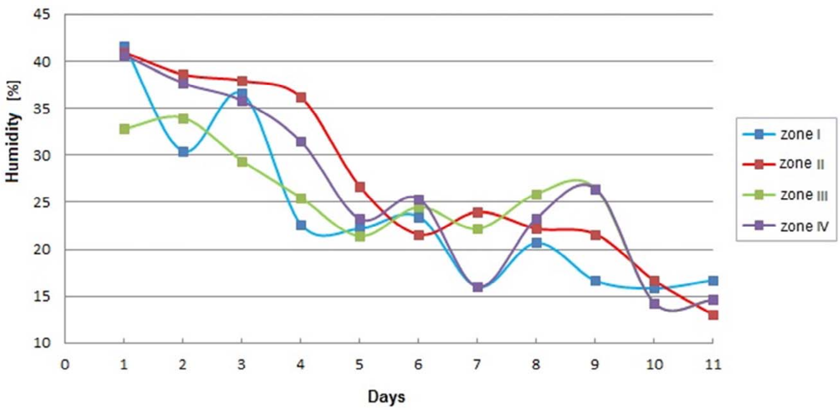

Fig. 10 Humidity variation of stored material during the aeration process, in the 4 zones of the platform

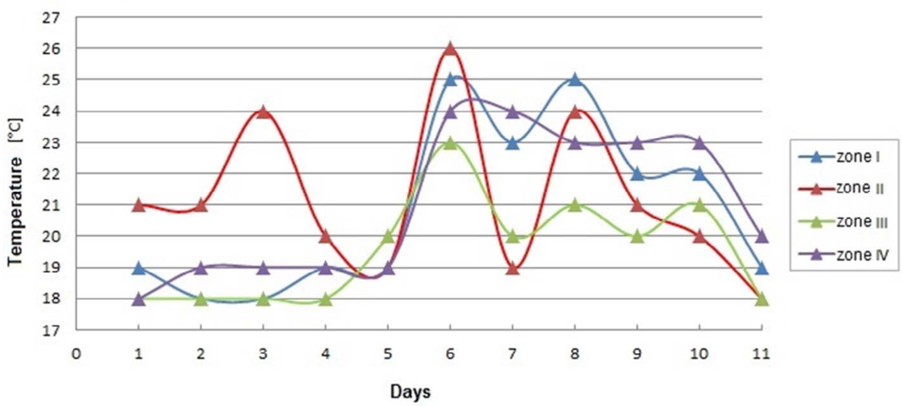

Fig. 11 Temperature variation in fodder mass during the aeration process, in the 4 zones of the platform

It appears, by linking data from the two types of charts (fig. 8 and 9), how parameters influencing the evolution of decreasing atmospheric humidity values of fodder table (fig. 11), in all 4 areas.

By making the average of the values measured by the four areas of the platform aeration is demonstrated that after 30 hours of the ventilation at a temperature of approximately 19ºC (Fig. 13), the material of the lost moisture content of from 39% to 23% (Fig.12).

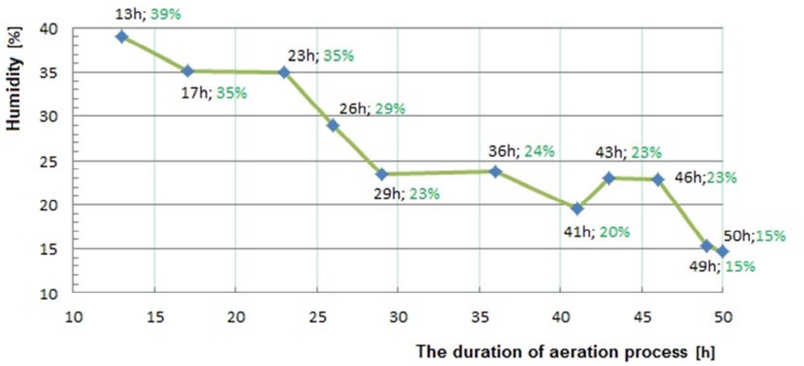

Fig. 12 Average humidity variation measured in stored mass fodder at different hourly intervals during the process of aeration

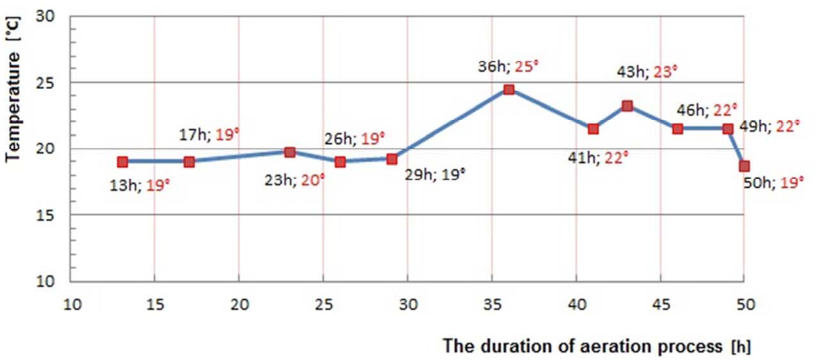

Fig. 13 Average temperature variation measured in stored mass fodder at different hourly intervals during the process of aeration

Within 30-50 h, even if the temperature of the fodder increased at a time by about 6ºC (recorded after 36 h of aeration), Fig.13, loss of humidity was relatively stable at approx. 7-8 % only in certain intervals (Fig. 13).

CONCLUSIONS

- Since the harvesting green fodder contains a large amount of water 70-85%, for as quickly as reduction of humidity under to 18%, considered to be optimal for storage, proceed to the conservation fodder as hay through the process of aeration.
- In order to meet the needs of livestock farmers in hilly and / or mountainous who are interested in that area of grassland it operates to assure the necessary fodder for the entire calendar year, were studied air atmospheric parameters used as a process of aeration.
- Research conducted two different years and two different periods have highlighted how atmospheric humidity and air temperature can influence the drying time.
- Weather conditions for the two periods were differentiated by warm weather first and the second by rainy weather, as a result, the duration of the aeration process up to completing for the second period drying fodder, was increased by 3 days.
- Enhancing the duration process of ventilation determines the increase costs and may influence the final product price, on the other hand, harvested fodder in a period of precipitation and storage humidity at 35-40%, and ventilated up to completing drying will lead to considerable advantages such as reducing losses of fodder and preserving their nutritional qualities.

ACKNOWLEDGEMENTS

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 551.58:631.23
Prethodno priopćenje
Preliminary communication

MICRO-CLIMATIC EFFECT OF SHADING PLASTIC NETS FOR CROP PROTECTION IN MEDITERRANEAN AREAS

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SUMMARY

Mediterranean areas are characterized by hot summers that can determine bad environmental conditions for the growth of vegetable crops cultivated inside greenhouse. In Southern Italy, the traditional technique often employed by farmers during summer to reduce sun radiation and excessive internal air temperature is the whitening of the external side of the greenhouse plastic film through painting it with liquid calcium carbonate. More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties, as a way to more effectively control the micro-climatic conditions inside closed greenhouse and tunnel. Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shade effect with some specific features useful for creating more favourable microclimatic conditions for the crop growth.

With the aim to analyze the efficacy of different greenhouse shading techniques, an experimental trial was carried out by comparing two commercial plastic nets characterized by different shade effects, respectively equal to 60 % and 36%. These two plastic nets were tested in laboratory, where their radiometrical characteristics were determined. The same plastic nets were then installed on two different small-scale tunnels located in Southern Italy, in which inside air and relative humidity were measured during some late spring days. The results obtained through these experimental trails enabled to start a comparative analysis of the performances of the two tested shading nets, highlighting the role that a correct selection of the most suitable net may play on the final results in terms of crop protection from high temperatures and sunburns.

Key words: plastic nets, crop shading, radiometric characteristics, micro-climatic effect.

INTRODUCTION

Excessive levels of solar radiation may determine negative effects on the crop growth. Sunlight can affect indeed more than the opening and closing of plant stomata. While some plants have specialized proteins that protect them from sunburn, others do not, and intense solar radiation can damage their leaves. Plants that are not adapted to full or intense sunlight can develop heat stress. Many plants are susceptible to leaf scorch, where parts of the plant die due to excessive water loss through transpiration. In addition to slowing or halting photosynthesis, heat stress and leaf scorch can make plants more susceptible to disease or insect infestations. Most of these negative effects may be avoided, mostly in the case of crop protection under greenhouse, when some suitable shading devices are properly employed (Castronuovo et al., 2015; López-Marín et al., 2012; Statuto et al., 2013).

In order to control hot indoor air temperate, one of the most common traditional solution utilized by growers in Southern Europe is the shading of the greenhouse against excessive solar radiation through the application of calcium hydroxide (*i.e.*, slaked lime) or other chemicals on the cover of the greenhouse (so-called, *whitening*) to create some shade and then limit the raising of the air temperature (Gázqueza et al., 2012).

More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties, as a way to more effectively control the late spring and summer micro-climatic conditions inside close greenhouse and tunnel (Picuno et al., 2008; Kitta et al., 2012). Plastic nets are usually characterized by a shading factor, ranging from 10% to 90%, which represents the capacity of the net to reduce the incoming solar radiation, related to the average value of the transmissivity of the net in the solar wavelength band from 380 nm to 760 nm (Schettini et al., 2012).

A plastic net performs indirect effects as well, when it is employed to cover close greenhouse and tunnel. Due to its influence on the values of the main microclimatic parameters (temperature, relative humidity, carbon dioxide concentration, solar radiation, *etc.*), it could play, if used as standalone cover or even in synergy with a cladding plastic film, a fundamental role on creating more favourable microclimatic conditions during the crop growth (Picuno & Abdel-Ghany, 2016). Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shade effect with some specific features useful for creating suitable conditions for the crop growth and to guarantee healthy conditions for workers. Each plastic net modifies the solar radiation that arrives on the crop, by reducing the light flow and varying the available radiant spectrum. Apart from the net structure, the spectrum of the transmittance is also influenced by the diameter of the thread, color and thickness of the net, and the radiometric properties of absorbance, transmittance and reflectance of the plastic material (Sica & Picuno, 2008).

Different shading strategies using plastic nets were recently developed by some Authors. Abdel-Ghany et al. (2015) evaluated the effect of different shading configurations on the solar and thermal radiation in a greenhouse. The results showed that external roof-shading is desirable, as it reduced the generated thermal radiation in the greenhouse by 21% and 15% during the day and night time, respectively and reduced the greenhouse air temperature during the day. The internal shading (roof and side walls) is undesirable, since it drastically increased the generated thermal radiation in the greenhouse by 147% and strongly increased the greenhouse air temperature during the day. Shading the side-walls is not recommended because it significantly reduces the transmitted solar radiation in the morning and afternoon (when the outside irradiance is low) and is useless at around noon when the outside irradiance is extremely high.

The use of coloured plastic nets was examined by some researchers, with the aim to partially limit the incoming solar radiation so as to define optimal condition for the crop growth. With this aim, Schettini et al. (2012) investigated the influence of different coloured nets on peach trees. The nets positively influenced the fruit characteristics, such as size, colour and sugar content, in comparison to open-field. The higher growth observed under some red-coloured film can be attributed to its capacity to increase the level of radiation emitted in the red-wavelength range, where photosystem absorption by trees is optimal. Such results are consistent with the results obtained using coloured nets as covering material for ornamental plants (Schettini et al., 2011).

The geometry of a net-house may play also a considerable role in the diffusion of radiation under a shading net, since the transmitted radiation may not fulfill the crop growth requirements. To approach this problem, Abdel-Ghany et al. (2016) have designed and realized two innovative types of net-house models (polygon and curved-arch net-houses), each one of them having seven surfaces made up of different net types. The spectral radiative properties of 32 nets were examined and three nets were selected to cover the surfaces of each model. The results showed that the PAR and microclimate in the net-houses and in a cooled greenhouse used for comparison were similar, but the net-house reduced water consumption and electric energy consumption both in summer and in winter.

Plastic covers plays a critical role not only towards the internal environment, influencing the crop growth, but also towards the external surrounding landscape, strongly influencing the visual aspect of the rural land (Statuto et al., 2016; Tortora et al., 2015). From this point of view, a suitable landscape planning approach appears absolutely necessary, in order to consider in a holistic way all aspects connected to the use of plastic nets in agricultural application (Statuto et al., 2015).

Despite their widespread use, however, neither growers nor net producers have clear ideas about the relationship between the net typology optimization for a specific application and the technical characteristics of the net. The choice often depends on empirical or economic criteria, not on scientific considerations (Castellano et al., 2008; Shahak, 2008).

In this paper, an experimental trial was carried out by comparing two commercial plastic nets characterized by different shading effects, so as to compare their effect on the internal micro-climate of a greenhouse, depending on their different radiometrical properties.

MATERIALS AND METHODS

Two plastic nets with different shading effect - respectively equal to 60% and 36% (fig. 1) - were analyzed in in the Laboratory of Material Tests of the SAFE School of the University of Basilicata (Italy), where their spectro-radiometrical characteristics in the UV-VIS-NIR wavelength were determined through a Jasco V-570 spectro-radiometer.

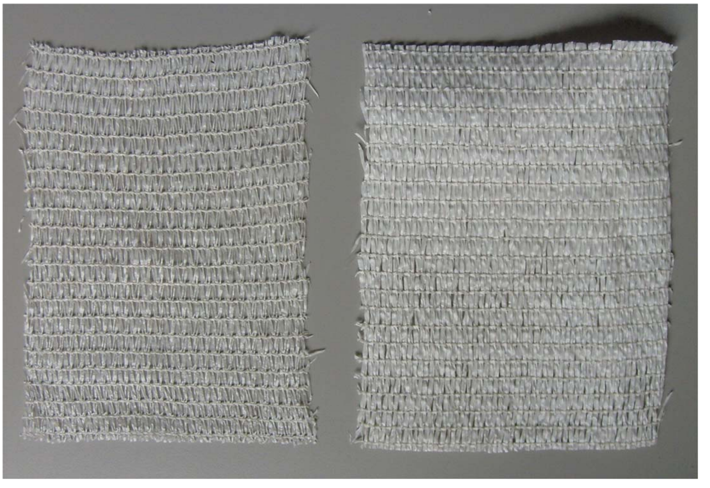

Figure 1. The two tested nets having different shading effect (36% - left; 60% - right).

In order to evaluate the shading effect of these two different plastic nets on the internal environment of the greenhouse, as well as their performance on the general thermodynamic inside conditions, two small tunnels (fig. 2) reproduced in scale were realized in an experimental area located in Pontecagnano (Southern Italy).

Figure 2. Trial small-scale tunnel covered with a 36% (left) and 60% (right) shading net.

These experimental small-scale tunnels, both covered with an EVA plastic film, were left without any cultivation. Inside air temperature and relative humidity were recorded during spring 2016 by CS500-L probes (modified version of Vaisala's 50Y Humitter, Campbell Scientific Inc, Utah, USA). The relevant data were recorded by a CR10X data-logger (Campbell Scientific Inc, Utah, USA).

RESULTS AND DISCUSSION

The results of the spectro-radiometrical analysis over the tested materials are reported in Tables 1 and 2, in terms of the main characteristics measured in different significant ranges within the solar spectrum.

In the case of the white plastic net with 36% shading effect, its level of transmittance (over 60% - Table 2) joined to its significant reflectance - that generates mutual progressive reflections with the greenhouse cladding sheet inside the greenhouse - confirms once more that shading nets should be employed only outside the greenhouse (Abdel-Ghany et al., 2016), in order to fully express their potential of shading the incoming solar radiation.

Table 1. Results of the spectro-radiometrical analysis on the 60% shading net.

Range	Wavelength nm	Transmittance %	Reflectance %	Absorptivity %	Shading effect %
Solar	200 - 2500	45.19	27.82	26.99	54.81
PAR	400 - 700	28.90	47.46	23.64	71.10
Solar IR	700 - 2500	52.15	26.75	21.10	47.85
UV	280 - 380	6.75	6.66	86.59	93.25
UVA	320 - 380	6.78	6.91	86.31	93.22
UVB	280 - 320	6.71	6.25	87.04	93.29

Table 2. Results of the spectro-radiometrical analysis on the 36% shading net.

Range	Wavelength nm	Transmittance %	Reflectance %	Absorptivity %	Shading effect %
Solar	200 - 2500	62.63	18.06	19.31	37.37
PAR	400 - 700	47.82	28.08	24.72	52.18
Solar IR	700 - 2500	68.91	17.66	13.43	37.82
UV	280 - 380	28.43	5.80	65.77	71.57
UVA	320 - 380	28.73	5.99	65.28	71.27
UVB	280 - 320	27.94	5.50	66.56	72.06

In figures 3 and 4 the diagrams of solar transmittance and reflectance of the two tested nets along the whole UV-VIS-NIR wavelength [200 – 2.500 nm] are reported.

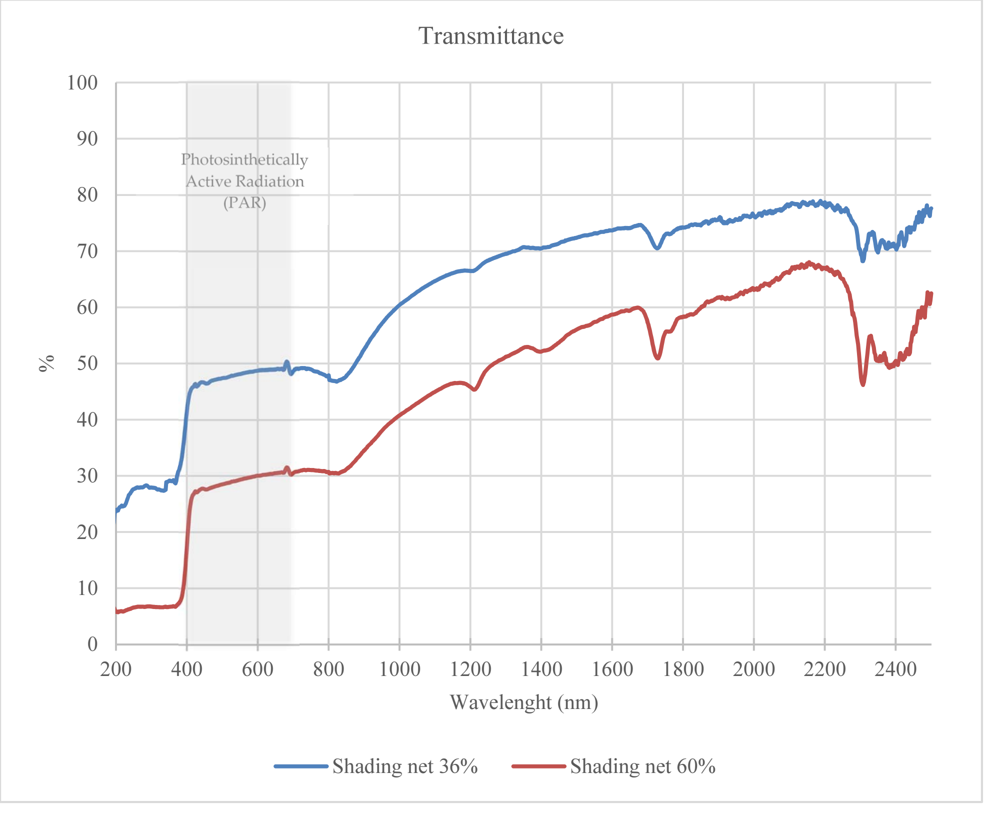

Figure 3. Transmittance of the two nets in the UV-VIS-NIR wavelength.

From the results of the spectro-radiometric analysis performed in the solar range, it would be deduced that the shading effect declared by the plastic net producer seems quite close to the value that was detected (i.e., the complement to 1 of the transmissivity coefficient). This value, that could be evaluated into the different wavelength ranges (i.e., UVB, UVA, PAR, etc.) may give further information about the effective capability of the net to protect the crop from excessive solar radiation. It seems particularly interesting the value that the two tested shading nets present in the UVA and UVB ranges, in which the shading effect is very high - around 50-90% higher than the nominal shading effect of each net - so effectively protecting crops from possible sunburn and scorch.

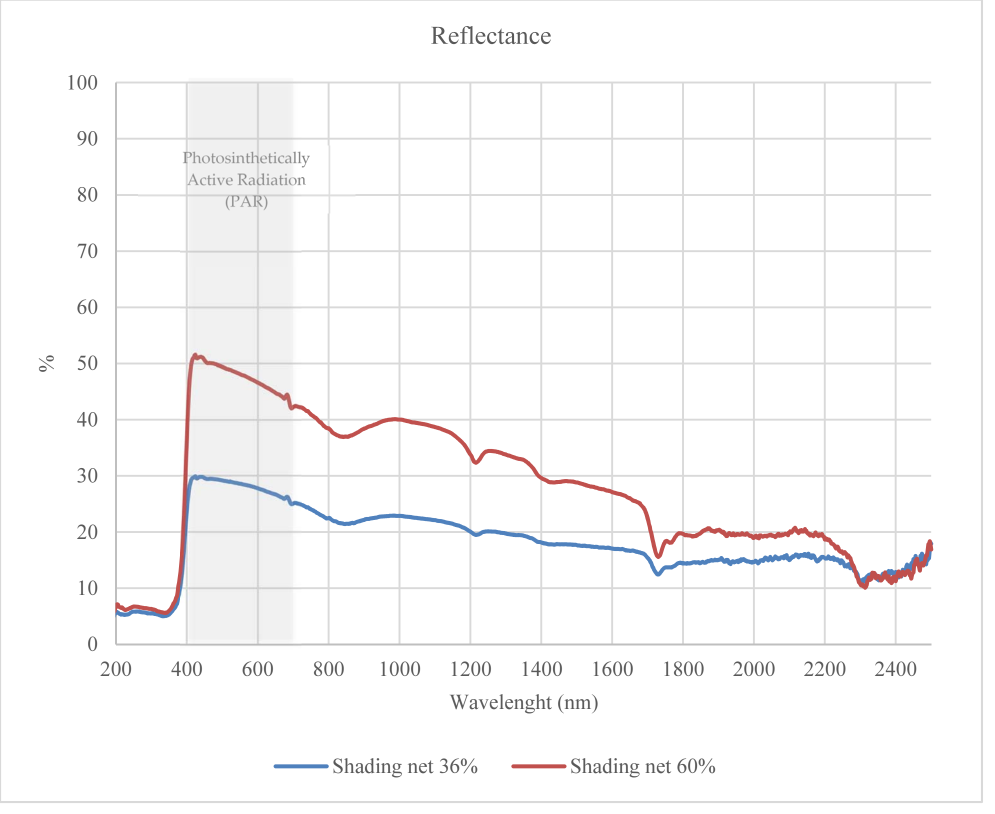

Figure 4. Reflectance of the two nets in the UV-VIS-NIR wavelength.

The difference between the shading factor of the two plastic nets did not seem to have significant influence on the thermodynamic behaviour within the two different small-scale tunnels during the testing period. As it is reported in figure 5, temperatures within these close small structures were almost the same along three trial days of late spring (16-18 June 2016).

A different behaviour was detected, however, in the case of relative humidity, that in the case of the small-scale tunnel covered with the 60% shading net, was higher during daytime. The values of the relative humidity under the two scale-tunnels covered with the two different shading nets were very similar, conversely, during the night (fig. 6). The difference in the level of relative humidity, at the same temperature, could be connected to different levels of enthalpy that the air inside the scale-tunnel covered with different shading nets is probably able to capture during daytime.

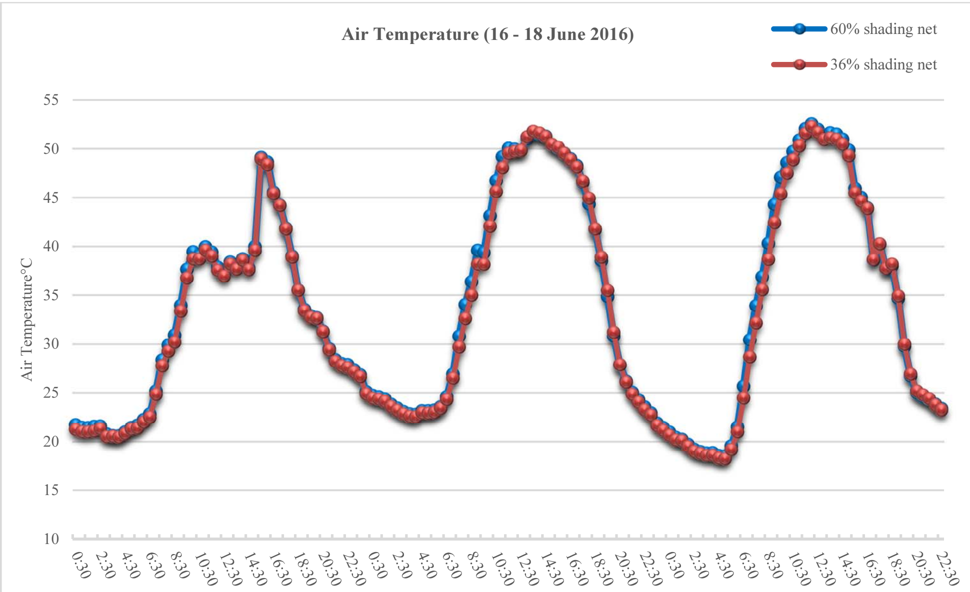

Figure 5. Air temperature detected in the trial greenhouses.

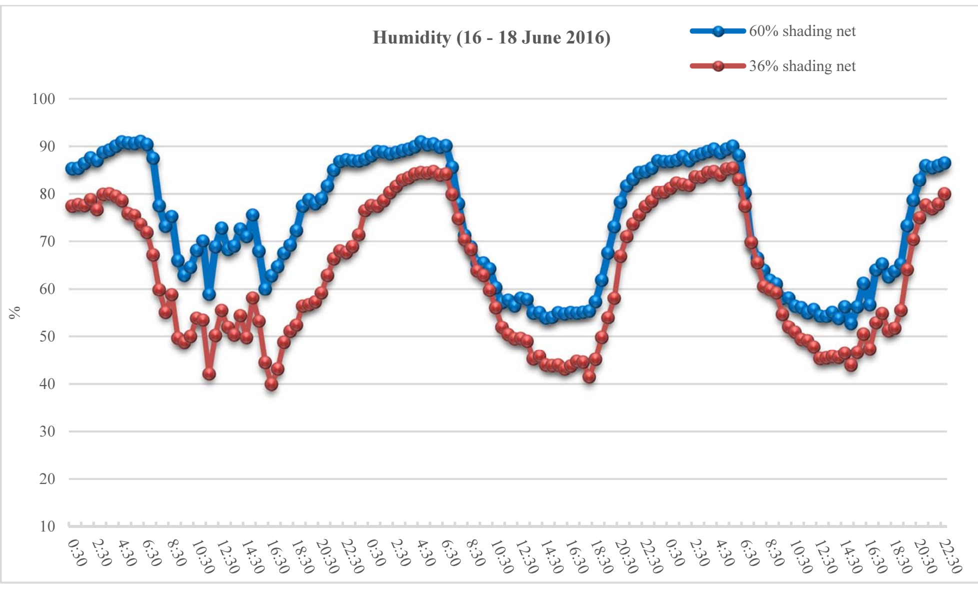

Figure 6. Relative humidity detected in the trial greenhouses.

From the results of the present research, it would be concluded that an accurate evaluation of shading effects of a plastic net for different wavelength ranges (e.g., UVA, UVB, PAR, etc.) may give useful hints for the evaluation of the its technical performance, in terms of real efficacy in protecting the crops from excessive sun radiation and possible consequent damages to the crop, *e.g.*, sunburn, scorch, *etc.*

Since, at present, only the global shading factor is usually reported by the industries as a technical information on the leaflet that accompanies the material, from the analysis of the two different shading nets it appears very important that nets would be accompanied by technical information about the shading effect along the whole solar range. A specific information about the shading factor in the principal wavelength ranges - mostly in the Photosynthetically Active Radiation and UVA/UVB bands - seems very meaningful, taking into account the different effects on the crop as well as on the protected environment.

CONCLUSIONS

The progressive extensive use of agricultural plastic nets in protected agriculture that was recorded during the last years, thanks to their beneficial effects on the crop compared to a decreasing price, sets fundamental issues concerning the need of a suitable design phase of their technical characteristics (polymer, dimensions, thread properties, *etc.*) that play a considerable role on the greenhouse internal microclimate. Nets are currently often employed as covering elements without any proper design, only basing on the knowledge of some technical characteristics. The lack of a specific Standard for determining the spectro-radiometrical characteristics of agricultural nets - with the consequence that laboratory test may be conducted on the basis of Standards applicable to different materials (*e.g.* glass, or transparent film) - still asks further investigations aimed to support an improvement of the technical properties of the plastic nets, in order to make them more finalized to the biological necessities of the crop.

From the present research, it was clear that transmittance coefficients, detailed at the different wavelength ranges playing a role in the crop growth, appear as an indispensable tool, able to classify the covering material in relation to the micro-climatic parameters of the protected environment, the quality of the radiation, the temperature and the air flow. More research is anyway needed to characterize different types of nets for specific purposes, as well as to quantify the effects of the shading effect on the greenhouse internal climate and crop response. Also the duration of a plastic net, depending on the site and condition of application still needs further investigations.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 551.583:633
Izvorni znanstveni rad
Original scientific paper

THE USE OF AGRICLIM MODEL IN AGRICULTURE PRODUCTION ANALYSES IN NOVI SAD

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SUMMARY

Agriclim is model selected for assessment changes in agro-climatic indices (Trnka et al., 2008). The model results are useful to describe the expected agro-climatic conditions in agriculture production. On the base of model results, it is possible to interpret and suggest adaptation measures in combination with crop model results (Trnka et al., 2008). In this paper Agriclim model is used to calculate agro-climatic indices for main field crop growing season periods in Serbia: from October to June (OJ) winter growing season and from April to September (AS) spring growing season for Novi Sad location. Simulations were done for 2030 under A1B scenario and 2050 year under A2 scenario. The CO_2 concentrations were used from IPCC Report, 2007. Input data included: daily observed maximum and minimum temperatures, precipitation, evaporation, solar radiation and wind speed for the period 1971-2000 assumed from Republic Hydrometeorological Service of Serbia (RHSS) and out results from ECHAM climate model (Roeckner et al., 2003), downscaled with Met & Roll weather generator (Dubrovsky, 1996, 1997) for 2030 and 2050 year.

For period October – June, when winter cereals are grown, the result analyses included temperature and precipitation for: October - March (OM) period, December – January – February (DJF) and April – May – June (AMJ) period, the average number of frosty days. For period April – September, when spring varieties are grown, it is analysed: temperature and precipitation for whole growing season from April till September and for driest months June-July-August (JJA), the average number of tropical days for JJA period and the effective temperature sum above 10°C.

The results showed, that the temperature is expected to rise during each period of growing season, with significantly lower precipitation, except in winter months DJF. The effective temperature sum is expected to rise. The average number of frosty days is expected to be less and more tropical days in future climate conditions in a comparison with 1971-2000 period.

On the base of result analyse, it is concluded that field crops grown in winter period (OJ) should have benefit in future conditions and spring crops are expected to be negatively affected by rising temperature and significantly lower precipitation during summer months.

Key words: Agriclim model, agro-climatic indices, climate change, filed crops, development and crop yield.

INTRODUCTION

Climate changes are well-established opinion in science community in the 20th century (Houghton *et al.,* 1996), while the average global surface temperature has increased 0.6 ± 0.2°C over the 20th century (IPCC, 2001). It is necessary to analyse possible changes in agro-climatic indices and crop needs. On the base of this knowledge, it is possible to analyse the impact of expected conditions on crop development and yield. In Serbia, the main field crop production is organized during two growing periods: from October till June and from April till September. The Agriclim results with crop model results are important in testing and preparation of adaptation measures in agriculture production in future conditions.

Novi Sad is located in northern part of Serbia, in the Panonian lowland, with continental climate and mostly good structured chernozem soil. Serbia is a country in development and agriculture production is very important part of economy.

An expected increasing variability in temperature and precipitation (Southworth *et al.,* 2002) including more frequent extreme weather events (Rötter *et al.,* 2012), cause higher variability in crop yield.

Agriclim model was tested and used in COST 734 action for expected agro-climatic conditions for European countries.

In results it is analysed: a) absolute change in temperature and relative change in precipitation for defined periods; b) the average number of frosty days; c) the average number of tropical days; d) the effective temperature sum above 10°C.

MATERIAL AND METHOD

The observed daily weather data for 1971-2000 for Novi Sad location were used from Republic Hydrometeorological Service of Serbia (RHSS). The out results from ECHAM model (Roeckner *et al.,* 2003), downscaled with Met & Roll weather generator for 2030 under A1B scenario and 2050 under A2 scenario, were used for future climate conditions. The CO_2 concentrations were assumed from IPCC Report 2007. For A1B scenario CO_2 concentration was 451 ppm and for A2 scenario, CO_2 concentration was 532 ppm. The weather data included: maximum and minimum temperatures, precipitation, evaporation, solar radiation and wind speed.

Agriclim model was used as a tool to calculate agro-climatic indices in future conditions. On the base of a daily input data: maximum and minimum temperatures, precipitation, evaporation, solar radiation and wind speed, model may calculate average temperature and precipitation for some periods of growing season (OM, DJF, AMJ, MAM, AS, JJA), the number of days with extreme temperature as frost days (day with minimum temperature lower than 0°C), frosty days (day with maximum temperature lower than 0°C), summer days (day with maximum temperature above 25°C, tropical days (day with maximum temperature above 30°C). Model also may calculate the effective temperature sum above 10°C, the average day of snow cover and the date of appearance of spring and autumn frost.

In paper is calculated absolute change in temperature and relative change in precipitation for OM, DJF, AMJ, MAM, AS, JJA periods for 2030 under A1B scenario and 2050 under A2 scenario according to 1971-2000 period. Also, it is analysed the average number of frosty days for January – February period and the average number of tropical days for June – July – August period.

RESULTS

Analyses for OJ winter growing period. For OM period, the temperature is expected to increase for 1.1°C in 2030 and for 2.5°C in 2050. For DJF winter months, the temperature is expected to increase for 1.2°C in 2030 and for 2.6°C in 2050 and in AMJ period for 0.8°C in 2030 and 1.7°C in 2050 year (Tab. 1). The precipitation in OM period is expected to be higher for 22.8% in 2030 and 29.5% in 2050. In DJF period is also expected more precipitation for 23.0% in 2030 and 69.0% in 2050. Only in spring months AMJ is expected decrease in precipitation for 9.6% in 2030 and 16.4% in 2050 (Tab. 2). The analyse of average number of frosty days showed less days in future conditions, 5 days less in 2030 and 8 days less in 2050 than in 1971-2000 period.

Analyses for AS spring growing season (Jancic et al., 2015). During AS period is expected the temperature increase for 1.1°C in 2030 and 2.5°C in 2050 year. In JJA period is expected that temperature raise for 1.3°C in 2030 and for 2.9°C in 2050 year (Tab. 1). In AS period, the precipitation showed a significantly decrease for 15.5% in 2030 and 29.7% in 2050. The most significant decrease in precipitation is expected in JJA period for 22.7% in 2030 and for 42.4% in 2050 year (Tab. 2). The analyse of average tropical days number showed that it is expected more days with maximum temperature above 30°C. In 2030 it is expected 9 days more and in 2050 is expected 23 days more. The effective temperature sum above 10°C is expected to be higher for 247.1°C in 2030 and for 555.8°C in 2050.

Table 1. Observed temperature for 1971 – 2000 (°C) and absolute change (°C) in temperature for 2030 and 2050 for OM, DJF, AMJ, AS and JJA period for Novi Sad location

	OM	DJF	AMJ	AS (Jancic et al., 2015)	JJA (Jancic et al., 2015)
1971-2000 (°C)	4.9	15.9	15.9	17.9	20.7
2030 (°C) Absolute change	1.1	0.8	0.8	1.1	1.3
2050 (°C) Absolute change	2.5	1.7	1.7	2.5	2.9

Table 2. Observed precipitation for 1971 – 2000 (mm) and relative change (%) in precipitation for 2030 and 2050 for OM, DJF, AMJ, AS and JJA period for Novi Sad location

	OM	DJF	AMJ	AS (Jancic et al., 2015)	JJA (Jancic et al., 2015)
1971-2000 (mm)	214.8	85.8	191.5	359.4	208.0
2030 (%) Relative change	22.8	23.0	-9.6	-15.5	-22.7
2050 (%) Relative change	29.8	61.3	-16.4	-29.7	-42.4

CONCLUSIONS

After OJ results analyse, it is concluded that cereals grown in this period will have benefit from climate change. The rise in temperature and precipitation is expected to be significant during winter months. The crops should have more water before winter months and will also correctly use nutritions. Water reserves are expected to be more available at the beginning of spring part of growing season when the winter wheat is sensitive to drought. The less frosty days and higher temperatures will make better conditions for less damages to crops in winter period.

In AS period, a significantly higher temperature and significantly lower precipitation is expected to have a great negative influence on crop development and yield. Especially in summer months JJA, when the crops are in anthesis phenology phase and grain filling period. In those phenology phases the plants are very sensitive on drought, and expected more tropical days may cause a physiology stress on crops. Higher temperatures, more tropical days and higher effective temperature sums may cause advance in maturity, shorter grain filling period and growing season, and significantly lower yield.

After AS agro-climatic analyse and with a knowledge of crop physiology need, it may be concluded that adequate adaptation measure may be a controlled irrigation, in a moment of crop water deficit and with adequate quantity to keep high yield.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

INFLUENCE OF NATURAL FIBERS ON THE MECHANICAL PROPERTIES OF STARCH BASED BIOPLASTICS

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SUMMARY

Expanding the use of composite materials in almost all areas of activity is influenced by many factors such as: the need for lighter materials but with certain mechanical properties, the concerns regarding environment and health, the need to reduce energy consumption, sustainable production methods, etc.

Degradable composites are materials composed of a polymer matrix derived from renewable sources (polysaccharides, vegetable oils) or fossil sources (synthetic polymers such as: polyethylene, polypropylene, polyesters, etc.) reinforced with natural fibers or agricultural byproducts.

One of the most used and studied bio-composite materials is the one that uses starch as matrix. Using natural fiber to reinforce the biodegradable matrix provide improved properties, good mechanical properties, low weight and certain advantages on environmental protection.

This paper presents the influences of natural fibers reinforcement on mechanical properties of biodegradable materials obtained by thermoplastic extrusion of native starch blends (with amylose content of 21%),

Key words: composites, starch, natural fibers, mechanical properties,

INTRODUCTION

In general, a mixture of two or more different materials, forming a new material with improved properties compared to the constituents taken separately, is considered a composite material. In a composite material there are two main components: the matrix and the reinforcement, which retains theirs identity from the start but the composite material obtained, behaves as a whole (forces acting on the material are transmitted simultaneously throughout the entire composite material).

The matrix role is to keep the reinforcement together and to protect it, to give the desired shape to the material and to distribute the forces more evenly to the reinforcement. The reinforcement role is to take over the forces in order to get an increase in strength, rigidity, etc. of the material.

Many composite materials are obtained from components of petroleum origin (particularly those with polymeric matrix and / or synthetic reinforcing fibers) with applications in various areas such as: aeronautic and aerospace structures construction, machinery, automobiles and ships constructions, agriculture machinery, medicine, chemistry, electronics and energy, consumer goods, optics etc. [1], [2].

A great problem is recycling or destruction of composite materials after use, in terms of environmental non-aggressiveness and low cost. Following the awareness of environmental pollution problems, replacing the synthetic composite materials with bio-composite materials with a biodegradable matrix and natural fibers is considered of fundamental importance [3].

Agricultural residues (including stalks of most cereal crops, rice husks, coconut fibers, etc.) are excellent potential alternative materials to substitute plastic products, due to their availability. Apart from their abundance and renewability, the utilization of agricultural residues is advantageous to the economy, environment, and technology, due to their low density, low manufacturing energy demand, low CO_2 emission, and high level of biodegradability, when compared to thermoplastic polymer composites reinforced by inorganic fillers [4], [5].

Also, the polymers based on thermoplastic starch represent a viable alternative due to availability and low price of this material, even if their practicability is limited by poor mechanical properties and low resistance to moisture. [6].

Mechanical properties of thermoplastic starch and its blends can be improved by mixing it with natural fibers. This was attributed to the chemical similarity of vegetable fiber and starch, which provides a good compatibility between them [7].

This paper presents some preliminary results on obtaining starch-based composite materials with the reinforcement of natural fibers and some mechanical properties of these new materials.

METHODS

We prepared two types of samples and for their preparation we used: starch, glycerol, water, Poly(butylene adipate-*co*-terephthalate) (PBAT) and Miscanthus fibers.

For one type of samples we used, as matrix, thermoplastic starch made from industrial non-modified corn starch (with a 21% content of amylose, initial water content on wet basis (wt.b) was 10.76% and the density was 0.561 g/cm^3), glycerol (with a concentration of 99.5% and a density of 1.262 g/cm^3) and water (from water supply system). The ratio of starch/ glycerol/ water was 55/28/17.

For the other type of samples we used, as matrix, a mix of starch (21% content of amylase, water content on wet basis (wt.b) was 10.76% and the density was 0.561 g/cm3) and PBAT. The starch was dried at 75 °C, for 5 hours before blending with PBAT. The characteristics of PBAT (Ecoflex F BX 7011) used, supplied from BASF are shown in table 1.

Table 1. PBAT (Ecoflex F BX 7011) material properties

Property	Value	Test Method
Density (g/cc)	1.25 to 1.27	ASTM D792
Melt Index, g/10min (190°C/2.16Kg)	2.7 to 4.9	ASTM D1238
Melting Point, °C	110 to 120	DSC
Tensile Strength, (MPa)	34	ASTM D638
Elongation, %	700	ISO 527
Water Permeation Rate, g/(m^2*d)	140	DIN 53122

Miscanthus is a herbaceous perennial grass from Poaceae family, growing to 0.5-2 meters tall, rarely up to 4 meters, forming dense clumps from underground rhizomes, with leaves of 25-75 cm tall and 0.3-2 cm wide.

Poly(butylene adipate-co-terephthalate) (PBAT) is a biodegradable polymer with high ultimate elongation but low modulus.[8]. Its flexibility and toughness improves the blends with other biodegradable polymer that is strong and rigid. Peng Zhao at al. observed that when 5% PBAT was added in a blend with PLA the elongation of the blend is tremendously increased by 200%. [9]

For the first type of samples (TPS matrix) the blend was: 56%-starch, 27%glycerol, 7%water and 10 % Miscanthus fibers. To prepare this samples we used an extruder Collin ZK 25, we pre-mixed the starch with the fibers, and glycerol with water. The components were mixed by the twin co-rotating screws of the extruder at max. temperature of 120 °C and 120 rot/min.

For the second type of samples (starch and PBAT matrix) the blend was: 60 % - starch, 30 % PBAT, 10 % - Miscanthus fibers. To prepare the samples we used a Brabender internal mixer with a 30 cm^3 mixing chamber and two co-rotating rotors. The components were mixed for 10 min, at 140 °C, with rotors speed of 60 rot/min

Figure 1. Tensile test of sample with TPS matrix on Instron 3360 Series

Mechanical test was performed on an Instron 3360 Series Dual Column Tabletop Universal Testing Systems., tensile test for samples with TPS matrix (fig. 1) and bending test for samples with PBAT matrix (fig. 2).

The samples obtained were 25 mm width and 4 mm thickness (fig.3)

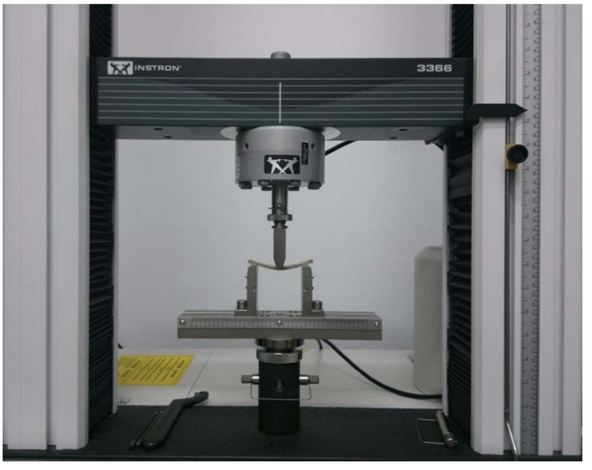

Figure 2. Bending test of sample with PBAT matrix on Instron 3360 Series

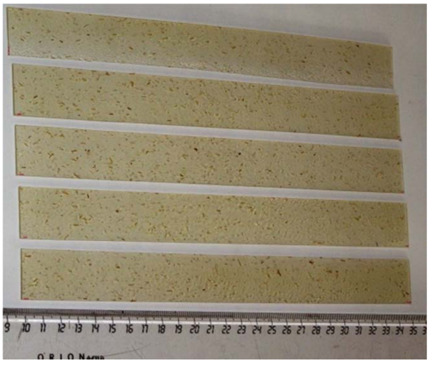

Figure 3. The aspect of samples for tensile tests

RESULTS AND DISCUSSION

The mechanical properties of starch based materials are their weak point and to improve the resistance under tensile stress it is necessary to reinforce these materials with fibers. The Miscanthus fiber dispersion within this material show that the composite had poor interfacial bonding and the fibers seem to be pulled out during the fracture process [10].

The results of tensile test on 4 samples of composite material with matrix of thermoplastic starch and 10% Miscanthus fiber as reinforcement are presented in table 2. We can observe that reinforcement with Miscanthus fibers determine a greater stiffness of the material proven by low mean value of tensile strain 0.90 % and high mean value for E-modulus 1269.21 MPa.

The results of bending tests on 3 samples of composite material with PBAT in matrix and 10% Miscanthus fiber as reinforcement are presented in table 3. The low mean value of E-modulus, 463.24 MPa, demonstrate that using PBAT in the matrix improved considerably the elasticity of composite materials based on starch and reinforced with Miscanthus fibers.

Table 2. Tensile properties of composite material with TPS matrix and Miscanthus fiber reinforcement

Sample	Tensile stress at maximum load [MPa]	Tensile strain at maximum load [%]	Tensile stress at break [MPa]	E-Modulus [MPa]
1	6.35	0.60	1.39	1483.32
2	6.95	0.35	5.37	2270.17
3	4.22	1.73	3.37	662.03
4	3.15	0.92	2.22	629.63
Mean value	**5.17**	**0.90**	**3.09**	**1269.21**

Table 3. Bending properties of composite material with starch- PBAT matrix and Miscanthus fiber reinforcement

Sample	E-Modulus [MPa]	Flexure stress at Tensile Strength [MPa]	Flexure strain at Tensile Strength [%]	Flexure stress at Break [MPa]
1	337.26	10.717	5.107	10.701
2	327.67	11.150	5.097	11.139
3	724.79	12.618	4.299	11.963
Mean value	**463.24**	**11.495**	**4.834**	**11.267**

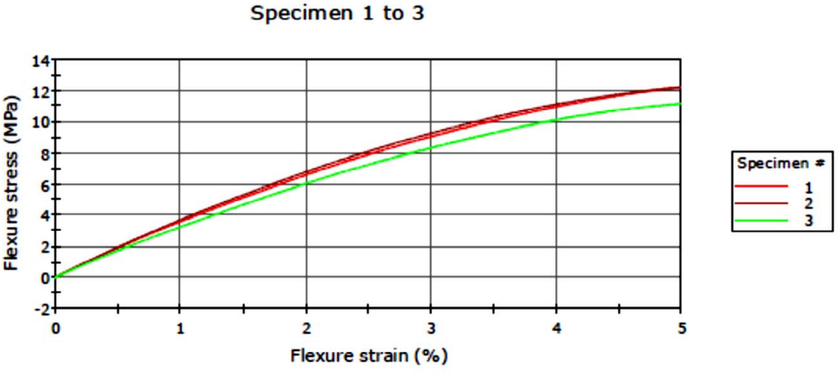

Figure 4. Variation of flexure stress (MPa) function of flexure strain (%) at bending test.

From fig.4 we observe that the results for tested samples are close, meaning that the behavior of the composite material with a blend of starch and PBAT as matrix and Miscanthus fibers as reinforcement is predictable and constant.

CONCLUSIONS

Two types of samples were prepared: one with thermoplastic starch as matrix and the other one with a blend of starch and PBAT as matrix. Both types had 10% of short Miscanthus fiber as reinforcement.

The samples were tested in order to obtain preliminary data about their mechanical properties.

Reinforcing with Miscanthus fiber of a thermoplastic starch matrix improve the tensile stress resistance but leads to a greater stiffness of the material proven by low mean value of tensile strain- 0.90 % and high mean value for E-modulus-1269.21 MPa.

Using a blend of starch and PBAT as matrix for the composite material reinforced with Miscanthus fiber, leads to low mean value of E-modulus, 463.24 MPa, which means that improves considerably the elasticity of composite materials.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

OPTIONS OF VOLUNTEER POTATO MANAGEMENT IN SUBSEQUENT CROPS IN THE ROTATION

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SUMMARY

To verify the possibility of volunteer potato control in subsequent crops of the crop rotation (maize and cereals) field trials were established in the Potato Research Institute (Valečov Research Station) between 2013 and 2016. Following active ingredients were used for control: fluroxypyr, mesotrione, foramsulfuron, iodosulfuron-methyl Na and thiencarbazone-methyl. Compared to non-treated control a significant effect of evaluated active ingredients on reduction of potato tuber weight was found. The highest efficacy (80.7 %) was recorded for fluroxypyr (300 g/ha). Using a reduced rate (200 g/ha) of fluroxypyr the efficacy was reduced to 72.9 %. The combination of foramsulfuron (45 g/ha), iodosulfuron-methyl Na (1.5 g/ha) and thiencarbazone-methyl (15 g/ha) reached the efficacy of 73.5 %. The lowest efficacy (59.7 %) was recorded for mesotrione (144 g/ha).

Keywords: volunteer potato, yield, herbicides

INTRODUCTION

Under the conditions of the Czech Republic, volunteer potatoes in crops following potatoes in the rotation are an important weed difficult to control. Volunteer potatoes have high competition ability for light, water and nutrients and they substantially reduce yields and production quality and simultaneously, they increase necessary cost for control. Nieuwenhuizen et al. (2010) refer that in Western European cropping rotations, volunteer potato plants are a major weed problem, mainly because they spread Phytophthora infestans, which causes late blight in potato crops. The manual labour that is required for control of these plants can be reduced by using automated detection and control of volunteer potato plants in sugar beet fields. Machine vision was used to detect volunteer potato plants in real time conditions at a travel speed of 0.8 m s-1. Dose effect studies were performed to determine the right dose for control of volunteer plants with micro-sprayer-applied glyphosate in a gel. In a field trial the biological efficacy of the system reached the level controlling 84% of the volunteer potato plants.

The problem of volunteer potatoes is caused by a change in the growing technology, especially harvest. Using potato diggers and loaders without operators, tuber losses are higher than using potato harvesters, where operators prevent losses on the machine. Another cause consists in climate change, and/or warm winter, when soil is not frozen enough and volunteer potatoes are not destroyed. It is a worldwide problem. Yazaki et al. (2013) refer that in Japan they compared tuber survival by soil frost control based on estimated soil frost depth by numerical soil temperature model and soil frost control based on farmers' voluntary effort. Most unharvested tubers are distributed at 0-0.15 m depths. The target soil frost depth was set as 0.30 m based on the relation between soil frost depth and tuber killing depth: the depth at which the soil temperature decreases to the critical temperature of -3°C from a previous study. Soil frost control remarkably decreased survival to less than 0.5% of unharvested tubers if soil frost depth exceeded 0.30 m. Consequently, the target soil frost depth was confirmed as appropriate for almost complete tuber elimination. This finding is also confirmed by results from our studies (Kasal and Čepl, 2013). Fig. 1 illustrates course of freezing in individual years. The strongest soil freezing was measured in January and February 2012, up to the depth of 50 cm. Only this freezing completely destroyed volunteer potatoes and prevented their distribution in subsequent crops. Since 2013 annual soil freezing was low and in 2016 it resulted in high distribution of volunteer potatoes in cultivated potato crops, which were grown in four consecutive years. Elimination of volunteer potato distribution belongs to prerequisite of certified seed potatoes and therefore the official body responsible for seed potato certification in the Czech Republic had to restrict potato crops in case of volunteer potato distribution.

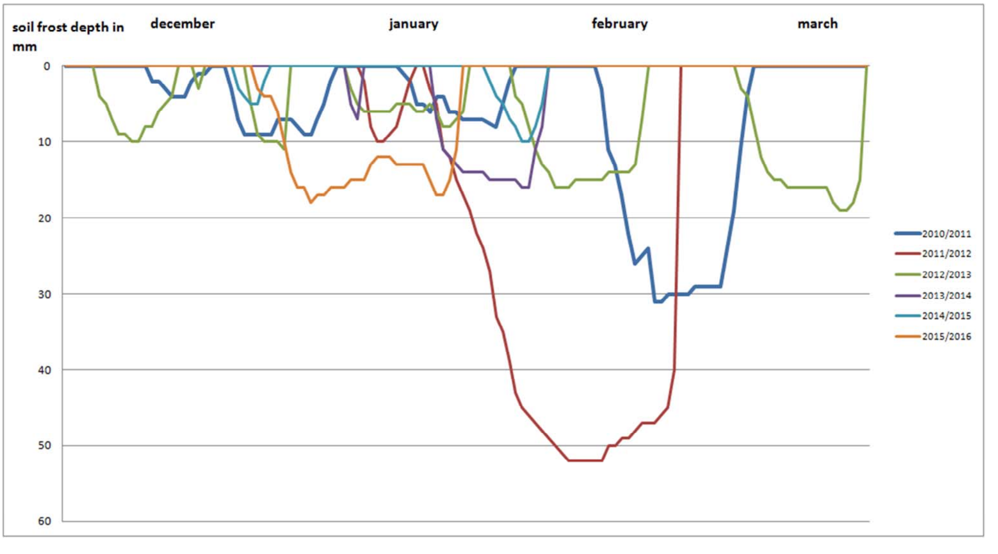

Fig. 1: Soil frost depth (mm) between 2010 and 2016

In addition to findings and elimination, verification of the way of volunteer potato regulation using selective herbicides in the most frequent subsequent crops – maize and cereals was also necessary. Under the conditions of the United States the issue of herbicide combinations for control of volunteer potatoes was solved by Koepke-Hill et al. (2010), the highest efficacy was recorded for mesotrione, similar results were also obtained by Allemann et al. (2016). Harris (2010) evaluated herbicide GF-1374 (100 g a.i./l fluroxypyr+80 g a.i./l clopyralid+2.5 g a.i./l florasulam). He found an evidence of a possible response to spray application volume for potato control. Five trials were established in 2008 to investigate the control of volunteer potatoes by GF-1374 applied at 1.5 litres/ha at either 200 or 400 litres/ha application volume. Applied at 200 litres/ha, GF-1374 achieved 88.7% mean control. This increased to 93.2% when applied at 400 litres/ha.

Tadayon and Islami (2010) performed a trial in sugar beet. Their treatments consisted of 4 types of herbicides (Control, Pyramin, Goltex and Betanal) and 4 volunteer potato density (0, 1, 2 and 4 plant m^{-2}). The results showed that there were significant differences between herbicides and volunteer potato density on sugar beet traits. The highest shoot dry weight of sugar beet plants was obtained from Pyramin herbicide. The highest LAI and root weight of sugar beet were achieved at Pyramin application and 0 volunteer potato density, and the lowest LAI and root weight of sugar beet were achieved at control and 4 volunteer potato density treatments.

On our station harvest losses were studied (Kasal and Čepl, 2013). It was found that between 33 and 256 thousands tubers (between 0.4 and 6.5 t/ha weight of all tubers) were left on the plot after the harvest, based on the type of harvester. If the same harvesters were evaluated on different plots, as Pearson Maverick or Grimme GZ 1700, we found that losses did not depend on the type of harvester, but on setting of harvesting apparatus for prevention of tuber losses. An exemption is the harvester Fortschritt E 686, for which the highest losses were found in all studied years and on contrary, harvester Spirit 4100, which always belonged to the best as regard as tuber losses.

METHODS

A study performed in the Potato Research Institute (Valečov Research Station) between 2013 and 2016 was focused on the effect of selective herbicides in subsequent crops (maize, cereals) on elimination of volunteer potatoes under conditions of the Czech Republic.

Valečov Research Station is situated in the potato production region under conditions of typical mildly gleyed cambisol, with medium heavy soil and loamy to sandy topsoil. The altitude of the locality is 460 m, annual mean temperature is 7.0 °C and annual amount of rainfall is 652 mm.

Graded rates of following active ingredients were used in following variants:

– Variant 1: 200 g/ha fluroxypyr (0.8 l/ha Starane 250 EC)
– Variant 2: 300 g/ha fluroxypyr (1.2 l/ha Starane 250 EC)
– Variant 3: 144 g/ha mesotrione (0.3 l/ha Callisto 480 SC + Atplus 0.5%)
– Variant 4: 45g/ha foramsulfuron, 1.5 g/ha iodosulfuron-methyl Na and 15 g/ha thiencarbazone-methyl (1.5 l/ha Maister Power)
– Variant 5: no application

In small-plot trials herbicides were applied into emerged potato crop in the stage BBCH 20 - 30. Plots were planted with common potato density, i.e. 44 444 plant/ha (spacing of 0.75 m x 0.30 m). Control variant was without any treatment.

Tuber weight, size distribution, yield recovery and mean tuber weight were studied and subjected to statistical assessment.

RESULTS AND DISCUSSION

Results were obtained in the common potato crop, i.e. they inform about standard comparable efficiency. In subsequent crops, in which applied herbicides are selective (cereals, maize), the observed standard efficacy will be also influenced by particular intensity of volunteer potato distribution and application date. We can suppose that these factors will always result in higher efficiency.

The results of mean of absolute values of tuber weight (TW) from studied years and statistical measurement (Fig. 2) show that all used variants reached a statistically significant TW reduction compared to non-treated control. The highest efficiency was recorded for the variant 2 – 300 g/ha (80.7 %) fluroxypyr, followed by the variant 4 – 45 g/ha foramsulfuron, 1.5 g/ha iodosulfuron-methyl Na and 15 g/ha thiencarbazone-methyl (73.5 %), variant 1 – 200 g/ha fluroxypyr (72.9 %) and the worst results were found in the variant 3 – 144 g/ha mesotrione (59.7 %).

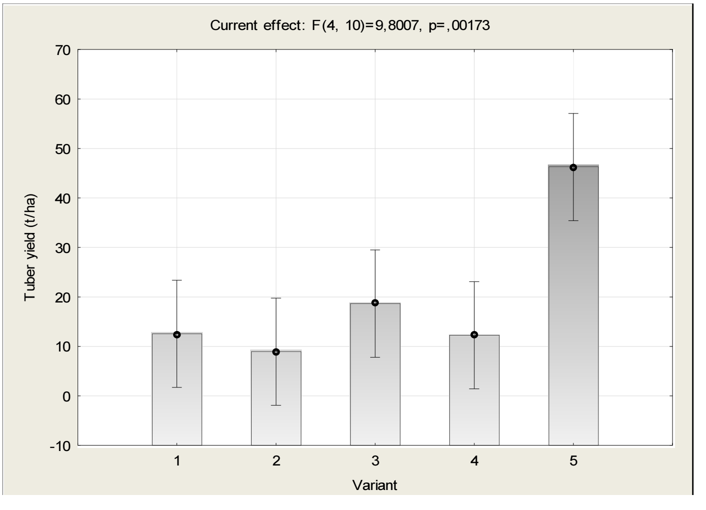

Fig. 2: The effect of applied herbicides on total potato weight between 2014 and 2016

These results partly correspond to findings of other authors, e.g. Boydston (2001) showed that an application of fluroxypyr at the eight leaf stage of potato plants gave 83 % control. This herbicide caused damage to the potato plant foliage and reduced the weight of tubers. Allemann et al. (2013) add a further benefit of fluroxypyr. Applied to potato plants, 10-20 cm tall, at the rate of 576 g/ha this herbicide causes severe scorching and distortion of potato foliage and is translocated to daughter tubers, so affecting the plant capacity to produce viable tubers in the year following application. The mentioned rate is almost double than the highest rate tested in our trial (300 g/ha), which is also the highest rate as regard as the threshold of economic efficiency. The lowering of sprouting capacity and viability of survived tubers we also confirmed for this rate in our studies.

In individual years the efficiency of applied herbicides differed (Fig. 3).

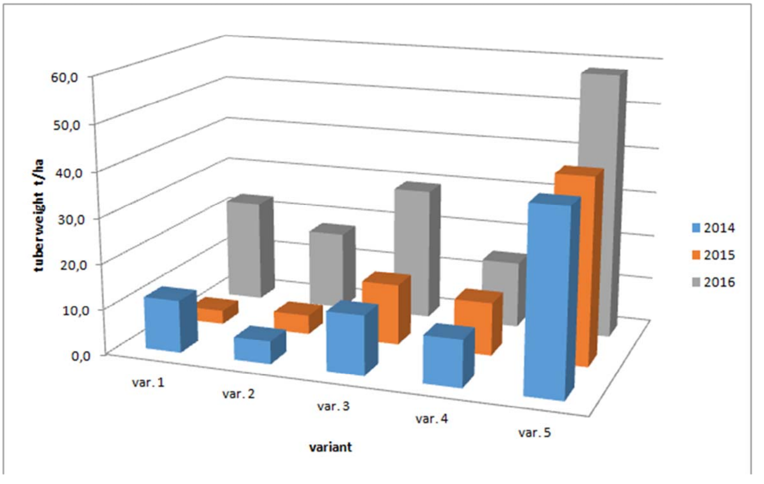

Fig 3: The effect of applied herbicides on tuber weight in individual studied years

The efficiency expressed as TW in Fig. 3 depends on level of non-treated control. In 2016 optimal conditions for TW formation were set and non-treated control reached 58.2 t/ha. The highest efficiency was found in the variant 4 (45 g/ha foramsulfuron, 1.5 g/ha iodosulfuron-methyl Na and 15 g/ha theincarbazone-methyl) with the weight of 14.7 t/ha (74.7 % efficiency). On contrary, the lowest efficiency was recorded for the variant 3 (144 g/ha mesotrione) with 29.4 t/ha TW (49.5 % efficiency).

In 2015 and 2014 the level of TW in non-treated controls was similar – 40.1 and 37.7 t/ha.

The most efficient variant in 2015 was the variant 1 (200 g/ha fluroxypyr), where 3.1 t/ha TW was detected (92.5 % efficiency) and in 2014 the most efficient was the variant 2 – 2.0 t/ha TW (87.4 % efficiency). The lowest efficiency was found in the variant 3 in all studied years.

Except for fluroxypyr, herbicide efficiency of tested active ingredients is also confirmed by other authors. Steiner et al. (2005) divided 22 herbicides into three groups based on the efficiency. The group with the highest efficiency also involved mesotrione, which we on contrary found as the lowest efficient, the rates were identical; however, concentration of volunteer potato distribution could not be compared.

The effect of applied herbicide on TW in individual tuber size categories was studied (Figs 4-6). In the category of small tubers, i.e. less than 35 mm, no differences were found between variants. Tendentiously higher weight of small tubers was recorded for the variant 4, what is a negative finding – small tubers more easily survive in the soil and infest subsequent crops. In the category of medium tubers (35-55 mm) tendencies were confirmed and in the case of size more than 35 mm significance of values identical with TW of all tubers was found.

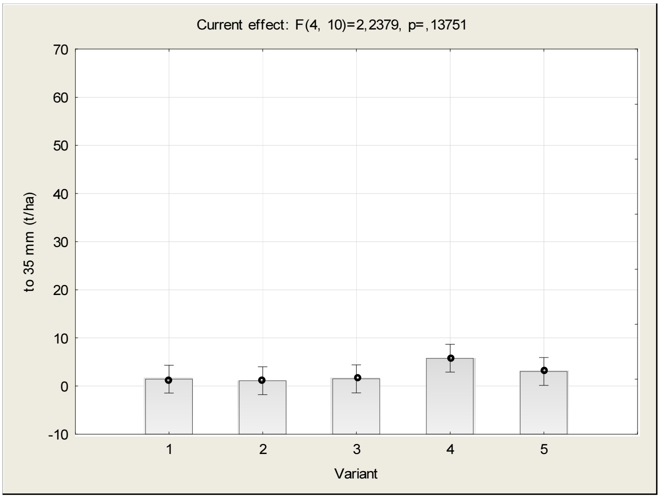

Fig. 4: The effect of applied herbicides on potato weight size of less than 35 mm between 2014 and 2016

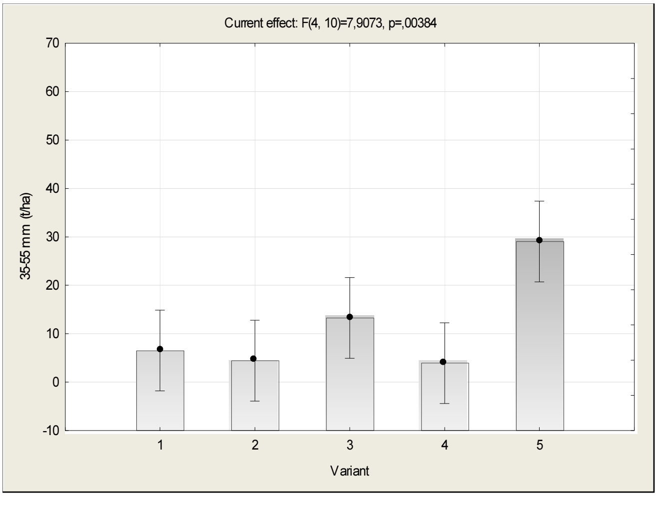

Fig. 5: The effect of applied herbicides on potato weight size of 35-55 mm between 2014 and 2016

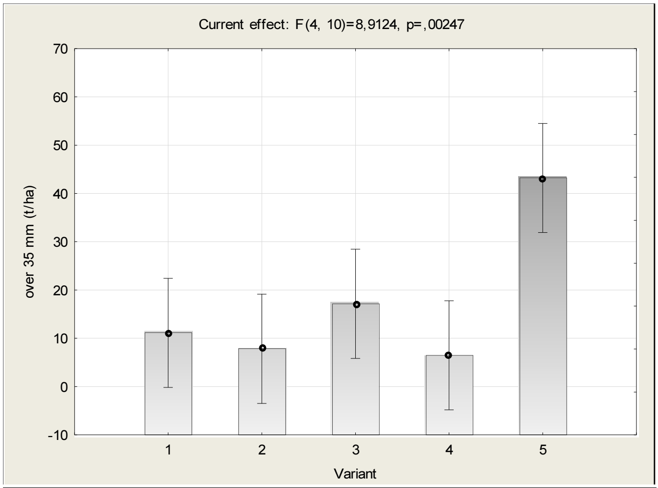

Fig. 6: The effect of applied herbicides on potato weight size of more than 35 mm between 2014 and 2016

Table 1: The effect of variants on percentage distribution of potato tuber size categories

Tuber size distribution (%)	Variant	Year			Mean	F – test for variants
		2014	2015	2016		
< 35 mm	1	24.93	18.68	3.52	15.71ab	*2.54*
	2	35.76	17.35	4.66	19.26ab	
	3	10.45	8.55	6.74	8.58 ab	
	4	9.24	65.55	59.09	44.63 a	
	5	4.81	13.94	2.55	7.10 b	
	Mean	17.04a	24.81a	15.31a		
	F - test for year		0.29			
35 - 55 mm	1	56.76	58.77	48.69	54.74 ab	*5.02*
	2	51.37	49.66	49.16	50.06ab	
	3	61.26	73.92	74.24	69.81 a	
	4	39.56	26.55	31.19	32.43b	
	5	41.62	85.18	61.54	62.78a	
	Mean	50.11a	58.82a	52.96a		
	F - test for year		0.34			
> 55 mm	1	18.31	22.55	47.79	29.55a	*0.15*
	2	12.87	32.99	46.19	30.68a	
	3	28.30	17.53	19.02	21.62a	
	4	51.20	7.90	9.72	22.94 a	
	5	53.58	0.88	35.91	30.12a	
	Mean	32.85a	16.37a	31.73a		
	F - test for year		1.61			

Table 1 presents the effect of evaluated herbicides on relative potato tuber distribution in size categories. In all variants the tendency to higher distribution of the smallest tubers was found compared to non-treated control. However, it was statistically significant only to the variant 4. It is interesting that in percentage distribution of the category of largest tubers statistically significant differences were not found.

CONCLUSIONS

The results from the trials confirmed the possibility of successful volunteer potato regulation in subsequent crops – maize and cereals.

– The highest efficiency (80.7 %) was found using 300 g/ha fluroxypyr

– Using the same active ingredient, however, a reduced rate (200 g/ha), the efficiency was decreased to 72.9 %.

– The combination of active ingredients foramsulfuron (45 g/ha), iodosulfuron-methyl Na (1.5 g/ha) and thiencarbazone-methyl (15 g/ha) reached 73.5 % efficiency

– The lowest efficiency (59.7 %) was recorded for active ingredient mesotrionin (144 g/ha)

ACKNOWLEDGEMENT

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 634.7:634.73
Prethodno priopćenje
Preliminary communication

DETERMINATION OF THE CONNECTION FORCE BETWEEN BERRIES AND STEM IN BLUEBERRY PLANTS

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SUMMARY

The berries of a blueberry plant are connected one-by-one to the stem with stalks. A blueberry harvester equipped with a rotary picking reel is used for harvesting blueberries mechanically. During mechanical harvesting, the berry is removed from the plant stem by pulling. The berries separate from the stem when the pulling force of the teeth of the picking reel is greater than the connection force of the berries. However, it must be taken into account that blueberry berries are fragile, even elastic to some extent, but certain mechanical forces may cause plastic deformations to the berries, which may damage them. Damaged blueberries have no commercial value for serving on dish. This must be taken into account while modelling the picking unit of a blueberry harvester and the constructional and cinematic parameters of the machine must be selected in a way that the teeth of the picking rake exert soft forces to the berry during contact and pulling the berry off. Therefore, the purpose of this study is to determine experimentally the connection force between berries and stem in blueberry plants.

Key words: agricultural engineering, blueberry harvesting, picking rake teeth, connection force, experiment.

INTRODUCTION

The increasing cultivation area of commercially cultivated blueberries and increasing costs of manual harvesting has resulted in increased interest in mechanical harvesting (van Dalfsen & Gaye, 1999). The mechanical harvesting of blueberries requires that the berries are pulled off from the stem using some working element or picking device. The picking device of the harvester of lowbush blueberries (*Vaccinium angustifolium* Ait.) consists of a drum or a picking reel with horizontal rotary axis which removes the berries from the stems (Käis & Olt, 2010; Arak & Olt, 2014). The working elements of the picking reel (Figure 1) are its hinged horizontal picking rakes which contain picking teeth rigidly attached to the shafts. In order to remove the berries, the drum and its teeth are rotated clockwise, the plants remain between the teeth and as the drum rotates, the teeth pull the berries away from the stem.

The most important quality indicator of a blueberry's berry is its texture, which is mostly described by its hardness, viscosity, elasticity and adhesiveness (Giese, 1995; Li et al., 2011). The fact that blueberries are sensitive to crushing may become a problem for mechanical harvesting (Yu et al., 2012). As nearly a half of the blueberries are usually harvested to be served fresh on dish (Strick & Yarborough, 2005), then these berries must be of high quality and look perfect and, therefore, avoiding crushing is of utmost importance in harvesting these berries mechanically. In order to avoid the mechanical damaging of the berries, the picking teeth must have elastic design (Olt & Arak, 2012).

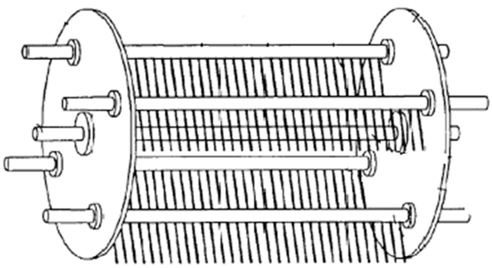


Figure 1: The principle of blueberry harvester's picking reel.

The purpose of this study was to determine the connection force between berries and stem in order to acquire source data for choosing the material for preparing the picking reel's elastic teeth with suitable mechanical properties.

METHODS

The fieldworks were performed in the Marjasoo Farm whose blueberry plantation has been established on depleted peat milling fields. The object of study was the lowbush blueberry (*Vaccinium angustifolium* Ait.), which is the most common variety in blueberry plantations established on depleted peat milling fields in Estonia.

In order to determine the connection force of the blueberry, it is reasonable to use a scheme whose operation is similar to the picking rake. From the mechanical point of view the stem of the blueberry plant is attached to the ground and the blueberry's berry to the plant's stem. During the mechanical harvesting process the blueberry's berry is lifted up by the teeth of the picking rake and pulled off from the stem, which is attached to the ground.

Arising from the abovementioned, the physically modelled test device for determining experimentally the connection force between blueberry's berries and stem (Figure 2) consists of a device for fastening the plant's stem, a jaw equipped with rigid teeth for grabbing the berry, a gripper, a mechanism for changing the jaw's position on the vertical plane, a force sensor attached to the shaft of the jaw and a reader for recording data. The plant has been attached to the gripper as follows. Tensile Force Tester Instron 5969L2610 is used to determine the force applied to the berry. The technical specifications of the test device have been presented in Table 1.

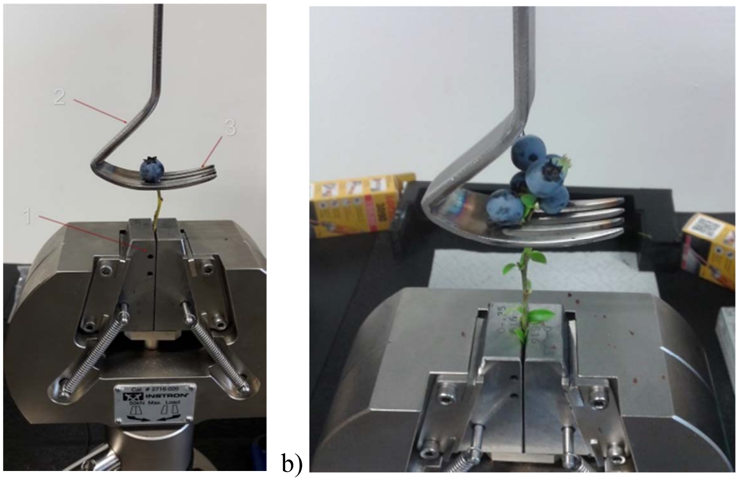
a) b)


Figure 2: Test device for determining the connection force of one berry (a) and a bunch of berries (b).

The berries may be attached to the stem as bunches. Such a position may affect the measuring results and separate tests were performed to determine the connection force of bunches of berries (Figure 2b).

Table 1 Technical specifications of the test device

No.	Part	Technical description	Parameter
1	Sensor	Loadcell 1kN	Measuring range ±1 kN, accuracy ±0.25% of the indicated force
2	Reader	Instron 5969L2610	
3	Gripper		Material (AISI304) thickness 2.5 mm, distance between teeth 2.6 mm
4	Jaw	Face VEE JAW S16	

The test device's operation is the following. Plants with berries are cut from near the ground in the plantation, put in a sealed plastic bag to avoid drying and brought to the laboratory within one hour. The plant's stem is fastened to the gripper (Figure 2a, 1) and the berry or the bunch of berries is placed between the jaw's (Figure 2a, 2) teeth (Figure 2a, 3). Subsequently, an actuator mechanically attached to the jaw is started. As the jaw moves vertically upwards (with the speed 5 mm/min) the plant attached to the gripper starts to extend and the tension between the berry and the plant's stem starts to increase until the berry is removed from the plant's stem. The maximum tensile strength allows determining the connection force between the blueberry's berry and plant's stem.

RESULTS AND DISCUSSION

The tests were performed on 3rd and 10th of August 2015 and 3rd of August 2016 and they included the measurement of the connection force between the stem and both ripe and unripe berries and bunches of berries.

The test results of the measurement (3rd of August 2015) of the connection force of ripe berries (7 specimens, diameter 6.9 mm to 10.9 mm) has been illustrated in Figure 3.

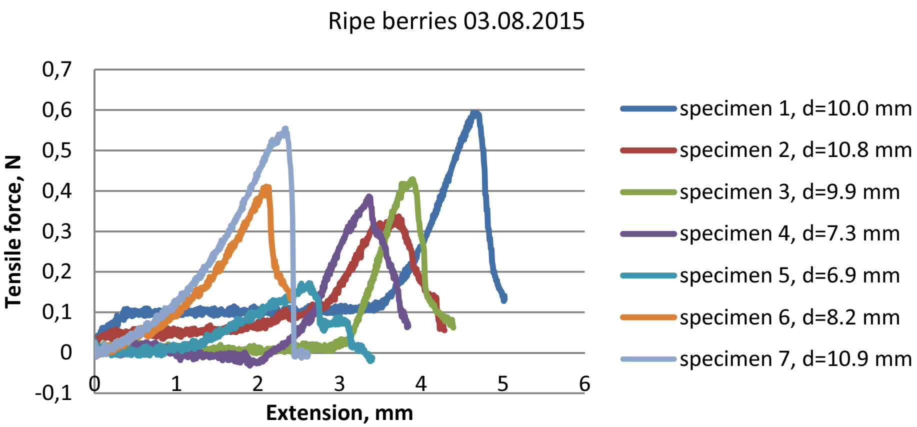


Figure 3: Connection force of ripe berries.

The values of the connection force of unripe and ripe berries measured according to the abovementioned method have been presented in Table 2.

Table 2: The average (F_{aver}), minimum (F_{min}) and maximum (F_{max}) connection force of unripe and ripe berries, number of tests *n* and berry diameter *d*.

	Unripe berries			Ripe berries		
Date	3.08.2015	10.08.2015	3.08.2016	3.08.2015	10.08.2015	3.08.2016
n	5	6	10	7	6	7
d	7.6–9.4	8.0–10.8	6.5–9.1	6.9–10.9	9.8–13.1	11.1–13.2
F_{min}, N	1.57	1.91	1.93	0.59	0.99	0.83
F_{aver}, N	1.42	1.45	1.15	0.41	0.51	0.66
F_{max}, N	1.27	1.00	0.89	0.17	0.29	0.53

The test results indicate that the tensile strength or connection force of individual unripe berries was in the range of 0.89–1.93 N. The test results showed that there is a positive correlation with average strength between the connection force and berry diameter of unripe berries where the value of correlation coefficient *r* is 0.63.

To these results the type B expanded uncertainty U_B evaluation can be applied using the following formula

$$U_B(F) = t_{\infty,95\%}\frac{e_p}{3}, \quad (1)$$

where F stands for the value of measured strength, $t_{\infty,95\%}$ stands for Student's coefficient at 95% confidence level and e_p expresses the maximum tolerance limit.

The type B expanded uncertainty values for the determination of minimum and maximum connection force of unripe berries was 0.0015 N and 0.0032 N respectively.

The tensile strength or connection force of ripe berries was in the range from 0.17 to 0.99 N and mean value 0.53 N. The tests showed that there is a positive correlation with average strength (r = 0.52) between the connection force and berry diameter of ripe berries. The type B expanded uncertainty values for the minimum and maximum values are 0.0003 N and 0.0016 N. The mean value's confidence limits at 95% confidence level are determined using the following formula

$$\left(F_{aver} - t_{n-1,95\%}\frac{s}{\sqrt{n}};\ F_{aver} + t_{n-1,95\%}\frac{s}{\sqrt{n}};\right), \quad (2)$$

where s stands for standard deviation. The upper and lower limits of standard deviation at 95% confidence level is 0.39 N and 0.65 N respectively, whereby the upper limit may be regarded as the minimum force required to harvest the majority of the berries.

The connection force of berries which are attached to the stem as bunches is larger than that of single berries. The connection force of berries in bunches was also measured in the test of 3rd of August 2015, where the bunch consisted of 30 berries, 18 (60%) of which were ripe (diameters 8.6–13.6 mm), 3 were semi-ripe (6.7–8.5 mm) and 9 were unripe (2.9–8.9 mm). The force that was needed to remove the berries from the stem was within the range of 1–8.5 N. All of the berries were removed from the stem individually, which can be seen in Figure 5, whereat 90% of the berries were removed without a tail.

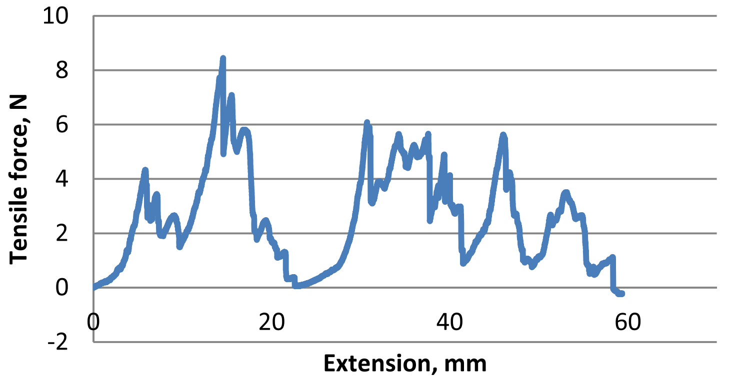


Figure 5: The connection force of blueberry's berries in bunches on 3rd of August 2015.

In the test performed a week later, on the 10th of August 2015, where the bunch consisted of 39 berries, 31 (79.5%) of which were ripe (diameters 8.1–11.7 mm), 2 were semi-ripe (8.3–8.4 mm) and 6 were unripe (5.3–7.7 mm). The force that was needed to remove the berries from the stem was within the range of 0.8–5.8 N (Figure 6). All of the berries were removed from the stem individually, whereat 95% of the berries were removed without a tail.

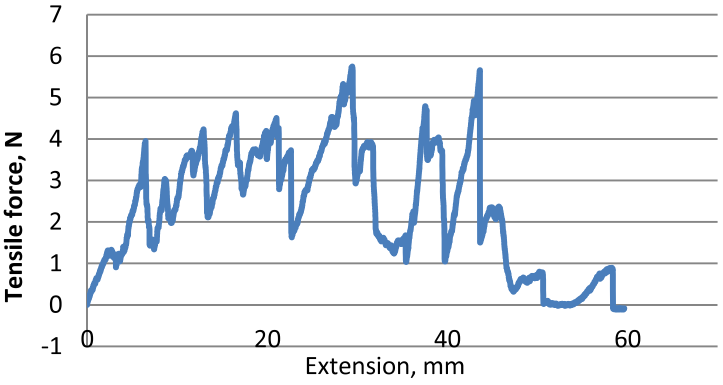


Figure 6 The connection force of blueberry's berries in bunches on 10th of August 2015.

CONCLUSIONS

This experimental study allowed determining the connection force between the blueberry's berry and stem for single berries and bunches of berries. The connection forces of single unripe berries were in the range of 1–2 N, for ripe berries the force was up to 1 N. Berries attached as bunches are removed from the plant's stem individually, however, their connection force is up to 9 N. The results obtained are used as source data for choosing the material for preparing the picking reel's elastic teeth with suitable mechanical properties.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.358:634.574
Izvorni znanstveni rad
Original scientific paper

DETERMINATION OF OPTIMUM SHAKING FREQUENCY AND AMPLITUDE OF PROTOTYPE BODY SHAKER USED FOR MECHANICAL HARVESTING OF PISTACHIO

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SUMMARY

Important problems have been seen during harvesting of different fruit trees in Turkey. The highest cost in fruit growing constitutes harvesting process as 43.99% of total cost. In this research, a body shaker which was mounted to tractor three-point linkage system and driven by power take off system was designed and manufactured to decrease the cost of harvesting of tree fruits. A tractor with 70 BG power is enough to transport and operate this body shaker. This prototype was functioned with a system including a hydraulic pump taking movement from power take-off and hydraulic motor. Body shaker could be controlled by only one person. Harvesting tests using different frequencies and amplitudes were carried out with body shaker. Two pistachio tree cultivars namely Siirt and Kirmizi were used during the harvesting tests. Pistachio fruits which remained on the branch and leaved from branch were weighed separately to determine of harvesting efficiency. For this aim, performance of body shaker was determined. As a result, the best performance result was determined using 40 Hz frequency and 20 mm amplitude. The harvesting efficiency values in harvesting tests carried out using 40 Hz frequency and 20 mm were calculated 93.27% for pistachio cultivar of Siirt and 87. 06% for pistachio cultivar of Kirmizi.

Key words: body shaker, fruit harvesting, pistachio nut

INTRODUCTION

Pistachio nut (*Pistachio Vera* L.) is a perennial plant growing in inner South Eastern Anatolia regions of Turkey. Turkey is one of the most important pistachio producer countries, with 128.000 tones annual pistachio production, and Turkey comes after Iran (446.647 tonnes) and the United States of America (213.000 tonnes) (FAO, 2011). The most popular pistachio cultivars in Turkey are Kirmizi, Siirt and Uzun.

Tree shakers are widely used to harvesting of different kinds of tree fruits. Limb shakers are especially popular and have the advantage of speed, particularly in orchards having many primary limbs. Limb shakers usually achieve a somewhat better removal of fruit on plant trees (Horvath and Sitkei, 2001). About tree shakers, structure of both trunk and main roots and the ratio of fruit detachment force have been studied since 1960's (Adrian & Fridley, 1965; Fridley 1983; Keçecioglu, 1975; Sansavini &Costa 1986; Parameswarakumar & Gupta, 1991; Polat et. al. 2011, Gezer et. al, 1998, Sessiz & Özcan 2005, Lang 2006).

There are two broad approaches for the mechanical harvesting considerations. One of these approaches is the mass harvesting method, namely harvesting indiscriminately from the whole tree or a portion, without direct concern for individual fruits. The other is individual fruit harvesting, namely harvesting each fruit as distinct and separate from adjacent fruits. In individual fruit harvesting, several fruits could be harvested at the same time by separators (Schertz & Brown, 1968). Examples of detaching device being considered for the mass harvesting of fruit include limb shakers and trunk shakers. The basic principle of limb shaking is based on the transmission of vibratory forces to the limb (Horvath & Sitkei, 2001) proposed a new tree model which analyses three different kinds of trunk motion. Based on acceleration measurements in the soil body, a new mass component was included, in addition to the common mass components. The analyses of dynamics and power requirement of the system have shown that the elastic deformation of the trunk will continuously be higher as attachment height increases, resulting in a significant decrease in the net power requirement.

The objective of this research is to investigate the mechanical harvesting of pistachio nut cultivars in Turkey. Designing, manufacturing and testing of a prototype body shaker for determining optimum operation conditions namely shaking frequency and amplitude values were also aimed.

MATERIAL AND METHODS

Design and Manufacturing of Body Shaker and Seizure Platform

After computer aided designing of body shaker, manufacturing of prototype system was carried out in workshop of Harran University Machine Factory in Sanliurfa City of Turkey. Main parts of body shaker are roof, oil tank, oil-cooling system, boom, hydraulic pump, hydraulic motor, oil transmitting pipes, vibrator heads, boots and control panel (Fig. 1).

Fig. 1. Manufacturing process of body shaker

Fig. 2. Orchard tests with body shaker

Performance tests were carried out in pistachio orchards as seen in Fig. 2.

Body shaker was driven with power take-off and tractor electric system. The movement taken from power take-off stimulated by hydraulic pump. Hydraulic pump transmitted the oil to the hydraulic motors on vibrator system.

Pistachio orchards used for harvesting tests

Harvesting tests with the body shaker for Siirt and Kirmizi pistachio cultivars were conducted in orchards that are belong to Pistachio Research Institute during harvesting season (September and October). Trees in the orchards are 35 years old and were planted with intervals of 8x8 mm.

Determination of harvesting efficiency and work success

Orchard trials with body shaker were carried out in Tagem-Pistachio Research Institute in Turkey. Vibrating process with body shaker was conducted during the harvesting of pistachio fruits by applying different amplitude and frequency values. 3 different amplitude values were applied as 10,15 and 20 mm. Values of frequency were selected as 20, 30, and 40 Hz. After each amplitude and frequency applications, the fruits dropped from the tree were collected by a catching mechanism. Fruit bulks that were dropped from the tree and staying on the tree were weighted separately. Harvest efficiency was calculated using these weighted fruit amounts by the equation as given below (Polat et al. 2007):

$$Harvesting\ efficiency\ (\%) = \frac{K_1}{K_1 + K_2} x100$$

In this equation;

K_1 is the mass of product (kg/tree) collected from branch as mechanical (harvested);

K_2 is the mass of product (kg/tree) which could not be dropped (staying on the branch).

As a result of these trials with body shaker, optimum shaking amplitude and frequency providing the most appropriate harvest efficiency were determined.

RESULTS AND DISCUSSION

Results of harvesting efficiency values

Harvesting trials were carried out during in September and October months as three replications for each frequency and amplitude values. Average values of results of three-years obtained for Kirmizi cultivar were given in Table 1.

Table 1. Harvesting efficiency values determined after body shaker trials for Kirmizi pistachio cultivar

Amplitude (mm)	Frequency (Hz)	Harvesting Efficiency (%)			
		1st year	2nd year	3rd year	Average
10	20	22.21	25.1	22.76	23.36
	30	36.43	38.09	37.4	37.31
	40	53.83	52.1	57.89	54.61
15	20	35.22	34.49	36.71	35.47
	30	56.29	54.5	56.58	55.79
	40	63.25	66.21	66.69	65.38
20	20	67.42	65.37	69.95	67.58
	30	79.46	74.54	82.67	78.89
	40	87.66	83.42	90.11	87.06

As a result of harvesting tests, the lowest harvesting efficiency was obtained in body shaker with 10 mm amplitude and 20 Hz frequency values. On the other hand, the highest harvesting efficiency was obtained with body shaker with 20 mm vibrating amplitude and 40 Hz vibrating frequency. 87.06 % of the fruits on the tree was harvested during test conditions of 20 mm amplitude and 40 Hz frequency when the highest harvesting efficiency was obtained. The reason of staying of pistachio nuts on the tree after mechanical harvesting was examined. It was found that the split resistance of pistachio fruits staying on the tree is somewhat high compared to pistachio fruits that could be dropped by mechanical shaking. The reason of this higher split resistance can be explained that fruits not dropped are still in ripening period or some part of the remaining fruits includes hollow fruits.

Three-years average values for harvesting efficiency results obtained for Siirt cultivar pistachio were given in Table 2.

Table 2. Harvesting efficiency values determined after body shaker trials for Siirt pistachio cultivar

Amplitude (mm)	Frequency (Hz)	Harvest Efficiency (%)			
		1.year	2.year	3.year	Average
10	20	27.62	25.98	27.66	27.09
	30	33.62	34.5	35.85	34.66
	40	48.69	48.13	46.96	47.93
15	20	40.03	35.72	37.72	37.83
	30	59.17	58.87	59.31	59.12
	40	65.9	69.23	72.04	69.06
20	20	73.21	72.84	78.25	74.77
	30	81.83	82.16	85.91	83.30
	40	92.48	92.8	94.53	93.27

In this research, the lowest harvesting efficiency value for Siirt cultivar pistachio for every three years determined after using of body shaker was determined as 27.09% in the conditions of 10 mm amplitude and 20Hz frequency. On the other hand, highest harvesting efficiency was calculated as 93.27% in the conditions of 20 mm amplitude and 40 Hz frequency.

The reason of pistachio nuts were not dropped was examined throughout the vibration tests using body shaker. Similar to trials results of Kirmizi cultivar pistachio, fruit splitting resistance of the pistachio nuts remained on the branch was determined somewhat high. In addition to this, pistachio nuts remaining on the branch consist of either immature or hollow fruits. Therefore, falling down of these immature or hollow fruits by means of vibration method is rather difficult. Therefore, in this research, ratio of fruits, (empty and full) remaining on the branch after mechanical harvesting were determined. Sola-Guirado et al. 2016 searched on vibration parameters assessment to develop a continuous lateral canopy shaker for mechanical harvesting of traditional olive trees. In this research they found that fruit detachment is influenced by the point of application of the vibration to the tree. For this reason in this research, pistachio fruit plucking resistance namely detachment force measurements were also performed. The results about these measurements were conducted for each pistachio cultivars separately after harvesting trials carried out using operation conditions of 20 mm amplitude and 40 Hz frequency in which the highest harvesting efficiency was obtained. Obtained results were given in Table 3.

Table 3. The ratio of full and empty pistachio nuts remained on the branch after mechanical harvesting

Cultivars	Ratio of full and empty pistachio nuts		Fruit Plucking Force
	Full (%)	Empty (%)	(N)
Siirt	43	57	315
Red	52	48	291

After mechanical harvesting of Siirt cultivar; only 43% ratio of remained fruits ratio on the branch (5.47% of all fruits on the tree) was determined as full fruits. For Kirmizi cultivar of pistachio fruits, full fruit ratio was determined as 52% (9.89% of all the fruits on the tree). Average values of fruit plucking force of the fruits remaining on the branch were measured as 315 N for Siirt cultivar and 291 N for Kirmizi cultivar. These results showed that it is very hard to fall down all pistachio fruits remained on the branch. Because using of higher frequency and amplitude values than optimum values can seriously harm the trees.

CONCLUSIONS

According to results of this research, pistachio cultivation should be performed by taking into consideration mechanization since the beginning. It is somewhat too hard to conduct mechanization practices in pistachio nut gardens in which growing is not carried out in accordance with mechanization. These difficulties have been encountered in mechanical harvesting. Planting intervals, tree's corolla structure and disorder of body form shape have constituted a problem for mechanical harvesting. Particularly pruning procedure in pistachio nut must be carried out with a great attention if mechanical harvesting is also performed. Until the vibration reaches the end of the branch in vibrating mechanical harvest machines especially in branch shakers, it fades and turns into a whipping movement.

The highest harvesting efficiency was obtained in harvesting trials carried out with 20 mm amplitude and 40 Hz frequency using body shaker. Approximately 90% harvesting efficiency was obtained for both pistachio cultivars after harvesting process conducted with this frequency and amplitude values. It was seen that much higher efficiency values may be result of permanent damage in body form of the trees.

Fruit harvesting is generally performed by means of the hand throughout the world using manual labour due to the fact that it is still cheap and growers are worried about the detrimental effects of mechanical harvesting to the trees. Nonetheless, labour cost and difficulties in finding of labour have been increasing day recently. Thus, mechanical harvesting becomes unavoidable for growers of pistachio nuts and other fruits. In this research, a body shaker that can be connected to the tractor and removed any time and that have lower cost compared to self-propelled shakers was designed and tested for pistachio trees. Results showed that this system with optimum frequency and amplitude can be suggested to obtain high harvesting efficiency for pistachio harvesting safely.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 551.58:631.234:728.98
Prethodno priopćenje
Preliminary communication

MICROCLIMATIC PARAMETERS DURING RASPBERRIES PRODUCTION IN TUNNEL TYPE GREENHOUSE

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SUMMARY

Agricultural production in greenhouse represents the most intensive form of agricultural production. This is a very complex production system that needs to be well maintained and with great attention. The aim of this paper is to present preliminary research results on raspberry production in greenhouse and in the open field regarding the microclimatic production conditions. In this paper, results on microclimatic production conditions in the tunnel structure greenhouse and in the open filed are presented. The raspberry variety Heritage (Rubus Heritage) was grown in the 7 x 24 m tunnel greenhouse covered with the single PE folia and in the open filed. Results show that production conditions in the greenhouse enable prolonged harvesting (September, October) till the first frosts. Air temperature, air relative humidity and solar radiation were measured and analyzed. Temperature inside the greenhouse varied along the greenhouse and during the day but the variations were not significant enabling the uniform production conditions during the day. Air relative humidity did not show significant variation concerning the open field and greenhouse production. Solar radiation showed high losses in the morning hours. Only 25.82 % of solar energy was available to the plants.

Key words: raspberry, microclimate parameters, tunnel greenhouse.

INTRODUCTION

Intensifying the agricultural production has always been the imperative for the human population having in mind its growth rate and tendency of increased need for food due population growth, especially due limited arable land. Greenhouse production system is a very complex system that enables whole-year plant production, complete environmental (production) control, higher product quality, higher yield per m^2 and, thus, higher profit (Dimitrijević *et al.*, 2015). Establishing this king of plant production demands high investments and high yearly production costs. At the same time this system is energy demanding production system. Comparing to the open filed production, energy inputs in greenhouse vegetable production can be 50% higher (Đević and Dimitrijević, 2010). High energy demand can only be justified if higher yield are obtained and, thus, higher energy output.

Raspberry fruits are used as fresh and in food industry for making jams and fruit cake dressings. Due to its high nutrition properties it represents an important part of the human dietary routine and is one of the most appreciated fruit species. Raspberry production in Serbia begins after World War I. In the 1988 raspberry becomes the most important berry fruits in the former Yugoslavia (Stanisavljević *et al.*, 1989) having the same leading place nowadays in Serbia. The highest production of raspberries in Serbia was achieved in 2011. (123 456 t) on the total area of 21 340 ha having the average yield of 5.77 t/ha (FAO Production Yearbook, 2012) that was 3-4 times higher than the previous average yields in this region. This clearly indicates the great potential for the intensification of raspberry production.

Without quality sorts of raspberries, there is no profitable production and good fruit placement. Fostering raspberries in the PE rain shelters systems (Comeau *et al.*, 2012) and in greenhouse in the world is fairly well developed, especially in a country where is higher consumption of fresh raspberries (SAD, Netherlands, Belgium, England, Canada and others) and in the countries from which exports fresh raspberries (Spain, Italy) (Nikolić *et al.*, 2015). Techniques such as polyethylene rain shelters have been introduced in areas where untimely precipitations can be frequent because precipitations have been linked to reductions in small fruit yield and shelf-life due to rain-driven epidemics of phyto-pathogens (Xiao *et al.*, 2001). A few studies have suggested that rain shelters, through reduced disease pressure, can increase crop yield and productivity (Masaki, 1987), However, rain shelters have the potential to cause a decline in photosynthesis through a possible loss of light energy that can be reflected or absorbed by some types of covering material. For instance, Rohloff *et al.* (2004) reported decreases in photosynthetic active radiation (PAR) of as much as 47% in sunny conditions under their polyethylene rain shelters. The other possibility for intensive raspberry production is growing in greenhouse structures. Protected cultivation of red raspberry (*Rubus idaeus* L.) in greenhouses or plastic tunnels for the fresh market is increasing, especially production for an extended marketing season (Brennan *et al.*, 1999; Raffle, 2004; Dale, 2008). However, according to Carew et al. (2000b), there has been little research that allows this system to be optimized.

In Serbia production of raspberries in greenhouse is slowly developing in the last few years. The sort is grown in most cases is Heritage. The aim of this research was to investigate microclimate parameters in tunnel type of greenhouse. Analyzed the variation of temperature, relative humidity and solar radiation inside the greenhouse construction, and differences in measurements inside and open filed.

MATERIAL AND METHODS

Microclimatic production parameters in the raspberry *Rubus Heritage* production were monitored in the open field and greenhouse production. For the purpose of research, a tunnel type of greenhouse was used. Tunnel width was 7 m, its length 24 m and height 3, 25 m. It was covered with 180 µm PE UV film. Experiment was carried out on a private property in Milićevo Selo near Požega, Serbia (43°47'50.04''N, 20°5'35.20''E). Air temperature and humidity were measured using the sets of WatchDog loggers 150 Temp/RH, t=0,6 °C, RH=3 % and WatchDog Data Logger Model 450-Temp, Relative Humidity- Temp/RH, t=0,6 and RH=3%. Measuring interval was 15 minutes. Production conditions were tracked and analyzed in the autumn 2016.

Statistical analysis of the results was based on variance analysis, F tests and LSD tests which were used for determine if the temperature is uniform along the greenhouses. The t test was used to determine if microclimatic conditions inside the greenhouse are different than the parameters at the open filed. Data used for the analysis represent the five days average values.

RESULTS AND DISCUSSION

Temperature distribution

Temperature measurements in the tunnel type of greenhouse show that temperature varies along the greenhouse (Fig. 1). During the night hours the highest temperature was observed in the central part of the tunnel and the lowest temperature was measured in the south part of the greenhouse (Tab. 1). Statistical analysis showed that temperature differences of 0.02 °C are not significant. Temperature measurements in 7h in the morning also showed that temperature varies along the greenhouse. The highest temperature was observed in the north part and the lowest were measured in the south part of the tunnel. Variance analyses showed that differences of 0.02 °C are not statistically significant. At 13h temperature measurements showed more intense variation along the greenhouses. The lowest temperature was observed in the central part (23.9 °C) and the highest temperature was measured in the south part (35. 34 °C). Variance analyses showed that differences of 23,54 °C are very significant. Measurements at 19h also showed the difference exist but statistical analysis showed that these differences are not significant.

Table 1 The average temperatures inside the greenhouse and in the open filed

Time	Inside the greenhouse, °C			Open field, °C
	North side	Central part	South side	
01h	7.65	7.68	7.25	7.42
07h	8.72	8.5	8.24	7.91
13h	29.16	25.07	32.29	21.5
19h	12.48	12.87	12.09	12.72

Based on the results it can be concluded that the temperature variation in the production of raspberries in the tunnel type of greenhouse exist along its length of the greenhouse but are not of statistical significance except in the midday period where there are "hot" spots that must be regulated introducing the forced ventilation, or using the roof openings.

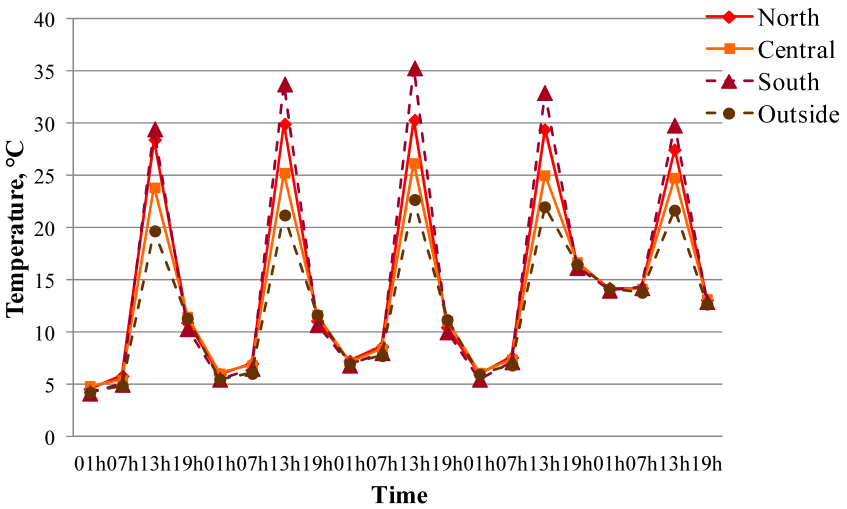

Figure 1 Temperature variation inside and outside the tunnel greenhouses.

Differences between inside and outside temperatures (Tab. 1) are very important parameter. In autumn production, greenhouse provides higher temperatures during the day and night. If these differences are significant, venting system should be provided. Natural ventilation thorough the door or roof openings is enough in these situations. All measurements except in 13 h (Tab. 2) show that temperature differences in the greenhouse and in the open filed raspberry production are not significant.

Table 2 Statistical analysis of the average temperatures inside the greenhouse and in the open filed

Parameters	Time			
	7 h	13 h	19 h	1h
Absolute difference, $\vert \overline{x}_1 - \overline{x}_2$	0.58	7.34	0.23	0.11
Standard error, $S_{\overline{x}_1 - \overline{x}_2}$	2.19	0.79	1.48	2.44
t statistics	0.26	9.29**	0.15	0.04

* $t_{0,05,\,8} = 1.86$; ** $t_{0,01,\,8} = 2.89$

In midday hours temperature inside the greenhouse was, in average, 7.34 °C higher. This difference was statistically evaluated as very significant. Since raspberry likes sun and higher temperatures, this differences can be taken as beneficial. Attention must be paid in summer period where combination of higher temperature and more intensive solar radiation can damage the raspberry leaves.

Air relative humidity

Low soil moisture and air can have a negative effect on the fruit quality. In these conditions raspberry root grows poorly and reduces the number of burgeons. On the other hand, the excess water in the soil and the air can also have a negative effect on the raspberries fruit quality. Air humidity varies during the day and along the greenhouse length and height (Hanan, 1998). It is stated that the pattern of variation depends on greenhouse type of construction its dimensions, covering material and the plant species that is produced in the greenhouse. Figure 2 shows air humidity variation during the day inside the tunnel greenhouse and in the open filed.

Measurements of the air relative humidity show that differences exist (Tab. 3), but they are not significant. During the experiment, tunnel side ventilation was opened (both sides).

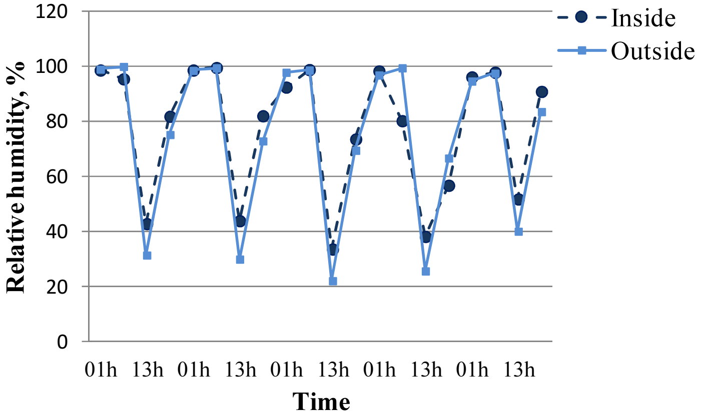

Figure 2 Air relative air humidity inside and outside the tunnel greenhouses

Table 3 Statistical analysis of the average relative humidity inside the greenhouse and in the open filed

Parameters	Time			
	7 h	13 h	19 h	1h
Absolute difference, $\overline{x}_1 - \overline{x}_2$	4.02	12.2	3.45	0.52
Standard error, $S_{\overline{x}_1 - \overline{x}_2}$	6.51	28.12	6.40	1.41
t statistics	0.62	0.43	0.54	0.37

* $t_{0,05,\,8} = 1.86$; ** $t_{0,01,\,8} = 2.89$

This is one of the reasons why the differences in air relative humidity inside the greenhouse and in the open field are small. Side openings were opened in the summer production period since the temperature inside the greenhouse was higher than the optimal oneness for raspberry.

Solar radiation

Solar radiation is one of the most important factors that influence overall energy efficiency of the greenhouse production (Nelson, 2003). Quantity of solar energy that reaches the plants inside a greenhouse depends on the greenhouse construction type, its covering material, orientation and the production time of the year. Raspberry is plant that likes sun. It does not like the shadow except in the summer periods, when solar radiation energy is too high. Measurements of solar radiation outside and inside the tunnel greenhouse showed that there are differences (Fig. 3). Results showed that in the morning hours the amount of solar radiation energy that was on the plants disposal is very low. In average, only 25.82 % of outside solar energy was transmitted into the greenhouse. In the midday hours 51.12 % of the solar energy was on the plants disposal in greenhouse. The losses of energy varied from 74.18 % to 48.88 %.

Statistical analysis showed that both morning and midday differences are very significant (Tab. 4).

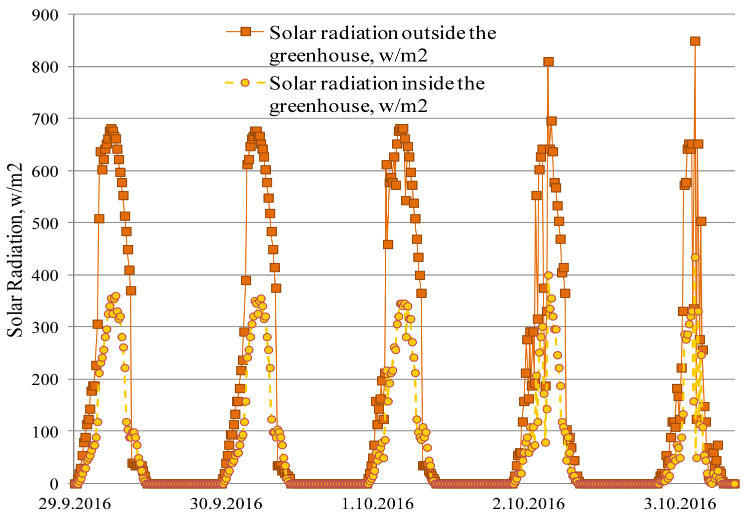

Figure 3 Solar radiation inside and outside the tunnel greenhouses

Table 4 Statistical analysis of the average solar radiation inside the greenhouse and in the open filed

Parameters	Time	
	7h	13 h
Absolute difference, $\overline{x}_1 - \overline{x}_2$	8.5	304.57
Standard error, $S_{\overline{x}_1 - \overline{x}_2}$	1.03	30.56
t statistics	8.25**	9.96**

* $t_{0,05,\,8} = 1.86$; ** $t_{0,01,\,8} = 2.89$

The reason for such low energy transmittance can be searched in the fact that greenhouse was covered with the shade net that has been used in the summer hot days but was note removed prior the experiment. The next phase in the research will be tracking the production parameters in the closed tunnel greenhouse without the shading net. This phase should start in the spring of 2017 as a part of a National research project.

CONSLUSIONS

Results show that air temperature in the tunnel structure greenhouse raspberry production varies during the day and along the greenhouse length. The differences in outside and greenhouse inside temperature were not significant except in the midday hours. This result was expected having in mind the thermal effect of the PE film. The reason of having this small differences in temperature inside and outside greenhouse, is existence of the side ventilation openings that were opened in the summer period and have not been closed in the autumn period

The same effect of the side ventilation was observed for the air relative humidity that did not differed much inside the greenhouse and in the open field. These conditions were beneficial making the production conditions in the greenhouse favorable for the raspberry since the temperatures were uniform and the air relative humidity was not high.

The research showed that in autumn production there is no need to use shading net, because it reduces the amount of solar energy that reaches the plants inside the greenhouse.

In the greenhouse, raspberry harvesting lasts until the first frosts, if heating system is not used. This type of production has a very high profitability potential but more detailed research must be carried in order to define the optimal type of structure for this king of production, to define the optimal production conditions, period when shade net is needed and when it must be removed, period when the side ventilation openings should be opened and when should be closed. All this is for the reason of creating and maintaining optimal raspberry production conditions.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 502.7:631.95
Prethodno priopćenje
Preliminary communication

BIOSYSTEMS ENGINEERING TECHNIQUES FOR HABITAT RESTORATION IN PROTECTED AREAS

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SUMMARY

A rural landscape is the final result of the mutual interaction among several natural ecosystems with the artificial intervention of the Man, who transformed the rural land, joining the agricultural production needed for human life with the control and care of extra-urban territory. A rural landscape includes the physical elements of landforms, the hydrological components and transitory elements such as lighting and weather conditions, strictly connected with living elements of land cover including indigenous vegetation, flora and fauna, as well as their possible spontaneous way of organization into different ecosystems. Human elements include different forms of land use, buildings and other rural constructions, who play a central role in determining the formal and substantial characteristics of the extra-urban landscape, influencing the agricultural environment and the visual perception of its landscape. Combining both their physical origins and the cultural overlay of human presence, often created over millennia, a rural landscape reflects a living synthesis of people and place that is vital to local and national identity, helping to define the self-image of the people who inhabit it, and a sense of place that differentiates one region from others.

The diffusion of intensive agriculture, together with the expansion of urban areas and consequent enlargement of the anthropic activities onto the rural landscape, determined a general loss in wetland areas all over the World. Because of the high rate of wetland loss over the last century, it has become routine to mitigate these losses by designing and executing specific targeted technical interventions, i.e., building or restoring existing constructions able to create local micro-environment favourable for some amphibian and reptile species, restoring existing wetlands or constructing new artificial ones, etc. Several studies have demonstrated anyway the difficulty of replicating natural habitats when attempting to create suitable habitat for these species.

In the present paper, the final results of an international Project – named: "ARUPA", financed by the EU LIFE+ Programme – aimed to guarantee the survival and increase in the population of some species of amphibians and reptiles in a protected area, are reported. The actions of the project were taken in the natural protected area surrounding the City of Matera (one of the UNESCO site of the Basilicata Region – Southern Italy) that is an EU Community Interest Site and Special Protection Zone as well. During this Project, some biosystems engineering techniques were employed, through specific constructions for the conservation and re-inclusion of some endangered species. Among these constructions, some dry-stone walls were built or restored, as well as some artificial ponds were realized. Their engineering design and construction aspects, which would contribute to the preservation of the local rural landscape, are here reported and discussed.

Keywords: Rural landscape; biosystems engineering; dry-stone walls; temporary ponds.

INTRODUCTION

A rural landscape includes the physical elements of landforms, water bodies and other morphological components, as well as living elements of land cover, including indigenous vegetation. Some transitory elements, such as lighting and weather conditions, would play a significant role as well. In this natural context, human elements are also often present, including different forms of land use, buildings and structures, *etc*. Combining both their physical origins and the cultural overlay of human presence, often created over millennia, a rural landscape reflects a living synthesis of people and place that is vital to local and national identity. The character of a landscape helps to define the self-image of the people who inhabit it and a sense of place that differentiates one region from other regions.

A rural landscape may be considered, far from being a mere passive expression of a visual component, as the result of the active interactions among several ***natural*** systems, in some cases connected to form different ecosystems. A landscape is therefore the final result of the interaction of the territory, including its own characteristics – geological, morphological, hydrological, *etc.* – with living organisms, *i.e.*: flora, fauna, *etc.* This interaction has been usually shaped by the ***artificial*** intervention of the Man, who transformed the agricultural land, joining the agricultural production needed for human nutrition with the control and care of extra-urban territory. All these aspects should be taken into the highest consideration during the landscape planning process [Dal Sasso & Caliandro, 2010; Picuno P., 2012].

Within this historic role played by humans, rural constructions play a fundamental role in determining the formal and substantial characteristics of the extra urban landscape, influencing the agricultural environment and the visual perception of its landscape [Hernández et al., 2004; Picuno et al., 2011; Tortora et al., 2015]. Some rural constructions, however, in addition to performing their primary role of support to agricultural production, may also play a proactive role in supporting suitable conditions for the persistence of some natural species that live in the extra-urban environment. In this paper, an example of effective implementation of biosystems engineering techniques, through the construction of specific elements able to support the resettlement of some amphibian and reptile endangered species in one protected area in Southern Italy, are reported.

BIOSYSTEMS ENGINEERING TECHNIQUES FOR HABITAT RESTORATION

Some of the interventions made by humans for populating and benefit the extra-urban land have been those aimed to delimit the country estate boundaries through dry-stone walls [Picuno P., 2015]. These interventions, aimed to physically demarcate boundary limits, avoiding forensic disputes, have at the same time deeply characterize the landscape, since they did not only constitute an evident construction clearly marking the territory, having at the same time realized, at micro-scale, a fertile environment in which some amphibian and reptiles species would grow, thanks to the local different soil humidity. These special conditions, mostly in sunny areas – as those located in Mediterranean Europe, *e.g.*, Southern Italy – that in summer suffer for being hot and dry, have allowed the survival of species that, otherwise, would have probably not survived [Picuno P., 2016].

A similar effect is that one connected to the diffusion of temporary ponds - also referred to as vernal pools, ephemeral wetlands, or various combinations thereof - within the rural land. The diffusion of intensive agriculture, together with the expansion of urban areas and consequent enlargement of the anthropic activities onto the rural landscape, determined a general loss in wetland areas all over the World. Because of the high rate of wetland loss over the last century, it has become routine to mitigate for these losses by restoring existing wetlands or constructing new artificial ones. Several studies [Brown et al., 2012; Drayer and Richter, 2016] however, have demonstrated the difficulty of replicating natural habitats when attempting to mitigate or create habitat for amphibians. Identification and quantification of specific characteristics that differ between natural and constructed wetlands are important information for land managers and policy-makers, for an improvement of current constructed habitats and for the success of future amphibian enhancement projects.

The inclusion of the Mediterranean temporary ponds as a priority habitat for conservation in the Habitats Directive (EC-EDG, 1992) highlights the importance of these ecosystems and the necessity to conserve them. Mediterranean temporary ponds constitute one type of temporary pond and are considered a priority habitat type in Europe. According to the Interpretation Manual of European Union Habitats, these are very shallow temporary ponds (a few centimetres deep), which exist only in winter or late spring. According to the Ramsar Convention, temporary ponds are usually small (< 10 ha) and shallow wetlands which are characterized by alternating of flooded and dry phases, and whose hydrology is largely autonomous. They occupy depressions, often endorheic, which are flooded for a sufficiently long period to allow the development of hydromorphic soils and wetland-dependent aquatic or amphibious vegetation and fauna communities. However, equally importantly, temporary ponds dry out for long enough periods to prevent the development of the more widespread plant and animal communities characteristic of more permanent wetlands. One of the main characteristics of temporary ponds is their isolation. If they were connected to more permanent habitats, this would probably cause the colonization of species typical of permanent habitats and the disappearance of those typical of temporary habitats due to competition and predation [Pérez-Bilbao et al., 2015].

Petranka and Holbrook [2006] have given prescriptive measures for the spatial configuration of pools at the landscape scale. These Authors urged restoration ecologists who are designing creation or restoration projects to consider whether natural pools are patchy (clustered, allowing free flow from pool to pool within a single amphibian population) or distant (suggesting a meta-population structure with limited interaction among pools). Calhoun et al. [2014] noted that one needs to think about particular species to assess whether pools are “patchy” or “distant.” Since, for example, permanent created pools did not support wood frogs and marbled salamanders, those species remained restricted to natural, ephemeral pools. According with Brown et al. [2012], for most amphibians with complex life cycles, standing or slow-moving water is necessary for the egg and tadpole development stages. The establishment of several wetlands in close proximity to one another is typically optimal for long-term persistence. Thus, careful consideration of the placement of wetlands within the surrounding landscape is necessary. Petranka and Holbrook [2006] indicated also that a “patchy population” wetland complex design, characterized by large variability in wetland size, hydro-period, and spatial proximity, was better than a meta-population design. Several studies indicated that upland habitat composition was important for connectivity among wetlands. Wetland creation and restoration may be effective for enhancing amphibian abundance and diversity, and thus may be a valuable tool for mitigating amphibian population declines [Brown et al., 2012].

Comparing amphibian communities of shallow and deep constructed wetlands to natural wetlands, so as to identify which wetland characteristics affect species communities, Drayer and Richter [2016] reported that constructed wetlands did not sufficiently replicate natural wetlands with respect to the amphibian community. Bellakal et al. [2014] concluded that smaller lakes are more favourable than the larger ones, in relation with a shore effect proportionally higher due to vegetation. These artificial wetlands increase the number of suitable habitats for pond-spawning species (frogs, toads), provide good compensation for the reduction of natural wetlands and may be adopted by managers as a new function (species conservation) for hill lakes. Denton & Richter [2013], considering that wetlands built for mitigation often do not replicate lost natural wetlands in structure or ecological processes, underscored the need for monitoring constructed wetlands to assess ecological condition.

Finally, Calhoun et al. [2014] resumed the existing literature about vernal pools, giving advice and general recommendations to practitioners gleaned from the literature. These Authors recommended that practitioners consider the complex ecology of pool ecosystems and the historical and current distribution of pools and other wetlands in their local context before designing pool mitigation projects. Vernal pools provide the core breeding habitat for reptiles and amphibians (*e.g.*, frogs, salamanders, *etc.*), but they are often inadequately protected because of their small size and ephemeral nature. Creation usually occurs as part of a proactive program to augment or diversify habitat by building new pools. Most natural vernal pools have shallow littoral zones available with gradual slopes to the centre, which has been linked to greater species richness compared to constructed wetlands. Natural wetlands to have significantly lower slope (measured as depth at 1 m from shore - mean = 9.1±0.8 cm) than constructed wetlands (15.4±1.6 cm). Steep, abrupt slopes may cause access problems for salamanders and may limit the growth of vegetation. Additionally, shallow areas can be important for predator avoidance, thermoregulation of amphibians for growth and to decrease the occurrence of diseases. Optimal slopes vary from pool to pool depending on typical levels of winter and fall rains.

MATERIALS AND METHODS

The Project ARUPA (*Azioni urgenti per la salvaguardia degli anfibi e rettili della Gravina di Matera - Urgent actions for the safeguard of reptiles and amphibians in the "Gravina di Matera" river*) was financed by the LIFE+ Programme of the European Union in the year 2008 (Contract number: LIFE08NAT/IT/000372). Aim of this Project was to guarantee the survival and increase in the population of some species of amphibians and reptiles in the Special Protection Area (SPA) IT9220135 of this location (www.arupalife.eu). The Project actions were taken along the "Gravina" torrent, flowing close to the City of Matera (Southern Italy), one of the most important key site for the following species: Zamenis situla, Triturus carnifex, Triturus vulgaris, Bombina pachypus.

The Project site is important also at the European level because the abovementioned species populations can be found elsewhere in the Mediterranean area. At the regional level (as far as two Italian regions are concerned, *i.e.*, Apulia and Basilicata), the site is a strategic area for the conservation of *Elaphe quatuorlineata*. While the City of Matera is an UNESCO site, the "Gravina" of Matera is one of the most spectacular rocky landscapes of Italy, witnessing the ancient relationship between man and nature. The whole surrounding territory is characterized by a soft rock, formed by deep furrows that form cliffs, caves, ravines used by the man who has lived since prehistoric times. The deep canyons that separate the plateau are the most common landscape element in the protected area. Of great suggestion, the Gravina of Matera - a huge limestone groove that crosses the park, with its twenty kilometers in length - constitutes an human, natural and environmental heritage of inestimable value. A seemingly desolate land but that hides the natural and historical riches of exceptional value. The Gravina of Matera from 1995 is included in the SIC site (Site of Community Interest) and SPA (Special Protection Area) "Gravine di Matera" included in the "Natura 2000 Network", *i.e.* the network of natural and semi-natural areas of Europe, born with the objective to contribute to the safeguard of the biodiversity of the habitats, the flora and the wild fauna. Currently, the Gravina torrent is affected by an unacceptably high level of pollution, which has reduced, if not cancelled, the presence of faunal and floral components in close contact with water.

In order to preserve the disappearance of amphibians and reptiles and to mitigate the threat factors, the ARUPA Project has put in place initiatives to ensure the survival of populations through renaturalization of the watercourse, reforestation, creation of forest nurseries and farms for the multiplications of the endangered species of amphibians, reptiles, as well as some works specifically designed basing on biosystems engineering criteria, *i.e.*: restoration of dry stone walls and realization of some temporary ponds/vernal pools. These biosystems engineering techniques were designed on the basis of a general survey of the whole area and the relevant implementation of all key parameters within a Geographical Information System (GIS), specifically aimed to the definition and design of the Project works. On this basis, the following works were realized:

- Construction of about 2,000 meters of drystone walls around the most threatened areas
  (Reference habitat: 92A0 *Salix alba* and *Populus alba galleries*)
  (Reference species: *Zamenis situla, Elaphe quatuorlineata, Testudo hermanni*)
- Restoration of some small wetlands – temporary ponds
  (Reference species*: Bombina pachypus, Hyla intermedia e Triturus carnifex, Triturus italicus* (*Lissotriton italicus*), *Elaphe quatuorlineata*)
- Realization of some grounded water storage tanks/vernal pools
  (Reference species: *Triturus carnifex, Triturus italicus (Lissotriton italicus), Bombina variegata*.)

RESULTS AND DISCUSSION

Construction of drystone walls around the most threatened areas

The dry-stone walls were constructed with the aim to:

- create new refuge and trophic habitats for many species of invertebrates and small vertebrates, especially for the endangered amphibian and reptile species;
- support the realization of better soil moisture conditions;
- promote a traditional artefact suitably integrating within the surrounding landscape, able to improve the creation of ecological corridors as well;
- increase the margin effect, expanding the ecotonal bands.

While some existing – but often severely damaged – dry-stone walls were repaired, in the other cases, some brand new walls were included into the rural landscape, in areas planned on the basis of the results obtained through the implementation of the GIS. These new dry-stone walls were built *ex-novo*, on the basis of the traditional way in which these rural constructions were realized in the two neighbouring regions - Apulia and Basilicata - by using local limestone rocks trapped and blocked together without the use of any mortar (fig. 1), basing on a small foundation that was realized under each dry-stone wall, by digging the soil for 15-20 cm.

Figure 1 - Construction of a new dry-stone wall under the ARUPA Project.

The *ex-novo* built dry-stone walls were realized with a cross section having an isosceles trapezoidal shape (fig. 2), according with three different dimension sets (lower base/higher base/height of the trapezoid):

60/40/80 cm; b) 80/60/130 cm; c) 100/70/170 cm.

Figure 2 - Dry-stone wall constructed under the ARUPA Project.

The existing dry-stone walls were repaired adopting suitable technical adjustments, so as to better fit into the rural environment, by reducing the impact on the vegetation having developed in the margin and on the habitats of existing animals and plants that have consolidated over time, essential to maintain the multiple functions performed by the wall.

Restoration of small ponds

N. 3 small temporary ponds, for a total surface area of about 2 hectares, characterized by a variable water level, were realized in order to increase the availability of areas suitable for the target species (fig. 3). Each temporary pond was provided with a water supply channel and two weirs, for water loading and unloading.

For the creation of each temporary pond, the soil has been excavated to the depth of 40-50 cm, then adequately sealed on its bottom using a waterproof fabric sheet made of special bio-compatible material. Each pond was then delimited along its perimeter by a little embankment 50 cm height, made with the excavated soil, that was adequately shaped and compacted, topped with oblique side rails. The ditches feed the areas through small channels regulating the waters, which can be closed as soon as the water level of the ditches decreases and then maintain for as long as the flooded areas. Given the ability to fast colonization by native aquatic plants typical of the area, after completion of construction operations, a preliminary planting of a total area of 1 hectares of these species with rhizomes and seeds of local ecotypes found within the surrounding areas and from the Project vegetal nursery was finally realized as well.

Figure 3 – Small temporary pond constructed under the ARUPA Project.

Grounded water storage tanks/vernal pools

In the Project area there are several tanks / pools in the open air that were traditionally used for water supply and that, at present, given the socio-economic changes that have occurred within the agricultural sector, have largely lost their initial function. However, they retain an important role in the conservation of amphibians and reptiles in the area, which is largely devoid of surface water due to its karst nature. In analogy to what was already experimented in Italy under other LIFE+ projects, two reservoirs having an average depth of 1.5 m located in the centre of a land of irregular shape of about 1000 square meters, were realized. On the bottom of each basin, an underground tank at least 4 m deep with a flask shape (Fig. 4a) was incorporated. This type of tank, traditionally used for irrigation purposes, has proven its high ecological efficiency in permitting the survival of many species of amphibians during lean periods in which, while during winter the reservoir looks like a normal quagmire (fig. 4b), during summertime the tank (located in the lowest part) retains a sufficient amount of water to keep alive sufficient specimens of invertebrate amphibians. In relation to possible risks to humans and/or animals, suitable ladders for both security reasons and for inspection-monitoring were realized. The low depth of the collected water does not represent anyway a real danger neither for the man or the animals.

Figure 4 – Scheme of a traditional grounded water storage tank (a); Grounded water storage tank/vernal pool realized under the ARUPA Project (b).

CONCLUSIONS

Within the modern concept of landscape protection, the safeguard of each ecosystem included in the rural land plays a central role. With the aim to contribute to the protection of rural land – able to counterbalance the results of a wrongly planned expansion of urban areas, as well as an indiscriminate diffusion of intensive agriculture with an heavy environmental impact on the rural landscape - suitable actions mitigating these losses may be effectively implemented, through including in the rural landscape suitable elements able to protect natural components.

Biosystems engineering techniques have revealed a powerful tool for recreating suitable conditions for the survival and proliferation of endangered amphibian and reptile species that, mostly in very sensitive areas – like that one in which the EU LIFE+ Programme has financed the ARUPA Project – may support the sustainable development of the European Countries. The contribution that biosystems engineering may play in the protection of rural landscape - thanks to its powerful *know-how* deriving from its special mission to design constructions engineered to host biological productions, having no other comparable example in the wide epistemological sector of building construction – appears therefore fundamental. The birth, growth and development of living vegetal or animal organisms contained inside rural buildings raise indeed architectural and technical issues that are absolutely original, constituting an unique and unrepeatable technological model with no similar comparison in other building sectors. Biosystems engineering may play therefore a crucial role in supporting the extra-urban land planning, since rural constructions are strictly connected with the surrounding environment, due to the need of the farmer to live in close contact with animal husbandry and agricultural land, in harmony with the natural elements, joining the agricultural production with the control and care of extra-urban land.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

ELEMENTS TO OPTIMIZE OF THE EDUCATIONAL AND FORMATIVE MANAGEMENT OF ENGINEERS SPECIALIZED FOR JOBS IN THE AGRICULTURE'S MECHANIZATION

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ABSTRACT

An efficient and profitable agriculture depends mainly on the high professional level of employees, especially those that concept, design and operate in the agricultural sectors. This paper presents a methodological approach to problem analysis and solution of technical education identified in the education and training of mechanical engineers as able to support the modernization and mechanization of the processes and systems of agricultural technologies. It has designed and implemented a complex questionnaire with which investigated 5 series of graduates from 4 specializations, with multiple opportunities to enter the labor market for agriculture. The findings were processed and interpreted, and the conclusions being found important recommendations for improved management educational programs of study so that, in addition to professional skills acquired during their studies to have a greater incentive to shift engineer graduate to agriculture, highly mechanized, modern and efficient.

Key words: education, engineers, jobs, mechanization, agriculture.

INTRODUCTION

Occupation of people in agricultural work is among the oldest that over time evolved together with technological advances. Currently, the Romanian agriculture struggles between the state of subsistence and ecology. With European integration, the agricultural sector in Romania has started to develop, stimulated investment and the allocation of European funds. Thus, from 93 billion Euros in 2007, the Romanian agriculture has now to more than 150 billion Euros, contributing with 4.7% to GDP. [7]

Romania currently has a total land area of 13.3 million hectares, of which over 9.4 million hectares of arable land. Unfortunately, most of the farms are of subsistence, these farmers' families working especially for its livelihood. Over 52% of subsistence crops in the European Union are in Romania. [7]

During the last decade the academic concern regarding the efficiency increasing of the study programs and the employability of the university graduates have become a hot topic. [5] The education process is a process that requires continuous improvement and for this improvement the Government must continuously invest to achieve performances [2]. That the investments in the educational shouldn't overlooked because the economic report over the next decade and the investments in high education field are correlated [1]. The investment in higher education sector is associated with a future economic growth of a country. The current trends from USA suggest that as many as 45 percent of engineers are not employed in engineering jobs. As China and India increasingly compete with the U.S. in the production of engineers and enrollment in U.S. engineering programs continues to lag behind other four-year degrees, training a consistent number of quality engineers is a critical issue for the workforce. Anecdotal evidence of problematic post-graduation attrition that is, attrition related to controllable factors in students' educational experiences that push them away from engineering careers, as opposed to attrition of students who wish to creatively apply their skills in other occupations coupled with the need for engineers in the workforce motivated this research. [6].

Higher education sector must be continuously updated to meet the demands of the labor market. It's necessary to modernize this sector which could become one of the causes of rising unemployment among young people [3]. The growth strategy in next ten years for Europe, [4] offers the strategic framework for education, with a set ambitious goals that can contribute to the human capital of the EU by creating high levels of employment and social progress, the following: the share of young people aged 30-34 years with a tertiary level of education which should be at least 40%, and an average of at least 15% of adults aged 25-64 should participate in lifelong learning. These criteria were translated into national targets to reflect the situation and enable each Member State to contribute to the common goal.

Romanian job market, in agriculture, offers many opportunities for university graduates. In the past 10 years the most wanted professionals in agriculture were engineer's agronomists, many opened their own businesses. Their average monthly income, rose in the first 5 years of experience, from Euro 450 to almost 1000 Euro, most continue to persevere in agriculture. For business development, agriculture companies, agricultural entrepreneurs have great need by engineers, with knowledge in mechanics, electronics, thermal engines, hydraulics, as well as English. The high value of EU funds available to Romanian farmers, determines adding of new skills such as in project management, and in the orientation to towards attracting European funds, namely counselling for farmers. These skills can determine the possibility of escalation of salaries to 1500-2000 Euro. [7]

As a result of technological developments in the field of agriculture to be competitive in this field are required engineers well-trained specialists, both in modern agriculture and related areas, such as PC/programming, chemistry, mechanics, electronics, construction, and so on. The complexity of agricultural machinery, the high level of mechanization (in many cases even robotics), obliges companies to hire highly trained specialists in agriculture-related fields. Graduates from these related areas, although trained in their specialization lose very long time to integrate into the firm agricultural because of the lack of specific knowledge. Therefore, it is necessary to optimize study programs that lead to increase the skills graduates at the end of studies.

Thus, it is considered appropriate a comprehensive study on the optimization of education and training of graduate engineers, in accordance with the real requirements of jobs in agriculture.

METHODS

To achieve the objectives of this research were used some qualitative methods specific for labor market research. Mainly were taken exploratory surveys and interviews conducted among graduates, all consumers of POLITEHNICA University Timisoara (UPT) educational and training services, some of they have become already employers. There are many years in the tradition of the UPT bear direct links with both the economic environment and with graduate engineers. To streamline this activity UPT were formed two internal bodies: Brokerage Office of Media Relations Society and Information and Counselling Centre of Students in UPT. [8] At least one year after graduation, all graduates must return for lifting certificate. On this occasion, graduates complete a questionnaire, which includes questions that lead in forming a view as conclusive on the level of satisfaction of graduate engineers on skills and knowledge acquired during their studies, relative to the requirements of busy work.

Building on this positive experience, it has undertaken this study at the Department of Mechanical machinery, equipment and transport (MMUT) within UPT. it was selected four majors coordinated by the Department MMUT, with closer ties to agriculture, and the graduates can make an important contribution to more efficient operation of modern agriculture.

The four majors are:

a) Mechanical Engineering (ME)
b) Systems and thermal equipment (STE)
c) Machines and equipment for agriculture and food industry (MEAF)
d) Machines and hydraulic and pneumatic systems (MHPS)

Thus, it was collected data from the questionnaires complemented by graduates of the 4 specializations, from 5 series of graduates, from the period 2010-2014. In this study could be included 385 graduates, (that means 88.30%) out of the total 436 graduates.

The information drawn from the answers completed in questionnaires by graduates were divided into 3 categories:

– Information about graduates employed,
– Information regarding employability in the labor market
– Information on the intention to continue graduate studies (next cycle).

During research have been used some discussions in small groups of graduates and collaborators.

Feedback collected from graduates indicated, two lines of response: answers to questions and adding additional comments. Both lines were harnessed to improve the education process and the curriculum.

RESULTS AND DISCUSSION

The resulting situation was analyzed, interpreted and then sent to university management in order to assess or to impose the corrective measures where it is considered necessary.

The results of the questionnaire were used in making various statistics related to the employability of graduates on the labor market, orientation of graduates in the labor market, measure of the study programs utility in the career. Graduates who responded to the questionnaire had the right to keep his identity anonymous, but most graduates preferred answers to be nominals. Afterwards, the questionnaires were sorted after majors and the collected information were centralized under the above categories. From the collected data, the following information categories were selected:

- graduates who do not have a job;
- graduates that are employed in the specialization where they studied;
- graduates that are employed in other specialization than the one studied. (Table 1.)

Table 1 Data collected from questionnaires, about jobs

Graduates/specialization	ME	STE	MEAF	MHPS	
not have a job	8	6	4	5	**23**
employed in specialization	51	41	51	52	**195**
employed other specialization	49	36	33	49	**167**
	108	83	88	106	**385**

The analysis continued by determining of the percent of jobs included in the general field of mechanical engineering. Thus, was identified 275 jobs directly related to mechanical engineering, occupied by the graduates of the four majors, which is a percentage of 71.43%. The situation on specializations can be seen from the graph shown in Figure 1

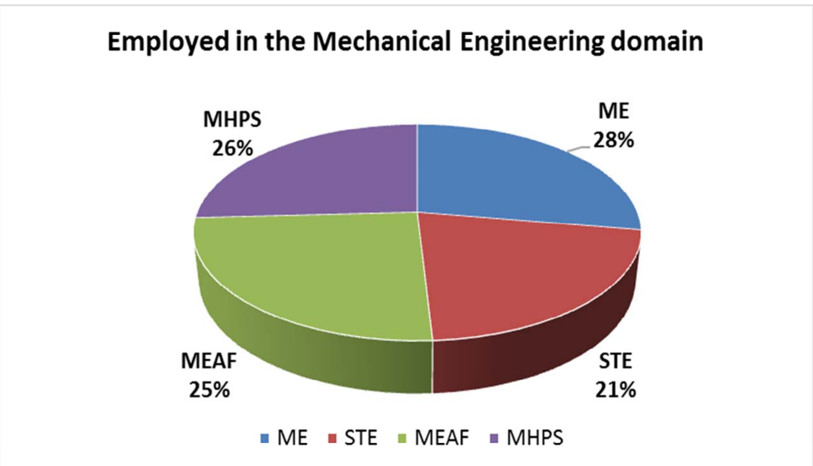

Figure 1. - The situation of graduates employed in Mechanical engineering domain, depending on the specialization graduated.

Further, the above information was correlated with the overall of the achieved assessment knowledge acquired in the educational experience during the studies in UPT by the graduates, according to the following rating scales: very good / great extent /good / satisfactorily / at all.

Table 2 Data collected from questionnaires about satisfaction with studies made in UPT

Graduates	ME	STE	MEAF	MHPS	
very good	46	33	51	48	178
great extent	41	31	30	41	143
Good	14	13	5	11	43
Satisfactorily	7	6	2	6	21
at all	-	-	-	-	-
TOTAL	108	83	88	106	385

Through this questionnaire were also identified 194 graduates who have decided to continue their education by master courses and 12 their willingness doctoral enrolment.

The questionnaire and interview methods were used further to collect information about the orientation of the engineering graduates towards the agriculture sector. Then were identified all the jobs with specific agricultural filled by graduates of the 5 series. The share of employed graduates in companies with agricultural specific was 14.81%. The situation on specializations is represented in Figure 2.

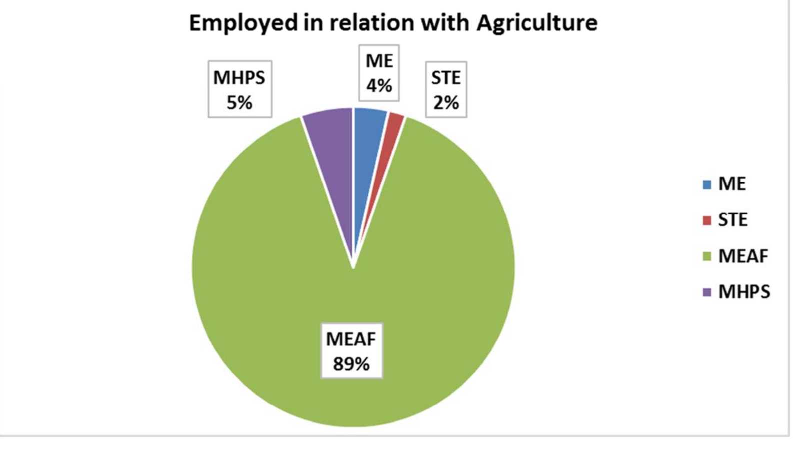

Figure 2. - The situation of graduates employed in Agriculture domain, depending on the specialization graduated

In addition to the data collected, more important information was gathered following discussions with graduates during events organized by the UPT.

Among the questions asked graduates engineers, were the following:

„Why do you not choose for engineering career in agriculture field?"

„What stopped you to choose mechanization of agriculture?"

Top of the graduates' responses are presented in Table 3:

Table 3. - Top of the graduates responses

Additional questions	The graduates' explanations
„Why do you not chose for an engineering career in agriculture field?"	- Lack of specific knowledge of agriculture - Lack of knowledge related to agricultural management - Low prestige of jobs from agriculture - Rural decay
„What stopped you to choose mechanization of agriculture?"	- The lack of general knowledge in the field - Lack of knowledge about specific works and equipment for agriculture

Using the data collected were created prerequisites for starting discussions about steps necessary to optimize the educational and training system, based by primary criterion university efficiency in providing of the competent engineers to contribute effectively to the modernization of agriculture.

After the analysis performed by the university management, the reports were sent to faculty boards / General Directorate of Quality Assurance from UPT to take measures and to correct the situation. But, in designing the necessary measures should not be forgotten the need for detection of native skills of students good for the complex field of agriculture.

As with any field, to choose a job in agriculture is important the passion, which sometime is from pleasant memories of childhood. But this election can be from a simply choosing pragmatic, made from the wish of to have a professional practice, in connection with the management of natural resources. For orientation of the mechanical engineer to agriculture, it is necessary to complement the educational process, with minimal notions of biology and management exploitation of natural resources.

CONCLUSIONS

The improvement of efficiency of educational training of the mechanical engineers, more useful for agricultural mechanization, can begin with introduction of some facultative disciplines oriented on agriculture (from basic to modernity). This quality of education can be greatly improved through a process continuous of dialogue with students and potential beneficiaries of graduates.

The students in the final year must have also the prospect of work in agriculture, with better orientation on labor market. The success of their first job in the agricultural sector can be ensured through appropriate training during the period of study, through elective courses with specific themes introductory in the peculiarities of the agricultural, through visits, participation in internships of practice, and the undergraduate final thesis, direct applicable in an agricultural unit. Through better compatibility between from the training level of engineers at the time of graduation and the requirements multidisciplinary agriculture, it shortens the adaptation period, being carried out a real employability, increasing the degree of the graduate's satisfaction to the educational structure of the study program. Thus, is achieved an improvement of the multidimensional dynamic relationship from the university and agricultural business environment.

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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MOGUĆNOSTI I OGRANIČENJA KOD ZAPOŠLJAVANJA AGRONOMA: STAVOVI STUDENATA AGRONOMSKOG FAKULTETA SVEUČILIŠTA U ZAGREBU

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SAŽETAK

U radu se istražuju stavovi studenata diplomskih studija Agronomskog fakulteta o mogućnostima i ograničenjima zapošljavanja nakon završetka studija. Istraživanje je provedeno sredinom 2015. godine na uzorku od 89 ispitanika. Veliki dio (93,3%) ispitanika izjavio je da često razmišlja o zaposlenju nakon studija, dok ih istovremeno samo nešto više od petine i ima jasnu viziju o svojoj budućoj poslovnoj karijeri. Ispitanici su suglasni kako usvajanje znanja utječe na povećanje samopouzdanja i samouvjerenosti (86,5%) te kako pronalazak posla najviše ovisi o vlastitim sposobnostima (68,5%). Više od polovice ispitanika (59,6%) nakon završenog studija htjelo bi raditi u javnom sektoru i to najviše u Ministarstvu poljoprivrede (12,4%) te različitim poljoprivrednim agencijama (12,4%). Razlog tome je još uvijek u Hrvatskoj veća stabilnost radnog mjesta i percepcija sigurnijeg prihoda u javnom nego u privatnom sektoru. Oko 78% ispitanika želi ostati živjeti i raditi u Hrvatskoj ali su spremni su zbog posla promijeniti mjesto življenja unutar Hrvatske (18%). Najveći dio ih očekuje da će se zaposliti unutar godine dana nakon završetka studija (60,7%), a neki (5,6%) imaju već osiguran posao nakon studija.

Ključne riječi: studenti, agronomi, tržište rada, Hrvatska

UVOD

Jedna od posljedica ekonomske krize je smanjenje broja zaposlenih osoba te umanjenje prilika za novo zapošljavanje posebice mlađeg dijela populacije, koji se najčešće na tržištu rada pojavljuju sa višom razinom obrazovanja. Tako mladi, po završetku studija, postaju dijelom tržišta rada.

Hrvatska je ulaskom u Europsku uniju (EU) postala dio velikog zajedničkog tržišta radne snage. Kao veliko ograničenje zapošljavanja izvan Hrvatske je nedostatak radnog iskustva što sa drugim ograničenjima (zanimanje, jezik, zakonska ograničenja) ne pogoduje smanjenju domaće nezaposlenosti te više od 1/3 osoba nakon završenog tercijarnog obrazovanja završava na Zavodu za zapošljavanje (Obadić i Majić, 2013).

Stopa nezaposlenosti u RH iznosi 17,1%, a u EU 9,8% (HZZ). Stopa nezaposlenosti mladih ljudi u Hrvatskoj vrlo je visoka te iznosi 45,5% u odnosu na EU gdje je ona 22,2%.

Nezaposlenost u 28 država članica EU dosegnula je rekordnu razinu u vrijeme gospodarske krize. Prema izvješću Europske komisije (2013), nezaposlenost mladih u većoj mjeri je ovisna o poslovnom ciklusu i stopa nezaposlenosti brže je rasla među muškarcima nego ženama. Također su znatno veće stope nezaposlenosti među mladima, niskokvalificiranim radnicima i državljanima trećih zemalja.

Nemogućnost zaposlenja nakon završenog studija može dovesti do negativnih posljedica, ekonomskih ali i socijalnih. Sve države, pa tako i Hrvatska, provode pasivne i aktivne mjere za poticanje zapošljavanja odnosno smanjenja nezaposlenosti.

U današnjem društvu, obilježenim ubrzanim razvojem tehnologije i globalizacijom koji utječu na sve sfere života, visokoškolske institucije imaju sve važniju ulogu. Usklađenost obrazovnih programa visokoobrazovnih institucija s potrebama tržišta rada danas je vrlo važna. Tijekom godina došlo je do promjene poimanja studiranja i razloga upisa studija Prilikom upisa na studij, budući studenti su motivirani različitim očekivanjima. Predmet istraživanja ovog rada je percepcija spremnosti studenata diplomskih studija Agronomskog fakulteta u Zagrebu (AFZ) za tržište rada, odnosno vlastite zapošljivosti.

Cilj rada je bio istražiti motive studenata diplomskih studija Agronomskog fakulteta za odabir studijskog programa te spremnost njihovog uključivanja na tržište rada.

MATERIJAL I METODE

U Hrvatskoj ne postoji konzistentna politika visokoškolskog obrazovanja pa je više prisutna inercija kod brojnosti polaznika pojedinih znanstvenih područja i fakulteta nego smisleno „usmjeravanje“ s podizanjem stope „brze upošljivosti“.

Posebno zabrinjava sve duže razdoblje od okončanja studija do prvoga zapošljavanja pri čemu mladi često propitkuju svoju odluku o ispravnosti odabira završenog studija.

Na Agronomskom fakultetu u Zagrebu moguće je upisati jedan od ukupno 14 diplomskih studija, od čega tri imaju po dva odnosno četiri usmjerenja. Svaki studij traje 4 semestra, a može se upisati najmanje 120 ECTS-a. Završetkom dvogodišnjeg diplomskog studija stječe se akademski naziv magistar/magistra inženjer/inženjerka uz naznaku studija. Ukupan broj studenata diplomskih studija na Agronomskom fakultetu u Zagrebu koji su upisani u akademskoj godini 2014./2015. je 871.Za potrebe rada provedena je on-line anketa među studentima diplomskih studija Agronomskog fakulteta u Zagrebu, a dobiveni podaci su obrađeni i analizirani u statističkom programu SPSS 21.0. Korištena je jednovarijantna (analiza jedne varijable) i dvovarijantna (dvosmjerna tabulacija ili „ukrštanje“) obrada podataka. Rezultati su potom analizirani primjenom statističkog χ^2 (hi-kvadrat) testa pri značajnosti p<0,05.

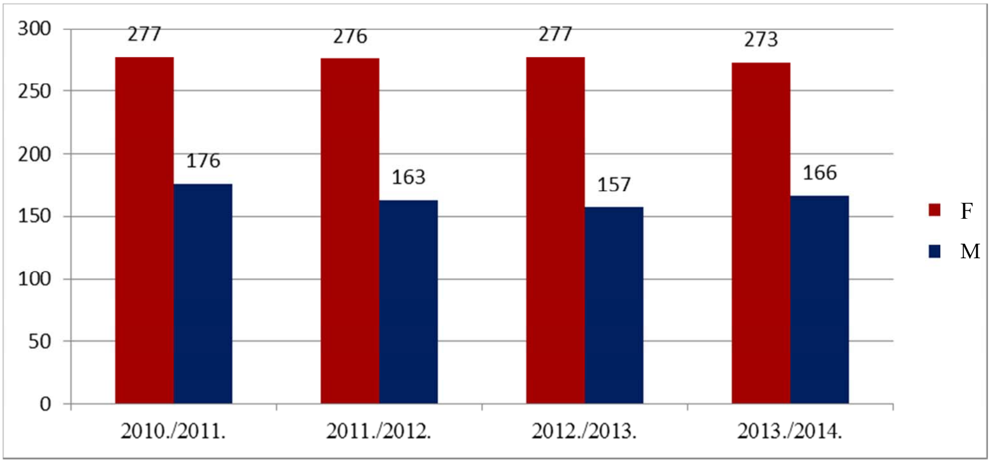
Istraživanje je provedeno u razdoblju od 20. travnja do 02. lipnja 2015. godine. Za potrebe istraživanja izrađen je anketni upitnik koji je sadržavao 16 pitanja od kojih 13 zatvorenog tipa i tri otvorenog tipa. Anketni upitnik ispitanici su mogli ispuniti isključivo on-line putem koji je poslan na različite e-mail adrese pojedinih diplomskih studija te putem društvene mreže Facebook, a uzorak je bio neprobabilistički odnosno prigodan. U istraživanju je sudjelovalo 89 ispitanika diplomskih studija od ukupno 871 studenata upisanih u akademsku godinu 2014./2015. (Kovačević 2015).

Korišteni su i sekundarni izvori podataka kao što su dostupna znanstvena i stručna literatura te službene statističke baze podataka (Državni zavod za statistiku, EUROSTAT).

REZULTATI I DISKUSIJA

Osnovna obilježja uzorka

U istraživanju je sudjelovalo 89 ispitanika, od čega 68,54% žena i 31,46% muškaraca. Trendovi posljednjih desetak godina pokazuju kako se na AFZ upisuje više žena nego muškaraca te ukupno više iz urbanih područja i najčešće sa završenim gimnazijskim obrazovanjem (Zrakić i Juračak, 2012).



Grafikon 1: Broj upisanih studenata u I. semestar diplomskog studija na AF prema spolu
Graph 1: Number of students enrolled in the first term of graduate studies at the Faculty of Agriculture by gender
Izvor: Godišnja izvješća Agronomskog fakulteta u Zagrebu za pojedine godine
Source: Annual reports of the Faculty of Agriculture in Zagreb for individual years

Prosječna dob ispitanih je 23 godine (maksimum 27, a minimum 21 godinu). Najviše ispitanika navelo je grad kao mjesto odrastanja (50,6%), na selu je odraslo 39,3% ispitanika, a 10,1% navodi oboje. Rezultati istraživanja pokazuju kako je 80,9 % ispitanika do sada radilo preko Student servisa. Studentski poslovi pomažu im podmiriti troškove života te financirati studij, a na taj način već tijekom studija stječu radne navike, iskustva te različite kontakte. Stjecanje radnih navika tijekom studija važna je komponenta daljnjeg razvoja stručne karijere (Zrakić i Grgić, 2015).

Motivi za upis na odabrani studij

Kao motivi upisa na odabrani studij ispitanicima su ponuđeni odgovori sa mogućnošću suglasja 1 = potpuno se slažem do 5 = uopće se ne slažem.

Tablica 1: Motivi za upis na odabrani studij (%)
Table 1: Motivation for choosing the selected study (%)

Odgovori /Responses	4+5*	3*	1+2*	Srednja vrijednost/Average
Radit ću posao koji želim / I will have a job that I want	58,5	28,1	13,5	3,6
Bit ću „akademski obrazovan/a"/ I will have an academic degree	86,1	11,2	2,2	4,3
Imat ću višu plaću / I will have a higher salary	62,9	24,7	12,4	3,7
Za dobar posao treba diploma / A university diploma is required for a good job	58,4	20,2	21,4	3,6

Izvor: Vlastito istraživanje * stupanj suglasnosti (%) (1-uopće se ne slažem...5-u potpunosti se slažem)/Source: Own research * degree of agreement (%) (1-strongly disagree ... 5-strongly agree)

Glavni motiv za upis na diplomski studij najvećem dijelu ispitanika je bio *da će biti akademski obrazovan*, a tu izjavu ocijenili su prosječnom ocjenom 4,34.

Međutim i ostali ponuđeni odgovori su visoko motivirajući kao što je *imat ću veću plaću* (srednja vrijednost: 3,72), *za dobar posao treba diploma* (srednja vrijednost: 3,63) te *radit ću posao koji želim* (srednja vrijednost 3,58).

Dvo-varijantnom analizom utvrđeno je da je kod motiva upisa na odabrani studij „imat ću veću plaću" utvrđena statistički značajna razlika obzirom na spol ispitanika ($p<0,05$). Motiv korisnosti izraženiji je kod muške populacije. Slično su zaključili i Kesić i Previšić, 1998 tj. da je zadovoljstvo studenata veće ako dolazi iz hedonistički motiva kao što su zainteresiranost za znanstveno područje i zadovoljstvo odabranom profesijom, nego iz motiva korisnosti, odnosno mogućnosti zaposlenja, dobre zarade i sl.

Stečeno znanje tijekom studija i tržište rada

Pri kraju studiranja, a neki i ranije promišljaju što i kamo nakon odlaska sa fakulteta, jesu li znanja i vještine dostatni za nastavak profesionalne karijere, što je bilo dobro, loše ili što je nedostajalo da bi se lakše i sa manje stresa uključili u radni proces.

Veliki dio (93,3%) ispitanika izjavio je da „često razmišlja o zaposlenju nakon studija“ dok istovremeno ih samo nešto više od petine „ima jasnu viziju o svojoj poslovnoj karijeri nakon studija“.

Tablica 2: Stavovi ispitanika o zapošljavanju (%)
Table 2: The views of the respondents on employment (%)

Odgovori /Responses	4+5*	3*	1+2*
Često razmišljam o zaposlenju / I often think about employment	93,3	3,4	3,3
Imam jasnu viziju o poslovnoj karijeri/ I have a clear vision of the business career	29,2	52,8	18,0
Imam želju pokrenuti privatni posao/ I want to start my own business	65,0	22,5	22,5
Imam mogućnost za vlastiti posao/ I have an opportunity to start my own business	32,6	24,7	42,7
Razgovor za posao za mene je stresna situacija/ A job interview is a stressful situation for me	56,1	22,5	21,3
Pronalazak posla najviše ovisi o vlastitim sposobnostima/ Finding a job mostly depends on one's own abilities	68,5	27,0	4,5
Usvajanje znanja utječe na povećanje samopouzdanja i samouvjerenosti/ Acquiring knowledge affects the increase in self-esteem and self-confidence	86,5	11,2	2,2

Izvor: Vlastito istraživanje * stupanj suglasnosti (%) (1-uopće se ne slažem...5-u potpunosti se slažem)/Source: Own research * degree of agreement (%) (1-strongly disagree ... 5-strongly agree)

Dobro je da velik dio njih (65%) ima želju za „*pokretanjem vlastitog posla*“ što bi trebale podržati i za to nadležne institucije (od državnih do financijskih) jer ih je 32,6% odgovorilo sa „*imam mogućnost pokrenuti vlastiti posao*“. Ispitanici su suglasni kako usvajanje znanja utječe na povećanje samopouzdanja i samouvjerenosti (86,5%) te kako pronalazak posla najviše ovisi o vlastitim sposobnostima (68,5%). Svjesni stanja u kojem se nalazi agrokompleks a posebice poljoprivreda i sukladno trendovima u ekonomski razvijenom svijet još manji dio (27%) ih „*nakon studija namjerava tražiti posao samo u svojoj struci.*“

Osim procjene vlastitih sposobnosti, ispitanici razmišljaju i o institucijama uključenim u njihovu izobrazbu. Većina ispitanika (94,4%) smatra kako bi obrazovna ustanova trebala aktivnije informirati studente o tržištu rada putem različitih tribina, sudjelovanjem gostiju iz privrede na predavanjima ili organiziranjem „info dana“ o različitim mogućnostima nakon studija.

Tablica 3: Stavovi o učinkovitosti obrazovnih programa (%)
Table 3: The views on the effectiveness of educational program (%)

Odgovori/Responses	4+5*	3*	1+2*	Ẋ
Obrazovna ustanova trebala bi aktivnije informirati studente o tržištu rada/ Educational institutions should actively inform students about the labour market	94,4	3,4	2,2	4,6
Stručna praksa koju obavljamo tijekom studija doprinosi pripremi za tržište rada/ Practical work that we perform during the study contributes to the preparation for the labour market	31,5	28,1	40,4	2,8
Stipendije privatnih tvrtki i korporacija doprinose razvoju vještina potrebnih za tržište rada/ Scholarships of private companies and corporations contribute to the development of skills required for the job market	48,3	39,3	13,4	3,5
Bolja povezanost obrazovnih ustanova i realnog sektora povećava mogućnost zaposlenja nakon studija/ Better connectivity of educational institutions and the real sector increases employment opportunities after the study	78,7	19,1	2,2	4,0
Samostalni zadaci tijekom studija dobra su priprema za tržište rada/ Independent tasks during the studies are a good preparation for labour market	67,4	21,3	11,2	3,8

Izvor: Vlastito istraživanje * stupanj suglasnosti (%) (1-uopće se ne slažem...5-u potpunosti se slažem)/Source: Own research * degree of agreement (%) (1-strongly disagree ... 5-strongly agree)

Mnogi ispitanici su stava da bi „bolja povezanost Fakulteta i privrede povećala mogućnost lakšeg zapošljavanja" kao i da „su vrlo bitne stipendije privatnih tvrtki u usmjeravanju studenata tijekom studija".

Značajnom potporom u stjecanju znanja bitnih za „lakše" zapošljavanje smatraju i samostalne zadatke tijekom studija kojih imaju nedovoljno, odnosno njihovu važnost shvatili su pri kraju studiranja.

Kritični su i prema već obavljenoj stručnoj praksi za koju njih 40,4% kaže da je bitna i korisna kod pronalaženja posla. Ili kako je naveo jedan ispitanik „*Studentska praksa potpisana između fakulteta i samo jedne firme je beskorisna, puna propusta. Na primjer, studenti agroekonomike obavljaju stručnu praksu u nekoj poljoprivrednoj firmi i umjesto da budu provedeni kroz svoj odsjek, rade na čišćenju prostora za životinje. U tom slučaju studenti diplomskog studija određenoj firmi služe kao besplatna radna snaga.*"

Uvijek smo kritični prema svojim znanjima i to posebice ako ih uspoređujemo sa nama konkurentnim osobama ili skupinama. Uspoređujući svoja znanja s potrebama EU tržišta osjeća se strah koji može biti i iracionalan, ali njih 39,3% smatra da su stečena znanja i poželjna na EU tržištu. Nešto povoljnija je njihova procjena o stečenim vještinama te ih 42,7% smatra da su kao takve i potrebne na EU tržištu.

Tablica 4: Stavovi ispitanika o stečenom znanju
Table 4: The views of the respondents on the acquired knowledge

Odgovori/Responses	4+5*	3*	1+2*	Ẋ
Znanje koje sada imam poželjno je na tržištu rada EU/ The knowledge that I have now is desirable on the EU labour market	39,3	48,4	12,3	3,4
Vještine kojima sada raspolažem poželjne su na tržištu rada EU/ The skills I have now are desirable on the EU labour market	42,8	43,8	13,4	3,4
Studiranjem usvajam radne navike/Studying develops my work habits	64,1	19,1	16,8	3,7
Tijekom studiranja usvojio/la sam znanja i vještine koje će mi pomoći u pronalasku posla/ During the study I adopted knowledge and skills that will help me find a job	50,5	36,0	13,5	3,5
U trenutku završetka studija smatram da ću biti spreman/a za tržište rada/ At the time of the completion of the study I believe that I will be ready for a labour market	42,7	36,0	21,4	3,3

Izvor: Vlastito istraživanje* stupanj suglasnosti (%) (1-uopće se ne slažem...5-u potpunosti se slažem)/Source: Own research * degree of agreement (%) (1-strongly disagree ... 5-strongly agree)

Preko dvije trećine (64,1%) ih smatra da se studiranjem usvajaju i radne navike, ali manji dio (50,5%) ih vjeruje da će im dobivena znanja i vještine biti i od pomoći kod pronalaska posla. Zato ih manje od polovice misli da su spremni za tržište rada i zahtjevnosti koje se pred njih postavljaju.

Idućim pitanjem željeli smo saznati koliko su studenti upoznati s mjerama zapošljavanja.

Tablica 5: Stavovi ispitanika o informiranosti i o mogućnostima zapošljavanja (%)
Table 5: The views of respondents on awareness of opportunities of employment (%)

Odgovori/Responses	4+5*	3*	1+2*	Ẋ
Upoznat/a sam s aktivnim mjerama politike zapošljavanja mladih/ I am familiar with the active measures of youth employment policy	64,0	19,1	16,9	3,7
Često sudjelujem na sajmovima poslova koji se organiziraju/ I often participate in organized job fairs	15,8	16,9	67,3	2,2
Tijekom studija raspitujem se o mogućnostima zapošljavanja/ During the study I inquire about employment opportunities	58,4	29,2	12,4	3,6

Izvor: Vlastito istraživanje * stupanj suglasnosti (%) (1-uopće se ne slažem...5-u potpunosti se slažem)/Source: Own research * degree of agreement (%) (1-strongly disagree ... 5-strongly agree)

Samoinicijativa kod traženja posla vrlo je bitna jer je uspjeh često rezultat velikog napora i truda, posebno u uvjetima velike nezaposlenosti. Više od 50% ispitanika tijekom studija raspituje se o mogućnostima zapošljavanja, ali tek nešto više od 15% njih često sudjeluje na sajmovima poslova koji se organiziraju. Ovi podaci ukazuju na nedostatak poduzetničkog duha kod ispitanika i nedovoljnu aktivnost pri samostalnom traženju posla.

Očekivanja nakon završetka studija

Većina ispitanika (80,9%) suglasno je da diplomski studij koji pohađaju doprinosi stručnom i znanstvenom napretku poljoprivrednog sektora. Općenito, znanje je postalo faktorom konkurentnosti te su sve veći zahtjevi za visokim kvalifikacijama. Viša razina znanja i bolja obrazovna struktura radne snage dovodi do inovacija i novih spoznaja te do samog napretka poljoprivrednog sektora.

Radna nesigurnost ponekada i precijenjena ili prenaglašavana kod mladih značajno utječe na želje za sektorskim zapošljavanjem.

Više od polovice ispitanika (59,6%) nakon završenog studija željela bi raditi u javnom sektoru i to najviše u Ministarstvu (12,4%) te različitim poljoprivrednim agencijama (12,4%). Razlog tome je još uvijek u Hrvatskoj veća stabilnost radnog mjesta i percepcija sigurnijeg prihoda u javnom nego u privatnom sektoru. Prema rezultatu χ^2 testa, postoji statistički značajna razlika između spolova prema preferenciji radnog mjesta u javnoj službi ($p<0,05$).

Tablica 6: Željeni sektor i djelatnosti nakon završetka studija (N=89)
Table 6: The desired sector and activities after graduation (N=89)

Javni sektor/Public sector			Realni sektor/Real sector		
Odgovor/ Response	Učestalost/ Incidence	%	Odgovor/ Response	Učestalost/ Incidence	%
Ministarstvo/ Ministry	11	12,4	Primarna proizvodnja/ Primary production	17	45,9
Lokalna uprava/ Local government	10	11,2	Prerađivačka industrija/ Processing industry	5	5,6
Državna uprava/ Public administration	9	10,1	Konzultantske usluge/ Consulting services	14	15,7
Agencije/Agencies	11	12,4	Nešto drugo/Other	1	11,0
Savjetodavna služba/ Advisory service	10	11,2			
Nešto drugo/Other	1	1,1			

Izvor: Vlastito istraživanje/Source: Own research

Nešto manji dio ispitanika (40,4%) nakon završenog studija radije bi se zaposlio u „realnom" sektoru te od toga najviše u primarnoj proizvodnji (20,2%), a zatim u konzultantskim uslugama i prerađivačkoj industriji.

U novije doba mnogo je rasprava o besperspektivnosti za mlade u Hrvatskoj i ogromnoj želji za odlaskom u druge zemlje Unije te čak i dalje, u preko oceanske države.

Tablica 7. Mjesto rada nakon završenog studija (N=89)
Table 7. Place of work after graduation (N=89)

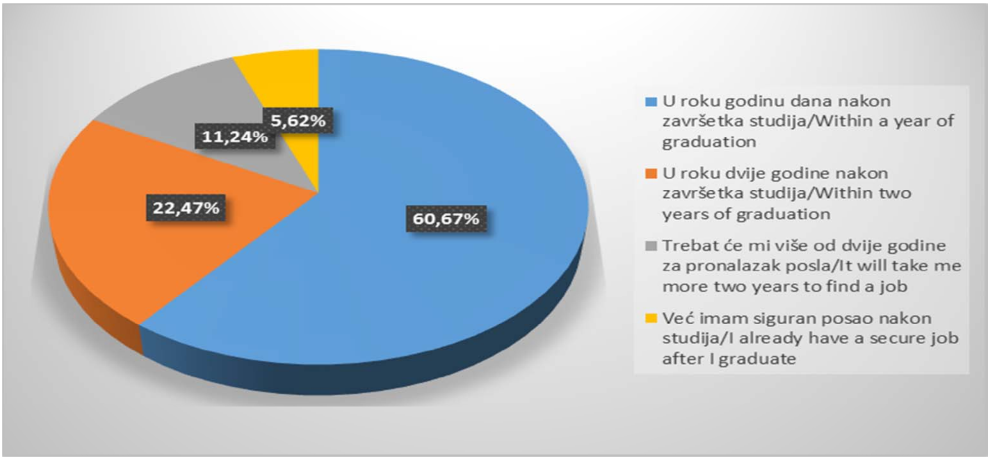
Odgovor/Response	Učestalost/Incidence	%
Hrvatska/Croatia	69	77,5
Inozemstvo/Abroad	20	22,5
Ukupno/Total	89	100,0

Izvor: Vlastito istraživanje/Source: Own research

Ipak, gotovo 78% ispitanika želi ostati živjeti i raditi u Hrvatskoj ali spremni su zbog posla promijeniti mjesto življenja unutar Hrvatske. Manji dio (18%) ih nije spremno promijeniti mjesto življenja unutar Hrvatske. Studenti smatraju kako u Hrvatskoj ima prostora i mogućnosti za napredak te da upravo svojom strukom mogu doprinijeti unapređenju sektora poljoprivrede i poboljšanju stanja u društvu u cjelini. U istraživanju provedenom početkom 2015. godine od strane Hrvatskog zavoda za zapošljavanje (HZZ) oko 34% ispitanih bi napustilo Hrvatsku zbog posla (Repalust i Velimirović, 2015).

Kao razloge za ostanak i rad u Hrvatskoj ispitanici su naveli obitelj, prijatelje, strah od nepoznatog.

Kao razloge za odlazak u inozemstvo ispitanici su naveli veće plaće, bolji odnos prema radnicima, veće opće mogućnosti.



Grafikon 2: Očekivanja o pronalasku posla nakon završetka studija
Graph 2: The expectations of finding a job after graduation
Izvor: Vlastito istraživanje/Source: Own research

Iako je manji dio ispitanika naveo kako ne želi otići iz Hrvatske ukoliko u roku od godine dana ne pronađu posao jedan dio će ga ipak potražiti u inozemstvu. Najveći dio ih očekuje da će se zaposliti unutar godine dana nakon završetka studija (60,7%), a neki (5,6%) imaju već osiguran posao nakon studija.

ZAKLJUČAK

Za većinu ispitanika motiv upisa na Fakultet bio je buduća pripadnost skupini „akademski obrazovanih" (prosječna ocjena 4,34) te da će u budućnosti „imat višu plaću" (prosječna ocjena 3,72). Više od polovice ispitanika želi raditi u javom sektoru.

Veliki dio ispitanika (77,5%) želi ostati raditi u Hrvatskoj te bi ih 82% zbog zaposlenja promijenilo mjesto življenja unutar Države. Mladi su vrlo optimistični u pogledu prvog zaposlenja te ih 60,7% ispitanika očekuje da će se zaposliti u roku godinu dana nakon završetka studija. Ali istovremeno ih 67,4% smatra kako bi obrazovna ustanova trebala aktivnije informirati studente o tržištu rada.

Ispitanici znanje, vještine i informacije dobivene tijekom studiranja smatraju nedostatnim za potrebe tržišta rada. Na izjavu: „U trenutku završetka studija smatram da ću biti spreman/a za tržište rada" tek je nešto više od 49% ispitanika odgovorilo da se s njom i slaže, dok njih 36% nisu mogli procijeniti slažu li se ili ne. Više od 90% ispitanika često razmišlja o zaposlenju nakon studija ali je slaba njihova inicijativa da poduzmu aktivne mjere još za vrijeme trajanja studija jer čak više od 67% ispitanika ne sudjeluje na sajmovima poslova koji se organiziraju. Polovica ispitanika izjasnila se da ima želju pokrenuti vlastiti posao, ali svega 5,6% je onih koji za to imaju i realnu mogućnost.

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THE POSSIBILITIES AND LIMITATIONS IN THE AGRONOMISTS EMPLOYMENT: ATTITUDES OF STUDENTS OF UNIVERSITY OF ZAGREB FACULTY OF AGRICULTURE

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ABSTRACT

This paper studies the attitudes of the Faculty of Agriculture graduate students and their possibilities and limitations of employment after graduation. The survey was conducted in mid-2015 on a sample of 89 respondents. A large share (93.3%) of respondents said that they often think about employment after the study, while at the same time just a little more than one fifth of them has a clear vision of their future business career.

Respondents agree that the acquisition of knowledge affects the increase of self-esteem and self-confidence (86.5%) and fact - how to find a job - depends mostly on their own abilities (68.5%). More than half of respondents (59.6%) after graduating would like to work in the public sector, mostly in the Ministry of Agriculture (12.4%) and various agricultural agencies (12.4%). The reason for this is still greater position stability and perception of secure income in the public than in the private sector in Croatia.

Approximately 78% of respondents would like to continue living and working in Croatia but are willing to change place of living because of work within the Croatian borders (18%). The largest part of them expected to be hired within a year after graduation (60.7%), and others (5.6%) have already secured job after studies.

Key words: students, agronomists, labour market, Croatia

45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 373.68:631.17
Prethodno priopćenje
Preliminary communication

POZNAVANJE POLJOPRIVREDNE MEHANIZACIJE STUDENATA PRVE GODINE AGRONOMSKOG FAKULTETA SVEUČILIŠTA U ZAGREBU I POLJOPRIVREDNO PREHRAMBENOG FAKULTETA UNIVERZITETA U SARAJEVU

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SAŽETAK

U radu se daju rezultati istraživanja o poznavanju poljoprivredne mehanizacije studenata prve godine studija Agronomskog fakulteta u Zagrebu (AFZG) i Poljoprivredno-prehrambenog fakulteta u Sarajevu (PPFSA). Cilj rada je usporednom analizom dobivenih rezultata istraživanja ispitati poznavanje poljoprivredne mehanizacije pri čemu polazimo od pretpostavke da ne postoje značajnije razlike između studenata pojedinih fakulteta. Za potrebe rada korišten je anketni upitnik, a dobiveni rezultati obrađeni su pomoću SPSS-a.

Istraživanje je provedeno u listopadu 2016. godine pri čemu je anketirano ukupno 240 studenata prve godine preddiplomskih studija i to po 120 sa svakog fakulteta.

Veći je udio ženske populacije (69,2% AFZG; 61,7% PPFSA). Većina ispitanih je odrasla u urbanoj sredini (69,2% AFZG; 65,8% PPFSA). Na AFZG većina upisanih je s gimnazijskim obrazovanjem (63,3%) a na PPFSA s nekom završenom stručnom nepoljoprivrednom srednjom školom (43,3%). Iz srednje poljoprivredne škole znatno više ih je na PPFSA (23,3%) nego na AFZG (10,0%).

Istraživanje je pokazalo da najveći dio ispitanika ne zna upravljati niti jednim poljoprivrednim strojem (77,5% AFZG; 70,8% PPFSA), a većina ostalih ih zna upravljati traktorom, zatim motokultivatorom, te frezom.

Ispitanici znaju da kombajn ne služi za obradu tla (54,2% AFZ; 75,2% PPFSA) te da je to stroj za žetvu. Iako većina zna da se četveorednom sijačicom u jednom prohodu sije u četiri reda, ipak ih 10% na AFZG te 20% na PPFSA misli da se u jednom prohodu sije tri, pet ili čak 8 redova.

Istraživanje je pokazalo da su studenti upoznati s važnošću upotrebe mehanizacije u poljoprivredi, ali i s ekonomičnim upravljanjem, naglašavajući pri tom povezivanje poljoprivrednika sa svrhom smanjenja troška mehanizacije u proizvodnom procesu. Iako ih veći dio smatra da je za upravljanje mehanizacijom potrebno formalno obrazovanje (55,8% AFZG; 55,9% PPFSA) iznenađujuće je malo voljnosti pohađanja modula koji izučavaju tu tematiku (1,7% AFZG; 10,1% PPFSA). Veću razinu znanja o poljoprivrednoj mehanizaciji imaju muški ispitanici i oni odrasli na selu.

Ključne riječi: poznavanje poljoprivredne mehanizacije, studenti, agronomija, Hrvatska, Bosna i Hercegovina

UVOD

Suvremena poljoprivreda susreće se s mnoštvom izazova od kojih su dva globalna i to 1) kako podmiriti rastuću globalnu potražnju koju određuju povećanje broja stanovnika i prosječnih dohodaka te 2) kako očuvati proizvodne resurse od onečišćenja i pri tome zadovoljiti potražnju proizvoda proizvodnjom prema ekološkim principima.

U takvim uvjetima visoko školski obrazovni sustav u području agronomije dobiva na svojoj složenosti, a poljoprivredna mehanizacija na dodatnom značenju zadržavajući svoju osnovnu zadaću a to je podržati razvoj poljoprivrede u skladu s potrebama tržišta.

Uloga poljoprivrede tijekom povijesti se mijenja zadržavajući svoju središnju funkciju a to je podmirenje prehrambenih potreba pučanstva. Mijenja se i njena uloga u ekonomskom razvitku, ali postizanje željenog stupnja ukupnog ekonomskog je ostvareno tek nakon rješenja poljoprivrednog razvitka i zadovoljenja što veće razine prehrambenih potreba vlastitog pučanstva (Diamond, 2007; Landes, 2003; Tracy, 1996).

U ekonomski razvijenim zemljama sve veća pozornost se posvećuje održivom poljoprivrednom razvitku s naglašenim drugim poljoprivrednim funkcijama kao što su socijalna, ekonomska i ekološka. Iznova se propitkuje „industrijski“ pristup poljoprivredi naglašavajući njenu ulogu u čuvanju prostora i narušavanju sve do uništenja ekosustava.

Iako se povremeno javljaju ideje o „drugačijoj poljoprivrednoj proizvodnji“, rastuća potražnja za hranom uvjetuje neophodnost primjene suvremenih tehničkih dostignuća među kojima je jedna od najvažnijih poljoprivredna mehanizacija. Ona je jamac primjene tehnoloških operacija u optimalnim rokovima što izravno utječe na količinski dovoljno i ekonomski prihvatljivu proizvodnju hrane kako za domaćeg tako i za inozemnog potrošača (Nikolić i sur., 2009).

Poljoprivredna mehanizacija počinje se primjenjivati u obliku lokomobila, parnog stroja na kotačima koji bi pogonio poljoprivredne strojeve (npr. za vršenje žita) i bio je preteča parnih traktora koji se javljaju sredinom devetnaestog stoljeća. Nakon toga oni se dorađuju i poprimaju sadašnje karakteristike te mnogi traktor smatraju jednim od najvažnijih konstruktorskih dostignuća dvadesetog stoljeća.

Današnji tehnološki proces u poljoprivredi nezamisliv je bez svekolike poljoprivredne mehanizacije uporabljene od pripreme tla do čuvanja i dorade poljoprivrednih proizvoda, kako u biljnoj tako i u stočarskoj proizvodnji.

Poljoprivredna mehanizacija postaje sve sofisticiranija i sve skuplja, što izravno utječe na troškove proizvodnje. Primjena najnovijih tehničkih rješenja kod poljoprivredne mehanizacije iziskuje i sve više znanja onih koji upravljaju njome posebno jer se radi o vrlo skupim strojevima. Zbog toga se posebna pozornost posvećuje praktičnim ali i teorijskim znanjima korisnika mehanizacije.

Praktična znanja se mogu stjecati formalnim, neformalnim i informalnim obrazovnim procesima. Teorijska znanja najčešće se stječu u okviru visokoškolskog obrazovanja i to na poljoprivrednim fakultetima ili srodnim institucijama.

Iako su znanja o poljoprivrednoj mehanizaciji prije upisa ili neposredno nakon upisa visokoškolskog procesa u prosjeku mala i ne moraju biti u uskoj vezi s konačnim znanjima nakon završetka školovanja, ona mogu poslužiti drugoj svrsi. Prvenstveno su korisna za planiranje programa postojećih studija ili osmišljavanje specijalističkih studija.

Do sada je bilo malo istraživanja poznavanja poljoprivredne mehanizacije studenata agronomije te možemo spomenuti nekoliko novijih radova (Grgić i sur. 2014; Grgić i sur. 2016).

U istraživanju iz 2013. godine pošlo se od pretpostavke da studenti prvih godina Agronomskog fakulteta nedovoljno poznaju poljoprivrednu mehanizaciju te zbog toga tijekom studija trebaju steći više znanja o toj problematici. Istraživanje je pokazalo da je znanje ispitanika o poljoprivrednoj mehanizaciji na zadovoljavajućoj razini unatoč tomu što većina (71,6%) ne zna upravljati niti jednim poljoprivrednim strojem. Ispitanici uglavnom prepoznaju važnost mehanizacije za poljoprivrednu proizvodnju kao i potrebu njene što primjerenije uporabe. Međutim, više od dvije trećine ispitanika (67%) ne bi, kao izborni, upisali modul na kojem bi više učili o poljoprivrednoj mehanizaciji. Viša razina poznavanja mehanizacije zabilježena je kod muškog dijela ispitanika te onih koji su odrasli u ruralnom području. Do sličnih rezultata došlo se i u anketi iz 2015. godine.

Tako je i kod ovoga istraživanja cilj da se usporednom analizom dobivenih rezultata ispita poznavanje poljoprivredne mehanizacije pri čemu se pošlo od pretpostavke da ne postoje značajnije razlike između studenata pojedinih fakulteta.

MATERIJAL I METODE

Istraživanje je provedeno početkom mjeseca listopada 2016. na Agronomskom fakultetu Sveučilišta u Zagrebu (AFZG) i na Poljoprivredno-prehrambenom fakultetu Univerziteta u Sarajevu (PPFSA). Anketirano je ukupno 240 studenta/studentica prve godine i to po 120 sa svakog fakulteta. Uzorak je bio prigodan, anketa bila nenajavljena te obavljena 5.10.2016. godine u vrijeme nastave.

Za potrebe rada primijenjena je anketa dizajnirana za istraživanje 2013. godine (Grgić i sur., 2014) koja se sastojala od ukupno 17 pitanja otvorenog, poluotvorenog i otvorenog tipa. Za mjerenje stupnja slaganja s određenim izjavama korištena je Likertova skala od pet stupnjeva. Skala se sastoji od niza tvrdnji posvećenih različitim aspektima nekog stava. Stupanj suglasnosti je bio na pet-stupanjskoj skali kao: „uopće se ne slažem", „ne slažem se", „niti se slažem niti ne slažem", „slažem se", „u potpunosti se slažem".

Nakon logičke kontrole, kodiranja i unosa, obrada podataka je obavljena pomoću statističkog paketa SPSS. Odgovori su križani s nezavisnim varijablama (mjesto odrastanja, spol, studij), a u analizi rezultata primijenjen je statistički hi^2-test i ANOVA.

REZULTATI I DISKUSIJA

Neka obilježja školovanja agronoma u Hrvatskoj i Bosni i Hercegovini

Jedinstveno uređenje obrazovanja u BiH ne postoji na državnom nivou, a nadležnosti za ovu oblast su dodijeljene njenim organizacionim jedinicama. Prema tome, one se nalaze na nivou institucija (Ministarstvu obrazovanja) Republike Srpske, pojedinačno svakom od deset kantona u FBiH, te Brčko Distriktu. Iz ovoga proizlazi, osim obimne i komplicirane administracije, neusuglašenost obrazovnog sustava na cijelom području BiH, te nepostojanje zajedničke strategija na državnom nivou. Ovo je jedna od pretpostavki koja je dovela do formiranja većeg broja poljoprivrednih fakulteta unutar BiH. U BiH djeluju sljedeći poljoprivredni fakulteti, odnosno fakulteti koji u svom studijskom programu imaju odsjek agronomije: Poljoprivredno-prehrambeni fakultet Univerziteta u Sarajevu, Poljoprivredni fakultet Univerziteta u Banja Luci, Agromediteranski fakultet Univerziteta „Džemal Bijedić" u Mostaru, Agronomski i prehrambeno-tehnološki fakultet Sveučilišta u Mostaru, Biotehnički fakultet Univerziteta u Bihaću, Poljoprivredni fakultet Univerziteta u Istočnom Sarajevu i Tehnološki fakultet Univerziteta u Tuzli. Iako, s jedne strane ovakva situacija olakšava dostupnost i mogućnost upisa ove vrste studija kandidatima koji se odluče za studiranje agronomije, sa druge strane negativno utječe na kvalitetu prije svega upisanih studenata (zbog veće mogućnosti izbora fakulteta i smanjene konkurencije na listama upisa), a samim tim i kadra koji uspješno završi neki ciklus bolonjskog studija. Druga negativna posljedica ovolikog broja fakulteta jest neplanska produkcija (hiperprodukcija) kadra koji na kraju studija ima veoma malu mogućnost zaposlenja u struci.

S druge strane, usprkos postojanju većeg broja poljoprivrednih fakulteta u BiH, primjetan je nedostatak visoke strukovne škole na cjelokupnom području BiH. Ovakav koncept, gdje se više pozornosti poklanja praktičnom radu i učenju, nego teoretskom aspektu poljoprivredne proizvodnje, svakako bi mogao biti zanimljiv mladim ljudima koji su samostalno pokrenuli neku poljoprivrednu proizvodnju (posljednjih godina je primjetno povećanje broja mladih ljudi koji po prvi put pokreću neki poljoprivredni biznis, najčešće proizvodnju jagodičastog voća). Broj upisanih studenata na Poljoprivredno prehrambenom fakultetu u Sarajevu varira u posljednjih pet godina i kreće se od 172 (ak. god. 2016/2017) do 250 (ak. god. 2015/2016). Studenti se uglavnom odlučuju na upis fakulteta najbližeg mjestu boravka što im umanjuje troškove studiranja. Zbog navedenog, primjetno je kako studenti koji upisuju ovaj fakultet uglavnom dolaze iz središnje Bosne kojima Sarajevo i jest najbliže mjesto s mogućnošću studiranja agronomije.

Republika Hrvatska ima dugu tradiciju visokoškolskog obrazovanja pa tako i agronoma. Današnji Agronomski fakultet u Zagrebu utemeljen je 1919. godine te su nakon toga njegovi članovi sudjelovali u pokretanju skoro svih poljoprivrednih fakulteta prostora bivše države.

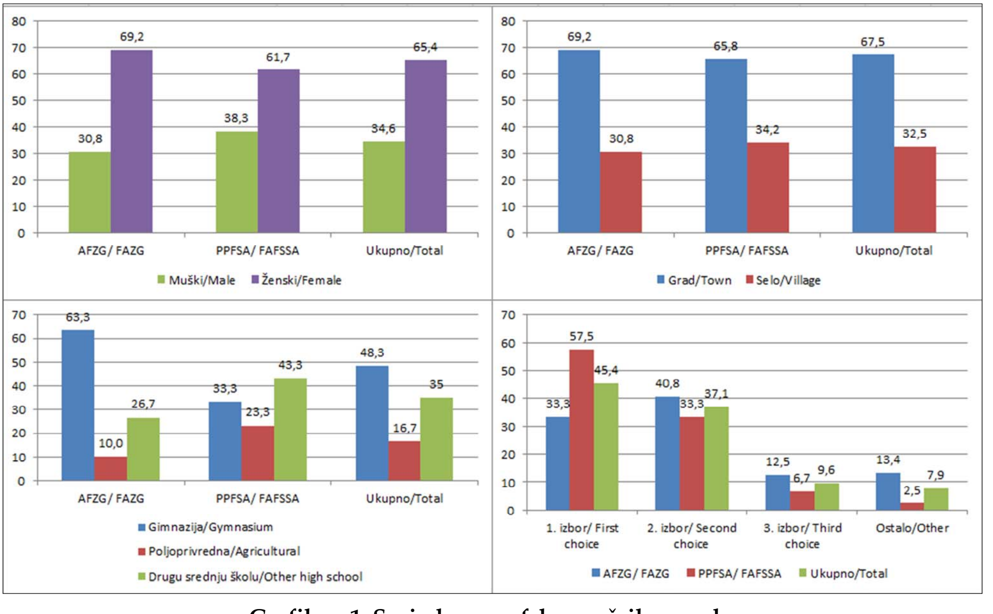
Danas se agronomi školuju na nekoliko visokoškolskih ustanova kao što su Agronomski fakultet Sveučilišta u Zagrebu, Poljoprivredni fakultet Sveučilišta u Osijeku, Odjel za akvakulturu Sveučilišta u Dubrovniku, Sveučilišni studijski centar za studije mora Sveučilišta u Splitu te Odjel za ekologiju, agronomiju i akvakulturu Sveučilišta u Zadru. Osim toga, značajan broj polaznika upisuje Visoko gospodarsko učilište u Križevcima,, Veleučilište u Slavonskom Brod, Veleučilište u Rijeci, Veleučilište "Marko Marulić" u Kninu te Veleučilište u Požegi gdje se školuju za agronome.

Značajne su rasprave o brojnosti, odgojnosti ustanova i broju polaznika s obzirom na „potrebe na tržištu", a također su prisutne i značajne rasprave o brojnosti studija i/ili studijskih programa na pojedinim fakultetima. Tako Agronomski fakultet Sveučilišta u Zagrebu ima devet preddiplomskih i trinaest diplomskih studija. Prisutne su i rasprave o broju predmeta, „preklapanjima" sadržaja, obuhvatu i kvaliteti izvedbe te provedbenosti bolonjskog procesa s obzirom na brojnost polaznika po skupinama naročito kod vježbi i seminara, odnosu „teoretskog i praktičnog", terenskoj nastavi, stručnoj praksi itd.

Neka obilježja uzorka

Većina ispitanika u ovom istraživanju su bile žene (65,4%) pri čemu je taj udjel veći na AFZG (69,2%) nego na PPFSA (61,7%). Također, većina ih dolazi iz gradova odnosno urbaniziranih sredina (67,5%) pri čemu je također udjel veći na AFZG. Za spomenuta obilježja nije zabilježena statistički značajna razlika između dva uzorka studenata (spol χ^2= 1,492, df=1, p>0,05; mjesto odrastanja χ^2= 0,304, df=1, p>0,05). Potencijalni uzrok tomu jesu prisutni procesi deruralizacije i deagrarizacije u ruralnim prostorima (Grgić i sur. 2014) ali postoji mogućnost da se ta razlika poveća u budućnosti. Tijekom dužeg razdoblja mijenja se i struktura upisanih studenata s obzirom na stupanj srednjoškolskog obrazovanja. Veći dio anketiranih završio je gimnaziju (48,3%) pri čemu je velika razlika između AFZG (69,2%) i PPFSA (33,3%). Veće razlike između fakulteta su i kod udjela sa završenom srednjom poljoprivrednom školom (dvostruko više na PPFSA nego AFZG) ali i onih sa završenom drugom srednjom školom. Razlika je i statistički značajna obzirom na završeno srednjoškolsko obrazovanje (χ^2= 22,334, df=2, p<0,05) studenata pojedinih fakulteta.

Prilikom završetka srednje škole i položene Državne mature, studenti rangiraju poželjne fakultete za upis. S obzirom na razlike u školskim sustavima evidentne su i razlike između ova dva fakulteta koje su i statistički značajne (χ^2= 22,956, df=8, p<0,05). U Hrvatskoj kod upisa na fakultet postoji mogućnost apliciranja na 10 različitih studija dok je to u Bosni i Hercegovini u pravilu na dva studija (iznimno i na više) Zbog toga je AFZG bio prvi odabir za 33,3% upisanih, a za 57,5% upisanih je to bio PPFSA. Već uključenjem drugog odabira (AFZG 40,8%; PPFSA 33,3%) smanjuju se razlike između fakulteta.



Grafikon 1. Sociodemografske značajke uzorka
Graph 1. Some socio-demographic sample features
Izvor/Source: Vlastito istraživanje/Authors research

Ispitanici i poljoprivredna mehanizacija

Sve navedene karakteristike uzorka mogu upućivati na predznanje studenata o poljoprivrednoj mehanizaciji. Grgić i sur. (2014) u svom istraživanju konstatirali su da „podrijetlo, spol i vrsta završene srednje škole značajno utječu na mogućnost korištenja odnosno upravljanja nekim od poljoprivrednih strojeva od strane anketiranih". Tako je istraživanje 2015. pokazalo da čak 77,3% ispitanih ne zna upravljati niti jednim poljoprivrednim strojem što je u odnosu na 2013. godinu bilo povećanje od 5,7% (Grgić i sur. 2016). Najveći dio ispitanih zna upravljati traktorom, zatim motokultivatorom te frezom. Za razliku od rezultata iz 2013. godine niti jedan ispitani ne zna upravljati kombajnom. Isti autori navode „pretpostavka je da će taj postotak u budućnosti biti i veći."

Tablica 2. Poznavanje upotrebe pojedinih strojeva u poljoprivrednoj proizvodnji (% ispitanika)
Table 2. Knowledge of using some machines in agricultural production (% of respondents)

		AFZG/ FAZG	PPFSA/ FAFSSA	Ukupno/ Total
U obradi tla ne koristi se/In soil tillage we don't use	traktor/tractor	4,2	5,1	4,6
	motokultivator/ motocultivator	31,7	8,5	20,3
	kombajn/combine	54,2	75,2	64,6
	drljača/harrow	10,0	11,1	10,5
	ukupno/total	100,0	100,0	100,0
Poljoprivredni kombajn je/Combine harvester is	kombinacija dvije ili više proizvodnji/ combination of 2 or more productions	1,7	7,0	4,3
	stroj za obradu tla/soil tillage implement	13,3	9,6	11,5
	stroj za mužnju/milking machine	1,7	0,9	1,3
	stroj za izgnojavanje na velikim farmama/manure handling equipment	3,3	2,6	3,0
	stroj za žetvu/harvesting machine	80,0	79,8	79,9
	ukupno/total	100,0	100,0	100,0
Četveroredna sijačica za kukuruz u istom prohodu sije (koliko) redova?/How many rows can four-row corn seeder sow?	dva/two	2,8	4,6	2,2
	tri/three	0,0	1,9	0,9
	četiri/four	91,7	82,4	87,3
	šest/six	3,3	0,9	2,2
	osam/eight	3,3	4,6	6,6
	koliko se naštima/ as many as it is set to sow	1,7	4,5	0,9
	ukupno/total	100,0	100,0	100,0
Rigolanje je/Deep ploughing is	problem kod preživača/ issue at ruminants	4,2	13,9	8,8
	postupak kod žetve pšenice/ procedure in wheat harvest	13,3	16,7	14,9
	oranje na dubinu više od 50 cm/ ploughing over 50 cm	65	45,4	55,7
	usitnjavanje prije sjetve/ crumbling prior to sowing	17,5	24,1	20,6
	ukupno/total	100,0	100,0	100,0

Izvor/Source: Vlastito istraživanje/Authors research

Kako se radi o polaznicima prve godina preddiplomskog studija, jednostavnim pitanjima smo pokušali istražiti osnovna znanja o korištenju poljoprivrednih strojeva odnosno poljoprivrednih priključaka.

Tijekom ankete pokušalo im se pojasniti pojmovi od kojih se traže točni odgovori na zadano pitanje izbjegavajući navođenje na povezanost pitanja i odgovora.

Rezultati su relativno slični prethodnim istraživanjima, ali uočene su manje razlike između pojedinih fakulteta.

Prvi korak u biljnoj proizvodnji je priprema tla i kao pojam je poznat većini ispitanika.

Dvije trećine anketiranih (64,6%) je znalo da se kombajn ne koristi u obradi tla pri čemu je znatno više na AFZG (75,2%) nego na PPFSA (54,2%). Oko petine (20,3%) misli da je to motokultivator (AFZG 31,7% te PPFSA 8,5%). Manji dio (10,5%) smatra da je to drljača bez značajnijih razlika između ispitanika kao i da je to traktor (4,65%). Zabilježena je statistički značajna razlika u navedenim odgovorima studenata pojedinih fakulteta (χ^2= 19,887, df=8, p<0,05).

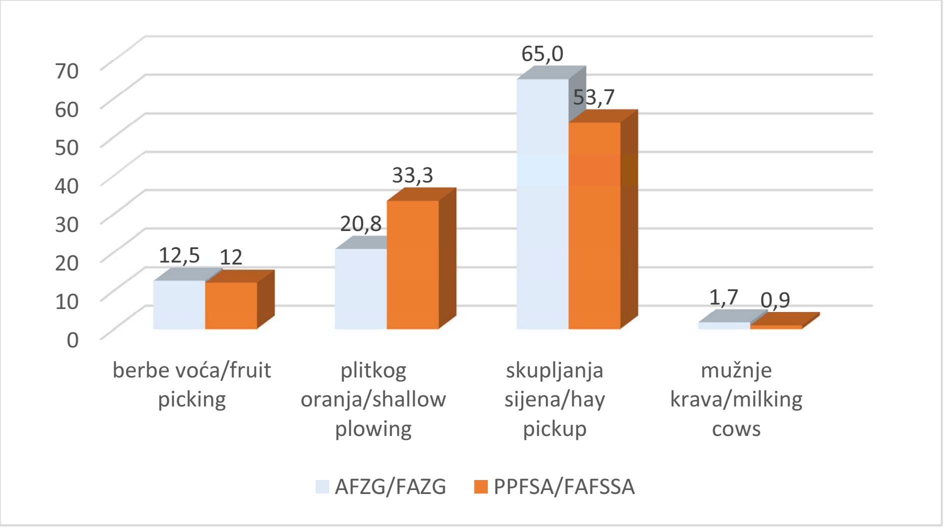
Muški ispitanici su u znatnom većem postotku (77,3%) točno odgovorili u odnosu na žene (59,8%). Također, ispitanici odrasli u ruralnoj sredini u većoj mjeri su znali točan odgovor (80,0%) nego oni iz urbanih (58,3%).

Na izravno pitanje „Što je poljoprivredni kombajn?" većina ih je dala točan odgovor bez većih i statistički značajnih razlika između fakulteta (χ^2= 4,985, df=4, p>0,05).

Većina (79,9%) ispitanika zna da četveroredna sijačica za kukuruz u istom prohodu sije u 4 reda, a ostali misle da su to dva, tri, osam ili čak onoliko redova na „koliko se naštima". Kod ovog odgovora zabilježena je statistički značajna razlika obzirom na pripadnost fakultetu (χ^2= 15,965, df=5, p<0,05).

Postupak rigolanja je jedan od načina osnovne obrade tla prije podizanja nasada. Za rigolanje se koriste jednoobrazni plugovi velikih dimenzija tzv. rigoleri (Grgić i sur. 2016). Većina ispitanih na pitanje „Što je rigolanje?" dala je točan odgovor, odnosno više od polovice (55,7%) znalo je da je to oranje na dubinu više od 50 cm. Prosječno, znatno više ih je sa PPFSA (65,0%) nego sa AFZG (45,4%). Da je rigolanje postupak usitnjavanja prije sjetve, smatra 20,6% ispitanika, postupak kod žetve pšenice 14,9% te problem kod preživača 8,8%. Hi kvadrat testom je i kod ovog pitanja zabilježena statistički značajna razlika u odgovorima obzirom na pripadnost fakultetu (χ^2= 11,671, df=3, p<0,05).

Rol-preša odnosno valjkasta preša (balirka) je stroj koji se koristi za sakupljanje i pripremu sijena za skladištenje ili „konzervaciju" (Grgić i sur. 2016) što zna većina ispitanika (59,6%). Iako postoje razlike između fakulteta, ona nije statistički značajna (χ^2= 4,783, df=3, p>0,05).



Grafikon 2. Kod kojih tehnoloških procesa se koristi valjkasta preša?
Graph 2. At which technological process we use roll baler?
Izvor/Source: Vlastito istraživanje/Authors research

Ispitanicima je u anketnom upitniku ponuđeno nekoliko izjava/stavova povezanih s poljoprivrednom mehanizacijom za koje su mogli izraziti stupanj suglasnosti i to sa stupnjevima „uopće se ne slažem (1)", „ne slažem se (2)", „niti se slažem niti ne slažem (3)", „slažem se (4)" ili „u potpunosti se slažem (5)".

Na poslovanje poljoprivrednika utječe mnoštva čimbenika od kojih se najznačajnijim smatraju promjene cijena repromaterijala, ali i relativno visok trošak mehanizacije (kupnja, trošak pogonskog goriva, amortizacija) (Grgić i sur., 2016). Od ponuđenih konstatacija na skali suglasnosti za ispitanike na prvom mjestu je tvrdnja da bi udruživanje proizvođača doprinijelo smanjenju troškova nabave poljoprivredne mehanizacije.

Moderno bavljenje poljoprivredom kombinacija je poljoprivredne mehanizacije, napredne tehnologije te površine obradivog zemljišta.

Same investicije iziskuju velika novčana sredstva i rijetko si koji poljoprivrednik može priuštiti kompletnu poljoprivrednu mehanizaciju. Kako većina poljoprivrednih kućanstava nema dovoljno sredstava akumuliranih iz vlastita poslovanja, pri nabavljanju strojeva i opreme moraju uzimati kredite ili su primorani nabavljati neodgovarajuće strojeve (tehnički zastarjele, istrošene, slabe pogonske snage) te s njima improvizirati u obavljanju agrotehničkih zahvata (Grgić i Šnajder, 1999). Samo značajnim povećanjem proizvodnih površina poljoprivrednih gospodarstava i usmjeravanje na tržnu proizvodnju uz primjenu odgovarajućih strojeva mogu se postići pozitivni ekonomsko-financijski učinci (Filipović i sur., 2005).

Kao i u istraživanjima 2013. i 2015. godine anketirani su značajno vrednovali tvrdnju da je poljoprivredna mehanizacija jedan od preduvjeta uspješne proizvodnje, a uspješnu proizvodnju pri tome su definirali kao količinu proizvodnje po jedinici kapaciteta te manji utrošak rada ljudi tj. ljudskog rada. Ovaj put su tu tvrdnju ocijenili s prosječnom ocjenom 3,90 pri čemu su je ispitanici sa PPFSA vrednovali važnijom (4,03) nego sa AFZG (3,77).

Odgovori na ovo pitanje odnosno stupanj (ne)slaganja s navedenom izjavom kod studenata pojedinih fakulteta se statistički razlikuju (F=3,998, p<0,05).

Zajednička karakteristika, ali na različitoj razini, poljoprivrede Hrvatske i Bosne i Hercegovine su neorganiziranost, nestandardiziranost i usitnjenost poljoprivredne proizvodnje te bi izlaz trebalo potražiti u poticanju poslovnog povezivanja proizvođača. Udruživanjem proizvođači dobivaju mogućnost zajedničkog korištenja mehanizacije i snižavanja troškova proizvodnje (npr. strojni prsteni). U suprotnom, visoki fiksni troškovi negativno utječu na profit i uzrokuju gubitke (Asi i sur., 1999.). Važnost udruživanja ima prosječno visoku vrijednost (3,77) bez značajnih razlika između fakulteta (F=0,022, p>0,05).

Tablica 3. Suglasnost s nekim tvrdnjama o poljoprivrednoj mehanizaciji i ANOVA
Table 3. Agreement with some statements about farm machinery and ANOVA

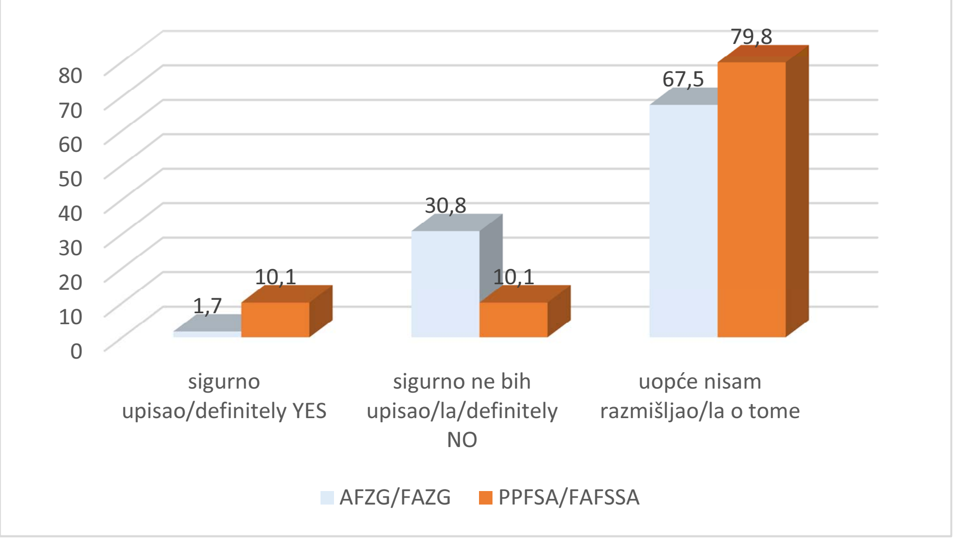
	Fakultet/ Faculty	N	Mean*	Sta. dev.	F	*p*
Svaki poljoprivrednik za uspješnu proizvodnju treba poljoprivrednu mehanizaciju/ Every farmer needs machinery for succesful production	AFZG/ FAZG	120	3,77	1,019	3,998	**0,047**
	PPFSA/ FAFSSA	120	4,03	0,983		
	Ukupno/Total	240	**3,90**	1,007		
Udruživanje proizvođača smanjilo bi troškove nabave poljoprivredne mehanizacije/ Producers merging would decrease expenses of buying machinery	AFZG/ FAZG	120	3,78	0,874	0,022	0,882
	PPFSA/ FAFSSA	119	3,76	1,057		
	Ukupno/Total	239	**3,77**	0,968		
Za stručno upravljanje mehanizacijom potrebno je i formalno obrazovanje/ Professional machinery management needs proper education	AFZG/ FAZG	120	3,52	1,029	0,773	0,380
	PPFSA/ FAFSSA	120	3,39	1,169		
	Ukupno/Total	240	**3,45**	1,101		
Poljoprivrednici rado prihvaćaju inovacije u poljoprivrednoj mehanizaciji/ Farmers gladly accept inovations in farm machinery	AFZG/ FAZG	120	3,19	0,946	8,242	**0,004**
	PPFSA/ FAFSSA	118	3,55	0,984		
	Ukupno/Total	238	**3,37**	0,980		
Primjena mehanizacije smanjuje troškove proizvodnje/ Farm machinery decreases production expenses	AFZG/ FAZG	120	3,13	0,987	5,764	0,017
	PPFSA/ FAFSSA	120	3,46	1,107		
	Ukupno/Total	240	**3,30**	1,059		
Poljoprivredna mehanizacija je u Vašoj državi u odnosu na druge države EU u prosjeku „mlađa“/ Average age of farm machinery in your country is”younger“ in comparison to other EU countries	AFZG/ FAZG	120	3,23	1,158	2,671	0,104
	PPFSA/ FAFSSA	119	2,97	1,285		
	Ukupno/Total	239	**3,10**	1,227		
Primjena mehanizacije smanjuje onečišćenje okoliša/ Using of farm machinery decrease nature pollution	AFZG/ FAZG	120	2,26	0,992	23,666	**0,000**
	PPFSA/ FAFSSA	120	2,98	1,273		
	Ukupno/Total	240	**2,62**	1,194		
Primjena mehanizacije smanjuje produktivnost u poljoprivredi/ Using of farm machinery decrease productivity in agriculture	AFZG/ FAZG	120	2,08	1,094	9,767	**0,002**
	PPFSA/ FAFSSA	118	2,55	1,251		
	Ukupno/Total	238	**2,31**	1,196		

* uopće se ne slažem -1; u potpunosti se slažem -5/ completely disagree -1; completely agree-5
Izvor/Source: Vlastito istraživanje/Authors research

Anketirani su podijeljenog mišljenja za tvrdnju kako je formalno obrazovanje potrebno boljem korištenju mehanizacije (više ih je sa AFZG) kao i da poljoprivrednici rado prihvaćaju inovacije kod mehanizacije (naglašenije kod PPFSA). Također su svjesni da poljoprivredna mehanizacija utječe na onečišćenje okoliša ali i da značajno djeluje na povećanje produktivnosti rada u poljoprivredi.

Zadovoljavajuća razina poznavanja problematike poljoprivredne mehanizacije nije kod anketiranih polučila veću želju za užom specijalizacijom kod upisa diplomskog studija.

Mali dio bi upisao diplomski studij koji izučava poljoprivrednu mehanizaciju iako se tijekom preddiplomskog studija sadašnje mišljenje može i promijeniti.



Grafikon 3. Voljnost upisa (% ispitanika) diplomskog studija koji izučava poljoprivrednu mehanizaciju
Graph 3. Willingness of enrollment (% of respondents) graduate study which is connected with farm machinery
Izvor/Source: Vlastito istraživanje/Authors research

Postoji statistički značajna razlika u odgovorima studenata odabranih fakulteta o mogućnosti upisa diplomskog studija čiji je predmet izučavanja poljoprivredna mehanizacija (χ^2= 21,008, df=2, p<0,05).

ZAKLJUČAK

Poljoprivredna mehanizacija je sve zahtjevnija u pogledu potrebnih znanja osoba koji je koriste odnonosno koji njome upravljaju. Istraživanje je pokazalo da ne postoje značajnije razlike u poznavanju poljoprivredne mehanizacije između anketiranih studenata prve godine Agronomskog fakulteta u Zagrebu i Poljoprivredno-prehrambenog fakulteta u Sarajevu. Nisu zabilježene niti statistički značajnije razlike kod pojedinih statvova vezanih za istraživanu problematiku. Kod studenata jednog i drugog fakulteta prisutan je nedostatak prakse u poljoprivrednoj proizvodnji, odnosno poznavanja upravljanja poljoprivrednim strojevima. Takva konstatacija potvrđuje trend gdje agronomiju biraju u sve većem udjelu studenti koji nemaju doticaja s poljoprivredom u praksi što može biti indikatvino prilikom kreiranja obrazovnih programa. Takav trend će se vjerojatno nastaviti i u budućnosti.

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STUDENTS' KNOWLEDGE ABOUT THE AGRICULTURAL MECHANIZATION ON UNIVERSITY OF ZAGREB FACULTY OF AGRICULTURE AND UNIVERSITY OF SARAJEVO FACULTY OF AGRICULTURE AND FOOD SCIENCE

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ABSTRACT

The paper presents the results of research on the first-year students' knowledge about agricultural mechanization on Faculty of Agriculture in Zagreb (FAZG) and Faculty of Agriculture and Food Science in Sarajevo (FAFSSA).

The aim is to examine the knowledge of agricultural mechanization by comparative analysis of the results in which we assume that there are no significant differences between students' knowledge of certain faculties. For these purposes questionnaire was used and data obtained were analyzed using SPSS.

The survey was conducted in October 2016, with the sample of 240 first year students of undergraduate studies (120 from each faculty).

There was larger share of female (69.2% FAZG; 61.7% FAFSSA). Most of respondents grew up in urban areas (69.2% FAZG; 65.8% FAFSSA). On FAZG most respondents were with the gymnasium education (63.3%) and on the PPFSA most of them were with a completed professional non-agricultural high school (43.3%). There was higher share of respondents with completed agricultural secondary school on the FAFSSA (23.3%) than on the FAZG (10.0%). Research has shown that most of the respondents do not know how to manage even one agricultural machinery (77.5% FAZG; 70.8% FAFSSA), and most of others know how to run a tractor, motocultivator and/or rotary cultivator. The respondents know that the harvester is not used for soil treatment (54.2% FAZG; 75.2% FAFSSA) and that it is a machine for harvesting. Although most of respondents know that the four row-seeder sown in four rows in one pass, however, 10% (FAZG) and 20% (FAFSSA) of them think that seeder can sow three, five or even eight rows in one pass. Research has shown that students are aware of the importance of the use of mechanization in agriculture, and also with the need of efficient management, emphasizing the farmers' cooperation, all with the purpose to reduce the cost of mechanization in the production process.

Although the most of them considers that the management machinery required formal education (55.8% FAZG; 55.9% FAFSSA), there is surprisingly little willingness to attend collegiums that studied this topic (1.7% FAZG; 10.1% FAFSSA). Male respondents and those who grew up in the rural area have a higher level of knowledge about agricultural mechanization.

Key words: knowledge of agricultural machinery, students, agronomy, Croatia, Bosnia and Herzegovina

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45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 331.45:631.11
Prethodno priopćenje
Preliminary communication

IMPROVEMENT OF SAFE & HEALTHY WORK SYSTEMS IN AGRICULTURAL SME'S

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SUMMARY

The systems for management of safe & healthy work in SME from agriculture present specifically proprieties as: work in open spaces, many and great risks, low qualification of operators for a lot of activities per worker, discontinuous work, deep consequences on environment etc. The paper presents the results of analysis of risk factors for 10 SME (Small to Medium Enterprises) from agriculture in Timis and Arad counties, based on OHSAS 18000 and statistic approach by the use of questionnaires. There were correlated, the risk/factors, workplace, qualification, position and the characteristic elements of SME (equipment, dimensions, type and cultivation technologies, incomes etc.). The results of questionnaires were centralized, normalized and statistical analyzed. The opinion analysis concluded on necessity for force action on Alcohol interdiction, Existing of firefighting equipment and Healthy and rested at workplace. Also, there was identified statistical significance in the case of correlation between Training at work and Healthy and Rested at workplace, and correlation between Instructions for mechanical equipment and Instructions for maintenance and repair.

Keywords: health & safety work management systems, SME, risk, factors.

INTRODUCTION

Actually, work in agriculture exploitations is a very riskily activity (sometimes classified as „hazardous occupation with high rates of injury and death" (Morgaine K.C. et al., 2014), determined by a complex system of factors.

Firstly, most of work is performed outdoor condition, which could create heavy work conditions (strongly cold or heat, high or less humidity, solar radiation, etc.), that generate a lot of health risk (Ju Youn Kwon et al., 2015). Also, work in agriculture suppose a lot of activities (agro technical, maintenance, repairing, transportation, handling, etc. (Gen Qiuqing et al., 2015; Cluoser J.M. et al., 2015), a lot of equipment and machinery, (from the most rudimentary to the most advanced (Barrasa M. et al., 2013; Pompei D. et al., 2015), that generate one of the highest risks from different categories: physic, chemical, electrical, and generally environmental. Thereby, even there are few standardized tools available to assess safety and health in agricultural operations, there are a number of groups of agricultural workers, including Hmong refugees and immigrants, for which virtually no information on safety and health conditions is available (Neitzel R.L. et al., 2014).

On the other hand, most of the workers in small and medium farms have low levels of professional qualification and median on occupational risk is low. The workers crisis generates in high developed economies the use of immigrants, that received low work compensation and has bad social status (Liebman A. K. et al., 2016). Another high risk exposed category is youth farm workers (Arcury T.A. et al., 2014; Perla M.E. et al., 2015).

Currently there are many strategies concerns for rising levels of professional qualification and knowledge of health & safety risks by dedicated national strategies (eg. Swedish, Lundquist P. et al., 2014), including the use of trainings (Morera M.C. et al., 2014).

Continuous improvement in the safe & healthy work management systems (S&HWMS) of SMEs from agriculture is similarly PDCA (Plan-Do-Check-Act), and suppose generating of politics by organizing, planning and implementation, ranking and acting according to continuous improvement principles. But, such applications involve the use of more resources (increasing of costs by new protection equipment, instructions, trainings, technical measures), sometimes over the financial possibilities of SME from agriculture.

Paper ranks in a specific hierarchy the most important risk factors and measures for optimize the best functionality of S&HWMS in agriculture. The main objective of the paper is to analyze the S&HWMS from 10 agricultural SME having principal activity cultivation of cereals (excluding rice). Connected, there are secondary objectives as: comparative analyze of S&HWMS for optimizing their activity for safe and healthy work (S&HW); establishing correlation between specific elements of S&HWMS; establishing elements for optimization; establishing improvement measures and efficiency of S&HWMS.

METHOD

Starting at previous experience (Gusetoiu I.R. et al., 2013; Gusetoiu I.R. et al., 2012), was proposed an investigation of persons about ranking of risk factors and subsequent statistical analysis. According to the methodology, presented in figure 1, firstly were established the factors according to statistic of fatal accidents, injuries, and work illness (28 factors (F1-F28), according to table 1). These factors were posted in questionnaires, each questioned person made ranking by given qualification from 0 (lowest level of importance) to 10 (highest level of importance).

The questionnaires were distributed to workers and management (32 persons, coded E1-E32, from 10 SME situated in Arad county, west of Romania), and the results were. The results were centralised in 2 table for each 14 factors. The statistical analysis calculated next parameters: sum of points, average (arithmetic mean), median, and confidence (dispersion).

The considered risk factors covered a large spectre of activities, and application of safe & healthy measurements is, simultaneously, issue of individual and organization.

By introduction of hypothesis that the 28 factors selected initially for investigation of safe & healthy work management systems must have 100% effect, the sum of initial points was recalculated according to the confidence (100 – V) [%].

The reinterpreting of new sum of points give a new hierarchy, used for selection of half factors (14 factors).

In the second step, by similar hypothesis were selected only 7 factors, considered as significant.

Because could be a dependence degree between analysed factors, statistical analyze supposed the existence of a critical point, from where is impossible to determine the implication degree of each part.

Therefore, it must be calculated the correlation coefficient between couple of different factors for selection of significant correlation.

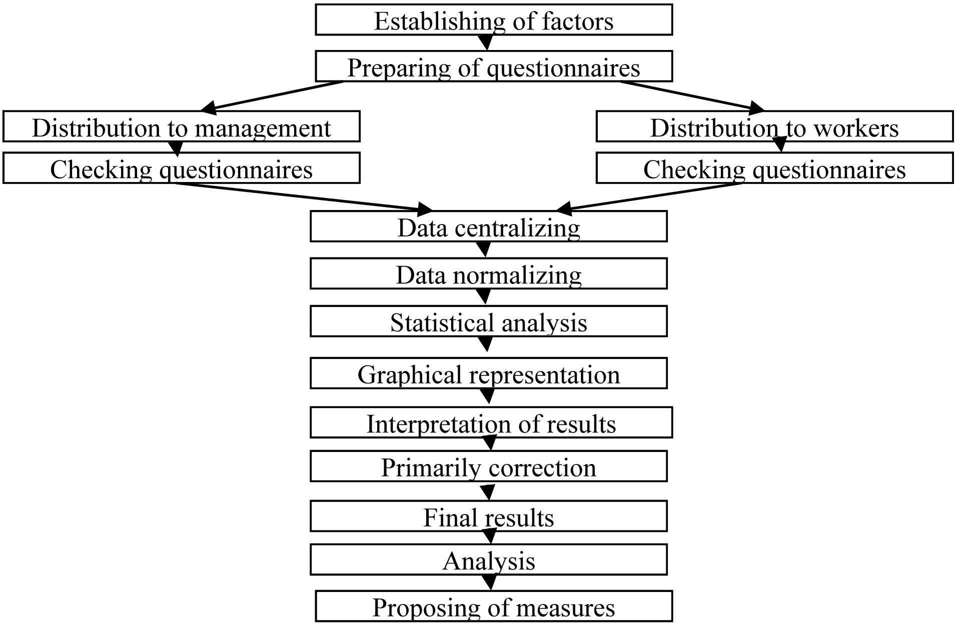

Figure 1. Research methodology

RESULTS AND DISCUSSION

Table 1 presents the results of factors ranking according to sum of received points.

The results are completed with the values of mean, median, dispersion and variation.

According to presented methodology, table 2 point out the results of ranking for risk factors after second reduction, selection only for 7 factors, considered as significant.

Table 1. Results of factor's ranking according to sum of points

Code	Factor (Safety requirements)	Mean	Median	Dispersion	Variation, V [%]	Sum of points
F25	Alcohol interdiction	9.15	10	1.41	15.4	293
F24	Healthy and rested at workplace	8.96	9	1.12	12.5	287
F22	Connection to ground of equipment	8.84	9	1.39	15.7	283
F14	Instructions for maintenance and repair	8.71	8.5	1.17	13.4	279
F26	Training at work	8.65	9	1.35	15.6	277
F4	Existing of firefighting equipment	8.56	8	1.29	15.1	274
F13	Instructions for mechanical equipment	8.56	8.5	1.36	15.9	274
F1	Displaying at visible place of Evacuation Plan	8.46	8	1.52	17.9	271
F16	Existing of WC and sink	8.34	9	1.49	17.9	267
F9	Existing of Work instructions	8.31	8	1.37	16.5	266
F27	Periodical training	8.31	8.5	1.73	20.8	266
F2	Periodical exercises for evacuation	8.18	8	1.22	15	262
F5	Pictures with risks at workplaces	8.18	8	1.02	12.5	262
F15	Existing of lockers	8.18	8	1.57	19.2	262
F21	Verifying and maintenance of individual protection equipment	8.09	8.5	1.55	19.1	259
F23	Natural light at workplaces	8.09	8	1.55	19.1	259
F10	Guideline existence	8.03	8	2.16	26.9	257
F20	Existing of protection systems at mechanical equipment	7.96	8	1.75	21.9	255
F12	Proper storage of hazardous substances	7.9	8	2.03	25.7	253
F3	Preparing and signalizing of smoking place	7.81	8	1.46	18.8	250
F6	Pictures with individual protection equipment at workplaces	7.68	8	0.99	12.9	246
F11	Determining of noxious	7.34	7	1.78	24.3	235
F18	Medical exams	7.34	8	2.07	28.2	235
F7	Marking of traffic routes	7.15	8	1.76	24.6	229
F17	Risk evaluation	6.81	8	3.04	44.6	218
F8	Propaganda	6.68	7	2.64	39.5	214
F19	Reporting of nonconformities	6.34	7.5	3.1	48.9	203
F28	40 h training	5.87	7	3.63	61.8	188

Analysis of resulted questionnaires and statistical parameter confirm differences between opinion, almost in the case of 40 h training, reporting of nonconformities, risk evaluation and propaganda, that demonstrate a low level of risk education measures, or superficial approach in agriculture.

People agrees about the importance and impact of the use of pictures (with individual protection equipment or with risks at workplace), periodical exercises or evacuation and healthy and rested at workplace

Table 2. Ranking of risk factors after second reduction

Code	Risk Factor (Security Requirement)	Sum	Median	Mean	Disper-sion	Variation V[%]
F25	Alcohol interdiction	475.76	14.83	14.86	1.85	12.47
F24	Healthy and rested at workplace	468.18	14.6	14.63	1.67	11.45
F22	Connection to ground of equipment	459.21	14.62	14.35	1.56	10.91
F14	Instructions for maintenance and repair	453.94	13.92	14.18	1.37	9.67
F26	Training at work	449.58	14.53	14.04	1.51	10.81
F4	Existing of firefighting equipment	447.61	13.81	13.98	2.08	14.88
F13	Instructions for mechanical equipment	444.6	13.71	13.89	1.52	10.99

Table 3 presents the results of calculated correlation coefficients (Pearson coefficient).

Table 3. The result of calculated correlation coefficients

	F25	F24	F22	F14	F26	F4	F13
F25	X						
F24	0.37	X					
F22	-0.35	-0.2	X				
F14	-023	0.02	-0.38	X			
F26	-029	*-0.52*	0.24	-0.37	X		
F4	-036	-035	-0.13	-0.25	0.14	X	
F13	-0.29	-0.35	-0.10	*0.47*	-0.17	0.3	X

From table 3 results that only two couple of factors could be considered significant correlations: between F26-F24 and between F13-F14 (the highest values).

The first couple of factors, F26-F24 (Training at work and Healthy and rested at workplace), indicates generally, in all investigated SMEs involved in agriculture from Arad county organizational problems, and the second couple of factors, F13-F14 (Instructions for mechanical equipment and Instructions for maintenance and repair), indicates for the same investigation group technical problems.

CONCLUSIONS

The paper proposed a sequence that could be introduced in a method to optimize the measures for intervention from the safe & healthy work management systems (S&HWMS) of SMEs from agriculture, by adopting a procedure similarly PDCA (Plan-Do-Check-Act). This includes ranking of risk factors by psychological experiment, based on investigation of workers and managers about rank of risk factors.

The choosing of risk factors must cover all field of requirements: organizational requirements, technical requirements and legal requirements, lasts been, sometimes, specific to each country, even there are (only for EU countries) EC directives and other decisions.

Ranking of factors is necessarily because the SME's resources are limited and each measure for safe & healthy work means costs, which could affect the position of enterprise in global market.

Because the proposed sequence in the method is based on human opinion, the results could be different, but statistical approach focus the results with acceptable level of significance in the case of correlation between Training at work and Healthy and Rested at workplace, and correlation between Instructions for mechanical equipment and Instructions for maintenance and repair.

These factors must be the first step of intervention.

Also, even the correlation has lower significance level, must force action on Alcohol interdiction, Existing of firefighting equipment and Healthy and rested at workplace (the lower significance level could be explained by a superficial perception on legal provisions).

Last positions in ranking for Medical exams, Marking of traffic routes, Risk evaluation, Propaganda, Reporting of nonconformities and 40 h training, demonstrate a low level of education regarding safe & healthy work management systems (S&HWMS) of SMEs from agriculture and impose increasing the number and improvement of such actions.

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Snaga održavanja

ULJA I MAZIVA ZA POLJOPRIVREDU

INA MAZIVA

http://atae.agr.hr/