UDC 631

ISSN 1333 - 2651

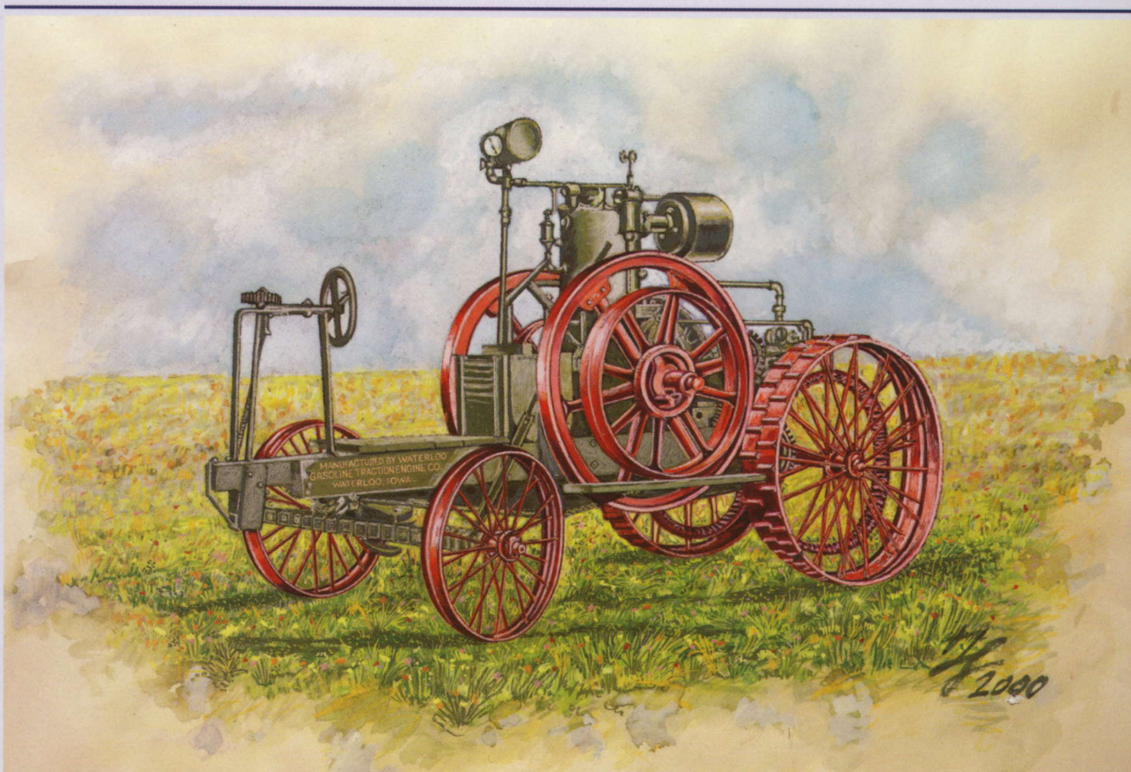
UNIVERSITY OF ZAGREB FACULTY OF AGRICULTURE
AGRICULTURAL ENGINEERING DEPARTMENT
FACULTY OF AGRICULTURE UNIVERSITY OF OSIJEK
FACULTY OF AGRICULTURE UNIVERSITY OF MARIBOR
AGRICULTURAL INSTITUTE OF SLOVENIA
HUNGARIAN INSTITUTE OF AGRICULTURAL ENGINEERING
CROATIAN AGRICULTURAL ENGINEERING SOCIETY

CIGR AAESEE AAAE EurAgEng

**PROCEEDINGS OF THE
37. INTERNATIONAL SYMPOSIUM ON
AGRICULTURAL ENGINEERING**

Actual Tasks on Agricultural Engineering

OPATIJA, CROATIA, 10. - 13. FEBRUARY 2009



SVEUČILIŠTE U ZAGREBU AGRONOMSKI FAKULTET
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
FAKULTETA ZA KMETIJSTVO UNIVERZE V MARIBORU
KMETIJSKI INŠTITUT SLOVENIJE
MAĐARSKI INSTITUT ZA POLJOPRIVREDNU TEHNIKU
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU
AAESEE

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

ZBORNIK RADOVA

37. MEĐUNARODNOG SIMPOZIJA IZ PODRUČJA MEHANIZACIJE POLJOPRIVREDE

OPATIJA, 10. - 13. veljače 2009.

Izdavači *Published by*	Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, Svetošimunska 25, 10000 Zagreb HINUS, Miramarska 13 b, Zagreb
Glavni i odgovorni urednik *Chief editor*	Silvio Košutić e-mail: skosutic@agr.hr
Tehnički urednik *Technical editor*	Hrvoje Zrnčić
Organizacijski odbor *Organising committee*	Krešimir Čopec, Goran Fabijanić, Dubravko Filipović, Zlatko Gospodarić, Igor Kovačev, Đuro Banaj, Robert Zimmer, Viktor Jejčić, Miran Lakota, Tomaž Poje, Rajko Bernik
Znanstveni odbor *Scientific committee*	Nikolay Mihailov (Bulgaria), Silvio Košutić, Robert Zimmer, (Croatia), Peter Schulze-Lammers, Joachim Müller (Germany), Daniele De Wrachien, Ettore Gasparetto (Italy), Maohua Wang (P.R. China), Victor Ros (Romania), Milan Martinov (Serbia), Jaime Ortiz-Canavate (Spain), Vilas M. Salokhe (Thailand), Bill A. Stout (USA)
Naklada *Number of copies*	200

ISSN 1333-2651

http://atae.agr.hr

Slika s naslovnice korištena je dobrotom autora gospodina Dušana Jejčiča
Cover painting is printed by courtesy of author Mr Dušan Jejčič
Oblikovanje naslovnice / Cover design: Marko Košutić

Svi radovi u Zborniku su recenzirani.
All papers in Proceedings are peer reviewed.

Radovi u Zborniku su indeksirani u bazama podataka od 1997.:
Papers from the proceedings have been indexed since 1997 into databases:

Current Contents Proceedings, ISI - Index to Scientific & Technical Proceedings, CAB International - Agricultural Engineering Abstracts, Cambridge Scientific Abstracts - Conference Papers Index, InterDok.

POTPORA – SUPPORT

MINISTARSTVO ZNANOSTI, OBRAZOVANJA I ŠPORTA REPUBLIKE HRVATSKE

MINISTARSTVO POLJOPRIVREDE, RIBARSTVA I RURALNOG RAZVOJA

SAME DEUTZ-FAHR ŽETELICE
ŽUPANJA

POLJONOVA
SESVETE

GRAMIP – TPS
DUBRAVA

INA
ZAGREB

SIP
ŠEMPETER, SLOVENIJA

AGROGROM
SAMOBOR

AGROMARKETING
ZAGREB

PREDGOVOR - PREFACE

Zahvaljujući stalnoj potpori kolega iz struke, strukovnih udruga (HUPT i HAD), trgovačkih kuća-predstavnika svjetskih proizvođača poljoprivrednih strojeva i opreme, Ministarstva znanosti obrazovanja i športa, Ministarstva poljoprivrede, šumarstva i vodnog gospodarstva, te međunarodnih udruga Poljoprivredne tehnike (EurAgEng, CIGR, AAAE i AAESEE) uspjeli smo organizirati i 37. Simpozij ”Aktualni zadaci mehanizacije poljoprivrede”. Ovaj 37. po redu Zbornik sadrži 61 rad od čega : Bosna i Hercegovina, Brazil, Bugarska, Estonija, Islamska Republika Iran, Izrael, N.R. Kina, Kosovo, Litva, Njemačka i Sjedinjene Države Amerike ima (1), Mađarska (2), Italija (3), Srbija i Turska (4), Hrvatska (5) Slovenija (6) i Rumunjska (26) radova. Zahvaljujemo se svim sponzorima koji su svojom potporom omogućili održavanje ovakvog skupa, autorima referata, kao i svim učesnicima na interesu. Posebno se zahvaljujemo Ministarstvu znanosti i tehnologije Republike Hrvatske na stalnoj potpori. Svim učesnicima želimo ugodan boravak u Opatiji za vrijeme održavanja Simpozija.

Due to long-term support of our colleagues, our associations (CAES, CSA), commercial representatives of the world famous agricultural machinery and equipment producers, Ministry of sciences, education and sport, Ministry of agriculture, forestry and water management and finally world known associations for agricultural engineering (EurAgEng, CIGR, AAAE and AAESEE) enabled organizer to carry out 37th symposium ”Actual tasks on Agricultural Engineering”. This proceedings contains 61 papers among them are: Bosnia and Herzegovina, Brazil, Bulgaria, Estonia, Germany, Islamic Republic Iran, Israel, Lithuania, Kosovo, P.R. China and USA with (1), Hungary with (2), Italy (3), Serbia and Turkey with (4), Croatia with (5), Slovenia with (6) and Romania with (26) papers. We would like to thank authors, reviewers, participants and especially sponsors for their contribution to organize the symposium. We especially emphasize sponsoring of Ministry of Sciences and technology of Republic of Croatia who support us for 14 years. Finally we wish all participants, our colleagues pleasant time, weather and company during symposium.

Chief Editor
Prof. dr. Silvio Košutić

Zagreb, siječanj-January 2009.

SADRŽAJ – CONTENTS

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 628.1:631.67
Pregledni rad
Review paper

SUSTAINABLE WATER MANAGEMENT SYSTEMS FOR FOOD AND FEED: PRESENT AND PROSPECTUS

RAMESH KANWAR

Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, Iowa 50011, e-mail: rskanwar@iastate.edu

SUMMARY

According to statistical data and sustainable resources management systems expert's knowledge author analysis present global situation, showing improved and sophisticated ways of water, food and land management finally trying to predict our future.

Key words*: Sustainable management systems, water, food, natural resources*

INTRODUCTION

Recent trends in global population growth rates show that growth rates have been declining recently but by 2050 the planet could have more than 9 billion people. Increased population growth rates have added more than 2.3 billion on earth between 1970 and 2000. If we look at the global picture on the availability of water supplies and capacity of land to produce food and feed, we see a frightening outlook. Although average food production has kept pace with the increased population, available water supplies for irrigation are declining and water quality of most available water supplies has deteriorated steadily because of intensification of agriculture and lack of investment on watershed planning to maintain contaminant-free drinking water supplies. One of the most important questions facing the global society today is how to produce enough food to feed the increasing human population in the world. Another parallel question facing the society is how much water would be needed to produce enough food to feed the increasing population and from where additional water resources would be generated under constant climate change scenarios. Answers to these questions are not easy.

The demand for freshwater is increasing as the world's population continues to increase. Several recent studies have indicated that severe water shortages will occur for more than one-third of the world's human population by 2025, especially in heavily populated countries like India and China. Some countries, such as the United States, Canada, Australia, and Japan, are extremely fortunate to have safe and abundant supplies of freshwater. In addition, some of the emerging issues of global water management would be geo-political in nature requiring the development and implementation of international sound water policies to solve water conflicts within and between countries. Many challenges to food, water, and environmental sustainability can be addressed through improved educational curricula on water management and climate change to train world class water professionals to solve complex water problems in the 21st century.

One of the challenges in the 21st century facing global food security is the availability of an adequate supply of water to grow crops, vegetables, fruits and animals to meet the ever growing demand from the increasing world population. The second major challenge for the global society is the degradation of environment (especially water quality) and loss of land and water for agricultural use. Major causes of land and water degradation in the world are related to contamination of water supplies from municipal, industrial, and agricultural sources in addition to salinity and water logging of soils from canal irrigation, and groundwater pumping at an alarming rate for irrigation. In certain areas of India, groundwater tables have been lowered more than 70 meters in last 30 years. Large irrigation systems in the State of Nebraska in the USA are lowering the groundwater tables in one of the largest aquifers systems at a rate even faster than

India. Previous programs on water conservation and protecting land from degradation have focused primarily on irrigation management practices using purely technical solutions but did not take into consideration the other socio-economic-political factor for long-term sustainability. To solve this serious threat to food security we need to develop a strong vision and effective strategies at the watershed and basin scales to make correct decisions by developing grassroots partnerships of local citizens at municipal and farm-levels and using holistic and farmer-centered approaches to treat land, water, food, people, ecology, and industries as components of a ***"large economic and environmentally sustainable water and food production system."*** Experts have been debating the earth's capacity to produce enough food to feed 8 to 10 billion people. To answer this question, we need a clear understanding between the relationships of water availability, water quality, and sustainable food production and environmental systems.

RELATIONSHIP BETWEEN WATER, FOOD, WATER QUALITY AND HUMAN HEALTH

The impact of increased population on the environment will be severe. The intensification of agriculture to feed the increasing population, especially under irrigated conditions, has brought environmental quality problems including soil erosion, land degradation and decreased water quality. In order to provide food security the final question would be: ***what are the impacts of intensive agriculture and irrigation systems on the degradation of land and water resources?***

While as much as 95 percent of the world population growth is projected in the developing countries where by the year 2050, 87 percent of the world population is expected to live in the developing countries and most of this increase will be in Asia. India and China together have more than 36% of the world population to feed. This will add enormous stress on the available soil, water, and energy resources for domestic, industrial, and agricultural use, although world food grain production has increased significantly as a result of increased scientific knowledge and the availability of increased water use for irrigation. In spite of these gains, 830 million people remain under nourished - 45% in India and China alone. Maintaining a good standard of living for the growing population will require a renewable water resources capacity of 1000 m^3 per person per year. China and India are developing future water resources management plans on renewable water supplies of 500 and 250 m^3 per person per year respectively to sustain their economics. Many other countries will have less renewable water resources for their economic growth. In contrast to population growth, water resources are finite. An increasing population will require more food and in many areas it will mean more depletion and pollution of water resources. This might result in less water available for industrial and municipal demands. At the beginning of this century, 90 percent of all water used in the world was for irrigation. Currently it is about 70 percent, and by the end of year 2005 it is expected to be about 60 percent. These data indicate that we must grow more food with less water using more intensive agriculture that uses fertilizers and pesticides. Recently, drinking water supplies have been found to contain nitrate, a majority of which may have come from agricultural fertilizers. Besides NO_3-N, some traces of common pesticides have also been found in the water. Since the first discovery of a pesticide in the groundwater in 1979, 46 pesticides have been found to contaminate groundwater as a result of normal agricultural use. These data clearly indicate water quality deterioration has taken place and the impacts on environmental quality in the future are going to be even more severe.

Availability of global water supplies and quality of freshwater will decrease in the coming years as increased population pollutes rivers and lakes with domestic, municipal, industrial, and agricultural water. More than five million people die every year because of water borne diseases and 1.5 billion get sick every year due to poor quality water. Therefore, water management strategies are needed on the use and management of poor quality water for agriculture, especially in low income areas of the world where environmental quality will further degrade.

Table 1 gives a summary of water resources on earth. This table shows that only 2.5% of the total volume of water available on earth is fresh water. About 70% of this fresh water is in the form of glaciers or permanent ice locked up in green land and Antarctica and deep ground water aquifers. Main sources of water available for human consumption and agricultural use are rivers, lakes, and shallow ground water which are less than 1% of all fresh water on earth (Gleick, 2000). Therefore, we simply cannot afford to pollute this precious source of fresh water.

Table 2 gives global water withdrawal and consumptive uses for the year 2000. This table shows that total water use has increased from 579 km^3/yr in 1900 to 3,927 km^3/yr in 2000 and the largest water withdrawal has occurred in Asia. Also, future withdrawal rates are expected to grow 2 to 3% annually until 2025 (Gleick, 2000). Table 3 gives global water withdrawal and consumptive use for three major categories (agricultural, industrial and municipal use) and shows that agricultural water use continues to make 85% of all consumptive use on a global basis. Table 4 gives annual available renewable water resources for countries in south Asia, China and the USA. This table shows that agriculture continues to be the major user of renewable water withdrawals.

Table 1 Major water reservoir/sources on earth (Gleick, 2000)

Water sources	Volume (1000 km^3)	% of total water	% of total fresh water
Salt water sources			
Oceans	1,338,000	96.54	-
Saline ground water	12,870	0.93	-
Saltwater lake	85	0.006	-
Total		97.48	
Fresh water sources			
Glaciers/ground ice	24,364	1.76	69.56
Ground water	10,530	0.76	30.06
Lakes	91	0.007	0.26
Rivers	2.12	0.0002	0.006
Marshes/wetlands	11.5	0.001	0.03
Total		2.52	

Table 2 Global water withdrawal and consumption by continent (1900-2025) (Gleick, 2000)

Continent	Historic and Forecasted Water use km^3/yr					
	1900	**1940**	**1960**	**1980**	**2000**	**2025**
Europe						
Withdrawal	37.5	185	445	491	534	619
Consumption	17.6	54	158	183	191	217
North America						
Withdrawal	70.0	221	410	677	705	786
Consumption	29.2	84	138	221	243	269
Africa						
Withdrawal	41.0	49	86	168	230	331
Consumption	34.0	39	66	129	169	216
South America						
Withdrawal	15.2	28	69	111	180	257
Consumption	11.3	21	44	71	104	122
Australia and Oceania						
Withdrawal	1.6	6.8	17.4	29	33	40
Consumption	0.6	3.4	9.0	15	19	23
Asia						
Withdrawal	414.0	689	1,222	1,784	2,245	3,104
Consumption	322.0	528	952	1,324	1,603	1,971
Total						
Withdrawal	579	1,065	1,989	3,214	3,927	5,137
Consumption	415	704	1.243	1,918	2,329	2,818

Table 3 Global water withdrawal and use for selected categories (1900-2025) (Gleick, 2000)

Category	1990	1950	1980	2000	2025
Population (million)	-	2,542	4,410	6,181	7,877
Irrigated area (m. ha)*	47.3	101	198	264	329
Agricultural use (km^3/yr)					
Withdrawal	525	1,122	2,179	2,560	3,097
Use	406	849	1,688	1,970	2,331
Industrial use (km^3/yr)					
Withdrawal	37.8	181	699	768	1,121
Use	3.4	14.4	59	85	133
Municipal use (km^3/yr)					
Withdrawal	16	53	207	389	649
Use	4.2	14	42	64	84

*Irrigation is the largest water consumer in the world

Table 4 Annual renewable water resources and withdrawal rates for selected countries in Asia and the USA for the year 2000 (Gleick, 2000)

Country	Renewable water resource (km^3/yr)	Renewable withdrawal (km^3/yr)	Agricultural use (km^3/yr)
Bhutan	95	0.02	0.01
Bangladesh	1210	14.6	12.6
India	1908	500	460
Nepal	210	29	28.6
Pakistan	429	156	151
Sri Lanka	50	9.8	9.4
China	2830	526	405
USA	2478	469	197

For some countries in South Asia (especially Nepal, Pakistan, and Sri Lanka), agricultural water use is more than 95% of the total withdrawal. This brings more questions on the efficiency of water use for agricultural purposes. Increased efficiency in water use in agriculture can save water for other uses. Also, improved water use efficiency in irrigation can result in more food production without increasing additional demands on fresh water. Maintaining a good standard of living will require renewable water resources capacity of 1000 m^3 per person per year in countries with thriving economy (Bouwer, 1993). China is developing future management plans on renewable water supplies of 500 m^3 per person per year to sustain its economy whereas India's planners are using 250 m^3 per person per year. Many others will have less renewable water resources for their economic growth (Bouwer, 1993). Table 5 gives data on domestic water use for countries in south Asia (Gleick, 2000). A minimum of 50 liters per capita/person per day (lpcd) is recommended for domestic water use by the World Health Organization and the World Bank (5 lpcd for drinking, 20 lpcd for sanitation and hygiene, 15 lpcd for bathing, and 10 lpcd for cooking). Table 5 shows that except for Pakistan, all others countries in south Asia are using less water for domestic use. Billions of people on the earth lack access to the basic requirement of 50 lpcd. More than 60 countries in the world with the total population of 2.2 billion report average domestic water use of less than 50 lpcd.

Table 5 Country population and per capita domestic water use for countries in south Asia for the year 2000 (Gleick, 2000)

Country	Population (million)	Estimated domestic water use (litres per capita per day, lpcd)
Bhutan	2.03	10
Nepal	24.35	12
Bangladesh	128.35	14
Sri Lanka	18.85	18
India	1000.77	31
Pakistan	156.01	55
China	1276.30	22
USA	277.83	203

Table 6 Areas affected by soil degradation processes in India (Velayutham and Bhattacharyya, 2000)

Degradation type	Area affected (m ha)	% of total land area
i) Erosion		
Water erosion	148.9	43.5
Wind erosion	13.5	4.1
ii) Chemical degradation		
Salinization	10.1	3.1
Loss nutrients	3.7	1.1
iii) Water logging	11.6	3.5
Total affected area	187.7	57.7
iv) Soils with no degradation		
v) Stable terrain	90.5	27.5
vi) Soils/land not fit for agriculture	32.2	9.8
	18.2	5.5
Total geographical area	328.7	100.0

A recent study conducted in Iowa on "effects of agricultural development on biodiversity: lessons from Iowa" showed that trends in changes of biodiversity, population, and development are quite similar to those observed on a global scale (Bultena et al., 1996). It has been reported that in 1780, about 1,200 American Indians lived in Iowa. Iowa's population increased from 10,500 in 1836 to 97,000 in 1846 and 2.8 million in 1995. This dramatic increase in human population in some 150 years has destroyed some of the most preserved and productive ecosystems of the world. Increased population in Asia has contributed significantly to the degradation of natural resources, especially soil, air, and water. The desert soils located in central and western part of China have been prone to wind and water erosion. The soils in Indo-Gangetic Plains have supported intensive agriculture for more than 300 million people in India and have been brought under intensive irrigation systems. Long-term irrigation of these soils has degraded a certain percentage of area due to salinity, alkalinity and water-logging conditions (Velayutham and Bhattacharyya, 2000) (Table 6). Similar examples of soil degradation can be seen in other Asian countries, China

China has some of the largest river basin systems of the world. Yellow river in China is the mother river of China providing food and livelihood for than 200 million people. India is one of the few Asian countries in the world that is extremely rich in water resources. The surface and groundwater resources totaling 231 Mham are plenty to meet India's growing irrigation and industrial development needs for the year 2050. But the key question is, can a country like India protect its water resources from further degradation? Many of Asia's surface water supplies have become heavily polluted because of domestic, agricultural, and industrial pollution. That is the biggest challenge Asia faces today.

MAJOR CHALLENGES: DEGRADATION OF LAND AND SOIL AND POSSIBLE SOLUTIONS

Soil Erosion: The major reason for soil degradation is soil erosion. Increased population pressure is causing deforestation and bringing marginal lands into cultivation. Intensive agriculture on fragile and steeper soils, forest cutting, hill grazing, lack of conservation tillage methods and heavy rainfall are the main reasons for severe soil erosion. On many lands, soil erosion rates vary from 20 to 100 tons/ha/yr but averages around 16 tons/ha/yr. Soil erosion is a serious problem in the rainfed agricultural areas and needs immediate attention to improve the soil's productive capacity. Experience has shown that no-tillage and other conservation tillage systems must be practiced on highly readable soils. These tillage systems will help to increase organic matter and reduce soil erosion. Other practices include contouring, terracing, grass waterways, strip cropping and innovative crop rotations. In addition, planting trees and shrubs on hill slopes and promoting rotational grazing along stream banks and forest areas will significantly reduce erosion. All these practices must be implemented within watersheds that are prone to erosion due to agricultural activities. *Another important effort that is needed is the role of public policy and public investment to encourage farmers to implement soil saving methods.*

Loss of soil fertility: Loss of soil fertility has occurred due to its agricultural production methods for thousands of years. Unsustainable agricultural practices have allowed the loss of organic matter and soil nutrients. Intensive cultivation of soils for growing two to three crops a year, especially in irrigated and rainfed agriculture, is continuously depleting the soil's fertility.

Salinization of soils and control practices: Salinization of soils has occurred worl-dwide under long-term irrigation practices. In India alone, the net area under irrigation increased from 22 Mha in 1957 to about 51.3 Mha in 2000. Improper management of irrigation (such as low irrigation efficiencies, inadequate drainage for canal irrigation, and over-exploitation of groundwater for irrigation) has resulted in rising water-tables and accumulation of salts near the surface. Abrol and Bhumbla (1971) estimated that about 7 million ha soils are affected by salinity and alkalinity in Gangetic Plain alone and nearly 50% canal irrigated soils are suffering from salinization and alkalization due to poor drainage, inefficient irrigation systems, and socio-political reasons. In some areas of the world, salinity problems are increasing at such a fast rate that these areas may become totally unfit for producing any vegetation.

Waterlogging and salinity: Poor planning and mismanagement of irrigation systems in India, Pakistan, China, Uzbekistan, Kazakistan, and other Asian countries have resulted in rising of water tables causing salinization and waterlogging problems in some of the most productive agricultural lands. The problem of rise in water table is more severe in arid and semi-arid regions of India and central Asia. In Uzebekistan and Kazakistan excessive irrigation has raised water tables by as much as 29 m. In India and Pakistan, the rise in water tables is mainly in areas irrigated by canal irrigation and open distributaries. In Punjab, Haryana, and western Uttar Pradesh, shallow groundwater is pumped and used to meet extensive network of irrigation system. This has caused significant water withdrawal from good quality aquifer, and has resulted in more discharge from aquifers compared to their annual recharge from rainwater.

Nitrate and pesticide pollution of groundwater: Generally, chemical use in Asia is low, therefore, nitrate and pesticide pollution of groundwater is not a serious problem for the majority of the groundwater aquifers. However, in certain areas of India (such as Punjab, Haryana, and Uttar Pradesh) and Asia, intensive grain production systems have used fertilizer and pesticide application rates similar to the United States. Several studies have indicated that 11 to 48 percent of applied nitrogen in maize-wheat production systems have leached to groundwater systems. Kanwar et al. (1997) have reported NO_3-N and pesticide losses to shallow ground water systems under intensive agriculture for conventional and conservation tillage systems.

BEST PRACTICES TO REDUCE ENVIRONMENTAL DEGRADATION AND CONSERVE WATER RESOURCES

Best management practices (BMPs) are practices that can be used to control soil erosion, minimize nonpoint source pollution, and are economically, socially, and environmentally acceptable. The following BMPs could possibly be used to control environmental degradation of soil and water resources:

BMPs for Minimizing Waterlogging: Much of the waterlogging in Asia has occurred due to canal irrigation. The best practice to minimize the increase of waterlogging in canal irrigated areas is to provide an improved drainage system to lower high water tables in the waterlogged areas. The installation of subsurface drainage systems and pumped drainage could provide the needed relief to bring waterlogged areas under productive agriculture. Once water tables are lowered, deep rooted crops can help reclaim these areas permanently.

BMPs for Minimizing Salinity: One of the best-known BMPs to correct the salinity/alkalinity problem is the reclamation of sodic and saline soils through chemical and biological amelioration. Sodic soils can be easily reclaimed using gypsum and solubilizing calcium and sodium salts and flushing them out of the active root zone. These methods have been found to be extremely successful in India and Pakistan. Other methods are biological controls including increasing vegetation and proper management of irrigation and drainage practices. Without adequate drainage systems, accumulated salts cannot be flushed out.

Conservation Tillage and Cropping Systems: Several conservation tillage systems (namely no-till, ridge till, and chisel plow) have been used to reduce soil erosion and energy input costs. In recent studies conducted at Iowa State University (Kanwar et al., 1997), it has been concluded that conservation tillage systems increase infiltration, organic matter, adsorption, microbial activity, and chemical leaching to groundwater. Diverse cropping systems are currently used in south Asia. Narrow row width and densely planted crops, such as small grains and legumes, affect infiltration and runoff volumes. These cropping systems seem to reduce soil erosion and chemical concentrations in the runoff water. Crop rotations also affect the use of chemicals. Also crop rotations offer a greater diversity of pesticide use within a watershed to control nonpoint source pollution.

Manure Management Systems for Water Quality Control: In some Asian countries (for example Taiwan, Korea, Thailand, and Malaysia) , animal production systems are contributing significantly to surface water contamination. Simple structures to store animal manure and apply manure to croplands for plant nutrients are the best management systems. India and China have used this practice of manure management for centuries. In India, China, and Nepal, the use of biogas digesters for biogas production are very common and could be promoted in other Asian countries.

Contouring, Terracing, and Buffer Strips: Terracing and contour farming have been used for centuries in Asia to control and conserve soil and water. Contour farming can reduce soil erosion by as much as 60 to 80 percent compared to up and down method of farming. Also, vegetative filter and buffer strips and waterways could be used to control soil erosion and water quality problems.

Conservation of Water and Improving Efficiencies of Irrigation and Drainage Systems*:* The only best solution to solve water availability problems across the globe is to promote water conservation practices. One of the major problems is low irrigation efficiency. Farmers must be given adequate training to improve their irrigation methods. Also, introduction of new methods, such as sprinkler and drip methods, can save water and will significantly improve irrigation efficiencies. New methods of irrigation will help to increase nutrient efficiency and reduce water contamination due to agricultural chemicals. Irrigation and drainage practices are typically considered as production practices rather than BMPs for water quality enhancement. Irrigation management is important in controlling water quality related problems.

SUMMARY AND CONCLUSIONS

Asia has been blessed with two major natural resources, relatively productive land and a good reservoir of water resources. At the same time, Asia has 36% of the world's population and one of the highest population density and population growth rates. Increased population pressure is expected to shrink per capita land for agriculture in the years to come. Demand for finite water resources is increasing and with the increase in population, contamination of water resources is on the rise. Also, an increase in population means intensification of agricultural production systems to feed the growing population. Intensification of agriculture has increased soil erosion due to deforestation, waterlogging due to poorly managed irrigation systems, increased soil salinity, and pollution of drinking water supplies. All these factors have added enormous stress on available land and water resources. Unless best irrigation and cropping management systems are developed in agricultural watersheds to conserve the scarce resources of water and protect degrading land and water resources, water and food security is very much at risk for the global society.

REFERENCES

1. Abrol, I.P. and D.R. Bhumbla. 1971. Saline and alkali soils in India: their occurance and management. Paper presented at FAO/UNDP seminar on soil fertility research. FAO world soil research rep. 41:42-51.
2. Bultena, G.L., M.D. Duffy. S.F. Jungst, R.S. Kanwar, B.W. Menzel, M.K. Misra, P. Singh, J.R. Thompson, A vander valk, and R. Willham. 1996. Impacts of agricultural developments on biodiversity: Lessons from Iowa. In: Biodiversity and Agricultural Intensification-Partners for development and Conservation (Editors: J.P. Srivastava, N.J.H. Smith, and D.A. Forno), The World Bank Book Publication, Washington, DC.
3. Bower, H. 1993. Sustainable Irrigated Agriculture: water resources management in the future. Irrigation J. 43(6):16-23.
4. Gleick, P.H. 2000. The world's water 2000-2001, the biennial report on freshwater resources. Island Press, Washington, D.C.
5. Kanwar, R. S., T.S. Colvin, and D.L. Karlen. 1997. Effect of ridge till and three tillage systems and crop rotation on subsurface drain water quality. J. Prod. Agric. 10:227-234.
6. Velayutham, M. and T. Bhattacharyya. 2000. Soil resource management. In: Natural Resource Management for Agricultural Productivity in India (Editors: J.S.P Yadav and G.B. Singh). Indian Society of Soil Science, New Delhi, India.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.9:556.3
Pregledni rad
Review paper

DEBRIS AND HYPER-CONCENTRATED FLOWS: OVERVIEW AND PERSPECTIVE

DANIELE DE WRACHIEN[1], STEFANO MAMBRETTI[2]

[1] Department of Agricultural Hydraulics, State University of Milan, Italy
[2] DIIAR, Politecnico di Milano, Italy

ABSTRACT

Debris and hyper-concentrated flows are among the most destructive of all water – related disasters. In this context, achieving a set of debris and hyper-concentrated flow constitutive equations is a task which has been given particular attention by scientists during the second half of the last Century.

In relation to these issues, the paper reviews the most updated and effective procedures nowadays available, suitable to predict the triggering and mobilising processes of these phenomena

These tools will allow, on one hand, to better focus what to observe in the field and, on the other hand, improve both mitigation measures and hazard mapping procedures.

***Key words**: Debris flow, rheological behaviour of the mixture, numerical models, laboratory and field tests.*

INTRODUCTION

Debris and hyper-concentrated flows are among the most destructive of all water-related disasters. They mainly affect mountain areas in a wide range of morpho-climatic environments and in recent years have attracted more and more attention from the scientific and professional communities and concern from the public awareness due to the increasing frequency with which they occur and the death toll they claim. These phenomena do not allow a sufficient early warning, as they are characterised by a very short time-scale and, therefore, defence measures should be provided, especially when they are associated to flash floods or dam failures. To this end, the identification of effective procedures aimed at evaluating the probability of these extreme events and the triggering and mobilising mechanism has turned to be an essential component of the water and land use planning processes. This concept leads to a new integrated risk management approach, which comprises administrative decisions, organisation, operational skill and the ability to implement suitable policies. The broadness of the question requires approaches from various perspective. To this end, the dynamic behaviour of these hyper-concentrated water sediment mixtures and the constitutive laws that govern them play a role of paramount importance.

Debris flow modelling requires a rheological pattern (or constitutive equation) that provides an adequate description of these flows.

One of the main difficulties met by the approaches available is linked to their validation either in the field or in a laboratory environment. Greater research needs to be directed towards a thorough investigation of the above mentioned issues.

Such knowledge is essential in order to assess the potential frequency of these natural hazards and the related prevention and mitigation measures .

With reference to these issues, this paper aims to provide the state-of-the-art of debris flow rheology, modelling and laboratory and field investigations, along with a glance to the direction that debris flow in-depth studies are likely to follow in future,

DEBRIS FLOW MODEL DEVELOPMENT

A thorough understanding of the mechanism triggering and mobilising debris flow phenomena plays a role of paramount importance for designing suitable prevention and mitigation measures. Achieving a set of debris flow constitutive equations is a task which has been given particular attention by the scientific community (Julien and O'Brien, 1985; Chen, 1988). To properly tackle this problem relevant theoretical and experimental studies have been carried out during the second half of the last century.

Research work on theoretical studies has traditionally specialised in different mathematical models. They can be roughly categorized on the basis of three characteristics: the presence of bed evolution equation, the number of phases and the rheological model applied to the flowing mixture (Ghilardi et al., 2000).

Most models are based on the conservation of mass and momentum of the flow, but only a few of them take into account erosion/deposition processes affecting the temporal evolution of the channel bed.

Debris flow are mixtures of water and clastic material with high coarse particle contents, in which collisions between particles and dispersive stresses are the dominant mechanisms in energy dissipation. Therefore, their nature mainly changes according to the sediment concentration and characteristics of the sediment size (Hui-Pang and Fang-Wu, 2003).

The rheological property of a debris flow depends on a variety of factors, such as suspended solid concentration, cohesive property, particle size distribution, particle shape, grain friction and pore pressure.

Various researchers have developed models of debris flow rheology. These models can be classified as: Newtonian models (Johnson, 1970), linear and non linear viscoplastic models (O'Brien et al., 1993), dilatant fluid models (Bagnold, 1954), dispersive or turbulent stress models (Arai and Takahashi, 1986), biviscous modified Bingham model

(Dent and Lang, 1983), and frictional models (Norem et al., 1990). Among these, linear (Bingham) or non – linear (Herschel – Bulkey) viscoplastic models are widely used to describe the rehology of laminar debris/mud flows (Jan, 1997).

Because a debris flow, essentially, constitutes a multiphase system, any attempt at modelling this phenomenon that assumes, as a simplified hypothesis, homogeneous mass and constant density, conceals the interactions between the phases and prevents the possibility of investigating further mechanisms such as the effect of sediment separation (grading).

Modelling the fluid as a two – phase mixture overcomes most of the limitations mentioned above and allows for a wider choice of rheological models such as: Bagnold's dilatant fluid hypothesis (Takahashi and Nakagawa, 1994), Chézy type equation with constant value of the friction coefficient (Hirano et al., 1997), models with cohesive yield stress (Honda and Egashira, 1997) and the generalized viscoplastic fluid Chen's model (Chen and Ling, 1997).

Notwithstanding all these efforts, some phenomenological aspects of debris flow have not been understood yet, and something new has to be added to the description of the process to reach a better assessment of the events. In this contest, the mechanism of dam-break wave should be further investigated. So far, this aspect has been analysed by means of the single-phase propagation theory for clear water, introducing in the De Saint Venant (SV) equations a dissipation term to consider fluid rheology (Coussot, 1994).

Many other models, the so-called quasi-two-phase-models, use SV equations together with erosion/deposition and mass conservation equations for the solid phase, and take into account mixture of varying concentrations. All these models feature monotonic velocity profiles that, generally, do not agree with experimental and field data.

Rheology

The rheological property of debris and hyper-concentrated flows depends on a variety of factors, such as the suspended solid concentration, cohesive property, size distribution, particle shape, grain friction, and pore pressure. So, modelling these flows requires a rheological model (or constitutive equation) for sediment-water mixtures.

A general model which can realistically describe the rheological properties of debris flow should possess three main features (Chen, 1988). The model should:

- describe the dilatancy of sediment-water mixtures;
- take into account the so-called soil yield criterion, as proposed by Mohr-Coulomb;
- assess the role of intergranular or interstitial fluid.

The earliest of such rheological models was empirically formulated by Bagnold (1954).

On the whole, a rheological model of debris and hyper-concentrated flows should involve the interaction of several physical processes. The non-Newtonian behaviour of the fluid matrix is ruled, in part, by the cohesion between fine sediment particles. This cohesion contributes to the yield stress, which must be exceeded by an applied stress in order to initiate fluid motion. For large rates of fluid matrix shear (as might occur on steep alluvial fans) turbulent stresses may be generated. In these cases, an additional shear stress component arises in turbulent flow from the collision of solid particles under large rates of deformation.

In view of theoretical soundness behind the development of different non-Newtonian fluid models, different Authors (Bailard 1978; Hanes 1983) have questioned the validity of Bagnold's empirical relations. Limitations in Bagnold's model may be attributed to the ambiguity in the definition of some rheological characteristics as the grain stress.

To overcome these problems, Chen (1988) developed a new generalised viscoplastic fluid (GVF) model, based on two major rheological properties (i.e. the normal stress effect and soil yield criterion) for general use in debris flow modelling.

The analysis Chen conducted on the various flow regime of a granular mixture identified three regimes: a quasi-static one, which is a condition of incipient movement with plastic behaviour, a microviscous pattern at low shear rates, in which viscosity determines the mixture behaviour, and finally a granular inertial state, typical of rapid flowing granular mixtures, dominated by intergranular interactions. Chen developed his model starting from the assumption that a general solution should be applicable through all three regimes.

All the models previously reviewed feature monotonic velocity profiles that, generally, do not agree with experimental and field data. In many tests (Takahashi, 1981) "*S*" reversed shaped trends have been observed, where the maximum shear rate is not achieved near the bed, but rather between the bed and the free surface. The main discrepancy is derived from the assumption of a debris flow as a uniform mixture. In fact, the solid concentration distribution is usually non-uniform due to the action of gravity, so that the lower layer could, consequently, have a higher concentration than the upper layer. Higher concentration means higher cohesion, friction and viscosity in the flow.

Wan (1994) proposed a multilayers model known as the laminated layers model that features a stratified debris flow into three regions from the bed to the surface: a bed layer, in which an additional shear stress is dominant in momentum exchange; an inertial layer, where the dispersive stress of the grains is dominant; and an upper viscoplastic layer, which can be represented by the Bingham's model.

Later on, Takahashi (1991) developed the so-called unified model of inertial debris flow, by altering the constitutive equations from the theory of granular mixtures and suspended load transport. In this model, the Author hypothesized the flow as a two-layer system: a lower layer dominated by collisions, and an upper one composed of the turbulent suspension.

The relative extension of the two layers depends on the concentration and diameter of the particles: the range goes from the stony debris flow, in which only collision layer exists, to muddy debris flow in which the entire flow is composed of a turbulent layer.

The one-layer models are unable to adequately feature the entire thickness of the flow and, therefore, it has recently become common to use multi-layers models that combine two or more constitutive relationships in order to analyse adequately these phenomena. The coefficients of the rheological models have wide ranges of variation and, therefore, in evaluating them considerable errors are committed. On the other hand, some empirical equations of velocity are necessary in any debris flow disaster-forecasting measure, although the hydraulics of debris-flow is not theoretically comparable to that of a traditional water flow.

Triggering and Mobilising Processes

Debris flow resulting from flash flood or a sudden collapse of a dam (dam-break) are often characterised by the formation of shock waves caused by many factors such as valley contractions, irregular bed slope and non-zero tailwater depth. It is commonly accepted that a mathematical description of these phenomena can be accomplished by means of 1D SV equations (Bellos and Sakkas, 1987).

During the last Century, much effort has been devoted to the numerical solution of the SV equations, mainly driven by the need for accurate and efficient solvers for the discontinuities in dam-break problems.

A rather simple form of the dam failure problem in a dry channel was first solved by Ritter (1892) who used the SV equations in the characteristic form, under the hypothesis of instantaneous failure in a horizontal rectangular channel without bed resistance. Later on, Stoker (1949), on the basis of the work of Courant and Friedrichs (1948), extended the Ritter solution to the case of wet downstream channel. Dressler (1952) used a perturbation procedure to obtain a first-order correction for resistance effects to represent submerging waves in a roughing bed.

Lax and Wendroff (1960) pioneered the use of numerical methods to calculate the hyperbolic conservation laws. McCormack (1969) introduced a simpler version of the Lax-Wendroff scheme, which has been widely used in aerodynamics problems. Van Leer (1977) extended the Godunov scheme to second-order accuracy by following the Monotonic Upstream Schemes for Conservation Laws (MUSCL) approach. Chen (1980) applied the method of characteristics, including bed resistance effects, to solve dam – break problems for reservoir of finite length.

Flux splitting based schemes, like that of the implicit Beam-Warming (1976), where applied to solve open channel flow problems without source terms and, in general, reported good results. However, these schemes are only first order accurate in space and employ the flux splitting in a non conservative way. When applied to some cases of dam-break problems, these tools gave much slower front celerity and higher front height when compared to experimental tests. Later, Jha et al. (1996) proposed a modification for achieving full conservative form of both the continuity and momentum equations, employing the use of the Roe’s average approximate Jacobian (Roe, 1981). This produced significant improvement in the accuracy of the results.

Total Variation Diminishing (TVD) and Essentially Non Oscillation (ENO) schemes were introduced by Harten (1983) for efficiently solving 1D gas dynamic problems. Their main property is that they are second order accurate and oscillation free across discontinuities.

In the past ten years, further numerical methods to solve flood routing and dam-break problems, have been developed, that include the use of finite elements or discrete/distinct element methods (Asmar et al., 1997).

Finite Element Methods (FEMs) have certain advantages over finite different methods, mainly in relation to the flexibility of the grid network that can be employed, especially in 2D flow problems. In this context, Hicks and Steffer (1992) used the Characteristic Dissipative Galerking (CDG) finite element method to solve 1D dam-break problems for variable width channels.

The McCormack predictor-corrector explicit scheme is widely used for solving dam-break problems, due to the fact that it is a shock-capturing technique, with second order accuracy both in time and in space, and that the artificial dissipation terms TVD correction, can be easily introduced (Garcia and Kahawita, 1986)

The main disadvantage of this solver regards the restriction to the time step size in order to satisfy Courant-Friedrichs-Lewy (CFL) stability condition. However, this is not a real problem for dam-break debris flow phenomena that require short time step to describe the evolution of the discharge. To ease the time step restriction, implicit methods could be considered. In this case, the variables are calculated simultaneously at a new time level, through the resolution of a system with as many unknowns as grid points. For non-linear problems, such as the SV equations, the resulting system of equations is also non-linear and either a linearisation or an iterative procedure is required. This extra computation time is, usually, compensated by the possibility of achieving unconditional or near unconditional stability for the scheme or allowing the use of very high CFL numbers. Attempts along this line of work were presented by Alcrudo et al. (1994) who introduced in the McCormack scheme TVD corrections to reduce spurious oscillations around discontinuities, both for 1D and 2D flow problems. Mambretti et al. (2008) and De Wrachien and Mambretti (2008) used an improved TVD-Mc Cormack-Jameson scheme to predict the dynamics of both mature (non-stratified) and immature debris flow in different dam break conditions.

LABORATORY AND FIELD STUDIES

To validate both the rheological and dynamic models, herewith described, comparisons need to be made between their predictions and results of laboratory and field tests. Agreements between the computational and experimental results are essential since they allow the assessment of the models' performance and suggest feasible development of the research.

The experimental point of view in debris flow research, however, encounters considerable problems that are yet to be fully overcome, connected largely to the accuracy of measuring techniques and flow simulation in experimental tests. Lastly, field studies are probably the most difficult and costly study approach of debris flow; the difficulties encountered are connected to their considerable complexity and the difficulty of direct observation. The exceptional and infrequent conditions in which debris flows occur do not generally permit a sufficient number of observations for the same type of field reality to deduce the specific behavioural laws for that area. Reference to different territorial situations also highlights another problem: that of the homogeneity of data, given the substantial territorial peculiarity in which the phenomena occur. Besides, field data are essential in determining the quality of any mathematical model, as they are especially important for estimating velocity, discharge, concentration, yield stress, viscosity and grain-size.

This need requires the use of laboratory experimentation when the previous problems cannot be overcome, and in certain cases it is the only possible path to follow.

Within this ground, many experiments have been carried out, ranging from solid transport (little amount of particles in a large environment of clear water) to dry granular flow, where water is not present.

An empirical picture of debris flow physics can be drawn from a combination of real-time field observations (Okuda et al., 1980); detailed measurements during controlled field and laboratory experiments (Takahashi, 1991), and analyses of debris flow paths and deposits (Fink al., 1981).

With regard to field investigations, some properties of debris flow materials can be measured in a static state, such as the grain size distribution (Coussot and Proust, 1996), whereas other characteristics depend on the mechanics of debris propagation.

Few reliable techniques exist to measure properties of flowing debris. Grossly invasive procedures such as plunging buckets or sensors into the flows conspicuously change the dynamics of the debris, while their behaviour has discouraged attempts to use non-invasive techniques such as ultrasonic, X ray, and others (Lee et al., 1974).

With regard to the rheological properties, many experiments (Coussot, 1997) have shown that the Herschel-Bulkley equations fit quite well laboratory data. One of the criticism that may be moved to these tests is related to the scale effect.

Successful models of debris flows must describe the mechanics of mobilization as well as the subsequent flow and deposition processes. Mobilization requires failure of the mass, a quantity of water to saturate the solid phase, such a change of energy, from gravitational to kinetic, to modify the motion pattern from sliding along a failure surface to a more widespread solid-liquid mixture that can be assessed as flow.

In this context, while the mechanics of the triggering propagation and stoppage processes is quite well understood (Ellen and Fleming, 1997; Gregoretti and Di Silvio, 1997) the empirical expressions (Marchi and Tecca 1996; D'Agostino et al., 1996) when applied to real cases provide a broad spectrum of results that must be compared and validated on the basis of physically based procedures (Mambretti, 2007).

Different flumes and experimental setups have been used, depending on the particular aspect of flow under investigation. Experimental tests are performed by changing the bottom roughness, the solid material characteristics and the volumetric concentration of the mixture (Smart and Jaeggi, 1983; Mambretti et al., 2008). Deposition occurs when the kinetic energy falls under a critical threshold (Johnson, 1970).

On the whole, laboratory and field data are essential in determining the quality of any mathematical model, as it is especially important for estimating velocity, discharge, concentration, yield stress, viscosity and grain-size (Lorenzini and Mazza, 2004).

However, the achievement of good agreement between theoretical and experimental results does not justify indiscriminate extrapolation for the various territorial situations, which have very different boundary conditions from standard laboratory conditions.

Assuming that the scientific research path cannot exclude an accurate observation and description of the phenomenon in question, without which the analysis of physical processes, that generate it, would become extremely artificial and uncertain, it is hoped that any attempt at improving the interpretation of the phenomenon involves critical comparison between the theoretical, experimental, and field approaches, as well as extensive osmosis process between the same approaches.

CONCLUDING REMARKS

Debris and hyper-concentrated flow result from the interaction of hydrological processes with geological processes and are triggered when soils get saturated and the stability of the slope is no longer maintained. These flows are among the most destructive of all water-related disasters. In this context, the recognised need to improve knowledge on the mechanics of these solid-liquid flows, highlighted by a critical analysis of the current international state-of-the-art, represent the seeding of the present work.

Although the main aspects that rule the mechanics of these phenomena seem to be understood, it has to be underlined the relative scarcity of experimental (laboratory and field) data, the only ones that allow effective check of the models nowadays available in different flow conditions and the estimation of the rheological parameters they contain.

Greater research needs to be directed towards understanding the nature and the behaviour of these flows. Such knowledge is essential in order to estimate the potential frequency of these natural hazards and design suitable prevention and remediation measures.

The ideal sequence that should be pursued in the approach to the difficult task of the management and mitigation of hyper-concentrated and debris flow can be obtained as follows (De Wrachien, 2006):

- first, a systematic collection of field data should be carried out in order to provide a large base of reliable data that could allow a better knowledge of the existing risk trends and a deeper understanding of the mechanics of the phenomena, along with their general behaviour and effects;
- secondly, effective mathematical models, which strongly depend on data and measurements collected and performed in the field for their calibration and design, should be constantly developed, updated when needed, tested and applied;
- hazard mapping techniques and identification of possible scenarios, which need reliable models to be effective and sound, should then be set up;
- on the basis of the knowledge achieved in the previous steps, the best mitigation solutions should be identified, designed and built up;
- finally a program of systematic observations on the sites, where risk has been mitigated, should be planned and carried out to detect any shortcoming and test the efficiency of the investigations.

Each of the above studies and investigations needs improvements and depends, to achieve them, on improvements in other fields. From all these activities would emerge the best direction to be followed in future debris flows in-depth studies and investigations.

REFERENCES

1. Alcrudo F., Garcia Navarro P., Computing two – dimensional flood propagation with a high resolution extension of McCormack's method in Proc. of International Conference on Modelling of Flooding Propagation over Initially Dry Areas, Milan, 1994
2. Arai M., Takahashi T., The Karman constant of the flow laden with high sediment in Proc. of the 3rd International Symposium on River Sedimentation University of Mississippi, 1986, pp. 824 – 833
3. Asmar B.N., Lanston P.A., Ergenzinger Z., The potential of the discrete method to simulate debris flow in Proceeding of the First International Conference on Debris Flow Hazard Mitigation: Mechanics, Prediction and Assessment, Eds. Chen, New York, 1997
4. Bagnold R.A., Experiments on a gravity – free dispersion of large solid spheres in a Newtonian fluid under shear in Proceedings of the Royal Society of London, Series A, 225, 1954, pp. 49 – 63
5. Bailard J.A. An experimental study of granular-fluid flow thesis presented to University of California at San diego, California, 1978
6. Beam W.M., Warming R.F., An implicit finite – difference algorithm for hyperbolic system in conservation – law form Journal of Computational Physics, 22, 1976, pp. 87 – 110
7. Bellos V., Sakkas J.G., 1D dam – break flood propagation on dry bed Journal of Hydraulic Engineering, 1987, ASCE 113(12), pp. 1510 – 1524
8. Chen C.J., Laboratory verification of a dam – break flood model Journal of Hydraulic Division ASCE, 106(4), 1980, pp. 535 – 556
9. Chen L.C., Generalized visco-plastic modelling of debris flow Journal of Hydraulic Engineering, 1988, 114, pp. 237 – 258
10. Chen C.L., Ling C.H., Resistance formulas in hydraulics based models for routing debris flow in Debris Flow Hazard Mitigation: Mechanics, Prediction and Assessment, Eds. Chen, New York, 1997, pp. 360 – 372
11. Courant R., Friedrichs K.O., Supersonic flow and shock wave Interscience Publisher Inc., New York, 1948
12. Coussot P. Steady, laminar, flow of concentrated mud suspensions in open channel, Journal of Hydraulic Research, Vol. 32, n. 4, pp.535-559, 1994
13. Coussot P., Mudflow rheology and dynamics Rotterdam, 1997
14. Coussot P., Proust S. Slow unconfined spreading of mudflow Geophys. Res., 101(I31 I), 25, 217-229, 1996.
15. D'Agostino V., Cerato M., Coali R. Extreme events of sediment transport in the eastern Trentino torrents. Atti del Convegno INTERPRAEVENT, Band 1, pagg. 377-386, 1996.
16. Dent J.D., Lang T.E., A biviscous modified Binghman model of snow avalanche motion Annals of Glaciology, 4, 1983, pp. 42 – 46

17. De Wrachien D. Debris and hyper-concentrated flows, in G. Lorenzini, C.A. Brebbia, D.E. Emmanouloudis (eds) Monitoring, Simulation, Prevention and Remediation of Dense and Debris Flow, Rhodes, Greece, 2006

18. De Wrachien D., Mambretti S. Dam – break shock waves: A two – phase model for mature and immature debris flow Second International Conference on Debris Flow, 18 – 20 June 2008, The New Forest, United Kingdom

19. Dressler R.F. Hydraulic resistance effect upon the dam – break functions Proc. of Royal Society of London A(257), 1952, pp. 185 – 198

20. Ellen S.D., Fleming R.W. Mobilization of debris flows from soil slips, San Francisco Bay region, California, in Debris Flows Avalanches: Process, Recognition, and Mitigation, Rev. Eng. Geol., vol. 7. edited hy L E. Costa and G. F. Wieczorek, pp. 31-40, Geol. Soc. of Am., Boulder. Colorado., 1987.

21. Fink J.H., Malin M.C., D'Alli R.E., Greeley R. Rheological properties of mudflows associated with the spring 1980 eruptions of Mount St. Helens volcano, Washington Geophys. Res. Lett.. 8, 43-46, 1981.

22. Garcia R., Kahawita R.A., Numerical solution of the De Saint Venant equations with the McCormack finite – difference scheme International Journal of Numerical Methods in Fluids, 1986, 6, pp. 259 – 274

23. Ghilardi P., Natale L., Savi F., Debris flow propagation and deposition on urbanized alluvial fans, Excerpta, 14, 2000, pp. 7 – 20

24. Gregoretti C., Di Silvio G. Gradually varied debris flow along a slope Proc. Of First Int. Conf. on Debris Flow Hazards Mitigation: Mechanics, Prediction and Assessment, pp 767-776, New York, ASCE, 1997

25. Hanes D.M. Studies on the mechanics of rapidly flowing granular-fluid materials, Thesis presented to University of California at San Diego, California, 1983

26. Harten A. High resolution schemes for hyperbolic conservation laws Journal of Computational Physics, 49, 1983, pp. 357 – 394

27. Hicks F.E., Steffer P.M. Characteristic dissipative Galerking scheme for open channel flow Journal of Hydraulic Engineering ASCE, 118(2), 1992, pp. 337 – 352

28. Hirano M., Hasada T., Banihabib M.E., Kawahasa K., Estimation of hazard area due to debris flow in Debris Flow Hazard Mitigation: Mechanics, Prediction and Assessment, Eds. Chen, New York, 1997, pp. 697 – 706

29. Honda N., Egashira S., Prediction of debris flow characteristics in mountain torrents in Debris Flow Hazard Mitigation: Mechanics, Prediction and Assessment, Eds. Chen, New York, 1997, pp. 707 – 716

30. Hui-Pang L., Fang-Wu T., Sediment concentration distribution of debris flow Journal of Hydraulic Engineering, 129(12), 2003, pp. 995 – 1000

31. Jan C.D., A study on the numerical modelling of debris flow in Debris Flow Hazard Mitigation: Mechanics, Prediction and Assessment, Eds. Chen, New York, 1997, pp. 717 – 726

32. Jha A.K., Akiyama J., Vra M., A fully conservative Beam and Warming scheme for transient open channel flows Journal of Hydraulic Research 34(5), 1996, pp. 605 – 621

33. Johnson A.M. Physical processes in geology Freeman Ed., San Francisco, 1970

34. Julien P.Y., O'Brien J.S., Physical properties and mechanics of hyperconcentrated sediment flows in Proceeding Spec. Conference on Delineation of Landslides, Flash Flood and Debris Flow Utah, USA, 1985, pp. 260 – 279

35. Lax P., Wendroff B., Systems of conservation laws Comp. on Pure and Applied Mathematics 13, 1960, pp. 217 – 237

36. Lee J., Cowin S.C., Templeton III J.S. An experimental study of the kinematics of flow through hoppers. Trans. Soc. Rit., 18, 247-269, 1974.

37. Lorenzini G., Mazza N. Debris flow. Phenomenology and Rheological Modelling WIT Press, Ashurst Lodge, Southampton, UK, 2004

38. Mambretti S. Valutazione della magnitudo di colate detritiche in funzione del tempo di ritorno nel bacino di Val Gola (BG). GEAM – Geoingegneria Ambientale e Mineraria, Anno XLIV, n. 1, aprile 2007, pp. 15 – 24 (*in Italian*)

39. Mambretti S., Larcan E., De Wrachien D. 1D modelling of dam – break surges with floating debris Biosystems Engineering, Vol. 100(2), June 2008, pp. 297-308

40. Marchi L., Tecca P.R. Magnitudo delle colate detritiche nelle Alpi Orientali Italiane Geoingegneria Ambientale e Mineraria 33, 1996 (*in Italian*)

41. McCormack R.W., The effect of viscosity in hypervelocity impact cratering AIAA Paper, 1969, 75-1

42. Norem H., Locat J., Schieldrop B., An approach to the physics and the modelling of the submarine flowslides Marine Geotechnical 9, 1990, pp. 93 – 111

43. O'Brien J.S., Julien P.J., Fullerton W.T., Two – dimensional water flow and mudflow simulation, Journal of Hydraulic Engineering, 1993, 119, pp. 244 – 261

44. Okuda S., Suwa H., Okunishi K., Yokoyama K., Nakano M. Observations on the motion of a debris flow and its geomorphological effects, J. Geomorphol., suppl. 35, 142-163, 1980

45. Ritter A. Die Fortplanzung der Wasserwellen Zeitschrift des Vereines Deutscher Ingenieure 36(3), 1892, pp. 947 – 954 (*in German*)

46. Roe P.L. Approximate Riemann solver, parameters vectors and difference schemes Journal of Computational Physics, 43, 1981, pp. 357 – 372

47. Smart G., Jaeggi M. Sediment transport on steep slopes Mitteilungen der Versuchsanstalt fur Wasserbau, Hidrologie und Glaziologie, ETH Zurich, 64, 1983

48. Stoker J.J. The breaking of waves in shallow water Annuals New York Academy of Science 51(3), 1949, pp.360 – 375

49. Takahashi T. Debris flow Rev. Fluid Mechanics, 13, pp. 57-77, 1981

50. Takahashi T. Debris Flow, 165 pp., A. A. Balkema, Brookfield. Vt.. 1991.

51. Takahashi T., Nakagawa H., Flood / debris flow hydrograph due to collapse of a natural dam by overtopping Journal of Hydroscience and Hydraulic Engineering, 1994, 12, pp. 41 – 49

52. Van Leer B., Towards the ultimate conservative difference scheme Journal of Computational Physics 23, 1977, pp. 263 – 275

53. Wan Z. Hyper-concentrated flow Monograph Series of IAHR, Rotterdam, 290 pp., 1994

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 624.13:631.459
Tehnička bilješka
Technical note

GEOTECHNOLOGY USE TO PREDICT RAINFALL EROSIVITY AND ITS RELATIONSHIP TO LAND USE AND MANAGEMENT AT ESPIRITO SANTO BRAZIL

JOSÉ EDUARDO MACEDO PEZZOPANE, NATHÁLIA SUEMI SAITO, ROBERTO AVELINO CECÍLIO, ALEXANDRE ROSA DOS SANTOS

Centro de Ciências Agrárias, Universidade Federal do Espírito Santo, C.P. 16, 29500-000, Alegre-ES, Brazil

SUMMARY

This paper presents the use of geoprocessing tools to predict and to develop spatial distribution map of rainfall erosivity (R), and to analyze its relationship with land use and management. Espirito Santo State is located in the Southeastern Region of Brazil, between the latitudes -17°53' and -21°17' and the longitudes -39°39' and -41°52', with very irregular relief. Rainfall data were obtained from 88 rain gauge stations. Land use and management data were obtained from the Instituto Brasileiro de Geografia e Estatística (IBGE) and on images of the CBERS-2 (China-Brazil Earth Resources) satellite, which has a spatial resolution of 20 m. Empirical equations were used to calculate R-factor to all the rain gauge stations. R-factor spatial distribution map was developed using spherical kriging interpolator, which was the method that presented minors values of percentile average error (6.70%), root mean square error (514.49 m) and the greaters values of correlation coefficient (0.71) and index of agreement (0.56). R-factor map was classified in: high erosivity (HE) (0.851%), average erosivity (AE) (67.59%) and low erosivity (LE) (31.54%). Land use and management was classified in: Forest (F) (32% of the area), Agriculture (A) (58.38%) and Not Vegetated (NV) (9.62%). Land use and management and R-factor maps were crossed, using ArcGis 9.2 software, resulting in: F-HE (0.44%), F-AE (23.30%) and F-LE (8.22%); A-HE (0.40%), A-AE (38.54%) and A-LE (19.43%); NV-HE (0.001%), NV-AE (5.75%) and NV-LE (3.88%). Despite of the irregular relief and high rainfall amount of Espirito Santo State, HE areas were lower than 1% of the State. AE areas occupied more than 2/3 of the surface, being 38.5% of this surface was occupied by agriculture. These values are preoccupying, because enormous areas of degraded pastures are abandoned in this State, causing *more intense erosion when compared to areas with forest covering. NV areas, which generally presents greater susceptibility to erosion, are not contributing in an alarming way to soil degradation, therefore represents only 9.62% of total area. Forest covering assists in the reduction of runoff due to the damping of the raindrops that improves infiltration and reduces soil erosion susceptibility. In general, Espirito Santo State doesn't presents high susceptibility to soil erosion due to its great vegetal covering. Data presented at this paper can be widely used at soil erosion studies, to assist in natural resources use, handling and conservation and to apply at environmental models of remote sensing software.*

Key words: *Remote sensing, RUSLE*

INTRODUCTION

The geotechnology is highly influenced by broadcast debate around the growing environmental degradation of the planet and the challenge a truly sustainable development of achievement (Bitar et al., 2000).

In Brazil, one of the attrition factors that most seriously have contributed to the soil unproductive, rivers and dams silting, damage to engineering works and impoverishment of the rural population is without doubt the water erosion is facilitated and accelerated by man with inadequate soil management practice (Bertoni & Lombardi Neto, 2005). The annual soil and water losses in Brazilian agricultural areas caused by water erosion in order of US$ 4.2 billion per year, representing related costs to fertilizers replacement, the lower productivity, higher production cost, water treatment, roads maintenance and increased energy consumption, beyond others (Hernani et al., 2002).

To minimize the problems caused by erosion, the planning of the rational soil use has been done through the Universal Soil Loss Equation - Revised (RUSLE). Among RUSLE factors, rain erosivity (R) factor express the rain potential, expected in an unprotected area, causing water erosion (Bertoni & Lombardi Neto, 1993; Alves, 2000).

The R factor is calculated directly from data rain gauge, but in Brazil, these records are scarce and often difficult to access. Some authors propose the empirical use of equations, in addition to the geoprocessing techniques use for the establishment of integrated soil and water conservation plans (Fujihara, 2002). In that sense, the use of geographic information systems might facilitate the analysis process; also facilitate the handling information in large areas, which is expensive by conventional methods.

Thus the models use is capable to estimate the losses caused by erosive process as fundamental importance to the choice of practices to conserve water and soil that can minimize these impacts.

This paper presents the use of geoprocessing tools to predict and to develop spatial distribution rainfall erosivity (R) map, and to analyze its relation with land use and management at Espirito Santo State, Brazil.

METHODS

The work was conducted in the Remote Sensing Laboratory of Núcleo de Estudos e Difusão de Tecnologia em Floresta, Recursos Hídricos e Agricultura Sustentável (NEDTEC) at Universidade Federal do Espírito Santo (UFES).

The study area includes the Espirito Santo State, which is one of the 27 Brazil's federations units. It is located between the latitudes 17° 53' à 21° 17' to the South of Ecuador and longitude of 39° 39' e 41° 52' West of the Prime Meridian, rugged topography, corresponding to a total area of 46.077,519 km². Because of the State provide a rugged topography, climate is characterized by a wide range of climatic factors, mainly east-west regarding precipitation.

The meteorological data regarding rainfall, were collected from 88 (eighty-eight) raingauge stations. These data were obtained in Sistema de Informações Hidrológicas da Agência Nacional de Águas - ANA (HIDROWEB) is itself of historical pluviometrics, with at least 25 years. The data of use and occupancy soil were obtained in the Instituto Brasileiro de Geografia e Estatística (IBGE) and on images of the CBERS-2 (China-Brazil Earth Resources) satellite, which has a spatial resolution of 20 m.

To predict the average monthly rates of erosivity used to empirical equation proposed by Lombardi Neto & Moldenhauer (1992) which links the index of erosivity (R) and the index of rain (Rc). The determination of the average annual erosivity was obtained by the sum of monthly average values of erosivity.

For software ArcGis 9.2 and through the extension of 3D Analyst Arcmap estimated to be up and developed a spatial map of the R factor for the entire state by interpolation of meteorological data off the elements by the method of kriging.

The study was based on overlapping maps that characterize the erosivity annual average and the classes of use and occupation of land suitable for the development of water erosion in the State of Espirito Santo. For this, the R-factor map was classified in: high erosivity (HE), average erosivity (EA) and low erosivity (LE) and Land use and management was classified in: Forest (F), Agriculture (A) and Not Vegetated (NV).

Land use and management and R-factor maps were crossed, using ArcGis 9.2 software, resulting in: Forest with high erosivity (F-HE), Forest with average erosivity (F-AE) and Forest with low erosivity (F-LE); Agriculture with high erosivity (A-HE), Agriculture with average erosivity (A-AE) and Agriculture with low erosivity (A-LE); Not Vegetated with high erosivity (NV-HE); Not Vegetated with average erosivity (NV - AE) and Not Vegetated with low erosivity (NV-LE).

RESULTS AND DISCUSSION

Using the kriging method the data interpolation from erosivity presented minors percentile average values of error (6.70%), root mean square error (514.49) and the greaters values of correlation coefficient (0.71) and index of agreement (0.56). The R factor map showed: 0,851% of areas with HE, 67,596% of AE and 31,539% of LE. The land use and management map presented: 32% of the area with F, 58.38% with A and 9.62% with NV.

Land use and management and R-factor maps were crossed resulting in: F-HE (0.44%), F-AE (23.30%) and F-LE (8.22%); A-HE (0.40%), A-AE (38.54%) and A-LE (19.43%); NV-HE (0,001%), NV-AE (5.75%) and NV-LE (3.88%) (Figures 1 and 2).

The total HE areas were lower than 1% of the State, AE areas occupied more than 2/3 of the surface, being 38.5% of this surface occupied by agriculture. NV areas therefore represent only 9.62% of total area.

The North and Northeast state region had low erosivity index when contrasted to the South and central mountain region showing average to high erosivity.

Despite the irregular relief and high rainfall amount at Espirito Santo, HE areas were lower than 1% of the State. These areas with HE are concentrated on higher relief regions represented by the southern region, where due to the influence of relief occur so-called orographic rainfall.

However, even if 2/3 of the state is represented by AE, it generates great concern, becau-se enormous degraded pastures areas are abandoned in this State, causing more intense erosion when compared to areas with forest covering, because when the plant cover is total or partially removed in rugged areas, the runoff flows faster, increasing the volume and powering the R factor. Thus, it is initiated by erosion, causing great damage to the ground. Furthermore, the ground lost by water erosion is generally more fertile, containing the nutrients plants, humus and some fertilizer that the farmer has applied (Bertoni & Lombardi Neto, 2005) further increasing the soil degradation.

Bertoni & Lombardi Neto (2005) argue, also, that land with severe erosion become difficult to work, and the grooves that are formed preventing its management, making useless them, getting to be abandoned, which often occurs at Espirito Santo State as mentioned earlier.

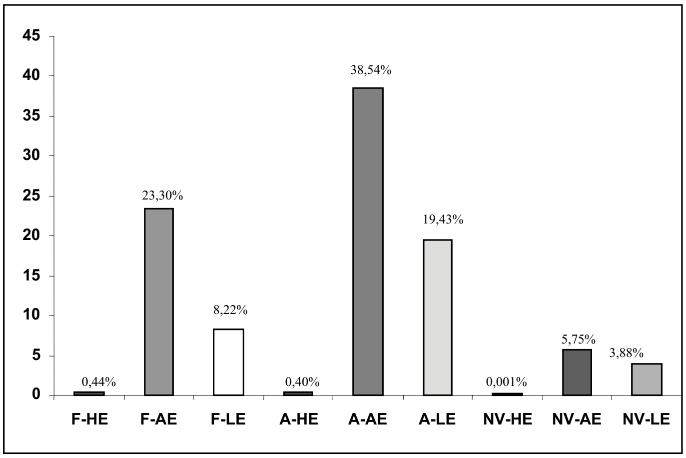


Figure 1 Percentage distribution between rainfall erosivity and land use at Espirito Santo State

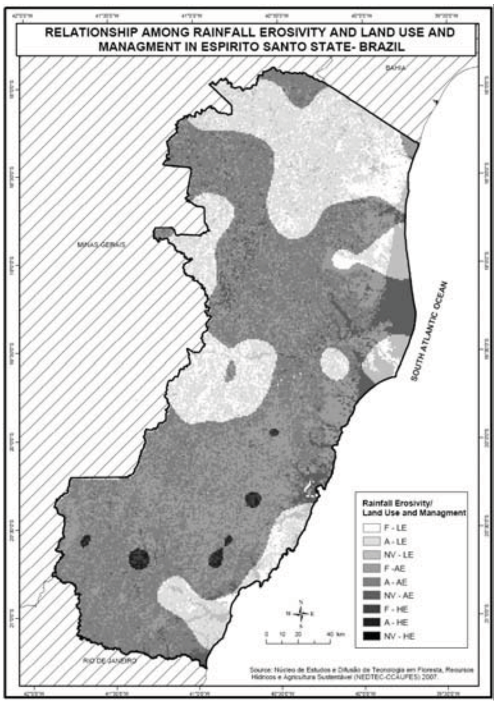


Figure 2 Map related to rainfall erosivity and land use at Espirito Santo State

The NV areas, which generally presents greater susceptibility to erosion, are not contributing in an alarming way to soil degradation, therefore represents only 9.62% of total area.

Forest covering assists in the reduction of runoff due to the damping of the raindrops that improves infiltration and reduces soil erosion susceptibility. When it falls into a land covered with dense vegetation, a drop of rain is divided into many droplets, also decreasing, and the force of impact. In ground uncovered, it does loose and pepper particles of soil, which are easily transported by water (Bertoni & Lombardi Neto, 2005).

The erosivity index showed low to the north and northeastern state region. This is explained by the fact of region lower relief and greater water deficit. However, the knowledge about the soil type for use in this region is important because it directly reflects the properties of soil, and with that, in the infiltration process that is fundamental to understanding the erosion dynamics (Heathwaite et al., 1990).

According to Rosa (1990), the updated knowledge of the ways of ground use and occupation, and its use history, has been a vital factor to study the processes that develop in the region, becoming a critical importance, inasmuch as the effects, causing environment deterioration. The processes of intense erosion, desertification, flooding, and silting of watercourses have been examples of day-by-day misuse.

In this context, the demands on geotechnology at Espirito Santo State, are now connected, especially the needs of characterization, assessment and solution of problems arising from the continued strengthening of relations between human activities and environment, particularly the use of natural resources, from the perspective of sustainability. Their contribution is in relation to surface water sources, control of soil erosion in order to prevent the silting of reservoirs and dams and the resulting loss of storage capacity.

CONCLUSION

Through data analysis from rainfall and erosivity use and soil occupancy obtained, for Espirito Santo State, satisfactory correlation results from these data with the erosion processes.

Thus, in order to promote best soil and water practice, use, management and conservation at Espirito Santo State through geotechnology technical, and other factors must be taken into account, mainly, the average index of the erosivity place (which represents the potential of erosive rains) and type of vegetation cover.

The areas zoning at risk through the association of these data will allow the models application and faster projects implementation of conservation and more comprehensive since such data are more easily obtained.

Therefore, the general objective is presented to geotechnology, faced to the challenge of sustainable development, is to provide government agencies to acquire information geoclimatics-geotechnical actually useful for urban and rural land use planning and management by the competent bodies. With emphasis on those that are objectively providing the identification, evaluation and monitoring of geological processes and climate induced, especially erosive.

ACKNOWLEDGEMENTS

To FAPES (Fundação de Apoio à Ciência e Tecnologia do Espírito Santo), for supporting this research.

REFERENCES

1. Alves, M., (2000). Estimativa da perda de solo por erosão laminar na bacia do rio São Bartolomeu-DF usando técnicas de geoprocessamento. Relatório Técnico apresentado ao Instituto Nacional de Pesquisas Espaciais. São José dos Campos (SP)
2. Bertoni, J.; Lombardi Neto, F., (1993). Conservação do solo. São Paulo - SP, Ícone
3. Bertoni, J.; Lombardi Neto, F., (2005). Conservação do solo. São Paulo: Ícone: 5ed.
4. Bitar, O.Y.; Iyomasa, W.S.; Cabral Jr., M., (2000). Geotecnologia, tendências e desafios. São Paulo em perspectiva, São Paulo, Fundação Seade 14:78-90.
5. Fujihara, A. K., (2002). Predição de Erosão e capacidade de Uso do Solo Numa Microbacia do Oeste Paulista Com Suporte de Geoprocessamento, Dissertação de Mestrado em Ciências do Solo, Piracicaba

6. Heathwaite, A.L.; Burt, T.P.; Trudgil, S.T., (1990). Land use controlo n sedment production in a lowland catchment, outh-west Ensgland. In: Soil Erosion on Agricultural Land, 69-86

7. Hernani, L.C.; Freitas, P.L.; Pruski, F.F.; De Maria, I.C.; Castro Filho, C. & Landers, J.C., (2002). A erosão e seu impacto. In: Manzatto, C.V.; Freitas Júnior, E. & Peres, J.R.R., eds. Uso agrícola dos solos brasileiros. Rio de Janeiro, Embrapa, 47-60

8. Lombardi Neto, F.; Moldenhauer, W.C., (1992). Erosividade da chuva: sua distribuição e relação com perdas de solo em campinas, SP. Bragantia, Campinas 51:189-196

9. Rosa, R.A., (1990). Utilização de imagens TM/LANDSAT em levantamento de uso do solo. In: VI Simpósio Brasileiro de Sensoriamento Remoto, Manaus, Anais..., vol 2. São José dos Campos, INPE, pp 419-425

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.42/.43
Stručni rad
Expert paper

APPLICATION OF A PHASE DETECTOR BASED UPON TDR DESIGN FOR SOIL MOISTURE MEASUREMENTS

WANG KEDONG, WANG YIMING

College of Information and Electrical Engineering, China Agricultural University
No.17 Qinghua Donglu Road, Mail Box 63, Beijing 100083, P.R. China

ABSTRACT

There are many commercially available TDR systems which can be used to measure soil moisture, but most of them are expensive since they are designed for universal use. The shape of TDR trace at the reflecting point is often used to characterize the properties of circuit faults, while it is not so important for soil moisture measurement. So sinusoidal electromagnetic signal can be adopted instead of voltage pulse signal and the expensive high-speed sampling oscilloscope can be eliminated by using a simple phase detector. A new method of determining soil moisture based on TDR using phase detecting technology is present in this paper. Single-frequency sinusoidal voltage signal is adopted as test signal instead of voltage pulse with very short rise-time and phase detector instead of high-speed sampling oscilloscope. The phase error between reflected signal and incident signal is measured to determine the travel time of test signal along with probe embedded in moist soil, form which the soil's volumetric water content is inferred. The system exhibits high accuracy and resolution in travel time measurement. Deviations not exceed $0.02m^3/m^3$ between the measuring result of this system after calibration and gravimetric sampling method can be achieved in sandy soil with volumetric water content up to $0.35m^3/m^3$.

Key words *Phase detector, time domain reflectometry, volumetric water content, dielectric constant*

INTRODUCTION

In the telecommunications industry TDR is used to indicate locations and characters of faults in cables or circuit boards [1]. The location of electronic break where the test signal is reflected back can be determined by the product of travel time and propagation velocity of the electromagnetic wave in the cable. The dielectric constant of a material is related to this propagation velocity. Davis and Chudobiak (1975) introduced TDR for their research on dielectric properties of soil [2]. Topp *et al.* (1980) used TDR to measure the apparent dielectric constant (K_a) of soils and calculated the water content (θ) using an empirical third-order polynomial [3~4]. Dalton *et al.* (1984) indicated that the attenuation of a TDR trace can be used to calculate the bulk soil electrical conductivity [5]. Probes with an insulated coat have been used successfully by Mojid et al. (1998) to reduce signal attenuation in highly saline soils [6].

MATERIALS AND METHODS

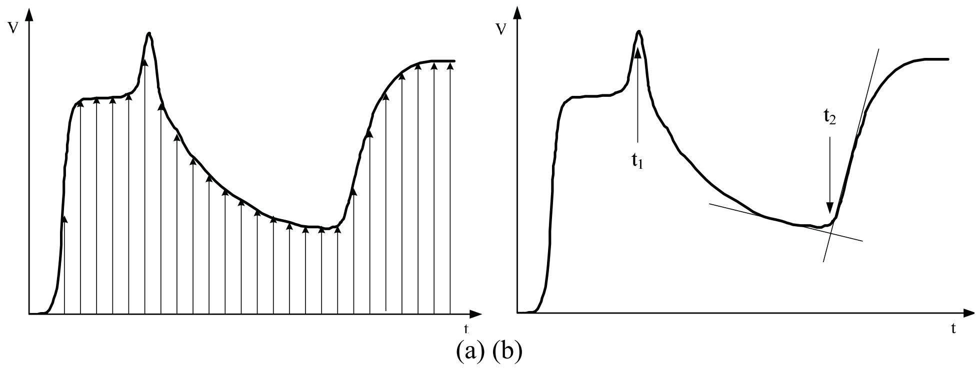
Principles of TDR

The conventional TDR system generates an electromagnetic pulse with very short rise time (about 100ps) and sends it through a probe buried in the soil. The pulse is reflected at the end of the probe and returns back to the receiver. The whole TDR waveform is acquired by a high-speed sampling oscilloscope. The dual-tangent method has been adopted to determine the travel time of test signal (Figure 1). In Figure 1, t_1 indicates the time when the signal enters the probe and t_2 indicates the time when the signal is reflected at the end of the probe. The bulk dielectric constant of soil around the probe is calculated by:

$$K_a = \left(\frac{c}{v}\right)^2 = \left(\frac{c(t_2 - t_1)}{2L}\right)^2 \tag{1}$$

where c is the speed of electromagnetic waves in free space, $(t_2$-$t_1)$ is the travel time of test signal in the probe and L is length of the probe. Since the dielectric constant of water (about 80 temperature of 25°C) is much greater than that of air (1) or soil solids (2~5), the apparent dielectric constant (K_a) of moist soil is highly depended on its volumetric water content (θ). The volumetric water content can be determined according to the Topp Formula [4]:

$$\theta_v = -5.3\times10^{-2} + 2.92\times10^{-2} K_a - 5.5\times10^{-4} {K_a}^2 + 4.3\times10^{-6} {K_a}^3 \tag{2}$$



(a) (b)

Figure 1 (a) TDR waveform is acquired by high-speed sampling oscilloscope and (b) The travel time is determined using dual-tangent method in conventional TDR systems

The shape of the TDR trace at the reflecting point is often used to characterize the properties of circuit faults, while it is not so important for soil moisture measurement. So the sinusoidal electromagnetic signal can be adopted instead of a voltage pulse signal, consequently the expensive high-speed sampling oscilloscope can be eliminated by using a phase detector.

TDR Based on Phase Detector

A single-frequency sinusoidal waveform is generated by a phase-locked loop (PLL) synthesizer, which is divided into two parts. One of them is passed through a delay line to serve as the incident signal while the other is applied to the probe. An impedance-matched network is used at the connection of the test cable from the P-TDR system to the probe rods to avoid reflecting at the head of the probe. The reflected signal from the end of the probe is extracted by a circulator. The phase detector compares the phases of the incident and reflected signals and creates an output of DC current which corresponds to the phase difference of the aforementioned (Figure 2).

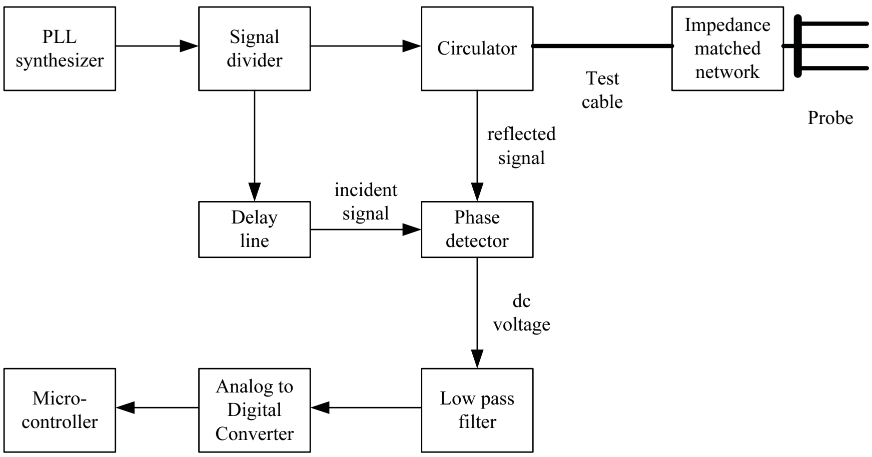


Figure 2 Major components of P-TDR system

To see how the travel time of a test signal is obtained let the signal of the PLL be represented as

$$u_0 = A_0 \sin(\omega t + \varphi_0) \tag{3}$$

where A_0 is the amplitude of the signal, ω is the angular frequency, and φ_0 is the original phase. The incident and reflected signals fed to the phase detector are

$$u_i = A_i \sin(\omega t + \phi_0 + \omega t_i) \tag{4}$$

and

$$u_r = A_r \sin(\omega t + \varphi_0 + \omega t_r) \tag{5}$$

where t_i and t_r are time for the incident and reflected signals traveling from PLL to phase detector. So the phase difference between the reflected and incident signals is

$$_{\Delta}\varphi = \omega t_r - \omega t_i \tag{6}$$

The travel time of reflected signal, tr, is logically divided into two segments: One is the travel time for test signal to traverse the length of probe (marked as tp, which is the time we are mainly interested in) and the other is the extra time used by the test signal to pass though the test cable and circuits inside the P-TDR system (marked as tc). Formula (6) then changes to

$$_{\Delta}\varphi = \omega t_p + \omega (t_c - t_i) \tag{7}$$

$$t_p = \frac{_{\Delta}\varphi - \omega (t_c - t_i)}{\omega} \tag{8}$$

By measuring the phase difference of the signals with the probe being removed from the P-TDR instrument (thus t_p equals to 0), the value of $\omega(t_c\text{-}t_i)$ is determined. Thus the travel time of test signal along the probe buried in the soil can be calculated with its angular frequency and the phase difference measured by the phase detector.

RESULTS AND DISCUSSION

Travel Time Measurement

To evaluate the performance of the P-TDR system we first measured the travel time of test signal along coaxial cables. A cable about 1.2 meters long was attached to a P-TDR instrument instead of a soil moisture probe. The end of the coaxial cable represents an open circuit. The accurate length of the cable in the test was recorded as well as the result of the P-TDR instrument. Then the coaxial cable was cut off by several millimeters and successive measurements and records were made. The theoretical travel time of a test signal is calculated by

$$t = \frac{2L\sqrt{\varepsilon_c}}{c} \tag{9}$$

where L and ε_c are the physical length and relative dielectric constant of the cable under test. The data of these measurements are shown in Figure 3 and Table 1.

The results of the P-TDR instrument are well accordant to the theoretical values. The average error of these measurements is about 6 picoseconds. The resolution of travel time measuring with the P-TDR system is less than 1 picosecond.

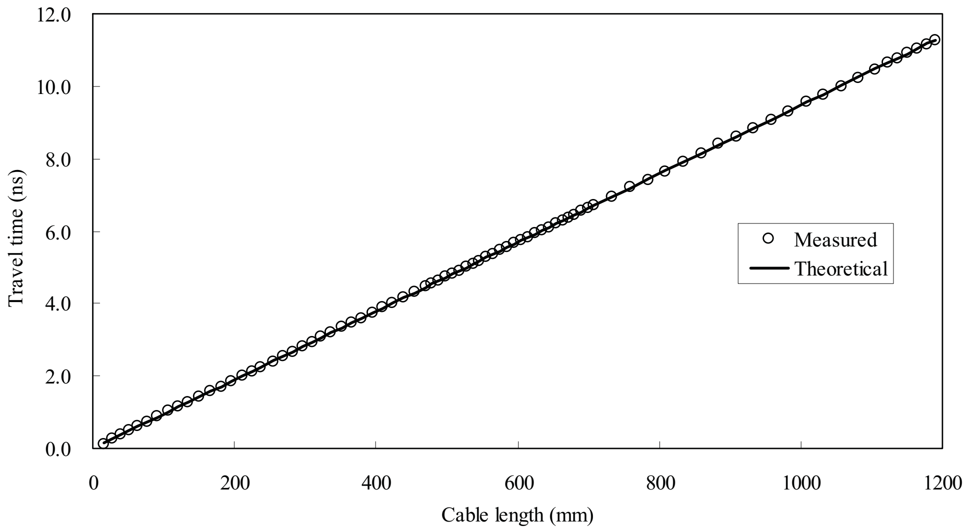


Figure 3 Measured and theoretical travel time of test signal along coaxial cables

Table 1 A portion of the data measured in coaxial cables

length (mm)	15	121	225	323	424	527	625	734	983	1191
theoretical time (ns)	0.132	1.148	2.126	3.072	4.024	5.002	5.929	6.960	9.313	11.281
measured time (ns)	0.142	1.146	2.132	3.060	4.017	4.993	5.922	6.955	9.314	11.285
deviation (ps)	10	-2	6	-12	-7	-9	-7	-5	1	4

Soil Moisture Measurement

In the P-TDR system, a three-rod probe is used to measure the soil moisture. Rods are coated by insulation material to reduce signal attenuation. Since these coatings significantly influence the resulting permittivity Ka, specific θ - tp calibration is required.

Fourteen samples of sand soil were prepared for calibration. The volumetric water content of these samples varied from 0.02m3/m3 to 0.35m3/m3. The probe was placed in each soil sample and the travel time was measured by the P-TDR instrument. Meanwhile the accurate volumetric water content was measured by using gravimetric sampling method. As shown in figure 4, the volumetric water content can be modeled by a third-order polynomial function, which coefficients are calibrated using least square method and the values of the coefficients of this calibrating formula are stored in an EEPROM inside the P-TDR instrument.

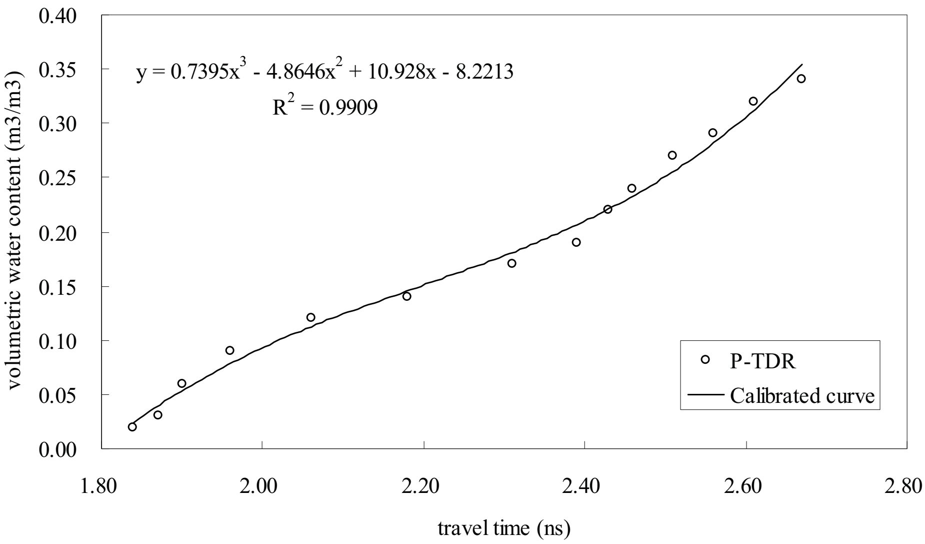


Figure 4 Calibrated curve for P-TDR system

Another set of soil samples was prepared to verify the performance of the P-TDR instrument after the calibrated curve was obtained as described above. Thus the P-TDR instrument will output the volumetric water content which was calculated according to the calibrated formula despite travel time. The results were compared with those of the gravimetric sampling method in Table 2.

Table 2 Soil moisture measurement results of P-TDR and gravimetric sampling method

gravimetric (m^3/m^3)	0.018	0.063	0.097	0.148	0.174	0.223	0.273	0.3	0.324	0.348
P-TDR (m^3/m^3)	0.031	0.047	0.084	0.163	0.18	0.222	0.262	0.291	0.324	0.353
deviation (m^3/m^3)	0.013	-0.016	-0.013	0.015	0.006	-0.001	-0.011	-0.009	0.0	0.005

As shown in table 2, the results of the P-TDR instrument deviate from that of gravimetric sampling method. The deviation is due partly to the additional reflection of test signal at the connection between the test cable and the probe rods. This unwanted reflection can not be eliminated because the impendence of the rods will change along with the physical condition of the soil in which the probe is buried. But by using an impedance-matched network in the P-TDR system, the influence of this reflection has been reduced to an acceptable degree.

CONCLUSIONS

In this paper we have presented a new implement of TDR using a single-frequency sinusoidal test signal along with a phase detecting technology. It is verified that soil moisture can be measured by using this P-TDR system in the laboratory.

ACKNOWLEDGMENTS

This study was supported by the Hi-Tech Research and Development (863) program of China (2006AA10Z264).

REFERENCES

1. Jones S.B., Wraith J.M. and Or D. Time domain reflectometry measurement principles and applications. Hydrological Process, 2002, 16: 141–153.
2. Davis J.L. and Chudobiak W.J.. In situ meter for measuring relative permittivity of soils. Geol. Surv. Can. Pap. 1975, 75(1A):75–79.
3. Topp G.C., Davis J.L., and Annan A.P.. Electromagnetic determination of soil water content: Measurement in coaxial transmission lines. Water Resources Research, 1980, 16:574–582.
4. Topp G.C., Yanuka M., Zebchuk W.D. and Zegelin S.. Determination of electrical conductivity using time domain reflectometry: Soil and water experiments in coaxial lines. Water Resources Research, 1988, 24:945–952.
5. Dalton F.N., Herkelrath W.N., Rawlins D.S. and Rhoades J.D.. Time domain reflectometry: simultaneous measurement of soil water content and electrical conductivity with a single probe. Science, 1984, 224: 989–990.
6. Mojid M.A., Wyseure G.C.L. and Rose D.A.. The use of insulated time-domain reflectometry sensors to measure water content in highly saline soils. Irrigation Science, 1998, 18: 55–61.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.9:662.75:665.334
Pregledni rad
Review paper

SIMULATION OF THE COMBUSTION CHAMBER GEOMETRIC SHAPE WITH THE LIQUID LENGTH PHASE PENETRATION OF BIOFUEL JET SPRAY

FLORIN MARIAŞIU, BOGDAN VARGA

The Technical University of Cluj-Napoca, Faculty of Mechanic,
florin.mariasiu@arma.utcluj.ro, +040264 401 609

ABSTRACT

In terms of appearance and use in present of numerous alternative fuels to fossil fuels, it is necessary to realize experiments and develop theories related to current operational processes of internal combustion engines. In this regard, the study of the combustion chamber geometric shape with the particularities of injection process (type of injection, fuel characteristics, physical parameters, etc.), necessary to optimize the functional cycle of internal combustion engine and to achieve the current values of European legislation pollution.

In this scientific paper, starting from mathematical models developed until now, we taking into account a greater number of factors that influence the process injection. The study of proposed model was making by simulating the behavior space-temporal structure biofuel jet (especially the liquid phase development) inside of the combustion chamber in conditions of different cases of spray/wall interaction, using the finite elements method (FEM).

***Key words**: internal combustion engine, simulation, model, liquid, biofuel.*

INTRODUCTION

It is well known that biofuels based on vegetable oils is a source of renewable energy whose recognition is growing as alternative fuel, with so much as how this fuel is became the basic fuel in agriculture.

In the present method of obtaining biodiesel from vegetable oils and animal fats is the process of transesterification, but even using this method the final product (DME – dimethylester) is characterized by a greater viscosity compared with diesel fuel [1]. The immediately effect of biodiesel greater viscosity is forming inside of the injected jet fuel into the combustion chamber of drops of fuel with large diameters, with directly consequences in engine performance reduction and increased pollutant emissions.

After numerous experimental studies of the use of biodiesel in internal combustion engines, inside of the Laboratory of Biofuels (Technical University of Cluj-Napoca), was found that CO, CO_2, HC and smoke emissions decrease, but is an increase with 10-12 % of NO_x emissions [1,6].

Starting from the premise that smoke emissions is due to the impact jet fuel (liquid phase) with cold walls of the cylinder, has been made in a first phase trough CFD methods simulation the study of the shape of the combustion chamber influence over the length of penetration of the liquid phase jet of considered biofuel (RME – Table 2).

METHOD

For implementation in the CFD simulation environment (Star-CD) has a mathematical model that defines the behavior of a jet biofuel elected to the proposed model and developed by Grover Jr. and Assanis [3], with minimal changes by taking into account the another two supplementary forces that have influence on injected fuel particles (Saffmann force and gravitational force).

Choosing the mathematical model was based on qualitative analysis between this one and other mathematical models developed by different authors or implemented in areas of CFD simulations used in the present (Table 1).

Table 1 Comparision between the mathematical models of fuel jet behavior [3,4]

Feature	Splashing Droplet Sizes From Statistical Distribution	Dry/Wet Wall Splash Criteria	Solves the Mass Conservation Equation	Solves the Momentum Conservation Equation	Solves the Energy Conservation Equation	Separate Model for Viscous Dissipation and Wall Film Energy
O'Rourke and Amsden	x	x	x		x	
Gosman		x	x	x	x	
Grover Jr. and Assanis	x	x	x	x	x	x

Also, an important role in the alleging of the Grover Jr. and Assanis model was the existence of viscous secondary dissipation effect model, with great importance in simulation of biofuel jet spray. The maximum spread of droplet upon impact (d_R) is given by [5]:

$$\frac{d_R}{d_i} = \left[\frac{We + 12}{3(1 - \cos\alpha_i) + 4\left(\frac{We}{\sqrt{\mathrm{Re}}} \right)} \right]^{1/2} \tag{1}$$

where d_i- is the initial drop diameter, We- the Weber number and Re- the Reynolds number. The rebound angle α_R is related to the incident angle α_i, by an empirical curve fit of [2]:

$$\alpha_R = 0.3155\alpha_i + 62.239 \tag{2}$$

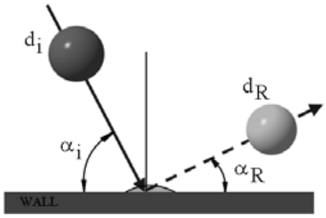


Figure 1 The impact process of injected fuel drops with the combustion chamber wall

RESULTS

Mathematical model has been incorporated into the simulation environment Star-CD, and simulation conditions were considered:

- The ambient air environment density was 10 kg/m^3 at 450K (176.85ºC);
- The combustion chamber wall was at 700K (426.85 ºC);
- The injection pressure p_{inj} = 180 bar;
- The injector orifice diameter $\varnothing_i$ = 0.15 mm;
- Distance between combustion chamber wall and the injector orifice was considered at H = 40 mm.

Table 2 Physical and chemical properties of RME [1]

Properties	Rapeseed oil
Density at 15^{o}C, [kg/dm^3]	0.886
Caloric power, [MJ/kg]	36.2
Cinematic viscosity at 20^{o}C [mm^2/s]	7.25
Cetane number	54
Pour point, [^{o}C]	<-15
Flash point, [^{o}C]	140

The biodiesel spray jet impact angles (θ_{cc}) with the combustion chamber walls were considered as 0^o, 20^o, 30^o and 40^o. The results obtained from simulation was use to determine the relationship between the biofuel jet impact angle with the equivalent diameter of spots of biodiesel on combustion chamber walls (made from liquid phase of fuel jet).

Results obtained by computer simulation are shown in figures 2 and 3.

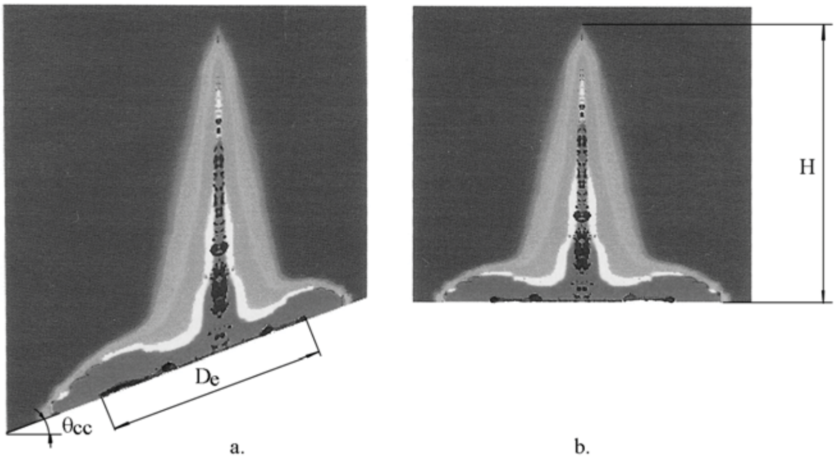


Figure 2 Simulation of biofuel jet impact with the combustion chamber wall (a- 20o impact angle, De= 30.7 mm; b-0o impact angle, De= 25.4 mm)

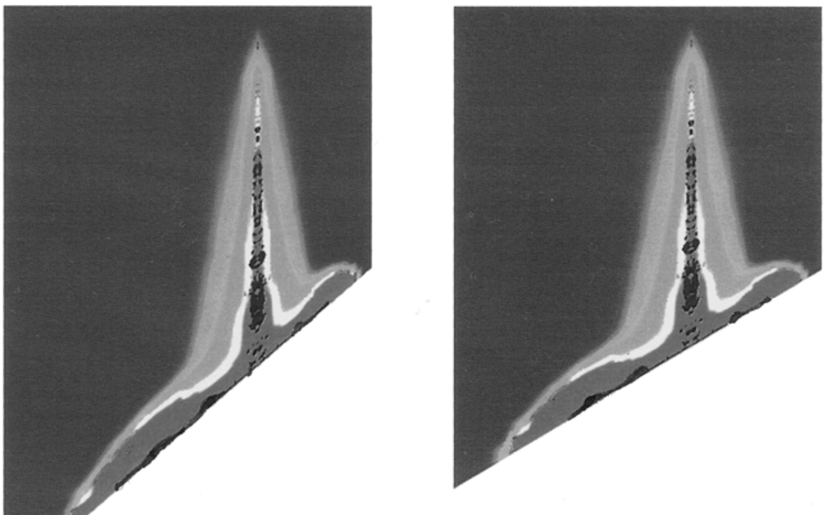


Figure 3 Simulation of biofuel jet impact with the combustion chamber wall (c- 40o impact angle, De= 43.7 mm; d-30o impact angle, De= 36.8 mm)

Note that the equivalent diameter (D_e) of spots of biodiesel made from fuel jet liquid phase with impact of the combustion chamber walls increase with increasing of the fuel jet combustion chamber wall impact angle (figure 2, 3). The variation and interdependence between above mentioned parameters can be represented using mathematical functions of the form.

$$D_e = 21.28 \cdot e^{0.18 \cdot \theta_{cc}} \tag{3}$$

$$\theta_{cc} = 28.37 \cdot \ln D_e - 0.046 \tag{4}$$

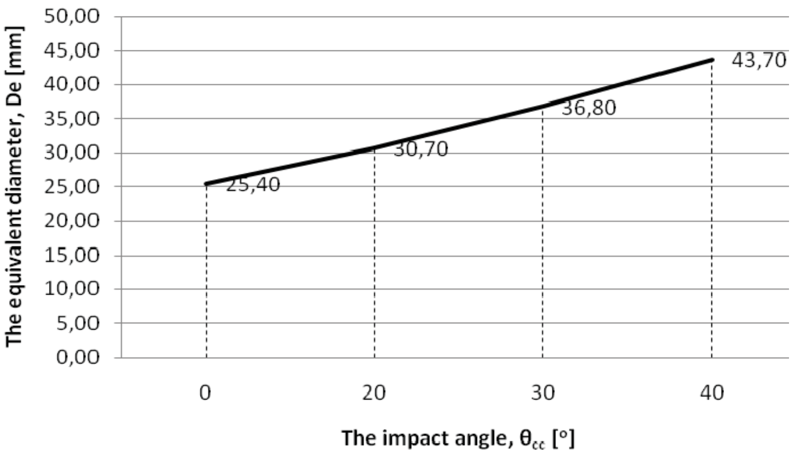


Figure 4 Variation of the equivalent diameter with the biofuel jet impact angle

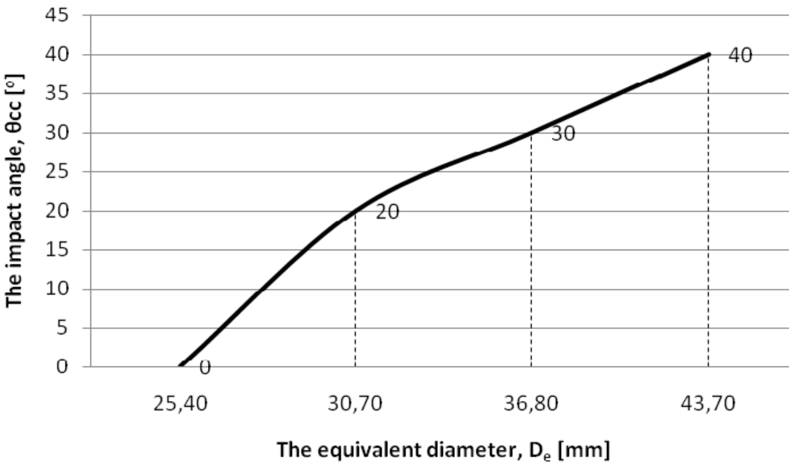


Figure 5 The variation of the biofuel jet impact angle with the equivalent diameter

CONCLUSIONS

- Note that with the increasing of the biofuel jet impact angle with the walls of the combustion chamber is increasing the mass of biodiesel that comes in contact with cold walls of the combustion chamber, leading to increasing smoke emissions.
- The best results (minimum area of the fuel spot on combustion chamber wall) are obtained for 0^o value of the angle of impact, which show premises to develop design of a new chamber of the benefits of lower smoke emissions.
- Future studies are needed to do experimentally (the experimental stand with the help of optical cylinder engines etc.) to validate the data obtained by simulation.

ACKNOWLEDGEMENTS

This article was developed through the support and help given by CNCSIS in the research grant No. 175/ PN-2008-II Idei.

REFERENCES

1. Burnete, N., et.al. (2008). The Diesel Engines and Biofuels for Urban Transportation (in Romanian), Mediamira Press, Cluj-Napoca, Romania, ISBN 978-973-713-217-8.
2. Mundo, C., Sommerfeld, M., Tropea, C. (1995). Droplet-Wall Colissions: Experimental Studies of the Deformation and Breakup Process, International Journal of Multiphase Flow 21, 151-173.
3. Pasandideh-Fard, M., Qiao, Y., Chadra, S., Mostaghimi, J. (1996). Capillary Effects During Droplet Impact on a Solid Surface, Physics of Fluids Journal no.8, 650-659.
4. Grover Jr., R., Assanis, D. (2004). A Comparison of Classical Atomization Models against Current Experimental Measurements within a Zero-Dimensional Framework, ILASS Americas, 17th Annual Conference on Liquid Atomization and Spray Systems, Arlington, USA.
5. Naber, J., Reitz, R. (1988), Modeling Engine Spray/Wall Impingement, SAE Technical Paper no. 880107.
6. Trujillo, M., Mathews, W., Lee, C., Peters, J. (2000). Modeling and Experiment of Impingement and Atomization of a Liquid Spray on a Wall, International Journal of Engine Research 1 (1), 87-105.
7. Todoruţ, A., Barabás, I., Burnete, N., Mariaşiu, F. (2006). Chemical pollution evaluation of sunflower oil based biofuels blends, paper no. MVT20061033, in 1st International Conference „MOTOR VEHICLE AND TRANSPORTATION MVT 2006", Timisoara, Romania.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 665.334.9
Prethodno priopćenje
Preliminary communication

RAPESEED OIL FUELLED TRACTORS – OPERATION AND EMISSION CHARACTERISTICS

KLAUS THUNEKE, THOMAS GASSNER, PETER EMBERGER

Technologie- und Förderzentrum, Schulgasse 18, D-94315 Straubing, GERMANY

SUMMARY

Rapeseed oil fuelled tractors gain more and more importance in Germany. Due to the differences between diesel and rapeseed oil fuel properties, such as kinematic viscosity and ignition behaviour, conventional diesel engines have to be adapted to the demands of rapeseed oil fuel. Up to now tractors were usually retrofitted by specialised workshops, but recently series produced rapeseed oil fuel compatible tractors are offered by the agricultural machinery industry. Because of the fairly new technology and ongoing diesel engine development, operational reliability, engine performance and emission characteristics of rapeseed oil fuelled tractors under practice conditions are widely unknown. Thus, it is the aim of a research project, to monitor operation data and assess exhaust gas emissions of rapeseed oil fuelled tractors.

Objects of investigation are two, with single-tank systems converted rapeseed oil fuelled tractors, which are used in agricultural practice. Important operation data (e. g. exhaust gas temperature, fuel temperature) are recorded continuously and fuel as well as engine oil qualities are analysed. The measurement of power output, fuel consumption and exhaust gas emissions takes place recurrently at a test stand on the basis of EU-Directive 2000/25/EG. Result discussion is done in terms of the compliance with emission standards and differences between rapeseed oil and diesel fuel operation. The results of this work may help to assess operational reliability and emission behaviour of rapeseed oil fuelled tractors. Furthermore advices for reliable tractor operation can be given and the compliance with emission standards can be reviewed.

The two tractors showed almost no failures within the investigated period. However, due to the accumulation of rapeseed oil fuel in the engine, a more frequent engine oil exchange (every 250 operating hours) is necessary. Power output is 5 to 10% higher with rapeseed oil and specific fuel consumption is equal to diesel fuel operation.

The tractors fulfil the demands of the appropriate exhaust gas stages I and II for carbon monoxide (CO), hydrocarbons (HC) and particulate mass with rape-

seed oil fuel. However, the limiting value for nitrogen oxides emissions (NO_X) is exceeded up to 15 %. Comparing diesel and rapeseed oil fuel operation, latter shows lower emission levels for CO, HC and particulate mass but higher NO_X. In general idle and low load operation with rapeseed oil fuel leads to higher particulate mass and CO emissions in comparison to diesel fuel, whereas during middle and heavy load operation particulate mass and CO emissions are equal or less. Nitrogen oxides are little higher with rapeseed oil than with diesel fuel at all test modes of the engine operating map. But on the other hand hydrocarbons are reduced significantly. Although present exhaust gas regulations can be fulfilled widely, efforts have to be undertaken to comply with future demands.

Keywords: *rapeseed oil fuel, emissions, operation behaviour, tractor*

INTRODUCTION

The use of rapeseed oil fuel in vegetable oil compatible tractors has environmental benefits and increases agricultural value added. Additionally, a reduction of fuel costs can be achieved in many cases. Uncertainties, inhibiting higher market relevance, are long term operation reliability, warranty agreements for adapted engines and compliance with exhaust gas emission regulations. Thus, the Technologie- und Förderzentrum in Straubing is investigating together with the LVFZ Kringell and financed by the Bavarian State Ministry for Agriculture and Forestry two rapeseed oil fuelled tractors in practical use (Figure 1). The objective is, besides continuous monitoring of operational characteristics, engine oil and fuel quality, to determinate emission characteristics by recurrent measurement.

Figure 1 Rapeseed Oil Compatible Tractors Fendt Farmer Vario 412 and Deutz-Fahr Agrotron TTV 1160 at LVFZ Kringell

METHODS

Objects of investigation are a Deutz-Fahr Agrotron TTV 1160, adapted to rapeseed oil fuel by a single-tank system of the company Hausmann and a Fendt Farmer Vario 412 tractor, retrofitted also with a single-tank system of the company VWP. Important data of the tractors are shown in Table 1.

During the investigated period of two years operation data such as different fuel temperatures, exhaust gas temperature, engine oil temperature, etc. are recorded continuously (Table 2). Additionally, fuel and engine oil qualities are analysed.

Table 1 Technical Data of the Tested Tractors

Tractor Manufacturer	Deutz-Fahr	Fendt
Tractor Model	Agrotron TTV 1160	Farmer Vario 412
Number of Cylinders	6	4
Engine Power in kW	119	94
Engine Type	Deutz BF6M1013EC	Deutz BF4M2013C
Year of Manufacture	2005	2003
Default Exhaust Gas Stage	II	I
Adaptation Company	Hausmann	VWP
Operating Hours at Time of Adaptation	250	new
Operating Hours at Time of Measurement	245-1525	1940-3230

Table 2 Measured Operation Data of the Deutz-Fahr Agrotron TTV 1160

Code	Measured Parameter
Bh / v / GPS	Operating hours / Driving speed / GPS-Position
n_T / P_{TR}	Engine speed / Engine load
B	Fuel consumption
DH1/2	Injector heating on, off 70/100 °C
T_{LU1}	Ambient air temperature
p_{LL}	Charging air pressure
T_{KT1} T_{KE} T_{KR}	Fuel temperature: Storage tank / Injector / Fuel return system
$T_{AZ1\text{-}6}$	Exhaust gas temperature (Exhaust manifold, 6 cylinders)
T_{Oel}	Engine oil temperature
T_W	Coolant temperature

The measurement of engine power, fuel consumption and exhaust gas emissions took place at the TFZ test stand (Figure 2) on the basis of EU-Directive 2000/25/EG with a power take-off dynamometer. Thereby, eight test modes within the engine operating map are run through (Figure 3). All limited exhaust gas components: carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC) and particle mass are recorded. The results of every single test mode are added up with specified weighting factors. Emission results are stated in g/kWh, assuming a power loss for transmission between engine and power take-off of 10%.

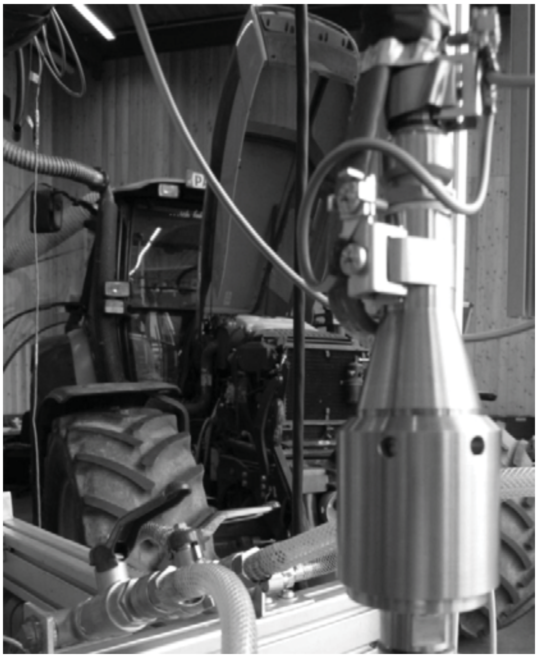


Figure 2 Deutz-Fahr Agrotron TTV 1160 at the Exhaust Gas Stand of the TFZ

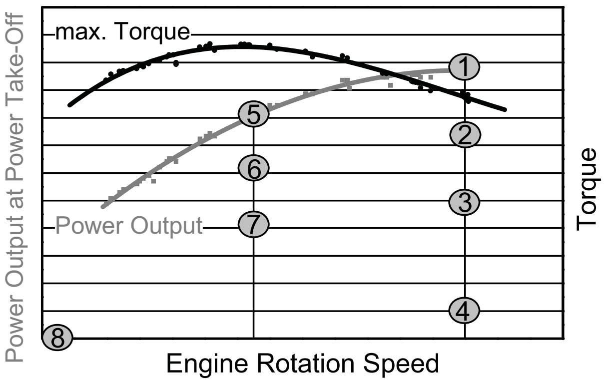


Figure 3 Eight Test Modes within the Engine Operating Map according to 2000/25/EG for Emission Tests

RESULTS

Operational Reliability

Within the investigated period of 22 months from March 2006 to December 2007 the two tractors proved their full suitability in practical use, completing 1300 operating hours each. During that time technical malfunction did not occur. Solely in one case a pressure loss in the fuel system of the Deutz-Fahr tractor, derived from a fatigue of the fuel pump, led to lower power output. However, this was not a direct consequence of rapeseed oil use.

Operation Characteristics

For ascertainment of operation characteristics during engine operation, important parameters were monitored every 120 seconds (initially every 300 s). As it can be seen in Figure 4, the Deutz-Fahr tractor was operated over 20% of the investigated time at full load. Low load operation up to 20% engine load demanded some 30%, the residual 50% fell upon partial load (20 to 90% engine load).

Fuel temperature in the tank of the Deutz-Fahr tractor was according to Figure 4 for more than half of the totally recorded 605 operating hours between 40 and 55 °C. These high temperatures arise from fuel heating in pumps, in the pre-heated filter as well as in fuel pipes running through the cylinder head. Such heated fuel circulates via the fuel cooler, together with the leak oil of the injectors, back into the tank. Due to accelerated aging processes of once heated rapeseed oil, the tank should be emptied largely before long-term stoppage and refilled with high quality rapeseed oil fuel again.

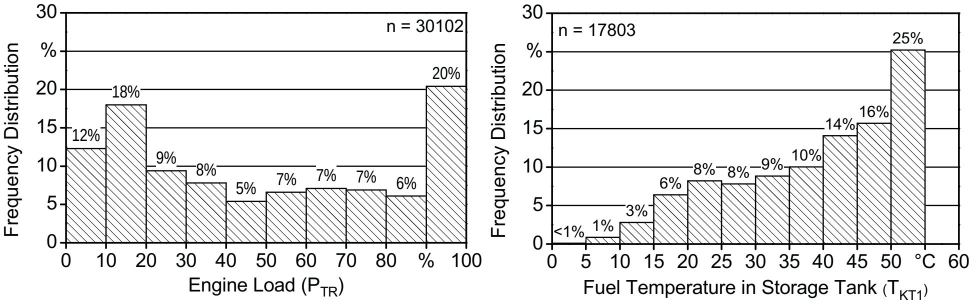


Figure 4 Frequency Distribution of Engine Load Levels (left) over 1085 Operating Hours and Fuel Temperature Levels in the Storage Tank (right) over 605 Operating Hours of the Deutz-Fahr TTV 1160

Engine Oil

The accumulation of rapeseed oil fuel in the motor oil requires earlier engine oil exchange for rapeseed oil fuel than for diesel fuel operation. Results with the Deutz-Fahr tractor show a linear increase of fuel content in the engine oil of 5% within 60 operating hours. For the Fendt tractor the increase is 5% within 130 operating hours (Figure 5).

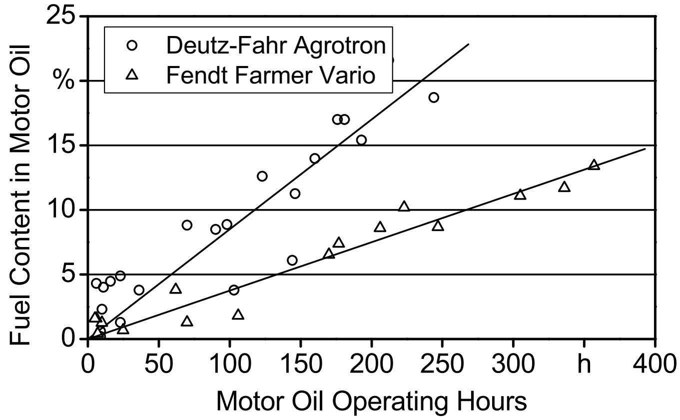


Figure 5 Fuel Content in the Motor Oil Depending on Motor Oil Operating Hours for several Engine Oil Fillings of Two Tractors

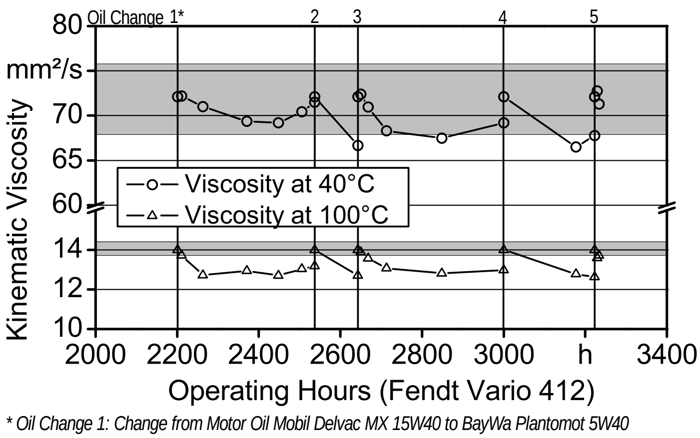


Figure 6 Kinematic Viscosity of Motor Oil Samples of the Fendt Farmer Vario 412 during several Motor Oil Fillings

Maximum tolerable fuel contents in the motor oil can not be quoted as an absolute value because they depend on oil composition and engine operation characteristics (e. g. oil temperature). For the Fendt tractor with a relatively small oil volume and high motor oil temperatures, the same oil exchange interval of about 200 operating hours is necessary despite a lower fuel entry rate in comparison to the Deutz-Fahr tractor. This can be deduced from motor oil analyses that show an increase in viscosity at some 200 operating hours after an initial decrease, caused by rapeseed oil entry (Figure 6 and Figure 7). This lower turning point marks the beginning of an unregulated motor oil aging and should therefore not be exceeded. In future, fuel entry in the motor oil is to be minimised, oil temperature has to be limited by an appropriate and effective motor oil cooling system and developments to a purpose designed motor oil with low polymerisation tendency has to be promoted. Besides that, the contribution of improving rapeseed oil fuel quality (e g. by additives) has to be evaluated.

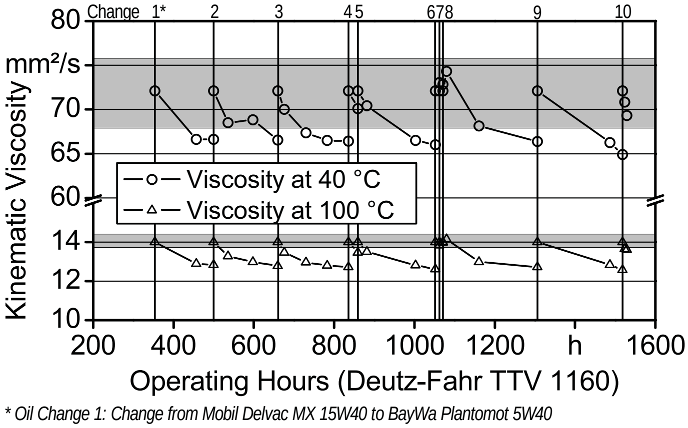


Figure 7 Kinematic Viscosity of Motor Oil Samples of the Deutz-Fahr TTV 1160 during several Motor Oil Fillings

Power Output and Fuel Consumption

The results show a slight increase of power output and torque up to 10% during rapeseed oil operation (Figure 8). This can be explained by higher injected fuel amounts in consequence of earlier injection nozzle opening and higher fuel pressure in the nozzle due to differences in fuel characteristics, such as viscosity and compressibility. However, for electronically controlled injection systems (e. g. common-rail) a lower power output is expected, because of equal injection amounts (same nozzle opening time) and a 4% lower heating value of rapeseed oil fuel.

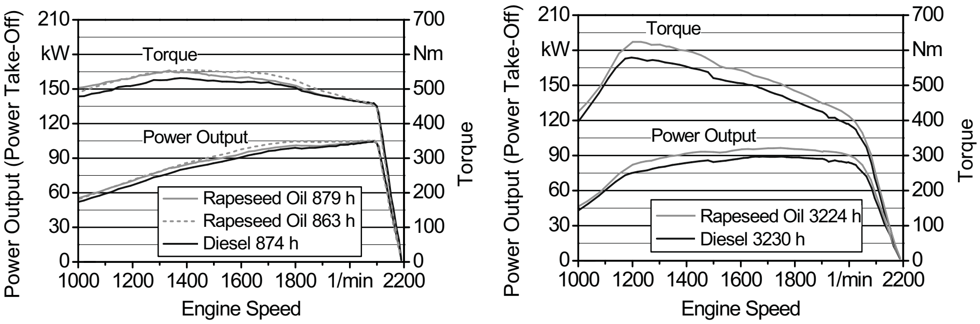


Figure 8 Power Output at Power Take-Off and Torque of the Deutz-Fahr TTV 1160 (left) and the Fendt Famer Vario 412 (right) with Diesel and Rapeseed Oil Fuel

At about the same percentage as the power output increase (10%), the mass related specific fuel consumption is increasing when using rapeseed oil. However, the volume based fuel consumption with rapeseed oil is just about equal to diesel fuel operation, due to the higher density of rapeseed oil (Figure 9).

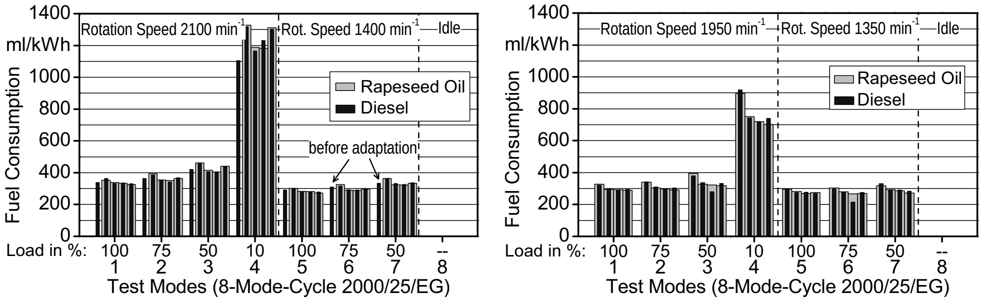


Figure 9 Volumetric Specific Fuel Consumption of the Deutz-Fahr TTV 1160 (left) and the Fendt Famer Vario 412 (right) with Diesel and Rapeseed Oil Fuel

Emissions

Results of emission measurements according to directive 2000/25/EG are shown in Figure 10 for the Deutz-Fahr tractor and in Figure 11 for the Fendt tractor. With the tested tractors the relevant emission standards (exhaust gas stage II and I) are proven to be fulfilled with rapeseed oil fuel for CO, HC and particle mass, but not for NO_X. Besides the Deutz-Fahr Agrotron TTV 1160, when fuelled with diesel fuel, both tractors even meet the limiting values for HC of stage IV. Also particle mass emissions of the Fendt tractor (stage I) with rapeseed oil fuel were in the same range of the future limiting values of stage III B and IV, which even though will be determined by an alternative test cycle.

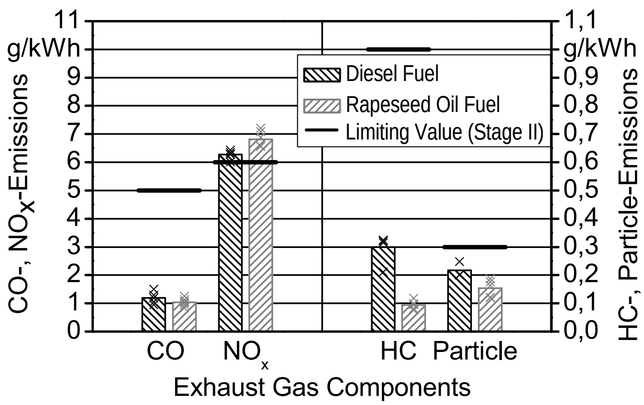


Figure 10 Limited Exhaust Gas Emissions with Rapeseed Oil and Diesel Fuel of a Deutz-Fahr Agrotron TTV 1160 in Comparison to Limiting Values of Exhaust Gas Stage II

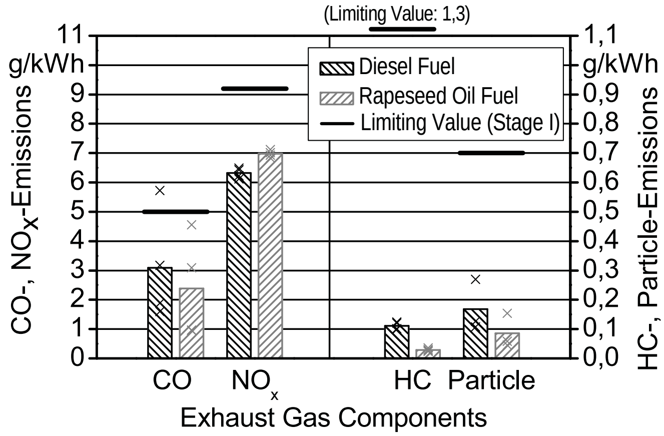


Figure 11 Limited Exhaust Gas Emissions with Rapeseed Oil and Diesel Fuel of a Fendt Farmer Vario 412 in Comparison to Limiting Values of Exhaust Gas Stage I

Apart from NO_X, rapeseed oil fuel operation has advantages for limited emission components compared to diesel fuel, in particular for HC. A detailed look at the emissions of both tractors reveals, that idle and low load operation with rapeseed oil fuel leads to higher particulate mass and CO emissions in comparison to diesel fuel, whereas during middle and heavy load operation particulate matter and CO emissions are equal or less. The emission characteristics of both tractors do not show any trend over the investigated operation time.

Comparing emissions between rapeseed oil and diesel fuel operation, it has to be considered, that engines can only be optimised properly for either, rapeseed oil or diesel fuel. Because of the fact that there is no sophisticated optimisation of the presently available retrofitted conventional diesel engines, a high potential of emission reduction can be deduced. With fuel specific optimisation of the engine, the engine operating map and exhaust gas aftertreatment systems, the fulfilment of upcoming emission demands appears to be feasible with rapeseed oil fuel. Further tests will be conducted, focussing also on series produced stage III tractors, provided by the machinery industry, and other not limited emission components.

CONCLUSIONS

Both rapeseed oil fuelled tractors showed a high reliability during operation. The basis for that were a careful technical supervision and maintenance, skilled operators, a convenient operational profile as well as a high rapeseed oil fuel quality according to pre-standard DIN V 51605. For reducing maintenance work future development should aim especially on the reduction of fuel entry into the motor oil. Regarding emission behaviour, rapeseed oil operation has advantages in terms of the reduction of limited exhaust gas components, apart from NO_x. However, new engine and exhaust gas aftertreatment technology require further adaptation measures for rapeseed oil use.

Because of the non-restrictive suitability for practice use of the investigated rapeseed oil fuelled tractors, confidence of the operators was very high and tractors are further operated with rapeseed oil fuel. Higher maintenance work is accepted for the sake of implementing an independent fuel supply in agriculture.

ACKNOWLEDGEMENT

The authors would like to thank greatly the Bavarian State Ministry for Agriculture and Forestry for financing this research project. Special thanks go to Wolfgang Löw from the LVFZ Kringell of the Bavarian State Research Centre for Agriculture for the excellent co-operation. The entire report is available at www.tfz.bayern.de.

REFERENCES

1. European Union (2000): Directive 2000/25/EG of the European Parliament and the Council of 22 May 2000 on action to be taken against the emission of gaseous and particulate pollutants by engines intended to power agricultural or forestry tractors and amending Council Directive 74/150/EEC

2. Thuneke, K.; Gassner, T.; Emberger, P.; Remmele, E.; Widmann, B. (2008): Untersuchungen zum Einsatz rapsölbetriebener Traktoren beim Lehr-, Versuchs- und Fachzentrum für Ökologischen Landbau und Tierhaltung Kringell. Berichte aus dem TFZ. Straubing: Technologie- und Förderzentrum im Kompetenzzentrum für Nachwachsende Rohstoffe (in preparation)

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 621.436:631.372
Pregledni rad
Review paper

RAZVOJ MOTORJA Z ŽARILNO GLAVO ZA POGON TRAKTORJA

VIKTOR JEJČIČ

Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko, Hacquetova 17, SI - 1000 Ljubljana, viktor.jejcic@kis.si

IZVLEČEK

Dvotaktne dizelske motorje z žarilno glavo so proizvajalci masovno vgrajevali v traktorje v obdobju od dvajsetih pa do konca petdesetih let, zadnje primerke v proizvodnji pa srečamo še na začetku šestdesetih let prejšnjega stoletja. Termin motor z žarilno glavo označuje poseben sistem zgorevanja mešanice goriva in zraka v zunanji komori. To je v bistvu dizelski motor, ki dela v dveh taktih. Motor z žarilno glavo se loči od standardnega štiritaktnega dizelskega motorja po tem da ima manjšo stopnjo kompresije, ki znaša od 1:6 do 1:8. Segrevanje zraka pri taki kompresijski stopnji ne zadostuje za samovžig. Zato se gorivo vbrizga v stisnjeni zrak v posebni komori – »žarilni glavi«, kjer se tudi vžge. Traktorski motorji z žarilno glavo so bili ponavadi eno valjne izvedbe z horizontalno nameščenim valjem. Prednost motorjev z žarilno glavo pred štiritaktnimi bencinskimi motorji, ki so jih vgrajevali nekateri proizvajalci traktorjev je v tem da je motor precej bolj enostaven in robusten (odpadejo različni deli motorja, kot so: ventili, uplinjač, svečke, baterijska vžigalna naprava itn.). Druga prednost tega motorja je bila tudi ta da je lahko deloval z različnim gorivi slabše kakovosti. Obstajale so tudi ideje v novejšem času da bi se ti motorji (v stacionarni izvedbi) uporabljali za proizvodnjo električne energije v državah v razvoju. Tovrstna uporaba je izredno zanimiva, ker bi državam v razvoju omogočila uporabo lokalno proizvedenih goriv npr. rastlinska olja iz različnih oljnic, ki niso primerne za proizvodnjo olja za prehrano, poleg tega pa lahko uspevajo na degradiranih zemljiščih.

***Ključne besede**: dvotaktni dizel motor, žarilna glava, traktorji*

UVOD

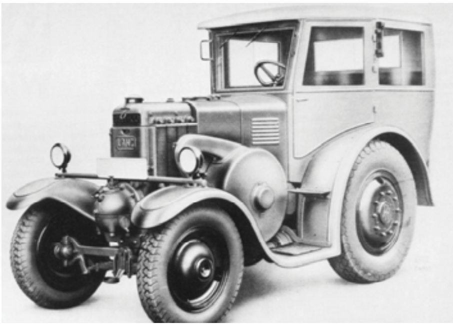
V preteklosti so bili traktorji opremljeni z različnimi pogonskimi motorji. Izvedbe s parnimi motorji so bile prisotne na koncu devetnajstega in začetku dvajsetega stoletja.

Bencinski motorji so bili vgrajevani na traktorje vse do začetka petdesetih let prejšnjega stoletja v Evropi. Prvi traktor z dizelskim motorjem v Evropi je ponudil nemški proizvajalec Benz – Sendling, v dvajsetih letih prejšnjega stoletja v ZDA pa Caterpillar svojo gosenično izvedbo traktorja na začetku tridesetih let prejšnjega stoletja. V Evropi so se dizelske izvedbe traktorjev hitro razširile že pred drugo svetovno vojno prejšnjega stoletja. Od srede dvajsetih let prejšnjega stoletja pa do konca petdesetih let prejšnjega stoletja so v Evropi bile precej razširjene v proizvodnji izvedbe traktorjev z motorji z žarilno glavo, ki so bili v uporabi celo do začetka osemdesetih let prejšnjega stoletja. To so bili dvotaktni dizelski motorji z žarilno glavo, ki so za pogon uporabljali cenejše oblike goriva – težko olje. Zanimivo je omeniti da se v ZDA motorji z žarilno glavo na traktorjih niso nikoli udomačili. Traktorje z bencinskimi motorji pa so v ZDA uporabljali vse do začetka osemdesetih let prejšnjega stoletja. V ZDA so v času druge svetovne vojne in v začetku petdesetih let prejšnjega stoletja v uporabi bile tudi izvedbe traktorjev z bencinskimi motorji, ki so za pogon uporabljali utekočinjeni naftni plin (angl. Liquid Petrol Gas ali skrajšano LPG). V Evropi pa je kot zanimivost potrebno omeniti še traktorje, ki jih je poganjal lesni plin. To so bili traktorji opremljeni z bencinskimi ali dizelskimi motorji, ki so bili v uporabi v obdobju druge svetovne vojne in takoj po njej. V petdesetih letih prejšnjega stoletja so nekateri nemški proizvajalci začeli proizvajati traktorje opremljene z dvotaktnimi bencinskimi motorji. To so bili traktorji majhne moči, ki so bili prisotni samo krajše obdobje na trgu. V eksperimentalne namene so bili razviti tudi traktorji, ki so jih poganjale gorivne celice, fotovoltaične celice oziroma električna energija iz njih, električne izvedbe z akumulatorjem za shranjevanje energije itn. Vendar se je dizelski motor do sedaj izkazal, kot nenadomestljiv za pogon traktorjev in verjetno bo še lep čas tako na področju traktorske tehnike zaradi njegovih številnih prednosti, ki presežejo slabosti oziroma ugodnega razmerja med njegovo ceno in izkoristkom motorja (Jejčič).

ZGODOVINSKI RAZVOJ MOTORJA Z ŽARILNO GLAVO

Stacionarni motor z žarilno glavo je bil prvič narejen v Veliki Britaniji leta 1892 v tovarni Richards Hornsby and Sons. Izumil ga je Herbert Akroyd Stuart, ki je prototip naredil že leta 1886 ter ga leta 1890 patentiral (patent sta prijavila Herbert Akroyd Stuart in Charles Richard Binney). Pomembno je tudi omeniti da je Akroydov izum bil v proizvodnji že dve leti pred Dieselovim motorjem, v podjetju Richards Hornsby and Sons pa so naredili celo 32 417 motorjev po njegovi koncepciji! Po trditvah nekaterih strokovnjakih je originalnost Dieselovega izuma kompresijskega motorja samo v višji kompresiji motorja v primerjavi s Stuartovim motorjem. Današnji dizelski motor združuje koncepcijo direktnega vbrizga goriva in kompresijskega vžiga goriva (predstavljeno že v Stuart - Binney patentu). Leta 1896 so v podjetju Richard Hornsby and Sons naredili tudi prvi traktor s Stuartovim motorjem in lokomotivo. Oba stroja štejeta za prva vozila z motorji s kompresijskim vžigom na svetu. Pozneje je Stuartov motor bil izpopolnjen s strani Mieza in Weissa v ZDA s kombiniranjem z dvotaktnim motorjem, ki ga je razvil Joseph Day.

Motorje z žarilno glavo so začeli masovno aplicirati za ladijsko uporabo na švedskem na začetku prejšnjega stoletja. Motorje z žarilno glavo je proizvajalo več različnih proizvajalcev npr. podjetje Bolinder je izdelovalo eno, dvo in štirivaljne motorje z žarilno glavo z močjo od 7 KM do 600 KM. V ladijski uporabi (veliko jih je bilo namenjenih za pogon ribiških ladij) so bili motorji z žarilno glavo razširjeni v vseh skandinavskih državah do začetka šestdesetih let prejšnjega stoletja, ko so jih začeli zamenjevati sodobnejši dizelski motorji. Poleg ladijske uporabe so začeli motorje z žarilno glavo na švedskem uporabljati tudi za druge namene, kot je uporaba v energetiki, kmetijstvu, industriji itn.. Švedsko podjetje J.V.Svensons Motorfabrik je začelo s proizvodnjo motornega pluga leta 1912, izdelovali pa so ga do leta 1925. V podjetju Munktells Mekaniska Värkstads (Švedska) pa so začeli s proizvodnjo traktorjev z motorji z žarilno glavo leta 1913. Masovna vgradnja motorjev z žarilno glavo v traktorje pa se je začela pri nemškem Lanzu (od leta 1921 do 1957). Kmalu po Lanzu je tudi veliko drugih evropskih proizvajalcev traktorjev začelo vgrajevati ta tip motorja (proizvajalci iz Italije, Francije, Madžarske, Nemčije, Avstralije, Južne Amerike itn.). Poznejši modeli Lanz Buldoga so bili opremljeni z menjalnikom z več prestavami, električno razsvetljavo, pnevmatikami itn. Izpiljena varianta je vidna na sliki 1. Zadnji modeli Lanz Buldoga in modeli ostalih proizvajalcev traktorjev z žarilno glavo iz konca petdesetih let prejšnjega stoletja pa so bili opremljeni z električnim zaganjačem, oblikovno pa niso posebej odstopali od traktorjev tistega časa z bencinskimi in dizelskimi motorji.

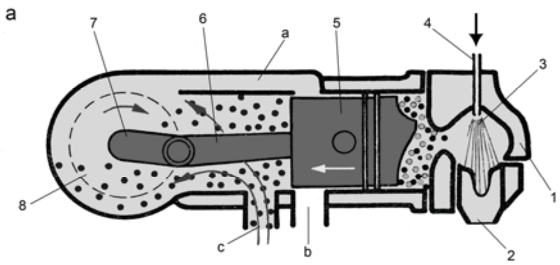


Slika 1 Traktor z motorjem z žarilno glavo, vidna je na prednjem delu (Lanz, Bulldog)

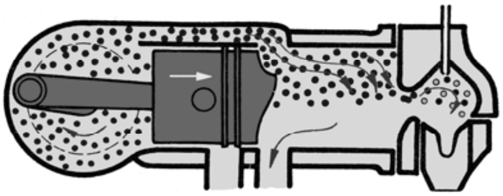
DELOVANJE MOTORJA Z ŽARILNO GLAVO

Po načinu delovanja motorje, ki so se vgrajevali v traktorje lahko razdelimo v več skupin: štiritaktni bencinski motorji, dvotaktni bencinski motorji, motorji z žarilno glavo (dizelski dvotaktni motorji), štiritaktni diezelski motorji in dvotaktni dieselski motorji.

Termin motor z žarilno glavo označuje poseben sistem zgorevanja mešanice goriva in zraka v zunanji komori. To je v bistvu dizelski motor, ki dela v dveh taktih. Zrak prihaja v valj motorja v taktu vsesavanja, ko se bat spušča proti spodnji mrtvi točki. V tem taktu se gorivo vbrizga v žarilno glavo z mehansko batno črpalko skozi šobo za vbrizg goriva. Zaradi vbrizga goriva in segrevanja žarilne glave se gorivo uplini. Zrak v valju se potem začne gibati proti zgornjem delu valja (takt kompresije) in skozi odprtino v žarilno glavo, kjer se komprimira, njegova temperatura pa začne naraščati. Uplinjeno gorivo iz žarilne glave se premeša s komprimiranim zrakom in vžge zaradi kompresije in temperature žarilne glave. Izgorelo gorivo potisne bat navzdol, ki poganja ročično gred povezano z vztrajnikom.



a)



b)

Slika 2 Sestavni deli motorja z žarilno glavo: 1 – žarilna glava, 2 – prostor za grelec za začetno segrevanje žarilne glave, 3 – zgorevalni prostor, 4 – šoba za vbrizg goriva, 5 – bat, 6 – batnica, 7 – ročična gred, 8 – prostor za tlačenje zraka; a – odprtina za dotok stlačenega zraka v valj, b – odprtina za izpuh zgorelih plinov, c – odprtina za vsesavanje zraka;

V momentu ko se bat nahaja v zgornji mrtvi točki (slika 2. a) se s pomočjo črpalke za gorivo vbrizga gorivo (plinsko olje) v stlačeni zrak skozi šobo (št. 4) v zgorevalni prostor (št. 3 - žarilna krogla), kjer se gorivo vžge. Po vžigu goriva in zgorevanju goriva se zveča tlak zgorelih plinov na bat, ki potisnejo bat v spodnjo mrtvo točko (slika 2. b). Ko plini potisnejo bat proti spodnji mrtvi točki, bat najprej odpre odprtino označeno z **b** za izpuh plinov. Ker zgoreli plini imajo na koncu ekspanzije večji tlak od zunanjega zraka, plini uhajajo z veliko hitrostjo iz valja. Nekoliko pozneje se odpre tudi prostor označen z **a**. Iz prostora označenega s št. 8 začne prihajati stlačeni zrak skozi odprtino **a** v valj. Ko bat pride do zgornje mrtve točke se vžge vbrizgano gorivo (mešanica goriva in zraka) v valju in proces se ponovi. Zrak prihaja (motor ga vsesava) skozi odprtino **c** v prostor, označen z št. 8 ko se bat giblje od spodnje proti zgornji mrtvi točki. Ko se bat giblje od zgornje proti spodnji mrtvi točki pa se zrak v prostoru št. 8 stlači. (po Fantoniju)

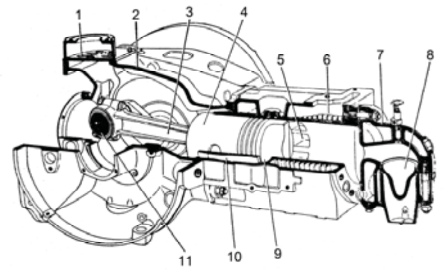
Motor z žarilno glavo se loči od standardnega štiritaktnega dizelskega motorja po tem da ima manjšo stopnjo kompresije, ki znaša od 1:6 do 1:8. Segrevanje zraka pri taki kompresijski stopnji ne zadostuje za samovžig. Zato se gorivo vbrizga v stisnjeni zrak v posebni komori – »žarilni glavi«, kjer se tudi vžge. Zgorevalna komora »žarilna glava« je v večini primerov dobro vidna na sprednjem delu traktorja, kar mu daje tudi značilno obliko. Tlak stisnjenega zraka v zgorevalni komori znaša približno do 16 bar. Motor se spravi v pogon tako da se zgorevalna komora segreje z bencinskim ali petrolejskim gorilnikom, kar traja nekaj časa (lahko tudi električnim). Gorilnik se vstavi v posebno odprtino v žarilni glavi. Ko je komora segreta do žarenja se motor zažene z ročnim zaganjačem ali pri nekaterih izvedbah že z elektro zaganjačem (pri zadnjih izdelanih modelih teh motorjev na traktorjih). Pri starejših Lanz Bulldogih je za zagon bilo potrebno po segrevanju žarilne glave sneti volan, ki je služil tudi kot, zaganjač (izraz "kurbl" v uporabi med traktoristi). Za hitri zagon motorja so se uporabljali tudi posebni eksplozivni naboji, ki so se vstavili v odprtine na žarilni glavi in tako pognali motor, vendar so jih uporabniki malo uporabljali zaradi razmeroma visoke cene. Ko motor enkrat deluje gorilnik ni več potreben, ker je žarilna glava segreta zaradi zgorevanja goriva v njej. Na zgornjem delu žarilne glave je bil nameščen ventil s katerim se je reguliral dotok goriva v zgorevalno komoro žarilne glave. Pri neobremenjenem motorju se gorivo usmeri s pomočjo ventila da skozi šobo prihaja v zgorevalno komoro v zelo ozkem curku, pri obremenjenem pa se ventil odpre tako da

gorivo prihaja v širokem curku. Traktorski motorji z žarilno glavo so bili ponavadi eno valjne izvedbe z horizontalno nameščenim valjem. Prostornina teh motorjev se je gibala ponavadi od 4000 cm^3 do 13 000 cm^3, nominalno št. vrtljajev pa od 600 do 1200 vrt./min. (odvisno od izvedbe). V praznem hodu so imeli zelo majhno št. vrtljajev npr. Lanz, Bulldog, 300 – 350 vrt./min. Prednost motorjev z žarilno glavo pred štiritaktnimi bencinskimi motorji, ki so jih vgrajevali nekateri proizvajalci traktorjev iz tega obdobja je v tem da je motor precej bolj enostaven in robusten (odpadejo deli motorja kot so: ventili, vplinjač, svečke, vžigalna naprava itn.). Druga prednost tega motorja je bila tudi da je lahko deloval s plinskim oljem slabše kakovosti. Tlak vbrizga goriva pri teh motorjih znaša do 10 bar zato je črpalka za vbrizg goriva enostavnejša in cenejša od črpalke pri dieselskem motorju.

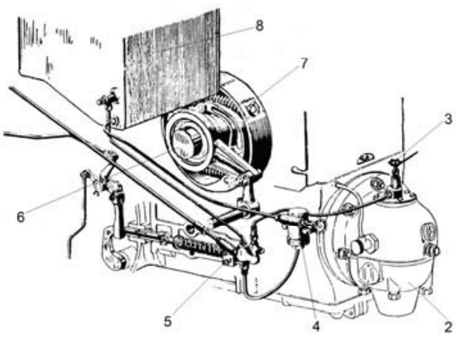
Hlajenje motorjev z žarilno glavo je bilo v večini primerov vodno – termosifonsko. Tudi del žarilne glave je hladila voda. Nekateri motorji z žarilno glavo pa so imeli že vodno hlajenje pod tlakom (s pomočjo črpalke za vodo). Ta sistem je podoben termosifonskem s to razliko da je v tok vode iz hladilnika v vodni plašč vstavljena črpalka, ki pospeši cirkulacijo vode, ki na ta način hitreje ohlaja motor. Mazanje teh motorjev je tlačne izvedbe s posebno oljno črpalko. Olje je prihajalo do vseh površin, ki se tarejo npr. stene valjev, batne osi, ležaji na ročični gredi itn.

Tabela 1 Bistvene razlika med dizelskim motorjem in motorjem z žarilno glavo

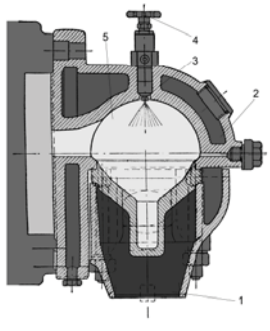
Dizelski motor	Motor z žarilno glavo
Uporablja se samo kompresijski vžig	Uporablja kompresijski vžig in toploto razvito v žarilni glavi za vžig goriva
Gorivo se vbrizga v končni fazi kompresijskega takta	Gorivo se vbrizga v žarilno glavo v času takta sesanja ko zrak gre v valj motorja
Kompresijsko razmerje 1 : 15 - 20	Kompresijsko razmerje 1 : 6 – 8
Gorivo - mineralno dizelsko gorivo v skladu s standardom za goriva za dizelske motorje	Gorivo – različne frakcije nafte, rastlinsko olje, živalske maščobe, odpadna motorna olja, zemeljski plin ter celo premogov prah itn.



Slika 3 Prerez skozi prostorsko prikazan motor z žarilno glavo traktorja (Lanz, Bulldog): 1 - odprtina za vsesavanje zraka, 2 - ohišje, 3 - batnica, 4 - bat, 5 - odprtina za izpuh, 6 - valj, 7 - glava valja, 8 - žarilna glava za vžig goriva, 9 - odprtina za vstop zraka v valj, 10 - kanal za zrak, 11 - ročična gred



Slika 4 Črpalka za dovod goriva in regulator števila vrtljajev na traktorju z žarilno glavo (Lanz, Bulldog): 1 – žarilna glava, 2 – odprtina za gorilnik za segrevanje žarilne glave, 3 - ventil za nastavljanje curka goriva na šobi nameščeni v zgorevalni komori, 4 – filter za gorivo, 5 – črpalka za gorivo, 6 – del, kjer se natakne zaganjač (volan) na ročično gred motorja, 7 – regulator števil vrtljajev motorja, 8 – rezervoar za gorivo



Slika 5 Prerez skozi žarilno glavo (Lanz, Bulldog): 1 – odprtina za gorilnik za segrevanje žarilne glave, 2 - prostor za vodo za hlajenje žarilne glave, 3 – šoba za gorivo, 4 - ventil za nastavljanje curka goriva v zgorevalni komori, 5 – zgorevalna komora

Prednosti motorja z žarilno glavo

Prednosti motorja z žarilno glavo v primerjavi s parnim strojem, ki je na začetku dvajsetega stoletja bil masovno razširjen v uporabi na kmetijskih in drugih lokomobilah je v tem da ga je precej bolj enostavno izdelati in upravljati. V primerjavi s celotnim parnim strojem in kotlom za pripravo pare ima neprimerno manjše število delov. Parni stroj potrebuje najmanj eno osebo za nadzor kotla ter dodajanje vode in goriva. Motor z žarilno glavo v primeru da je opremljen z avtomatskim sistemom mazanja in regulatorjem, ki nadzoruje dobavo goriva, lahko pustimo ure in ure (celo dneve) v delovanju brez nadzora. Druga zelo pomembna stvar je njegova varnost. V primeru da je varnostni ventil na kotlu zatajil je lahko prišlo do nevarne eksplozije (redkost pri izpiljenih izvedbah parnih strojev v tistem času vendar se je kdaj tudi zgodilo). Drugi problem je bil da v primeru da je nivo vode v kotlu postal prenizek je lahko prišlo do talitve ali razpadanja kotla. Motor z žarilno glavo je za uporabo izredno varen, če je ostal brez goriva se je enostavno ustavil, hladilna voda (zaprti krog hlajenja najpogosteje) pa v primeru da je prišlo do izpuščanja, povzročila pregretje motorja (ne eksplozije) in njegovo ustavljanje zaradi poškodbe. Zaradi dolgega časa predgrevanja motor z žarilno glavo ni bilo problem zagnati tudi v območjih z hladno klimo, kot je npr. v Kanadi in Skandinavskih državah. Sama konstrukcija motorja je tudi bolj enostavna v primerjavi z bencinskimi izvedbami (ni električnega sistema za vžig goriva odpade pa tudi kotel, ki je obvezno prisoten pri parnem stroju). Zaradi nizkega kompresijskega razmerja pa ga tudi ni bilo problem zagnati. Motorji z žarilno glavo so imeli izredno dolgo življensko dobo zaradi počasnega teka. Znani so primeri, ko so ti motorji delovali tudi do 40 000 delovnih ur na traktorjih.

Slabosti motorja z žarilno glavo

Motor z žarilno glavo je imel zelo ozko območje števila vrtljajev, tako da ga je bilo težko uporabiti za pogon osebnih ali tovornih vozil. Največ se je uporabljal za pogon traktorjev, gradbenih strojev, manjših ladij in stacionarnih strojev, kjer število vrtljajev motorja ne igra pomembne vloge. Čas zagona, ki je daljši, kot pri drugih motorjih pa ni igral pomembne vloge, ker so ga uporabljali za pogon strojev, ki tečejo veliko ur ali dni in omenjeni čas predstavlja samo majhen odstotek od celotnega časa delovanja.

Na traktorje so proizvajalci vgrajevali eno valjne motorje z žarilno glavo izjemno velike prostornine, ki je dosegala tudi do 20 000 cm^3. Delovanje zaradi enega valja je bilo nemirno, zaradi ležeče izvedbe valja pa so se vibracije prenašale na celoten traktor v vzdolžni smeri ter na samega voznika. Motor z žarilno glavo je bil omejen glede razmerja med svojo maso in močjo. Zaradi nizkega kompresijskega razmerja v primerjavi z dizelskim motorjem je imel tudi nižji izkoristek, moč in število vrtljajev. Večina motorjev z žarilno glavo je imela maksimalno število vrtljajev 100 vrt./min., v tridesetih letih prejšnjega stoletja pa so dizelski motorji že dosegali število vrtljajev 2000 vrt./min..

Opuščanje motorjev z žarilno glavo

Dizelski motor je v prvi fazi zaradi svoje velikosti in teže bil namenjen samo za pogon ladij in velikih stacionarnih strojev. Vbrizg goriva pri prvih velikih izvedbah ladijskih dizelskih motorjev je bil rešen s pomočjo visokega tlaka stlačenega zraka, ki je zajel gorivo, ki je prihajalo v zračni tok (zračna podpora). Šele uvajanje mehanskega načina vbrizgavanja goriva je omogočilo zmanjševanje dimenzij in mase dizelskega motorja tako da ga je bilo mogoče vgraditi tudi v cestna vozila. Mehanska črpalka in vbrizgalne šobe, ki jih je dejansko razvil že Herbert Akroyd Stuart za svoj motor z žarilno glavo ter pozneje dodelal Robert Bosch je omogočila da so dizelski motorji postali praktični za uporabo. Dizelskim motorjem so z tem izumom povečali kompresijo in število vrtljajev, kar je omogočilo razvoj hitro tekočih dizelskih motorjev. Z uvajanjem manjših in lažjih izvedb dizelskih motorjev je začelo obdobje zatona motorjev z žarilno glavo. Dizelski motorji lahko dosegajo tudi do 50 % izkoristek. Razvoj manjših dizelskih motorjev v tridesetih in štiridesetih letih prejšnjega stoletja, ki so bili primerni za pogon električnih generatorjev na agregatih za proizvodnjo električne energije je tudi s tega področja izrinil motorje z žarilno glavo.

ZAKLJUČEK

Motorji z žarilno glavo so danes v javnosti skoraj popolna neznanka. Masovno so jih vgrajevali v traktorje v obdobju od dvajsetih pa do konca petdesetih let, zadnje primerke pa srečamo še na začetku šestdesetih let prejšnjega stoletja npr. francoski traktor proizvajalca Vierzon. Značilni traktorji s tem motorjem so od naslednjih evropskih proizvajalcev: Lanz, Landini, Orsi, HSCS, Bubba, Ursus, S.F.Vierzon, Bolinder, Marshall itn. V današnjem času se najdejo maloštevilni motorji z žarilno glavo v odmaknjenih delih sveta, kjer služijo za pogon stacionarnih strojev ter na nekaterih starih evropskih izvedbah ladij za ribiške namene v severnem morju in turistično plovbo po rekah in kanalih severne Evrope. Motorji, ki se danes uporabljajo v letalskem modelarstvu so zelo podobni (razlikujejo se po visokem številu vrtljajev) po načinu delovanja takratnim motorjem z žarilno glavo in predstavljajo zadnjo reinkarnacijo motorjev z žarilno glavo. Obstajale so tudi ideje v novejšem času da bi se ti motorji v stacionarni izvedbi uporabljali za proizvodnjo električne energije v državah v razvoju. Tovrstna uporaba je izredno zanimiva, ker bi državam v razvoju omogočila uporabo lokalno proizvedenih goriv npr. rastlinska olja iz različnih oljnic, ki niso primerne za proizvodnjo olja za prehrano, poleg tega pa lahko uspevajo na degradiranih zemljiščih.

LITERATURA

1. Bedosti A. (1995). Il trattore agricolo. Edagricole – Edizioni Agricole, Bologna, 11 - 12
2. Fantoni R. (1954). Poljoprivredni strojevi. Poljoprivredni nakladni zavod Zagreb, Zagreb, 119 - 121
3. Flücht H., Blum H. (1942). Schlepper und anbaugeräte. Handbuch des Deutschen Schlepperbaues, Verlag A.H. Flücht, Berlin – Charlottenburg, 32 - 36
4. Jejčič V. (1999). Obnavljamo stari traktor. Tehnika in narava, ČZD Kmečki glas, Ljubljana 1(3): 52 - 53
5. Jejčič V. (2007): Traktor. ČZD Kmečki glas, Ljubljana, 15 - 17

DEVELOPMENT OF HOT BULB ENGINES FOR TRACTOR DRIVING

SUMMARY

Two - cycle hot bulb engines or heavy oil engines were built on a mass scale in tractors by manufacturers in the period from the twenties until the end of the fifties, but the last specimens could be still encountered at the beginning of the sixties of the previous century. The term hot bulb engine designates a special combustion system of a mixture of fuel and air in the external chamber. Essentially, this is a diesel engine functioning at two cycles. The hot bulb engine differs from the standard four-cycle diesel engine by having a lower compression ratio ranging from 1:6 to 1:8. Heating of air at such compression ratio does not suffice for self-ignition, so the fuel is injected in compressed air in a special chamber – »hot bulb«, in which it ignites. Hot bulb engines were usually one-cylinder types with horizontally installed cylinder. The advantage of hot bulb engines over four-cycle petrol engines, which were introduced by some tractor manufacturers from that period, lies in the fact that the engine is simpler and more robust (engine parts, such as valves, carburettor, electric device for fuel ignition etc., become redundant). Another advantage of this engine was its ability to function with different fuels of lesser quality. Recently, some ideas were considered to use these stationary engines for driving of stationary machines and for electricity production in developing countries. This is an extremely interesting offer since it would allow the developing countries to utilise locally produced fuels, such as pure plant oils from various oil plants that may be produced from oil seeds which are unsuitable for food and on degraded lands.

***Key words**: two-cycle diesel engines, hot bulbs, tractors*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.94:629.114.2:631.372
Stručni rad
Expert paper

TRACTION BAR TESTING OF A 220 HP TRACTOR IN SIMULATED AND ACCELERATED REGIME, ITS ANALYSIS BY FEM FOR DETERMINING RUPTURE RESISTANCE

V. VLADUŢ[1)], M. MATACHE[1)], N. FAUR[2)], S.ŞT. BIRIŞ[3)], G. PARASCHIV[3)], S. BUNGESCU[4)]

[1)]INMA Bucharest, [2)]Polytechnic University of Timisoara, [3)]Polytechnic University of Bucharest, [4)]Agricultural University of Timisoara - Romania

SUMMARY

The traction bar, as well as other traction equipments, is usually tested at fatigue on the tests installation in simulated and accelerated behaviour to a number of 2000000 cycles (in accordance with the Directive 89/173/CEE) in order to determine if after the stresses strains or ruptures arise. In this case with the help of an analysis programme using finite elements bares fatigue behaviour was simulated on the computer, being precisely determined the most solicitudes points and the maximum risk areas where the ruptures will arise.

Key words*: testing, deformation, tractor, analysis, fatigue*

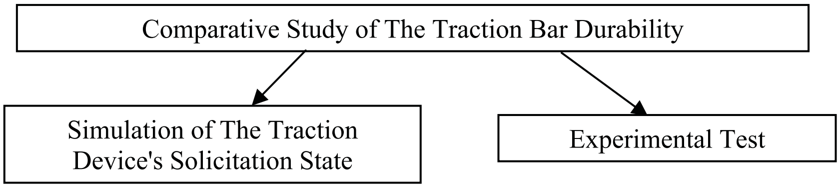
INTRODUCTION

The traction bar of the Universal Tractor T 195 – U model is mounted on the rear chassis of the tractor and has as objective establishing the connection between the towing vehicle and the towed vehicles. It is a subassembly strong stressed and represents one of the components which contribute essentially to safety in exploitation. This one is a swinging bar type and it is positioned in the longitudinal median plane of the tractor (Figure 2).

For satisfying the tough requirements in exploitation, this bar has to be subjected to the following tests:

- type tests: these are executed on a randomly chosen specimen from the series production and have as purpose the conformity evaluation with the technical documentation "series valid"

- allotment tests: are executed by specialized staff, on the manufacturing flux and at the allotment ending and have as purpose the conformity verification of the traction device with the technical documentation "series valid"
- supervision tests: are effectuated for product conformity supervision with the specified conditions in the company standard.



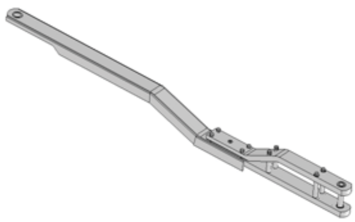


Figure 1 Geometric Model [1]

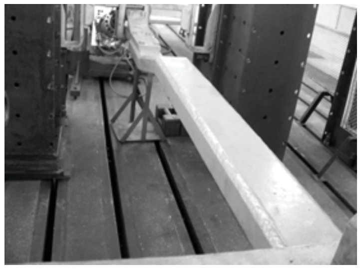


Figure 2 Testing Stand [1]

MATERIALS AND METHOD

For tractor's T 195 - 1U traction bar certification/homologation obtaining, in view of mounting it on tractors or to sell it as spare parts, it is necessary a study regarding the resistance and the lifetime of the product in the case of an equivalent load with the real one, effectuated on the base of a simulation with the finite elements method [1] and checked by an experimental test [2], [3], [4].

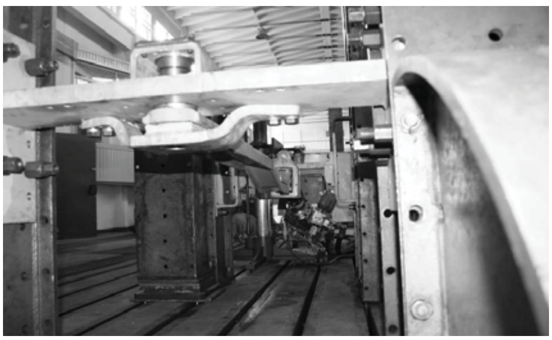


Figure 3 Full view at the weariness tests of the traction bar on the HYDROPULSE installation from INMA Bucharest endowment

Experimental tests

The experimental test was realized inside the National Institute for Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest [2], [3], [4] on the presented testing stand in Fig. 3÷5.

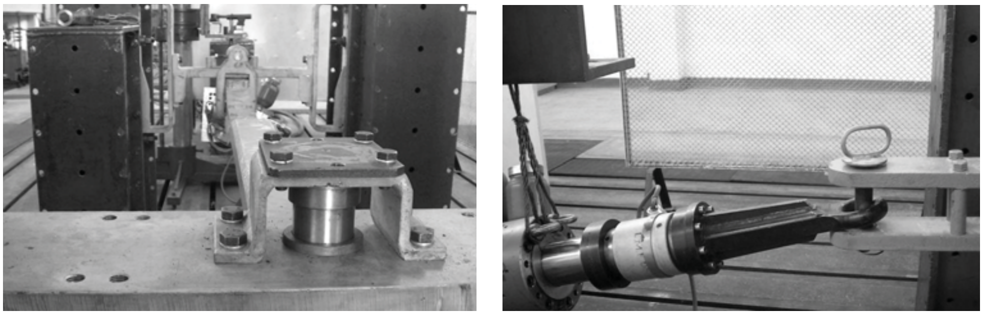


Figure 4 Details of the HYDROPULSE type installation

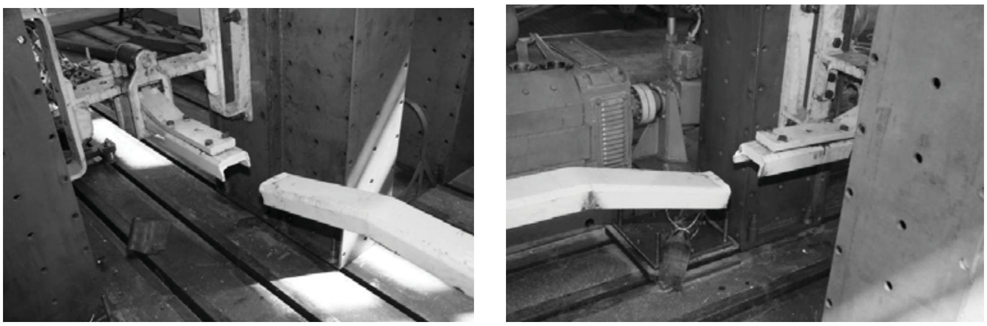


Figure 5 Full views of the area in which produced the breakage at weariness of the traction bar

Used hypothesis

- *load* with a force leaning 24,9° towards the horizontal line, applied after a pulsating cycle with the asymmetry degree R_s=0,06; F_{max}=84,9 KN; F_{min}=5 KN;
- *suspension* identical with the one realized on the INMA's stand;
- *the geometric model* was realized based on the documentation made available by INMA. It was realized the assembly traction bar based on all the execution drawings, using SolidWorks 2007 software.

The materials from which the traction devices are made from are:

- steels of general use for constructions (STAS 500/2);
- high quality carbon steels for heat treatment (STAS 880);

- cast iron with nodular graphite (SR EN 1563);
- steels for pipes without welding (STAS 8183).

The analysis with the finite elements method was applied on the geometric model presented in figure 1 and was realized using simulation program Ansys.

For geometric model digitization were used elements of type Solid 186, the digitized model having 32199 elements cu 62078 nodes (Fig. 6) [1];

The conditions on contour and the load applied to the geometric model consist of a fixed suspension device fix (Fig. 7a), a suspension device which enables the traction device's displacement on the axial direction (Fig. 7b) and a traction force applied under an angle of 24,5° towards the horizontal line (Fig. 7c) [1].

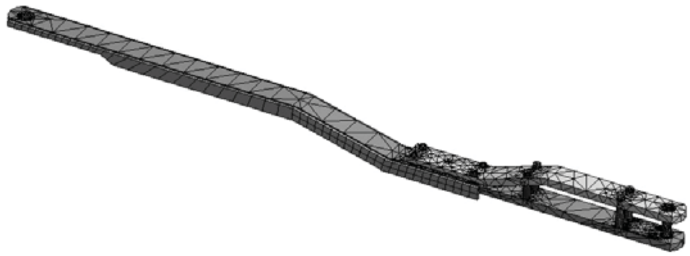
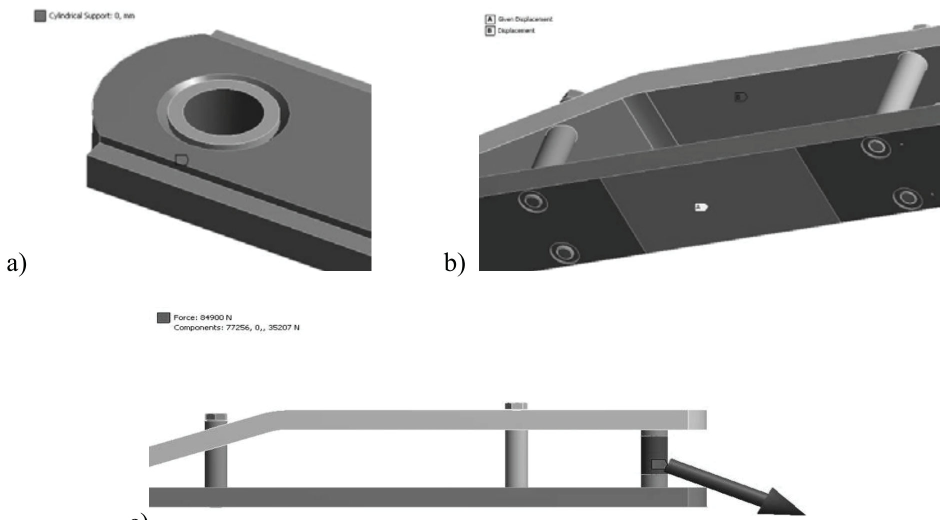


Figure 6 Digitized model



a) b) c)

Figure 7 Conditions on contour

RESULTS AND DISCUTIONS

The static analysis's results using the finite element method have permitted a relieving of the tension and deformation state (fig. 8, 9 and 10) as also the ascertainment of the critical areas:

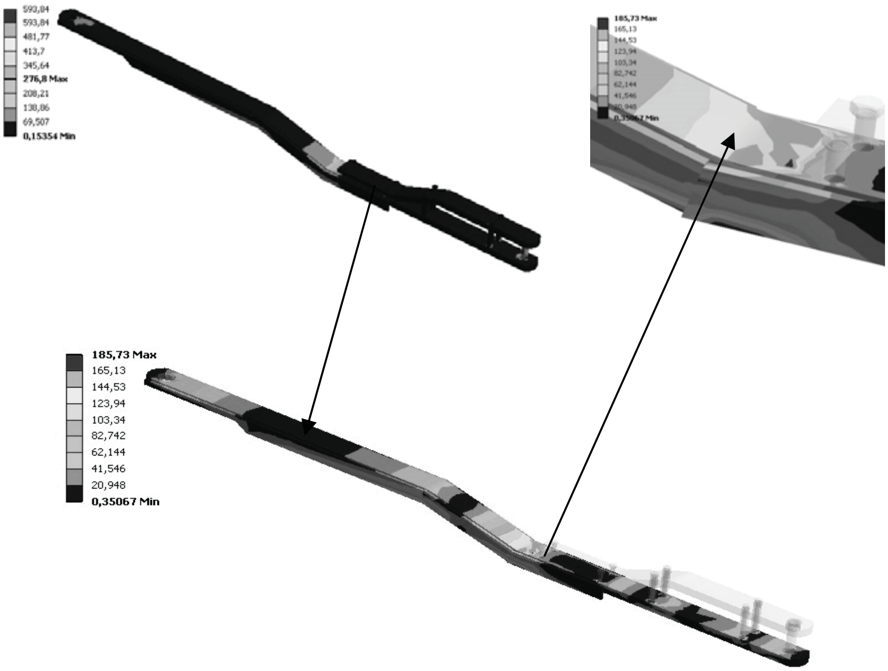


Figure 8 Von Mises equivalent tension [MPa]

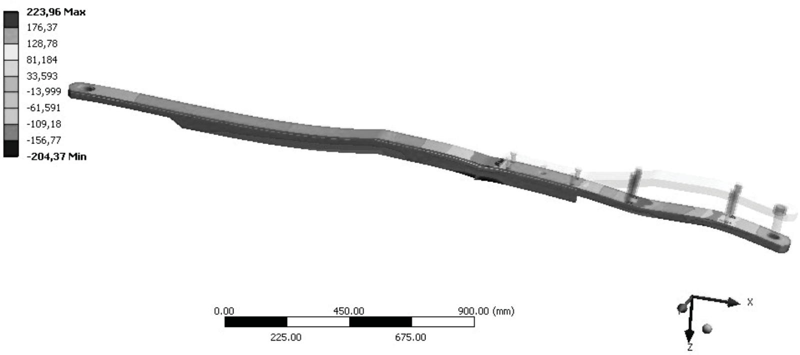


Figure 9 Normal tension σx [MPa]

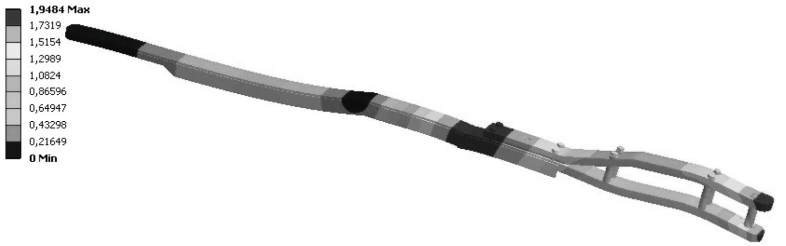


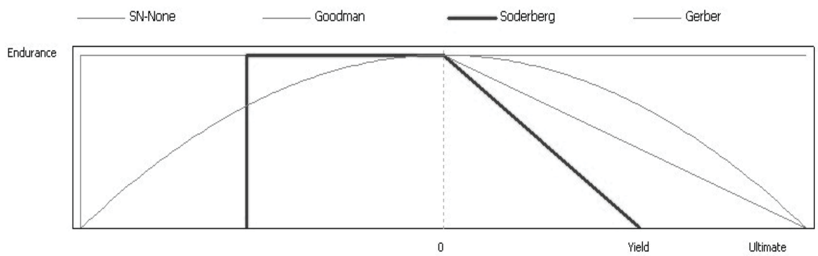
Figure 10 Total deformation [mm]

The determination of the lifetime and of the weariness safety coefficient

The weariness calculus was realized on a number of $1e^7$ solicitation cycles with constant amplitude based on the equivalent distribution Von Mises.

The asymmetry coefficient of the solicitation cycles is: R= 0,058

The lifetime calculus was realized based on the limit cycles theory, diagram Haigh, for which was used the Soderberg schematization (Fig. 11)



$$\frac{\sigma_{aL}}{\sigma_{-1}} + \frac{\sigma_{mL}}{\sigma_C} = 1$$

Figure 11 Soderberg schematization (safety coefficient) [1]

Figure 12 Lifetime

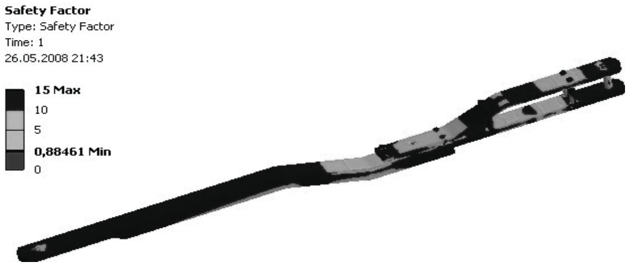


Figure 13 Safety coefficient

CONCLUSIONS

- After the weariness tests effectuated at INMA Bucharest the traction bar broke in two halves, according to Fig. 5, in the welding area of the strengthening nervures, at 1070 mm from the axle of the linkage bolt to the trailer.
- The number of cycles experimental determined at which it has been produced the breakage was of 1.805.320 complete cycles of traction solicitation.
- The static calculus model elaborated in view of simulating the solicitations by adopting the presented calculus hypotheses, has confirmed the endangered area in which appear the maximum tensions, which corresponds to the breakage area. From this conclusion resulted a first confirmation of the right choice of the calculus model.
- Based on the weariness phenomenon simulation with the finite elements method it was calculated the lifetime expressed by the total number of cycles of 1.798.000.
- Comparatively between the experiment and the numeric simulation there is a percentage error of 0,5 %, which confirms the right choice of the calculus model.
- The cost price of the simulation is much more reduced comparative with the one of the experiment.
- The calculus model elaborated this way can be used efficiently for studying the durability of new constructive versions of the traction bar.

REFERENCES

1. Cernescu A., Faur N., Vlăduţ V., Biriş S. - Studiu asupra comportării la oboseală a dispozitivului de tracţiune pentru Tractor T 195 - 1U, International Workshop "The Modelling with Finite Element and The Solicitation State Simulation of a Industrial Component ", 27 May 2008, ISIM Timişoara;
2. Mihai M., Ganga M., ş.a. - Încercarea mecanică a barei de tracţiune asamblate a tractorului Zimbru 2200, Research report, INMA Bucureşti, 2007.

3. Vlăduţ V., Ganga M., Matache M., ş.a - Încercări complexe de echipamente pe instalaţia de încercări simulate şi accelerate tip hidropuls în cadrul reţelei cu utilizatori multipli, Research report, INMA Bucharest, 2007;

4. Vlăduţ V., Ganga M., Matache M., ş.a - Demonstrarea impactului rezultatelor încercărilor complexe asupra armonizării produselor la cerinţele pieţei UE, Research report, INMA Bucharest, 2007.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.14.012.55
Stručni rad
Expert paper

EVALUATION OF THE TIRE – GROUND SHEAR AREA: COMBINING THE MODEL AND EXPERIMENTAL DATA

[1] RADU ROSCA, [1] PETRU CARLESCU, [1] DAN CAZACU, [1] BOGDAN AVARVAREI, [2] EDWARD RAKOSI, [2] GHEORGHE MANOLACHE

[1]University of Agricultural Sciences Iasi, Romania
[2]Technical University "Gh. Asachi" Iasi, Romania.

SUMMARY

The tire driving force is the resultant of the elementary shear forces acting under the running gear contact area; while the tire – ground contact area may be assumed to be constant, the sheared area varies during the tractive activity exerted by the tire. As a result, it may be considered that the tractive force is the result of the elementary forces acting along the portion of the contact area that participates in the shearing process. Starting from this idea, the paper tries to evaluate the shearing area using a traction model previously developed by the authors and experimental traction data. The traction model and the field tests referred to the driving tires of a Romanian U-650 tractor; comparison between experimental data concerning the traction force given by the traction model allowed evaluation of the shear area, using a Komandi type relationship, assuming that shear area is linked to the tire-ground contact area by the means of a wheel slip depending parameter D(s). Using the LABFit software in order to calculate the coefficients involved in the D(s) relationship developed by G. Komandi led to conclusion that this equation did not seem to be appropriate for the evaluation of the shear area, at least not for our test conditions. A much better goodness-of-fit between the measured traction forces and the ones predicted by our model was achieved when a power type relation was used in order to describe the D(s) parameter.

***Keywords**: tire traction, wheel slip, traction model, shear area*

INTRODUCTION

The traction of the wheel is a complex physical process and prediction of the traction performance of a tractor wheel depends largely on the model of the tire-terrain interaction.

Some models use analytical approaches (commercial CAD or FEM programs), others use semi-empirical or empirical approaches (based on the model proposed by Bekker, Wong etc.) [1].

The semi-empirical method for traction prediction developed by Bekker assumes that the vertical deformation of the soil under the wheel load is similar to the one produced by a sinkage plate and that the shear deformation of the soil due to a traction device is similar to the shear action performed by a rectangular or torsional shear device. In this paper, the semi-empirical approach is used in order to evaluate the wheel-soil pressure and shear stress in soil; as shown in other papers [6, 7], the results given by this model are confirmed by experimental data. The values of the soil constants used by the model are obtained from plate penetration tests and shear stress-shear displacement tests.

In most of the developed traction motion models the shearing surface is considered to be constant. As Komandi has shown in [5], "The shearing surface varies while the tire develops the tractive force but, for practical purposes, shear stress does not change, except for a very small decrease which may occur after sliding begins. The shearing surface can vary from zero to the entire contact surface". Taking these facts into account we decided to combine a previously developed model for predicting the shear stress and experimental traction data in order to establish whether the Komandi equation may be applied for our soil conditions, or, otherwise, to find a valid equation for the variable shearing surface.

TRACTION MODEL

The traction model is based on the schematics shown in Figure 1a. The model assumes that, under the vertical load (G), the wheel sinks into the soil, reaching depth (z_c) and the load induces tire deflection (z_p). As a result, the radius of the contact patch becomes r_d ($r_d > r_0$), and the circular length of the contact patch is:

$$l_c = 2 \cdot \beta \cdot r_d = 2 \cdot \alpha \cdot r_0 \,. \tag{1}$$

From Figure 1 we have:

$$z = O\overline{E} - O\overline{A} \tag{2}$$

and we finally get:

$$z = r_d \cdot [\cos(\beta - \varphi) - \cos \beta] \tag{3}$$

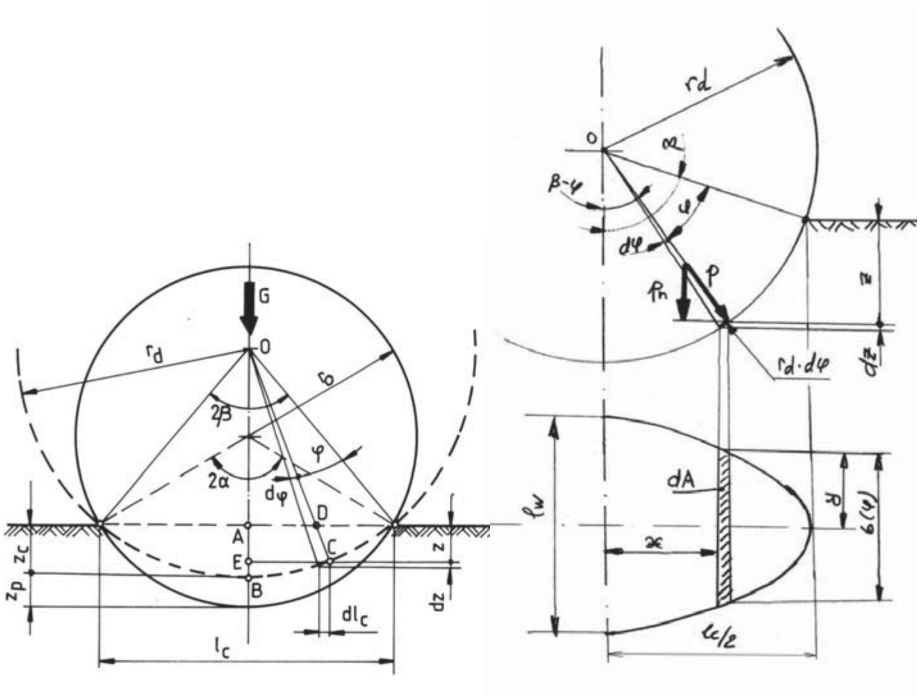
Using the Bekker equation $p = k \cdot z^n$ results in:

$$G = \int_0^{2\beta} p \cdot b(\varphi) \cdot r_d \cdot \cos(\beta - \varphi) \cdot d\varphi =$$

$$= k \cdot \int_0^{2\beta} r_d^{n+1} \cdot \left[\cos(\beta - \varphi) - \cos\beta\right]^n \cdot b(\varphi) \cdot \cos(\beta - \varphi) \cdot d\varphi, \tag{4}$$

where, according to Figure 1b:

$$b(\varphi) = \sqrt{\frac{1 - 4 \cdot l_w^2 \cdot r_d^2 \cdot \sin^2(\beta - \varphi)}{l_c^2}} \tag{5}$$



a) b)

Fig. 1 Schematics of the model

Assuming the tire is perfectly elastic, we have [3]:

$$G = q_p \cdot b \cdot \frac{4}{3} \cdot \left(\alpha^3 \cdot r_0^2 - \beta^3 \cdot r_d^2\right) \tag{6}$$

where q_p is the volume deflection constant of the tire.

From (4) and (6) we get:

$$k \cdot \int_0^{2\beta} b(\varphi) \cdot r_d^{n+1} \cdot [\cos(\beta - \varphi) - \cos\beta]^n \cdot \cos(\beta - \varphi) \cdot d\varphi +$$

$$+ \frac{4}{3} \cdot b \cdot q_p \cdot \beta^3 \cdot r_d^2 = \frac{4}{3} \cdot b \cdot q_p \cdot \alpha^3 \cdot r_0^2 \tag{7}$$

From Figure 1 we also have:

$$z_c = r_0 - z_p - r_0 \cdot \cos\beta \tag{8}$$

$$z_p = r_0 \cdot (1 - \cos\alpha) - r_d \cdot (1 - \cos\beta) \tag{9}$$

The system consisting of equations (1), (7), (8) and (9) is solved with a computer program, using an iteration process, as shown in [7].

The contact patch is assumed to have an elliptical shape [12], with l_c the major axis and l_w the minor axis; the area of the contact patch is:

$$A_t = \frac{\pi}{4} \cdot l_c \cdot l_w \text{, if } l_w < b \tag{10}$$

$$A_t = \frac{l_c \cdot l_w}{4} \cdot (\pi - 4 \cdot k_f) \text{, if } l_w = b \tag{11}$$

According to Komandi [5], the traction force is given by the sheared area and not by the overall area of the contact patch; moreover, the sheared area varies during the tractive activity exerted by the tire:

$$A_{sh} = A_t \cdot D(s) \tag{12}$$

$$F_t = \tau \cdot A_{sh} - R_r \tag{13}$$

where A_{sh} is the sheared area, s is the wheel slip, F_t is the traction force, τ is the shear stress on the tire-terrain interface and R_r is the wheel rolling resistance. The variable parameter D(s) is given by Komandi as a function of wheel slip:

$$D(s) = 1 - (1 - s) \cdot e^{-c_1 \cdot l_c^{m_1} \cdot s^{m_2}} \tag{14}$$

and the values of the constants c_1, m_1 and m_2 depend upon the nature of the ground surface, as shown in Table 1.

Table 1 Values of the constants

Contact surface	c_1	m_1	m_2
Concrete road	30	0.8	1.2
Wheat stubble loam soil	7	0.6	1.0
Sand, wheat stubble	5	0.5	1.0
Bare loose sand	20	0.8	1.0

EXPERIMENTAL SETUP

For this work the U-650 tractor was modeled. The main characteristics of the tractor and drive tire are shown in Table 2.

Table 2 Characteristics of the U-650 tractor and drive wheels

Item	Value
Load on the drive tire [kN]	11.75
Type of drive tire	14.00 – 38
Overall diameter of tire [m]	1.58
Tire width [m]	0.367
Lug width [m]	0.04
Lug length [m]	0.24
Lug height [m]	0.025
Distance between lugs [m]	0.195
Transversal radius of the undertread [m]	0.3

During the experiments, drive wheel slip and net traction force Ft,ef,r were measured directly; the results are shown in Figure 2. The experimental data were collected during field tests of the U650+P2V ploughing unit (aiming to evaluate the quality of the plough's working process); during these tests drive wheel slip was not allowed to exceed 30% because such high values must be avoided during the ploughing process. Soil characteristics of the test field are shown in Table 3.

The rolling resistance and shear stress were evaluated using the procedure presented in [6, 7].

As the traction force is known and shear stress, contact patch area and rolling resistance are given by the traction model, the D(s) term in equation (12) was calculated with the formula:

$$D(s) = \frac{F_{t,ef,r} + R_r}{\tau \cdot A_t} \tag{15}$$

Then the software package LABFit [9] was used in order to evaluate the goodness of fit of a mathematical expression to the calculated values of the D(s) parameter, using the "Curve fit" subroutine. LAB Fit is a software for Windows developed for the treatment and analysis of experimental data. With LAB Fit there is the possibility to: treat similar data; treat non-similar data; determine propagated error; plot 2D and 3D graphs; execute calculations; extract data (x;y) from a 2D graph (digitizing); curve fitting.

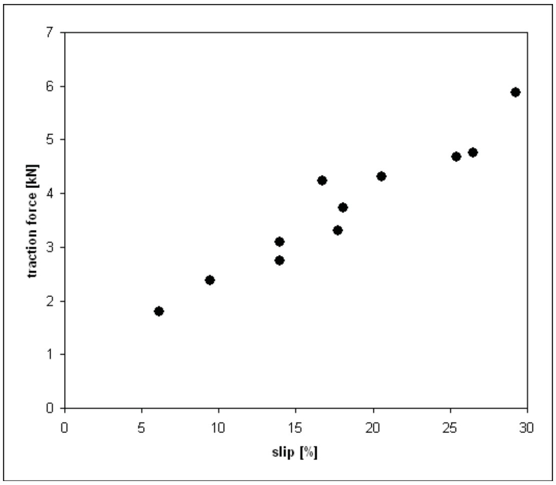


Fig. 2 Experimental results concerning the net traction force

Table 3 Characteristics of the test soil

Item		Value
Soil deformation modulus, K [m]		0.05
Coefficients for the sinkage equation	k	55
	n	1.3
Soil cohesion, c [kPa]		25
Angle of internal friction, φ [^{0}]		32
Cone penetrometer index, CI [kPa]		970
Soil type		chernozem cambic mezocalcaric
Soil texture		clay loam
Soil moisture [%]	0-10 cm	18
	10-20 cm	18.5
Soil porosity [%]	0-20 cm	53.5
Bulk density [g/cm^3]	0-10 cm	1.24
	10-20 cm	1.31

RESULTS AND DISCUSSION

The results concerning the D(s) parameter, starting from experimental traction data and using the relation (14) are shown in Table 4.

Fitting the Komandi type relationship to the values of the D(s) parameter led to the results shown in Figure 3. The equation for the D(s) parameter is:

$$D(s) = 1 - (1 - s) \cdot e^{-1.349 \cdot (l_c)^{-1.393} \cdot s^{0.657}} \; .$$

Table 4 Values for the D(s) parameter

Slip	D(s)
0.06	0.4065
0.09	0.4740
0.14	0.5990
0.17	0.5779
0.18	0.6330
0.20	0.7090
0.25	0.753
0.26	0.763
0.29	0.812

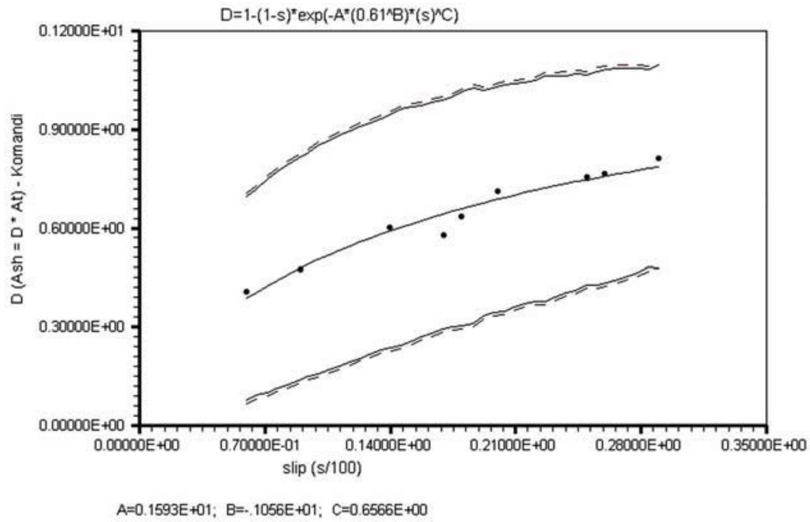


Fig. 3 Results concerning the Komandi type equation

Unfortunately, the coefficients involved in this equation register very high values of the standard deviation and, in the meantime, Figure 3 displays very large confidence and predict bands. As a result we concluded that, for the soil conditions taken into account, the Komandi type relationship does not fit very well to the experimental data.

Using the functions library of the LABFit software we tried to find a better fit to the experimental data. As a result we found a power type equation:

$$D(s) = a \cdot s^b,$$

where a = 1.4 ± 0.07877 and b = 0.449 ± 0.0335. The correlation coefficient for this set of data was r^2 = 0.96933 and the results are depicted in Figure 4, which displays much narrower confidence and predict bands compared to the Komandi type equation.

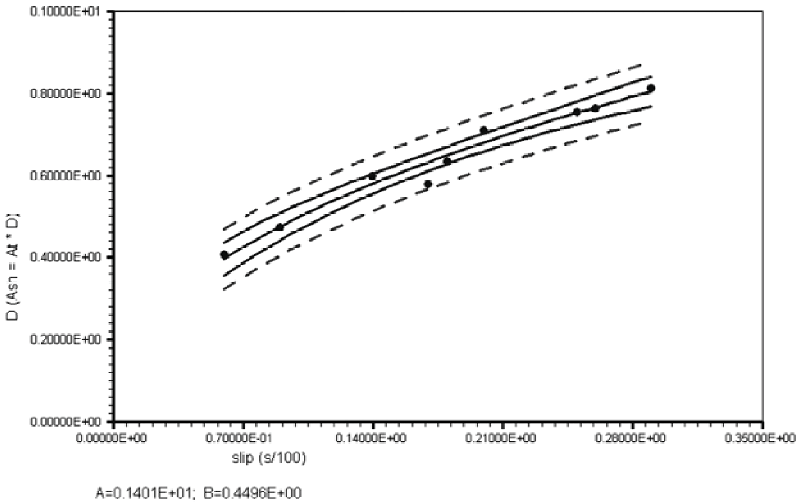


Fig. 4 Results referring to the power type equation

A comparison between the predicted values of the D(s) parameter (for the two equations taken into account) and the values obtained from experimental data (see Table 4) is presented in Figure 5.

In order to compare the results given by the traction model and experimental data, in terms of traction force, the relation (13) was used and the results are shown in Figure 6. Using the percentage of points within 95% confidence interval of data (Pw95CI) as a measure of degree of fit of model to experimental data [8] we found that, for the power type equation of the D(s) parameter, 88.9% of the points fall within this interval, compared to only 44.4% when the Komandi equation is used. The mean absolute deviation (MAD), representing the mean of the absolute value of deviation between each model prediction point and its corresponding data point, has a value of 0.2010 for the power type relation and respectively 0.3637 for the Komandi type equation.

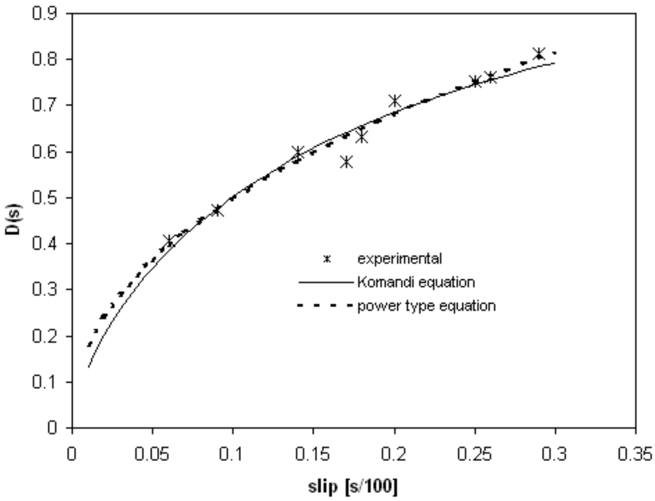


Fig. 5 Comparative results for the D(s) parameter

Computation of the mean scaled absolute deviation (MSAD) [8] shows that, on average, the model is 1.193 standard errors off from the experimental data when the power type relationship is used, compared to MSAD = 2.323 for the Komandi relation.

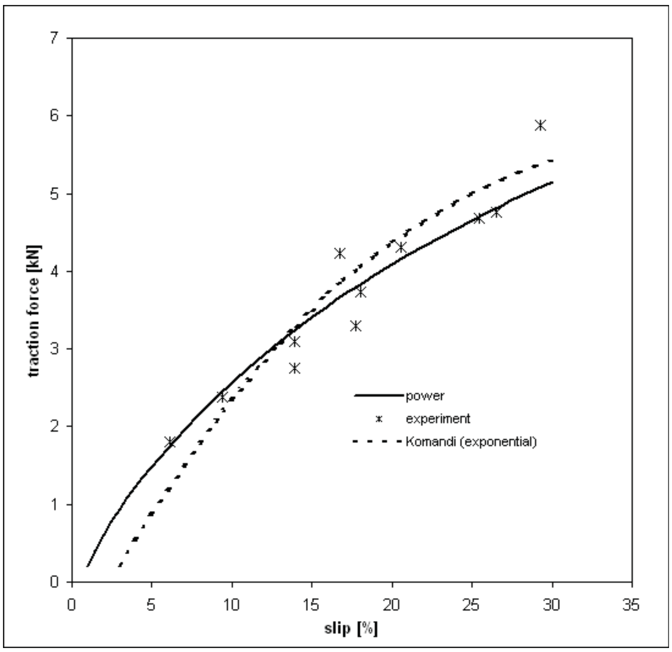


Fig. 6 Traction force

Figure 7 shows the predicted shear area for the two equations taken into account – the Komandi type and the power type.

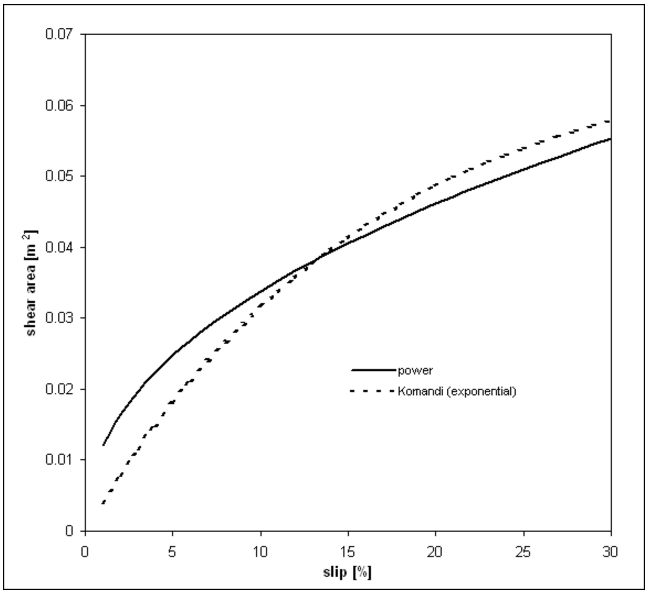


Fig. 7 Predicted shear area

CONCLUSIONS

- A previously developed traction model and experimental data were used in order to calculate the traction force and shear area.
- The shear area was supposed to be linked to the tire-ground contact area by the means of a wheel slip depending parameter D(s).
- Using the LABFit software in order to calculate the coefficients involved in the D(s) relationship developed by G. Komandi led to conclusion that this equation did not seem to be appropriate for the evaluation of the shear area, at least not for our test conditions.
- A much better goodness-of-fit between the measured traction forces and the ones predicted by our model was achieved when a power type relation was used in order to describe the D(s) parameter.

REFERENCES

1. Bekker G.M. (1969). Introduction to terrain-vehicle systems. Univ. of Michigan Press, Ann Arbor.
2. Bekker G.M. (1962). Theory of land locomotion. Univ. of Michigan Press, Ann Arbor.
3. Ghiulai, C., Vasiliu, Ch. (1975). Vehicle dynamics (in romanian). Didactical and Pedagogical Publishing House, Bucharest.
4. Komandi, G. (1993). Reevaluation of the adhesive relationship between the tire and the soil. Journal of Terramechanics, 30, 2: 77-83.
5. Komandi G. (1998). A kinematic model for the determination of the peripheral force. Journal of Terramechanics, 34, 4: 261-268.
6. Rosca R., E. Rakosi, Gh. Manolache (2004). Wheel Traction Prediction - A Comparison Between Models and Experimental Data. SAE Technical Paper Series 2004-01-2707.
7. Rosca R. et al. (2008). Tire traction models-comparative analysis and validation. In: Proceedings of the 36th International Symposium Actual Tasks on Agricultural Engineering, Opatija Croatia, p. 93-104.
8. Schunn C.D., Wallach D. (2005). Evaluating goodness-of-fit in comparison of models to data. In W. Tack (Ed.), Psychologie der Kognition: Reden and Vorträge anlässlich der Emeritierung von Werner Tack, p. 115-154. Saarbrueken, Germany: University of Saarland Press (at http://www.lrdc.pitt.edu/schunn/gof/index.html).
9. Silva, Wilton P. and Silva, Cleide M. D. P. S., LAB Fit Curve Fitting Software (Nonlinear Regression and Treatment of Data Program) V 7.2.45 (1999-2009), online, available from world wide web: <www.labfit.net>, date of access: 2008-oct.-14.
10. Upadhyaya, S.K., Dvoralai, Wulfson, Jubbal, G. (1989). Traction prediction equations for radial ply tyres. Journal of Terramechanics, 26, 2: 149-175.
11. Upadhyaya, S.K., Dvoralai, Wulfson, Jubbal, G. (1990). Review of traction prediction equations. ASAE Paper 90 – 1573, St. Joseph, Michigan.
12. Upadhyaya, S.K., Dvoralai, Wulfson (1990). Relationship between tire deflection characteristics and 2-D tire contact area. Transactions of the ASAE, 33,1: 25-30.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.11.012.55:631.372
Izvorni znanstveni rad
Original scientific paper

INFLUENCE OF AGRICULTURAL TIRES' ELASTIC PROPERTIES IN TRACTOR HANDLING TEST

M. CUTINI, C. BISAGLIA

Agriculture Research Council – Unità di Ricerca per l'Ingegneria Agraria; via Milano 43, 24047 Treviglio BG, Italy; e-mail: *maurizio.cutini@entecra.it*

SUMMARY

The development of the EU legislation is carrying on to a growing interest in the behaviour of agricultural tractors at high speed. The lateral forces acting on a tractor characterise the tractor behaviour in line-change tests and consequently, on road transport with trailers or implements. A key role on dynamic behaviour is attributable to the tires characteristics. A first approach has been carried out to evaluate the effect of lateral forces on an agricultural tractor during handling tests in laboratory and on track, with three different couple of rear tires.Tests in laboratory have first characterised the lateral and vertical stiffness of the tires. On track a double lane change test was carried out following the ISO 3888-2; the roll and the steering angles were acquired. The amplitude and the number of the acts of the driver on the steering wheel resulted the output data of the tests on track. A correlation between indoor and outdoor tests has been found. A greater vertical stiffness of the tire gives always less roll angle of the vehicle, instead there's an ideal trend of the lateral stiffness for the operator's feedback.

***Key words**: Agricultural tractor, handling, tire, lateral forces*

INTRODUCTION

The handling of the road vehicle is still in phase of study but often the developed methodologies are internal tests of manufacturers. In 1997 the American National Highway Traffic Safety Administration (NHTSA), started a scientific study to improve handling testing methodology to evaluate the tendency to rollover. The study was necessary for the increasing number of vehicle with high centre of gravity, in particular the so called Sport Utility Vehicles (SUV), that seemed statistically to have the greatest risk of rollover. The scenario was that of a car on a road without obstacles. It takes into account several manoeuvres that could lead to rollover and that must have be repeatability, discriminatory (not all the tested vehicles must rollover), likelihood (similar to the manoeuvres on road, i.e. in emergency situation), measurable (the rollover tendency must be numerically measurable). Eight typologies of manoeuvres were considered based above all mainly on three of them in different conditions of braking and surface friction: the double lane change test (fig.1), the J-turn (fig.2) and the Toyota Fishhook (fig.3)

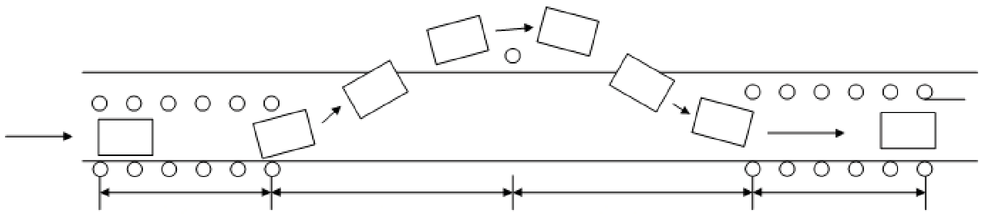


Figure 1 Typology of a double lane change test.

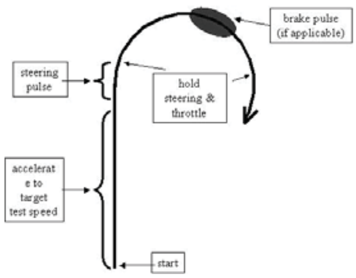


Figure 2 The J-turn manoeuvre

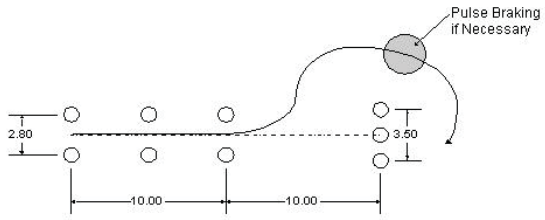


Figure 3 The Fishhook manoeuvre

In automotive has interest also the “sinusoidal sweep” that consists of a sweep input on the steering wheel used for evaluating the resonance response to the roll of the vehicle. Beside the geometry of the vehicle, a key role in the dynamic behaviour is attributable to the tires.

Following this experience, the CRA-ING of Treviglio has carried out a first approach of handling tests on an agricultural tractor both in laboratory and on track conditions.

Aim of the tests was to evaluate the elastic properties, in static and operational conditions, of agricultural tires, and to define the effect of the lateral forces on tractor.

METHODS

This study follows a particular double lane change test defined in the ISO-3888 part two (of which the famous “Elk Test” is a particular case), developed for simulating the response of the vehicle in emergency situation (fig.4).

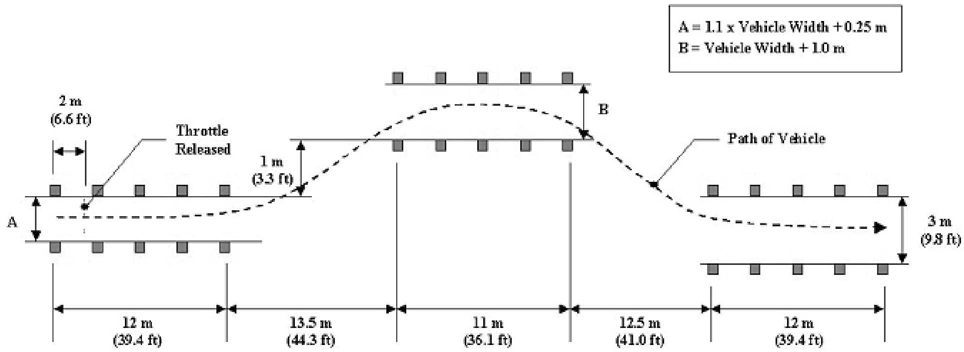


Figure 4 The double lane change test scheme according to the ISO-3888

The vehicle is driven straight at the desired speed, the engine is left when entering in the first lane change, in the second is used again. Brakes are not touched. Test is positive if the traffic cones are not touched.

MATERIALS

A 4WD tractor 61.9 kW nominal power fitted with three different couple of rear tires (table 1) has been tested. The front tires had the measure of 380/70-R20, a load index of 120/A8 and were inflated at 2.0 bar.

Table 1 Tested tires

	Tire A	**Tire B**	**Tire C**
Rear-measure	540/65R28	420/70R30	420/85R28
Rear-load index	142/A8	134/A8	139/A8

The front track width was 1520 mm and the rear 1670, the wheelbase was 2240 mm.

In table 2 is reported the tractor mass distribution.

Table 2 Mass distribution of the tested vehicle

	Front mass [kg]	**Rear mass [kg]**	**Total mass [kg]**
Not ballasted	1455	1810	3265
Ballasted	795	3440	4235

Tests were carried both in laboratory and on a test track.

Test indoor were intended to characterise the elastic properties (k) of the tires, in particular the vertical elastic costant (at compression) of a single tyre (k-C), the lateral elastic costant of the single tyre (k-L) and with the tyres mounted on tractor and. For this last test, the front axle of the tractor was picked up by a crane for having a null vertical reaction on the ground for not influencing test on the rear axle that was adopting the tested tires. A hydraulic cylinder was used for pulling laterally the tractor (fig.5).

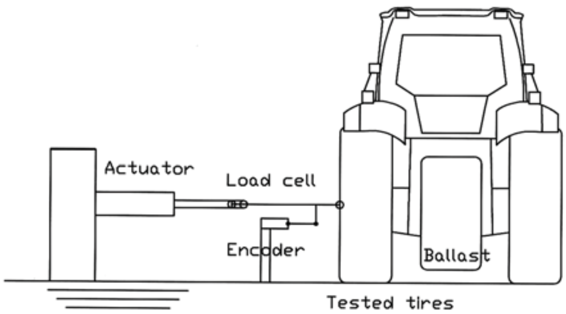


Figure 5 The testing plant for evaluating lateral elastic constant of the rear tires.

The force and the displacement were measured by a load cell AEP T20 and a cable encoder Celesco 1000 mm full range.

The measures of the lane change test were carried out by simulating with Scilab^{TM} the trajectory for obtaining the desired lateral acceleration of 0,8g at different speeds (ranging between 30 and 40 km/h). The software gave the position of the traffic cones.

After the first tests on track the trajectory was slightly modified and the target became a lateral maximum acceleration of 0,7g at 37 km/h. The final speeds chosen for the tests were 35, 37 and 39 km/h.

The inflate pressure of tests were 120 and 160 kPa. The lateral acceleration (accelerometer Lebow +/-4g), the roll angle (measuring the distance from the ground by laser Sensotech), and the displacement of the cylinder of steering of the front axle (encoder Sensotech) were acquired.

The behaviour of the tractor has been evaluated by the acts of the driver on the steering wheel measured as degree of steering of the front axle.

The parameters of interest are three, but in this work only the first two have been taken in account. They are reported in order of importance:

- amplitude of the peaks;
- number of peaks;
- diverging from the ideal trajectory.

Pulling test in laboratory and tests on track were replicated with tires inflated at 120 and at 160 kPa (indicated with 12 and 16 for describing tractor's setting during tests, i.e.: k-L12).

RESULTS

In table 3 are listed the elastic properties of the tested tires in the considered conditions.

Table 3 Elastic costant of the tested tires at different inflation pressure

Tyre	Value	k-L12	k-L16	k-C12	k-C16
A	N/mm	290	370	340	370
B	N/mm	310	370	300	350
C	N/mm	330	410	310	360

The tests at 160 kPa are reported, as example, also in fig. 6 and 7.

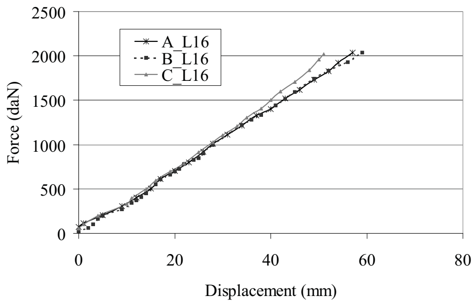


Figure 6 The k-L at 160 kPa

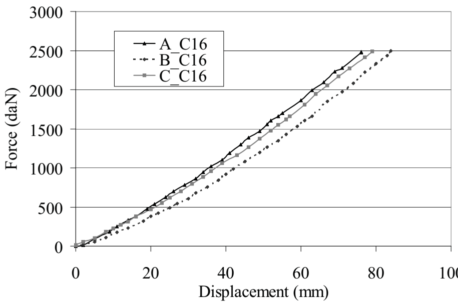


Figure 7 The k-C at 160 kPa

The most rigid tire was tire A at compression and tire C at lateral forces.

On the other hand the softest was tire A laterally and tire B vertically.

These result of the lateral charcteristic were partially confirmed by the test of lateral force on the rear axle of the tractor where tire C was always the most rigid, but tire A and B have shown a different behaviour (Fig. 8). Results are similar at 120 kPa.

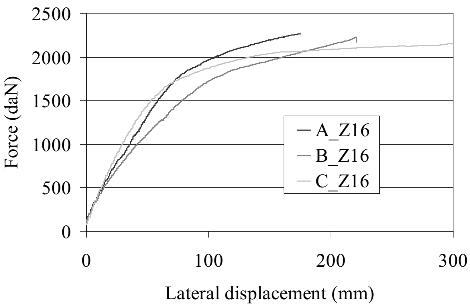


Figure 8 The lateral characteristic of tires on tractor at 160 kPa

First approaching of the tests on track showed that results of interest are obtained only if the tire exchanges lateral forces with the ground, this means:

- a surface with high friction is necessary;
- load on the tested tires is necessary.

Consequently, tests on track were carried only on asphalt (μ≈1) and with tractor ballasted.

To improve testing repeatability (verified in several and different conditions during preliminary and official tests) is preferable to constrain the trajectory as much as possible with traffic cones because the change of pressure or of tires during tests had influence on the second lane change driver's approach.

The results have analysed above all two main values:

- roll angle of the vehicle
- actuation on the steering wheel of the operator

The roll angle has been measured in degree at the centre of the vehicle, results have confirmed that with higher forward speed the roll angle grows up for the higher lateral acceleration (fig. 9). The higher inflate pressure gives, as expected, lower roll angle for the higher elastic costant (fig. 10).

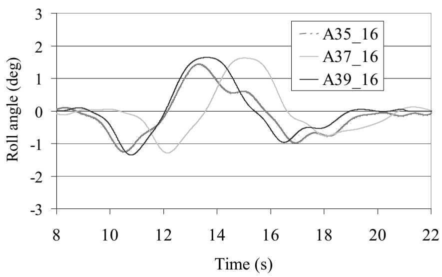


Figure 9 Roll angle with tire A at 160 kPa and different forward speed

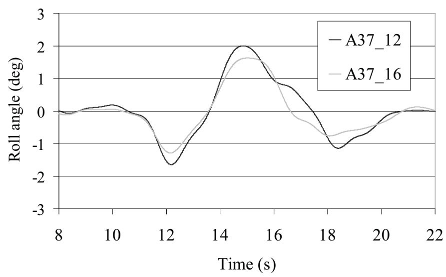


Figure 10 Roll angle with tire A at 37 km/h and at different inflate pressure

The values obtained from the different settings have shown that more stiffness at compression gives always lower angle roll of the vehicle.

The cases of 39 km/h at 160 kPa (fig.11) and 120 kPa are reported in tab.4 and fig. 9.

Table 4 Maximum roll angle of the vehicle at 39 km/h

Tyre	Roll angle (deg)	
	160 kPa	120 kPa
A	1,64	2,25
B	2,41	3,17
C	2,57	2,79

Less roll angle has resulted always preferable from the driver. This fact seems confirming that a grater elastic costant at compression, for the actual type of agricultural tires, is always better.

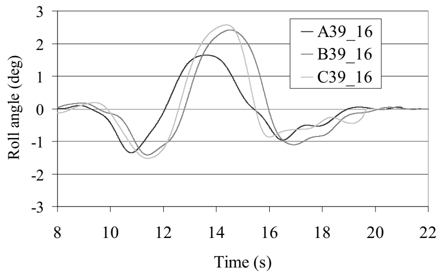


Figure 11 Trend of the roll angle at 160 kPa and 39 km/h with the three different tires

Looking at the results of the acts of the driver on the steering wheel, the test was focused on the 37 km/h so it's expected a quite linear response at 35 km/h and more acts at 39 km/h (es. tire A in fig. 12), and it's also possible to expect that the amplitude of the input and the number of acts could grew up with forward speed.

The results confirm what expected but not in the same way for all the tires. The amplitude of the peaks was effectly the most importance data, confirmed also from the operator's feedback.

But, in this case, the less amplitude was not correlated to a lateral stiffer tire.

Tire B had lower peaks at 160 kPa, tire A had a opposite trend, and tire C was quite similar (figg. 13, 14 and table 5). In fact there is an ideal trend of the elastic curve of fig.8 that gives the desired feedback to the operator. Too rigid tire in the first part of the curve and too soft in the second requires more drivers's acts.

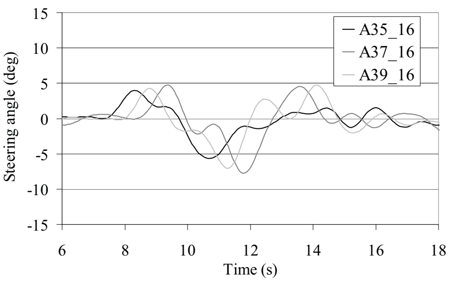


Figure 12 Amplitude and acts on the steering for tyre A, at 160 MPa and39 km/h

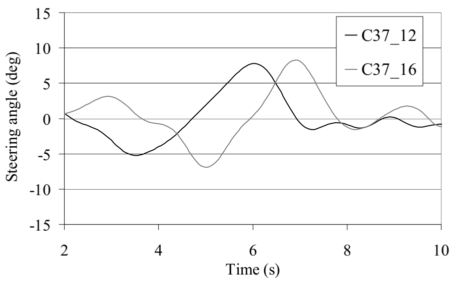


Figure 13 Amplitude and acts on the steering for tyre C, at 160 kPa and37 km/h

Table 5 Steering angle value, peak to peak

Tyre	Steering angle (value)	Test conditions			
		37 km/h		39 km/h	
		120 MPa	160 MPa	120 MPa	160 MPa
A	deg	15,5	18,5	15,4	18,6
B	deg	23,2	16,1	25,7	22,1
C	deg	17,2	18,2	23,8	20,36

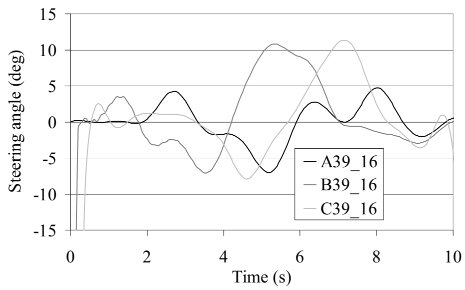


Figure 14 Different behaviour of the three tires at 160 kPa and 39 km/h

It's possible to note the different influence on the vehicle behaviour of the three couple of rear tires. The results of the first approach respects the driver's feedback response carrying on to investigate deeply the methodology.

Beside, tests need more data to be validated statistically, to evaluate the different driver as variable and to define the role of the three parameter of evaluation. This aim will interest the next approach at the project.

CONCLUSIONS

The behaviour of the rear tires of a tractor during turning has been reproduced in laboratory and a double lane change test has been carried out on track. A correlation between indoor and outdoor tests has been found. The amplitude and the number of the acts of the driver on the steering wheel resulted the output data of the tests on track.

Next step of the project will investigate deeply the influence of the driver and the role of the parameter of evaluation.

REFERENCES

1. Braghin F., F. Cheli, E. Sabbioni, M. Cutini, C. Bisaglia, 2007. Validation of a MB agricultural vehicle model through indoor and outdoor experimental tests. XXXII CIOSTA-CIGR Section V, 17-19 September, Nitra (Slovack Republic), Part I, p. 130-138.

2. Cutini M., C. Bisaglia, 2008. Agricultural tires' behaviour during laboratory reproduction of lateral forces. In: Proceedings CD of International Conference "Innovation technology to empower safety, health and welfare in agriculture and agro-food systems", p. 1-5, (Book of Abstracts p. 105), 15-17 September, Ragusa (Italy).

3. Directive 2003/37/EC of the European Parliament and of the Council of 26 May 2003 on type-approval of agricultural or forestry tractors, their trailers and interchangeable towed machinery, together with their systems, components and separate technical units and repealing Directive 74/150/EEC.

4. ISO 3888-1:1999, Passenger cars – Test track for a severe lane-change manoeuvre. Part 1: Double lane change.

5. BOSCH, 2004, Automotive Handbook, 6th edition, Professional Engineering Publishing.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.49:631.431.73
Prethodno priopćenje
Preliminary communication

SOIL PRESSURE DETERMINATION IN REAL-FIELD AND SIMULATED-LABORATORY

V. VLADUȚ[1)], L. POPA[1)], A. DANCIU[1)], S. BUNGESCU[2], S. ŞT. BIRIŞ[3)], G. PARASCHIV[3)]

[1)]INMA Bucharest Romania, [2)]Agricultural University of Timişoara Romania
[3)]Polytechnic University of Bucharest Romania,

SUMMARY

The paper has as goal the determination of soil pressure in real (field) and simulated (laboratory) conditions - by realizing complex tests on the tests installation in simulated and accelerated regime type Hydropulse, for simulating static compression test of tires towards the soil. For each of these tests: in real or simulated conditions (on hydropulse) have been realized more trials, considering: the dimensional characteristics of the tires, testing conditions in exploitation, the results of tires dynamic characteristics determination (in case of testing in real conditions), respective: brief description of testing method, testing equipment, testing site, measurement devices and equipments used, calibration, static compression test, test results (in case of simulated tests on hydropulse). In case of laboratory effectuated tests on the tests installation in simulated and accelerated regime type Hydropulse, for simulating the static compression test of tires towards the soil have been used one plate of 15 mm thickness, with the dimensions Lxl similar with the contact trace of tractor/combine wheels of which value we want to find out. It has been built a box of 1 m^3 from sheet-metal with 3 mm thickness, reinforced, with the dimensions: 1x1x1 [m], especially built for this test, in which have been mounted the 8 force sensors Flexi Force Tekscan, type W-B201-L (maximal range used for this test 10N/50,24 mm^2), acquired especially for this type of trials for being installed in soil at different depths.

***Key words**: testing, deformation, soil, tractor, combine, rolling parts, compaction*

INTRODUCTION

Because of the big contact surface of the tire with the deformable soil, the pressure on the soil is more reduced than in the case of tire rolling on a rough surface. With all these ones, the pressure on soil exceeds sometimes the admitted limit for protecting the soil structure. The imposed requirement is that the tire pressure on soil do not exceeds 1,0 daN/cm^2, at field works and 3,0÷3,5 daN/cm^2 at transportation works on field roads [2]. The experimental data attests that, generally, the minimum limit of 1,0 daN/cm^2 is respected by the tractors driving wheels which have tyres with big diameter and section width and, at which the pressure on soil is close to 1,0 daN/cm^2, but it is exceeded by the front wheels, of direction, at which the pressure on soil is close to 2,0 daN/cm^2. At the transportation trailers the pressure on soil exceeds often the limited pressure of 3,5 daN/cm^2. To avoid the soil settling, with all its negatives after-effects, it is necessary that in tires exploitation to be applied some measures which will conduct to the pressure reduction on soil, knowing that this depends on: load on tire, inflating pressure, tire dimensions and the rolling pattern, the tire stiffness, etc [4, 5].

In theory, the tire pressure on soil (p_s) is given by the sum between the inflating pressure (p_u) and the pressure difference given by the tire casing stiffness (Δ):

$$p_s = p_u + \Delta_p \text{ [daN/cm}^2\text{]}$$

If it's neglected the stiffness, the pressure on soil is relative equal to the tire inflating pressure. The real pressure on the deformable soil is determined experimentally by direct measurements between the soil surface and tire.

In practice it is calculated and compared the conventional pressure on soil [3, 6] which is the ratio of the load on the tire and the supporting surface (A) of the tire on a flat terrain, determined by direct measuring of the print or calculated with the relation:

$$A = \pi \cdot f' \sqrt{(D_e - f') \cdot (B_e - f')} \text{ [cm}^2\text{]}$$

in which:

f - the tire radial deformation;

D_e – exterior diameter;

B_e – section width;

In this case the pressure on soil (p_s) is calculated by division the load on tire (Q_r) to the supporting surface (A):

$$p_s = \frac{Q_r}{A} \quad \text{[daN/cm}^2\text{]}$$

The value of this pressure is given in the technical books of different tractors, agricultural machines and trailers.

MATERIALS AND METHOD

The effectuated tests were concentrated especially on:

- The determination of pressure on soil and the comportment to tires natural rolling:
    - frontal for harvester-thresher C 110H;
    - frontal and in the back for tractor U 445 (45 HP);
    - frontal and in the back for tractor U 650M (65 HP).
- static test at compression, on hydropulse (in laboratory), simulating the pressing on the field soil, for the following tires:
    - frontal for harvester-thresher C 110H;
    - frontal and in the back for tractor U 445 (45 HP);
    - frontal and in the back for tractor U 650M (65 HP).

For each of this tests: in real conditions or simulated (on hydropulse) were elaborated experimental tests, which contain: the tires dimensional characteristics, the exploitation testing conditions, the results of tires dynamic characteristics determination (in case of real conditions testing), respective: the compendious description of the testing way, the testing place, measuring apparatus and equipments used, calibration, static compression test, testing results (in case of hydropulse simulated tests).

In case of laboratory effectuated tests on the testing installation in simulated and accelerated regime type hydropulse, for simulating the *static compression test of the wheels (tires) beside the soil* were used a pair of plates of 15 mm thickness, with dimensions L x l similar to the *contact stains* of the tractor/harvester wheels of which value we want to find out.

For this it was realized a box of 1 m^3 of sheet metal with thickness of 3 mm, reinforced, with dimensions: 1 x 1 x 1 [m], specially executed for this test, in which there were mounted the *8 force sensors Flexi Force* Tekscan, type W-B201-L (maximum domain used for this test 10 N / 50,24 mm^2), specially acquired for this type of tests, for being mounted in soil at different depths (figure 1) [8].

Figure 1 The force sensor Flexi Force applied on soil before being covered by soil and to the depth of 75 cm and after it was covered to the depth of 5 cm

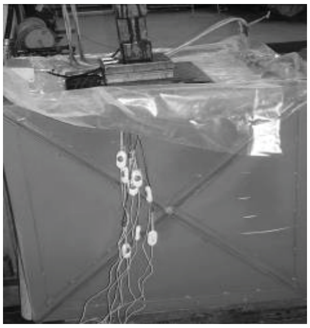


Figure 2 Force sensors applied to the depth of 5÷75 cm with the outputs towards the laptop and the acquisition board

Figure 3 The tests command centre and the soil humidity measuring with humidometer type HH2

Before beginning the tests there was measured the soil humidity for each effectuated test. This was realized using a humidometer for soil, type HH2 (figure 3 - right).

The force measuring system was mounted in the box, beginning with 5 cm from the top level of the box (all the box was filled with soil), from 10 to 10 cm, until the depth of 75 cm. The force measuring system (the force sensors– figure 4) was connected to an adapting module (consisting of amplifiers and analog-numeric converter on 8 bits) and coupled to the serial interface 4RS 232 for connecting it (by USB) to the adapting module (acquisition system) and laptop.

Figure 4 Force sensor Flexi Force, Laptop and acquisition system

Pressing on the plate was achieved with the help of a 10 kN cylinder and of some intermediary devices, assured by INMA Bucharest.

The testing equipment: Testing installation in simulated and accelerated regime type Hydropulse – Germany (figure 5).

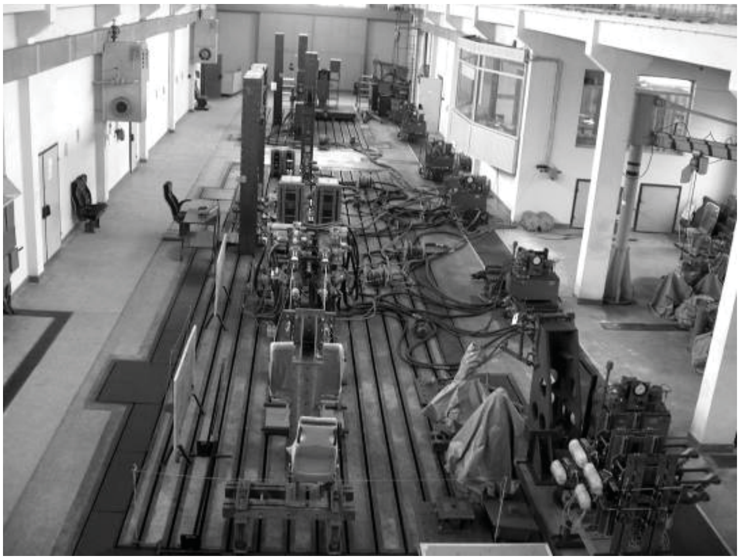


Figure 5 Testing installation in simulated and accelerated regime type Hydropulse

RESULTS AND DISCUSSION

For the verification of the results there were effectuated more determinations: in field and laboratory, for *determinations the pressure on soil and the comportment to natural rolling of tires*, respectively for *the static compression test for driving and direction wheels* from: the harvester thresher C 110H, the tractor U 445, the tractor U 650:

Next it will be presented a testing model (for *field determinations*) and a testing model (for *laboratory determinations* – on hydropulse)

Field determinations - real conditions [1, 7]

- Product: driving wheel (front) harvester C 110H;
- Test: the pressure on soil determination and the comportment to natural rolling of tires 18,4-26, 8PR D-165R3 from the harvester thresher C 110H;
- Dimensional characteristics of tires 18,4-26, 8PR D-165R3;

For determining the dynamic characteristics and the comportment to natural rolling in exploitation conditions specific to agriculture, there were tested two tires 18,4-26, 8PR D-165R3.

The tires constructive characteristics, after the data of the producing company, are presented in table no. 1.

Table 1 Constructive characteristics of tires 18,4-26, 8PR D-165R3

Characteristics given by the producing company	M.U.	Value
Section width	mm	467
Exterior diameter	mm	1.450
Static radius	mm	670
Maximum load	kg	2.265
Pressure at maximum load	bar	1,4
Maximum working speed	km/h	30
Recommended rim	-	16 x 26

Dynamic characteristics:

- the rolling circumference and the effective rolling radius;
- under load radial and lateral deformation;
- the supporting surface and pressure on soil.

The tires 18,4-26, 8PR D-165R3 were mounted as driving wheels, on the front axle of a cereal harvester C 110H.

The working conditions, at which the tires were subjected, were framed in the normal limits of the exploitation regime, according to table no.2.

Table 2 Testing conditions in exploitation

Tractor on which were tested	Using domain	Load on tire [kg]	Regime pressure [bar]	Working speed	
				Agricultural works [km/h]	In transportation [km/h]
Auto propelled harvester C110H	Works in big culture and at harvesting	3.120	1,6÷1,7	1,2 ÷ 7,6	14,7 ÷ 26,3

In given working conditions, as the tires dynamic rolling on soil parameters, there were determined: the rolling circumference, the effective rolling radius, the pressure on soil and the lateral and radial deformation under load of the tires casings.

The values of these dynamic parameters are presented in table no. 3.

Table 3 The effective rolling dynamic parameters

Determination conditions Load [kg] / Pressure [bar]	Rolling circumference [mm]	Effective rolling radius [mm]	On soil supporting surface [cm^2]	Pressure on soil [daN/cm^2]	Under load deformations	
					Lateral [%]	Radial [%]
3.120 / 1,6	4.083	650	1.868	*1,32*	10,8	10,4

There were tested to natural rolling in agriculture specific conditions, two tires *18,4-26, 8PR D-165R3*, which were mounted on the front axle of harvester C 110H, as driving wheels.

The tested tires have diagonal profile with cord (2+4) Ny 940/2 with 128 f/dm.

The tires dynamic rolling parameters were determined in corresponding conditions of load and pressure (working speed in field of 8 km/h and a load bigger with 37% than the maximum admitted load at speed of 30 km/h).

In working conditions with a load of 3.120 kg and a pressure of 1,6÷1,7 bar, the tires rolling circumference was of 4.083 m, the rolling radius of 650 m and the pressure on soil of 1,32 daN/cm^2.

The measured lateral deformation was of 10,8% and the radial deformation of 10,4%.

Laboratory determinations - simulation conditions

- Product: driving wheel (front) harvester C 110H
- Test: Static compression test;
- Applied force: *1.000 daN*;

The test comprises two stages:

- stage A – calibration of the testing equipment;
- stage B – the proper test of the *driving wheel of harvester C110H* for determining the pressure on soil;

For simulating the static compression test for the frontal wheel of harvester C 110H there were used two plates of 15 mm thickness, with dimensions L x l similar to the contact stain of the frontal wheel of harvester C 110H, namely 525 x 510 [mm].

The force measuring system was mounted in the box beginning with 5 cm from the top level of the box (the box was filled with soil), from 10 to 10 cm, until the depth of 75 cm. The force measuring system was connected to an adapting module and coupled to the serial interface for coupling it to the acquisition system and laptop.

The pressing on the plate was realized with the help of a 10 kN cylinder and of some intermediary devices, assured by INMA Bucharest.

The testing equipment: Testing installation in simulated and accelerated regime type Hydropulse – Germany.

Measuring apparatus and equipments used:

- force sensors W-B201-L, maximum domain: 111 N / 71,3 mm^2.
- dynamometer (force cell) 10 kN;
- hydraulic cylinder series 9.60.61.9 / 87;
- cylinder control board – DCCH – 8, series 366.91/87/8;
- data acquisition board DAP 3200 – S.U.A.;
- soil humidometer type HH2, series 14/82;
- caliper 0 ÷ 150 mm series 14311;
- surveyor's tape 3 m, series 1.

By calibration it was tracked the correspondence between the provided signal by the tensometer dose and the one recorded by the acquisition board DAP 3200 – S.U.A.

Pressure variation in soil, represented in table no. I.

- Effective stroke (displacement) of the piston's bar during the test: 11,7 mm;
- Loading period: 20,75 sec;
- Maximum applied force: 1.000 daN;
- Soil humidity: 26,9 %.

Figure 6 Used equipments at the compression test

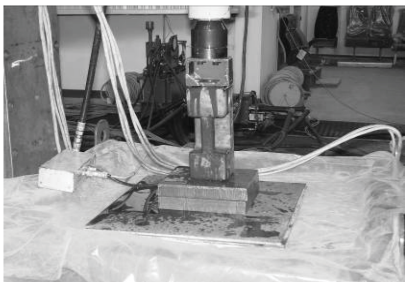


Figure 7 Aspects during the static compression test

Table 4 Test results

Sensor no.	Depth at which the sensor is mounted [cm]	Pressing force [N]	Contact stain surface [cm²]	Pressure in soil [N/cm²]
-	0,1	10.000	2.667,5	4,166666666
1	5	1,478	0,5024	2,941878981
2	15	1,914	0,5024	3,809713376
3	25	1,179	0,5024	2,346735669
4	35	1,474	0,5024	2,933917197
5	45	1,187	0,5024	2,362659236
6	25	0,8071	0,5024	1,606488854
7	65	0,5856	0,5024	1,165605096
8	75	0,03472	0,5024	0,06910828

S_1 = 525 x 510 = 267.750 mm^2 = 2.667,5 cm^2; $S_2 = \pi \cdot R^2$ = 3,14 x 16 = 50,24 mm^2 = = 0,5024 cm^2; where: R = 4 m (diameter of the contact pastille: ϕ = 8 m).

For the pressing force 3.120 kg (31.200 N) - similar to the field testing at the surface of soil, for the front axle of harvester C 110H, the pressure in soil will be 13 N/cm^2 (1,3 daN/cm^2).

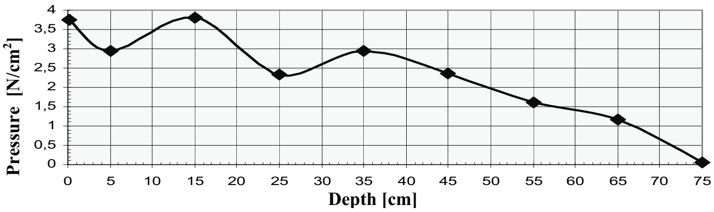


Figure 8 Pressure exercised on soil, function of depth

The pressure exercised on soil was determined at 8 different depths: 5; 15; 25; 35; 45; 55; 65 and 75 cm, where there were applied in soil the 8 sensors, on the actuating direction of the pressing force. For simulating the pressure exercised by the harvester's wheel (front) there was applied a compression force of 10.000 N with the help of a hydraulic cylinder, at soil's level, that being determined in a practical way, by weighing the harvester and finding the repartition on the two axles and finally on each wheel.

Also it was determined the contact stain size (area) too, this one being approximated with a rectangle with dimensions: 525 x 510 [mm]. The force was applied progressive until it reached the determined value in real conditions (10.000 N), moment in which there were measured too the forces in each of the 8 depths, for the load front axle of harvester C 110H - 3.120 kg (31.200 N), resulted a pressure in soil - *1,3* daN/cm^2, very nearly of the pressure in soil determined in field - *1,32* daN/cm^2.

In diagram from figure 8 we can observe the exercised pressure on soil at depths until 35 cm has a non-uniform variation, after that following a descendant curve, once with the increasing of the depth at which there were measured the values.

CONCLUSIONS

As a result of *the field* and *laboratory tests* (in real and simulated conditions) it outcome that the pressures exercised on soil determined in both conditions are very close, but in laboratory we have the advantage that we can determine this pressures at different depth (5; 10; 20; ... 100 cm) not only at the soil's surface.

Further more we recommend the determination of the pressure exercised on soil (*soil settlement)* in laboratory, in simulated conditions because this method is more quickly, more cheaply, it can be realised independently on the weather and it is selfsame exactly.

REFERENCES

1. Uceanu E., ş.a. - and others – Researches regarding the comportment to natural rolling of tires from the harvester C 110H, tractor U 445 and tractor U 650M, Research reports, INMA Bucharest, 2003÷2006;
2. Biriş S., Vlăduţ V., Bungescu S. - Analiza stadiului cercetărilor efectuate pe plan mondial privind fenomenul de compactare artificială a solului agricol, INMATEH I - 2006, page 197÷206, ISSN 1583 - 1019, 2006, Bucharest - Romania;
3. Biriş S., Vlăduţ V., Bungescu S. - Mathematical modelling of stress propagation in agricultural soil during the compaction phenomenon, The IInd INTERNATIONAL CONFERENCE - ADVANCED CONCEPTS IN MECHANICAL ENGINEERING (ACME), Tome L II (LVI), Fascicule 6C, page 247÷256, 2006, ISSN 1011-2855, Iaşi - Romania;
4. Uceanu E., Bolintineanu Gh., Vlăduţ V. - Researches regarding the identification of qualitative characteristics at the soil work, INMATEH V - 2007, no. 23, page 232÷244, ISSN 1583 - 1019, Bucharest - Romania;
5. Biriş S., Vlăduţ V., Bungescu S., Paraschiv G. - Researches regarding the utilization of ante-mouldboard in the ploughs building, PROCEEDINGS OF THE 35 INTERNATIONAL SYMPOSIUM ON AGRICULTURAL ENGINEERING "Actual Tasks on Agricultural Engineering", page 85÷96, 2007, ISSN 1333-2651, Opatija - Croaţia;
6. Biriş S., Maican E., Vlăduţ V., Bungescu S. - Researches regarding the implementation of Finite Element method in the study of artificial compaction phenomenon for the agricultural soils, 27th Congress Polish Society of Soil Science and International Scientific Conference „SOIL IN SPACE AND TIME", 2007, ISBN 978-83-7244-883-5, Warsaw, 3÷7 September 2007, Poland;
7. Vlăduţ V., Matache M., Bungescu S., Biriş S. - The determination soil deformation that sequel of the pressures exercised by rolling organs of tractors and self-propelled agricultural machines, LUCRĂRI ŞTIINŢIFICE - FACULTATEA DE AGRICULTURĂ, Publishing House AGROPRINT, vol. 40 (2), section 7 - Energetic Resources and machines for agriculture, page 505÷512, ISSN 1221-5279, 2008, Timişoara - Romania;
8. Vlăduţ V., Ganga M., a.o. - The complex researches regarding using of Finite Elements method for the artificial compacting study of agricultural soil under the action of the tractors and agricultural machines rolling parts - The complex testing for the validation of MEF analysis methods, Research reports, 2008, INMA Bucharest.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.312
Stručni rad
Expert paper

THE INFLUENCE OF WORKING SPEED, PLOUGH AND SOIL TYPE ON SOILS' BREAKING UP DEGREE AT SHALLOW TILLAGE

BOGDAN-VLAD AVARVAREI, RADU ROŞCA, ELENA-LILIANA CHELARIU

University of Agricultural Sciences and Veterinary Medicine IAŞI, Faculty of Horticulture, 3 Sadoveanu Alley, Iaşi – 700490, ROMANIA, email: bogdan_avarvarei@yahoo.com

SUMMARY

The aim of the paper is to present which is the influence of plough type, soil type and working speed on soils' breaking up degree when shallow tillage are performed. To achieve the goal were used two types of mouldboard ploughs, one of them is a conventional plough with three furrows (PP-3-30) and the second one is a reversible plough with three furrows on each side (PRP-3). The tractor used was a 65 HP one. The research took place on three different types of soil and we worked with four different speeds. The results showed that using the reversible plough leads to better values comparing with the usage of the conventional one.

Key words: *soil type, plough type, working speed, soils' breaking up degree.*

INTRODUCTION

Thanks to the importance of tillage, during the production processes in agriculture, an important and special role is awarded to scientific research, which must establish the most adequate ploughing units, from the technical and economic point of view. Ploughs, which are very used units, and that have been thoroughly studied and known at an international as well as national level, have reached a high technical stage, and the essential changes of the nowadays functional and constructive principles are very hard to carry out. So, each element that can provide even a small improvement in the quality of tillage, an increase in labour productivity, a decrease in the direct expenditures per hectare or in fuel and metal consumption, have an important role upon the increase of economic efficiency.

METHODS

To establish the optimal types of plough used for shallow tillage were studied the following two ploughing units:

a PP-3-30 conventional plough (figure 1);

a PRP-3 reversible plough (figure 2).

Figure 1 PP-3-30 plough

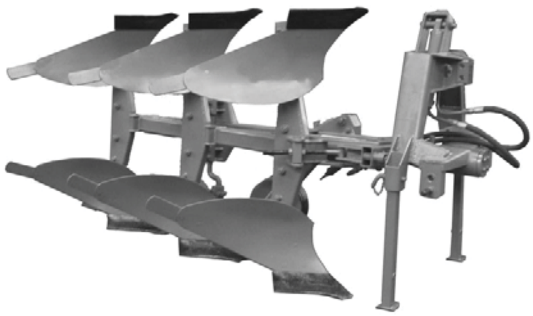


Figure 2 PRP-3 reversible plough

Soils' breaking up degree represent the percentage of soil aggregates with the diameter dimensions over 5 cm on working depth (Nedeff V., Sin Gh. and Băisan I., 1995; Onisie T. and Jităreanu G., 1999; Toma D. and Sin Gh., 1987). The following formula is used for concretion of soils' breaking up degree:

$$G_m = \frac{\sum_{i=1}^{i=n} \frac{M_{sa}}{M_{st}}}{n} \times 100 \ (\%)$$

where:

M_{sa} - soil mass with dimension of clods smaller that the conventional dimension of 5 cm, in the case of tillage;

M_{st} - total soil mass sample;

n - number of effectuated measurements, which must be minimum 3.

Table 1 The main technical characteristics of ploughs

Main characteristics	PP-3-30 plough	PRP-3 reversible plough
Number of furrows	3	3+3
Working width per furrow (cm)	30	30
Ploughs' working width (cm)	90	90
Ploughs' working depth (cm)	30	30
Weight of plough (kg)	360	625

Soils’ breaking up degree is determined with the help of a metric frame which have a wire net with 5 cm diameter holes. On tillage working depth, all the clods with a diameter dimension over 5 cm are weight and also the rest of soil, in minimum three different points on the plot.

The experiences were hosted, during 2005 - 2007, by the experimental plots of Agricultural Research-Development Station (S.C.D.A) Podu-Iloaie, Iaşi County, Romania, on three soil types with different specific resistance at tillage: a light soil (typical chernozem – variant 1); a medium soil (chernozem cambic mezocalcaric – variant 2) and a heavy soil (luvisol with moderate compaction – variant 3) on a winter wheat stubble-field (Table 2).

Table 2 Soil type variants

Working conditions	**Variant**		
	1	**2**	**3**
Soil type	Typical chernozem	Chernozem cambic mezocalcaric	Luvisol with moderate compaction
Soil texture	Loamy sand	Clay loam	Clay
Vegetal mass	Wheat stubble-field	Wheat stubble-field	Wheat stubble-field
Density of stubble-field (plants/m^2)	≈450	≈450	≈450
Height of stubble-field (cm)	15	15	15

The density of wheat stubble-field was around 450 plants/m^2 with an average height of 15 cm. Working speeds, which were used during experiments, were from the II H gear and had the following values: v_1= 4.48 km h^{-1}; v_2= 4.61 km h^{-1}; v_3= 4.85 km h^{-1} and v_4= 4.98 km h^{-1}. The working depth was a = 20 cm and working width was B_w = 90 cm.

The research imposed the determination of some soil features such as: soil moisture content, specific resistance at tillage, bulk density and penetration resistance. Analyses were provided by the already existed laboratories from S.C.D.A Podu-Iloaie, Iaşi County, Romania.

Soil moisture content was determine on three depths of the arable horizon (0 - 10; 10 - 20; 20 - 30 cm), in five repetitions. Soil samples were gathered using Kacinski soil auger, while soil moisture content was determined by drying the samples at a temperature of 105° C for 24 hours in a drying stove.

Bulk density (BD, g/cm^3) and penetration resistance (R_p, daN/cm^2), offers a good characterization of the soil under the aspect of compaction, providing values modifications function of arable horizon depth.

This fact allowed us to establish the values of BD (bulk density) and R_p (penetration resistance) indexes, on three different soil layers (0 - 10; 10 - 20 and 20 - 30 cm), and to observe the variation of them. In table 5 are presented the dates for bulk density (BD) and in table 6 are shown the recorded dates for penetration resistance (R_p).

Table 3 Soil moisture content on the three working variants

Depth (cm)	Repetition	Soil moisture content (%)		
		Variant 1	***Variant 2***	***Variant 3***
0-10	1	13.0	19.5	9.0
	2	12.5	19.0	10.5
	3	13.5	16.1	9.5
	4	13.0	18.1	10.4
	5	12.0	17.3	9.6
	Average	12.8	18.0	10.0
10-20	1	16.5	18.1	14.0
	2	16.0	19.1	14.5
	3	16.5	19.3	15.0
	4	17.0	18.1	15.5
	5	15.5	18.0	13.0
	Average	16.3	18.52	14.5
20-30	1	17.2	19.3	16.0
	2	17.3	20.1	16.5
	3	18.0	19.4	17.0
	4	18.2	20.0	17.5
	5	18.8	19.2	15.5
	Average	17.9	19.6	16.5

Table 4 Specific resistance at tillage on the three variants

Variant	Specific resistance at tillage (daN/cm^2)	Soil class
1	<0,35	Light soil
2	0,35-0,55	Medium soil
3	0,56-0,75	Heavy soil

Table 5 Bulk density at different depths

Variant	Depth (cm)	BD (g/cm^3)			
		Repetition			Average
		A	B	C	
1	0-10	1.16	1.18	1.17	1.16
	10-20	1.19	1.18	1.18	1.19
	20-30	1.20	1.21	1.21	1.20
	Average	1.18	1.19	1.19	1.186
2	0-10	1.23	1.24	1.22	1.23
	10-20	1.29	1.28	1.27	1.29
	20-30	1.30	1.31	1.30	1.30
	Average	1.27	1.27	1.26	1.266
3	0-10	1.45	1.46	1.47	1.45
	10-20	1.48	1.47	1.48	1.48
	20-30	1.49	1.50	1.49	1.49
	Average	1.47	1.48	1.48	1.476

Table 6 Penetration resistance at different depths

Variant	Depth (cm)	R_p (daN/cm^2)			
		Repetition			Average
		A	B	C	
1	0-10	12.0	13.0	14.0	13.0
	10-20	13.0	14.0	15.0	14.0
	20-30	14.0	15.0	16.0	15.0
	Average	13.0	14.0	15.0	14.0
2	0-10	16.0	14.0	15.0	15.0
	10-20	19.0	20.0	20.0	19.66
	20-30	21.0	23.0	22.0	22.0
	Average	18.66	19.0	19.0	18.88
3	0-10	55.0	62.0	57.0	58.0
	10-20	57.0	63.0	60.0	60.0
	20-30	58.0	66.0	62.0	62.0
	Average	56.66	63.66	59.66	60.0

Bulk density (BD), in average values, on a 0 - 30 cm depth, was of 1.186 g/cm^3 at variant 1 (typical chernozem); 1.266 g/cm^3 at variant 2 (chernozem cambic mezocalcaric) and of 1.476 g/cm^3 at variant 3 (luvisol with moderate compaction). The average bulk density of repetitions increases at the same time with the increasing of arable horizon depths.

Penetration resistance (R_p), in average values, for the same experimental conditions, were of 14.0 daN/cm^2 for variant 1 (typical chernozem); 18.88 daN/cm^2 for variant 2 (chernozem cambic mezocalcaric) and 60.0 daN/cm^2 for variant 3 (luvisol with moderate compaction). It is obviously that the greatest values of penetration resistance are characteristics to compacted and heavy soils (variant 3).

All the above results presented in tables 5. and 6. are in according with the agro-technical demands imposed to tillage by various authors (Brady N. C., 1996; Nedeff V., Sin Gh. and Băisan I., 1995; Onisie T. and Jităreanu G., 1999; Toma D. and Sin Gh., 1987) and shows the fact that during our research were very good conditions for a suitable tillage work.

RESULTS AND DISCUSSIONS

The values of soils' breaking up degree, in the conditions of performing tillage on those three types of soil (light, medium and heavy), with two ploughing units (U-650M+PP-3-30 and U-650M+PRP-3) and with v_1=4.48 km h^{-1}, v_2=4.61 km h^{-1}, v_3=4.85 km h^{-1} and v_4=4.98 km h^{-1} as working speeds, are presented in figures 3, 4, 5 and 6.

Figure 3 presents the data regarding v_1=4.48 km h^{-1} speed and we observe that soils' breaking up degree had superior values that the ones imposed by the agro-technical demands. The minimal imposed values for soils' breaking up degree are: 95 % for light soils; 75 % for medium soils and 55 % for heavy soils (Nedeff V., Sin Gh. and Băisan I., 1995; Onisie T. and Jităreanu G., 1999; Toma D. and Sin Gh., 1987).

For a light soil the breaking up degree obtained after tillage with PRP-3 reversible plough was with 0.4 % better that the one recorded when tillage was performed with PP-3-30 plough, having a value of 98.1 % in comparison with the value of 97.7 %. On a medium soil the breaking up degree recorded an improvement of 2 % at tillage with PRP-3 reversible plough (80.3 %) in comparison with the value 78.3 % obtained at processing tillage with PP-3-30 plough. In the case of a heavy soil the difference between the recorded values was of 1.4 % in the favour of performing tillage with PRP-3 reversible plough (69.9 %) while at tillage with a conventional PP-3-30 plough this index had the value of 68.5 %.

When tillage was performed with v_2=4.61 km h^{-1} working speed, breaking up degree had also superior values to the ones imposed by the agro-technical demands, for all three soil types (figure 4.). For variant 1 (light soil) the breaking up degree obtained after tillage with PRP-3 reversible plough was with 0.6 % better that in the case of processing tillage with PP-3-30 conventional plough, having a value of 97.6 % in comparison with the value of 97.0 %. On a medium soil the breaking up degree recorded an improvement of 1.8 % at tillage with PRP-3 reversible plough (79.3 %) in comparison with the value of 77.5 % obtained at tillage with PP-3-30 plough. In the case of a heavy soil the difference between the obtained values was of 2.9 % in favour of processing tillage with PRP-3 reversible plough (65.6 %) while at tillage with PP-3-30 plough this index had the value of 62.7 %.

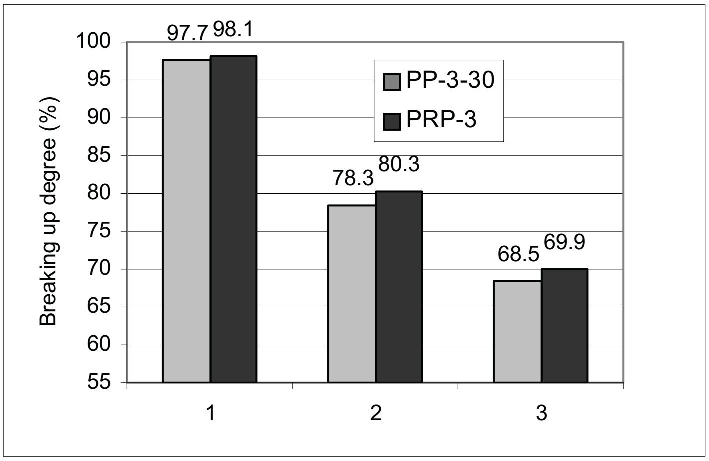


Figure 3 Variation of soils’ breaking up degree at v1 = 4.48 km h-1

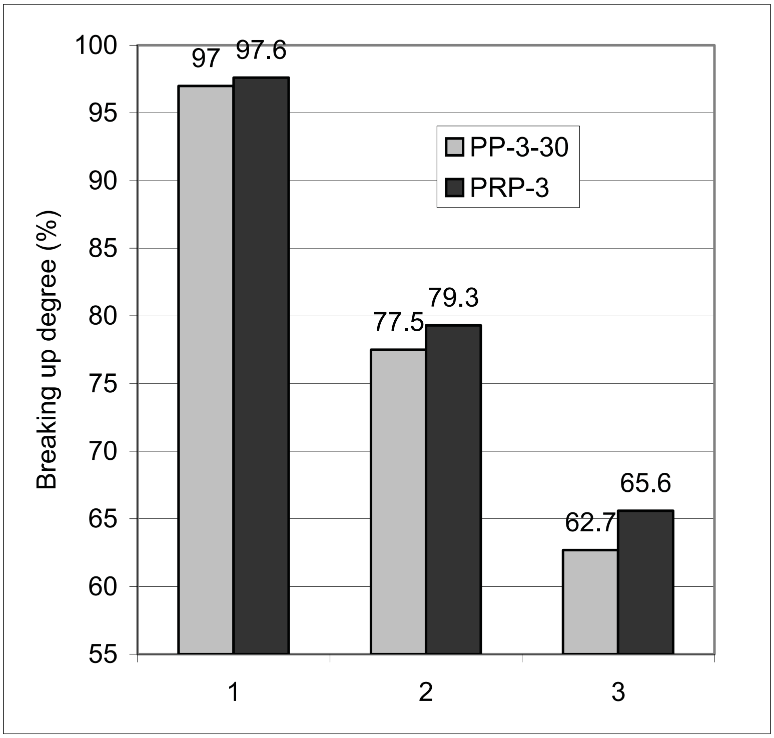


Figure 4 Soils’ breaking up degree at v_2 = 4.61 km h^{-1}

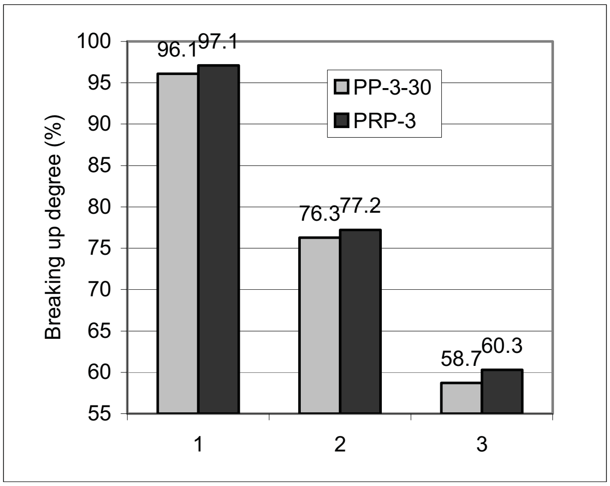


Figure 5 Soils' breaking up degree at v_3 = 4.85 km h^{-1}

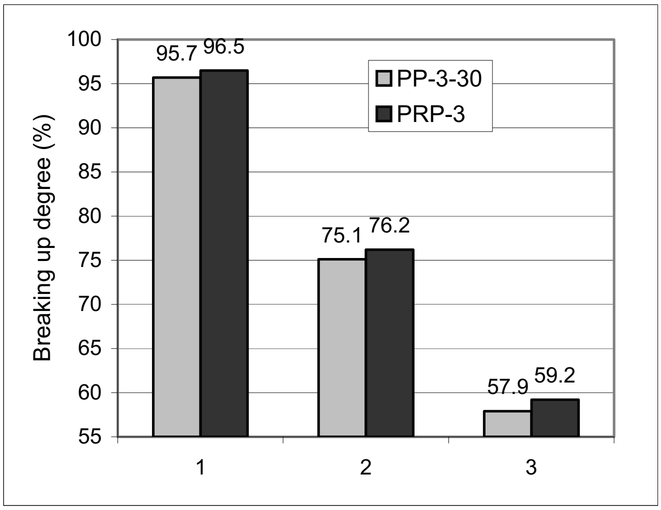


Figure 6 Soils' breaking up degree at v_4 = 4.98 km h^{-1}

At another speed gear (v_3=4.85 km h^{-1}) the breaking up degree, for all soil types, recorded superior values that the imposed ones (figure 5.). Soils' breaking up degree obtained after performing tillage with PRP-3 reversible plough on a light soil was with 1.0 % better that the value obtained at tillage with PP-3-30 plough, 97.1 % in comparison with the value of 96.1 % obtained at tillage with PP-3-30. On a medium soil, breaking up degree recorded an improvement of only 0.9 % at tillage with PRP-3 (77.2 %) in comparison with the value of 76.3 % obtained at tillage with PP-3-30 plough. As regarding heavy soil (variant 3), the difference between the obtained values was 1.6 % in favour of processing tillage with PRP-3 reversible plough (60.3 %) while at tillage with PP-3-30 conventional plough this index had the value of 58.7 %.

The data presented in figure 6., for the highest working speed (v_4=4.98 km h^{-1}), shows that the values of soils' breaking up degree, for all three soil types, are superior to the imposed values. For a light soil the breaking up degree obtained after tillage with PRP-3 reversible plough was with 0.8 % better that the one obtained tillage with PP-3-30, having a value of 96.5 % in comparison with the value of 95.7 % recorded at tillage a conventional plough. On a medium soil the breaking up degree recorded an improvement of 1.1 % at processing tillage with PRP-3 (76.2 %) in comparison with the value of 75.1 % recorded at tillage with PP-3-30. For heavy soil the difference was 1.3 %, at tillage processing with PRP-3 the value of 59.2 % was recorded while at using PP-3-30 the value was 57.9 %.

CONCLUSIONS

The results of this research show that if working speed increase, soils' breaking up degree will have smaller values. The lowest values of the index will be obtained at the highest working speeds. The greatest values of soils' breaking up will be obtained at the lowest working speeds.

The reason why we chose as working speeds, the above presented values (v_1=4.48 km h^{-1}, v_2=4.61 km h^{-1}, v_3=4.85 km h^{-1} and v_4=4.98 km h^{-1}) is the one that we consider if conclusive results are obtained at very small differences between working speeds the same interpretation will be obtained at great differences between working speeds.

Soils' breaking up degree determined in our research experiments had superior values in comparison with the minimal values imposed by the agro-technical demands.

Soils' breaking up degree will have the highest values when tillage is performed with the aggregate formed by U-650M tractor and PRP-3 reversible plough, and the lowest values will be recorded when tillage is performed with the aggregate formed by U-650M tractor and PP-3-30 conventional plough, on the same type of soil and with the same working speed.

So as a general conclusion we can say that performing tillage with a PRP-3 reversible plough will lead to better values of soils' breaking up degree face to the ones obtained at performing tillage with a PP-3-30 conventional plough, on the same type of soil and at the same working speed.

REFERENCES

1. Avarvarei B. V. (2007). *Researches regarding the establishment of plough type for superficial and normal ploughings.* Doctorate Thesis, University of Agricultural Sciences and Veterinary Medicine from Iaşi, ROMANIA.
2. Brady N. C. (1996). *The nature and properties of soils*. Macmillan Publishing Company, New-York, USA.

3. Nedeff V., Sin Gh., Băisan I. (1997*). Procese de lucru şi consumuri de energie la lucrările solului.* S. C. Agris – Redacţia Revistelor Agricole, Bucureşti, ROMANIA.

4. Onisie T., Jităreanu G. (1999). *Agrotehnica*. Editura "Ion Ionescu de la Brad", Iaşi, Romania.

5. Toma D., Sin Gh. (1987). *Calitatea lucrărilor executate mecanizat pentru culturile de câmp*. Editura "Ceres", Bucureşti, ROMANIA.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.312
Prethodno priopćenje
Preliminary communication

THE STRATIFIED COMPOSITE MATERIALS IMPLEMENTATION IN THE ENGINEERING OF THE MOULDBOARDS

SORIN – TIBERIU BUNGESCU[1], PAUL PARSAN[1], SORIN – STEFAN BIRIS[2], VALENTIN VLADUT[3], FLORIN IMBREA[1], IOAN PETROMAN[1]

[1]Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara – Department of Agricultural Machines, 119, Calea Aradului Street, Timisoara – Romania, Zip code 300645, e-mail: sobungi@yahoo.com
[2]"POLITEHNICA" University of Bucharest – Romania, 313, Splaiul Independentei Street, Bucharest – Romania, Zip code 060042, e-mail: sorin_biris@yahoo.com
[3]Research and Development National Institute for Agricultural and Food Industry Machines and Implements – INMA Bucharest, 6, Ion Ionescu de la Brad Blvd. Bucharest – Romania, Zip code 013813, e-mail: valentin_vladut@yahoo.com

SUMMARY

The paper presents the results of the author's researches on the line of pointing out the differences of behavior at the requirements of the stratified composite materials used in the moldboard's engineering of mechanic ploughs and pointing out the advantages in using the stratified composite materials in comparison with the traditional materials.

Key words: *stratified composite materials, moldboard*

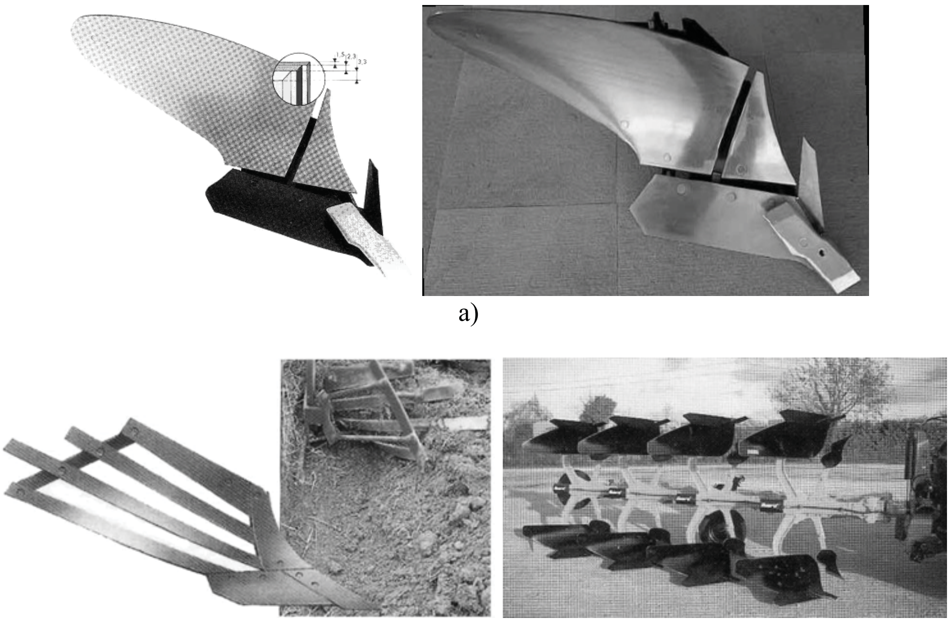
INTRODUCTION

During work the plough must be a very stable mobile technical system. The stability of the plough in work is the result of the effectuation of some accurate adjustments about the afferent mechanisms which define the parameters which estimate the achievement of the stability in work (by maintaining of a depth and breadth of work at constant values). At the insurance of this stability it contribute both the correct attaching of the plough at the tractor and the measure in which the materials the working mechanisms are manufactured from, it attenuate the negative influence of some disturbed factors which appear directly during the work such as: impacts, vibrations, land's variations of level, the appearance of some rigid obstacles.

The contribution of these negative factors it is also amplified by the modification tendency of the change of place surface's geometry of the furrow as a result of the abrasive and chemical wear of this surface. The abrasive wear has a decisive contribution in modification of the initial geometry of the working surface. As a result, the mechanical ploughs designers are concerned in finding some materials that satisfy maximum the counteracting possibility of the destructive and unbalance combined effect of all these factors. Therefore, both in the current stage and in the prospect the researchers' attention is pointed towards finding of some materials that, on one side, to answer more efficient to these requirements, and on the other side, to situated the cost at an acceptable level on the international market.

MATERIALS AND METHODS

Two laminated stratified composite materials realized by the companies from C.S.I. and the TRIPLEX material realized by the French company Huard (figure 1 a, c) used at moldboards of mechanical ploughs were studied by the author as part of the Polyvac laboratory of U.M. Timişoara, "Materials' Science and Thermic Treatments" Department from U.P. Timişoara and "Materials Technology" laboratory as part of MAT Craiova factory.



a)

b) c)

Figure 1 Types of moldboards achieved of stratified composite materials:
a) the moldboards of Huard French company with the material representation (g=10 mm);
b) the lamellar moldboard of Massey Ferguson American company achieved of a stratified composite material (g=12 mm); c) the plough with moldboard of “losange” type of Huard French company, achieved of stratified composite materials (g=10 mm)

RESULTS AND DISCUSSION

From functional, economic or aesthetic reasons exist today the tendency of replacement of the traditional materials(OLC45, OLC60, Si-Cr-V steel) with those obtained through mechanical mixture, at macroscopic scale, of two or more materials.

The integral utilization of the strength capacity of the used materials is an important way of reduction of the planned product's cost. From this point of view, the projection of any strength structures made up of composite materials has a supplementary component part given the projection of these from traditional material's microstructure in concordance with the most propitious behavior requirements in exploitation of the product. Today, the composite materials are specially created in order to respond to some exquisite exigencies as concerns the mechanical strength, rigidity, reduced specific weight, dimensional thermic and chemical steadiness, strength at tiredness, impact, wear and tear of the insulating properties, aesthetics, and last but not least the economic imperatives.

Today, on international plane, were achieved different laminated stratified composite materials for moldboards, resisting at wear, with great stability at abrasive wear and alternative requirements, which consist of at least two stuck materials (bound together) [1]. Thus it can combine the best properties of the constitutive materials, obtaining a superior material as to strength, rigidity, density, aesthetics, strength at corrosion, humidity and so on.

The great majority of the foreign companies achieve the mechanical plough’s' moldboar-ds from a laminated stratified compose material achieved from three stratums of steel (figure 2) [1]. This is constituted from a middle stratum, supple, achieved from a steel with content in carbon of 0,055 . . . 0,1%, that by its persistence reduces at minimum the risk of breaking through impact and from two external stratums achieved from steel with high carbon content, of about 0,7%, that is allied with chromium and elaborate in electrical furnace. These peripherical stratums are resisting at wear and have a great hardness. This laminated stratified composite material, after tempering, obtains a high strength, a good strength at impacts at which it also adds a great superficial hardness.

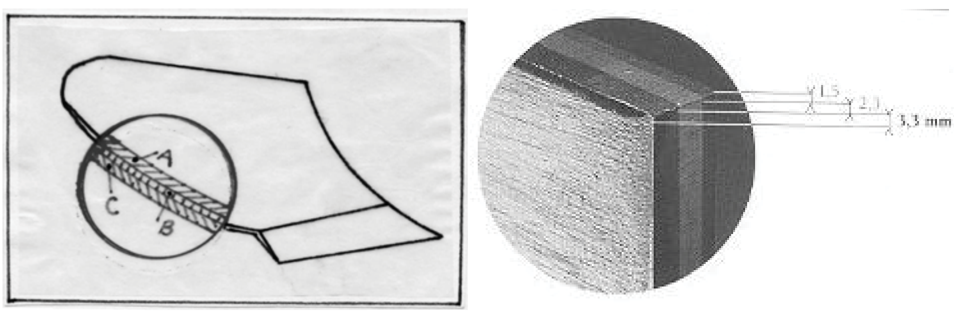


Figure 2 Detail regarding the laminated composite material used at mouldboards

In steeled state, the very fine grain of those two external stratums permits a gentle polishing and ensures a surface with a high degree of smoothing, that appreciably reduces the sticking possibility of the soil during the ploughing. These qualities ensure the moldboards a long duration in exploitation, superior to those with homogeneous hardness.

The composite materials in laminated state have a maximum hardness of 305 HB in accordance with the French technical standards NF 36361 and 269 HB in accordance with GOST 6765. These bounds are however over fulfilled in case of the steels with 1% C, fact that requires an annealing of the belts. After tempering in water, the hardness of these materials is of 60 Rc (608 HB) in accordance with French standards and 55 Rc in accordance with GOST standards.

In the tables 1 and 2 it presents the chemical composition for each stratum partly of the laminated composite materials achieved by different foreign and Romanian companies.

Table 1 The chemical composition of the material, mark KAP 85D, achieved by the Japanese company KAWASAKI

Stratum	C [%]	Si [%]	Mn [%]	$P_{max.}$ [%]	$S_{max.}$ [%]	$Cr_{max.}$ [%]	$Ni_{max.}$ [%]
A	0.80...0.90	0.15...0.35	0.30...0.90	0.035	0.035	0.25	0.25
B	0.15	0.30	0.25...0.50	0.035	0.035	0.057	0.057
C	0.80...0.90	0.15...0.35	0.30...0.90	0.035	0.035	0.25	0.25

Table 2 The chemichal composition of the material achieved by the Romanian company SIDEX S.A. GALAȚI

Stratum	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Ni [%]	Steel's mark
A	0.65...0.75	0.15...0.35	0.15...0.35	0.03	0.025	0.20	0.25	OSC7
B	0.07...0.14	-	0.35...0.65	max. 0.040	0.020...0.045	-	-	OLC10
C	0.65...0.75	0.15...0.35	0.15...0.35	0.03	0.025	0.20	0.25	OSC7

Two laminated stratified composite materials realized by the companies from C.S.I. and the TRIPLEX material realized by the French company Huard used at mouldboards of mechanical ploughs were studied by the author as part of the Polyvac laboratory of U.M. Timişoara, "Materials' Science and Thermic Treatments" Department from U.P. Timişoara and "Materials Technology" laboratory as part of MAT Craiova factory.

In the table 3 and 4 it presents the chemical composition for each stratum partly, of two laminated composite materials, determined by the author.

The variation of the hardness on section at the laminated stratified composite material achieved by the French company (tempering + low return), determinate by the author, in accordance with the quality standards "CITROEN" is presented in the table 5 and figure 3,a and that of those two materials realized by the companies from C.S.I.,determinated by the author, is presented in the tables 6 and figure 2,a,b.

In order to compare the stratified composite materials with traditional materials, as part of the MAT Craiova company were performed and studied samples of tin of 7 mm from

OLC60 and OLC45, at which were aplicated the following technology of thermic treatment: tempering followed by the return to 450^o C. The results that we obtained for the sample from OLC60 are presented in the table 7. The variation of the hardness on section for OLC60 is presented in figure 3,b.

Table 3 The chemical composition of the laminated composite material, number 1, studied by the author[1]

Stratum	Fe [%]	C [%]	Si [%]	Mn [%]	P [%]	S [%]	Cr [%]	Mo [%]	Ni [%]	Al [%]	B [%]	Co [%]	Cu [%]	Pb [%]
A	98.0	0.676	0.208	0.649	0.009	0.0233	0.067	0.004	0.075	0.034	0.0001	0.002	0.131	0.0002
B	99.1	0.077	0.023	0.261	0.010	0.0300	0.070	0.008	0.009	0.011	0.000	0.003	0.160	0.0002
C	98.0	0.619	0.210	0.656	0.009	0.0257	0.067	0.005	0.075	0.035	0.0001	0.002	0.134	0.0002

Table 4 The chemical composition of the material achieved by the French company HUARD (TRIPLEX material)[1]

Stratum	C [%]	Mn [%]	Si [%]	P [%]	S [%]	Cr [%]
A	0.75	0.70	0.20	0.035	0.025	0.20
B	0.10	0.40	0.15	0.035	0.035	0.000
C	0.75	0.70	0.20	0.035	0.025	0.20

Table 5 The values of hardness on section for the TRIPLEX material achieved by French companies

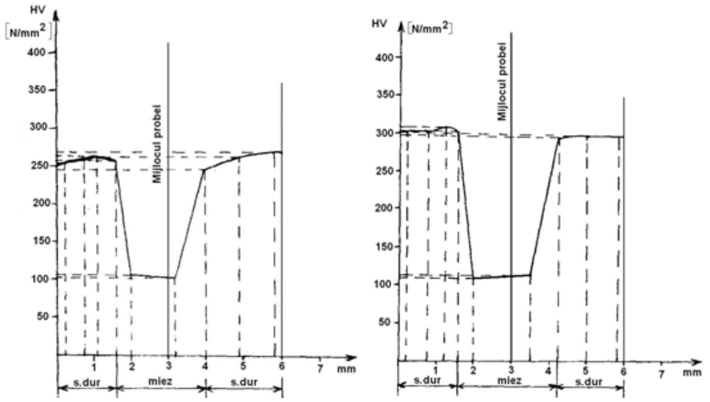
The distance from the surface of the sample [mm]	0	0.5	1	1.5	1.6	1.7	1.8	1.9	2	Core
Hardness HV	851	851	872	831	831	841	748	629	223	223
Hardness HRC	65.5	65.5	66	65	65	65.3	62	60	22	22

Table 6 The values of hardness on section and the tearing strength for the RED sample

RED sample								
The distance from the surface of the sample [mm]	0.2	0.8	1.2	2 (Core)	3.5 (Core)	4.2	5	5.8
Hardness HV [N/mm^2]	304	304	305	113	114	297	302	302
Hardness HB [N/mm^2]	289	289	290	108	109	284	287	286
Tearing strength [N/mm^2]	979	979	982	362	366	965	973	970

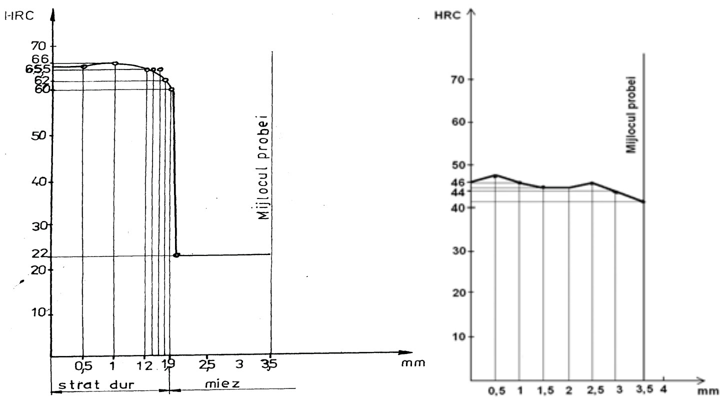
Table 7 The values of hardness on section for that OLC60 material, determinate by the author

The distance from the surface of the sample [mm]	0	0.5	1	1.5	2	Core
Hardness HRC	46	46	46	45	45	44



a) b)

Figure 3 The variation of the hardness on section for the two materials, realised by the companies from C.S.I, determinate by the author[1][2]: a) - Yellow sample; b) – Red sample



a) b)

Figure 4 The variation of the hardness on section for TRIPLEX tin (tempering + low return) and the variation of the hardness on section for the tin from OLC60 steel (tempering + return),determinate by the author[1][2]: a) – TRIPLEX material; d) – OLC60 steel

CONCLUSIONS

1. The duration of good efficient working in exploitation of the stratified composite materials is superior to the traditional materials.
2. The consumption of combustible decreases with about 9% in case of utilization the stratified composite materials.
3. The strength at wear is 2-3 time bigger in case of utilization of the stratified composite materials than in case of utilization of the traditional materials.
4. The existence of intermediary stratum with low hardness considerably improves the impact strength of these materials.
5. In the utilization’s conditions of the traditional materials OLC45 or OLC60 is obtained a hardness almost constant on the whole piece's section. This fact is caused by the great capacity of the respective steel to harden and the small thickness of the piece(7 mm), that leads to a tempering in depth. As a result of this fact appear a series of difficulties in the manufacturing process (fissures during the stamping of the hole, thermic treatment and breaking in fitting), assuring at the percent about 10% losses. Also, the hardness of the moldboards performed from OLC45 and OLC60 is much smaller, because of the low values of densities, which diminish the strength at wear during working.
6. The study performed praises that, with a view to avoiding the fissuring of the mechanical plough’s moldboards, is rather to be used laminated stratified composite materials.

RERFERENCES

1. Bungescu, S. (2001) - "Studies and researches regarding the stresses distribution on mouldboard’s surface of lamellar type with a view to construction's modelling and optimisation", Doctor's degree thesis, Timişoara;
2. Bungescu, S. (1998) – “Consideraţii teoretice privind distribuţia tensiunilor pe suprafaţa cormanelor plugurilor mecanice”, Referat nr. 2 al Tezei de doctorat, Universitatea POLITEHNICA Timişoara;
3. Bungescu, S. (2001) – “The researches on using the composite order in engineering of the mouldboards of mechanic ploughs”, Scientific Bulletin of the „POLITEHNICA” University of Timişoara, Transactions on MECHANICS, Romania, 46 (60) Tome, 2 Fascicle, pp. 91 – 98;
4. Bungescu, S.; Ştefan, C. (1998) – “Cu privire la evoluţia materialelor utilizate în construcţia cormanelor plugurilor mecanice”, Simpozionul “Tinerii şi cercetarea multidisciplinară”, Editura Sudura, Timişoara, pp. 245-254;
5. Bungescu S., Vladut V., Biris S., Tarcaet R., Paraschiv G. (2008) – „Thorough researches on using the stratified composite materials in engineering of the mouldboards of modern mechanic ploughs”,”Engineering and Management of Sustainable Development in Agriculture, Transports and Food Industry”, Lucrari stiintifice Nr. 25 , INMATEH 2008 – II, Bucuresti, pp. 56 – 60.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.51.01
Stručni rad
Expert paper

RESEARCH REGARDING THE INFLUENCE OF ANGLE OF FALL AND OF FURROW OVERTURNING TENDENCY ON COVERING DEGREE WITH SOIL OF THE VEGETAL REMAINS FROM PLOUGHING

GIGEL PARASCHIV[1], MAGDALENA-LAURA TOMA[1], SORIN-ŞTEFAN BIRIŞ[1], GHEORGHE VOICU[1], VALENTIN VLĂDUŢ[2]

[1]„Politehnica" University of Bucharest-Romania, 313, Splaiul Independentei Street, Bucharest-Romania, Zip code 060042, e-mail: paraschiv2005@yahoo.com
[2]Research and Development National Institute for Agricultural and Food Industry Machines and Implements - INMA Bucharest, 6, Ion Ionescu de la Brad Blvd. Bucharest – Romania, Zip code 013813, e-mail: valentin_vladut@yahoo.com

SUMMARY

The ploughing quality is good if, among other, the requirement regarding soil covering of the vegetal remains is accomplish too. This requirement is assess by covering degree with soil of the vegetal remains and has a minimal admissible value of 90%.

The experimental results (obtained in situ using the PP-2-30 M plough and the P-2V plough with variable working width), presented in this paper, prove that the agro-technical demand is not always accomplished.

After processing the experimental data, one can derive that this coefficient is influenced both by the slope of terrain to be ploughed and by the tendency of the furrow overturning for terrains having the slope higher than 6°.

Key words: *angle of fall, vegetal remains, ploughing*

INTRODUCTION

Technological working process of plough imposes a number of agro-technical or technological requirements that are taking into consideration in its designing, building and exploitation. Those requirements can be put up like this: depth and width of furrows made by plough must be constant along the ploughing; the cut furrows must be crumble, broke up and inverted, at the same time, it must be covered with soil the vegetal remains and fertilizers laying on the fields. On the ploughed soil are not allow large clumps, nor it is over grounding; the furrow bottom must be horizontal and smooth to avoid stagnation of water in low places and in furrow holes; the furrow wall must be straight, and in furrow ditch, clumps are not allowed. Other wise, plough has no proper working stability, which influence very much the ploughing quality; unploughed surfaces are allow inside the plot which can represent areas infested with weeds, and the plot ends must be closed with the final furrow inverted towards the plot.

Around 60% of Romanian ploughing area is uneven relief with different height slopes and, thus exposed to erosion phenomenon. The soil losses its fertile layer (which is transported downhill) and it is removed from agricultural use if the erosion expands. Soil works are one of the main factors that reduce the erosion processes if are done properly or emphasise erosion if are done wrongly.

MATERIAL AND METHOD

For sloped terrains, the direction of the ploughing, as well as the other works, is the general direction of the level curves (for smaller plots, with evenly slopes and low incline) or on the level curves for the flanks with different height slopes, with and big incline (over 18%).

The normal ploughing done on horizontal terrain imposes that the furrow overturning in a stabile equilibrium position, which requires that its centre of mass to be placed to the right of the supporting point C_1 (fig. 1).

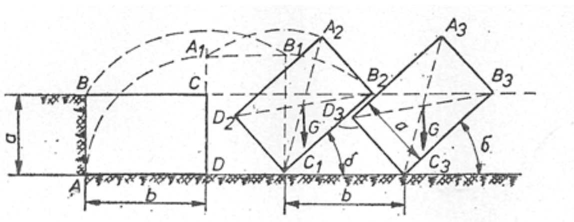


Fig. 1 The furrow kinetics for horizontal terrain ploughing

From the right-angled triangle $C_1D_3C_3$ one can establish the value of the furrow overturning angle δ:

$$\delta = arc\,sin\frac{C_3D_3}{C_1C_3} = arc\,sin\frac{a}{b} = arc\,sin\frac{1}{K} \tag{1}$$

The furrow will be situated in an indifferent equilibrium position for a coefficient K value of 1.27 and an overturning angle δ = 0.90 rad (52°), thus for a proper furrow overturning, one can impose: $K > 1.27$.

Slope ploughing is done along the level curves, with downhill overturning of the furrow, where $K < 1.27$ (fig. 2), and in uphill overturning case, $K > 1.27$ (fig. 3).

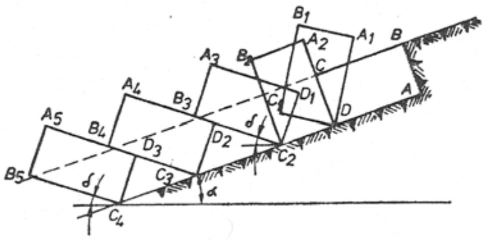


Fig. 2 The furrow kinetics for slope ploughing with downhill overturning of the furrow

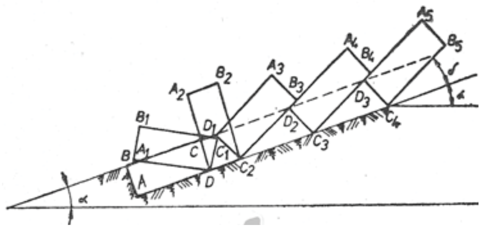


Fig. 3 The furrow kinetics for slope ploughing with uphill overturning of the furrow

For downhill overturning of the furrow, the slope angle α helps the overturning process, thus:

$$\frac{1}{K} = sin(\delta + \alpha) = \frac{a}{b} \quad \text{or} \quad K = \frac{1}{sin(\delta + \alpha)} \tag{2}$$

For uphill overturning of the furrow, the slope angle α renders more difficult the overturning process, thus:

$$\frac{1}{K} = sin(\delta - \alpha) = \frac{a}{b} \quad \text{or} \quad K = \frac{1}{sin(\delta - \alpha)} \tag{3}$$

One can write the general relation as

$$K = \frac{b}{a} = \frac{1}{sin(\delta \pm \alpha)} \tag{4}$$

where:

δ is limit angle of furrow overturn, equal to 0.90 rad (52°);

α - slope angle.

Using relation 4, one can calculate the coefficient K variation as a function of terrain slope.

For ploughing along the level curves, with upstream overturning of the furrow, done with normal plough-bodies, for the same working width of the plough-body, it cannot be accomplished the working depth as for the horizontal terrain ploughing. Thus, because the slope angle α decreases with its own value the overturning angle δ, which is foreseen for horizontal terrains. Maintaining the same value K, it appears the possibility to revert the furrow to its initial position (fig. 4). Thus, for this kind of ploughing, it appears the demand to increase the working width of the plough-body in order to maintain a normal depth, which increases the road resistance of the plough due to furrow section increase. To avoid this situation, the slope ploughings are done to a smaller depth that those on horizontal terrains.

Also for uphill overturning of the furrow, this is misplace to a higher height than for horizontal ploughing and requires an additional mechanical work for its lift leading to traction force increase and an additional energy consumption (*$\Delta h'$* > *Δh*) (fig. 4).

The imposed requirements to a good quality ploughing include the adequate coverage of the stubble fields and weeds, which is appreciate by the coverage degree with soil of the vegetal remains, having a admissible limit value of 90%.

Because this requirement is not accomplished in all cases, there were done experimental tests, with ploughing aggregates, in order to establish a relation between the angle of slope terrain, the angle of furrow overturning and the covering degree of vegetal remains.

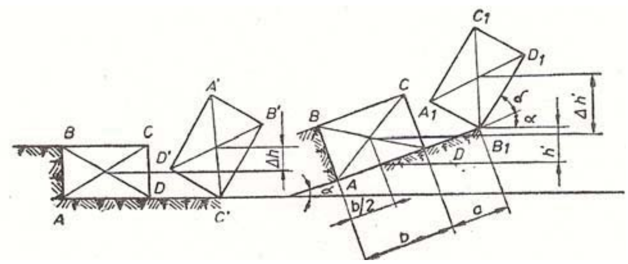


Fig. 4 The uphill kinetics of the furrow

The experimental tests were done using ploughing aggregates composed by 45, respectively 65 HP tractors and ploughs with 2 or 3 reversible plough-bodies and variable working width (fig. 5, 6, 7).

Fig. 5 Ploughing with 45 HP tractor

Fig. 6 Ploughing with 65 HP tractor on higher than 15º slope terrain

Fig. 7 Ploughing with 65 HP tractor on less than 15º slope terrain

RESULTS AND DISCUSSIONS

For slope ploughing, as shown, the coefficient *K* value is establish as function of slope angle and furrow overturning tendency (uphill or downhill). As a result, experimental tests were done on different slope terrains to several working depths and widths of the plough-body and they are presented in Table 1.

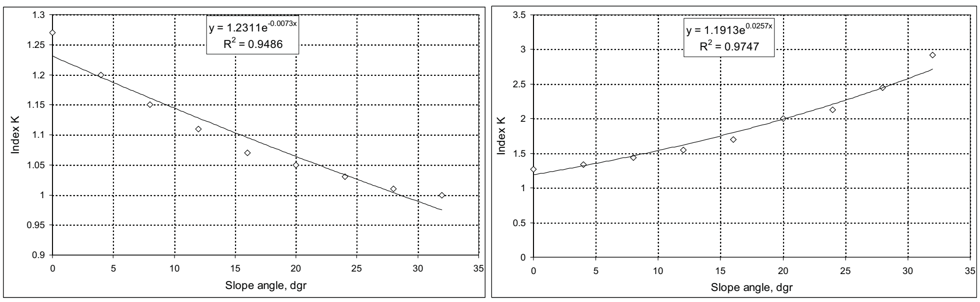
The coefficient *K* values, for slope ploughing with furrow overturning both uphill and downhill (values calculated based on the value of furrow overturning angle (52°) to which is added or subtracted the slope angle) are presented graphically in figure 8.

Experimental tests were done on terrains with slopes between 4 and 30°, at depths of ploughing of 16 – 25 cm and with plough-body working widths of 20 – 30 cm.

Experimental results regarding the soil coverage degree (CD) of the vegetal remains in different working conditions (slope, working width and depth) for uphill furrow overturning are graphically represented in figure 9 in which the coverage degree variation is presented for different slope angles and working depths.

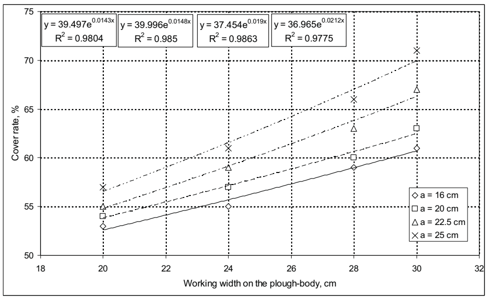
Table 1 The coefficient *K* values for different values of working depth and width

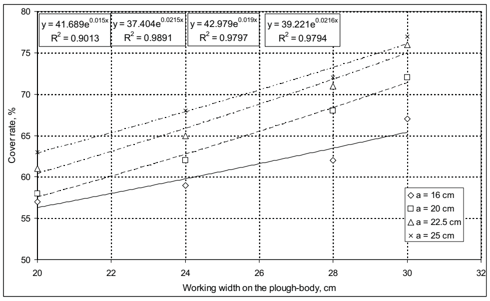
Working depth, a [cm]	Working depth of the plough-body, b [cm]	K	Working depth, a [cm]	Working depth of the plough-body, b [cm]	K
18	19.8	1.1	25	27.5	1.1
	21.6	1.2		30	1.2
	23.4	1.3		32.5	1.3
	25.2	1.4		35	1.4
	27	1.5		37.5	1.5
	28.8	1.6		40	1.6
	30.6	1.7		42.5	1.7
	32.4	1.8		45	1.8
	34.2	1.9		47.5	1.9
	36	2.0		50	2.0
20	22	1.1	30	33	1.1
	24	1.2		36	1.2
	26	1.3		39	1.3
	28	1.4		42	1.4
	30	1.5		45	1.5
	32	1.6		48	1.6
	34	1.7		51	1.7
	36	1.8		54	1.8
	38	1.9		57	1.9
	40	2.0		60	2.0



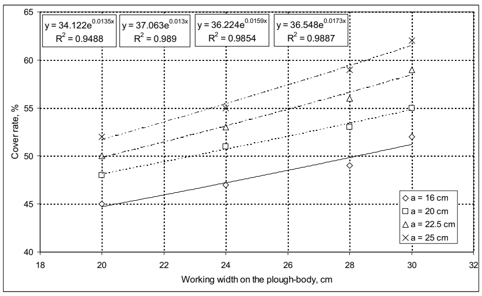
a) b)

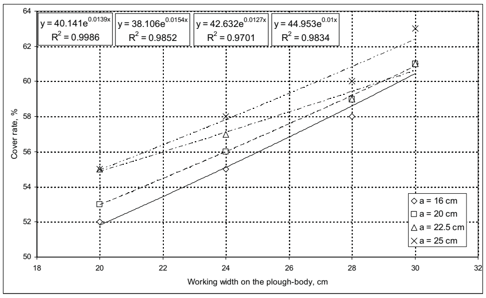
Fig. 8 The ratio *K* variation in relation to slope angle, on uphill (a) and downhill (b) furrow overturning



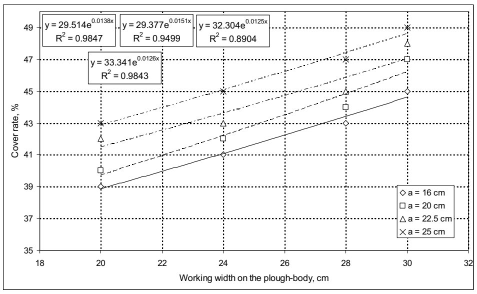


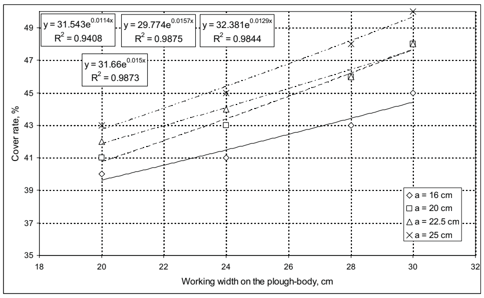
a) b)





c) d)





e) f)

Fig. 9 Variation of coverage degree of vegetal remains for slope ploughing with uphill furrow overturning
a) slope degree $\alpha = 4^o$; b) slope degree $\alpha = 8^o$;
c) slope degree $\alpha = 12^o$; d) slope degree $\alpha = 16^o$;
e) slope degree $\alpha = 20^o$; f) slope degree $\alpha = 24^o$;

CONCLUSIONS

Experimental results prove that agro-technical requirement related to the coverage degree of the vegetal remains (90%) is not realised in all cases. If on a plane terrain, the coefficient values exceed 90%, one cannot say the same thing for this coefficient when ploughing on slopes of 8 – 10°. In this case, especially when ploughs are adjust to minimum widths, the coefficient drops to about 52 – 53% for working depths of 16 – 20 cm.

Once the working width increases and large quantity of soil is moved, although the curves have the same shape, the minimum values obtain reach 75 – 77%.

Once the slope angle increases (20 – 24°), the values obtained for this coefficient decrease, reaching 39 – 40%.

Also, direction of furrow overturning influences this coefficient. When the furrow overturns downhill, for all adjusted working depths and widths, the coefficient exceeds 95%, having a slight rising tendency accordingly to slope angle increase.

Uphill furrow overturning is suitable for terrains expose to accentuated erosion phenomenon, as a result, in this case it is recommended to plough shallow but with maximum possible width of the plough-body.

REFERENCES

1. Budoi Gh., et. all (1996). Agrotehnica. Editura CERES, Bucharest
2. Căproiu Şt., et. all (1982). Maşini agricole de lucrat solul, semănat şi întreținere a culturilor. Editura Didactică şi Pedagogică, Bucharest
3. Paraschiv G., et. all (2008). Researches regarding the development of a soil preparation unit, according to the demands of sustainable agriculture, In: Actual Tasks on Agricultural Engineering, Opatija, Croatia, pp. 135 – 143

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.31
Stručni rad
Expert paper

THE INFLUENCES OF TILLAGE TOOLS CUTTING EDGE WEAR ON THE DRAFT

L.V. FECHETE-TUTUNARU, V. ROŞ, M. GHEREŞ

Technical University of Cluj-Napoca, Dept. of Road Vehicles and Agricultural Engineering, ROMANIA, e-mail: lucian.fechete@maar.utcluj.ro

SUMMARY

To evaluate the influence of tillage tools wear on draft, a series of soil bin test have been made using simple tools. The tools geometry was modelled through systemic analysis of soil-tool interaction in order to reveal the cutting edge influence. Along with several operating parameters, the tests results showed the influence of each factor and pair factors over tillage tools draft. The procedure was used to evaluate and predict the tillage tools durability and, it also can be developed and applied to different tools according to systemic analysis method.

Key words*: Tillage tools, wear, cutting edge, draft*

INTRODUCTION

Soil mechanical tillage represents a complex process with high energy and material use due to soil cutting resistance and abrasive properties. Optimising of this process must take into account all the parameters of the elements involved in the process, respectively the soil parameters, tool geometry parameters and process operating parameters.

One of the main issues within the tool geometry parameters refers to cutting edge which has a significant impact over the tool performance and agrotechnical conditions. In order to evaluate tillage tools from this point of view the researches made tries to relate, with the help of mathematical apparatus within an soil bin test, the parameters of cutting edge to the tool draft and more to the tool durability.

METHOD

Due to soil tillage process complexity and the multiple factors which are involved, it has been considered that the best approach of the research performed must rely on the systemic analysis of the process. The method used allow to quantify the parameters, variables and relations between by assimilating the working process with a system (Gill and Vanden Berg, 1968) dividing it in subsystems and modelling it with the help of mathematical apparatus.

Based on this method Ros et al (1993) was able to quantify the effects of different influence factors and parameters. More than that, he established several analytic relations in order to optimise the shape of the tillage tool. By developing the mathematical model used, the results showed the need to systematize the tool geometric parameters into three groups:

- *Tool macro geometry parameters*, which contain the tool shape and dimensions;
- *Working surfaces micro geometric parameters*, which have a very important role within soil-tool interaction as it influence the soil adhesion on the tool surfaces and by that largely the energy used and the quality of the agricultural work and also the tool wear and through this it's durability;
- *Cutting edges geometry parameters*, parameters which are modifying rapidly and continuous, many times representing the tool wear control parameters, with a significant influence over horizontal or vertical component of the tool draft (Fielke, 1996) respectively over energy consumption and quality of the soil tillage.

According to the previous stated based on the method of systemic analysis a simplified model of the soil-tool interaction was established (fig. 1).

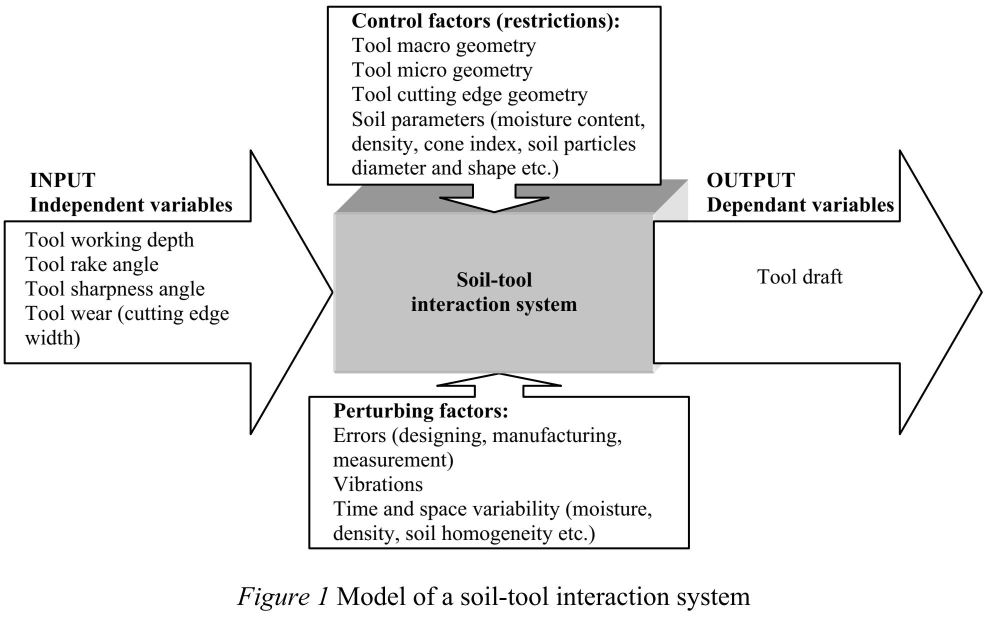


Figure 1 Model of a soil-tool interaction system

The soil used for experimentation corresponds to purely frictional no-structure soil respectively quartz sand washed and graded with particle diameter of maximum 0.3 mm. The choice of the soil is justified by the reduced number of soil parameters (soil without cohesion, structure etc.) which comply to the systemic analysis method and the statement expressed by Godwin and O'Dogherty (2007) "It should be noted that little data is available for very loose frictional soils".

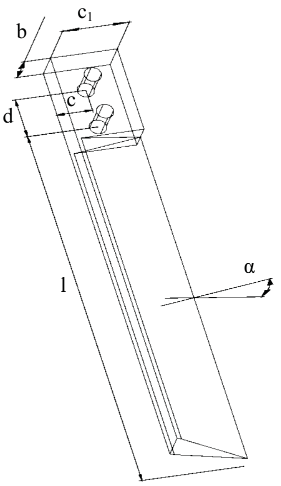


Figure 2 Tools geometric parameters

The tool model used was a simple towed wedge tool (fig. 2) having the cutting edge in a vertical plane, a very simple concept which allow to analyse the working process at a basic level and also represents the most used tool within conventional and conservation tillage.

There has been designed and manufactured a set of seven tools, each of it being worn out by reshaping the cutting edge respectively by changing for four times the width of cutting edge thus resulting an equivalent of 28 tools (tab. 1).

Within the soil bin of the laboratory equipment the tools were moved with a constant speed of 1.5 m/s on a circular trajectory with a diameter of 1.85 m.

Table 1 Tools geometric parameters

No.	Sharpness angle α [°]	Length l [mm]	Dist. c [mm]	Dist. c_1 [mm]	b [mm]	d [mm]	Cutting edge width j [mm]
1	15	290	30	83	20	68	0 2 4 6
2	30	290	21.5	46	20	68	
3	45	290	14	32	20	68	
4	60	283	12	31	20	68	
5	90	300	7	15	20	68	
6	120	300	7	15	20	68	
7	180	305	7	15	20	68	

To evaluate the effects of different geometric and functional parameters of the tillage tools, the propose experiment is a factorial standard one with combinations of all the factors levels (3x7x4x3). Based on the geometry tools and the equipment capabilities the independent parameters (factors, X_j) used and the dependant variables (response, Y) were summarized as follows (tab. 2):

Table 2 Experiment initial data

Experiment parameters			
No. of factors			4
No. of responses			1
No. of complete cases			252
Degree of freedom			180
Randomized			yes
Factors	**Levels**	**Units**	**Description**
Position	3	[mm]	Tool working position – correspond to different working depth (*d*)
Tools	7	[°]	Value of tool sharpness angle (ε)
Chamfer	4	[mm]	Tool cutting edge width (*j*) – cuantify the tool wear
Rake	3	[°]	Tool rake angle (α)
Response	**Units**	**Description**	
Draft	[N]	Horizontal component on the tool due to soil resistance force	

For all the 252 trials, made with an HBM Spider 8 DAQ system and corresponding force transducers for maximum sensibility, the measured data were processed and filtrated with a Butterworth low-pass filter. For the data obtained, a procedure of calculus of errors was established and applied.

The next step was to establish a statistic model to describe the impact of two or more categorial factors X_j over the dependant variable Y with the help of multifactor analysis of variance (ANOVA) and multiple linear regression procedures. The procedures tests can show if there are significant difference from statistical point of view between the means of the Y variable at different factors levels and if there is interaction between factors.

RESULTS AND DISCUSSION

The ANOVA table divides the overall variability among the 252 measurements into three components: main effects, interactions and residuals. Of particular importance are the F-ratios, values of the Fisher test and the associated P-values. Small P-values correspond to significant effects (less than 0.05 if operating at the 5% significance level).

Table 3 Analysis of variance for *Draft*

Source	Sum of squares	Difference	Mean square	F-ratio	P-value
MAIN EFFECTS					
A:*Position*	2.04985E6	2	1.02493E6	4493.70	0.0000
B:*Tools*	172430.	6	28738.4	126.00	0.0000
C:*Chamfer*	18725.7	3	6241.9	27.37	0.0000
D:*Rake*	964892.	2	482446.	2115.24	0.0000
INTERACTIONS					
AB	86442.5	12	7203.54	31.58	0.0000
AC	4769.99	6	794.999	3.49	0.0044
AD	339131.	4	84782.6	371.72	0.0000
BC	12745.2	18	708.065	3.10	0.0003
BD	53520.6	12	4460.05	19.55	0.0000
CD	3466.47	6	577.746	2.53	0.0279
ABC	7559.35	36	209.982	0.92	0.5993
ABD	69515.3	24	2896.47	12.70	0.0000
ACD	2836.27	12	236.356	1.04	0.4262
BCD	8576.58	36	238.238	1.04	0.4275
RESIDUAL	16421.8	72	228.081		
TOTAL (CORRECTED)	3.81089E6	251			

For the current experiment it can be seen that the factors and the combinations of factors have significant effects on dependent variable except the combinations between factor *Chamfer* and other two factors. Also, within the pair's combinations which include *Chamfer*, the P-value is near to the significant limit due to reduced influence of this tool variable over the total response by vertical working position of the tool in which soil pressure over the tool length is not uniform. Instead, if the tool cutting edge is horizontal and placed in the position of maximum soil pressure (as ploughshares) a magnified effect of the *Chamfer* factor on the *Draft* of the tool can be accounted. If graphically represented the ANOVA table, factors effect variability on residuals, it can be easily seen that for the factors analysed the differences are higher than the experimental errors and also can be highlight the effect magnitude of each factor.

A graphic representation of the mean *Draft* for each level of the factors with corresponding confidence limits (fig. 3) show statistic significant difference between the selected mean confidence levels. This aspect is partially true for factors *Chamfer* and *Tools*, where interval pairs are partially overlapping due to tool working position as previously mentioned. Similar, in fig. 4 there are graphically represented the interactions of paired factors with confidence limits. In the case that represented lines are approximately parallel, the factors are not interact with each other, if not, the effect of a factor depends the level of the other factor which is the meaning of the interaction. For a better understanding of the rapport between the analysed factors, paired factors interactions are presented in parallel by inversing the factors in the pair.

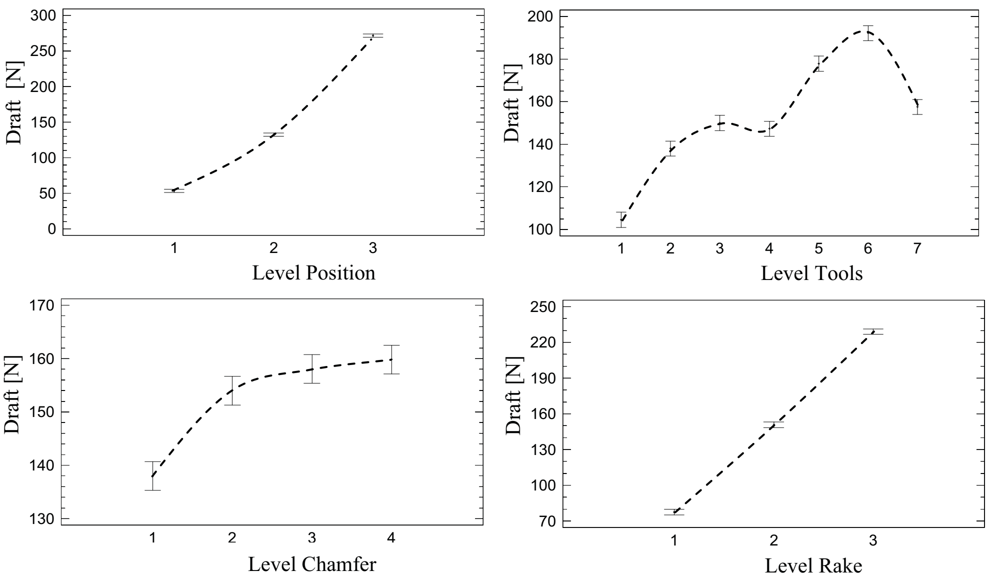


Figure 3 Factors influence and level dispersion over tool draft

The results obtained and presented in the paper, within the specific conditions of the experiment, shows similar behaviour of the tool response to depth or rake angle as presented in the literature, more than that it show the importance of preserving tool geometry respectively the geometry of the cutting edge. From the fig. 3 can be seen that increasing the *Chamfer* level which corresponds to more pronounced wear of the tool cutting edge, the curve obtained shows an accelerated increase of *Draft* and continuing to increase the *Chamfer* it stabilise the value of *Draft*. Also can be seen the influence of sharpness angle quantified by factor *Tools* were the value of the force can be doubled. It can be seen a local minimum of the curve represented which can indicate for different types of tillage tools, depending of their destination, an optimum sharpening angle. In order to explain objective the curvature between *Tools* levels 3-5 (respectively 45^o-90^o sharpening angle) it is necessary to use smaller steps of this factor in experimentation.

In order to establish a statistical model regarding the impact of the four factors under their quantitative form on the dependant variable a model of linear regression was used with the help of Box-Cox transformation to stabilise the variance of the deviations. The results of the statistical procedure are presented in tab. 4.

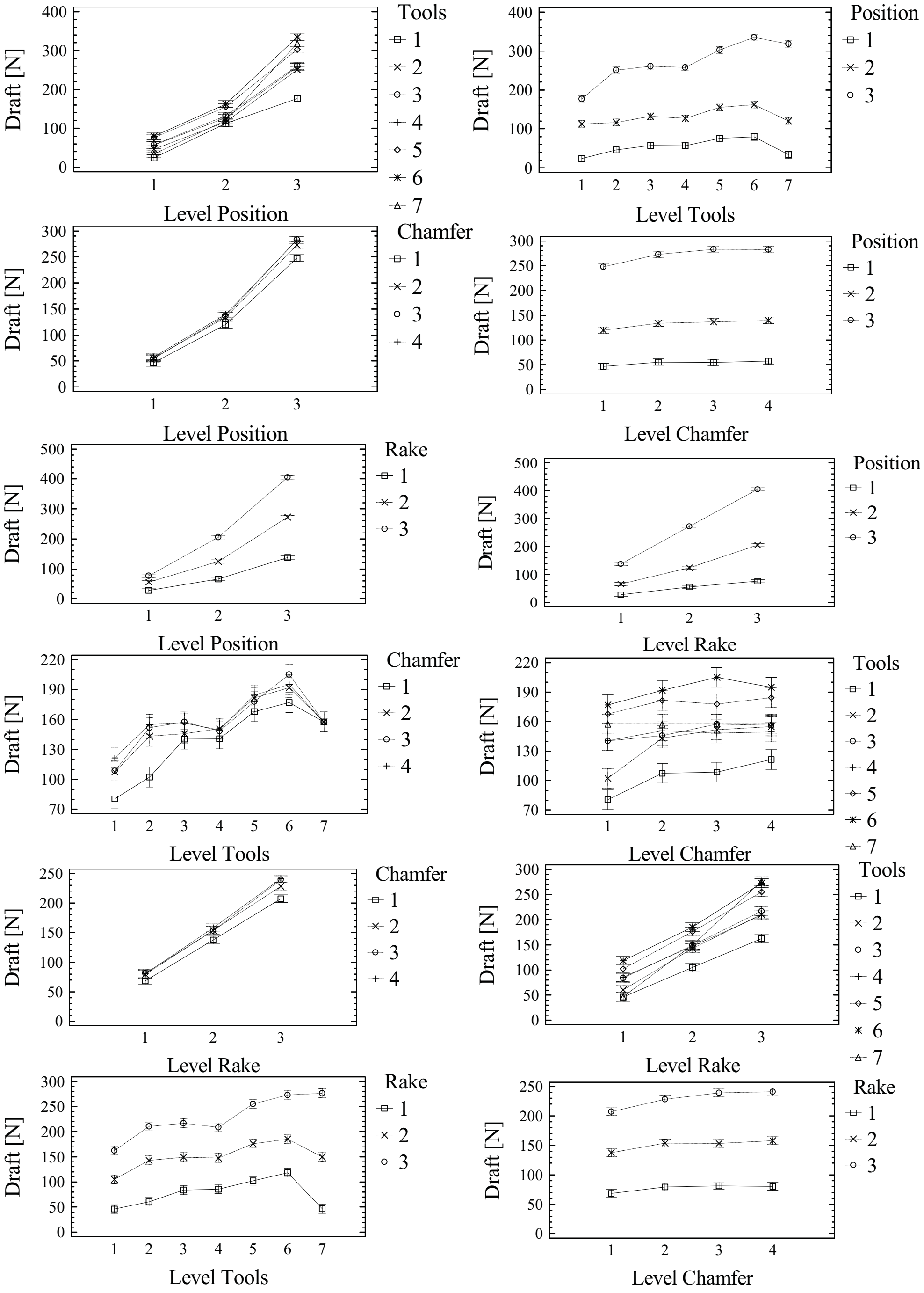


Figure 4 Factors pairs interaction

Table 4 Multiple liniar regresion procedure with Box-Cox transformation
(λ_1 =0.168077, λ_2 = 0)

Parameter	**Estimate**	**Standard error**	**T statistic**	**P-value**	
j	2.93538	1.07312	2.73537	0.0067	
α	1.23565	0.121422	10.1765	0.0000	
d	1.73553	0.0580237	29.9106	0.0000	
Analysis of variance					
Source	**Sum of squares**	**Difference**	**Mean Square**	**F-Ratio**	**P-Value**
Model	3.30734E7	3	1.10245E7	7268.47	0.0000
Residual	377671.	249	1516.75		
Total	3.34511E7	252			

R^2= 98.871 %, R^2 (adjusted for dif.) = 98.8619 %, Standard error of est. = 38.9455, Mean absolute error = 29.177, d (Durbin-Watson statistic)= 0.904059, h (Lag 1 residual autocorrelation) = 0.544671

The equation of the fitted model which describes the relationship between *Draft* and other three variables (variable ε was eliminated due to the fact that the term was not statistically significant at a confidence level of 95% or higher) is:

$$\mathrm{BoxCox}\,(Forta) = 2.93538 \cdot j + 1.23565 \cdot \alpha + 1.73553 \cdot d \tag{1}$$

where

$$\mathrm{BoxCox}\,(Forta) = 1 + \frac{(Forta^{0.168077} - 1)}{0.168077 \cdot 106.18^{-0.831923}} \tag{2}$$

Using the same procedure an estimation of wear influence on the draft has been made with direct implications over energy consumption and lost tillage tool material through wear. The data obtained were associated with initial results for the unworn tool and to several data's from Tomescu *et al.*

The first step consist in establishing a model which to describe the impact of tool sharpening angle (ε) over the linear wear (u). Using a simple model of linear regression the obtained equation is:

$$u = (10.0625 - 1.87473 \cdot \ln(\varepsilon))^2 \tag{3}$$

For the above equation, the percentage of the variability in u which has been explained by the fitted regression model (R^2) is 84.6% and the estimated standard deviation of the residuals (the deviation around the model) of 1.48 which can be used to create prediction limits for new observations.

The graphic representation of regression equation, the confidence limits and the prediction limits (fig. 5) show the large influence of the tool sharpening angle over the tool linear wear and so the importance of this angle in making a compromise between the tool draft (which increase with wear) and the volume of tilled soil.

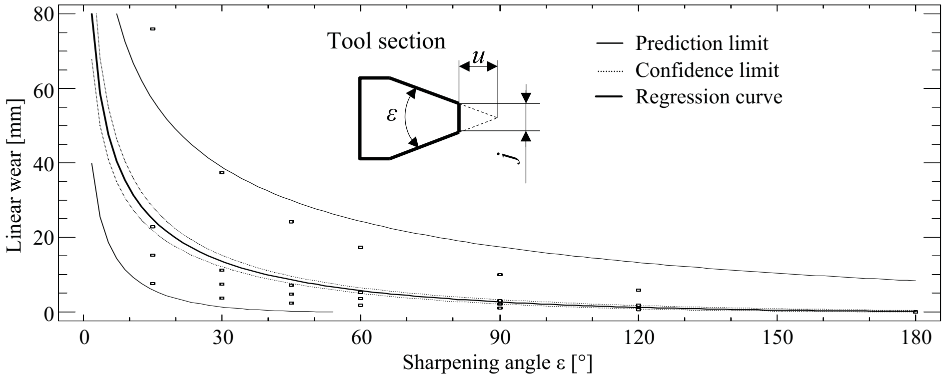


Figure 5 Tool sharpening angle influence over linear wear

Relating the obtained data to the results presented by Tomescu *et al*. respectively the wear mean intensity (3.24 g/ha) of the tillage tools of Romanian sowing machine SPC-6, another statistical model can be made to predict the tilled area (fig. 6):

$$\textit{Tilled area} = (0.886856 + 0.224812 \cdot u)^2 \qquad (4)$$

Similar graphic representations (fig. 6), as above, show the possibility to predict the tilled area as a function of linear wear or vice versa.

Using a multiple linear regression procedure the dependence between the tool draft and tilled area or linear wear and tool parameters (geometric and functional) can be established (Fechete, 2008).

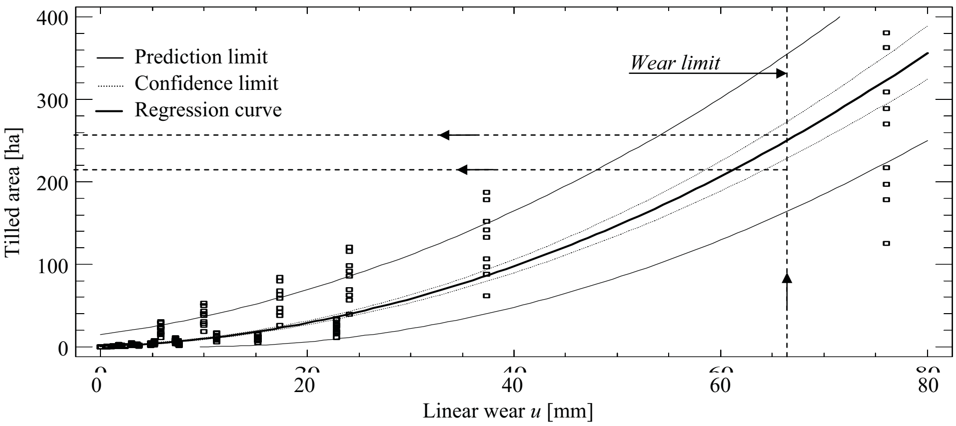


Figure 6 Correspondence between tool linear wear and tilled area

CONCLUSIONS

The systemic analysis procedure allows quantifying the parameters, variables and relationship between, and represents a powerful method to evaluate and optimise the tillage process. Through this method a concept of maintaining initial tool geometry emerges in order to obtain the performance requested respectively the desired agrotechnical conditions, the economical, technical and environmental objectives.

Applying the method used in this paper, different specific mathematical models can be obtained in order to predict the tools draft using different parameters or variables established through the systemic analysis method. Using the models presented, different parameters can be imposed to obtain the desired technical or economical durability.

REFERENCES

1. Fechete L.V. (2008). Cercetări privind optimizarea procesului de prelucrare mecanică a solului. Teză de doctorat . UTCN, Cluj-Napoca
2. Fielke J.M. (1996). Interactions of the cutting edge of tillage implements with soil. JAER, 63, p:61-72
3. Gill W.R., Vanden Berg G.E., (1968). Soil dynamics in tillage and traction. Agricultural Handbook No. 316, U.S. Government Printing Office, Washington D.C.
4. Godwin, R.J., O'Dogherty, M.J. (2007). Integrated soil tillage force prediction models. Journal of Terramechanics, 44, p:3-14
5. Karamusantas D. (1988). Contribuţii asupra analogiei geometriei brăzdării şi geometriei sculelor aşchietoare (Contribution on tillage tools and metal cutting tool analogy). Teză de doctorat. IPCN, Cluj-Napoca
6. Roş V. et al. (1995). Mathematical Modeling and Computer-aided Design of Passive Tillage Tools. Transactions of ASAE 38(3), p:675-683
7. Tomescu D. et al. (1971). Recondiţionarea şi mărirea rezistenţei la uzură a organelor active de la maşinile agricole. Editura Ceres, Bucureşti

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.331.53:631.53.043:633.15
Prethodno priopćenje
Preliminary communication

DESIGN, DEVELOPMENT AND FIELD EVALUATION OF A PUNCH WHEEL FOR PLANTING ON A CONSERVATION TILLAGE SYSTEM

Y. SABURI GERMI, J. ROBATI, M. ALIVAND RASHAKANI

Crop Production Technology Dep., Faculty of Agriculture, University of Maragheh, Maragheh, Iran. Javad_rebati2000@yahoo.com & ysabouri@gmail.com

ABSTRACT

Applying the precision planters such as punch planters is one of the methods for increasing yield performance by retaining the conservation tillage advantages. In this study, a type of dibble punch planter with seed plate metering device was designed and constructed for corn planting, and was tested in the field on three soil conditions (tilled, untilled with no residue, untilled with wheat residue) and at three forward speeds (1.5, 3, 4.5 kmh^{-1}). Then, the planter performance was evaluated with quality of feed index, miss index, multiple seed index, depth index and radius of contact cross section area in the field. Field test results showed that the second speed (3 kmh^{-1}) has relatively higher feed index. The difference of feed index was not significant between tilled soil and untilled soil (with residue) and also between v1 & v2. Also, the difference between the different levels of soil conditions and forward speeds was significant ($p<0.01$). It is concluded that optimum speed for applying this planter, was 3kmh^{-1} and it is suitable for no-till systems which have residue.

***Key words**: Punch planter, Conservation tillage, Miss Index, Multiple Index*

INTRODUCTION

In precision planting the exact distance between seeds on the row is provided and the even seed bed is produced. Though, applying the precision planters such as punch planters is one of the methods for increasing yield performance by retaining the conservation tillage advantages.

Because of the ability of punch planters to plant on the stony soils and on the soils with residues, they have been concerned specially these days.

In this study a punch wheel that is compatible with mechanical and pneumatic metering devices was designed and developed. This planter was evaluated during work on three fields with different tillage operations, three types of surface coverage and three levels of forward speed.

REVIEW LITERATURE

The planting depth of corn is 3-7 cm and in Iran it is 5-7 cm (Khodabande, N. 1992).

Using the conservation tillage system is the suitable solution to prevent the water and wind erosion, because of remaining plant residues on the field.

The result of bucket punch planter examination showed that, increasing the planter speed (0.8 to2.2 m/s), decreases the feed index (91% to 59%). (Adekoya et al. 1987)

A type of bucket punch planter was examined to evaluate the influence of type and level of residues at 2m/s. Results showed that with increasing residue level, miss and multiple seed indexes increases. (Molin,et al. 1998)

Precision seed metering and planting equally at high forward speed is an important problem in development of corn precision planters with seed plates. (Kepner et al. 1987).

Placing single seeds in to the holes at the spade punch planters needs to perfect harmony between metering unit and the holes. (Debicki et al. 1996)

MATERIALS AND METHODS

Design and development of the planter

Planter consisting of chassis, punch wheel, seed metering device, drive system, seed covering device and press wheel that mounting on a tractors three point hitch (fig.1).

Fig. 1 Constructed planter mounted on tractor

Planter chassis

Chassis was constructed with 27cm internal width and 180cm internal length.

Punch wheel

This wheel was constructed by a pipe with 50cm diameter (fig.2).

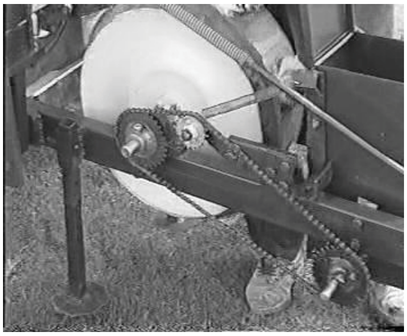


Fig. 2 Punch wheel and its attachment to planting unit

Punch cones

During the primary experiments on the apex angle of cones, the 90 degree cone was selected because it didn't disturb the shape of the seed bed and so these cones are determined for punch wheel. Conical puncher consists of two parts, cylindrical section with 1cm height and conical section with 5cm height. Eight cones are welded on punch wheel.(fig.3)

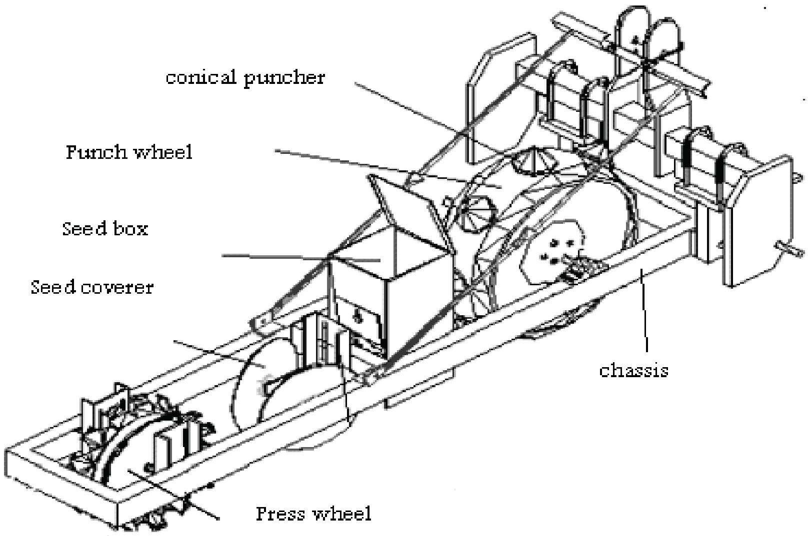


Fig. 3 Designed dibble punch planter

Fixed weights of punch wheel

Primary experiments were done on the field to achieve appropriate penetration rate. Due to the soil moisture and density, experiments showed lower penetration rate and for this reason weights were added into the punch wheel. When the weight was 87kg the rate of penetration improved.

Shaft of punch wheel

Diameter of this shaft was 30mm with circular cross section. The drive force was transferred to metering device through this shaft.

Seed coverer

These devices must be able to cut soil and plant residues and cover the seeds into the seed bed. For this reason two- disk type seed coverer was designed and constructed.

Field tests

Three plots at three position of faculty of agriculture Shiraz University in Iran were selected. Soil properties were fine, carbonatic, thermic and typic calcixerepts. The moisture of soil at depth of 15cm was measured 10.7% (db).

The tests were prepared as factorial tests and completely randomized design. The length of tested rows was 10 meters and the length of 6 meter from that was selected to data gathering stochastically. For each index in each replication 24 data were gathered.

Tests were done at three field conditions: disked soil with disk harrow operation (field1), untilled without residue (field2) and untilled with wheat stubble coverage (field3). The tests in each field were replicated at three forward speed levels of 1.5, 3 and 4.5 kmh-1. During the experiments the seed coverer and press wheel dismounted from the planter unit (fig.4).

Fig. 4 Planter unit during planting without seed covers and press wheel

Measured indices

Field measurements were done to determine basic quality indicators of newly designed punch planter like: feed index (holes with only one seed), missed seed index (holes without seed), multiple seed index (holes with more than one seed), seed depth index and radius of contact cross-section area index.

Fig. 5 Working quality of planter on stubble soil

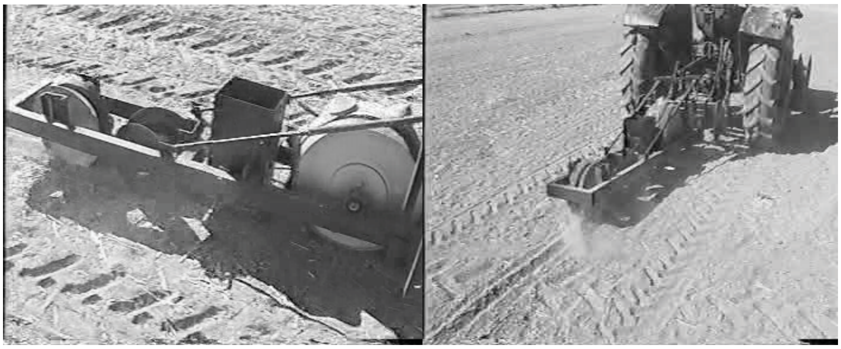


Fig. 6 Planter unit during planting with seed covers and press wheel

RESULTS

Table 1 ANOVA of effect of treatments on multiple index

F1%	F5%	F	MS	SS	DF	Source of variations
3.04	2.21	3.24**	0.7555	6.044	8	treatment
5.25	3.26	10.76**	2.489	4.978	2	Speed (A)
5.25	3.26	1.8ns	0.422	0.844	2	Soil type (B)
3.89	2.63	0.238ns	0.056	0.222	4	Interaction (AB)
			0.233	8.4	36	Error
				14.44	44	total

Because the effect of treatments was significant on multiple seed index, the differences between treatments were investigated. The results of experiments have been shown in fig.7.

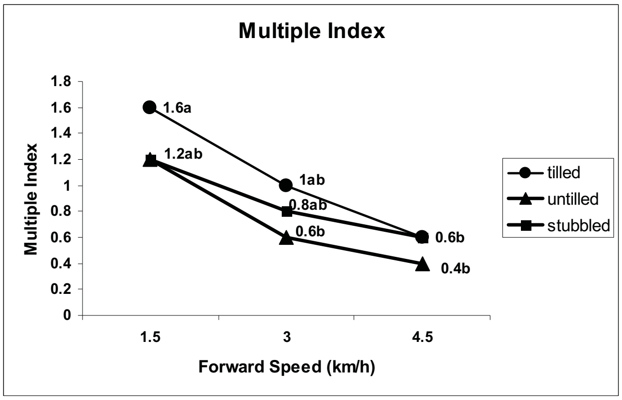


Fig. 7 Effects of treatments on Multiple seed index

From the results it is clear that v1= 1.5 km h^{-1} planter achieved significantly higher value of multiple seed index in comparison with two other velocities. Due to the definition of precision planting (Single seed planting), minimum amount of this index is desirable, then planting on tilled soil at v3= 4.5 km h^{-} is appropriate.

Because of short time available to load the plate cells at high speeds, amount of multiple planting decreases due to the increasing of speed at seed plate metering device. Other reason to this reduction is the high speed of cut off roller at high levels of forward speed that causes the elimination of excess seeds from cells.

Although the soil type hasn't significant influence on multiple seed index value, occurrence of the index's higher values were recorded on tilled soil, because the vibration effects produced from the soil surface conditions and help to eliminate the excess seeds from cells, is not significant at this soil.

Effects of treatments on miss index have been shown at table 2.

Table 2 ANOVA of effect of treatments on Missed seed index

F1%	F5%	F	MS	SS	DF	Source of variations
3.04	2.21	27.63**	27.688	221.51	8	treatment
5.25	3.26	54.16**	52.356	104.71	2	Speed (A)
5.25	3.26	59.95**	57.956	115.91	2	Soil type (B)
3.89	2.63	0.238ns	0.222	0.889	4	Interaction (AB)
			0.967	34.80	36	Error
				256.31	44	total

Minimum value of this index was determined at a1b1, a2b1, a1b3, a2b3. These combinations are different in comparison to other combinations at probability level $p<0.01$. The lowest amount of miss index was at untilled soil at forward speed $v_3 = 4.5\ kmh^{-1}$, combination a3b2. Effects of v1 and v2 on this index were not significantly different but had difference with v3 (fig.8).

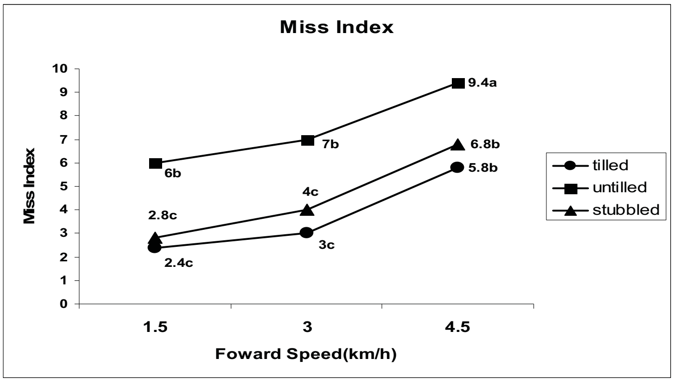


Fig. 8 Effects of treatments on miss index

Also, untilled soil showed significant different with other soil types ($p<0.01$).

Consequently, both of forward speed and soil type have significant effect on miss index. By increasing the speed, the available time for filling the seed plate cells are decreased and the vibrations that are implied from the roughness of untilled soil intensify this processes.

This is considerable that the less punches penetrate the soil, the more vibrations are implied to planter and the miss index is increased more.

Table 3 ANOVA of effect of treatments on quality of feed index

F1%	F5%	F	MS	SS	DF	Source of variations
3.04	2.21	21.15**	21.15	169.2	8	treatment
5.25	3.26	34.40**	34.40	68.80	2	Speed (A)
5.25	3.26	49.40**	49.40	98.80	2	Soil type (B)
3.89	2.63	0.40ns	0.40	1.600	4	Interaction (AB)
			1	36.00	36	Error
				205.2	44	total

Minimum amount of quality of feed index is related to a3b2 which has significant difference with other treatments (fig.9).

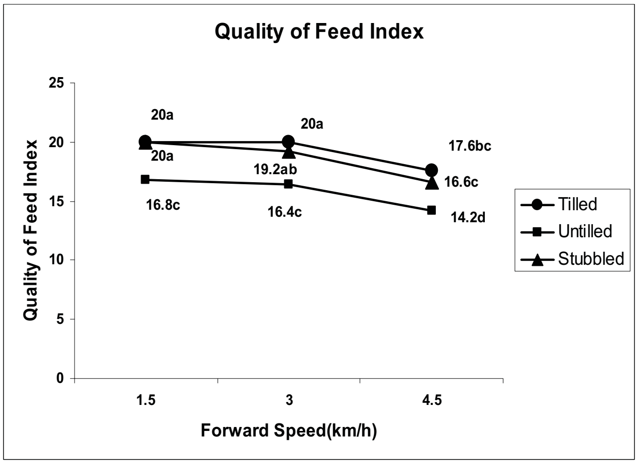


Fig. 9 Effects of treatments on quality of feed index

Due to the results, there are significant differences between the third level of forward speed and two other levels and between the untilled soil with two other soil types**.**

The other index that was measured was the depth of planting and the results of analysis have been presented at tables 4.

Table 4 ANOVA of effect of treatments on depth index

F1%	F5%	F	MS	SS	DF	Source of variations
3.04	2.21	128.1**	457.655	3661.2	8	treatment
5.25	3.26	43.56**	155.617	311.23	2	Speed (A)
5.25	3.26	476.1**	1668.7	3337.4	2	Soil type (B)
3.89	2.63	0.878ns	3.139	12.775	4	Interaction (AB)
			3.572	128.59	3	Error
				3789.8	44	total

Due to the results, although there are significant different among the effects of forward speed levels, but the maximum amount of difference is 7mm and between first and second level of forward speed this quantity decreases to 3mm. This difference between tilled and untilled soil is around 11mm (fig.10).

It must be considered that contact area between soil and cones, soil preparation type and soil moisture content were important factors that affected the penetration rate of cones.

Similar results were obtained for radius of cross section area index as for depth index (fig 11).

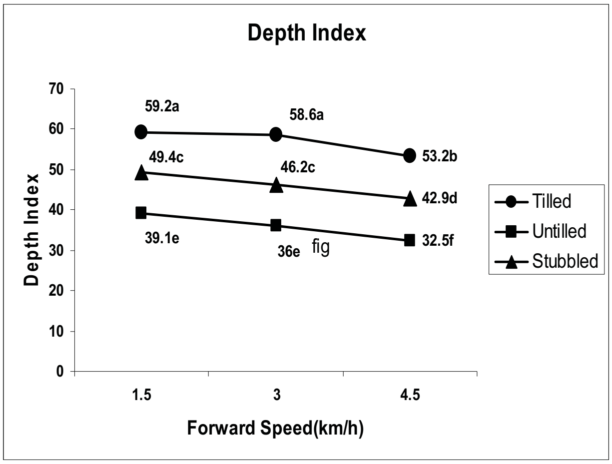


Fig. 10 Effects of treatments on depth index

Table 5 ANOVA of effect of treatments on radius of holes

F1%	F5%	F	MS	SS	DF	Source of variations
3.04	2.21	103.6**	220.471	1763.7	8	treatment
5.25	3.26	28.96**	61.629	123.25	2	Speed (A)
5.25	3.26	370.6**	788.641	1577.2	2	Soil type (B)
3.89	2.63	7.429**	15.809	63.237	4	Interaction (AB)
			2.128	76.592	3	Error
				14.44	44	total

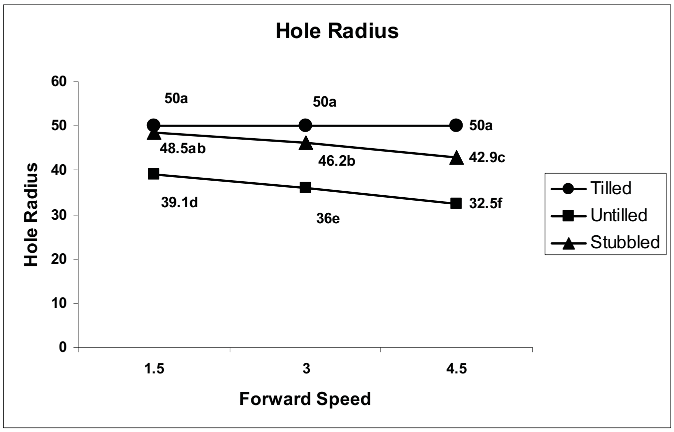


Fig 11 Effects of treatments on radius of holes

CONCLUSION

Results showed no significant difference between tilled and untilled stubble soil with first and second levels of speed on feed index.

No significant difference was observed between tilled and untilled stubble soil on multiple and miss indices; however, miss index increased and multiple index decreased by increasing in forward speed.

Similar results obtained about depth and radius of cross section area indices as increasing in forward speed resulted in decreasing both indices. Again a decrease in two indices was observed in all three soil treatments (tilled, untilled and untilled stubble soil).

Finally it was found that the planter showed an acceptable performance in $3kmh^{-1}$ forward speed on tilled and untilled stubble soil; however, improved performance results of dibble punch planter can be obtained by determination of optimum soil moisture content for punch planting, reduction of cross section of conical puncher, deep soil loosening before planting (which affects soil compaction rate) and increasing the accuracy of seed metering device.

REFERENCES

1. Adekoya, L. O. and W. F. Buchele. (1987). A Precision Punch Planter for Use in Tilled And Untilled Soils. J.Agri. Eng. Res. 37: 171-178.
2. Anonymous. Strip till: a practical solution for conservation tillage corn. March 15, 1999. Michigan farm news.
3. Brennman, G., and J. Fawcett.(1992). Are your fields ready for No-Till. www.abe.iastate.edu/machinery/aen-129.html.
4. Debicki, I. W.,and L. N. Shaw. 1996. Spade punch planter for precision planting.Transactions of the ASAE 39(4):1259-1267.
5. Kepner, R. A., R. Bainer,and E. L. Barger (1987). Principles of Farm Machinery.CBS Publishers and Distributors.
6. Khodabande, N. (1992). Cereals. Tehran Univercity publisher and distributer.
7. Molin, J. P., L. L. Bashford, K. Vonbargen, and I. Leviticus.1998. Design and evaluation of a punch planter for no-till systems.transactions of the asae 41(2)307-314.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 595.76:631.348.45:632.982.1:633.15
Stručni rad
Expert paper

TEHNIČKI ASPEKTI ODABRANIH STROJEVA ZA SUZBIJANJE ODRASLE KUKURUZNE ZLATICE

T. POJE[1], T. GODEŠA[1], D. STAJNKO[2], V. JEJČIČ[1], G. UREK[1], Š. MODIC[1], G. LESKOŠEK[3], M. RAK – CIZEJ[3], M. SAGADIN[2], M. LAKOTA[2]

[1]Kmetijski inštitut Slovenije, Hacquetova 17, SI – 1000 Ljubljana, e-mail: tomaz.poje@kis.si
[2] Fakulteta za kmetijstvo, Vrbanska 30, SI – 2000 Maribor
[3] Inštitut za hmeljarstvo in pivovarstvo Slovenije, Cesta žalskega tabora 2, SI – 3310 Žalec

SAŽETAK

Širenje kukuruzne zlatice unosi nove zahtjeve u odnosu na strojeve za nanos insekticida. Suzbijanje odrasle kukuruzne zlatice otežano je zbog visine kukuruza u srpnju i kolovozu. Predstavljene su eksploatacijske karakteristike raspršivača s topom i prskalice sa visoko namještenom armaturom za prskanje i cijevnim produžecima. Ventilator na raspršivaču veliki je potrošač pogonske snage (1. brzina 31,4 kW, 2. brzina 54,9 kW). Prskalica daje dobru sliku prskanja, ali ima relativnu malu radnu širinu. Kod obije aplikacije dolazi i do gubitaka kukuruza zbog prohoda strojeva.

Ključne riječi: *kukuruzna zlatica, zaštita, raspršivač s topom, prskalica sa visoko namještenom armaturom i cijevnim produžecima*

UVOD

Zaštita kukuruza od kukuruzne zlatice zasniva se na posrednim i neposrednim mjerama. Među posredne mjere spada stvaranje okolnosti za zdravi rast biljaka kako bi kukuruz lakše podnio napad kukuruzne zlatice. Takove mjere su: izbor mjesta rasta, agrotehničke mjere, plodored, izbor sorata, uzgoj tolerantnih hibrida, suzbijanje korova i samoniklog kukuruza, obrada tala, gnojenje. Neposredne zaštitne mjere usmjerene su direktno ka kukuruznoj zlatici.

Neposredne zaštitne mjere suzbijanja kukuruzne zlatice su biotehničke, biotične i kemijske. Kemijsko suzbijanje kukuruzne zlatice odvija se na više načina. Suzbijaju se i larve i odrasli kukci. Pri suzbijanju larvi moguće je koristiti sjeme tretirano s odgovarajućim insekticidom i nadalje insekticide aplicirati upotrebom mikrogranulatora na sijačicama.

Odrasla kukuruzna zlatica suzbija se pomoću specijalnih izvedbi prskalica (raspršivača). Cilj ovog rada je predstaviti prva iskustva stečena strojevima za suzbijanje odrasle kukuruzne zlatice u Sloveniji.

MATERIJAL I METODE RADA

U ovoj istrazi upotrijebili smo dva različita stroja. Prvi je raspršivač s topom za raspršivanje, a drugi njivska prskalica sa visoko namještenom armaturom i cijevnim produžecima.

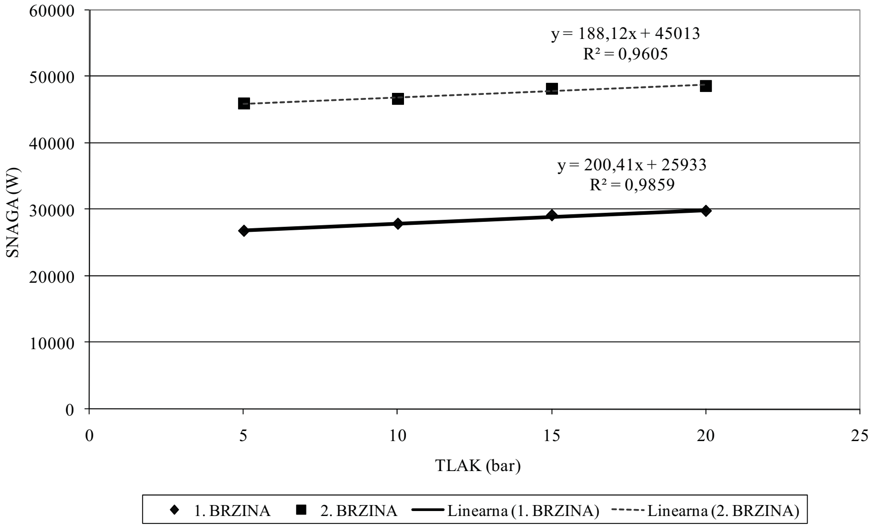
Slika 1 Prskalica sa visoko namještenom armaturom i cijevnim produžecima te raspršivač s topom za raspršivanje

Mjerni lanac za određivanje potrebne snage za pogon strojeva preko priključnog vratila traktora sastavljen je od tri dijela: a) senzora, b) mjernog pojačala, c) PC računala. Za mjerenje na priključnom vratilu traktora upotrijebljen je dinamometar T30FN Hottinger Baldwin Messtechnik, nazivne vrijednosti 2000 Nm. Digitalno mjerno pojačalo SPIDER 8, Hottinger Baldwin Messtechnik upotrijebljen je za ojačanje mjernog signala i sakupljanje podataka dobivenih mjerenjima. Za uzimanje podataka korišten je mjerni program Catman Hottinger Baldwin Messtechnik, a dobiveni rezultati statistički su obrađeni pomoću programa Excel. Frekvencija uzimanja uzoraka mjernoga signala iznosila je 10 Hz, dok je dužina pojedinog mjerenja zavisila o vremenskom toku rada strojem. Iz rezultata mjerenja momenta i broja okretaja izračunana je snaga za pogon. Kvaliteta škropljenja (raspršivanje) određivana je putem listića osjetljivih na vodu, koji su bili analizirani po standardnoj metodi.

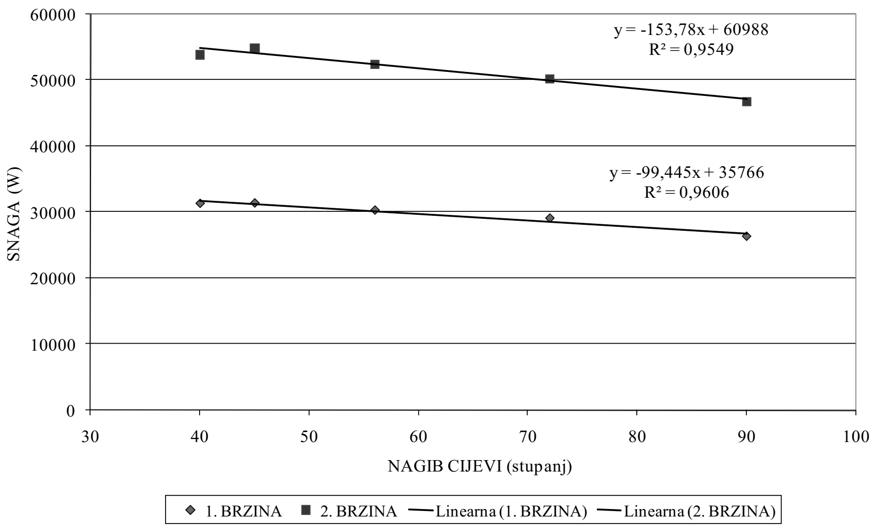
REZULTATI I DISKUSIJA

Potrebna snaga za pogon

Ventilator na raspršivaču veliki je potrošač snage (energije). Za sam pogon raspršivača u prvoj brzini ventilatora izmjeren je maksimalan moment 818 Nm i najveća potrebna snaga 46.8 kW. U drugoj brzini ventilatora moment pogona iznosio je 1142 Nm, a pri tom izmjerena potrebna pogonska snaga iznosi 68 kW. Pri normalnom radu raspršivača u prvoj brzini izmjeren je prosječan moment 531 Nm, a u drugoj brzini 947 Nm. Prosječna potrebna snaga u prvoj brzini ventilatora iznosi 31,4 kW, a u drugoj brzini 54,9 kW.



Slika 2 Potrebna snaga za pogon raspršivača obzirom na tlak i brzinu multiplikatora

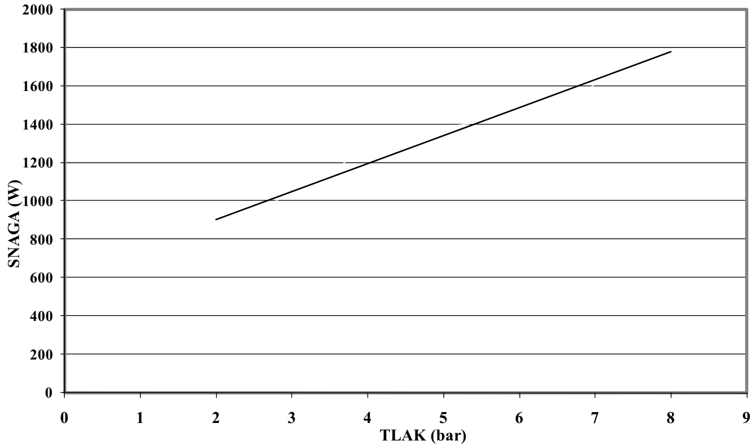


Slika 3 Potrebna snaga za pogon ventilatora raspršivača obzirom na naklon glavne cijevi topa i obzirom na brzinu multiplikatora

Izvedena su mjerenja potrebne snage za pogon kod različitog tlaka crpke. Tlak smo mijenjali od 5 do 20 bara s razmakom od 5 bara. Mjerenja su obavljena kako u manjoj tako i u većoj brzini multiplikatora. Iz pojedinih mjerenja izračunata je prosječna snaga za pojedinačni tlak i stupanj prijenosa. Iz tih vrijednosti je zatim izračunata linearna regresija za obije brzine multiplikatora. Obije regresije imaju jako visok R^2, i to iznad 0,96. Na slici 2 vidimo kako raste potrebna snaga obzirom na povećanje tlaka.

Raspršivač ima pomični top čiji nagib glavne cijevi i izlaznog otvora mogu se podešavati. Izvedena su mjerenja pri različitih brzinama ventilatora i pri nagibu glavne cijevi topa između 40 i 90 stupnjeva. Izlazni otvor uvijek je nastavljen vodoravno. Iz pojedinačnih mjerenja izračunata je prosječna snaga, a zatim i ukupna linearna regresija. Na slici 3 vidimo kako z narastanjem kuta naklona glavne cijevi pada potrebna snaga za pogon ventilatora.

Slika 4 prikazuje potrebnu snagu za pogon crpke pri različitim radnim tlakovima na prskalici sa visoko namještenom armaturom i cijevnim produžecima

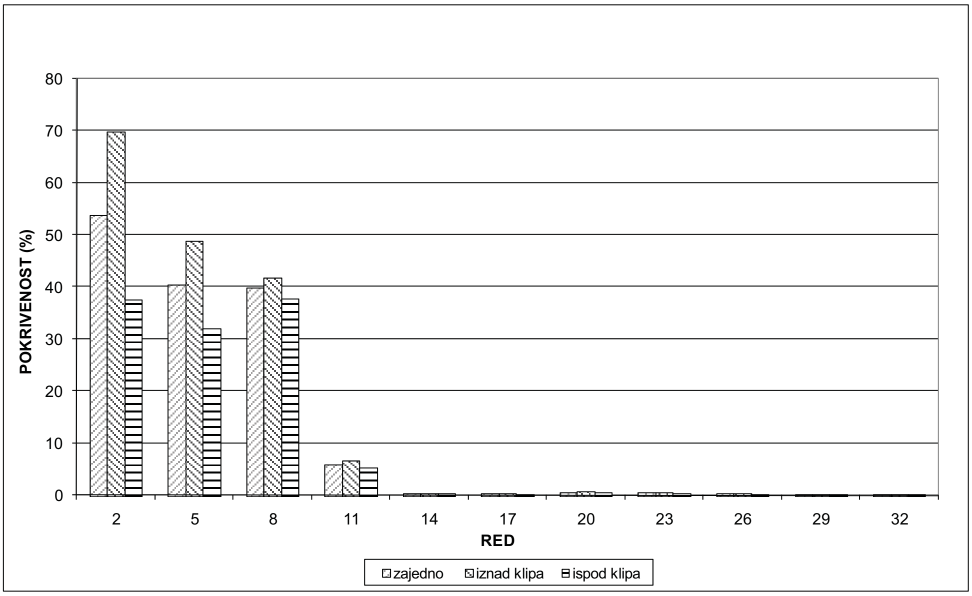


Slika 4 Potrebna snaga za pogon crpke na prskalici

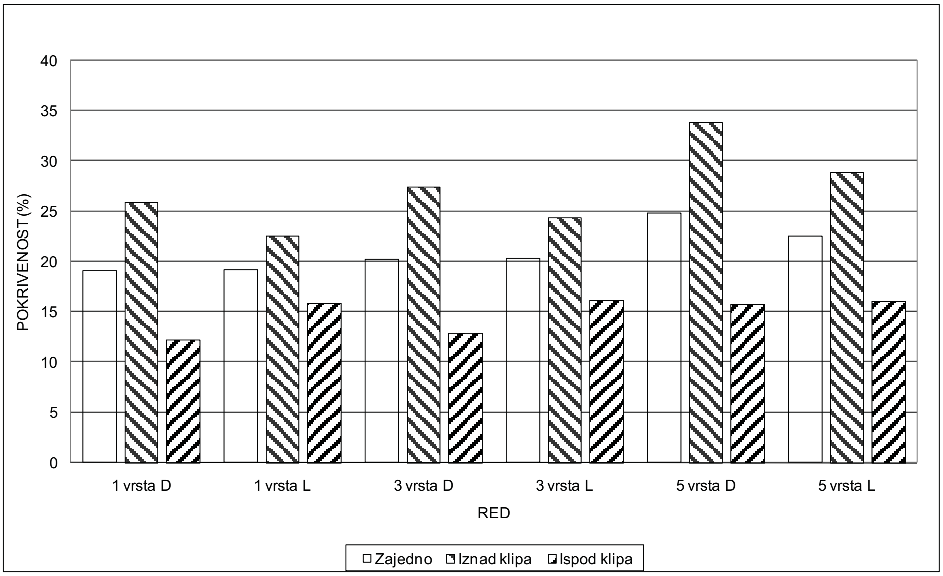
Kvaliteta nanosa škropiva

Ispitivali smo efikasnost raspršivanja pri potrošnji vode od 500 l/ha. Svi izmjereni faktori pokazali su, uz upotrijebljena namještenja i režim dijela raspršivača s topom za raspršivanje, da probojnost zračnoga mlaza (a time i sredstva za raspršivanje) kroz kukuruzne biljke opada nakon 8. reda. U 11. redu pokrivenost iznosi tek slabih 10%, a to ima obzirom na dosadašnja iskustva premalen biotični učinak na odraslu kukuruznu zlaticu. Zračni mlaz i sredstvo za raspršivanje sežu sve do 32. reda kukuruza.

Također smo ispitivali učinkovitost škropljenja prskalicom sa visoko namještenom armaturom kod potrošnje vode od 500 l/ha. Na slici 6 lijepo se vidi jednakomjerna raspoređenost škropiva po cjelokupnoj radnoj širini kako na lijevoj tako i na desnoj polovini armature. Isto tako se iz mjernih listića osjetljivih na vodu vidi da su iznad klipa u svim redovima bolje prekriveni s kapljicama nego ispod klipa. Škropljenje se je u usporedbi s raspršivačem pokazalo kao jako pouzdana i precizna metoda za suzbijanje odrasle kukuruzne zlatice, samo što je radna širina relativno malena.



Slika 5 Pokrivenost listića osjetljivih na vodu s kapljicama pri raspršivanju s raspršivačem



Slika 6 Pokrivenost listića osjetljivih na vodu s kapljicama pri škropljenju

Gubici zbog prohoda

Pri suzbijanju odrasle kukuruzne zlatice pregažena su najmanje 2 reda kukuruza. Šteta ovisi o klirensu traktora i odrvenjelosti kukuruznih stabljika, od termina prohoda, radne širine prskalice, širine parcele.

Tablica 1 Teoretski udio gubitaka u postotcima uslijed voznih putova pri različitim razmacima između redova i radnim širinama prskalice

Razmak između redova (cm)	**Udio gubitaka (%)**				
	Radna širina prskalice (m)				
	10 m	**12 m**	**18 m**	**24 m**	**36 m**
62,5	12,5 %	10,4 %	6,9 %	5,2 %	3,5 %
66	13,2 %	11,0 %	7,3 %	5,5 %	3,7 $
70	14,0 %	11,7 %	7,8 %	5,8 %	3,9 %
75	15,0 %	12,5 %	8,3 %	6,3 %	4,2 %

Biološka efikasnost insekticida

Tablica 2 Efikasnost po Henderson – Tilto-nu (u %) glede na različitu tehniko prskanja.

Efikasnost po Henderson –Tilton (%)		
Vrijeme posle prskanja (h)	**Prskalica sa visoko namještenom armaturom i cijevnim produžecima**	**Raspršivač s topom za raspršivanje**
24 h	79	75
96 h	62	48
144 h	46	35
192 h	21	22

U istraživanju biološke efikasnosti insekticida DESIS nije bilo većih razlika glede vrste aplikacije insekticida.

ZAKLJUČAK

Provođenje zaštite kukuruza od odrasle kukuruzne zlatice zbog visine kukuruza u mjesecu srpnju i kolovozu nije moguće upotrebom uobičajenih strojeva za zaštitu bilja. Prilagođene prskalice i raspršivači doduše omogućavaju dosta kvalitetnu aplikaciju insekticida, ali je problematična njihova relativno mala radna širina i gubici kukuruza, do koji dolazi zbog prohoda traktora i prskalice (raspršivača). Adaptirani strojevi za aplikaciju škropiva dostupni su doduše na tržištu, ali još nisu pronašli svoje mjesto među korisnicima, koji problematiku kukuruzne zlatice lakše rješavaju upotrebom plodoreda, sjemenom kukuruza obrađenim insekticidima, ili pak korištenjem mikrogranulatora za insekticide na kukuruznim sijačicama.

Raspršivač s topom za raspršivanje je zbog ventilatora relativno veliki potrošač pogonske snage, nanos škropiva u habitus kukuruza zavisi i od namještenja nagiba izlaznog otvora. Prskalica s visoko namještenom armaturom daje jednakomjerno sliku prskanja, ali je ograničena zbog relativno male radne širine.

LITERATURA

1. Dobrinčić R., Igrc Barčić J., Edwards R.C. (2002). Utvrđivanje štetnosti ličinki kukuruzne zlatice (Diabrotica virgifera virgifera LeConte) u uvjetima Hrvatske Agriculturae Conspectus Scientificus (ACS), 1 (67): 1 – 9
2. Godeša T. (2007). Zatiranje koruznega hrošča. Kmetovalec, Kmetijska založba Slovenj Gradec 1 (75): 10-12
3. Ivezić M., Majić I., Raspudić E., Brmež M., Prakatur B. (2006). Značaj kukuruzne zlatice u ponovljenom uzgoju kukuruza, Poljoprivreda 1 (12) Poljoprivredni fakultet u Osijeku : 35 - 40
4. Leskošek G., Godeša T., Rak – Cizej M. (2007). Possibilities for control of the western corn rootworm adults (Diabrotica virgifera virgifera LeConte) with different application techniques. 8. slovensko posvetovanje o varstvu rastlin, 6.-7. marec 2007, Radenci. Izvlečki referatov. Ljubljana, Društvo za varstvo rastlin Slovenije: 36- 37
5. Modic Š., Knapič M., Urek G. (2007). Population dynamics of the western corn rootworm (Diabrotica v. virgifera) in Slovenia. 8. slovensko posvetovanje o varstvu rastlin, 6.-7. marec 2007, Radenci. Izvlečki referatov. Ljubljana: Društvo za varstvo rastlin Slovenije: 70-71
6. Poje T., Godeša T., Jejčič V., Urek G., Modic Š., Leskošek G., Rak – Cizej M., Sagadin M., Lakota M. (2007). Pršilnik s pršilnim topom Unigreen APC 1000. Tehnika in narava 3 (11), ČZD Kmečki glas, 11: 25-27
7. Poje T., Godeša T., Jejčič V., Urek G., Modic Š., Leskošek G., Rak Cizej M., Sagadin M., Lakota M. (2008). Škropilnica Agromehanika AGS 1000 EN z visoko nameščenimi škropilnimi letvami. Tehnika in narava 1 (12), ČZD Kmečki glas: 10-12,
8. Rosner J., Foltin K., Pichler H., Neururer H., Rödler G. (2005). Der Maiswurzelbohrer in Österreich und Strategien seiner Bekämpfung. http://root.lako.at/versuche/pflanzenbau/pfls_du-eng/diabrotica_2005.pdf
9. Urek G., Modic Š. (2004). Occurrence of the Western Corn Rootworm (Diabrotica virgifera virgifera le Conte) in Slovenia. Acta agriculturae Slovenica 1 (83): 5-13

TECHNICAL ASPECTS OF MACHINES CHOSEN FOR THE CONTROL OF WESTERN CORN ROOTWORM ADULTS

ABSTRACT

The appearance of western corn rootworm brings new challenges to machines used for pesticide spraying. The control of western corn rootworm is difficult due to the height of maize crop in July and August. The current paper presents the exploitation characteristics of mistblower with cannon and sprayer with high installed spraying boom and hose drops with distribution nozzles. The ventilator of mistblower is a big consumer of driving power (the first speed of multiplier is 31.4 kW; the second one is 54.9 kW). The sprayer presents a good distribution pattern, but it has a relatively small working width. Both applications provoke maize losses due to machine passage.

Key words: *western corn rootworm, control, mistblower with cannon, sprayer with high installed spraying boom and hose drops with distribution nozzles*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 632.95.02
Pregledni rad
Review paper

BIOBED: PROTECTING ENVIRONMENT FROM PESTICIDE CONTAMINATION DURING FILLING AND CLEANING OF SPRAYER

ALI MUSA BOZDOGAN[1], NIGAR YARPUZ-BOZDOGAN[1], M. EREN OZTEKIN[2], HUSNIYE AKA-SAGLIKER[3], HUSEYIN YILMAZ[4]

[1]University of Cukurova, Faculty of Agriculture, Dept. of Agricultural Machinery, Adana/Turkey
[2]University of Cukurova, Faculty of Agriculture, Dept. of Soil Science, Adana/Turkey
[3]University of Cukurova, Yumurtalık Vocational School, Adana/Turkey
[4]Netkim Laboratory Equipment Marketing Co. Ltd., Adana/Turkey

ABSTRACT

Pesticides, which are used to control pests, are harmful for non-target organisms. Especially, during filling and cleaning of sprayer is important for point source contamination of pesticide. In UK, Germany and Sweden, 20-70% pesticide load in surface water catchments is derived from point sources. For protecting environment from pesticide contamination during filling and cleaning of sprayer can be reduced by using biobed, which contains straw, peat, and soil. The effectiveness, cheapness and simplicity of the biobed make it suitable for protecting environment. Generally, numbers of biobed increase year by year in the world. This study presents the information about biobed, its uses in world and Turkey. The first study about biobed was started in 2007 in Turkey.

Key words: *Sprayers, pesticide, environment protection*

INTRODUCTION

"BIOBED: A Biological System for Reducing Pesticide Contamination to Environment during Mixing and Loading of Sprayer before Spraying and Cleaning of Sprayer after Spraying". This project is funded by TUBITAK, The Scientific and Technical Research Council of Turkey, TOVAG 107O215. Pesticide is a broad term, covering a range of products that are used to control pests (Anonymous, 2008). Pesticides are extensively used in agriculture for crop protection after the discovery of DDT by Paul Muller in 1939. Worldwide, about 3 billion kg of pesticides is applied each year (Pimentel, 2005). In the

USA, approximately 500 000 tons active ingredient and more than 600 different pesticides types are applied annually (Downer and Hall, 1998; Pimentel, 2005). Despite the widespread application of pesticides in the USA at recommended dosages, pests destroy 37% of all potential crops (Pimentel, 2005).

Pesticides can cause serious environmental and public health problems (Pimental, 1992). According to Council Directive 91/414/EC, pesticide damage should be assessed by considering 10 modules: operator, worker, bystander, aquatic organisms, birds, earthworms, bees, beneficial arthropods, persistence in soil and leaching to groundwater (De Schampheleire et al., 2007). There is not much literature about the benefits of pesticides (Cooper and Dobson 2007), but some research regarding the negative effects of pesticides on environment and human health (Grixti et al., 2008; Knezevic and Serdar, 2009; Martinez-Lopez et al., 2009).

In Turkey, 2007, active ingredient consumption was 18 240 tons (ECPA, 2008). The amount of active ingredient used in Turkey was approximately 0.7 kg ha^{-1}. This value is lower than some EU countries such as 13.32 kg ha^{-1} for Portugal, 11.41 for The Netherlands, and 7.89 for Belgium (ECPA, 2008; FAO, 2008). In the world, use rates of a.i. have declined steadily from around 1.5 kg ha^{-1} in 1940 to less than 0.5 kg ha^{-1} in 1980 (Downer and Hall, 1998). More than 1/3 of Turkey's total pesticide use occurs in the Mediterranean and Aegean region, where intensive agriculture (Isin and Yildirim, 2007). Pesticide was used 4 800 t in Adana province of the Mediterranean region of Turkey (Anonymous, 2007). This value is more than 10% of Turkey's total pesticide use. Number of sprayers are approximately 1 000 000 in Turkey. Power Take-Off (PTO) driven sprayers contain approximately 25% of this value (TUIK, 2008). Number of PTO driven sprayers increased from 219 238 to 255 582 between in 2001 and 2007 (TUIK, 2008).

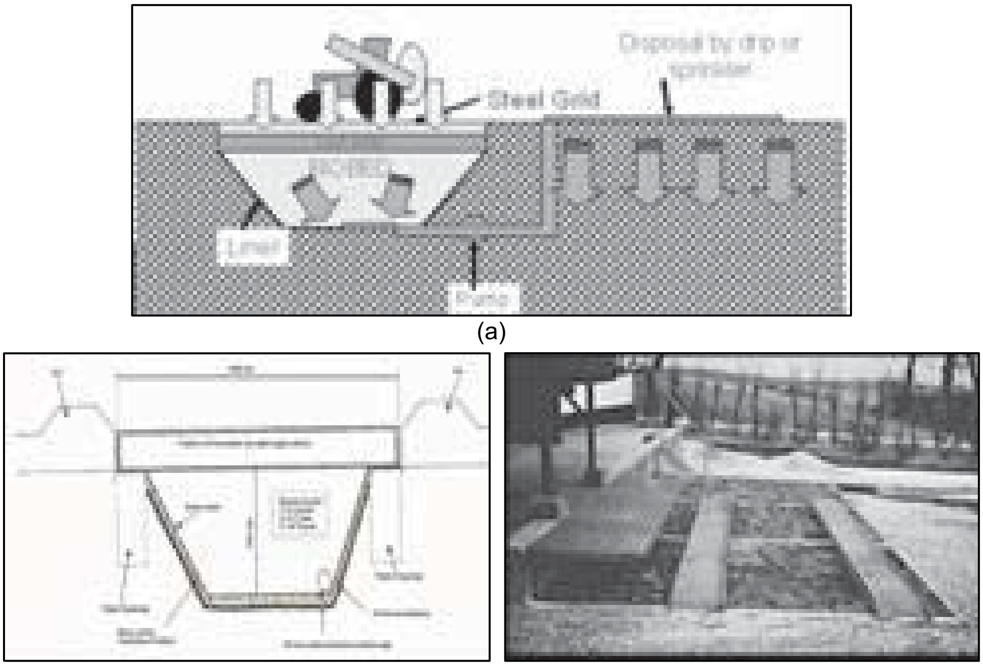
Filling and cleaning of sprayer has potential damage on the environment if operators do not take care of place for these procedures. Operators generally clean their sprayers 2 or 3 times per season in farmyard, field or near rivers, ditches in Turkey. According to Yılmaz et al. (2003), organochlorine pesticides were only detected in samples of Seyhan and Ceyhan rivers and drainage canals of the summer, period which is the peak of pesticide application. Moreover, they determined that in twenty soil samples taken during summer from the agricultural lands nearby, the same pesticides have been found, but with increasing concentrations. In UK, Germany and Sweden, 20-70% pesticide load in surface water catchment is derived from point sources (The Voluntary Initative, 2005). Effective method to minimize environmental contamination from pesticide, especially when filling and cleaning spraying equipment, a typical point sources of contamination is biobeds originated in Sweden (Castillo et al., 2008).

Biobed is a biological pit, which is used for reducing pesticide contamination to environment during filling and cleaning of sprayer. Biobed consists of three components in the ground: a) a clay layer at the bottom, b) biomix (straw, peat and soil), and c) a grass layer covering the surface (Castillo et al., 2008) (Figure 1).

a) The clay layer: Clay, with its low permeability and high sorption capacity, is used as an impermeable layer to decrease the water flow downward and to increase the pesticide retention time in the biobed (Castillo et al., 2008).

b) Biomix: The biomixture should have the ability to retain and degrade pesticides. Biobed mixture consists of straw (50%), soil (25%) and peat (25%) (Castillo et al., 2008; Anonymous, 2005). The straw stimulates the growth of lignin-degrading fungi and the formation and activity of ligninolytic enzymes, which can degrade many pesticides (Castillo et al., 2000; Castillo et al., 2001; Vischetti et al., 2007; Castillo et al., 2008). The peat gives sorption capacity and helps to keep the humidity (Vischetti et al., 2007; Castillo et al., 2008). The soil contributes, with sorption capacity and with other pesticide-degrading microorganisms (Vischetti et al., 2007; Castillo et al., 2008).

c) The grass layer: The grass layer contributes toward increasing the efficiency of the biobed. It also helps to regulate the moisture of the biobed (Castillo et al., 2008).



(a)

(b) (c)

Figure 1 General view of biobed (a: ADAS, 2006) (b: The Voluntary Initiative, 2005) (c: Anonymous, 2005)

BIOBEDS IN THE WORLD

The effectiveness, cheapness and simplicity of the biobed make it suitable for protecting environment. Generally, numbers of biobed increase year by year in the world. For example, France has 100 biobeds in 2004 and the numbers of biobeds have increased 500 in 2008. Moreover, number of biobed in England was 10 in 2004, it was reached 75 in 2008. In Turkey, there was no biobed in 2004, it was one in 2008 (Figure 2).

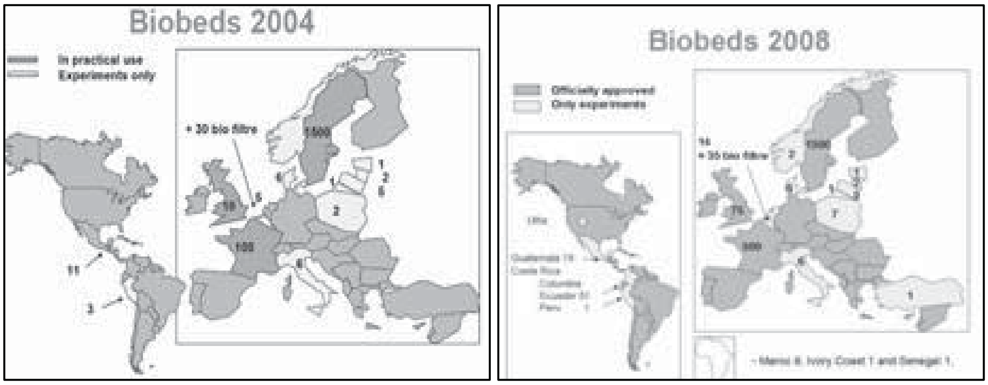


Figure 2 Numbers of biobeds in 2004 and 2008 (Husby and Börgartz, 2004; Husby, 2008)

BIOBED IN TURKEY

The biobed in Turkey is located in Adana province of the Mediterranean region. Its coordinate is 35^0 12' 22" E 36^0 47' 41" N. The project is funded by TUBITAK, The Scientific and Technical Research Council of Turkey, TOVAG 107O215. This project is the first study on biobed in Turkey and was started in 2007.

Preparation of biobed is illustrated in Figure 3.

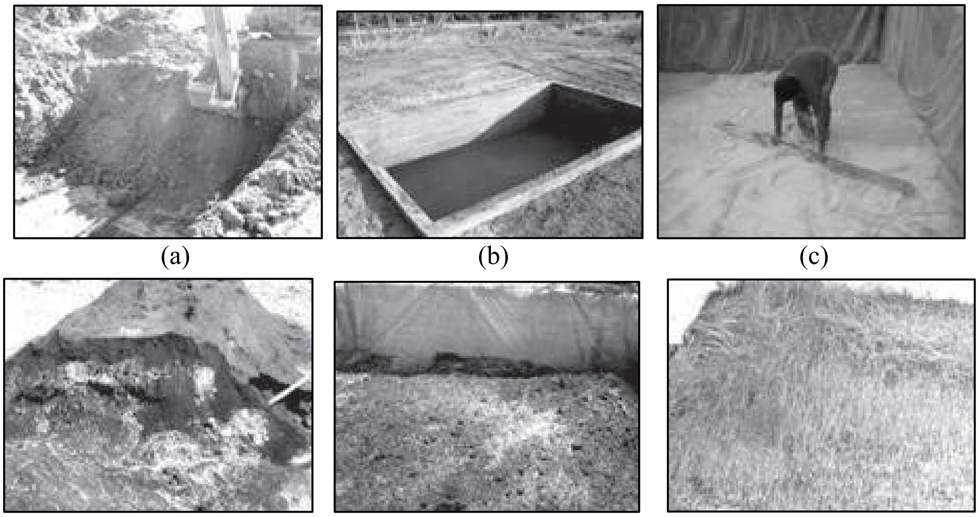


Figure 3 Biobed (a) excavated, (b) concrete constructed, (c) a clay layer, (d) biomix, (e) the biobed (20 m2) filled by biomix, and (f) a grass layer

A surface area of biobed is 5 m x 4 m. The depth of biobed is 0.8 m. The biomix was composed of straw (wheat), peat and local soil in a proportion of 50–25–25 percent of volume. The water-holding capacity for the biomix is approximately 50%. The main characteristics of the biomix and the soil tested in this study are reported in Table 1.

Table 1 Amount of organic C, pH and texture analysis of the biomix

Material	pH	C (%)	Clay (%)	Silt (%)	Sand (%)
Biomix (straw-peat-soil)	7.45	3.417	22.84	48.40	28.76

CONCLUSION

During filling and cleaning of sprayer the risks of pesticides contamination on environment is reduced by using of biobed. Some research has shown that biobeds are suitable for degrading pesticides (Wiren-Lehr et al., 2001; Fogg et al., 2004a; 2004b; Castillo and Torstensson, 2007; Coppola et al., 2007; De Wilde et al., 2007). Consequently, biobed is simple, effective, and cheap for protecting environment.

REFERENCES

1. ADAS, 2006. Environment Sensitive Farming: Practical advice for land managers
2. Anonymous, 2005. Online:http://www.odlingibalans.com
3. Anonymous, 2007. Turkish Republic Ministry of Agriculture and Rural Welfare, Crop Protection Division, Registered Agrochemicals in Turkey. Ankara, Turkey. Online: http:/www.adanatarim.gov.tr. (Turkish) Anonymous, 2008. Online: http://www.pesticides.gov.uk
4. Castillo, M. d. P., Ander, P., Stenström, J., Torstensson, L., 2000. Degradation of the herbicide bentazon as related to enzyme production by *Phanerochaete chrysosporium* in two solid substrate fermentation systems. World Journal of Microbiology & Biotechnology 16: 289-295.
5. Castillo, M. d. P. , Wiren-Lehr, S. v., Scheunert, I., Torstensson, L., 2001. Degradation of isoproturon by the white rot fungus *Phanerochaete chrysosporium*. Biol Fertil Soils 33:521-528.
6. Castillo, M. d. P. and Torstensson, L., 2007. Effect of biobed composition, moisture, and temperature on the degradation of pesticides. J. Agric. Food Chem. 55:5725-5733.
7. Castillo, M. d. P., Torstensson, L., Stenström, J., 2008. Biobeds for environmental protection from pesticide use- a review. J. Agric. Food Chem., 56:6206-6219.
8. Coppola, L, Castillo, M. d. P., Monaci, E., Vischetti, C., 2007. Adaptation of the biobed composition for chlorpyrifos degradation to southern europe conditions. J. Agric. Food Chem. 55: 396-401
9. Cooper, J. and Dobson, H. (2007) The benefits of pesticides to mankind and the environment. Crop Protection 26, 1337-1348
10. De Schamphelerie, M., Spanoghe, P., Brusselman, E., Sonck, S., 2007. Risk assessment of pesticide spray drift damage in Belgium. Crop Protection 26, 602-611.

11. De Wilde, T., Spanoghe, P., Debaer, C., Ryckeboer, J., Springael, D., Jaeken, P., 2007. Overview of on-farm bioremediation systems to reduce the occurrence of point source contamination. Pest Manag Sci 63:111–128.

12. Downer,R.A. and Hall,F.R., 1998. Chemistry and Drift Management: A Biologist's Perspective. Proceedings of the North American Conference on Pesticide Drift Management, Maine, USA, pp:187-195.

13. ECPA, 2008. Online: http://www.ecpa.be

14. FAO, 2008. Online: http://www.fao.org

15. Fogg, B., Boxall, A. B. A., Walker, A., Jukes, A., 2004a. Effect of different soil textures on leaching potential and degradation of pesticides in biobeds. J. Agric. Food Chem. 52: 5643-5652.

16. Fogg, B., Boxall, A. B. A., Walker, A., Jukes, A., 2004b. Degradation and leaching potential of pesticides in biobed systems. Pest Manag Sci 60:645–654.

17. Grixti, J. C., Wong, L. T., Cameron, S. A., Favret, C., 2008. Decline of bumble bees (Bombus) in the North American Midwest. Biological C onservation (Article in pres: doi:10.1016/j.biocon.2008.09.027)

18. Husby, J., Börgartz, M., 2004. European Biobed Workshop, 28-29 September, Malmö.

19. Husby, J., 2008. Personal communication.

20. Isin, S. and Yildirim, I. (2007) Fruit-growers' perceptions on the harmful effects of Pesticides and their reflection on practices: The case of Kemalpaşa, Turkey. Crop Protection 26, 917-922.

21. Knezevic, Z. and Serdar, M., 2009. Screening of fresh fruit and vegetables for pesticide residues on Croatian market. Food Control 20:419-422.

22. Martinez-Lopez, E., Romero, D., Maria-Mojica, P., Martinez, J. E., Calvo, J. F., Garcia-Fernandez, A.J., 2009. Changes in blood pesticide levels in booted eagle (Hieraaetuspennatus) associated with agricultural land practices. Ecotoxicology and Environmental Safety 72:45-50.

23. Pimental,D., 1992. Pesticides and world food supply. ACS Symposium series- American Chemical Society, USA, 309 p.

24. Pimentel,D., 2005. Environmental and economic costs of the application of pesticides primarily in the United States. Environment, Development and Sustainability 7:229-252.

25. The Voluntary Initiative, 2005. Design Manual:Pesticide Handling Areas and Biobeds.18 p.

26. TUIK, 2008. Turkiye Istatistik Kurumu, Online: http://www.tuik.gov.tr

27. Vischetti, C., Coppola, L., Monaci, E., Cardinali, A., Castillo, M. d. P., 2007. Microbial impact of the pesticide chlorpyrifos on Swedish and Italian biobeds. Argon. Sustain. Dev. 27:267-272.

28. Wiren-Lehr, S.v., Castillo, M. d. P., Torstensson, L., Scheunert, I., 2001. Degradation of isoproturon in biobeds. Biol Fertil Soils 33:535-540.

29. Yılmaz, H., Erbatur, O., Erbatur, G., 2003. Monitoring of pesticide and heavy metal discharge of the major rivers and drainage canals into the Mediterranean Sea in the north-east coastal zone, Turkey. Fresenius Environmental Bulletin 12(11):1407-1411.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.42:631.348.45
Stručni rad
Expert paper

"COSMOS" PROGRAM USED FOR THE STRENGTH CALCULUS OF THE SPRAYER'S NOZZLES

SORIN – TIBERIU BUNGESCU[1], WALTER STAHLI[1], SORIN – STEFAN BIRIS[2], VALENTIN VLADUT[3], FLORIN IMBREA[1], CORNELIA PETROMAN[1]

[1]Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara – Department of Agricultural Machines, 119, Calea Aradului Street, Nr. 119, Timisoara – Romania, Zip code 300645, e-mail: sobungi@yahoo.com
[2]"POLITEHNICA" University of Bucharest – Romania, 313, Splaiul Independentei Street, Bucharest – Romania, Zip code 060042, e-mail: sorin_biris@yahoo.com
[3]Research and Development National Institute for Agricultural and Food Industry Machines and Implements – INMA Bucharest, 6, Ion Ionescu de la Brad Blvd. Bucharest – Romania, Zip code 013813, e-mail: valentin_vladut@yahoo.com

SUMMARY

In specialty reference materials from our country and in the countries with an advanced agriculture it hasn't appeared yet a calculation methodology with a view to projection's optimization of these nozzles and on this line, the current paper, tries to bring a contribution in this field, benefiting by the advantages on which it presents the application of the analysis method with finite elements respectively program of computer "COSMOS/M".

Key words: *Finite Elements Method, COSMOS/M program, stress, digitization*

INTRODUCTION

The methods of pest and diseases control of the agricultural crops through chemical way, by sprinkling, hold the biggest weight from the methods applied and utilized in crops protection.

It is estimated that the application of this method represents about 75% from the altogether of the ways and methods of control with pesticides in agriculture.

The application of the liquid pesticides by sprinkling it is achieved under the aspect of a very fine film or under the aspect of some extreme small drops. The fineness of the dispersion it is estimated by the size of the particles' (drops') diameter. The uniformity constitutes a distinct specific feature, considering that a dispersion is all the more uniform as the quantity of the particles with the same diameter is bigger.

The spraying of the solid chemical substances it is achieved by means of the nozzles. For the achievement of a suitable spraying of the chemical substances and implicitly of a quality uniformity of these it is imperious necessary that the nozzles to have a long tiredness in time. Also, the nozzles must be strength at the chemical action of the utilized substances at the pest and diseases control in agriculture.

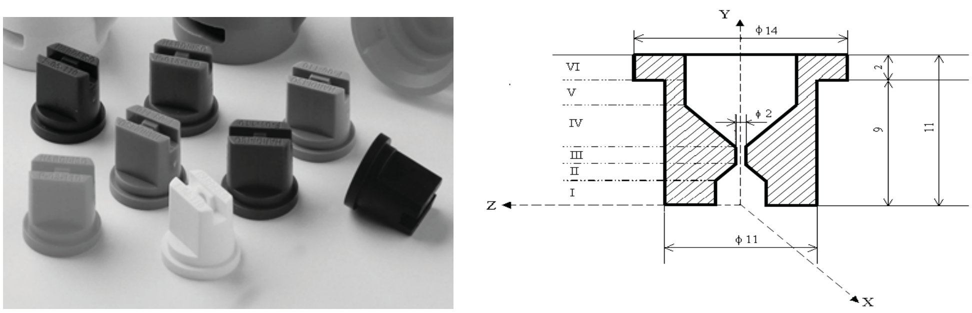
Therefore, the study of the strength state out of the nuzzle represents a very important present problem, which leads to the achievement of some nozzles which resist in time at both tiredness and chemical action of the sprinkled substances.

By means of "Finite Elements Method" (FEM) respectively of "COSMOS/M" program it could be performed the stress state modeling in the nozzles, finally the authors achieving one subprogram of calculus. On the basis of this subprogram, a complete study of the stress state was affected, using the "Finite Elements Method" (FEM).

Following the analysis with finite elements was calculated all component parts of the stress tensor from the network's knots, as well as, from the center of each finite element, for one working regime.

MATERIALS AND METHODS

Within the framework of the Strength of Materials Department from the Technical University Timisoara was studied the Hardy nozzles (figure 1), utilized at the sprinkling of the crops. The study followed the determination of the maximum stress zones, where can appear fissures or even tears during the working process, using the Finite Element Method and respectively the "COSMOS/M" program. For the calculus of the strength state out of the Hardy nozzle it was achieved a calculus subprogram.



a) b)

Fig. 1 a) The studied Hardy nozzles; b) Section through the studied Hardy nozzle.

In order to achieve molding as good as possible the nozzle was divided in six zones, conveniently selected.

The calculus was done for the most unpropitious case of loading that is when the sprinkling solution passes through the interior of the nozzle with a maximum pressure of 6 bar. This pressure was applied on the internal walls of the nozzle.

The digitization of the nozzle it was done using isoparameter elements of thin plate type, with four knots on element and eight degrees of freedom on knots (figure 2). The net of finite elements used it was achieved by variable step, with a denser net in zones of passing from a larger diameter to a smaller diameter of the nozzle. For the knots in the fastening zone of the nozzle in the body of the nozzle and implicitly on the platform of the sprinkling machine were introduced bottoming for all those eight degrees of freedom.

In the fastening points were considered hampered the changes of place and turnings in all directions (ox, oy, oz) considering these points as being embedding points.

We introduced as well as real constants, associate to the selected elements group, the thickness of the nozzle, Poisson's ratio for polyethylene ν = 0,26) and as well as material properties, the longitudinal resilience modulus($E = 14\cdot10^3$ MPa) and transversal resilience modulus.

There were determined σ_x, σ_y, σ_z and τ_{xy} stresses specific to the plane state of deformation, σ_1, σ_2 and σ_3 main stresses, as well as the equivalent stress in accordance to the 5th theory of strength (Von Mises), which it is calculated with the relation:

$$\sigma_{ech.} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1} \tag{1}$$

The stress state was also completed with a calculus of the change of place.

RESULTS AND DISCUSSION

Figure 2 presents a sample of the obtained by using the achieved subprogram and figure 3, 4, 5, represent the mode of accordance to the 5th theory of strength (Von Mises) in the case of Hardy nozzle.

```
*****************************************************************
*              C O S M O S / M
*                VERSION:   1.60
*                 DISTRIBUTED BY:
*        STRUCTURAL  RESEARCH  AND  ANALYSIS  CORPORATION
*              1661  LINCOLN  BLVD.  #200
*            SANTA MONICA,   CALIFORNIA   90404
*              TEL. NO.  (213)  452-2158
*             COPYRIGHT  1988   S. R. A. C.
*****************************************************************
DATE:   5/05/2007    TIME:    0:12:39
```

TITLE : THE UTILIZATION OF THE "COSMOS/M" COMPUTER PROGRAMME AT THE DETERMINATION OF THE STRESSES WHICH APPEAR IN THE NOZZLES FROM THE

MACHINERY OF PEST AND DISEASES CONTROL THROUGH CHEMICAL WAY IN THE EXPLOITATION PROCESS FROM AGRICULTURE

T O T A L S Y S T E M D A T A

NUMBER OF EQUATIONS . . . .(NEQ) = 3240

NUMBER OF MATRIX ELEMENTS . . . .(NWK) = 860508

MAXIMUM HALF BANDWIDTH . . . . (MK) = 1536

MEAN HALF BANDWIDTH . . . .(MM) = 265

NUMBER OF ELEMENTS. . . . .(NUME) = 760

NUMBER OF NODAL POINTS. . . . .(NUMNP)= 1140

SIZE OF EACH BLOCK. . . . .(MTBLK)= 8000

NUMBER OF BLOCKS. . . . . (NBLK) = 113

MAXIMUM DIAGONAL STIFFNESS MATRIX VALUE = .476175E+04

MINIMUM DIAGONAL STIFFNESS MATRIX VALUE = .274825E+03

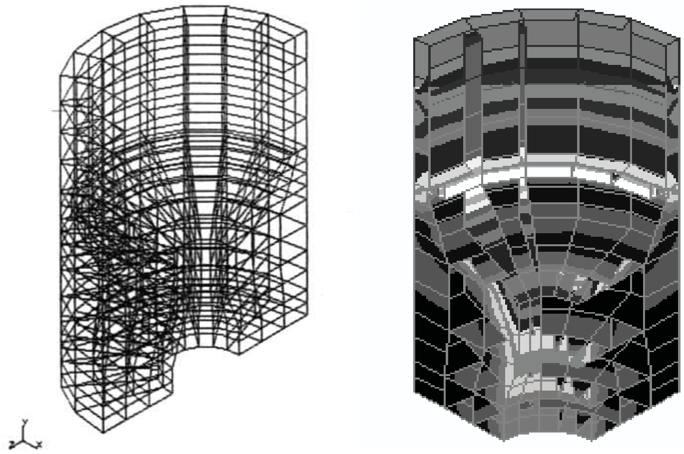
S T R E S S E V A L U A T I O N FOR S T A T I C A N A L Y S I S

STRESS OUTPUT FOR 3/D ELEMENT GROUP 1 CASE NO. 1

ELEMENT OUTPUT

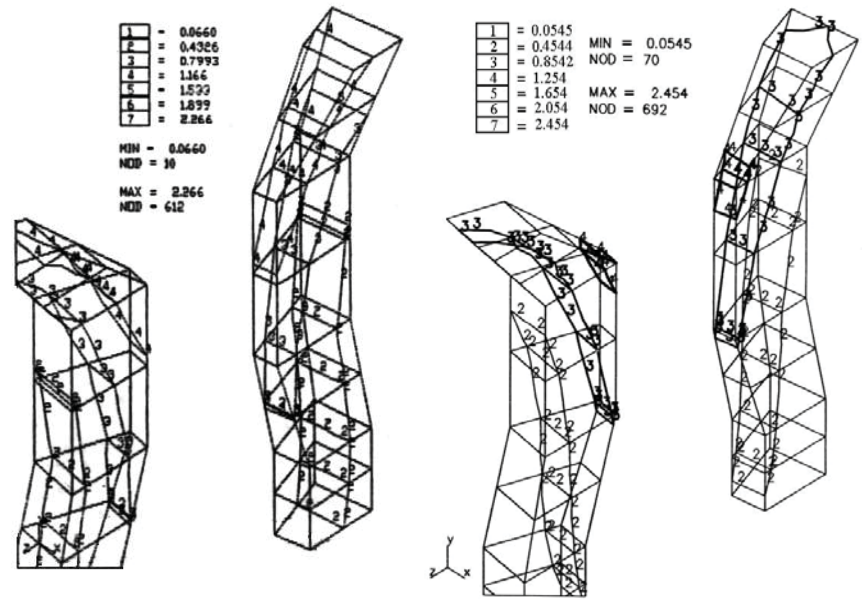
NUMBER	**NODE**	**SIGMA-X1**	**SIGMA-X2**	**SIGMA-X3**	**TAU-X12**	**TAU-X23**	**TAU-X13**	**VON MISES STRESS**
1								
CENTER		2.5000E-01	-2.6691E-03	-3.1385E-01	-3.5388E-03	-2.2014E-02	-9.3923E-02	5.1696E-01
	1	4.2813E-01	5.2146E-02	-3.0567E-01	-3.5020E-03	-2.1975E-02	-1.2204E-01	6.7090E-01
	2	4.7723E-01	5.2146E-02	-3.1211E-01	-3.5020E-03	-2.1975E-02	-1.3129E-01	7.2209E-01
	5	5.7959E-02	-5.7578E-02	-3.2302E-01	-3.5614E-03	-2.1965E-02	-6.3669E-02	3.5794E-01
	4	3.6635E-02	-5.7578E-02	-3.1586E-01	-3.5614E-03	-2.1965E-02	-5.8896E-02	3.3438E-01
	13	4.2815E-01	5.2198E-02	-3.0508E-01	-3.5162E-03	-2.2063E-02	-1.2194E-01	6.7038E-01
	14	4.7725E-01	5.2198E-02	-3.1144E-01	-3.5162E-03	-2.2063E-02	-1.3118E-01	7.2152E-01
	17	5.7976E-02	-5.7443E-02	-3.2234E-01	-3.5757E-03	-2.2053E-02	-6.3559E-02	3.5733E-01
	16	**3.6650E-02**	**-5.7443E-02**	**-3.1526E-01**	**-3.5757E-03**	**-2.2053E-02**	**-5.8799E-02**	**3.3384E-01**
2								
CENTER		2.9311E-01	3.3567E-02	-2.8597E-01	-1.0748E-02	-6.6438E-02	-9.6464E-02	5.4213E-01
	2	5.0637E-01	1.3677E-01	-2.9792E-01	-1.0735E-02	-6.6437E-02	-1.3377E-01	7.4397E-01
	3	5.2283E-01	1.3677E-01	-2.6316E-01	-1.0735E-02	-6.6437E-02	-1.3072E-01	7.2680E-01
	6	8.4409E-02	-6.9778E-02	-2.7457E-01	-1.0759E-02	-6.6434E-02	-6.0007E-02	3.4882E-01
	5	5.8781E-02	-6.9778E-02	-3.0956E-01	-1.0759E-02	-6.6434E-02	-6.1577E-02	3.6030E-01
	14	5.0639E-01	1.3688E-01	-2.9723E-01	-1.0736E-02	-6.6442E-02	-1.3366E-01	7.4335E-01
	15	5.2285E-01	1.3688E-01	-2.6252E-01	-1.0736E-02	-6.6442E-02	-1.3062E-01	7.2624E-01
	18	8.4426E-02	-6.9609E-02	-2.7393E-01	-1.0760E-02	-6.6438E-02	-5.9903E-02	3.4828E-01
	17	***5.8800E-02***	***-6.9609E-02***	***-3.0887E-01***	***-1.0760E-02***	***-6.6438E-02***	***-6.1465E-02***	***3.5970E-01***

Fig. 2 Sample with the obtained results



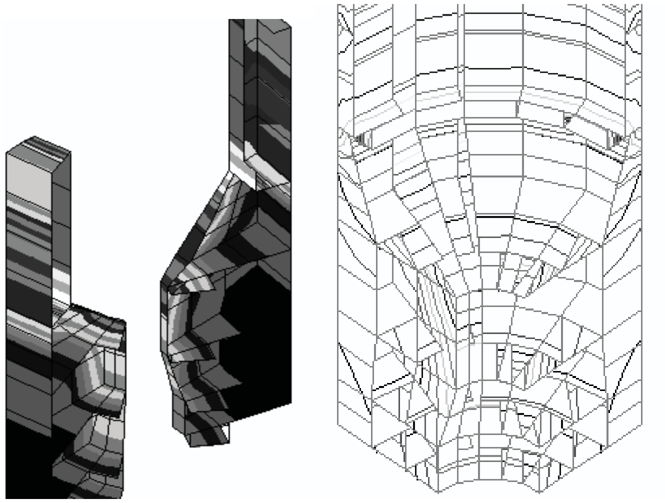
a) b)

Fig. 3 a) The digitization model of the Hardy nozzle; b) The distribution of the stresses in accordance to the 5[th] theory of strength (Von Mises) $\sigma_{ech(5)}$ for sectioned Hardy nozzle, established for the maximum pressure p = 6 bar



a) b)

Fig. 4 a) The distribution of the stress $\sigma_{ech.(5)}$ in the concentration zones of the stresses, in the section 1, for a maximum pressure p = 6 bar; b) The distribution of the stress $\sigma_{ech(5)}$ in the concentration zones of the stresses, in the section 2, for a maximum pressure p = 6 bar



a) b)

Fig. 5 a) The distribution of the stress in accordance to the 5th theory of strength (Von Mises) $\sigma_{ech(5)}$, in a section of the nozzle, for the maximum pressure p = 6 bar; b) The distribution of the stress $\sigma_{ech(5)}$ for sectioned Hardy nozzle, in the zone in which it is actual achieved the spraying of the liquid, for a maximum pressure of 6 bar

CONCLUSIONS

1. The stage of the current development of the scientific and technical level permits the utilization of the Finite Element Method as a fundamental theoretical method of the determination of stresses distribution in the nozzles from the machinery of pest and diseases control through chemical way.
2. In the context of potential's capitalization offered by the COSMOS/M programme in this field, the modelling of the stresses field became a certainty.
3. The theoretical cognition of the stresses distribution is of an unchallenged utility in the evolution's estimate of this process, experimental praised in the ground.
4. The study effected on the Hardy nozzle praised the fact that this is solicited at tiredness in time, because of the pressure which acts on its internal walls.
5. The biggest strengths are manifest in the zones in which the internal diameter of the nozzle is reduced (the zones of influence from a bigger diameter to a smaller diameter), fact that leads to the conclusion these zones are considered concentrators of strength.
6. In order to learn some pertinent conclusions as concerns the determination of the strength at the nozzles of the sprinkled machinery is imperious necessary to be studied as many types of such nozzles as possible, because at present there is a very varied range in the world, and the materials are more and more preferment (ceramics materials, composite materials).

RERFERENCES

1. Blumenfeld, M. (1995) – “Introduction in the finite element method”, Technical Publishing House, Bucharest;
2. Bungescu, S. (1996) - "Studies and thorough researches on the improvements` evolution of the engineering and processes achieved by the machinery for sickness and pest control in agriculture", Dissertation, "Politehnica" University, Timisoara;
3. Bungescu, S. (2002) – “The determination of the stresses’ distribution on the surface of the working mechanisms of the agricultural machineries benefiting by the performances of the finite element method (F.E.M.)”, IVth International Symposium “Young People and Multidisciplinary Research”, Publishing House “Sudura”, Timisoara, pp. 28 – 37;
4. Dumitru, I.; Faur, N. (1997) - " The Materials' Strength" (Theoretical basis in the Materials' Tiredness,Tear's Mechanic, Composite Materials and Numerical Methods), The multiplication center University "Politehnica" Timisoara;
5. Faur, N.; Dumitru, I. (1997) - Finite difference and finite element in the Materials' Strength", Publishing House "Mirton ", Timisoara;
6. Stahli, W. (2003) – “Machinery for the application of the phytosanitary treatments and foiled fertilizing of the vegetable crops”, Publishing House “AGROPRINT”, Timisoara;
7. *Zienkiewicz, O.C; Taylor, R.L. (1991) – “La methode des elements finis”, AFNOR, Paris;*
8. * * * * (1990)- "COSMOS/M USER GUIDE", Structural Research and Analysis Corporation, Santa Monica, California.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.94:631.354.2
Izvorni znanstveni rad
Original scientific paper

NEW STOCHASTIC MODELS FOR SIMULATION OF THE SEEDS SEPARATION PROCESS: PRACTICAL APPLICATION

GHEORGHE VOICU, CONSTANTIN TARCOLEA, TUDOR CASANDROIU

University „Politehnica" of Bucharest, Faculty of Biotechnical Systems Engineering
e-mail: ghvoicu_2005@yahoo.com; constantin_tarcolea@yahoo.com; cctu39@yahoo.com

ABSTRACT

In this paper we proposed some generalized models of the stochastic distributions given in the paper [12]. These new models from the paper are used for describing the variation separation intensity of seeds on sieve length. The considered probability laws are of the type eulerian and weibullean distributions. We compared different models and the best results obtained are presented in the paper. These models allow simulating and prediction of the separation processes of seeds at cleaning system sieves on length.

***Key words**: cleaning system, design of experiments, losses, regression, stochastic models*

INTRODUCTION AND LITERATURE REVIEW

It is know that the cleaning system is a very important equipment of a combine harvester because its performances influence the performances of the entire combine. The separation process takes place on the sieves of the cleaning system thanks to the oscillation movement of the sieves and of the ascending air flow, which permeates the layer of material due to the different densities of the this components [1,9].

The relative movements of the particles in the inner layer are favoured by the oscillation movement of the sieve, which, in turn, facilitates the gravimetric shifting of the seeds through the material layer, [1,14].

The separation process of the seeds from the pile material is influenced by numerous random factors which make its deterministic modelling by means of mathematical processes difficult to realize. The separation process of seeds while passing through the sieve was studied in a numerous number of theoretical and experimental research articles.

This lead to many types of proposed mathematical models which allow for anticipating the losses under particular working situations. Many authors studied the cleaning separation process on the sieves, made experimental and theoretical researches, and proposed different deterministic and stochastic mathematical models, [2, 3, 5, 10-13].

The natural variability, the large number of factors influencing the separation process and their inherent randomness are comprised in the mean value of the constants of mathematical models, [4, 5, 7, 9, 10, 12, 13].

The particles movement is random, due to the heterogeneity of physical properties of material and of the seeds. Therefore the modelling of the seeds separation process on sieves of a cleaning system can be based on stochastic theory [6, 8, 10, 12, 13].

The probabilistic concept applied in this study is the probability density function (p.d.f.), the derivative of the cumulative function.

An exponential function type model was developed based on the analogy between the process of seeds separation and the phenomenon of molecular diffusion expressed by the law of Fick [3].

The mathematical model proposed by Bottinger, developed from the model created by Kutzbach, provides information about the quantity of seeds remained on the sieve, [5].

According to the paper [9,10], it was constructed a Rosin-Rammler type relation and a logistic function, as a stochastic model for describing the seed separation process on sieve.

However, the history of Rosin-Rammler models goes back earlier, to the weibullean and eulerian functions. Our experimental researches show that the distributions can be symmetric or skewed, left or right. In the papers [8,12,13] were presented some Weibull and Euler models too.

Reflecting the need to increase the precision of describing the separation process, while incorporating the main design and functional parameters of the cleaning system, the authors suggested multiple linear regression functions for the logistic coefficients, [10].

Along the same line, applying dimensional analysis to the process of separation, the authors suggested a different mathematical model accounting for seven of the main design, functional and characterizing parameters of the material in the cleaning system, [2,11].

The present paper analyses same of these laws and focuses the study of new adequate weibullean and eulerian models, because these functions are adaptive for describing of evaluation of grain cleaning, for the given conditions, for each concrete case.

The simulating process of the seeds separation at cleaning system sieves of the cereal harvesters can be better modelling accordingly by the probabilistic perspective, because the statistical laws are a measure of expressing of uncertainty about the natural variability of the studied phenomena. These models are used too at the prediction seeds losses at cleaning system.

MATERIALS, METHODS AND PROCEDURES

In this paper we used an incomplete factorial design involving five factors, each restricted at two or three levels. It is impractical to use all treatment combinations. In practice it is useful to study many factors simultaneously, keeping the number treatment combinations as small as possible is. We selected some cases for various factors.

The experiments were conducted with wheat pile material on laboratory stand under simulation of different work conditions. The parameters of interest - which were modified during experiments, in order to determine their influence on the separation process - are: specific supply flow rate q; air flow velocity at the ventilator exit v_a; blinds opening D_j; straw parts per seeds ratio pp/s; oscillation frequency f. Our experimental stand sieve has the length of 1.2 m and the seeds were collected under the sieve in eight compartments, each with a length of 0.15 m. The seed losses were collected in an additional compartment [see paper 12].

These profiles can be described by means of different distribution laws [8].

The parameters of the proposed functions were estimated from the experimental data and the computations were carried out in Microcal Origin.

In the present paper we use the following continuous probability density functions:

$$f(x) = p1(x - p2)^{p3}(p4 - x)^{p5} \tag{1}$$

(a beta distribution without given boundaries)

$$f(x) = p1 \cdot x^{p2} \cdot e^{-p3 \cdot x^{p4}} \tag{2}$$

(a generalized gamma distribution)

$$f(x) = p1\, x^{p2}\, e^{-(p_3\, x + p4)^2} \tag{3}$$

(a delay gamma distribution)

$$f(x) = p1(x - p2)^{p3}\, e^{-p4(x - p2)^{p3+1}} \tag{4}$$

(a Weibull distribution with 4 parameters)

The parameter values and experimental results are presented in the table 1.

RESULTS AND DISCUSSIONS

For each experimental sample from table 1, the seeds separation intensity on the sieve length was graphically represented; the regression curves for the proposed models are provided in the fig.1.

The regression curve given in the paper is the least squares curve, which has the property that the sum of the squared vertical distances from it to points on the scatter diagram is a minimum.

Table 1 Separated seeds percentage (separation intensity) on sieve length

No. sample	Sieve length from which seeds are collected *x* (m)								
	0.075	0.225	0.375	0.525	0.675	0.825	0.975	1.125	1.275
1	*f = 280 osc/min; q = 0.15 kg/dm·s; v_a = 8 m/s; D_j = 12.5 mm; pp/s = 0.24*								
	2,7	9,6	33,5	36,2	13,2	3,6	0,8	0,2	0,2
2	*f = 280 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.25*								
	2,5	8,3	25,3	26,2	20,8	10,8	4,2	0,5	1,4
3	*f = 280 osc/min; q = 0.15 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.27*								
	1,7	6,2	23	27,1	22	12,6	5,6	1	0,8
4	*f = 280 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; pp/s = 0.27*								
	4,2	12	21,6	19,9	19,5	14,5	7,4	0,7	0,2
5	*f = 240 osc/min; q = 0.10 kg/ dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0.25*								
	8,3	23,5	41,8	20,9	4,2	0,8	0,35	0,1	0,05
6	*f = 335 osc/min; q = 0.20 kg/ dm·s; v_a = 10 m/s; D_j = 11 mm; pp/s = 0.252*								
	0,2	0,8	3,1	13,9	22,6	20,8	16,8	15,8	6
7	*f = 280 osc/min; q = 0,15 kg/dm·s; v_a = 6,2 m/s; D_j = 12,5 mm; pp/s = 0,25*								
	3,3	10	32,7	35,5	13,1	3,8	0,7	0,2	0,7
8	*f = 280 osc/min; q = 0,15 kg/dm·s; v_a = 10 m/s; D_j = 12,5 mm; pp/s = 0,25*								
	2	7,7	33,9	36,5	14,5	3,6	1	0,3	0,5
9	*f = 280 osc/min; q = 0,1 kg/dm·s; v_a = 5 m/s; D_j = 9 mm; pp/s = 0,26*								
	4,8	11,7	23,2	18,7	17,3	11,2	10,3	2,5	0,3
10	*f = 335 osc/min; q = 0,10 kg/dm·s; v_a = 8 m/s; D_j = 11 mm; pp/s = 0,25*								
	0,9	2,7	10,5	15,6	19,8	20,9	20	7,1	2,5

The computations were carried out in Microcall Origin, based on the non-linear regression of the proposed distribution functions with experimental data, and the results are presented in table 2; the regression coefficient values (p1,p2,p3,p4,p5), chi-squared and the correlation coefficients (χ^2, R^2) are presented for the models of equations (1), (2), (3), (4).

Testing for goodness-of-fit was a procedure which determined if a particular shape for the population frequency curve is consistent with the sample results obtained.

The developed models were tested using the chi-square statistic test and the coefficient of determination R^2. The quantity R^2 is the proportion of the original sum of squared deviations, which is removed by fitting the distribution.

An explication for the big variability of the samples is the diversity of work conditions and the natural variability of the physical properties of the materials. In other words, it must choose the adequate model for each practical case.

For comparison in table 3 are given the correlation coefficients for all the chosen probabilistic models.

From the analysis of values in tables 2 and 3, it results that the beta distribution without given boundaries (eq.3), the generalized gamma distribution (eq.2), and the weibullean law (eq.4) have a better goodness-of-fit with experimental data; the correlation coefficients have in most cases good values ($R^2 \geq 0.93$ for generalized beta distribution, $R^2 \geq 0.93$ for eulerian model, and $R^2 \geq 0.944$ for Weibull law.

For each experimental sample from the table 1, the seeds separation density of the sieve length was graphically represented.

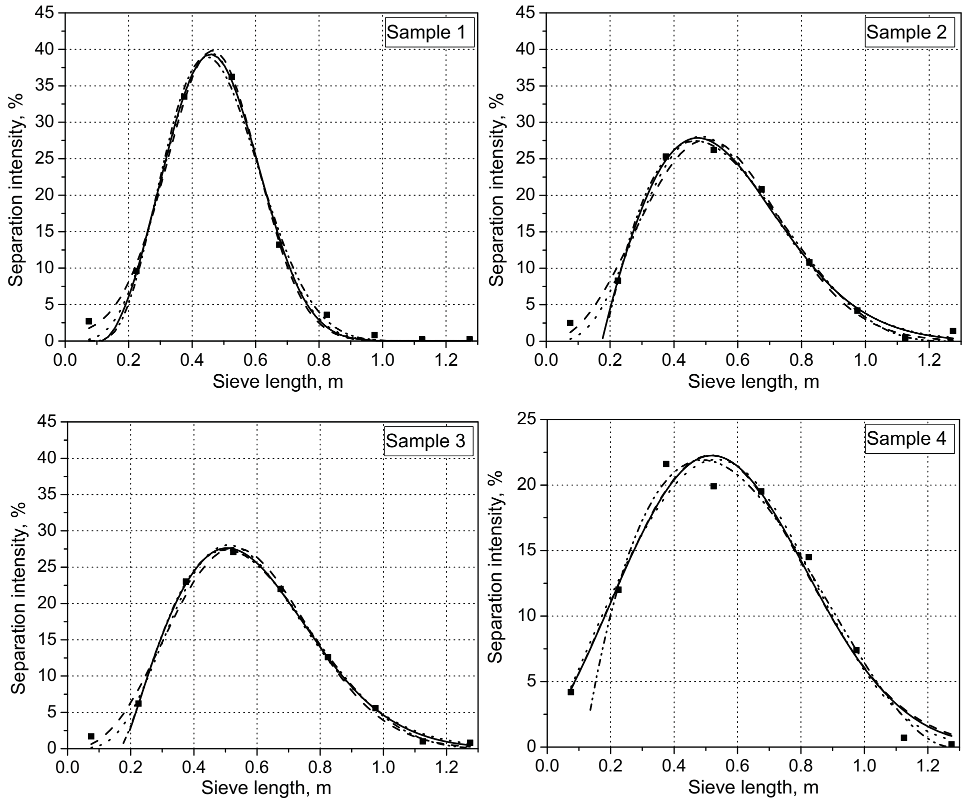
Table 2 The coefficients values p1, p2, p3, p4, p5 obtained through testing relations (1), (2), (3), (4) with experimental data, and correlation coefficients χ2 and R2

	S 1	**S 2**	**S 3**	**S 4**	**S 5**	**S 6**	**S 7**	**S 8**	**S 9**	**S 10**
$f(x)=p1(x-p2)^{p3}(p4-x)^{p5}$ (eq.1) - . . - . . -										
p1	11021.3	201.56	188.53	85.757	16723.7	77.148	10475.2	21070.8	2.682	46.301
p2	0.075	0.179	0.163	0.118	-0.290	0.355	0.075	0.075	-0.051	0.193
p3	4.007	1.083	1.511	0.910	10.851	0.849	3.660	4.203	2.213	0.818
p4	1.275	1.275	1.434	1.275	1.275	1.427	1.214	1.228	2.118	1.130
p5	8.941	3.025	4.158	1.918	15.292	1.261	7.560	8.571	7.012	0.344
χ^2	4.147	0.988	0.265	3.024	6.500	7.851	5.122	1.599	7.921	0.120
R^2	0.994	0.996	0.999	0.982	0.985	0.950	0.992	0.998	0.933	0.999
$f(x)=p1\cdot x^{p2}\cdot e^{-p3\cdot x^{p4}}$ (eq.2)										
p1	2856.6	7065.7	1399.7	53.478	194.131	64442.9	1681.1	45933.1	115.30	37.337
p2	3.667	3.810	3.206	0.949	1.343	6.848	3.313	5.322	1.301	1.413
p3	10.733	7.525	5.772	2.213	30.178	8.219	10.330	12.331	2.869	0.795
p4	2.594	1.381	1.762	3.214	4.865	1.096	2.767	1.861	1.844	6.202
χ^2	2.005	2.366	1.474	3.002	4.485	4.550	2.813	1.084	6.634	2.706
R^2	0.994	0.986	0.992	0.973	0.987	0.962	0.991	0.997	0.930	0.975
$f(x)=p1x^{p2}e^{-(p3x+p4)^2}$ (eq.3) – – – – –										
p1	21.082	151.36	249.08	36.586	8.990	185.38	13.849	1982.0	138.384	20.019
p2	-0.875	1.794	2.280	0.634	-1.712	3.442	-1.473	3.669	1.338	-0.458
p3	5.115	-2.607	2.496	-2.198	5.798	-1.843	5.198	3.888	-1.537	-2.668
p4	-2.562	0.628	-0.457	0.857	-2.562	0.316	-2.727	-0.765	-0.210	2.146
χ^2	1.421	2.982	2.080	3.561	0.605	5.923	1.552	1.239	6.642	5.303
R^2	0.996	0.983	0.988	0.968	0.998	0.950	0.994	0.996	0.930	0.951
$f(x)=p1(x-p2)^{p3}e^{-p4(x-p2)^{p3+1}}$ (eq.4) ________										
p1	523.72	138.74	142.5	94.699	460.60	82.836	562.94	460.02	80.94	13.79
p2	0.112	0.175	0.178	-0.075	-0.312	0.343	-0.017	0.154	0.007	-0.549
p3	1.8328	0.933	1.019	1.601	4.363	0.965	2.710	1.543	1.091	4.458
p4	13.016	4.945	4.791	2.382	5.888	2.645	10.669	12.633	2.550	0.165
χ^2	1.159	1.045	0.292	3.375	2.368	5.910	3.225	0.696	6.734	3.802
R^2	0.997	0.995	0.998	0.970	0.993	0.944	0.989	0.998	0.929	0.965

Table 3 The estimated values of correlation coefficients R2,equations (1-4)

	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10
$f(x)=p1(x-p2)^{p3}(p4-x)^{p5}$ (eq.1)										
R^2	0.994	0.996	0.999	0.982	0.985	0.950	0.992	0.998	0.933	0.999
$f(x)=p1\cdot x^{p2}\cdot e^{-p3\cdot x^{p4}}$ (eq.2)										
R^2	0.994	0.986	0.992	0.973	0.987	0.962	0.991	0.997	0.930	0.975
$f(x)=p1x^{p2}e^{-(p_3x+p4)^2}$ (eq.3)										
R^2	0.996	0.983	0.988	0.968	0.998	0.950	0.994	0.996	0.930	0.951
$f(x)=p1(x-p2)^{p3}e^{-p4(x-p2)^{p3+1}}$ (eq.4)										
R^2	0.997	0.995	0.998	0.970	0.993	0.944	0.989	0.998	0.929	0.965

In the fig. 1 are graphically representations of the experimental points and the regression curves for each model, respective (1), (2), (3), and (4).



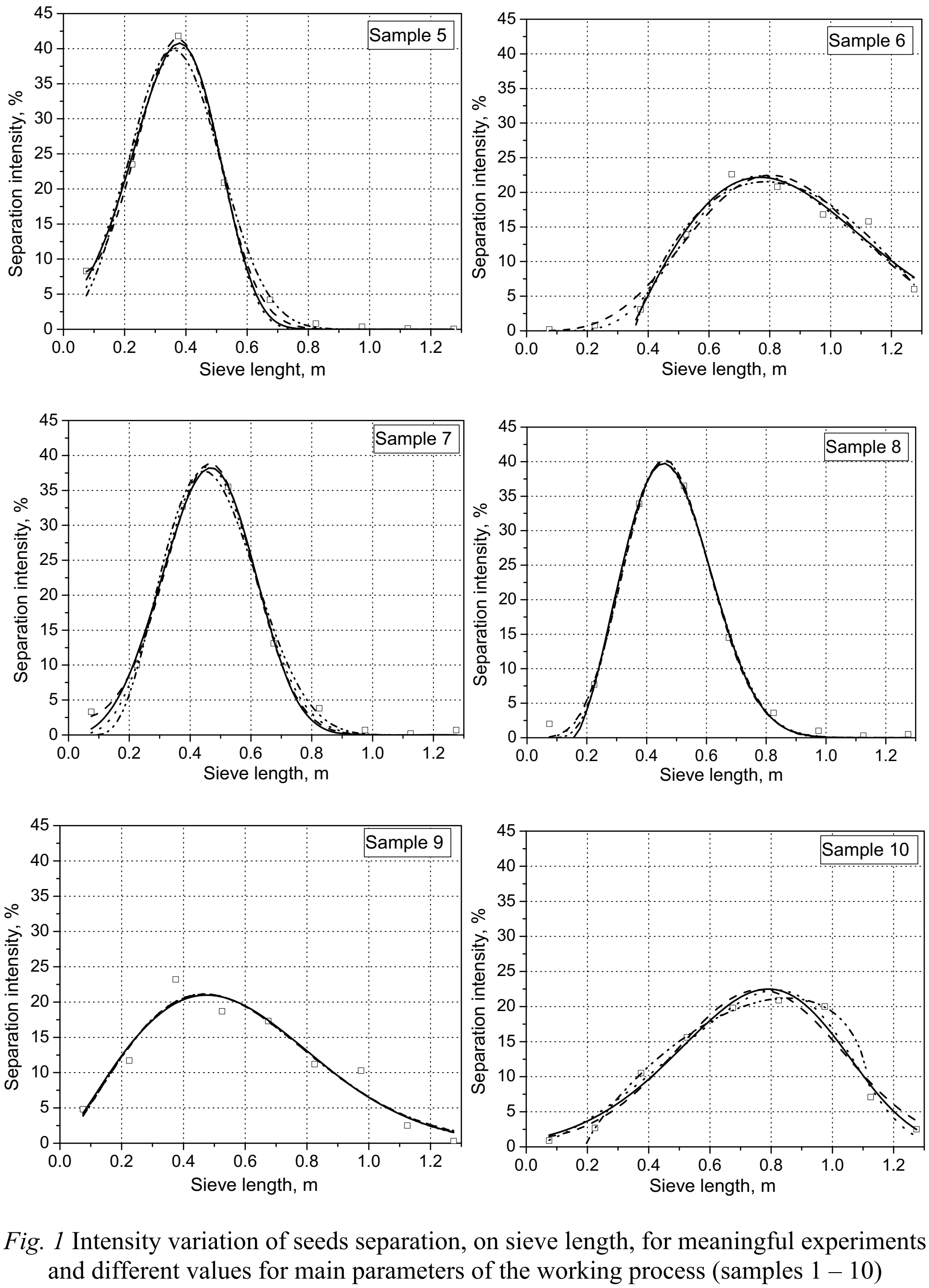


Fig. 1 Intensity variation of seeds separation, on sieve length, for meaningful experiments and different values for main parameters of the working process (samples 1 – 10)
□ – experimental points; — · · — generalized beta distribution (eq.1); . . . . . . generalized gamma distribution (eq.2); – – – – delay gamma distribution (eq.3); —— weibullean distribution (eq.4)

The graphs of these functions are much closer to experimental data for many cases (fig.1). It results that does not find a general rule for all cases, and that for each case must an adequate model used.

A requirement for any model is the improvement so as to make it more accurate. In this direction we proposed some generalized models of the stochastic distributions given in the paper [12].

For example the model (1) is an extended model of the distribution (4) from [12]. In the paper [12] this model has the boundaries assigned. So, the number of degrees of freedom is 5, instead of 3, what makes possible a better fitting. Similarly the models (2) and (3) are new generalized of the probability density gamma. Briefly saying, we proposed new generalized mathematical models with different applications in technical engineering, especially in the separation process modelling on the sieves of the cleaning systems.

CONCLUSIONS

The main purpose of the paper is to give adequate probability laws for the simulation the seeds separation process on the sieves of the cleaning systems. It was proposed adaptive stochastic models and it was analysed different statistical probability density functions for describing of evaluation of grain cleaning for working concrete cases .It results that for different cases agree different functions. The models have a good fitting to experimental data as shown by the chi-square and correlation coefficients. The paper presents proposes new approaches based on classical distributions. These results can be useful both in design work and in the practice, allowing the prediction of the seeds losses for the cleaning system of the harvesting combines.

REFERENCES

1. Baumgarten J., 1987, Laboruntersuchungen zur Auslegung und Führung des Separationsprozesses in einer Mahdrescherreinigungseinrichtung, Agrartechnick, nr.4, pp.165-168;
2. Căsăndroiu, T. Voicu Gh., Maican E., 2008, A mathematical model for the seeds losses prediction on the cleaning system sieves of the harvesting combines, Modelling and optimization în the machines building field MOCM-14, vol.2, Romanian Technical Sciences Academy, University of Bacău, pp.19-26;
3. Gregory J.M., Fedler C.B, 1987, Mathematical Relationship Predicting Grain Separation in Combines, Transactions of the ASAE, St. Joseph, MI, Vol. 30(6), pp. 1600-1604;
4. Heike H.D., Tarcolea C., 2000, Grundlagen der Wahrscheinlichkeitsrechnung und Statistik, Oldenbourg Verlag, München, Wien, pp.405-454.
5. Schreiber M., Kutzbach H.D., 2003, Modelling Separation Characteristics in Combine Cleaning Shoes, Landtechnik, nr.4, pp. 236 – 237.
6. Song A., Chung D.S., Nassar R., 1990, A Stochastic Compartmental Model Simulating a Grain Cleaning Process, American Society of Agricultural Engineers, vol. 33(3), pp.877-884;

7. Tarcolea C., Filipoiu A., Bontas S., 1989, Tehnici actuale in teoria fiabilitatii, Editura Stiintifica si Enciclopedica, pp.59-80.

8. Tarcolea C., Casandroiu T., Voicu Gh., 2008, Stochas tic Models for Simulating Seed Separation Process on Sieves, Proc. the 36th Symposium ”Actual Tasks on Agricultural Engineering”, Opatija, Croatia, pp.293-306.

9. Voicu. Gh., Căsăndroiu T., 2004, Comparative analysis of mathematical models used in account of separation process of the seeds on the cleaning sieves system from the cereals combines, Machinery Building, 11-12, pp.37-39.

10. Voicu Gh., Casandroiu T., Toma L., 2006. A multiple logistic regression statistical model to estimate grain losses on sieve cleaning system from combine, In Proceedings ”Actual tasks on agricultural engineering” of the 34th International Symposium on agricultural engineering, Opatija, Croatia, pp.481-491.

11. Voicu Gh., Casandroiu T., Stan G., 2007, Using the dimensional analysis for a mathematical model to predict the seeds losses at the cleaning system of the cereals harvester combines, U.P.B Sci. Bull., Series D: Mechanical Engineering, Vol.69, No.4, pp.29-40.

12. Voicu, Gh., Căsăndroiu T., Târcolea C., 2008, Testing stochastic models for simulating the seeds separation process on the sieves of a cleaning system, and a comparison with experimental data, ACS - Agriculturae Conspectus Scientificus, Zagreb, Croația, Vol.73, no.2, pp.95-101;

13. Voicu, Gh., Târcolea C., Căsăndroiu T., 2008, Eulerian and Weibullean Functions Used for Simulation the Seeds Separation Process on the Sieves of the Cleaning Systems, Journal of Agricultural Machinery Science, Vol.4, no.4, Izmir, Turkiye, pp.349-354;

14. Wang Y.S., Chung D.S., Spillman C.K, Eckhoff S.R., Rhee C., Converse H.H., 1994, Evaluation of Laboratory Grain Cleaning and Separating Equipment, Part I. American Society of Agricultural Engineers, Transactions of the ASAE, vol. 37(2), pp. 507-513;

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.563:633.15:636.085.522.55
Stručni rad
Expert paper

UZGOJ, KOŠNJA I USKLADIŠTENJE SILAŽNOG KUKURUZA U AG-BAG FLEKSIBILNO CRIJEVO

R. ZIMMER [1], S. PICHLER[2], S. KOŠUTIĆ [3], D. JELOŠEK [4]

[1] Poljoprivredni fakultet Osijek, Trg Sv. Trojstva 3, 31000 Osijek, zimmer@pfos.hr
[2] Bc Agroslavonija d.o.o., Ulica Jablanova 1, 31000 Osijek, agroslavonija-plant@os.htnet.hr
[3] Agronomski fakultet Zagreb, Svetošimunska 25, 10000 Zagreb, skosutic@agr.hr
[4] Pioneer sjeme Zagreb, Čulinečka cesta 2B/2, 10000 Zagreb, damir.jelosek@pioneer.com

SAŽETAK

Uzgoj, košnja i uskladištenje hibrida kukuruza PR34N43 obavljeno je na OPG „Simental Commercxe“ Osijek, lokacija Tenja. Nakon žetve pšenice obavljena je plitka obrada strništa tanjuračom, a zatim podrivanje u dubinu 60 do 70 cm i tanjuranje. U jesen 2007. u osnovnoj gnojidbi raspodijeljeno je složeno gnojivo NPK formulacije 7:20:30 u dozi od 430 kg ha^{-1}, a zatim je s plugom premetnjakom obavljeno oranje na 30 cm. U proljeće je sjetvospremačem zatvorena zimska brazda i raspodjeljena UREA u dozi 350 kg ha $^{-1}$, nakon čega slijedi fina priprema tla sa sjetvospremačem s kratkim klinovima i 25. travnja sjetva sijačicom Maxem-6. Prije nicanja usjeva obavljena je zaštita od korova s 2 l ha^{-1} Lumax-a, a poslije nicanja je za istu namjenu korištena kombinacija Motivel u dozi 1 l ha^{-1} + Cambio u dozi od 2 l ha^{-1}. Kultivacija nije obavljana. Košnja je obavljena silažnim kombajnom Claas Jaguar 900 s Corn crekerom i adapterom-header-om RU 600 Extra s 4 bubnja i zahvata 8 redova kukuruza. Inokulant za stočnu hranu u količini od 500 g na 100 l vode dodavan je Spotlyt uređajem na silažnoj preši AG-BAG G 6000 Europe. Prosječni urod silažnog kukuruza PR34N43 bio je 52030 kg ha^{-1}, a spremanje je obavljeno od 3 do 15. rujna. Silažni kukuruz uskladišten je u polietilensko crijevo promjera 244 cm i duljine 60 m. Analizirani uzorak silaže uzet 4. rujna imao je 74 boda (dobra silaža), a uzet 12. rujna imao je 50 bodova (osrednja silaža). Na istraživanom OPG u 2008. god. krma je uskladištena u ukupno 19 crijeva od folije dimenzije 60 m duljine i 2,44 m širine, odnosno temeljem ispunjenosti crijeva 90-92% spremljeno je 266 do 285 vagona silažnog kukuruza.

***Ključne riječi**: silažni kukuruz, silažna preša, crijeva od folije*

UVOD

Kukuruz je danas prva kultura našeg podneblja, kako po površinama, tako i po zastupljenosti u hranidbi domaćih životinja. Životinjama se daje kao prekrupljeno suho zrno, prekrupljeno zajedno s klipom, silirano zrno, silirano zrno i kao cijela biljka kukuruza. U ljudskoj prehrani kukuruz nalazimo pretežito kao kukuruzno brašno, gris, kruh, pahuljice, ulje, alkohol i bezalkoholna pića. A nalazimo ga i u raznim farmaceutskim, kozmetičkim, kemijskim, tekstilnim i drugim proizvodima.

U Hrvatskoj u ishrani stoke kukuruz se najčešće koristi kao silaža cijele biljke i po tom ima karakter voluminoznog krmiva. Za spremanje i uskladištenje silažnog kukuruza koriste se objekti različite izvedbe, koje se zajednički nazivaju silosima. Oni mogu biti u obliku silo-hrpe, trenč-silosa i silo tornja. Novija rješenja uskladištenja krme koriste tehniku kojom se silaža sprema u valjčaste bale višestruko omotane plastičnom folijom i crijeva od folije. Na području Istočne Hrvatske u eksploataciji su tri silo preše tipe AG-BAG 7000, jedna tipe AG-BAG 6700, jedna tipa AG-BAG 6000 i još dvije koje nisu proizvod te tvrtke. U Njemačkoj se tvrtka AG-BAG može naći na adresi www.ag-bag.de, a u Hrvatskoj na agroslavonija@os.htnet.hr. Njemačka tvrtka zagovara spremanje/konzerviranje u crijeva od folije silažu lucerne i/ili travne mase, silažu od cijele kukuruzne biljke, vlažno zrno kukuruza za svinje, vlažno zrno kukuruza za goveda, repnih rezanaca, cijele biljke ječma i prekrupljeni klip s komušinom. U ovom radu iznijeti su neki rezulati i stečena iskustva tijekom dvije godine istraživanja tog načina spremanja krme na području Istočne Hrvatske.

MATERIJAL I METODE

Uzgoj, košnja i uskladištenje silažnog kukuruza PR34N43 obavljeno je na mješovitom OPG „Simental Commercxe" Osijek, lokacija Tenja. Nakon žetve pšenice obavljeno je prašenje strništa tanjuračom, a zatim podrivanje u dubinu 60 do 70 cm i tanjuranje tla. U jesen 2007. u osnovnoj gnojidbi na tlo je raspodijeljeno mineralno gnojivo NPK formulacije 0:20:30 u količini 430 kg ha^{-1}, zatim je okretnim plugom s 4 plužne glave obavljeno oranje u dubinu 30 cm.

U proljeće je sjetvospremačem zatvorena zimska brazda i raspodjeljea UREA u dozi 350 kg ha^{-1}, nakon čega slijedi fina priprema tla sa sjetvospremačem s kratkim klinovima i 25. travnja sjetva sijačicom Maxem – 6 kasnog hibrida kukuruza PR34N43 iz grupe FAO 600. Prije nicanja usjeva obavljena je zaštita s Lumax-om u dozi 2 l ha^{-1}, a poslije nicanja korišten je Motivel u dozi 1 l ha^{-1} + Cambio u dozi od 2 l ha^{-1}.

Košnja je obavljena silažnim kombajnom Claas Jaguar 900, koji je imao uređaj za drobljenje zrna (Corn creker) i adapter RU 600 Extra s 4 bubnja i zahvaćao je 8 redi kukuruza. Vaganje uroda obavljeno je stacionarnoj kolnoj vagi na farmi „Simental Commerce" . Uskladištenje (utiskivanje) kukuruzne silaže počelo je 3., a završeno 15. rujna. Korištena je silažna preša AG BAG G 6000 Europe i crijeva od folije promjera 244 cm i duljine 60 m.

Dodatak (inokulant, aditiv) za stočnu hranu (četiri soja bakterije + četiri enzima) u količini od 500 g na 100 l vode dodan je u krmu pomoću Spotlyte uređaja dograđenog na silažnoj preši. Uzorci kukuruzne silaže iz crijeva od folije uzeti su sondom 60-tak dana nakon uskladištenja. Analiza silaže obavljena je u Insepcto d.o.o. Kontrola kakvoće robe u Osijeku.

Meteorološki podaci za pokusno polje pribavljeni su u Hrvatskom državnom hidrometeorološkom zavodu, postaja Zračna luka Klisa.

REZULTATI I DISKUSIJA

U vegetaciji kukuruza na pokusu uz mjesto Tenja Osječko-baranjskoj županiji izmjerena je količina i raspored oborina, te srednje mjesečne temperature zraka kako prikazuju tablice 1 i 2.

Tablica 1. Oborine (mm) tijekom vegetacije kukuruza i višegodišnji prosjek (Osijek)

Naziv	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**Ukupno**
2008.	76,1	50,6	114,5	88,9	70,1	27,8	85,4	38,2	551,6
1993-2008.	38,8	51,6	60,5	61,2	61,4	71,3	72,9	50,6	468,3

Na pokusno polje u vegetaciji kukuruza od ožujka do listopada 2008. palo je ukupno 551,6 mm ili 17,8 % više u odnosu na višegodišnji prosjek. Uočljiv je nedostatak oborina u kolovozu, svega 39,00 % višegodišnjeg prosjeka, te izraziti višak od 89,00 % iznad višegodišnjeg prosjeka u svibnju.

Tablica 2. Srednja mjesečna temperatura zraka, Osijek (°C)

Mjesec	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**Prosjek**
2008.	7,6	12,7	18,6	22,0	22,0	22,3	15,8	13,2	16,8
1993-2008.	6,0	11,2	16,6	19,6	20,9	20,2	15,3	11,8	15,2

Srednja mjesečna temperatura zraka u razdoblju uzgoja kukuruza bila je veća za 1,6 °C od višegodišnjeg prosjeka, odnosno, svi navedeni mjeseci u 2008.god bili su topliji od višegodišnjeg prosjeka.

Tablica 3. Prosječni sklop, visina biljaka, visina klipova od tla, visina košnje, duljina sječke i urod silažne mase

Hibrid	**Prosječni sklop**	**Podešen razmak zrna u redu (cm)**	**Visina biljaka (m)**	**Visina klipova od tla (m)**	**Visina košnje (cm)**	**Duljina sječke (cm)**	**Prosječni urod silažne mase (kg ha^{-1})**
PR34N43	60250	20,51	2,9-3,1	1,4 – 1,5	32-35	1,7-2,0	52030

Silažni kombajn Claas Jaguar 900 radio je brzinom v= 3,5 - 4,5 km h^{-1}, uz broj okretaja motor u rasponu n= 2050 - 2080 o min^{-1}. Uređaj za sječenje cijele biljke kukuruza imao je 20 noževa. Dimenzije prednjih guma bile su 800/65R32, a zadnjih 110/45-26,5.

Transport silaže obavljen je s dvosovinskim prikolicama Tehnostroj, koje su masu istovarale na betonsku podlogu neposredno pored silo preše. Utovar krme u silo prešu obavljaju u pravilu dva traktora snage motora 76 kW s kašikastim utovaračem. Kašika ima dimenzije 2,42 x 1,2 x 1,0 m, a prosječna masa silažnog kukuruza vlage 50,08% u kašici iznosila je oko 660 kg.

Masa silažnog kukuruza utiskuje se crijevo s tlakom oko 23 bara, a kontrola tlačenja obavlja vizuelno, tj. vertikalne oznake na crijevu duljine 12 smiju se istegnuti max do 13,5 cm. Duljina napunjenog crijeva u pravilu je 54 do 55 m i u njega stane, ovisno o vlazi, oko 14 do 15 vagona silažnog kukuruza. Praktična iskusta pokazuju da 2 do 3 m duljine crijeva na obje strne služe za zatvaranje crijeva. Prešu pogoni traktor snage motora 66 kW (90 KS). Dodatak (inokulant, aditiva) silažnoj masi obavlja se nadograđenim uređajem Spotlyte na silo preši, a tlak dodavanja je 0,83 do 0,96 bara (12 do 14 psi). Količina mješavine dodatka (500 g) i vode (100 vode) dovoljna je za oko 20 m duljine crijeva promjera 244 cm i duljine 60 m. Za zatvaranje crijeva na obje strane utroši se oko 5 do 6 m. Za punjenje jednog crijeva duljine 60 m, promjera 2,44 m i debljine 0,28 mm treba prosječno 4 do 4,5 sati rada. U 2008. god. na tom su gospodarstvu 3 radnika (2 na traktoru s utovarivačem i jedan uz silo prešu) za 12 sati rada napunila 3 crijeva duljina 60 m i promjera 2,44 m. Analiza dva ozorka silaže kukuruza uzeta 60-tak dana nakon uskladištenja prikazana je u tablici br. 4.

Tablica 4. Analiza uzoraka silaže kukuruza iz crijeva od folije

<table>
<tr><th>Naziv</th><th>Crijevo 1</th><th>Crijevo 2</th><th>Referentna metoda</th></tr>
<tr><td>pH</td><td>4,17</td><td>4,02</td><td rowspan="8">Po Fligeu</td></tr>
<tr><td>Hlapljive kiseline</td><td>Omjer kiselina</td><td>Omjer kiselina</td></tr>
<tr><td></td><td>Octena 37,74 %
Maslačna 0 %
Mliječna 62,26 %</td><td>Octena 88,51 %
Maslačna 0 %
Mliječna 11,49 %</td></tr>
<tr><td>Bodova</td><td>74</td><td>50</td></tr>
<tr><td>Ocjena</td><td>Dobra silaža</td><td>Osrednja silaža</td></tr>
<tr><td>Suha tvar</td><td>50,8 – 50,6</td><td>43,4 – 43,7</td></tr>
<tr><td>Datum uzimanja uzoraka</td><td>4. rujna 2008.</td><td>12. rujna 2008.</td></tr>
<tr><td>Datum analiziranja uzoraka</td><td colspan="2">13. studeni 2008.</td></tr>
</table>

Uskladištenu silažu kukuruza karakteirizirao je visoki udjel suhe tvari u momentu utiskivanja krme u crijevo. Iako je korišten dodatak hrani (inokulant) u potrebnoj dozi, silaža je nakon 2 mj dobila relativno slabije ocjene (74 bodova i 50 bodova) i svrstana je u dobru, odnosno osrednju silažu.

S aspekta ekologija postupak spremnja krme u crijeva od folije ni jednom svojom operacijom ne zagađuje okoliš. Krma dopremljena s polja istovaruje se na betonsku podlogu s koje je zahvaćaju traktori s kašikom i utovaruju u silo prešu. Prešanjem silažne mase čeličnim rotirajućim valjkom sa češljevima (grebenima) dobiva se zgusnuta krma u crijevu i potpuna isključenost pristup zraka. Zrak se iz crijeva ispušta posebno izvedenim ventilima, koji se postavljaju s gornje strane crijeva. Ukoliko se pojavi sok iz krme on ostaje zadržan u crijevu od folije i može se ispumpati. Kod izuzimanje krme traktorom s kašikom crijevo je potrebno razrezati samo na kraju s gornje strane, a dno crijeva treba koristiti kao zaštitu od prljanja krme.

Prema dosadašnjim stranim i domaćim iskustvima AG-BAG 6000 rentabilan je već nakon spremljenih 2000 t/god., tip 6700 nakon 4000 t/god. a najskuplja preša AG-BAG tip 7000 rentabilna je već nakon spremljenih 5000 t krme/godišnje. Cijena silažne preše tip 6000 + neophodna oprema je 46550 € bez PDV, a crijeva promjera 2,44 m i duljine 60 m je 2900 kn. Preša tip 7000 s neophodnom opremom košta 78000 € bez PDV, a cijena crijeva promjera od 3,0 m je 3900 kn. Trajnost preša je oko 10 godina.

UMJESTO ZAKLJUČKA

Na temelju dosadašnjih istraživanja i iskustava moguće je konstatirati slijedeće:

- Ispitivanje je obavljeno na imanju OPG „Simental commerce". Hibrid kukuruza PR34N43 posijan je 25. travnja, a košen od 3. do 15.rujna silažnim kombajnom Claas Jaguar opremljenim adapterom RU Extra s 4 bubnja za 8 redi kukuruza i uređajem (Corn creker) za drobljenje zrna;
- Silažni kukuruz prosječnog uroda Q= 52030 kg ha^{-1} je pomoću silažne preše AG-BAG G 6000 Europe uskladišten u polietilensko crijevo promjera 244 cm i duljine 60 m. Inokulant za stočnu hranu u količini od 500 g na 100 l vode dodavan je Spotlyt uređajem na silažnoj preši.
- Uzorak kukuruzne silaže uzet iz crijeva 4. rujna ocjenjen je sa 74 boda (dobra silaža), a uzorak od 12. rujna 2008. dobio je 50 bodova (osrednja silaža).
- Na OPG „Simental commerce" s velikim uspjehom i zadovoljstvom petu godinu zaredom koriste silažnu prešu AG-BAG 6000 Europe, a spremaju uglavnom silažni kukuruz i repine rezance. U 2008. god. spremili su 266 do 285 vagona silažnog kukuruza u 19 crijeva od folije.
- Prema našim saznanjima na području Istočne Hrvatske krma je (silažni kukuruz, prekrupljeno zrno kukuruza, repini rezanci) spremljena u oko 275 do 280 crijeva od folije različitih promjera i duljina.
- Prema mnogim stranim i domaćim korisnicima spremanje i konzerviranje krme u crijeva najbrži je način spremanja i najpouzdaniji način čuvanja različitih vrsta krme.

LITERATURA

1. Csermely, J., Bellus, Z., Kelemen, Z., Schmidt, J., Sipocz, J (2003): Silaža u crijevima od folije (s AG-BAG prešama), Izvješće o tehničkom i ekonomskom istraživanju proizvodnih tehnologija, broj 179 Instituta za poljoprivrednu tehniku Ministarstva poljoprivrede i razvoja zemlje FVM Müszaki Intezet; Gödöllö (tiskano u PUP broj 2/2003., Osijek)
2. Čuljat, M., (2003): Uskladištenje krme u crijeva AG-BAG prešom, PUP broj 4/2003., reportaža, Osijek
3. Čuljat, M. (2005): Tovljači junadi uspješni u europskim razmjerima, PUP broj 4/2005., Osijek
4. Domaćinović, M. (2006): Hranidba domaćih životinja, Poljoprivredni fakultet u Osijeku
5. Pucarić, A., Ostojić, Čuljat, M. (1997): Proizvodnja kukuruza, Hrvatski zadružni savez – Poljoprivredni savjetnik, 1997., Zagreb
6. Pioneer A DuPont Company: Tehnologija koja daje više, Pioneer sjeme Zagreb, 2005/06.
7. Steinhöfel, O, Weber, U. (2007). Siliranje u plastičnim folijama je konkurentno, BUDISSA Agroservice GMBH
8. Zimmer, R., Jelošek, D., Košutić, S., Bagarić, B. (2007): Tehnika u uzgoju i uskladištenju silažnog kukuruza u AG_BAG crijeva, Aktualni zadaci mehanizacije poljoprivrede, 35. Aktualni zadaci mehanizacije poljoprivrede, Opatija, 131-137

SILAGE CORN HARVESTING AND STORAGE IN AG-BAG FLEX-TUBES

SUMMARY

Production and storage of corn hybrid PR34N43 was completely performed at agricultural enterprise "Simental Commerce", Osijek in village Tenja. After the previous crop, winter wheat harvest, field was tilled with disharrow. Further tillage was subsoiling up to 60-70 cm and discharrowing. Fertilising was done as follows: basic fertilising with dose of 430 kg ha^{-1} NPK 7:20:30 was applied in autumn 2007., prior to ploughing. During spring of 2008., autumn furrow was leveled and after that UREA in dose of 350 kg ha^{-1} was applied and incorporated with seedbed implement. The corn sowing was done on 25th of April 2008. with Maxem-6 precision drill. Pre-emergence protection was done with Lumax in dose of 2 L ha^{-1}, while post-emergence was done with 1 L ha^{-1} of Motivel and 2 L ha^{-1} of Cambio. Harvest was performed with Class Jaguar 900 forage harvester, equipped with corn crecker and RU 600 Extra header. Silage inoculant, 500 g per 100 L of water sufficient for 20 m of tube lenght was applied by Spotlyt device integrated at silage bagger type AG-BAG G 6000 Europe. Dimensions of FLEX-TUBE storage were: 2,44 m in diameter, 60 m in lenght and 19 pieces of such Flex-Tubes storage were completed at experimental farm during silage harvest season 2008. According to degree of charging which was 90-92% 2660-2850 t of corn silage was stored in Flex Tubes

***Key words**: Silage corn, AG-Begger, Flex-tubes*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.317.7:631.37
Stručni rad
Expert paper

PRIMENLJIVOST GPS NAVOĐENJA U POLJOPRIVREDI ZEMALJA JUGOISTOČNE EVROPE

M. MARTINOV[1], M. GAVRIĆ[2], F. KIŠ[3], B. BRUNET[4], G. MICKOVIĆ[5]

[1]Milan Martinov, Fakultet tehničkih nauka, Novi Sad, [2]Milan Gavrić, TelventDMS, Novi Sad, [3]Ferenc Kiš, Tehnološki fakultet, Novi Sad, [4]Borislav Brunet, Pokrajinski sekretarijat za poljoprivredu, vodoprivredu i šumarstvo, Novi Sad, [5]Goran Micković, RES Trade, Novi Sad

SAŽETAK

Navođenje traktora i samohodnih poljoprivrednih mašina pri uklapanju prohoda dostiglo je nivo primenljivosti u praksi. To je praćeno sniženjem cena opreme, odnosno troškova primene. Cilj ispitivanja bio je: da se proveri raspoloživost DGPS, tj. korekcionih, signala na području jugoistočne Evrope (na primeru Autonomne pokrajine Vojvodine), da se sistematizuju tipovi sistema za navođenje i da se izradi računarski program, kalkulator za ocenu profitabilnosti primene.

Testirani su korekcioni signali Egnos, StarFire 1 i StarFire 2, a dobijeni su dobri rezultati, jer su odstupanja bila unutar definisanih navigacionih, odnosno dinamičkih grešaka. Raspoloživi uređaji za navođenje su klasifikovani prema automatizaciji, nivou dinamičke greške i mogućnosti povezivanja s traktorskim sistemom za kontrolu i upravljanje.

Osnove za ocenu ekonomičnosti postavljene su na bazi perioda otplate na bazi poređenja troškova primene i ostvarenih ušteda. Na osnovu podataka dobijenih od stručnih lica sačinjena je tabela s uobičajenim preklopima koji se ostvaruju pri operacijama u ratarskoj proizvodnji.

Jedan od zaključaka je da pri korišćenju korekcionog signala s greškom navođenja do 0,3 m i primenom uređaja za ručno upravljanje može da se ostvari profit i pri obradi manje od 150 ha.

Ključne reči: *GPS navođenje, korekcioni signal, profitabilnost*

UVOD

Civilna primena sistema za pozicioniranje GPS (Global Positioning System) poznata je još početkom devedesetih godina prošlog veka. Prva saopštenja o primeni GPS pozicioniranja u poljoprivredi, na području SEE (jugoistočne Evrope), potiču iz 1994. (Ronai i sar, 2004). Javnost je u više navrata obaveštavana o raznim mogućnostima i potrebama primene GPS u poljoprivredi (Tešić i sar. 1995, Gavrić i Sekulić, 2004, Ehlert i sar, 2004), pri čemu je najčešće pominjan pojam precizna ili lokacijski specifična poljoprivreda, te dokumentovanje proizvodnje, odnosno primena GIS (Geographic Information System). Tek kada je preciznost pozicioniranja dostigla visok nivo, ispodmetarsku apsolutnu grešku pozicioniranja (Sullivan et al, 2001), počela je primena GPS za navođenje i uklapanje prohoda traktora sa priključcima i samohodnih radnih mašina. Mada su tehnička rešenja bila poznata još krajem devedesetih godina, na primer, variable rate technology –VRT, visoka cena uređaja i pretplate na korekcione signale za ostvarenje visoke preciznosti navođenja, bili su ograničavajući faktori za sprovođenje ekonomski opravdane primene za većinu poljoprivrednika (Medlin and Lowenberg-DeBoer, 2000). Kada se to promenilo, stekli su se uslovi za široku primenu ove tehnologije, o čemu je saopšteno i kod nas (Martinov i Gavrić, 2006). Najveći napredak ostvaren je u primeni GPS pozicioniranja za navođenje i uklapanje prohoda. Najznačajniji efekti koji se postižu primenom GPS navođenja su:

1. Preklop se, u proseku, smanjuje s 10 na 5%.
2. U skladu sa smanjenjem preklopa smanjuje se i količina inputa, pre svega mineralnih hraniva i sredstava za zaštitu bilja, a u nekim slučajevima i semena.
3. Brzina kretanja pri radu može u proseku da se poveća za oko 13% (Buick i White, 1999).
4. Vreme okretanja na uvratini smanjuje se u proseku za 15%.

Nastanak oplazina (neobrađenih površina), usled manje tačnosti navođenja, takođe ima efekta na ekonomske pokazatelje, jer se na tim mestima smanjuje prinos. Pošto se teško meri, uvek se pretpostavlja da se primenjuje preklop, koji sa sigurnošću nastanak oplazina eliminiše.

U svim izvorima literature navodi se da je ograničavajući faktor za primenu GPS veličina i širina zahvata. Ušteda na smanjenju preklopa pored primenjivanog sistema, odnosno maksimalne greške, zavisi i od toga koja se operacija sprovodi, te to treba da se uzme u obzir pri razmatranju konkretnog slučaja.

Pored navedenih, postoje i druge prednosti primene GPS navođenja, i to:

1. Navođenje uz pomoć GPS-a moguće je i u slučaju smanjene vidljivosti: magla, prašina, noćni rad. (Moitzi, 2006, navodi da je preklop pri razrivanju/tanjiranju i ručnom navođenju, danju 10-20, a noću 40-50 cm. Pri korišćenju GPS navođenja preklop može da se svede na 5-10 cm u svim uslovima.)
2. U nekim operacijama, kao što je distribucija mineralnog hraniva širokozahvatnom mašinom po polju bez prepoznatljivih redova biljaka, GPS navođenje u razvijenim zemljama gotovo da nema alternative (Lowenberer-DeBoer, 1999).
3. Naprezanje rukovaoca, pre svega vida, znatno je smanjeno, što ima humanu, ali i funkcionalnu dimenziju. Odmorniji rukovalac duže i efektivnije radi.

4. Za korišćenje GPS navođenja nije potrebno veliko radno iskustvo, te rukovalac može da bude i početnik. Lowenberer-DeBoer (1999) navodi da mladi ljudi čak brže nauče i rado koriste GPS navođenje.
5. Priprema za primenu GPS sistema navođenja kraća je nego priprema za konvencionalne sisteme, na primer, ugradnja sredstva sa penom i markera.
6. Većina sistema za GPS navođenje ima integrisane i druge funkcije, koje mogu dobro da posluže za menadžment, knjigovodstvo, razne dokumentacije i planiranje proizvodnje u narednom periodu. Takođe, najsavremeniji sistemi, predstavljaju integralni deo sistema za kontrolu i upravljanje radom traktora i priključaka.

Sve izneto navodi da je primena GPS navođenja i uklapanja prohoda dostigla nivo primenljivosti u praksi. Stoga je postavljen zadatak da se proveri primena u zemljama SEE, na primeru Vojvodine, s tehničkog i ekonomskog stanovišta. To podrazumeva proveru tačnosti navođenja uz korišćenje raspoloživih korekcionih signala (DGPS), kao i razvoj postupka za ocenu ekonomičnosti primene.

MATERIJAL I METOD

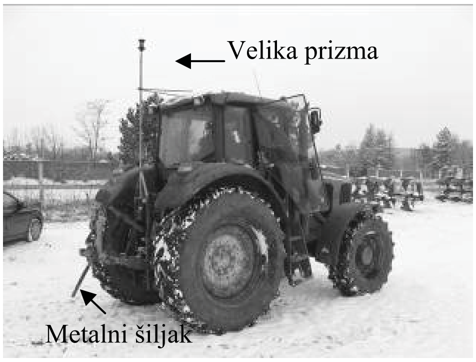
Dostupnost signala i tačnost pozicioniranja

U decembru 2007, na PD „Titel“ u Titelu, testirani su sledeći sistemi za GPS navođenje:

1. *Trimble EZ–Guide 500*, uređaj sa ručnim zakretanjem volana na bazi svetleće letve (*lightbar*) i 3D ekranskog prikaza, sa *EGNOS* korekcionim signalom.
2. *Trimble AgGPS EZ-Steer*, uređaj sa automatskim zakretanjem volana, sa *EGNOS* korekcionim signalom i terenskom kompenzacijom.
3. *John Deere Parallel Tracking*, uređaj sa ručnim zakretanjem volana na bazi praćenja slike na ekranu i *John Deere AutoTrack Universal*, uređaj s automatskim zakretanjem volana, uz korišćenje korekcionog signala SF 1 (*StarFire* 1).
4. *John Deere Parallel Tracking* i *John Deere AutoTrack Universal*, uz korišćenje korekcionog signala SF 2 (*StarFire* 2), dvofrekventni GPS prijemnik.
5. John Deere *AutoTrack Universal*, uz korišćenje sa RTK prenosive zemaljske stanice.

Pri testiranju simuliran je rad sa priključnom mašinom radnog zahvata 12 m. Na podiznom mehanizmu traktora, bio je postavljen alat za crtanje traga paranjem, prva varijanta, i prskalica sa mlaznicom za obeležavanje traga, druga varijanta. Razmak između tragova meren je na dva načina: pomoću uređaja za geodetsko merenje – totalna stanica, *Leica TPS–1201+*, sa dve prizme, malom i velikom, najviše klase tačnosti, u sve tri dimenzije i *Trimble Geoexplorer GeoXH*, GPS prijemnikom uz korišćenje AGROS mreže za korekciju u naknadnoj obradi signala (*postprocessing*). Početni razmak između tragova traktora meren je pomoću laserskog daljinomera *Leica DISTO^{TM} A5*.

Pozicije, odnosno putanje traktora, merene su i beležene kao serijski izlaz iz GPS prijemnika, kao pozicija prizme postavljene neposredno iza kabine traktora i kao očitane pozicije sa alatom odnosno prskalicom obeležene putanje.



Sl. 1 Traktor sa postavljenom velikom prizmom i metalnim šiljkom

Sl. 2 Rezervoar s obojenom tečnošću, pumpom i mlaznicom za ucrtavanje traga

Na osnovu očitanih putanja sa serijskih izlaza GPS prijemnika, generisani su KML fajlovi, koji su prikazani na programu *Google Earth*. Ovi fajlovi su bili osnova za utvrđivanje vrednosti dinamičkih, odnosno grešaka navođenja.

Pregled i sistematizacija dostupnih rešenja

Analizirani su podaci proizvođača opreme za GPS navođenje, mišljenja i ocene u stručnoj literaturi. Na osnovu toga obavljena je sistematizacija rešenja.

Ocena ekonomičnosti primene

Sprovedena je na osnovu poređenja troškova korišćenja uređaja za GPS navođenje i ostvarenih ušteda i izražena dobit (potencijalno gubitak). Podaci o preklopima za pojedine operacije u ratarskoj proizvodnji dobijeni su od vrsnih poznavalaca s terena. Takođe su prikupljena mišljenja i komentari o primenljivosti GPS navođenja. Razvijen je, za praksu pogodan, jednostavan program za izračunavanje ušteda.

REZULTATI I DISKUSIJA

Dostupnost signala i tačnost pozicioniranja

Pri svim merenjima broj korišćenih satelita za proračun bio je bar četiri, a kretao se i do devet. U toku merenja nije dolazilo do gubljenja signala, pa čak i L2, za dvofrekventni GPS prijemnik. Prosečna greška navođenja za sva četiri prolaza je:

- za korišćenje korekcionog signala *EGNOS* 0,25 m,
- za korišćenje korekcionog signala SF 1 0,16 m,
- za korišćenje korekcionog signala SF 2 0,06 m.

Za korišćenje korekcionog signala RTK stanice greška je bila zanemarljiva, odnosno manja od greške merenja razmaka među prohodima.

Pored testiranih signala na području jugoistočne Evrope dostupan je korekcioni signal *OmniSTAR*, za koji se plaća pretplata. Na raspolaganju su dve varijante, VBS s tačnošću koja je uporedljiva s SF 1 i HP uporedljiv s SF 2.

Na sl. 3 prikazan je primer prikaza rezultata u Google Earth-u.

Sl. 3 Greška pri korišćenju uređaja za ručno navođenje i korekcionog signala *Egnos*

Pregled i sistematizacija dostupnih rešenja

Proizvođači nude široku lepezu uređaja za GPS navođenje. Sa stanovišta greške navođenja, najjednostavnija rešenja koriste GPS prijemnike bez mogućnosti prijema DGPS, korekcionih signala. Greška navođenja je ređe ispod 0,5 m, te je primenljivost u poljoprivrednoj proizvodnji ograničena. Nudi ih samo manji broj proizvođača, a ponuda se smanjuje. Slede uređaji s jednofrekventnim GPS prijemnicima, koji su osposobljeni i za prijem korekcionih signala *EGNOS*, *OmniSTAR* VBS i *StarFire* 1. Greška navođenja je do 0,5 m, a najčešće do 0,3 m. Dvofrekventnim GPS prijemnicima, koji primaju i signal visoke tačnosti, L2, omogućeno je korišćenje korekcionih signala *OmniSTAR* HP i *StarFire* 2. Greška navođenja je do 0,1 m. Cena uređaja i pretplate na signal je viša. Nedostatak je i to što je u slučaju gubitka L2 signala, njegovo uspostavljanje sporo.

Najviša tačnost ostvaruje se primenom prenosive zemaljske (referentne) stanice. Tada se između stacionarnog i mobilnog prijemnika uspostavlja radio veza, te se stalno kontroliše greška pozicioniranja (na stacionarnom), te na osnovu nje koriguje i pozicija pokretnog prijemnika (rovera). Ovakvi uređaji ne koriste korekcione signale sa geostacionarnih satelita, jer ulogu korekcije preuzima referentna stanica. Domet radio veze između stacionarnog i pokretnog dela je 5 do 10 km. Samo jedan proizvođač koristi za ovakvu konfiguraciju jednofrekventne GPS prijemnike i kao rezultat proizvod ima veću grešku navođenja. Najčešće se koriste dvofrekventni, a takav sistem označava se s RTK (*Real*

Time Kinetics ili *Kinematics*). Greška je do 0,02 ili 0,05 m, te je omogućena primena u svim operacijama, pa i za ponavljanje prohoda iz godine u godinu. Obično jedna referentna stanica može da „opsluži“ pet pa i više pokretnih prijemnika, rovera.

Pri radu na parcelama s poprečnim nagibom dolazi do greške pozicioniranja koja je i do 0,5 m. Ona se eliminiše posebnim uređajem ugrađenim u GPS prijemnik, najčešće žiroskopskim. Time je povišena tačnost pozicioniranja, ali i cena prijemnika.

S stanovišta načina upravljanja skretanjem uređaji su ručni ili automatski. Kod ručnih, jeftinijih, rukovalac zakreće točak upravljača na osnovu smernica koje mu prikazuje displej uređaja. U početku su to bile letve s svetlećim LED diodama (*Light Emited Diodes*), ili skale s otklonom kazaljke. Osvetljene diode ili otklon kazaljke ukazivali su na odstupanje od pravilne putanje. Danas preovlađuje ekranski prikaz, a ekrani se razlikuju po tome da li su monohromatski ili kolor. Od značaja je i veličina ekrana. Neki od proizvođača ugrađuju kombinaciju letve s diodama i ekranskog prikaza.

Uređaji s automatskim navođenjem uglavnom imaju ekranski prikaz prethodnog i tekućeg radnog zahvata. Ovakvo navođenje, odnosno zakretanje upravljačkih točkova, ostvaruje se zakretanjem vratila upravljačkog točka, volana, a na raspolaganju je nekoliko rešenja. Veća preciznost pri automatskom navođenju ostvaruje se ukoliko se uređaj poveže na hidraulički sistem za skretanje. Ovo rešenje nije povoljno ukoliko se uređaj za GPS navođenje premešta s jednog na drugi traktor, posebno, ukoliko traktor za to povezivanje nije prilagođen fabrički. Danas renomirani proizvođači serijski, ili po porudžbini, pripremaju traktore za priključivanje uređaja za GPS navođenje. Tada vreme montaže/demontaže, može da bude i nekoliko časova. Najčešće se automatsko navođenje ostvaruje pri radnom zahvatu, dok se pri okretanju na uvratini upravljanje traktorom izvodi ručno.

U oba slučaja rukovalac zadaje širinu zahvata s kojom radi, a može da bira i vrstu putanje. Ona je od paralelne, do kružne, pri obradi u sistemu navodnjavanja s central pivotom. U početku su pojedini proizvođači posebno naplaćivali dodatne programe, na primer, za kretanje po krivini (*curve tracking*), dok je danas uobičajeno da korisnicima na raspolaganju stoji više softvera, bez posebne nadoknade.

Uređaji za ručno navođenje su prenosivi, nezavisni od drugih funkcija traktora, te mogu da se premeštaju s jednog na drugi, pa i na samohodne redne mašine. GPS uređaji s automatskim navođenjem su u najvećem broju slučajeva prilagođeni tome da se premeštaju s jednog na drugi traktor. Tako jedan uređaj može, posebno na manjim farmama, da se bolje iskoristi, odnosno, premešta s traktora na traktor, u zavisnosti od potrebne snage za pojedine radne operacije.

Najkompleksnija rešenja uređaja za GPS navođenje su ona koja se povezuju na integralni sistem kontrole i upravljanja traktorom pa i priključcima. U tom slučaju moguće je sprovođenje precizne poljoprivredne proizvodnje i sveobuhvatnog menadžmenta radom traktora.

Ocena ekonomičnosti primene

Proračun troškova je uprošćen do nivoa lake primenljivosti u praksi. Zbog očekivanog kratkog perioda povratka ulaganja u obzir nije uzimana diskontna stopa. U tab. 1 i 2 dat je postupak proračuna s navedenim primerom.

Tab. 1 Potrebni podaci za proračun troškova GPS uređaja

Podaci	Primer:
Nabavna vrednost GPS uređaja	13.000 €
Vek upotrebe GPS uređaja	5 god.
Krajnja vrednost GPS uređaja	2.000 €
Prosečna godišnja kamatna stopa	7,5%
Premijska stopa	1%
Stopa održavanja	0%
Cena korekcionog signala za 1 godinu	0 €
Prosečna vrednost GPS uređaja	7.500 €

Tab. 2 Proračun godišnjih troškova GPS uređaja za navođenje i uklapanje prohoda

Vrsta troškova	Obrazac za izračunavanje	Primer proračuna	Iznos, €/a
Amortizacija	$\frac{\text{Nabavna vrednost} - \text{krajnja vrednost}}{\text{vek upotrebe}}$	$\frac{13.000€ - 2.000€}{5\,\text{god.}}$	2.200
Troškovi kamata	*Prosečna vrednost x kamatna stopa*	7.500 € · 7,5%	562
Troškovi osiguranja	*Prosečna vrednost·x premijska stopa*	7.500 € · 1%	75
Troškovi održavanja	*Prosečna vrednost x·stopa održavanja*	7.500 € · 0%	0
Troškovi KS	–	–	0
Ukupni godišnji troškovi	*Zbir svih troškova GPS uređaja*		2.837

KS– korekcioni signal

U tab. 3 prikazane su srednje vrednosti pokazatelja rada u ratarskim operacijama relevantni za proračun ušteda pri primeni GPS navođenja. Prateći komentari su:

1. Primena navođenja i uklapanja prohoda za oranje u brazdi nema posebnog smisla. Delimično olakšava se i ubrzava okretanje na uvratini, posebno u uslovima smanjene vidljivosti, a navođenje olakšava rad manje iskusnog rukovaoca. Pri oranju izvan brazde mogu da se ostvare uštede i olakšanje rada primenom svih sistema, a posebno preciznijih.
2. Razrivanje, tanjiranje, predsetvena priprema i primena kombinovanih oruđa za osnovnu i dopunsku obradu, bez prevrtanja plastice, imaju slične uslove rada i preklope. Za širinu zahvata ispod 3 m primena navođenja, uz pomoć GPS-a, ne donosi uštede, a uštede, uz korišćenje sistema s greškom do 0,3 m, dobijaju na značaju tek za radne zahvate 4 m i više od toga. Što je veća širina radnog zahvata veća je i ušteda (Hüter et al, 2005, Holpp, 2006).
3. Najveće uštede u radu i repromaterijala mogu da se ostvare pri distribuciji mineralnih hraniva. Pri tome dobre efekte daje i sistem najmanje preciznosti. Pri

proračunu uštede u obzir treba da se uzme da su, za pravilan rad, neophodni markiranti, te da to zahteva dopunske troškove.

4. Velike uštede mogu da se ostvare pri zaštiti bilja. U svim slučajevima mogu da se ostvare značajne uštede vremena i sredstava. Uštede sredstava imaju poseban značaj sa stanovišta zaštite životne sredine (Gavrić, Martinov, 2007).
5. Primena GPS navođenja u setvi nema posebnog značaja, osim ukoliko se primeni sistem najveće tačnosti. Olakšano je okretanje na uvratini i formiranje pravca prohoda. Velika prednost promene GPS navođenja može da se ostvari pri konzervacijskoj obradi, kada brazdica markera, pa i pena, nisu dovoljno dobro vidljivi. Ipak, tada je od pomoći tek primena dvofrekventnog prijemnika, s korišćenjem korekcionog signala s greškom do 0,1 m.
6. U međurednoj kultivaciji ne očekuje se značajna pomoć sistema za navođenje, uz korišćenje GPS-a, osim opšteg slučaja smanjenja vremena okretanja na uvratini. Pomoć može da bude od velikog značaja pri radu u pogoršanim uslovima vidljivosti, a posebno pri radu noću.
7. Pri operacijama prihranjivanja i zaštiti bilja, u strninama, pojavljuju se značajne razlike, u zavisnosti od toga da li se ili ne, primenjuju stalni tragovi. U radu bez stalnih tragova ostvaruju se znatne uštede u prohodima i sredstvima.
8. Pri žetvi strnina može da se doprinese smanjenju broja prohoda, a posebno rasterećenju rukovaoca i manjoj širini radnog zahvata. Za širine radnog zahvata preko 7 m neophodna je neka vrsta navođenja. Navođenje uz pomoć GPS, koje se u drugo vreme koristi za traktore, dobro je rešenje.
9. Pri berbi kukuruza navođenje GPS-om nema pogodnosti, osim olakšanja okretanja na uvratini.
10. Pri košenju lucerke i trava navođenje posredstvom GPS-a može da doprinese svim navedenim tačnostima pozicioniranja. Na valovitim terenima i poljima nepravilnog oblika preklopi su i veći od onih, navedenih u tab. 3. Pri spremanju sena, mogu da se, uz korišćenje GPS navođenja i uklapanja prohoda, ostvare velike uštede, posebno zbog valovitosti terena i nepravilnih oblika parcela (Holpp, 2006). Veličina preklopa raste povećanjem širine zahvata i u procentima.
11. U uslovima rada u regionu, kada na ekonomske pokazatelje značajno utiče stepen iskorišćenja skupe mehanizacije, a manje ljudski rad, od posebnog značaja je to, što bi korišćenjem GPS navođenja moglo da se radi noću i u uslovima smanjene vidljivosti. To, takođe, važi za „špiceve“ radova, kada je neophodno da se iskoriste kratkotrajni povoljni uslovi za sprovođenje poljoprivrednih radova. Ovaj doprinos ekonomskim pokazateljima primene GPS navođenja ne može egzaktno da se izrazi, ali su svi poljoprivrednici svesni njega.

Razvijeni tabelarni program, nazvan GPS *AgroKalkulator*, u daljem tekstu KALKULATOR, koristi *Excel*, koji je sastavni deo svakog *Microsoft Office* paketa, te je dostupan na većini računara. Na primeru su prikazani rezultati proračuna isplativosti.

Tab. 3 Preklopi, kojima se obezbeđuje eliminacija oplazina, za konvencionalno navođenje i prosečne radne brzine izvođenja operacija

	Preklop, m	**Komentar**	**Radna brzina, km/h**	
			Oblast	Uobičajena
Oranje u brazdi	0,1-0,2[1]	Prati se prethodna brazda	6-8	7
Oranje izvan brazde	0,1 do 0,2	Vizuelno	5-9	7
Razrivanje/tanjiranje	0,3-0,6	Vizuelno	6-11	9
Predsetvena priprema	0,2-1,5	Vizuelno	8-12	10
Kombinovana oruđa	0,2	Vizuelno	6-9	7
P. distribucija MH, zahvat do 18 m	0,5-2	Vizuelno ili sa markirantima	8-12	10
P. distribucija MH, zahvat preko 18 m	1-2	Samo s markirantima	9-12	10
P. zaštita bilja, zahvat do 12 m	1-1,5	Vizelno ili sa markirantima	9-12	10
P. zaštita bilja, zahvat preko 12 m	0,2-1	Samo sa markirantima	6-8	7
Setva – uskoredna	0,05-0,2	Marker, pena	8-9	8
Setva – širokoredna	0,05-0,2	Marker, pena	6-8	7
Međuredna kultivacija	0,1-0,2	Vodi se međuredom	4-8	6
Prihranjivanje Š	0,5-2	Vodi se međuredom	8-10	9
Prihranjivanje U, stalni tragovi	0,5	Koriste se stalni tragovi	8	8
Prihranjivanje U, bez stalnih tragova	0,5-2	Koriste se vizir oznake	8-10	9
Zaštita bilja Š	0,1-0,2	Vođenje redom	6-8	7
Zaštita bilja U, stalni tragovi	0,1	Koriste se stalni tragovi	6-8	7
Zaštita bilja U, bez stalnih tragova	0,2-1	Koriste se vizir oznake	6-8	7
Žetva strnih žita, zahvat do 7 m	0,3	Vizuelno	6-8	7
Žetva strnih žita, zahvat preko 7 m	0,1-0,7	Vizuelno, preko 9 m obavezno automatsko nav.	4-8	6
Berba kukuruza	–	Praćenje reda	4-8	6
Košenje, zahvat do 3 m	0,1-0,15	Vizuelno	6-9	8
Košenje, zahvat preko 3 m	0,2-0,3	Vizuelno	6-9	8

P– površinska primena, bez razvijenih useva; Š– širokoredne biljne vrste; U– uskoredne biljne vrste; MH- mineralna hraniva; [1] primenjuje se samo uobičajeni tehnološki preklop

Primer

Imanje ima 150 ha pod ratarskim biljnim vrstama. Biljne vrste i površine su: pšenica 45 ha, kukuruz 60 ha, soja 45 ha.

Razmatra se primena uređaja za GPS navođenje i uklapanje prohoda sa ručnim navođenjem, koristi korekcioni signal *EGNOS* s očekivanom greškom, u praksi, do 0,3 m, a njegova cena je oko 2.000 €. Korišćeni su podaci o ceni radova i potrošnji goriva po hektaru Zadružnog saveza Vojvodine. Na sl. 4 prikazan je primer unesenih podataka.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1					RADNE OPERACIJE								
2		UNOS PODATAKA (POPUNITI ZELENA POLJA !)			DMH	Oranje	Predsetvena priprema	Setva	DMH/prihranjivanje	Zaštita 1	Zaštita 2	Žetva	Ljuštenje strništa
3	OSNOVNI PODACI	Cena mašinske usluge		€ / ha	7,91	0,00	19,47	0,00	7,91	12,31	12,31	52,26	0,00
4				din./ ha	630,00	0,00	1550,00		630,00	980,00	980,00	4160,00	
5		Repromaterijal	Naziv repromaterijala		min hran				min hrn	Herbicid	Herbicid		
6			Jedinica mere		kg				kg	kg	l		
7			Cena po jed. mere	€	0,38	0,00	0,00	0,00	0,38	16,33	30,15	0,00	0,00
8				din.	30,00				30,00	1300,00	2400,00		
9			Količina (jed.mere / ha)		300,00				100,00	0,30	1,00		
10			Vrednost repromaterijala	€ / ha	113,07	0,00	0,00	0,00	37,69	4,90	30,15	0,00	0,00
11				din./ ha	9000,00	0,00	0,00	0,00	3000,00	390,00	2400,00	0,00	0,00
12		Gorivo	Potrošnja goriva (lit/ha)		3,00		11,00		3,00	3,00	3,00	22,00	
13			Vrednost goriva	€ / ha	3,66	0,00	13,40	0,00	3,66	3,66	3,66	26,81	0,00
14				din./ ha	291,00	0,00	1067,00	0,00	291,00	291,00	291,00	2134,00	0,00
15		Cena radnog časa rukovaoca		€ / čas	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
16				din./ čas									
17		Cena radnog časa markiranta		€ / čas	2,26	0,00	0,00	0,00	2,26	2,26	2,26	0,00	0,00
18				Broj mark.	2				2	2	0		
19				din./ čas	180,00				180,00	180,00	180,00		
20	AGREGAT	Radna brzina (km/h)		bez GPS	10,00		10,00		10,00	7,00	7,00	7,00	
21				sa GPS	10,50		10,50		10,50	7,50	7,50	7,00	
22		**Povećanje radne brzine (%)**			**5,00%**	**0,00%**	**5,00%**	**0,00%**	**5,00%**	**7,14%**	**7,14%**	**0,00%**	**0,00%**
23		Radni zahvat (metar)			15,00		6,00		15,00	15,00	15,00	5,50	
24		Prekapanje između dva prohoda (metar)		bez GPS	**0,80**		**0,50**		**0,80**	**0,50**	**0,50**	**0,30**	
25				sa GPS	**0,30**		**0,30**		**0,30**	**0,30**	**0,30**	**0,30**	
26		Vremensko zadržavanje na uvratini (minut)		bez GPS	0,75		1,00		0,75	0,75	0,75	1,00	
27				% uštede	15,00%		15,00%		15,00%	15,00%	15,00%	0,00%	
28				sa GPS	0,64	0,00	0,85	0,00	0,64	0,64	0,64	1,00	0,00
29		Efektivni radni zahvat (metar)		bez GPS	14,20	0,00	5,50	0,00	14,20	14,50	14,50	5,20	0,00
30				sa GPS	14,70	0,00	5,70	0,00	14,70	14,70	14,70	5,20	0,00
31		**Povećana efikasnosti rad. zahvata (%)**			**3,33%**	**0,00%**	**3,33%**	**0,00%**	**3,33%**	**1,33%**	**1,33%**	**0,00%**	**0,00%**
32		Broj potrebnih prohoda u parceli		bez GPS	42	0	109	0	42	41	41	115	0
33				sa GPS	41	0	105	0	41	41	41	115	0
34				**Razlika**	1	0	4	0	1	1	1	0	0
35		Koeficijent iskorišćenja proizvodnog vremena			75%		75%		75%	75%	75%	75%	
36		Broj prohoda u toku godine			1		2		1	1	1	1	

Sl. 4 Primer unešenih podataka u Kalkulator za proizvodnju pšenice

Kalkulacija pokazuje da se primenom GPS uređaja ostvaruje, za pšenicu, ušteda od 10,5 € po hektaru, ili, na ukupnoj površini 474 € godišnje. Na isti način sproveden je proračun ušteda za proizvodnju kukuruza i soje. Uštede za kukuruz su 614 €, a za soju 297 €. Ukupno, za sve tri biljne vrste, ušteda, koja može da se ostvari primenom GPS uređaja za navođenje i uklapanje prohoda, je 1.385 € godišnje.

Troškovi primene GPS uređaja računaju se prema tab. 1 i 2. Za vek upotrebe 4 godine, konačnu vrednost 400 €, prosečnu kamatnu stopu 7,5%, i premijsku stopu 1%, bez troškova održavanja i plaćanja korekcionog signala godišnji troškovi su 468 €. Dakle, ostvaruje se godišnja dobit od 917 €, ili, za četiri godine korišćenja uređaja, 3.668 €. Period otplate ulaganja bio bi oko dve godine.

ZAKLJUČCI

Testovi su pokazali da je prijem korekcionih signala na području Vojvodine odličan, odnosno da se korišćenjem GPS uređaja za navođenje i uklapanje prohoda u praksi ostvaruju greške navođenja koje su čak ispod nivoa koji su definisani kao maksimalni.

Na tržištu postoji velika ponuda različitih sistema za GPS navođenje, od ručnih s korišćenjem besplatnog *Egnos* signala, do onih s automatskim upravljanjem i korišćenjem zemaljskih referentnih stanica koji su sastavni deo integralnog sistema kontrole upravljanja traktorom i priključcima.

Date su smernice za ocenu ekonomskih pokazatelja, koja je bazirana na poređenju troškova uređaja za GPS navođenja i mogućih ušteda. Razvijen je program, kalkulator, za proračun ušteda na bazi stanja i prakse pri poljoprivrednoj proizvodnji. Pokazano je da je primena uređaja za GPS navođenje isplativa već i na površinama ispod 150 ha. Najveće uštede mogu da se ostvare pri distribuciji mineralnih hraniva i zaštiti bilja.

Pored direktno merljivih ušteda brojne su i ostale. Tipično je to što je omogućen rad i pri uslovima lošije vidljivosti. Značajan je i efekat smanjenja zamora rukovaoca.

ZAHVALA

Ispitivanje je sprovedeno u okviru studija koje je finansirao Sekretarijat za poljoprivredu, vodoprivredu i šumarstvo Autonomne pokrajine Vojvodine.

LITERATURA

1. Buick R., White E. (1999). Comparing GPS Guidance with Foam Marker Guidance. In Robert, P.C., R.H. Rust and W.E. Larson, Proceedings of the Fourth International Conference on Precision Agriculture. St. Paul, MN, ASA/CSSA/SSSA, Madison, Wisconsin, pp. 247-256
2. Gavrić M., Sekulić P. (2004). Primena GIS-a i GPS-a u poljoprivredi. Zbornik radova Naučnog instituta za ratarstvo i povrtarstvo 40: 171-178
3. Gavrić M., Martinov M. (2007). Low Cost GPS-Based System for Site-Specific Farming at Flat Terrains – Case Study. Agricultural Engineering International, CIGR e-journal (Agricultural Engineering International), 9: Manuscript ATOE 07 004
4. Holpp, M. (2006). Parallelfahrsysteme für Traktoren – Technik und Wirtschaftlichkeit – ART–Berichte Nr 659. Forschungsanstalt Agroscope, Tänion (www.art.admin.ch)
5. Hüter J., Kloepfer F., Ulrike Klöble. (2005). Elektronik, Sateliten und Co – Precision Farming in der Praxis. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL), Darmstadt
6. Lowenberg-DeBoer J. (1999). GPS Based Guidance Systems for Agriculture. Purdue University, West Lafayette (www.purdue.edu).
7. Martinov M., Gavrić M. (2006). Navođenje traktora i mašina primenom GPS. Revija agronomska saznanja 16: 8-11
8. Medlin C., Lowenberg-DeBoer J. (2000). Increasing cost effectiveness of weed control. In: Precision Farming Profitability, SSM-3, editor: K. Erickson. Purdue University, West Lafayette, 44-51
9. Moitzi G. (2006). Autopilot in der Praxis, Erste Erfahrungen mit automatischen Lenk-systemen für Traktoren in Österreich. Universität für Bodenkultur, Department für Nachhaltige Agrarsysteme, Institut für Landtechnik, Wien

10. Ronai Đ., Smulevich I., Tešić M., Martinov M. (1994). Primena GPS (global positioning system) u poljoprivrednoj tehnici. Savremena poljoprivredna tehnika 20: 107-113

11. Sullivan M., Ehsani R., Walker J., Levison P., Lang L. (2001). Accuracy and Availability of WAAS for Precision Agriculture. ASAE Meeting Paper, No: 01-1155.

12. Anonim. (2005). Six steering systems in profi's sight. Profi International 12: 62-65

APPLICABILITY OF GPS GUIDANCE IN SOUTHEASTERN EUROPEAN AGRICULTURE

SUMMARY

The GPS guidance of tractors and self propelled agricultural machinery reached the level applicable in practice. It is also followed by the reduction of price, i.e. utilization costs. The objectives of the investigation were: to test availability of common DGPS signals in the region of SEE (Southeastern Europe), Serbian agricultural region Vojvodina as example, to systematize types of guidance systems for the potential users, farmers, and to create background for profitability calculation of GPS guidance use.

The results showed that the common correction signals, EGNOS, StarFire 1 and StarFire 2, are available in the region and that navigation, dynamic, errors are in the proclaimed range. The guidance systems are classified according to the class of precision-dynamic error, steering automation, and integration into tractor-machine steering and control system.

The backgrounds for economic evaluation are based on comparison of costs and saving, i.e. payback period. Common calculation based on investment and operational expenditures was used to calculate the costs. Costs benefits calculation, when GPS guidance was used, was based on the calculation which included working time, overlapping area and inputs reduction. The table of expected overlapping area that occurs by common farming operation, created as result of questionnaire of experienced professionals, was developed to be a base for this calculation. The final outcome of the calculation could be the number of cultivated hectares that enable payback in defined period, e.g. three years. For example, by using simple GPS guidance systems, with navigation error up to 0.3 m between two adjacent tracks, and manual steering, the profitability could be obtained for cultivating less than 150 hectares of field crops.

Key words: *GPS guidance, correction signal, profitability*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.317.7:631.35
Prethodno priopćenje
Preliminary communication

SOME ASPECTS REGARDING THE PRECISION FARMING CONCEPT USED IN THE HARVESTING PROCESS

NICOLAE FILIP, IOAN SIMU, AIRINEI DANIEL

Technical University of Cluj – Napoca, 103 – 105 Muncii Street, Cluj – Napoca, Romania

SUMMARY

The paper presents the research carried out in the Agricultural Machinery laboratory, regarding the possibilities to increase work efficiency using the sensor for tools guidance and GPS equipments for the geo-reference position in the working process of the agricultural machines.

The tests was developed in order to improve the sensors for displacement and position detection of the tools in the working process. The laboratory tests of the laser detection sensors and GeoGPS device used for scanning the land offer promising opportunities in order to increase the precision of the harvesting crop.

Key words: *GPS, laser, detector, test, data logger.*

PRECISION FARMING CONCEPT

The precision farming represents the most efficient way for increase the quality and for reduces the operating time for most agricultural works. The electronics revolution of the last several decades has spawned two technologies that will impact agriculture in the next decade. These technologies are Geographic Information Systems (GIS) and Global Positioning System (GPS). Along with GIS and GPS there have appeared a wide range of sensors, monitors and controllers for agricultural equipment such as shaft monitors, pressure transducers and servo motors. Together they will enable farmers to use electronic guidance aids to direct equipment movements more accurately, provide precise positioning for all equipment actions and chemical applications and, analyze all of that data in association with other sources of data (agronomic, climatic, etc). This will add up to a new and powerful toolbox of management tools for the progressive farm manager.

Precision farming should not be thought of as only yield mapping and variable rate fertilizer application and evaluated on only one or the other. Precision farming technologies will affect the entire production function (and by extension, the management function) of the farm [2].

Some benefits of this concept are exemplified by [4]:

- *Yield monitoring instantaneous* yield monitors are currently available from several manufacturers for all recent models of combines. They provide a crop yield by time or distance (e.g. every second or every few meters). They also track other data such as distance and bushels per load, number of loads and fields.
- *Yield mapping with GPS receivers* coupled with yield monitors provide spatial coordinates for the yield monitor data. This can be made into yield maps of each field.
- *Variable rate fertilizer*, express by variable rate controllers are available for granular, liquid and gaseous fertilizer materials. Variable rates can either be manually controlled by the driver or automatically controlled by an on board computer with an electronic prescription map.
- *Weed mapping*; the farmer can map weeds while combining, seeding, spraying or field scouting by using a keypad or buttons hooked up to a GPS receiver and data logger. These occurrences can then be mapped out on a computer and compared to yield maps, fertilizer maps and spray maps.
- *Variable spraying*, by knowing weed locations from weed mapping spot control can be implemented. Controllers are available to electronically turn booms on and off, and alter the amount (and blend) of herbicide applied.
- *Topography and boundaries*, using high precision DGPS a very accurate topographic map can be made of any field. This is useful when interpreting yield maps and weed maps as well as planning for grassed waterways and field divisions. Field boundaries, roads, yards, tree stands and wetlands can all be accurately mapped to aid in farm planning.
- *Guidance systems*; several manufacturers are currently producing guidance systems using high precision DGPS that can accurately position a moving vehicle within a foot or less. These guidance systems may replace conventional equipment markers for spraying or seeding and may be a valuable field scouting tool.
- *Records and analyses*; precision farming may produce an explosion in the amount of records available for farm management. Electronic sensors can collect a lot of data in a short period of time. Lots of disk space is needed to store all the data as well as the map graphics resulting from the data. Electronic controllers can also be designed to provide signals that are recorded electronically. It may be useful to record the fertilizer rates actually put down by the application equipment, not just what should have been put down according to a prescription map. A lot of new data is generated every year (yields, weeds, etc). Farmers will want to keep track of the yearly data to study trends in fertility, yields, salinity and numerous other parameters. This means a large database is needed with the capability to archive, and retrieve, data for future analyses.

Two research directions were connects in order to assure the harvest machines work parameters [1] :

- GPS device used for detect the position of agricultural machines and for realized the geo references (digitized) map of the land;
- The positioning sensors used in order to identify the network place of the tools for increase the ability to adjust the kinematics parameters according with the crop conditions.

If this approach represents an usual practice for most European countries, for our conditions the purpose of this approach represent a challenge which must be developed and adapted to our land and technologies conditions.

DESCRIPTION OF GPS EQUIPMENT AND SOFTWARE APPLICATIONS

For measurement purposes, GPS Pathfinder Pro produced by Trimble was employed. This comprises the following: receiver and antenna, recon with display, handling stick and connection cable (fig. 1).

Fig. 1 The Trimble GPS device: 1 – receiver and antenna; 2 – handling stick; 3 – recon with display for setting the operation system

The described GPS equipment has as operating systems Windows Mobile.

In order to do preliminary setting of the equipment as well as the measurements itself TerraSync software application from Trimble is used.

This application allows some simple operations, prior and subsequent to measurements, finally result a new file in a format compatible and acceptable within GIS. Graphic user interface (GUI) of TerraSync main window application, having few measured points is shown in figure 2 [1].

The file format generated by TerraSync application is then imported to ArcView software application from ESRI. This format allows marking of an electronic map, geo referenced in any wanted geographical coordinates system. On this map precise dimensions and positions of measured points could be read.

Measurement itself carried out using GPS equipment are preceding by main working parameters setting: coordinates system, measurement zone, altitude measurement checkpoint etc. Within this preliminary stage data dictionary file is set, this being the file that stores the effective data measured using GPS equipment.

After preliminary setting the measurement are done, the file is saved, visualization and eventual data sorting being done, all followed by file conversion for import in ArcView software application.

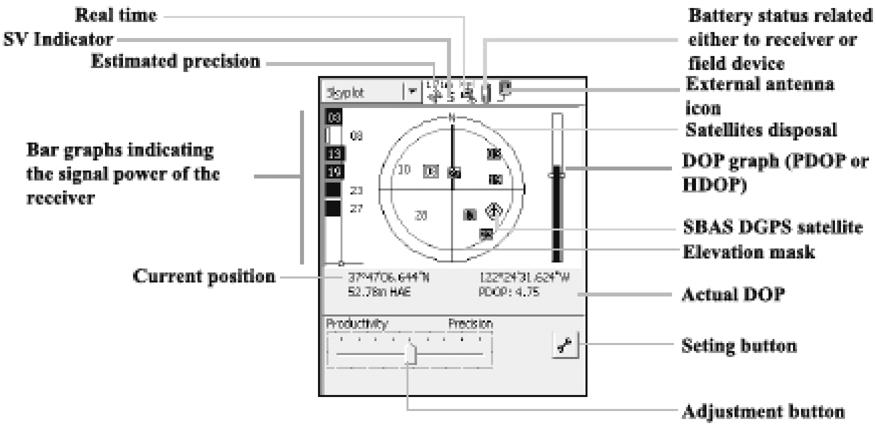


Fig. 2 GUI of TerraSync main window application

Operations diagram described above is shown in figure 3.

The accuracy of the GPS position set was verified using a simple evaluation of five points arbitrary considered and a zero reference point. Two devices were used for measure the distance between the references point and the other five’s considered points: the Trimble GPS and a metric wheel (conventional measurement). The differences between two measuring method used are presented in table no.1.

For relative error calculation the following relation was used:

$$\varepsilon = \left(1 - \left|\frac{V_{GPS}}{V_{conv}}\right|\right) \cdot 100 \qquad [\%] \tag{1}$$

where V_{conv} is the value measured by conventional means and *Vgps* is the value measured by GPS equipment means.

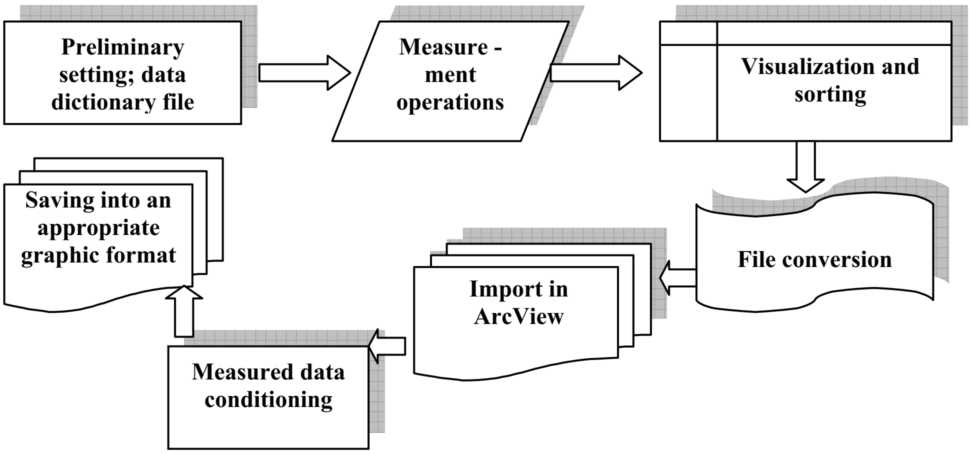


Fig. 3 The operation diagram of Trimble GPS

Table 1 Comparative values of measured data

Between points	Value obtained by GPS, m	Value obtained by metric wheel, m	Relative error, %
0-1	5,122	5,1	0,431
0-2	7,719	7,7	0,246
0-3	10,121	10,1	0,208
0-4	14,42	14,4	0,239
0-5	18,424	18,3	0,677

From the previously carried out experiments we can see that GPS equipment can get the utility in the harvest machine position mapping. In the absences of the yield mapping, this device it is bale to offer the basic information regarding the coordinate of the land and assure also the geo references of the machine in the crop process.

SENSORS USED IN THE HARVEST PROCESS

In order to evaluate the possibilities for an automatic management of the harvest machines work process, different sensor was tested in the laboratory conditions.

One of the most promising sensor for harvest application is the L-Gage sensor (fig. 4). The L-GAGE LT3 sensor uses "time-of-flight"technology for precise, long-distance gauging at the speed of light. The microprocessor-controlled laser distance-gauging sensor features a unique design for exceptional accuracy and range at a much lower cost than competitive laser-gauging devices. Precise performance make the LT3 an ideal solution for a variety of precision inspection applications. Important technical characteristics are [5]:

- Available in accurate diffuse-mode models with ranges to 5 m and retroreflective models with a 50 m range;
- Emits one million pulses per second;
- Reliably detects angled targets;
- Sensing Ranges: 1 2 3 4 5 . . . 50 m;
- Diffuse models with white targets: 0.3 - 5 m;
- Retro reflective models with retro reflector: 0.5 - 50 m;
- Diffuse models with gray targets: 0.3 - 3 m;
- Radiant power 0.15mW; 10ns PULSE, 1MHz 650 - 670 nm;

The sensor was tested in laboratory conditions in order to identify the time response in accordance with the work conditions for harvesting machines. One of the first test was carried out for evaluate the sensor possibilities to work with a logger interface in order to achieve data from the measurements and for find the time response according with kinematics parameters of the harvest process.

Using a voltage supply and an oscilloscope HM 507, the laboratory tests confirm the initial considerations regarding the sensor capability to identify with high precision the distance, in real time response.

Fig. 4 Laser radar; 1 – operating panel; 2 – transmitted - received wave; 3 – connection cables to the logger interface

The used possibilities of the laser sensor in the harvest process are presented in figure 5 [3].

The possible applications are (fig. 5):

1. control of the header position in the harvest process, according with the cutting device type and the yield conditions. In this respect, the sensor sensitivity assures the possibility to adjust the header highest in real time;

2. grain tank load detection represents a parameter which offers information regarding the quantity crop and the average production rate of the land;
3. regarding the combine speed detection, some conditions of the work process must be considered: the yield shape, the harvest machine speed and the weeds uncutted which decrease the resolution of the detection. In this respect, ultrasonic sensor is more appropriate for use;
4. other application consist in the straw detection as a possibility to evaluate the harvest process efficiency.

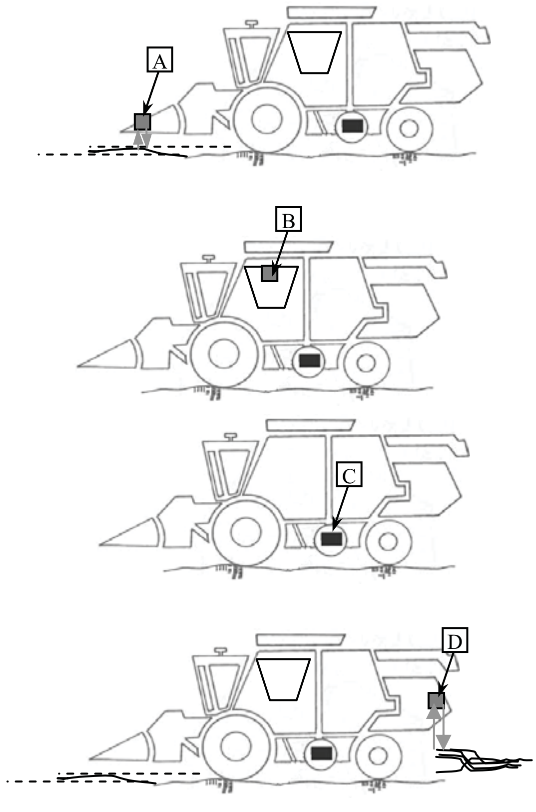


Fig. 5 Some possibilities for use the laser sensor in the harvest process

LABORATORY TESTS FOR EVALUATE THE LASER SENSOR DETECTION POWER

The aim of the research carried out was to test the possibilities to detect objects regarding the distance and the instantaneous position through the detection device the L-Gage laser sensor type LT3-PI.

The sensor main characteristics are [5]:

- Available in diffuse-mode models with ranges to 5 m and retro-reflective models with a 50 m range;
- Offered in dual-discrete or analog/discrete models;
- Features push-button TEACH-mode programming for custom sensing windows;
- Offers remote programming for added security and convenience;
- Includes push-button programming for three output response speeds;
- Simplifies alignment with a bright, visible laser spot;
- Emits one million pulses per second;
- Reliably detects angled targets.

The sensor contain a RS 422 interface which assure at the same time the communication with an microcontroller and the possibility to set it work condition in analog or digital way. For reed the analog output values from the sensor a communication interface was design using a serial RS 232 device. The communication management was established with a microcontroller PIC16F690 with TTL/CMOS – 5V gate (fig. 6).

The results of the simply objects detection were displayed using LabView program (see fig. 6). For simply and compound object the results was the same, but the reconstruction of the image and the resolution of the detection depend by the quality of the wave.

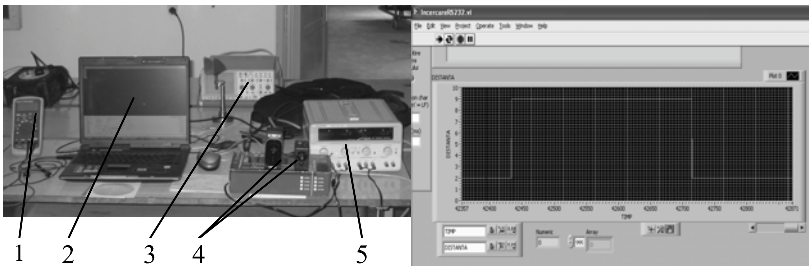


Fig. 6 The equipments and measuring devices used for tests and The result of simply object position detection; 1 – ampere meter; 2 – PC; 3 – oscilloscope HM 507; 4 – laser tested sensors; 5 – voltage supply

The tests carried out consist in an evaluation of the detection efficiency regarding the target (simply object) instantaneous position evaluation. In order verify the quality of the detection, a calibration test was carried out before to run the test. For increasing distances between the sensor and the target object, the output signal was registered and translated in length measurement unit.

The linear regression was calculated in order to estimate the detection error (fig. 7). The output signal values from designed interface were compared with the measured signal using the HM 507 oscilloscope.

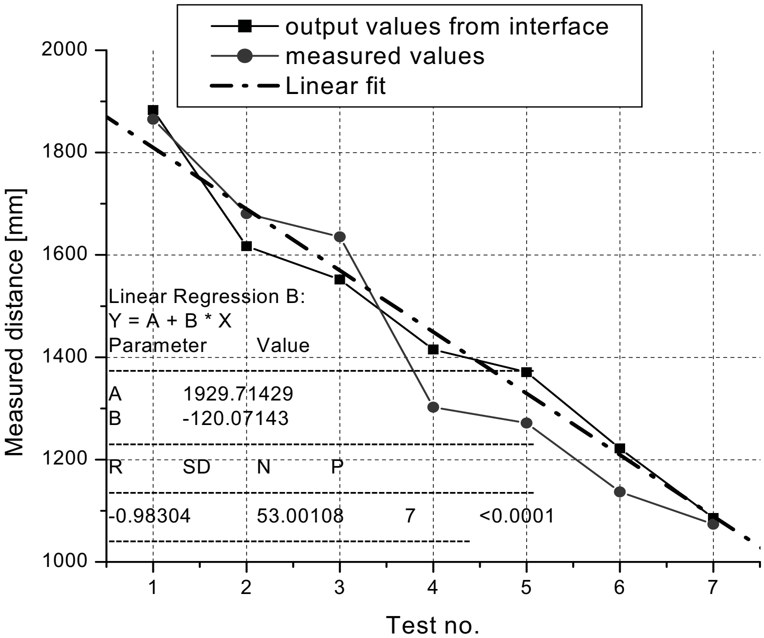


Fig. 7 Calibration and signal evaluation results

Regarding the error of the measurements, a simply data calculation show that the average error was around 0.9%. In this respect the distance evaluation or scaning method using the laser sensor and the designed interface may be imporove for harvesting electronic process management in order to increase the precission farming.

CONCLUDING REMARKS

The precision farming represents a challenge for all specialists in this field. The various industrial sensors designed with different technical parameters cover several applications for manage the harvest process.

The three step connection: sensor – GPS – logger interface, assure a real time harvest control and the possibility to adjust in real time the harvest machine work conditions.

The tests carried out in the Harvest machines laboratory of our faculty will be developed in order to evaluate also the ultrasonic and radar sensor as a possible devices for assure the most efficient work conditions for the combines.

The experimental results obtained show the possibility to scan any object using Laser Gage sensors.

Other application of the tested sensor regarding the precision farming purpose will be developed in the future, according with the farmer needs.

REFERENCES

1. Coldea, C., Filip, N. (2007). The GPS used for precision detection. In the volume V, Acta Technica Napocensis, pag. 235 - 260, Cluj – Napoca.
2. Filip, N. (2003). Masini Agricole de Recoltat. Editura Todesco, Cluj – Napoca, 2003. ISBN 973-656-459-2
3. Filip, N (2008). Research Regarding the Precission Farming Ussing Detection Sensors and GPS in the Work Technologies. Pag. 37 – 42.
4. Raj Khosla. (2002).Sensor in Yeld Monitoring, In Agronomy News revue of Colorado State University, volume 22, USA.
5. * * * (2006). Turck Industrial Automotion. Product catalogues and technical documentation.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 331.823:534.1:62-75
Prethodno priopćenje
Preliminary communication

ZAŠTITA RADNIKA ANTIVIBRACIJSKIM RUKAVICAMA

VLADO GOGLIA*, IGOR ĐUKIĆ*, ZLATKO GOSPODARIĆ**, DUBRAVKO FILIPOVIĆ**

* Šumarski fakultet Zagreb, Svetošimunska 25, 10 000 Zagreb
** Agronomski fakultet Zagreb, Svetošimunska 25, 10 000 Zagreb

SAŽETAK

Izlaganje vibracijama većeg intenziteta kroz duže vremensko razdoblje često vodi trajnim oštećenjima dijelova organizma te trajnoj nesposobnosti za rad. Taj je problem prisutan i kod mnogih poslova u šumarstvu. Mnoge se aktivnosti provode s ciljem da se izbjegnu posljedice izlagana vibracijama. Jedna od mjera zaštite od pretjeranog izlaganja vibracijama koje prenose na ruke je i korištenje antivibracijskih zaštitnih rukavica. Ocjena učinkovitosti zaštite upotrebom antivibracijskih rukavica je složena procedura i često ne daje očekivane rezultate. Na tržišu je široka ponuda antivibracijskih rukavica različitih prizvođača te je izbor onih koje će najbolje štititi radnika odgovoran i složen zadatak.

***Ključne riječi**: ergonomija, vibracije, antivibracijske rukavice*

UVOD

Izlaganje rukovatelja mehaniziranim sredstvima rada vibracijama visoke razine može imati po njega tragične posljedice. To je problem s kojim se susreću stručnjaci zaštite na radu u svim industrijskim granama. Kako je prema statističkim podacima vidljivo treba mu prići s pripadajućom pažnjom.

Posljedice izloženosti prekomjernoj razini vibracija uzrokom su više od 13 % sveukupnih profesionalnih oboljenja u Republici Hrvatskoj (Kacian, N., 1999). Šumarstvo se nažalost kao industrijska grana prema statističkim podacima svrstava u jednu od najrizičnijih djelatnosti, kako po povredama na radu, tako i po profesionalnim oboljenjima. Profesionalna oboljenja izazvana utjecajem vibracija u šumarstvu su posebice izražene. Stoga ne čudi čitav niz aktivnosti kako u Hrvatskim šumama d.o.o. tako i na Šumarskom fakultetu, usmjerenih prema smanjenju posljedica izloženosti vibracijama. Da bi se ispravno izabrale mjere zaštite prije svega treba poznavati prirodu vibracija koje se prenose na ruke kao i osjetljivost rukovatelja.

OSJETLJIVOST SUSTAVA ŠAKA-RUKA NA VIBRACIJE

Opće je poznata činjenica da svaki dio ljudskog organizma ima različite prirodne frekvencije. Izloženosti vibracijama čija se frekvencijska karakteristika može naći u rezonantnom području s vlastitim frekvencijama dijela ljudskog organizma multiplicira posljedice. To je samo po sebi razumljivo posebice u slučaju sustava šaka-ruka preko kojeg se uglavnom vibracije izravno prenose na tijelo rukovatelja. Isto tako je stručnoj javnosti poznata činjenica da je sustav šaka-ruka najosjetljiviji na vibracije u frekvencijskom rasponu 6-16 Hz (Goglia, 1997; Suchomel, J. and Slancik, M. 2005). Pored frekvencijske karakteristike samo je po sebi razumljivo da su od presudnog značaja još dva parametra za ocjenu opasnosti izlaganja vibracijama. To su:

- razine vibracija ili intenzitet i
- vrijeme izlaganja.

Stvarni intenzitet vibracija treba promatrati uzimajući usporedno u obzir kako frekvencijsku karakteristiku tako i razinu vibracija unutar relevantnog frekvencijskog spektra. Stoga međunarodna norma ISO 5849-1-2001 nalaže da se u izvješću o mjerenju vibracija obavezno navedu vrijednosti vrednovanih ubrzanja po osima. Vrednovanje ubrzanja se sukladno *Annexu A* iste norme izračunava prema relaciji:

$$c_{hw(x,y,z)} = \sqrt{\sum_{i=1}^{h} (W_{hi} c_{hi})^2}$$

gdje je: W_{hi} faktor vrednovanja ubrzanja u i-toj terci; a_{hi} je intenzitet ubrzanja vibracija u toj istoj terci u m/s^2. Tijek vrijednosti faktora vrednovanja W_{hi} u frekvencijskom rasponu zanimljivom sa stanovišta izloženosti vibracijama (6,3 do 1250 Hz) pokazuje sl. 1.

Procjene sveukupne izloženosti vibracijama, koje se prenose na ruke, se sukladno preporukama međunarodne norme ISO 5349-1-2001 vrši vektorskim zbrojem komponenata ubrzanja u pojedinim osima te se izračunava prema relaciji:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

Dnevna izloženost, na osnovu koje se procjenjuju rizici izlaganja, uključuje i vrijeme izlaganja te se prema preporuci izračunava iz relacije:

$$A(8) = a_{hv} \cdot \sqrt{\frac{T}{T_o}}$$

gdje je: T ukupno vrijeme dnevnog izlaganja vibracijama intenziteta a_{hv} dok je T_o frekventno vrijeme (raspoloživo vrijeme od 8 h odnosno 28800 s). Ukoliko se tijekom radnoga dana mijenja razina vibracija ili se mijenja njihova frekvencijska karakteristika valja dnevnu izloženost izračunati iz relacije:

$$A(8) = \sqrt{\frac{1}{T_o}\sum_{i=1}^{N} a_{hvi}{}^2 \cdot T_i}$$

gdje je: a_{hvi} sveukupna izloženost vibracijama (rezultantni vektor) za i-tu operaciju, N je broj i-te operacije, a T_i je vrijeme trajanja te iste operacije.

SMANJENJE DNEVNE IZLOŽENOSTI

Iz prethodnih relacije jasno proizlazi da se dnevna izloženost radnika može smanjiti na tri načina:

1. organizacijom na radilištu tj. kombiniranjem radnih aktivnosti tijekom smjene
2. smanjenjem vremena izlaganja
3. prigušenjem vibracija napose u onom frekvencijskom rasponu u kojem su ruke najosjetljivije.

Sve se te mogućnosti smanjenja izloženosti vibracijama koriste. U ovome se radu razmatra treći način smanjenja dnevnog izlaganja vibracijama-smanjenje izlaganja prigušenjem. Kako je poznato, svi ozbiljniji proizvođači ručnih mehaniziranih sredstava rada ulažu velike napore kako bi prigušili vibracije koje nastaju radom pogonskog motora i alata. Prigušenje se obično ostvaruje prigušnim elastičnim amortizerima kao i prigušnim materijalima na prihvatnim ručkama. Ukoliko je razina vibracija na prihvatnim ručkama i nakon mjerenja prije spomenutih prigušnih elemenata, iznad dopuštene razine, radnicima koji rukuju takvim sredstvima sugerira se upotreba antivibracijskih rukavica. Međutim, treba istaći velik broj znanstvenika s rezervom gleda na učinkovitost njihove primjene (Koton, 2002). O njihovoj učinkovitosti stručna javnost je upoznata vrlo malo ili nikako. Kakve rukavice treba koristiti vode se rasprave dugi niz godina, a da se pravi argumenti u tim raspravama uopće ne koriste. Pri izboru rukavica na raspolaganju stoji veliki broj proizvođača koji kao prigušne elemente u rukavicama ugrađuju razne materijale. Efikasnost pojedinih rukavica u prigušenju vibracija je prilično upitna te ju treba pobliže upoznati. No, prije nego li se pozabavimo ispitivanjem prigušnih svojstava rukavica treba spomenuti koji su sve zahtjevi kojima rukavice moraju udovoljiti. Rukavice moraju biti gipke kako bi omogućile nesmetano rukovanje u svim uvjetima. Moraju imati dobra toplinsko-izolacijska svojstva, moraju pružati zahtijevanu razinu zaštite od mehaničkih povreda, te na kraju trebaju omogućiti prigušenje vibracija.

Pozabaviti ćemo se ovim posljednjim zahtjevom mada treba naglasiti da i neki od prethodno spomenutih mogu izravno utjecati na izloženost vibracijama kao osjetljivost sustava šaka-ruka. Tako primjerice krute rukavice smanjuju prihvatnu silu, brzo umaraju rukovatelja pa se sa sredstva kojim se rukuje na ruke rukovatelja prenose vibracije sve viših razina. Isto tako slabija toplinsko izolacijska svojstva omogućuju pothlađivanje ruku rukovatelja te povećavaju njihovu osjetljivost na vibracije.

DEFINICIJA PROBLEMA

Učinkovitu zaštitu od prekomjernog izlaganja vibracijama, moguće je provesti tako da se priguši izvor vibracija. To podrazumijeva postavljanje prigušnih elemenata u lancu prijenosa vibracija na ruke rukovatelja. Prigušivači se u obliku tzv. amortizera redovito ugrađuju u samom mehaniziranom sredstvu rada. Na taj se način razina vibracija koje se pojavljuju na prihvatnim ručkama značajno smanjuje. Smatralo se da bi upotreba antivibracijskih rukavica s ugrađenim prigušnim umetcima mogla polučiti daljnja prigušenja. Pojavio se veliki broj proizvođača rukavica koji su svoje proizvode nudili pod nazivom „antivibracijske rukavice", a da nikada nije provedeno mjerenje i ocjena njihove učinkovitosti. Pojedini tipovi rukavica nude se po prilično visokim cjenama te predstavljaju značajni izdatak. Stoga se pristupilo razvoju takve metode mjerenje prigušnih svojstava rukavice koja bi bila primjenjiva u našim uvjetima, a mogla bi dati ocjenu efikasnosti antivibracijskih rukavica. Smatralo se da prigušna svojstva rukavica koje se koriste kao zaštita pri rukovanju određenim mehaniziranim sredstvima rada moraju odgovarati frekvenciskoj karakteristici izvora vibracija. Najbolja bi prigušna svojstva rukavice trebale pokazati u onom frekvencijskom području u kojem je intenzitet vibracija najveći. Identičan se pristup primjenjuje i kod odabira osobnih zaštitnih sredstava za zaštitu od buke. Stoga je prevladao stav da će se mjerenjima u stvarnim – pogonskim uvjetima, dobiti objektivan uvid u kvalitetu pojedinih tipova antivibracijskih rukavica.

METODA MJERENJA I MJERNI INSTRUMENTARIJ

Mjerenje vibracija izravno na prihvatnoj ručki te potom mjerenje istih na ruci rukovatelja nakon što se između ručke i ruke postavio prigušni sloj rukavica omogućuje uvid u učinkovitost prigušenja koje se rukavicama postiže. To se prigušenje može iskazati Odnosom rezultantnih vektora vrednovanih ubrzanja izmjerenih na ručki i onih izravno na ruci rukovatelja:

$$\alpha_p = \frac{WAS_2}{WAS_1}$$

gdje je: α_p – faktor prigušenja za kojeg se očekuje da bude <1; WAS_1 – rezultantni vektor vrednovanog ubrzanja na prihvatnoj ručki (***W**eighted **A**cceleration **S**um*, m/s^2; WAS_2 – rezultantni vektor vrednovanog ubrzanja na ruci rukovatelja nakon umetanja prigušnog sloja, m/s^2.

Prigušenje se može iskazati i u pojedinim osima, također odnosom vrednovanih ubrzanja u pripadajućoj osi na ruci rukovatelja i na prihvatnoj ručki:

$$\alpha_{x,y,z} = \frac{a_{hwx,y,z2}}{a_{hwx,y,z1}}$$

gdje je $\alpha_{x,y,z}$ – faktori prigušenja po osima za koje se isto tako očekuje da budu <1; $\alpha_{hwx,y,z1}$ – vrednovana ubrzanja vibracija po osima na prihvatnoj ručki, *m/s*^{2}; $\alpha_{hwx,y,z2}$ – vrednovana ubrzanja vibracija po osima na ruci rukovatelja nakon umetanja prigušnog sloja, *m/s*^{2}.

Za detaljniji uvid u prigušna svojstva antivibracijskih rukavica može se napraviti i frekvencijska analiza ubrzanja po osima po srednjim frekvencijama terci u frekvencijskom rasponu od 6,3 – 1250 *Hz* kako to međunarodne norme i preporučuju.

Za potrebe mjerenja izrađen je poseban nosač troosnog akcelerometra s naslonom podlogom. Preko naslone podloge troosni se akcelerometar postavlja ili izravno na prihvatnu ručku, ili se na prihvatnu ručku oslanja posredstvom prigušnog sloja antivibracijskih rukavica (sl. 1).

Slika 1 Troosni akcelerometar s nosačem

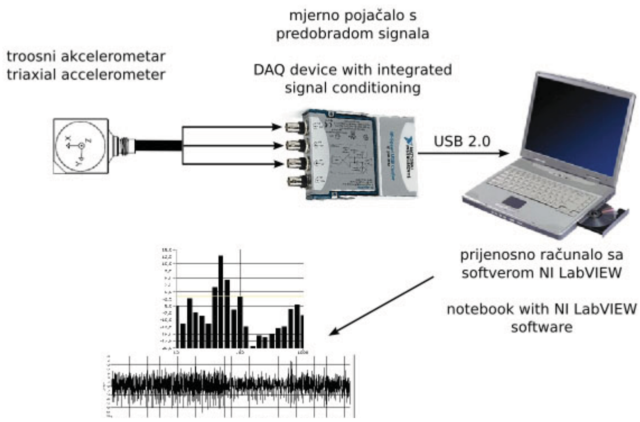
U prvom se slučaju vibracije mjere istodobno u sve tri osi izravno na prihvatnoj ručki, a u drugom se slučaju mjere vibracije koje se nakon prigušenja u prigušnom sloju prenose na ruku. Da bi se nosač posredstvom prigušnog sloja rukavica mogao smjestiti između ruke i prihvatne ručke, na rukavicama su napravljeni prorezi. Za ova mjerenja korištena je motorna pila STIHL MS640, S/N 162619034. Sva su mjerenja obavljena na prednjoj prihvatnoj ručki.

Mjerenja su obavljena kod tri režima rada i to:

- u praznom hodu,
- u punome gasu i
- tijekom rezanja.

Režimi rada pri kojima su mjerenja obavljena s ciljem da se ocjene prigušna svojstva rukavica odabrani su u skladu prije svega s onim režimima rada koji se očekuju tijekom rada motorne pile, a isto tako i u skladu s preporukama međunarodne norme ISO 7505.

Već je ranije spomenuto da je za mjerenja korišten troosni akcelerometar što podrazumijeva da su se ubrzanja vibracija mjerila istodobno u sve tri koordinatne osi. Položaj akcelerometra je bio usklađen s biodinamičkim koordinatnim sustavom propisanim međunarodnom normom ISO 8725-1985. Tijekom mjerenja korišten je mjerni sustav koji je prikazan na sl. 2. Za svaki režim rada uziman je reprezentativni vremenski uzorak na osnovu kojeg je bilo moguće iskazati više rezultata. Vremena usrednjavanja su uzimana u skladu s preporukama.



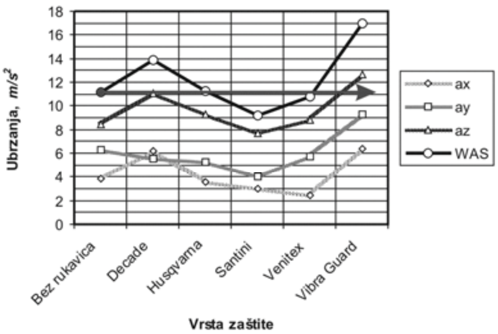
Slika 2 Shematski prikaz mjernog lanca

Za svaki se rezultat provodila i frekvencijska analiza ubrzanja vibracija po srednjim frekvencijama terci, izračunavane su vrijednosti vrednovanih ubrzanja po osima, te na kraju, izračunavani rezultantni vektori vrednovanih ubrzanja.

MJERENJA I REZULTATI MJERENJA

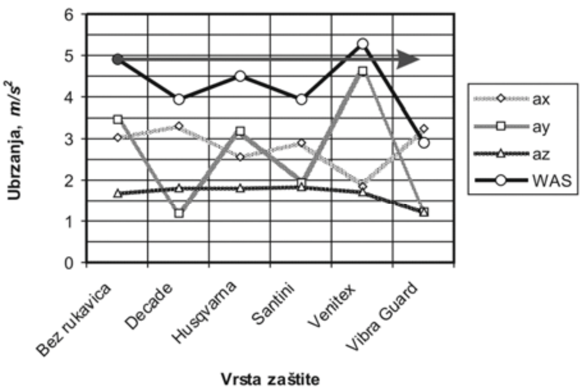
Za potrebe mjerenja pripremljena je prizma svježe posječene bukovine. Širina prizme bila je u skladu s preporukama međunarodne norme ISO 7505. Prije mjerenja na svim su rukavicama napravljeni prorezi kako bi se nosač akcelerometra mogao smjestiti izravno na ruku. Prigušni se sloj pri tom nalazio između podnožja nosača troosnog akcelerometra i ručke. Mjerenja su obavljena u sva tri smjera koordinatnih osi istodobno za tri režima rada i za svaki tip rukavica te bez rukavica na prednjoj prihvatnoj ručki motorne pile. Za svako je mjerenje uzimano po pet uzoraka na osnovu kojih je izračunavana aritmetička sredina. Frekvencijska je analiza obavljena za sva mjerenja. Zbog ograničenosti prostora na ovome mjestu nije moguće iznijeti i rezultate frekvencijske analize. Za svaku je os pri svim režimima rada izračunavana vrijednost vrednovanog ubrzanja vibracija te je na osnovu tih vrijednosti potom izračunavan rezultantni vektor vrednovanog ubrzanja. Vrijednosti vrednovanih ubrzanja vibracija po osima te WAS vrijednosti grafički su prikazane u dijagramima na sl. 3 do 6.

Kako je jasno vidljivo na sl. 3, mjerenja u praznome hodu pokazala su da samo jedan tip ispitivanih rukavica pokazuje relativno dobra prigušna svojstva. Kod dva tipa rukavica gotovo da nema nikakve razlike, dok je kod dva tipa rukavica došlo do povećanja razine vibracija. Slična su svojstva rukavice pokazale i u pojedinim osima, što je također jasno vidljivo na sl. 3.



Slika 3 Grafički prikaz vrijednosti vrednovanih ubrzanja vibracija za sve tri osi i WAS vrijednosti u praznome hodu

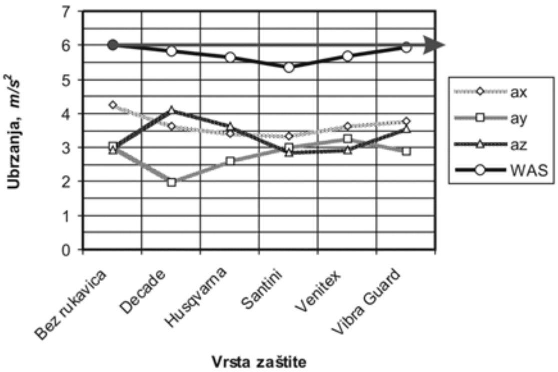
U punome gasu rukavice su pokazale puno bolja prigušna svojstva. To je vidljivo iz grafičkog prikaza WAS vrijednosti na sl. 4. Od pet ispitanih rukavica su četiri tipa pokazala dobra prigušna svojstva kod najvećeg broja okretaja, dok je kod jednog tipa rukavica izmjeren neznatni porast razine vibracija. Ovi su rezultati u skladu s rezultatima drugih istraživanja istog problema. Ona su, naime, utvrdila da antivibracijske rukavice dobra prigušna svojstva pokazuju jedino kod viših frekvencija.



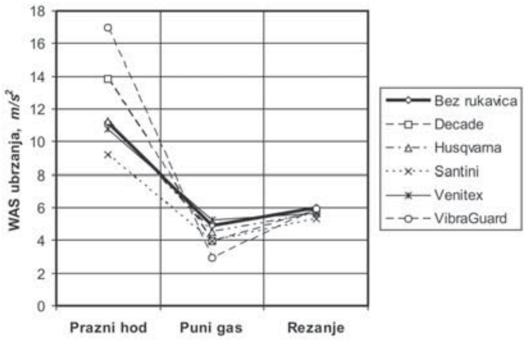
Slika 4 Grafički prikaz vrijednosti vrednovanih ubrzanja vibracija za sve tri osi i WAS vrijednosti u punom gasu

Na sl. 5 su grafički prikazane razine vibracija po osima, kao i WAS vrijednosti dobivene mjerenjima tijekom rezanja. Iz grafičkog je prikaza vidljivo da je od pet ispitanih tipova rukavica jedan pokazao dobra, dva tipa neznatna te dva tipa zanemariva prigušna svojstva. Kod rezanja nije ni na jednom tipu rukavica uočen porast WAS vrijednosti u odnosu na razinu vibracija izmjerenu bez upotrebe rukavica.

Zbirni Grafički prikaz WAS vrijednosti za sva tri režima rada prikazan je na sl. 6.



Slika 5 Grafički prikaz vrijednosti vrednovanih ubrzanja vibracija za sve tri osi i WAS vrijednosti pri rezanju



Slika 6 Zbirni grafički prikaz WAS vrijednosti

Iz slike je očito da su kod rezanja izmjerene zanemarive razlike razina vibracija bez rukavica i uz njihovu upotrebu. Te su razlike takve da mogu biti i posljedica uobičajenih i prihvatljivih pogrešaka mjerenja. Nasuprot tome, na istoj se slici vidi da su tijekom punoga gasa svi tipovi rukavica pokazali dobra prigušna svojstva. Posebno je dobra svojstva prigušenja pokazao jedan tip rukavica. Za razliku od rezultata mjerenja dobivenih pri rezanju i kod punoga gasa, u praznome hodu dva tipa rukavica ne samo da ne pokazuju svojstva prigušenja, već naprotiv, povećavaju ukupnu razinu vibracija.

ZAKLJUČAK

Mjerenjima je pokazano da postoje značajne razlike u prigušnim karakteristikama pojedinih tipova antivibracijskih rukavica. U praznome hodu neke od ispitanih rukavica ne samo da ne prigušuju vibracije, već i povećavaju njihovu ukupnu razinu. Iz tabličnih i grafičkih prikaza se vidi, da su vrijednosti vrednovanih ubrzanja vibracija u praznome hodu znatno većeg intenziteta od onih u punome gasu i tijekom rezanja. Pored toga, vrijeme rada pile u praznome hodu dosta je zastupljeno tijekom rukovanja pilom, pa su prigušna svojstva rukavica u tom režimu rada i te kako značajna. Tijekom rezanja mjerenja nisu pokazala značajne razlike sveukupne razine vibracija sa zaštitnim rukavicama i bez njih. Najbolja su prigušna svojstva rukavice pokazale kod najvećeg broja okretaja. To je ujedno i režim u kojemu pila najmanje radi tijekom korištenja, pa su nam u usporedbi s prethodna dva, prigušna svojstva u tom režimu rada i manje važna. Ovi rezultati ne predstavljaju usamljeni slučaj. Slični su rezultati dobiveni i u drugim nezavisnim istraživanja. Na temelju svega ranije navedenog može se zaključiti da postoje značajne razlike u prigušnim karakteristikama pojedinih tipova antivibracijskih rukavica. Stoga je za ispravan odabir rukavica nužno provesti prethodna mjerenja njihovih prigušnih svojstava.

LITERATURA

1. Dong, R. G., McDowell, T. W., Welkome, D. E., Smutz, W. P., Schopper, A. W., Warren, C., Wu, J. Z., Rakheja, S. 2003. On-the hand measurement methods for assessing effectiveness of anti-vibration gloves. International Journal of Industrial Ergonomics, 32, 283-298.

2. Dong, R.G., Welcome, D.E., McDowell, T.W., Wu, Y.Z. 2006. Measurement of biodynamic response of human Hand-arm system. Journal of Sound and Vibration, 294, 807-827

3. Goglia, V. 1997. Ergonomske značajke šumarske mehanizacije – problemi njihova mjerenja i vrednovanja. Mehanizacija šumarstva, 22(4), 209-217

4. Goglia, V., Gospodarić, Z., Beljo, R., Đukić, I., Kovačev, I. 2004. Izloženost vozača malog poljoprivrednog traktora vibracijama. Zbornik radova *Actual tasks on agricultural engineering*, Opatija

1. Griffn, M. J. 1998. Evaluating the effectiveness of gloves in reducing the hazards of hand-transmitted vibration. Ocupational and Environmental Medicine, 55, 340-348

5. Hewitt, S. 1998. Assessing the performance of anti-vibration gloves – a possible alternative to ISO 10891-1996. Annals of Occupational Hygiene, 42, 245-252

6. Kacian, N., 1999. Occupational diseases in Croatia, Work and Safety 3(1), 83-89.

7. Koton, J:, 2002. Prevention of hand-arm vibration syndrome by using antivibration gloves. Medycyna Pracy, 53, 423-431

8. Reynolds, D.D., Wolf, E. 2005. Evaluation of antivibration gloves test protocols associated with the revision of ISO 10819. Industrial Health, 43, 556-565.

9. Suchomel, J., Slancik, M. 2005. Influence of some ergonomic criterims on modelling and optimization technology in forestry. Proceedings of the International Conference „Management of human potential in enterprises“, Zilina, 354-359.

10. Warren, C., Wu, J. Z., Rakheja, S. 2003. On-the hand measurement methods for assessing effectiveness of anti-vibration gloves. International Journal of Industrial Ergonomics, 32, 283-298.

PROTECTION OF THE OPERATOR OF THE HAND TOOLS USING ANTIVIBRATION GLOVES

SUMMARY

There are various ways of reducing the health-hazards of hand-transmitted vibration. One of the possible protective measures is the use of the anti-vibration gloves, but their efectiveness is still subject to discussion and many experts are questioning it. The procedure for measurement and evaluation of the vibration transmissibility of the anti-vibration gloves is given in ISO 10819-1996 and EN ISO 10819-1996 as well as in the National Standard HRN ISO 10819-2000. Due to the numerous objections on the testing procedure recommended by the above standards many researchers prefer field- testing. In order to assess the efectiveness of anti-vibration gloves of five different manufactureres the Faculty of Forestry - University of Zagreb in co-operation with the public enterprise Hrvatske šume Ltd. carried out a field-testing. The paper reports on the testing results.

Key-words: *ergonomics, vibration, anti-vibration gloves*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 534.1:631.353:631.374
Izvorni znanstveni rad
Original scientific paper

VIBRATION RISK AND COMFORT CONDITIONS OF AGRICULTURAL TRACTOR'S OPERATOR DURING FORAGE HARVESTING

M. CUTINI, C. BISAGLIA

Agriculture Research Council – Unità di Ricerca per l'Ingegneria Agraria; via Milano 43, 24047 Treviglio BG, Italy; e-mail: *maurizio.cutini@entecra.it*

SUMMARY

The influence of different implements during forage harvesting on vibration comfort and safety of tractor's operator has been analysed under the comfort and safety aspects. Three 4WD tractor fitted respectively with a mower, a windrower and a round baler have been used. The comfort analysis has shown that forward speed resulted the most significant factor and discomfort increases, not linearly, with it. The vertical axis has resulted the most solicited. The analysis of safety conditions has shown that, in all the different settings, the action value has been exceeded so that the employer would have to establish a programme intended to reduce exposure to mechanical vibration. An analysis of the most influent parameters (i.e. machines working rate, dimension of the field, ect…) has shown the importance of the choice of the correct speed and of the operators turnover system.

Key words: *safety; vibrations; transport; forage harvesting*

INTRODUCTION

The vibration risk for tractor's operator depends above all from the level and the time of the exposure. In operations that involve several different tractors or implements the time of exposure is directly function of the working time of each operation and of the dimensions of the fields.

The CRA-ING Research Laboratory of Treviglio has analysed the influence of different implements during forage harvesting on comfort and on safety of tractor operator, the main factor influencing such operations and the possible way of optimisation.

METHODS

Tests aimed to evaluate the exposure to vibration of the driver measuring the accelerations at the three axes of the back and of the seat. The guidelines followed were established by the ISO 2631/1997. The analysis of safety and comfort (CI) were carried out.

Three different tractors (T) fitted respectively with a mower (M), a windrower (W) and a round baler (R) has been used (tab. 1). Tests were carried on the same field during the sequence of operations of spring forage harvesting.

Table 1 Tested tractors' settings

Tractor	Engine power kW	Type	Front mass kg	Rear mass kg	Total mass kg	Front tires	Rear tires	Wheelbase mm
T_1M	73	4WD	1245	3855	5100	540/65R24	600/65R34	2635
T_2R	88	4WD	2545	3200	5745	14.9R30	18.4R38	2730
T_3W	43	2WD	925	1505	2430	8.50R16	380/70R28	2030

Such as some of the main causes of discomfort from vibration are originated from the different mass distribution and from the speed, the tractors were tested at different forward speeds (according with the requirements of the specific task) for taking into account tires' influence on grassed field.

A portable instrumental chain based on two triaxial accelerometers, completed with a sixteen channels data recorder and a PC was used.

Relieves were two in each condition with random chosen of three for the monitoring of the repeatability. The maximum value is reported. The maximum difference considered for the CI values from the mean was of +/-0,1m/s^2.

RESULTS

The analysis has been divided in "comfort" and "safety" also if the results are strictly correlated.

Comfort analysis

The results are obtained using the filters and the weights reported in part 2 of the ISO 2631.

They are reported in table 2 and show that the speed was the most important factor affecting driver's comfort. The reason is that all the operations were carried on the same field so that the ground profile was not a variable.

The different kind of operation introduces low differences comfort level but the operation with mower solicited more the seat (S) than the back (B) values.

Table 2 Comfort results

Configuration	Speed (km/h)	Comfort index (m/s^2)	Seat (m/s^2)	Back (m/s^2)
TM	6	0,944	0.785	0.523
TM	9	1,692	1.424	0.913
TM	13	1,573	1.344	0.816
TW	6	1,191	0.823	0.861
TW	9	1,412	1.018	0.978
TR	5	0,682	0.435	0.366
TR	7,5	0.977	0.822	0.528

It's interesting to note that discomfort is not increasing linearly with the speed, in fact the value was quite low (comfortable) and similar at 5 and 7,5 km/h (TR) and 6 km/h (TM and TW) and uncomfortable but still similar at 9 km/h (TM and TW) and 13 km/h (TM).

The analysis of the values of the single axis shows that the solicitations on seat and back were still similar but the most stressed axis was always the vertical one (Z) both at the seat and at the back (tab.3).

This fact indicates a dominant vertical movement of the vehicle, usually typical of specialised tractor for their short wheelbase and a solicitation originating, mainly, from the rear tires.

The reason could be searched in the fact that, in particular with the mounted implement (mower - TM), the mass of the tractor during tests was mainly on the rear tires.

Table 3 Single axis comfort results

Configuration	Speed (km/h)	Seat vibration values (m/s^2)			Back vibration values (m/s^2)		
		S x	S y	S z	B x	B y	B z
TM	6	0.24	0.39	0.66	0.52	0.33	0.72
TM	9	0.51	0.69	1.17	0.89	0.56	1.32
TM	13	0.39	0.52	1.21	0.76	0.52	1.26
TW	6	0.36	0.43	0.62	0.98	0.58	0.64
TW	9	0.44	0.53	0.78	1.13	0.55	0.77
TR	5	0.23	0.24	0.3	0.35	0.42	0.31
TR	7,5	0.43	0.43	0.58	0.48	0.46	0.74

Safety analysis

The vibration transmitted were analysed with the whole body filters and weightings of the ISO 2631-1997 part 1. It could be remind that the exposure limit values for whole body vibration were of 0,5 m/s^2 for the daily exposure action value and of 1,15 m/s^2 for the daily exposure limit value.

The test results of the vibration exposure of the operator are reported in table 4.

All the operations (apart roundbailing at 5 km/h), considering the eight daily hours of work, require the employer to establish a programme intended to reduce exposure to mechanical vibration and the attendant risk.

Table 4 Safety results

Configuration	Speed (km/h)	Daily exposure value (m/s^2)			Equivalent exposure time value (h·min)		
		S x	S y	S z	Safety	Action	Limit
TM	6	0,336	0,546	0.66	4·14	4·35	24·17
TM	9	0,714	0,966	1.17	1·21	1·28	7·44
TM	13	0,546	0,728	1.21	1·16	1·22	7·14
TW	6	0,504	0,602	0.62	4·48	5·12	27·31
TW	9	0,616	0,742	0.78	3·02	3·17	17·23
TR	5	0,322	0,336	0.3	16·20	17·43	93·43
TR	7,5	0,602	0,602	0.58	5·05	5·31	29·12

The operations with mower at highest forward speeds didn't allow reaching the eight hours of daily working time. These values are strongly depending from the field surface and could result greater in other situation or settings. Beside, the suspension devices of the actual mowers could allow working with faster forward speed so the limit could effectively be the operator safety.

Data show that the employer has to establish a programme intended to reduce exposure to mechanical vibration and the attendant risk.

In particular:

- other working methods;
- appropriate work equipment producing the least possible vibration;
- provision of auxiliary equipment (as seats) to reduce WBV;
- appropriate maintenance programmes of the equipment;
- design and layout of the workplace;
- information and training;
- limitation of the duration and intensity of the exposure;
- appropriate work schedules with rest periods;

DISCUSSION

In this part of the work the two main corrective actions involved are analysed directly:

1. reducing the vibration level;
2. reducing the exposure time.

At point 1 results indicates that the main solicited axis is the vertical one (Z). The possibility of going slower is obviously the first feasible solution but it appears difficult or not realistic to apply in practice.

Improving dumping devices (i.e. seats, suspensions, suspended cab) could contribute to reduce the exposure values but they also could allow to go faster on field such as today implements, in particular mowers, could reach up to 20 km/h carrying up again, probably, exposure level. Looking at the spectrum of the solicitation it appears that high frequency could, anyway, contribute less than low ones. In figure 1 it's represented a qualitative trend of vibration level vs. forward speed. If the suspended vehicle (Y-SD) would maintain lower the increasing of vibration level going faster, than a not suspended vehicle (N-SD) the suspension could be useful.

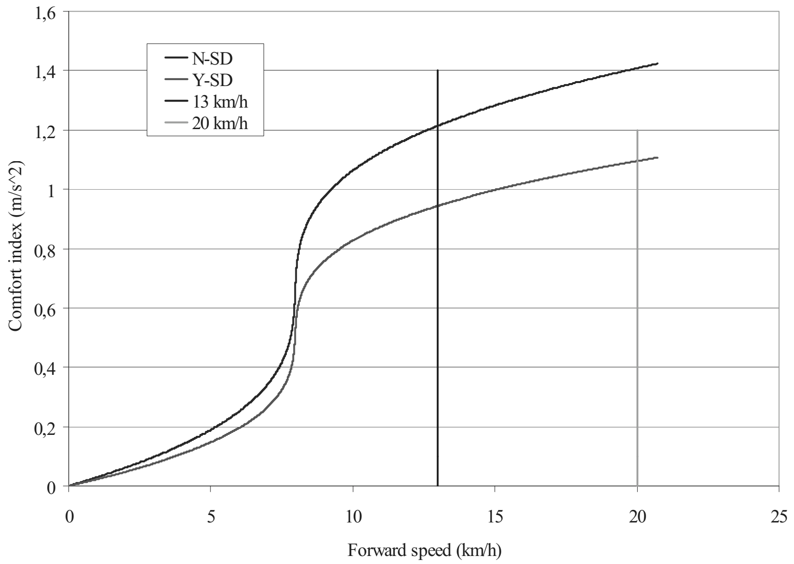


Figure 1 Qualitative trend of vibration level value increasing forward speed.

Point 2 could be reached first of all respecting the duration of the exposure time, but also adopting different implement, alternating the kind of job (i.e. TM with TW or TR).

It's important to note that practically the dimension of the field is of fundamental importance for defining the organisation of the job and the turn-over of the employers. It could be possible also working at higher speeds if the exposure time is lower due to smaller fields.

For wide extensions the combination of the machines and the organisation of the employment could furnish not only a better and faster work but also safer conditions.

In fact it's possible, from Directive 2002/44/EC, to calculate the daily exposure (indicated as A8 in the standard) expressed as equivalent continuous acceleration over an eight-hour period, calculated as root mean square (rms) value; the results are reported in table 5.

But if combined with the operational time of the machines it's possible also to calculate the equivalent continuous acceleration over 10 hectares worked (A10ha, value not reported in the standard) and it's possible to see that the exposure level with TM at 13 km/h is lower than at 9 km/h and the values obtained with the TW at 6 and 9 km/h are very similar. It's so possible to reduce the exposure time with the TM and implement changing.

Table 5 Implements working time and the equivalent continuous acceleration (A8)

Configuration	Speed (km/h)	Working time (h/ha)	Daily exposure A(8) (m/s^2)	Ten hectares exposure A(10ha) (m/s^2)
TM	6	0,73	0,66	0,63
TM	9	0,5	1,17	0,925
TM	13	0,34	1,21	0,789
TW	6	0,34	0,62	0,404
TW	9	0,24	0,78	0,427
TR	5	0,59	0,336	0,289
TR	7,5	0,5	0,602	0,476

Turnover system with kind of jobs with less exposure could allow to avoid working with lower speed, i.e. the less exposure A8 at 9 km/h of the mower (M9) is lost with the higher operative time of the 13km/h (M13) as shown for the 10 hectares value (A10ha) and same situation for the windrower at 9 km/h (W9). The little operative difference of the roundbaler could permit working at 5 km/h (R5) with a sensible gain on vibration exposure.

It's so possible to combine different utilisation of the implements, obviously respecting the working rate or time, to define the equivalent continuous acceleration (A8) and to obtain a sensible gain vs. the most stressing kind of job. Some examples are reported in table 6.

Table 6 Equivalent exposure time value of the single operation vs. combined

Configuration	Equivalent exposure time value (h·min)		
	Safety	Action	Limit
TM6	4·14	4·35	24·17
TM13	**1·16**	**1·22**	**7·14**
TW6	4·48	5·12	27·31
TW9	3·02	3·17	17·23
TR5	16·20	17·43	93·43
M6W6R5	5·56	6·26	34·4
M13W9R7	**2·24**	**2·37**	**13·51**
M13W9R5	**3·2**	**3·18**	**17·27**

CONCLUSIONS

The operator's comfort on a tractor fitted with different implements for forage harvesting has been evaluated. The forward speed was the most significant factor and discomfort increases, not linearly, with it. The vertical axis was the most solicited above all for the distribution of the tractors' masses.

The safety analysis has shown that, in all the different settings of the job, the action value has been exceeded so that the employer would have to establish a programme intended to reduce exposure to mechanical vibration and the attendant risk.

An analysis of the working rate of the machines and of the dimensions of the field has shown the importance of the choice of the correct speed and of the turnover system.

A correct planning could allow to establish the best condition for a fast and safe job.

ACKNOWLEDGEMENTS

The authors wish to kindly acknowledge the *Ministero dell'Agricoltura* for having founded this research project and all other partners of the project VIBRAMAG.

REFERENCES

1. Bukta A. J., K. Sakai, A. Sasao, S. Shibusawa, 2002, "Free play as a source of non linearity in tractor-implement systems during transport", Applied Engineering in Agriculture; vol.45(3): 503-508
2. Cutini M., Bisaglia C., Romano E, Assessment of tractor's tires influence on operator's comfort, XXXII CIOSTA-CIGR Section V, Advances in Labour and Machinery Management for a profitable Agriculture and Forestry, 2007, Nitra, Slovakia, Conference Proceedings, pp 183
3. Cutini M., C. Bisaglia, 2008. Assessment of comfort conditions of an agricultural tractor during operations with trailers. In: Proceedings CD of International Conference "Innovation technology to empower safety, health and welfare in agriculture and agro-food systems", p. 1-7, (Book of Abstracts p. 106), 15-17 September, Ragusa (Italy)
4. Ferhadbegovic B., Ch. Brinkmann, St. Bottinger, H. D. Kutzbach, Hohenheim Tyre Model – A Dynamic Model for Agricultural Tyres –- XVI CIGR World Congress, Ageng 03-07 September 2006, Bonn.
5. Kornecki T.S., A. J. Price, R. L. Raper, 2006, "Performance of different roller designs in terminating rye cover crop and reducing vibration", Applied Engineering in Agriculture; vol.22(5): 633-641
6. EEC 2002. Directive of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration). Directive 2002/44/EC, Official Journal of the European Communities (No L 177/13 6/7/2002)
7. ISO 2631-1997 Mechanical vibration and shock -- Evaluation of human exposure to whole-body vibration -- Part 1: General requirements.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 620.95:662.76 (497.4)
Pregledni rad
Review paper

STANJE I PERSPEKTIVE NA PODRUČJU POLJOPRIVREDNIH BIOPLINSKIH POSTROJENJA U SLOVENIJI

T. POJE, V. JEJČIČ

Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko, Hacquetova 17,
SI – 1000 Ljubljana, Slovenija, e-mail: tomaz.poje@kis.si, viktor.jejcic@kis.si

SAŽETAK

Početke proizvodnje bioplina u Sloveniji nalazimo u 80. godinama prošlog stoljeća. Nakon 2002. godine nanovo uspostavljene prilike i cijene otkupa električne energije od kvalificiranih proizvođača električne energije povećale su interes za izgradnju poljoprivrednih bioplinskih postrojenja. U 2008. godini aktivnih je 8 poljoprivrednih bioplinskih postrojenja, od kojih se 4 nalaze u fazi testnog rada. Ukupna instalirana električna snaga iznosi 10,7 MW. Kao osnovni supstrat upotrebljava se gnojevka, a za poboljšanje količine proizvedenog metana i bioplina još i energetske biljke, klaonički otpaci, organski otpaci. Bioplin se koristi samo za izgaranje u kogeneracijskim motorima za proizvodnju elektrike i topline. Toplinska energija nije iskorištena u potpunosti jer se većinom koristi tek na samim bioplinskim postrojenjima.

Ključne riječi: *poljoprivredna bioplinska postrojenja, bioplin, supstrati za proizvodnju bioplina, stanje u Sloveniji*

UVOD

Bioplin je obnovljivi vir energije koji nastaje putem anaerobnog (bez prisutnosti kisika) mikrobiološkog razgrađivanja organske tvari. Sastavljen je od različitih plinova, među kojima ima najviše metana. Sastav plinova može se mijenjati. Bioplin može sadržavati i druge plinove u manjim količinama, koji mogu utjecati na miris (smrad). To su različiti sumporni i dušikovi spojevi. Osobine bioplina zavise od vrenja (fermentacije) supstrata, koji se unose u bioplinsko postrojenje i mogu varirati. Gustoća bioplina iznosi približno 1,2 kg/m^3 kod 65% udjela metana. Kalorična vrijednost nalazi se između 4 i 7,5 kWh/m^3 (ovisno o sadržaju metana). Plamište se nalazi na približno 700 ºC (metan na 595 ºC).

Tablica 1 Volumenski udio različitih plinova u bioplinu

Tvar	Volumenski udio (%)
Metan – CH_4	45 - 65
Ugljični dioksid – CO_2	30 - 55
Vodena para – H_2O	0 - 10
Dušik – N_2	0 - 5
Kisik – O_2	0 - 2
Vodik - H_2	0 - 1
Amonijak – NH_3	0 - 1
Vodikov sulfid – H_2S	0 - 2

STANJE NA PODRUČJU POLJOPRIVREDNIH BIOPLINSKIH POSTROJENJA U SLOVENIJI

Počeci proizvodnje bioplina u Sloveniji

Počeci proizvodnje bioplina u Sloveniji sežu u 80. godine prošlog stoljeća. Prva dva bioplinska postrojenja nalaze se na postrojenjima za pročišćavanje otpadnih voda u Domžalama i na velikoj farmi svinja Ihan. Na Kmetijskom inštitutu Slovenije u osamdesetim godinama postojalo je mini istraživačko bioplinsko postrojenje namijenjeno istraživačkom radu na području bioplina. V tim godinama već su izrađene studije za gradnju poljoprivrednih bioplinskih postrojenja na gospodarstvima, koja bi kao osnovni i jedini supstrat upotrebljavala gnojevku, ali koja zbog drugih jeftinijih izvora energije tada nisu bila realizirana.

Proizvodnja bioplina prije 2002. godinom bila je ograničena na proizvodnju bioplina na postrojenjima za pročišćavanje otpadnih voda i na deponijama za komunalne otpatke (deponijski plin). Do 2002. godine proizvodnja bioplina odvijala se na osmim centralnim postrojenjima za čišćenje otpadnih voda, ali su samo četiri od njih upotrebljavale bioplin za proizvodnju topline i električne energije u sistemima za zajedničku kogeneraciju topline i električne energije. U ostalim postrojenjima zahvaćeni bioplin izgorio je na bakljama. Ukupna instalirana električna snaga u svim postrojenjima na bioplin iznosila je manje od 1 MW. Do 2002. godine prikupljanje deponijskog plina odvijalo se samo na petim odlagalištima otpadaka: u Ljubljani, Mariboru, Velenju, Celju i Izoli. Deponijski plin se koristio u energetske svrhe samo na deponiji Barje u Ljubljani, dok su ga na ostalim deponijama spaljivali na bakljama. Instalirana električna snaga postrojenja za korištenje deponijskog plina iznosila je 1,2 MW.

Vlada republike Slovenije je godine 2002 donijela Uredbu o pravilima određivanja cijena i otkupa električne energije od kvalificiranih proizvođača električne energije i Zaključak o cijenama i premijama za otkup električne energije od kvalificiranih proizvođača električne energije. Nanovo uspostavljene prilike i cijene otkupa električne energije od kvalificiranih proizvođača povećale su interes za izgradnju poljoprivrednih bioplinskih postrojenja.

Današnje stanje

Prema podacima iz 2008. godine proizvodnja bioplina odvija se na šestim centralnim postrojenjima (CČN) za čišćenje otpadnih voda: Domžale-Kamnik, Kranj, Ptuj, Škofja loka, Velenje i Jesenice. U gradnji so još postrojenja na nekim novim centralnim postrojenjima za pročišćavanje otpadnih voda. Ukupna električna snaga svih šest postrojenja za zajedničku proizvodnju - kogeneraciju topline i električne energije na bioplin iz otpadne vode iznosi 2,1 MW.

Prema podacima iz 2007. godine energetsko iskorištavanje deponijskog plina odvija se na trima odlagalištima komunalnih otpadaka: Ljubljana, Maribor i Celje. Proizveden deponijski plin upotrebljava se za proizvodnju topline i električne energije u plinskim SPTE sistemima. Ukupna instalirana električna snaga svih postrojenja iznosi 3,5 MW.

Veliki razvoj doživjela su poljoprivredna bioplinska postrojenja. U oktobru 2008 bilo je faktički u radu već 8 poljoprivrednih bioplinskih postrojenja. Bioplinska postrojenja trebaju dobiti status kvalificiranog proizvođača električne energije. Prema klasifikaciji Ministarstva za gospodarstvo ona spadaju među »druge KE« (druge kvalificirane elektrane). To su elektrane koje kao ulaznu energiju koriste bilo koju drugu vrstu obnovljive energije, koja nije fosilnog ili nuklearnog izvora; u tu grupu spadaju KE na bioplin od životinjskih i biljnih otpadaka u poljoprivrednoj djelatnosti. Svaki takav kvalificiran proizvođač električne energije naplaćen je prema jedinstvenoj godišnjoj cijeni (ELC) od 120,89 EUR za MWh proizvedene električne energije. On također ima pravo na jedinstvenu godišnju premiju (ELP) koja iznosi 68,51 EUR po MWh proizvedene električne energije. Te brojke vrijede od 15.10. 2008 za godinu 2008.

Slika 1 Karakteristična slika za bioplinsko postrojenje: armirano betonski digestori s poklopcima s duplom membranom; Na slici je Bioplinara BIOPLIN, Kolar Marjana s.p. u Logarovcima (Križevci pri Ljutomeru), koja ima 1000 kW motor za proizvodnju elektrike, a kao supstrat upotrebljava gnojevku od svinja, kukuruznu i travnu silažu

Tablica 2 Glavni podaci za poljoprivredna bioplinska postrojenja u Sloveniji (stanje u septembru 2008)

Bioplinsko postrojenje	**Supstrat**	**Veličina digestora [m^3]**	**Proizvodnja bioplina [m^3/dan]**	**Električna snaga kogeneracijskog postrojenja [kW$_e$]**
Bioplin Kolar Marjan s.p., Logarovci	Gnojevka od svija, kukuruzna i travna silaža, CCM	4 x 2200	10560	1000
Bioterm d.o.o., Letuš (Kmetija Flere)	Gnojevka od goveda, otpaci iz mljekare, kuhinjski organski otpaci	290 + 300 + 300 + 400	1500	60 + 62 + 150
Bioplinarna Farma Ihan; Ihan (FI-EKO d.o.o.)	Gnojevka od svinja, klaonički otpaci	4 x 1250	7000	1052
Bioplinarna Nemščak, Nemščak (Panvita EKOTEH d.o.o)	Gnojevka od svinja, kukuruzna silaža, klaonički otpaci	2 x 3200 + 2500	13500	835 + 625
Bioplinska naprava Ljubljana, Ljubljana (KOTO d.d.)	Gnojevka od goveda, krv, kuhinjski organski otpaci, sortirani biološki otpaci, flotat	2 x 500	4500	526
Bioplinarna Motvarjevci, Motvarjvci (Panvita EKOTEH d.o.o)	Gnojevka od svinja, kukuruzna silaža	3250 + 1100	9500	835
BIOENERG d.o.o., Črnomelj	Organski otpaci, gnojevka od svinja, kukuruzna silaža	2 x 1700	-	1360
Bioplinska naprava Lendava, Lendava (ECOS d.o.o.)	Gnojevka od svinja i goveda, trava i travna silaža, kukuruzna silaža, CCM, silaža od cijelih suncokreta	4 x 5650	43000	4245

Energetske biljke

Za povećanje količine bioplina sve više se pored gnojevke upotrebljavaju i drugi izvori organske tvari. Među njih možemo ubrojiti i takozvane energetske biljke, koje predstavljaju obnovljivi izvor energije, a proizvode se u energetske svrhe. Njihovom proizvodnjom i kasnijom proizvodnjom bioplina povećava se mogućnost djelomične samoopskrbe energijom, a poljoprivreda time dobiva mogućnost dodatnog razvoja. Kod proizvodnje energetskih biljaka postoji mogućnost pojave određene problematike kao što ograničena količina biomase. Moglo bi doći i do njihove previše intenzivne proizvodnje, što bi se odražavalo u poteškoćama s pesticidima i gnojivima. Problematičan bi mogao biti i preuski plodored, a to bi utjecalo na plodnost tala, otpornost biljaka itd. Javnost je također mnogo puta zbunjena i zbog konkurentnosti s poljoprivrednom proizvodnjom za hranu.

Austrijski podaci pokazuju da dobrih 28 % postrojenja upotrebljavaju 4 različite supstrate, odmah iza njih su bioplinska postrojenja (25 %) s 5 supstrata, dok samo jedan supstrat koristi tek 3,1 % bioplinskih postrojenja. Situacija je slična i kod nas, ali zbog relativno malog broja domaćih bioplinskih postrojenja još nije smisleno računati takve udjele.

Kukuruz kao energetska biljka ima najveći značaj među energetskim biljkama za proizvodnju bioplina. Ima i najveći potencijal što se tiče prinosa. Njegova proizvodnja, spremanje, konzerviranje, doziranje je razvijeno i manje više optimalno izvedljivo. Postoje različite mogućnosti proizvodnje kao glavni usjev, kao kombinacija s drugim biljkama, kao postrni usjev nakon prethodnih žitarica.

Upotreba bioplina

Krajem 2008 bioplin se u Sloveniji upotrebljava samo za proizvodnju električne energije i topline. Od 2007 godine Energetska Agencija Podravja radi na evropskom projektu MADEGASCAR, koji ima cilj promociju upotrebe plina i bioplina za pogon vozila ali za sada još nema vozila sa pogonom na bioplin. Nema ni postrojenja za pročišćavanje bioplina i slanje u plinovod.

ZAKLJUČAK

Energetska politika u Sloveniji naklona je postavljenju bioplinskih postrojenja s ciljem povećanja udjela obnovljivih izvora u primarnoj energetskoj bilanci, smanjenja emisije stakleničkih plinova i povećanja udjela proizvedene električne energije iz OVE. Vlada Republike Slovenije je određenjem odgovarajućih otkupnih cijena i premija za kvalificirane proizvođače električne energije nakon 2002. godine potaknula izgradnju poljoprivrednih bioplinskih postrojenja, koja pored gnojevke koriste i druge supstrate, većinom energetske biljke, koje iskazuju dobru produkciju metana, odnosno bioplina. Ukupna instalirana električna snaga na kogenaracijskim uređajima poljoprivrednih bioplinskih postrojenja iznosi 10,7 MW. Toplota se koristi za grijanje samog bioplinskog postrojenja i bližnjih objekata, ali trenutačno još nije uspostavljeno grijanje naselja.

LITERATURA

1. Al-Mansour F. (2008). Regionalna strategija in akcijski plan za razvoj proizvodnje bioplina v Sloveniji. Interno gradivo - delovno poročilo za projekt BIOGAS REGIONS, Institut "Jožef Stefan" – Center za energetsko učinkovitost, 16 str.

2. Biogas Regions Shining Examples (2008) Interno gradivo Oddelka za kmetijsko tehniko na Kmetijskem inštitutu Slovenije, 2008

3. Poje T. (2008). Bioplin in substrati za njegovo proizvodnjo. Strokovno predavanje na temo Biomasa in drugi obnovljivi viri energije. Zveza društev za biomaso Slovenije, Ptuj, 1. okt. 2008.

THE SITUATION AND PERSPECTIVE IN THE FIELD OF AGRICULTURAL BIOGAS PLANT IN SLOVENIA

ABSTRACT

The beginnings of biogas production in Slovenia reach back to the eighties of the former century. After 2002, the newly established circumstances and prices in the purchase of electricity from qualified electricity producers increased the interest in the construction of agricultural biogas plants. In 2008, eight agricultural biogas plants are in operation while four plants operate on the testing basis. The total electric power installed is 10,7 MW. Slurry is used as a basic substrate and, to improve the performance of methane and biogas, energetic plants, slaughterhouse wastes and organic wastes are used. Biogas is used only for the combustion in cogeneration engines for the production of electricity and heat. Heat energy is not utilized completely since in most cases it is used only on biogas plants.

Key words*: Agricultural biogas plants, biogas, substrates for biogas production, the situation in Slovenia*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 620.95:661.9
Prethodno priopćenje
Preliminary communication

BIOPLIN PRIDOBLJEN IZ ENERGETSKIH RASTLIN

PETER VINDIŠ, BOGOMIR MURŠEC, MIRAN LAKOTA, DENIS STAJNKO, MATJAŽ SAGADIN

Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede, Vrbanska 30, 2000 Maribor, Slovenija

POVZETEK

Proizvodnja bioplina se je v kmetijstvu dolgo časa povezovala skoraj izključno z rabo gnoja in gnojevke kot »surovine« za proizvodnjo bioplina. Vendar pa je v bioplinskih napravah mogoče energetsko izrabiti vse vrste organskih snovi, ki nastanejo na kmetiji (od čiste gnojevke in gnoja do povsem rastlinskega substrata – koruza, trava – npr. sudanska, detelja, krmna pesa, sončnice itd.), ki jih dovajamo v fermentor bodisi sveže ali kot silažo, do tako imenovanih zunanjih sosubstratov, ki nastajajo v živilski industriji (npr. bioostanki pri predelavi sadnih sokov, piva, mleka itd.) ter ostankov hrane (pomije iz velikih kuhinj, restavracij itd.) in celo ostankov zelenega odreza (pokošena trava ...). Razgradnja vrelne mase in s tem proizvedena količina bioplina na enoto substrata je odvisna od vrste substrata in njegovih sestavin. V ta namen smo zgradili digestor, s katerim merimo količino proizvedenega bioplina iz različnih substratov v različnih pogojih (mezofilni, termofilni). Proizvodnja bioplina iz energetskih rastlin je bila izvedena v skladu s standardom DIN 38414, v mezofilnem območju (35 °C). Proizvodnja bioplina se meri dnevno in istočasno se določa tudi sestava bioplina (CH_4, CO_2 in O_2) s plinskim detektorjem GA 45 Geotechnical Instruments. V poskus smo zajeli več energetskih rastlin: ščir (Amaranthus sp.), sirek (Sorghum halapense), koruzo (Zea mays), topinambur (Helianthus tuberosus) in sončnice (Helianthus annuus). Najvišjo vsebnost bioplina smo določili za sončnice 335 Nl/kg oSS, sledi koruza 327 Nl/kg oSS, sirek s 312 Nl/kg oSS, topinambur s 224 Nl/kg oSS in ščir s 197 Nl/kg oSS. Povprečna vsebnost metana v bioplinu je 51,8 - 62,8% in ogljikovega dioksida 32,4 - 40,0%. Pri vseh določitvah je vsebnost kisika pod 1%, kar kaže na anaerobno fermentacijo. Rezultati testiranj so kot najprimernejšo energetsko rastlino pokazali sončnice in koruzo z najvišjo vsebnostjo metana, medtem ko velja v prihodnje preizkusiti tudi druge alternativne energetske rastline (detelja, sudanska trava itd.).

Ključne besede: *bioplin, mini digestor, energetske rastline*

UVOD

Pri obstoječi porabi nafte in sedanjem stanju tehnike bodo zaloge nafte po 40 letih uporabe usahnile in po 60 letih bo porabljen ves zemeljski plin [1]. Glede na to, da so razen v Arabskem delu že dosežene maksimalne količine črpanja se bližamo točki ko bo potrebno zmanjševanje črpanja. Arabski del nahajališč je pa po nekaterih teorijah tako bogat z nafto, da bodo lahko sledili povečanju potreb po nafti. Mexico je največja proizvajalka poleg Arabskih držav. Ocenjuje se, da ima za cca 27 milijonov sodov zaloge. Večina izvozi v ZDA, ki prispevajo eno četrtino k svetovni porabi nafte. V nekaterih virih je navedeno, da je zaloge nafte skupno do 400 mrd ton v skupnem trajanju 118 do 125 let. Od tega je dokazanih 143 mrd ton rezerv, ki bojo trajale 41 let. Potencialne zaloge so ocenjene na 70 do 80 mrd ton, trajale naj bi 25 let. Če bi povečali produktivnost že obstoječih naftnih polj bi pridobili do 104 mrd ton nafte. Po nekaterih ocenah ostane še cca 80 mrd ton nafte v peščenjakih in v težki nafti [2].

Pri zgorevanju fosilnih energentov nastajajo toplogredni plini, med katerimi je tudi ogljikov dioksid. Njegova vrednost se je v zadnjih 100 letih v atmosferi povečala za tretjino. S sočasnimi raziskavami je bilo ugotovljeno, da se je globalna temperatura ozračja povečala za 0,6 ºC glede na čas pred industrijskim obdobjem. Predpostavlja se, da bo ob koncu stoletja globalna temperatura ozračja za 2 do 6 ºC večja glede na današnji čas [3]. Države, vključene v EU, imajo jasno navodilo, da do leta 2010 nadomestijo obstoječo fosilno energijo iz obnovljivih virov do vrednosti 12% porabljene bruto energije. To pa pomeni trikratno povečanje pridobivanja energije iz obstoječih obnovljivih virov energije v EU.

Proizvodnja bioplina iz kmetijske biomase je zelo pomembna in prispeva pomembno korist k ohranjanju narave [4] ter je dodaten vir zaslužka za kmetije. Proizveden je obnovljivi vir energije. Zelo močan je princip kroženja, predvsem dušika, ki se močno zadržuje v sistemu [5]. Izpusti metana med shranjevanjem gnoja se zmanjšajo, medtem ko je kvaliteta digestata visoka. Primerni substrati za digestijo v bioplinarnah so: energijske rastline, organski odpadki in živalski gnoj. Koruza (*Zea mays L.*), trave (*Poacae*), detelje (*Trifolium*), sudanska trava (*Sorghum sudanense*), sladkorna pesa (*Beta vulgaris*) in druge se lahko uporabljajo kot energijske rastline [6, 7, 8]. Koruza je prevladujoča rastlina za proizvodnjo bioplina. Ima največji potencialni pridelek glede na druge rastline v Osrednji Evropi.

Energetske rastline za uporabo v bioplinskih napravah postavljajo nove zahteve v pridelavi kmetijskih rastlin. Prvi pogoj je visok masni pridelek – kg/ha izbrane vrste rastline, sorte, ob tem pa še stroški gnojenja in zaščite rastline, ter možne tehnologije spravila pridelka [9].

METODE

Poskus pridobivanja bioplina je potekal na postrojenju, ki je bilo izdelano za potrebe pridobivanja bioplina iz energetskih rastlin in drugih možnih substratih primernih za predelavo v bioplin. Osnovna konstrukcija postrojenja je izdelana iz nerjavnega jekla in je dolga 2500 mm, visoka 1000 mm in široka 350 mm. Na najvišjem delu je polica na kateri so zunanje posode za odvečno tekočino. Spodaj je korito 2500 x 200 x 200 mm obloženo s stiroporom, ki preprečuje prevelike izgube toplote. V koritu je zraven eudiometrov postavljena še grelna črpalka, ki skrbi za stalno konstantno temperaturo in kroženje vode. Tako dosežemo čim bolj enakomerno temperaturo vode po vsem koritu. Eudiometri so pritrjeni na kovinski profil nad konstrukcijo, tako da se ne morejo prevrniti in da se jih da čim lažje odstranjevati in pritrjevati za potrebe poskusov. Na levi strani konstrukcije je pritrjen termometer in barometer, ki preko tipala meri temperaturo vode v koritu in posebej temperaturo zraka okolice.

Plinska aparatura obsega dvanajst plinskih celic. Vsaka celica je sestavljena iz reakcijske posode (500 ml fermentor) in eno dobro zaprto plinsko cevjo volumna 350 ml. Plinska cev - eudiometer vsebuje raztopino NaCl - natrijevega klorida z dodatkom citronske kisline. Povezana je z zunanjo posodo, kjer je raztopina. V fermentorjih proizveden bioplin izpodriva zaporno tekočino v plinski cevi v zunanjo posodo. Proizveden plin odčitamo na plinski cevi. Fermentorji so potopljeni v vodno kopel s konstantno temperaturo 35 °C (mezofilno temperaturno območje) in povezani s stekleno plinsko cevjo. Proizveden bioplin vsebuje 50 - 75% metana, 10 - 40% ogljikovega dioksida ter druge snovi (H_2, H_2S, N_2, NH_4 …). Točna sestava se določi s plinskim analizatorjem. Sestavo oziroma odstotek metana, ogljikovega dioksida in kisika preverjamo s plinskim analizatorjem Geotehnical Instruments GA 45. Slika 1 prikazuje mini digestor za potrebe laboratorijskih poskusov.

Slika 1 Mini digestor za potrebe laboratorijskih poskusov

Pridobivanje bioplina

Pridobivanje bioplina se je izvajalo po nemškem standardu DIN 38414, del 8, v mezofilnem temperaturnem območju (35 °C) [10]. Proizveden bioplin se poda v norm litrih na kilogram organske suhe snovi (Nl/kg oSS). Količina bioplina se preračuna glede na normalne pogoje; temperaturo 273 K in zračni pritisk 1013 mb.

Kot prvo je potrebno izpeljati normalni volumen proizvedenega bioplina (V_o) po enačbi:

$$V_o = V \cdot \frac{(P_l - P_w) \cdot T_o}{P_o \cdot T}$$

V_o – normalni volumen bioplina; v ml

V – volumen proizvedenega bioplina; v ml

P_l – zračni pritisk; v mbar

P_w – parni pritisk vode v odvisnosti temperature prostora; v mbar

T_o – normalna temperatura; T_o = 273 K

P_o – normalni pritisk; P_o = 1013 mbar

T – sobna temperatura; v K

Ta postopek se ponovi za vsak posamezni poskus z substratom in cepivom. Prav tako smo merili proizvodnjo bioplina iz cepiva.

$$V_{is} = \frac{\sum V_{is} \cdot m_{is}}{m_M}$$

V_{is} – volumen proizvedenega bioplina iz cepiva; v ml

ΣV_{is} – vsota proizvedenega bioplina iz cepiva za posamezen poskus; v ml

m_{is} – masa cepiva uporabljena v mešanici; v g

m_M – masa cepiva uporabljena v kontrolnem vzorcu; v g

Masa cepiva uporabljena v mešanici je bila 385 g, masa cepiva uporabljena v kontrolnem vzorcu pa 400 g. Vsota normalnega volumna bioplina v poskusa minus volumen proizvedenega bioplina iz cepiva nam da neto volumen bioplina, ki predstavlja volumen bioplina proizveden iz posameznega substrata oziroma energetske rastline.

Specifična proizvodnja bioplina je podana v norm litrih bioplina na kilogram organske suhe snovi (Nl/kg oSS) in se izpelje po enačbi:

$$V_s = \frac{\sum V_n \cdot 10^4}{m \cdot W_t \cdot W_v}$$

V_s – specifična proizvodnja bioplina v norm litrih bioplina na kilogram organske suhe snovi (Nl/kg oSS)

ΣV_n – neto volumen proizvedenega bioplina; v ml

m - masa uporabljenega substrata v poskusu; v g

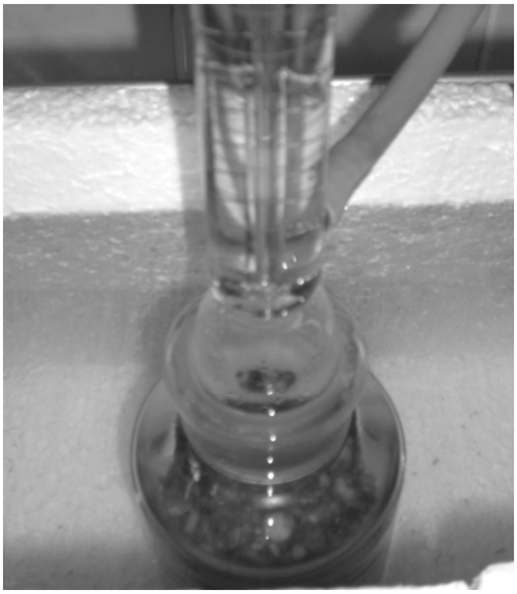
W_t - suha snov substrata; v %

W_v - izguba gorenja suhe mase v poskusu pri 550 °C; v %

Pri vsakem poskusu smo uporabili 15 gramov substrata oziroma silaže energetske rastline.

Cepivo

Aktivna svinjska gnojevka je bila zbrana iz obrata za pridobivanje bioplina, kjer kot substrate za predelavo v bioplin uporabljajo energetske rastline (koruza, proso). Vzorec smo filtrirali in ga uporabili kot cepivo. Z vzorcem smo tudi pripravili različna razmerja substrat/cepivo. Uporabili smo razmerje 15 gramov substrata in 385 gramov cepiva. Prav tako smo posebej merili proizvodnjo bioplina iz cepiva. Slika 2 prikazuje substrat/cepivo razmerje v vodni kopeli.



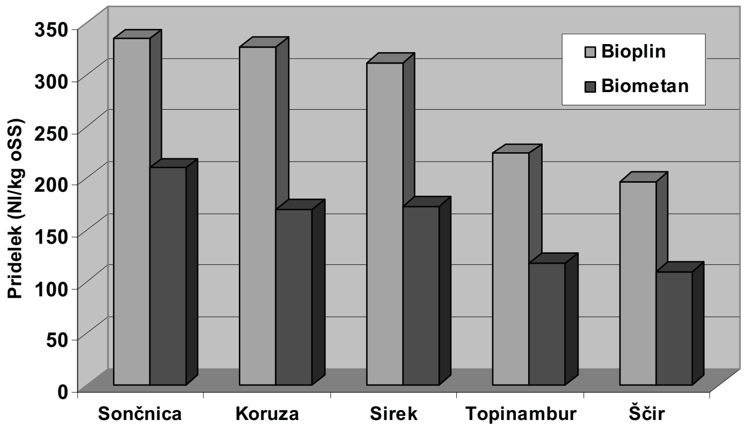
Slika 2 Substrat/cepivo razmerje v vodni kopeli

REZULTATI IN DISKUSIJA

Proizvodnjo bioplina smo spremljali 35 dni, kjer smo merili dnevno proizvodnjo in sestavo bioplina (CH_4, CO_2 in O_2). V poskus smo zajeli več energetskih rastlin: ščir (*Amaranthus sp.*), sirek (*Sorghum halapense*), koruzo (*Zea mays*), topinambur (*Helianthus tuberosus*) in sončnice (*Helianthus annuus*). Rastline so bile predhodno silirane v mini silose.

Najvišjo vsebnost bioplina smo določili za sončnice 335 Nl/kg oSS, sledi koruza 327 Nl/kg oSS, sirek s 312 Nl/kg oSS, topinambur s 224 Nl/kg oSS in ščir s 197 Nl/kg oSS. Slika 2 prikazuje povprečen pridelek bioplina in biometana za različne energetske rastline. Vse meritve so potekale v treh ponovitvah.

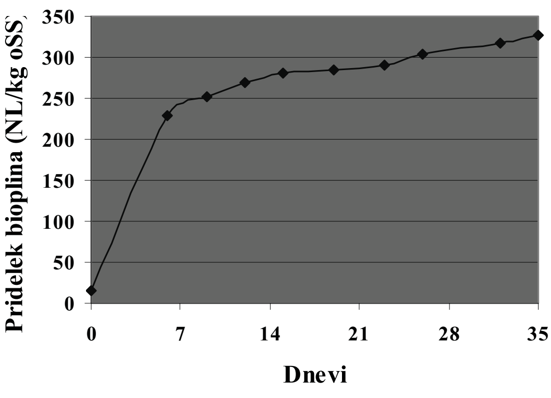
Poskus se je izvajal 35 dni, kjer smo spremljali pridelek bioplina in sestavo bioplina oziroma prisotnost treh pomembnejših kemijskih elementov (metan, ogljikov dioksid in kisik). Slika 3 prikazuje pridelke bioplina in biometana v Nl/kg oSS ter sestavo bioplina, glede na vsebnost metana, ogljikovega dioksida in kisika po posameznih energetskih rastlinah. Vsebnost CH_4, CO_2 in O_2 predstavlja povprečje 11 meritev posamezne ponovitve vsakega poskusa.



Slika 2 Pridelek bioplina in biometana v Nl/kg oSS za različne energetske rastline

Rastlina	**Bioplin (Nl/kg oSS)**	**Biometan (Nl/kg oSS)**	**CH_4 (%)**	**CO_2 (%)**	**O_2 (%)**
Sončnica	335	210	62,8	36,2	0,4
Koruza	327	170	51,8	40,0	0,6
Sirek	312	173	55,4	35,6	0,6
Topinambur	224	118	52,6	36,8	0,4
Ščir	197	110	55,5	32,4	0,7

Slika 3 Pridelek bioplina in biometana v Nl/kg oSS ter sestava bioplina po posameznih energetskih rastlinah



Slika 4 Pridelek bioplina (Nl/kg oSS) po dnevih pri koruzi

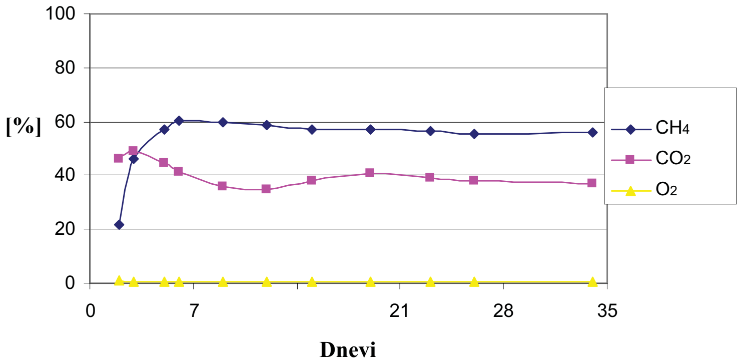
Iz tabele je razvidno, da imajo najvišji potencial za pridelavo bioplina oziroma biometana sončnice, katerim sledi sirek in koruza.

Slika 4 prikazuje pridelek bioplina (Nl/kg oSS) po dnevih pri koruzi v 35 dnevnem časovnem obdobju. Glavnina bioplina nastane v prvih 14 dnevih anaerobne fermentacije.

S plinskim analizatorjem Geotehnical instruments GA 45 smo merili sestavo bioplina. Plinski analizator omogoča meritve treh pomembnejših sestavin v bioplinu (CH_4, CO_2 in O_2). Slika 5 prikazuje sestavo bioplina pri koruzi glede na dan poteka poskusa. V 35 dnevih poskusa smo sestavo bioplina analizirali 11 krat.

Pri koruzi je vsebnost metana v razponu od 21,8 do 60,4% (povprečno 51,8%). Najvišja raven CO_2 je bila na drugi dan poskusa, 48,8%, in nato se je zmanjšala na 37% in ostala nespremenjena. Povprečna vsebnost CO_2 je 40%. Vsebnost kisika pod 1% kaže na prisotnost anaerobne fermentacije.

Največja razlika v sestavi bioplina se pojavi v prvem tednu anaerobne fermentacije in nato sestava bioplina ostane bolj ali manj stabilna.



Slika 5 Sestava bioplina pri koruzi

Z enakimi grafi bi lahko ponazorili tudi sestavo bioplina pri ostalih energetskih rastlinah. V poskusu smo uporabili koruzni hibrid Nexos, krmni sirek Autan, ščir A. cruentus G6, sončnico PR64A43 ter topinambur Bela.

SKLEPI

Proizvodnja bioplina iz kmetijske biomase pridobiva vedno večji pomen, saj ponuja koristi za okolje in je vir dodatnega dohodka za kmete. Gospodarska učinkovitost anaerobne fermentacije je odvisna od stroškov investicije, stroškov obratovanja bioplinarne in optimalne proizvodnje biometana. Bioplin je obnovljivi vir energije in zmanjšuje emisije CO_2.

Energetske rastline (sončnica, koruza, sirek, topinambur in ščir) smo silirali v mini silose in izpostavili anaerobni fermentaciji 35 dni, pri čemer smo merili proizvodnjo in sestavo bioplina. Poskusi so potekali z postrojenjem za pridobivanje bioplina iz različnih energetskih rastlin in drugih organskih odpadkov. Meritve so bile izvedene v skladu s standardom DIN 38 414, del 8. Štirje preizkusi s tremi ponovitvami se lahko izvedejo istočasno.

Najvišjo vsebnost bioplina smo določili za sončnice 335 Nl/kg oSS, sledi koruza 327 Nl/kg oSS, sirek s 312 Nl/kg oSS, topinambur s 224 Nl/kg oSS in ščir s 197 Nl/kg oSS. Povprečne vsebnosti metana v bioplinu so variirale od 51,8% do 62,8%, povprečne vsebnosti ogljikovega dioksida so variirale od 32,4% do 40,0%. Indikator anaerobne fermentacija je kisik, kar kaže na to, da so vsebnosti kisika bile pod 1%.

Rezultati testiranj so kot najprimernejšo energetsko rastlino pokazali sončnico, kateri sledi koruza in sirek, medtem ko velja v prihodnje preizkusiti tudi druge alternativne energetske rastline (sladkorna pesa, detelja, sudanska trava, itd.).

LITERATURA

1. Rempel H. (2003). Ressourcen und Verfügbarkeit von Energierohstoffen 2003. – XXVIII. 426 S., E. Schweizerbart́sche Verlagsbuchhandlung (Nägele und Obermiller), Stuttgart

2. Brenčič J. (2001). Znane in špekulativne zaloge fosilnih goriv. Seminar Energija in okolje. http://www.ee.uni-lj.si/EnergijaInOkolje/seminarji/2002/brencic.pdf

3. IPCC. (2001). International Panel for Climate Change. Brifings at the Conference of the Parties to the UNFCCC, Sixth Session, part two.: Climate Change, Impacts, Adaptation and Vulnerability. www.ipcc.ch/present/presentations.htm

4. Chynoweth D.P. (2004). Biomethane from energy crops and organic wastes. In: International Water Association (Eds.), Anaerobic Digestion 2004. Anaerobic Bioconversion . . . Answer for Sustainability, Proceedings 10th World Congress, vol. 1, Montreal, Canada: 525–530

5. Mo¨ller K. (2003). Systemwirkungen einer ‘‘Biogaswirtschaft’’ im o¨kologischen Landbau: Pflanzenbauliche Aspekte, Auswirkungen auf den NHaushalt und auf die Spurengasemissionen. Biogas J. 1: 20–29

6. Gunaseelan V.N. (1997). Anaerobic digestion of biomass for methane production: a review. Biomass Bioenergy 13 (1–2): 83–114

7. Weiland P. (2003). Production and energetic use of biogas from energy crops and wastes in Germany. Appl. Biochem. Biotechnol. 109: 263–274

8. Tong X., Smith L.H., McCarty P.L. (1990). Methane fermentation of selected lignocellulosic materials. Biomass 21: 239–255

9. Bernik R., Zver A. (2006). Rastlina kot obnovljivi vir energije (OVE) = Plants as renewable energy source (RES). Acta agric. Slov.. 87/2: 355-364

10. DIN 38 414, part 8 (1985). Determination of digestion behavior ‘‘sludge and sediments’’. Beuth Verlag, Berlin (in German)

BIOGAS PRODUCED FROM ENERGY PLANTS

SUMMARY

Biogas production in agriculture has for long time been linking almost exclusively with the use of manure and slurry as "raw material" for the production of biogas. However, in biogas plants can be energy-use all types of organic matter that may arise in the farm (from slurry and manure to fully substrate plant - corn, grass - eg. sudanese, clover, fodder beet, sunflower, etc.), which is delivered to fermentor in either fresh or as silage, to so-called external co-substrates arising from the food industry (biowastes processing of the fruit juices, beer, milk etc.) and residues of food (swill from large kitchens, restaurants etc.) and even the residue of green cut (cut grass ...). Decommissioning of the fermenting mass and the quantity of biogas produced per unit of substrate depend on the type of substrate and its components. For this purpose the digestor was built, with which we measured the quantity of produced biogas from different substrates in different conditions (mesophilic, thermophilic). The production of biogas from energy crops has been carried out in accordance with DIN 38414, in the mesophilic range (35 °C). Production of biogas was measured daily and at the same time determines the composition of biogas (CH_4, CO_2 and O_2) with gas detector GA 45 Geotechnical Instruments. In the experiment we capture more energy crops: amaranth (Amaranthus sp.), sorghum (Sorghum halapense), maize (Zea mays), jerusalem arthicoke (Helianthus tuberosus) and sunflower (Helianthus annuus). The maximum content of biogas we have set for the sunflower 335 NL / kg VS, followed by corn 327 NL / kg VS, sorghum with 312 NL / kg VS, jerusalem arthicoke with 224 NL / kg VS and amaranth with 197 NL / kg VS. The average methane content in biogas was 51,8-62,8% and carbon dioxide 32,4 – 40,0%. For all determinations the oxygen content was under 1% that indicates that the fermentation was anaerobic. Results of tests have shown the most suitable energy plant sunflower and maize with the highest content of methane, meanwhile in the future other alternative energy plants have to be tested (clover, sudan grass, etc.).

Key words: *biogas, mini digestor, energy plants*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:631.879:634.1
Stručni rad
Expert paper

POSSIBILITIES OF USING FRUIT PROCESSING RESIDUES AS A FUEL

M. DJEVIC, ALEKSANDRA DIMITRIJEVIC

Deparmtnet for Agricultural Engineering, Faculty of Agriculture,
University of Belgrade, Serbia,mdjevic@agrif.bg.ac.rs; saskad@agrif.bg.ac.rs

SUMMARY

Energy demand in the world and limited sources of fossil fuels impose larger amounts of renewable energies. Agriculture production can be very important factor as a renewable energy producer concerning large amounts of biomass from primary plant production. This potential, if used in a proper way can be very important source of energy. In recent times, besides primary plant production, fruit and plant processing industry has been recognized as potential source of energy regarding residues after processing. In that sense, aim of this paper was to estimate potential of food processing industry for producing biomass that can be used as fuel. As potentially good fruit species kernel and nut fruit species were analyzed. Results show that average annual amount of residues from fruit industry, in Serbia, can not be neglected. This burning material however, can not be used as primary and only heat source. It must be combined with coal. In the case of good quality coal its daily amount could be, approximately 30% lower. This is very significant fact considering today's energy consumption in the region.

Key words: *fruit, biomass, processing, kernel (pits), fuel, energy.*

INTRODUCTION

Limited resources of raw materials, in particular fossil energy fuels impose a question about more intensive use of renewable energy sources. Biomass is considered to have a great potential in solving this problem. It can be used as fuel for heating small and medium households that are close to biomass source or are agricultural producers aware of biomass importance. The importance of biomass and its exploitation is even higher in the region with intensive agricultural production.

At the moment wheat, soya, maize and sunflower straw as well as fruit and vine pruning residues are used for fuel production. However, there are some trials in using fruit processing residues such as kernels and shells as renewable energy source. The benefit of using this kind of material is that it represents ballast for processing industry, it is available in large amounts and in fact that it has economical combustion with very small amounts of ash. It can be used without any special preparation and processing. Further advantage is that fruit processing is mainly done in autumn when the heating season starts, so there is no need for any special storage facilities for long storage periods. This kind of material is also very suitable for small and medium burners in greenhouse production thus enabling earlier seeding, longer period of harvesting and more economical production.

The aim of this paper is to show what is the amount of food processing residues and, in that sense their energy value in order to be used as a fuel. Annual production of kernel fruit was analyzed in order to evaluate potential quantities of fruit for further processing and, in that sense, potential quantities of burning material. As a final result potential quantities of fuel from fruit processing industry were obtained.

MATHERIAL AND METHOD

In order to evaluate quantities of residues from fruit processing industry statistical data from Republic Institute for Statistic and Society of Fruit and Vegetable Producers were used. Analysis included kernel and nut fruit such as plums, cherry, sour cherry, apricot, peach and walnut. In order to evaluate energy potential of fruit processing residues as fuel, an experiment was conducted in Institute "Tamis" in Pancevo. For the experiment plum kernels were used as burning material for heating the offices at the Institute. There is a standard central heating system (with hot water) at the Institute and this system was used in the experiment (Figure 1). It consists of two boilers "Vulkan Super". Working pressure of the boiler was 1.5 bar and projected temperature was not to be over 900 C.

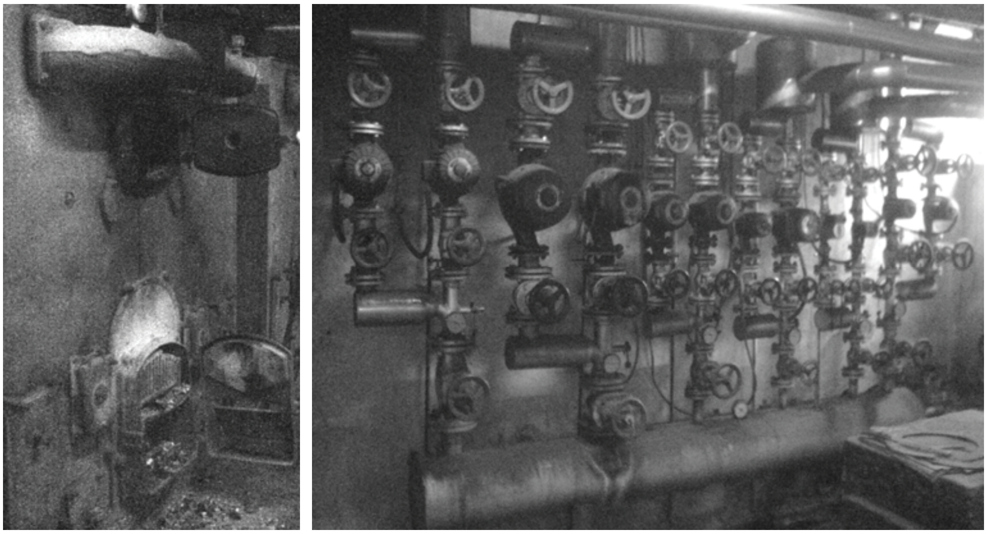


Figure 1 Burner and valve assembly

Filling of the burner with kernels was done manually. During the experiment several parameters were observed such as time to working temperature, water temperature at the start, water temperature at the end, outside temperature, temperature in the offices and quantities of coal and kernels.

RESULTS AND DISCUSSION

Data about fruit processing residues are not entirely investigated. However, some approximate evaluation can be made according to average fruit yield and based on biological characteristics of fruit and kernel. It is possible to estimate the share of a kernel in total mass of fruit and then, based on the total yield give some prediction about the amount of fruit residues potentially available.

Average fruit production in Serbia region for typical kernel and nut species is presented in table 1. Based on these values and characteristics of fruit and kernel potential available quantities of shells and kernels, that can be used as biomass potential, are given (Table 2).

Table 1 Fruit production in Serbia [8]

Specie	Average fruit yield, 000 t					
	2002	2003	2004	2005	2006	Average
Plums	197,00	571,00	561,00	304,00	556,00	437,80
Cherries	15,70	25,70	30,80	19,80	23,30	23,06
Sour cherries	48,90	86,20	112,30	63,90	80,50	78.36
Apricot	13,40	27,40	40,80	13,60	21,90	23,42
Peaches	42,30	55,80	58,00	51,60	59,10	53,36
Walnuts	10,20	24,90	22,20	20,60	23,80	20,34
Total	327,5	791,00	825,10	473,50	764,60	636,34

One part of total fruit production is used in fresh condition while the rest of it goes to food processing industry. Table 2 gives possible quantities in the case that all fruit is processed thus giving an idea about maximal biomass potential from the fruit industry. Kernels represent a ballast for food processing industry as well as for the individual farmers so it can be concluded that values in Table 2 could be more realistic if some kind of organized collecting, storage and distribution of kernels and shells to potential users is done.

However, present state at the fruit market indicates that greater share of total fruit production is directed to food processing industry. According to data obtained from Society of Fruit and Vegetable Producers of Serbia (Table 3) fruit is dominantly used for fruit pulp production, fruit juices, jam and compotes.

Table 2 Potential amount of fruit processing residues

Specie	Average fruit processing residues, t					
	2002	2003	2004	2005	2006	Average
Plums	1180	34260	33660	18240	33600	26268,0
Cherries	2198	3598	4312	2772	3262	3228,4
Sour-cherries	4401	7758	10107	5751	7245	7052,4
Apricot	670	1370	2040	680	1095	1171,0
Peaches	2961	3906	4060	3612	4137	3735,2
Walnuts	5100	12450	11100	10300	11900	10170,0
Total	16510	63342	65279	41355	61239	49545,0

Table 3 Fruit processing in Serbia [9]

Fruit processing and conservation, t	2002	2003	2004	2005	2006
Fruit pulp, pasteurized, frozen, canned	7517,00	6915,00	24753,00	14205,00	22938,00
Frozen fruit	25426,00	19591,00	66008,00	37880,00	61168,00
Fruit juices	52862,00	61570,00	140267,00	80495,00	129982,00
Jam	845,00	481,00	12376,50	7102,50	11500,00
Compotes	371,00	1335,00	8251,00	4735,00	7600,00
Walnuts without shells	14,44	13,00	41,26	24,00	38,23

Based on these values and the quantities of fruit needed for the production potential fruit processing residue quantity can be calculated. If heating value is known (Table 4) energy potential from fruit processing residues could be calculated (Table 5).

Table 4 Heating value data for fruit processing residues [12]

Type of biomass	Heating values (MJ/kg dry matter)		Approximate analysis (%)	
	Upper	Lower	Volatile part	Ash
Cherry pits	21,75		84,20	1,00
Peach pits	20,82	19,60	79,12	1,03
Plum pits	21,14		58,3	0,10
Walnut shells	20,18	18,99	78,28	0,56

Table 5 Energy potential of processing residues as fuel

Type of biomass	Average available amount, t	Energy potential, GJ/year
Cherry pits	7052,40	153389,70
Peach pits	3735,20	77766,86
Plum pits	26268,00	555305,52
Apricot pits	1171,00	24532,45
Walnut shells	10170,00	205230,60
Total	48396,60	1016225,13

Obtained values can be compared with available quantities of biomass from primary plant production (crop, fruit and vine). Crop production is most important source of biomass and its energy potential for Serbia region is around 40 000 TJ [5] while 900 TJ can be obtained from pruning residues from orchards and vineyards [10]. This values show that biomass potential from primary plant production must not be neglected.

Results from the experiment that was carried out at the Institute Josif Pancic can indicate what is real potential of fruit processing for heating of the buildings. The aim of the experiment was to see what effect have kernels, used as additional fuel, on total energy consumption. In Table 6 basic measured parameters are presented. Values obtained are collected during few days in March and April in 2005.

Table 6 Results from plum kernels usage as burning material

Measured parameter	Unit	Date								
		21.3.	22.3.	23.3.	24.3.	25.3.	28.3.	29.3.	30.3.	4.4.
Outside temperature	C^0	0.4	1.2	2.2	6.7	10.6	11.2	8.6	5.4	2.2
Time to working temperature	h	2	2	2,5	2,5	2,5	2,5	2,5	2,5	2
Water temperature on beginning	C^0	75	75	80	75	70	60	80	80	70
Water temperature at the end	C^0	60	60	72	66	60	52	70	70	60
Temperature in the offices	C^0	23	22	23	22	23	22	26	23	22
Number of burners		2	2	2	2	2	1	2	2	2
Coal used – Banovici	kg	540	360	360	360	480	360	240	240	240
Coal used – Kovinac	kg	144	-	-	288	-	-	-	-	-
Coal used – Vreoci	kg	-	270	315	-	-	-	-	-	-
Kernel used	kg	-	-	-	-	90	90	360	180	135
Total amount of coal	kg	684	630	675	648	480	360	240	240	240

In case of using only kernels it is observed that temperature growth was 100 C and that after a while drops to a constant level. It could also be seen that kernels should not be used as basic fuel but in combination with some light coal.

Results show that kernels can be an adequate supplement for light coal enabling lower energy consumption. Kernel usage can also influence lowering high caloric value coal quantity even for the 33%. In that case lower temperature on the end of the system was observed but no changes in heating quality in the offices. Figure 2 gives the quantities of coal and kernels used as fuel as well as the outside temperature.

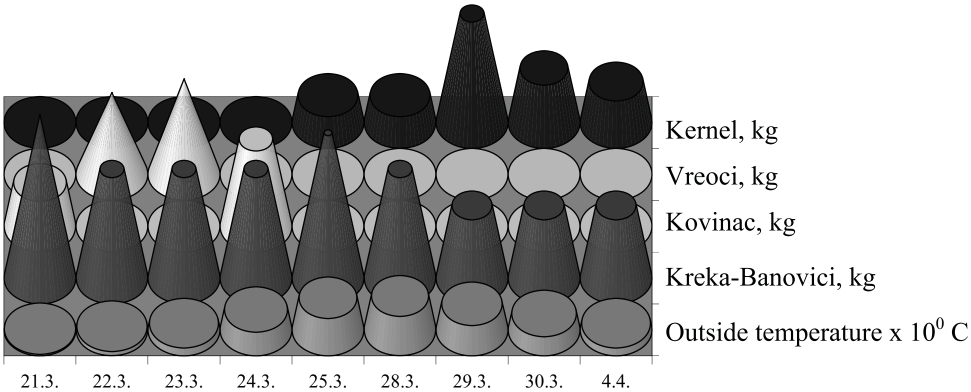


Figure 2 Coal and kernel consumption for measured period

Data show that temperature correction in offices can be done only with kernels leaving the coal consumption on a constant level. In that case more precise temperature regulation was obtained with kernels than in the case if coal is used. With combination of coal and kernel total coal consumption can be predicted with very good precision. In this way much of the energy can be saved as well as money.

CONCLUSION

Recent reports indicate that agriculture can be a very important supplier of biomass that, after simple processing can be used as fuel. Not very often pruning residues from orchards and vineyards as well as fruit processing residues are mentioned as potential renewable energy source. Quantities of kernels and shells after fruit processing must not be neglected, specially when this material represent ballast for the processing industry as well as for the individual farmers in sense of storage space.

Fruit processing industry in Serbia region is in state of intensive development. This leaves the problem of high quantities of kernels and shells storage. There was an idea to try to use this material for burning. Results confirm that these materials can be used as a fuel but not as main burning material but as additional combined with low caloric values coal. Results of investigation presented in this paper show that in the case of plum kernels use, energy saving in coal could be up to 60%. On the other side, these materials are easy on burning and do not leave much ash after burning. They are also very useful in fine temperature regulation thus enabling more significant energy and money saving.

REFERENCES

1. Aranda-Heredia E. (1981): Recolte mecanique de la biomasse a destination energetique: le bois de taille de l'olivier, Atti Simp. Intern. Meccanizz. Agricola. Bologna.
2. Gigler, J. K., de Mol, M. R., Curvers, M. W. P. A. (1966): Logistics of biomass fuel collection, Proceeding of 9^{th} European Bioenergz Conference, Copenhagen, Denmark
3. Jovanović, Lj. (1997): Biomasa usvetu, Biomasa - obnovljivi izvori energije, Monografija, Biblioteka naučnoistraživačkih dostignuća, Jugoslovensko društvo termičara, str. 19-24, Beograd.
4. Novaković, D., Đević, M., Veličković, M. (1997): Mehanizovano sakupljanje produkata rezidbe u voćnjacima, Časopis Jugoslovensko voćarstvo, Vol. 31, Br.119-120, str. 329-333, Čačak
5. Monografija - Novaković D., Đević M. i dr. (1997): Biomasa - obnovljivi izvor energije, Jugoslovnesko društvo termičara, Edicija Oka S., Jovanović Lj., str. 53-67. Beograd.
6. Pimentel D. (1980): Handbook of energy ultilization in agriculture CRC Press. Boca Raton.
7. Perunovic, P., Pecenjanski, I.: Koriscenje biomase u energetske svrhe, Zbornik radova, Znacaj i perspektiva briketiranja biomase, Ekološki pokret Vojvodine i Šumarski fakultet - Beograd, april 1996, 69-74, Vrnjačka Banja
8. Statistical Yearbook for Republic of Serbia for 2007.
9. Zajednica za voće i povrće Republike Srbije
10. Đeivć, M., Marković, N. (2005):Energetski potencijal biomase vinograda, Poljoprivredna tehnika, XXIX, br. 2, str. 45-53
11. Mićić J., Ercegović Đ., Novaković D., Đević M., Oljača V. M., Radivojević D., Božić S. (1997): Savremena poljoprivredna tehnika u biljnoj proizvodnji, Monografija, Univerzitet u Beogradu
12. Kitani, O. and C. W. Hall, eds. 1989. Physical properties of biomass. Biomass Handbook, pp. 880–882. New York: Gordon and Breach.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 632.931:634.1
Stručni rad
Expert paper

EXPERIMENTAL SETUP TO STUDY THE LOCAL RENEWABLE ENERGY POTENTIAL AND THE ENVIRONMENT INFLUENCE ON FRUITS GROWING

MUGUR BALAN[1], SORANA BOLBOACA[2], RADU SESTRAS[3], LORENTZ JANTSCHI[1]

[1]Technical University of Cluj Napoca
B-dul. Muncii 103-105; 400641 Cluj-Napoca; Romania
[2]"Iuliu Hațieganu" University of Medicine and Pharmacy Cluj-Napoca
Str. Emil Isac 13, 400023 Cluj-Napoca
[3]University of Agricultural Sciences and Veterinary Medicine
Cal. Manastur 3-5; 400372 Cluj-Napoca
mugur.balan@termo.utcluj.ro; sbolboaca@umfcluj.ro; rsestras@usamvcluj.ro; lori@academicdirect.org

ABSTRACT

The paper is presenting an experimental setup designed for a double purpose. The researches will be focused on the evaluation of the local renewable energy potential in the region of Cluj-Napoca, Romania and on the study of the environment influences on the plants growing, considering different horticultural species. The experimental setup is based on two complex wireless meteorological stations and two wireless leaf and soil moisture stations. The environment and weather parameters are systematically measured with a baud rate of one minute and stored in and a database, integrated into a web designed data acquisition system. The parameters characterizing different fruits growing are measured daily. Solar radiation together with wind speed and direction will be used to evaluate the local solar energy potential and the other measured parameters, such as outside temperature, quantity of precipitation, leaf wetness, soil wetness, soil temperature, air humidity, solar radiation, ultra violet radiation, etc., will be used to highlight the combined influence of these parameters to the growing process of different fruits, such as apples and pears.

Key words: *Solar, Wind, Monitoring, Environment, Data Acquisition, Database, Fruits*

INTRODUCTION

The paper approaches a very important subject for our day's complex situation, in both fields of renewable energies and agriculture. The world and financial and economical crisis is affecting both fields and both can offer viable solutions for the future development of the humanity.

In Cluj-Napoca, Romania, scientists from three important universities decided to cooperate and to develop a complex experimental setup, designed with a double purpose. The experimental equipment is used in a metropolitan area as a web based data acquisition system. The data are collected and stored into a database on a dedicated web server and will be used both to evaluate the local potential of the solar and wind energy on one hand and to study the influence of a large number of environment and weather parameters, on the growing process of different fruits, such as apples and pears.

The influence of different weather parameters are reported in the scientific literature, in paper such as [1] - [7].

Growth estimation, considering different weather parameters is presented in [8].

The humidity of the soil, resulting from irrigation and its influences is presented in [9]. The influence of the rain is approached in [10].

Different thermodynamic effects, such as evapotranspiration and evaporative cooling, are presented in [11] and [12].

From the renewable energies point of view, the paper is continuing previous researches of some authors of the paper, presented in [13…15].

METHODS

The experimental setup presented in the paper is characterized by a relative large coverage area. The measurement points are situated at about 9 km distance between each other, as indicated in figure 1.

In each measurement point were placed a weather station and a distinct leaf & soil moisture / temperature station. The weather station is of Vantage Pro2 Plus wireless type provided by the manufactured Davis Instruments from USA and the leaf & soil station is equally provided by the same manufacturer. Both measurement stations located on each measurement point are transmitting the collected data, based on a wireless radio communication system to a receiver console. A data logger is connected both at the console and at a computer connected to the internet.

Using the indicated performing equipment it was designed an original experimental setup able to be driven in a particular manner, to reach both objectives of the research: evaluation of the renewable energy potential and study the influence of the environment parameters to the growing process of the fruits.

Each weather station is providing the following parameters:

- Barometric pressure;
- Outside temperature;

- Relative Humidity;
- Rainfall;
- Solar radiation;
- Ultra violet radiation dose;
- Ultra violet radiation index;
- Wind direction;
- Wind speed.

Fig. 1 Placement of the measurement points in Cluj-Napoca, Romania

Each leaf & soil station is providing the following parameters:

- Leaf wetness (two measurement points);
- Soil moisture (four measurement points);
- Soil temperature (four measurement points).

The configuration scheme of the data acquisition system implemented on each measurement point is presented in figure 2.

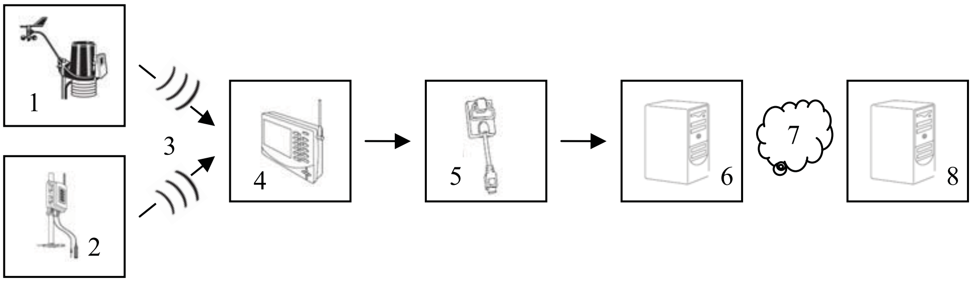


Fig. 2 Schematic configuration of each measurement point
1 - weather station; 2 - leaf & soil station; 3 - wireless radio communication; 4 - console; 5 - data logger; 6 - local PC; 7 - internet connection; 8 – server

Table 1 Main characteristics of the weather stations sensors

Parameter	**Characteristic**	**Value**	**Obs.**
Barometric pressure	Resolution	0.25 mm Hg	Other units are converted from Hg and rounded
	Range	406…850 mm Hg	
	Accuracy	±1.0 mm Hg	
	Elevation range	-460…4670 m	
Outside temperature	Resolution	1 °C	Converted from Fahrenheit and rounded
	Range	-40…+65°C	
	Accuracy	±0.5°C	
Relative Humidity	Resolution	1%	
	Range	0…100%	
	Accuracy	±3%	
Rainfall	Resolution	0.2 mm	With metric adaptor
	Range	0…19999 mm	
	Accuracy	±4%	
Solar radiation	Resolution	1 W/m^2	
	Range	0…1800 W/m^2	
	Accuracy	±5%	
Ultra violet radiation dose	Resolution	1 MED	
	Range	0…199 MED	
	Accuracy	±5%	
Ultra violet radiation index	Resolution	0.1 index	
	Range	0…16	
	Accuracy	±5%	
Wind direction	Resolution	1°	
	Range	0…360°	
	Accuracy	±4°	
Wind speed	Resolution	0.1 m/s	Converted from mph
	Range	0…67 m/s	
	Accuracy	±5%	

On each of the two local PC, located at each measurement point is continuously running dedicated software for data acquisition and specially realized software for the data transfer on the server, through the internet connection.

On the server, is continuously running a server type software application to receive the data from the two measurement points and to store the data in a specially designed database. A web based interface was created to interrogate the database and to display the user requested specific data. It can be selected specific values for specific data for specific periods such as one hour, one day, one month, one year, or user specified period.

The database from the server can be interrogated from distance from a computer, using internet connection and a browser.

The weather stations are equipped with sensors having the main characteristics indicated in table 1.

The weather stations are processing the data collected from the sensors and are providing the parameters indicated in table 2, using the equally indicated methods.

Table 2 Parameters calculated by the weather stations

Parameter	Calculation method
Dew point	World Meteorological Organisation equation
Rain rate	Rainfall / Time
Evapotranspiration	Penman-Monteith Equation
Heat index	Steadman (1979) modified
Temperature humidity sun wind index	NWS / NOAA* / Steadman (1979) modified
Wind chill	NWS / NOAA* / Osczevski (1995)

* US National Weather Service / National Oceanic and Atmospheric Administration

The leaf & soil stations are equipped with sensors having the main characteristics indicated in table 3.

Table 3 Main characteristics of the leaf & soil stations sensors

Parameter	Characteristic	Value	Obs.
Leaf wetness	Resolution	1	
	Range	0…15	
	Accuracy	±0.5	
Soil moisture	Resolution	1 cb	
	Range	0…200 cb	
	Accuracy	-	
Soil temperature	Resolution	1 °C	Converted from Fahrenheit and rounded
	Range	-40…+65°C	
	Accuracy	±0.5°C	

DISCUSSION

The actual state of the presented experimental setup is the following. The two weather stations are acquired and tested. The wireless transmission was tested for all the equipment. The local data acquisition system (hardware + software) was tested and two notebooks were acquired and dedicated to this activity. The server dedicated for data storing is acquired and tested. The server database was designed and is in the phase of implementation. To resume, all the positions 1 - 6 and 8 indicated on figure 2, are already tested and are working properly. The only element that must me realized, is the data transmission through internet from the two local PC to the server database.

CONCLUSIONS

Cooperation between researchers from three local Universities from Cluj-Napoca, Romania was established, in order to realize a complex experimental setup, with two goals:

- Evaluation of the local renewable energy potential;
- Study the influence of some relevant environment parameters to the growing process of different fruits, such as apples and pears.

The data systematically provided by the two types of measurement stations, with a baud rate of one minute, will be correlated by specific statistical methods, with daily measurements of fruits.

The data will be collected for a long time period, in order to extract and provide relevant information.

The presented experimental setup, have a large potential to extend the researches to other elements such as weather and environment parameters influence in a lot of agricultural applications. The data acquisition system can be also completed with analyzers of other environment parameters, such as polluting emissions in air, water or soil. The influences of these elements are also in the attention of the authors.

REFERENCES

1. Menzel, A. (2003) - Plant phenological anomalies in Germany and their relation to air temperature and NAO, Climatic Change 57 (3), pp. 243-263
2. Roujou de Boubee, D., Van Leeuwen, C., Dubourdieu, D. (2000) - Organoleptic impact of 2-methoxy-3-isobutylpyrazine on red Bordeaux and Loire wines. Effect of environmental conditions on concentrations in grapes during ripening, Journal of Agricultural and Food Chemistry 48 (10), pp. 4830-4834
3. Caprio, J.M., Quamme, H.A. (1999) - Weather conditions associated with apple production in the Okanagan Valley of British Columbia, Canadian Journal of Plant Science 79 (1), pp. 129-137
4. Gil, A., De la Fuente, E.B., Lenardis, A.E., López Pereira, M., Suárez, S.A., Bandoni, A., Van Baren, C., (...), Ghersa, C.M. (2002) - Coriander essential oil composition from two genotypes grown in different environmental conditions, Journal of Agricultural and Food Chemistry 50 (10), pp. 2870-2877

5. Warmund, M.R., Guinan, P., Fernandez, G. (2008) - Temperatures and cold damage to small fruit crops across the eastern United States associated with the April 2007 freeze, HortScience 43 (6), pp. 1643-1647
6. Szalay, L., Papp, J., Szabó, Z., Pedryc, A. (2006) - Influence of the changing climate on flower bud development of apricot varieties, Acta Horticulturae 717, pp. 75-78
7. Stover, E.W., Greene, D.W. (2005) - Environmental effects on the performance of foliar applied plant growth regulators: A review focusing on tree fruits, HortTechnology 15 (2), pp. 214-221
8. Mandal, S., Pal Choudhury, J., Chaudhury, S.R.B., De, D. (2007) - Growth estimation with artificial neural network considering weather parameters using factor and principal component analysis, Proceedings - 10th International Conference on Information Technology, ICIT 2007, art. no. 4418263, pp. 35-37
9. Jerapat, S., Siriphanich, J. (2008) - Effect of irrigation on dry matter of durian pulp cv. Monthong, Acta Horticulturae 768, pp. 251-255
10. Ortega, E., Dicenta, F., Egea, J. (2007) - Rain effect on pollen-stigma adhesion and fertilization in almond, Scientia Horticulturae 112 (3), pp. 345-348
11. Jaber, F., Shukla, S., Srivastava, S. (2007) - Evapotranspiration losses for drip-irrigated watermelon in shallow water table and sandy soil conditions, 2007 ASABE Annual International Meeting, Technical Papers 3 BOOK
1. 12. Iglesias, I., Salvia, J., Torguet, L., Montserrat, R. (2005) - The evaporative cooling effects of overtree microsprinkler irrigation on 'Mondial Gala' apples, Scientia Horticulturae 103 (3), pp. 267-287
12. Balan,M., Damian,M., Jantschi,L. (2008) - Preliminary Results on Design and Implementation of a Solar Radiation Monitoring System, Sensors, 2008 (8) pg. 963-978
13. Balan,M., Damian,M., Jantschi,L. (2008) - Solar Radiation Monitoring System, 36th International Symposium, Actual Tasks on Agricultural Engineering, 11-15 February 2008, Opatija, Croatia, pg. 507-517
14. Balan,M., Damian,M., Jantschi,L., Ion,I. (2008) - Study concerning the Influence of Some Working Conditions on the Heat Pumps Performances, 36th International Symposium, Actual Tasks on Agricultural Engineering, 11-15 February 2008, Opatija, Croatia, pg. 535-544

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.91:631.365.2
Stručni rad
Expert paper

PRELIMINARY RESULTS FROM THE TEST OF SOLAR DRYER

*MALIN TSVETKOV, **NIKOLAY MIHAILOV, *SVETLOZAR MITEV, **BORIS BORISOV

*Test Centre for Agricultural, Forest Machinery and Spare Parts – Ruse, Bulgaria, e-mail: testlab@dir.bg
**Angel Kanchev University of Ruse, Bulgaria, e-mail: mihailov@ru.acad.bg

SUMMARY

Solar food dryer with plane collector was evaluated at float. During tests the collector is closed with simple and K glass. Ambient, chamber and collector temperatures are measured at opened and closed solar food dryer valves.

***Key words**: solar food dryer, K glass, drying, temperature and collector*

INTRODUCTION

One of the most popular technological processes in the industry is drying. Very often it determines to a considerable extent the quality of the product. As the elimination of the moisture from the product requires a considerable quantity of energy, the elaboration of an installation with low energy consumption should represent an interest.

Bulgaria has the suitable micro-climate conditions for the usage of solar dryers.

PRESENTATION

The aim of the experiment is to evaluate the performance of a solar dryer at float when a simple or K glass is placed on top of the collector. The K-glass represents a transparent glass with crystal-white reflection tinge and high thermal protection. One side of the glass is processed with metal oxide.

The dryer built for the purpose is adjustable, passive, with a simple, plane solar collector. The performance of the collector is evaluated through the efficiency of collecting of solar energy. It is determined as a relation of the stored energy to the energy of the sunlight which falls to the surface of the collector. The efficiency of the solar collector depends on the velocity of the air flow through the collector, the geometry of the air canal, the efficiency of the absorbing surfaces (thermal accumulator) and the permeability of the covers.

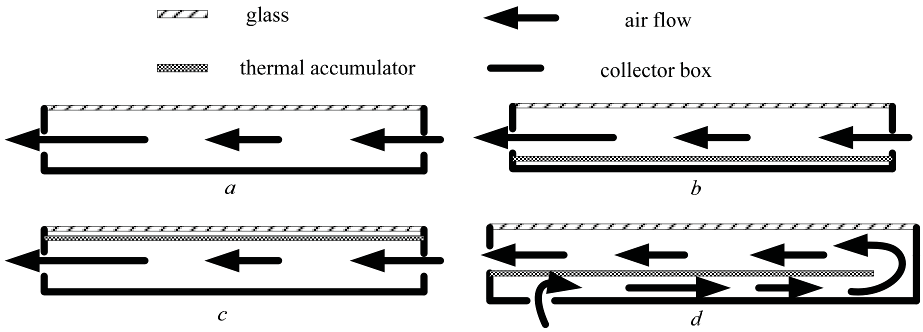


Fig. 1 Modifications of plane collector with and without absorber plate: a) The air flow passes through the collector without a thermal accumulator; b) The air flow passes above the thermal accumulator; c) The air flow passes below the thermal accumulator; d) The air flow circulate around the thermal accumulator

The simple type of a plane collector forms an air canal, the cover of which is absorbent and the efficiency reaches (45…50) % - (Fig. 1a) [3]. If a thermal accumulator is embedded in the air canal of the plane collectors, additional three modifications are formed (fig. 1 b, c and d). In that case the efficiency reaches (60…65) % [3].

The general look and the technological scheme of the dryer, designed and produced for the experiment, are shown on fig. 2 and fig. 3.

Fig. 2 General look of the dryer

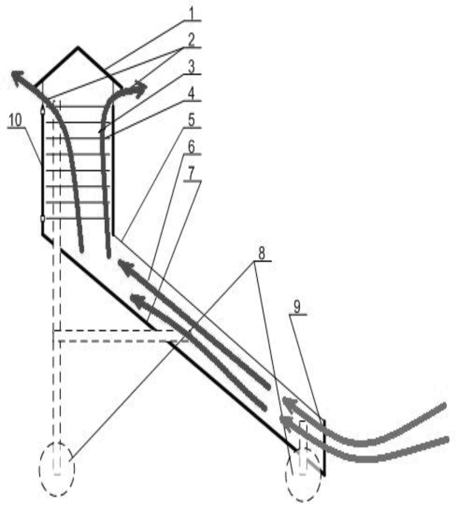


Fig. 3 Technological scheme of the dryer

An air collector 6 is used for the heating of the drying agent (air) by the sun energy. It is plane, inclined at an angle of 45° in relation to the earth surface. There is a glass cover 5 above it and inside it is painted in black. For the purpose of achieving a higher efficiency of the collector, it must have the right dimensions - the depth must be 1/15...1/20 part of its length [1]. Thermal shield is spread onto the dryer and its chamber 3. It secures high thermal insulation and prevents the appearance of mold in the chamber 3 when the dryer is not in use [2]. The chamber is situated on the upper end of the collector because in this way the convectional movement of the heated air is used. A possibility for forced movement of the air is created for the purpose of prevention of mold when no sun heat is present. The described dryer is mobile where the construction is mounted on wheels 8 and can be moved by one person only. In the chamber, grid trays 4 are situated one above another and the food is placed on them. By this arrangement, the heated air passes consecutively through all trays and leaves through the openings 2, situated on the upper part of the chamber 3 under the roof 1. The products for drying are placed on the trays through the door 10. The input opening 9 is situated on the fore part (down side) of the collector. A damper-type valve is mounted on it so that the air flow can be controlled as well as the velocity and the temperature of the air, and finally the dynamics of the drying process are controlled.

The tests were carried out on sunny and cloudless days when wind velocity was under 0,1 m/s. The ambient temperature t_{amb}, the temperature inside the drying chamber t_{int} and the collector t_c were measured. For measuring the temperature and the air flow velocity a combined device *testo 425* was used. Its measuring accuracy, when measuring the temperature, is to 0,1°C and when measuring the air flow – to 0,01 m/s. The measuring interval is 30 min, and at the same interval the dryer is repositioned so that the collector keeps facing the sun.

The test results are shown on fig. 4, 5, 6 and 7.

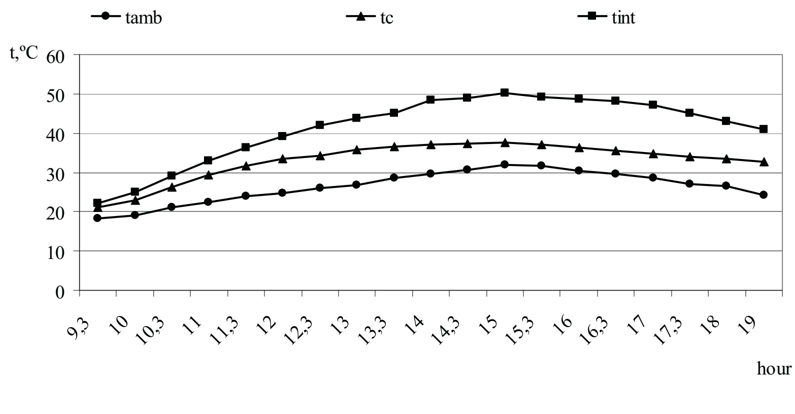


Fig. 4 Daily variation of the ambient temperature t_{amb}, the temperature inside the collector t_{int} and inside the chamber t_c when the damper-type valves are fully open and the collector is covered with K-glass

The maximum ambient temperature, reached at 15.30 o'clock, is 31,9°C. At the same time, the temperature inside the chamber is 37,6°C and inside the collector – 50,2°C. It is clear that the increase of the temperature in the chamber, when the valve is open, is insignificant - with 5,7°C.

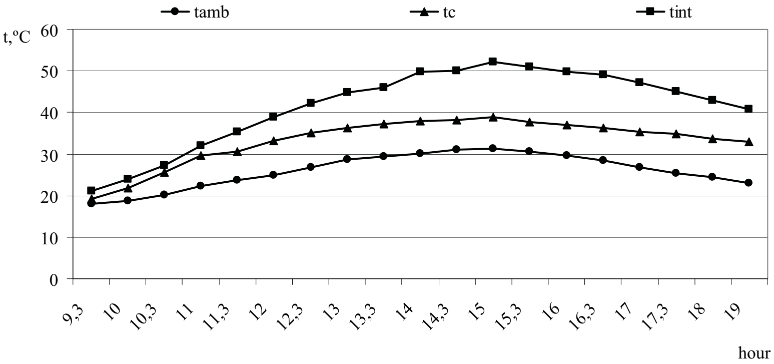


Fig. 5 Daily variation of the ambient temperature t_{amb}, the temperature inside the collector t_{int} and inside the chamber t_c when the damper-type valves are fully closed and the collector is covered with K-glass

When the valves are closed and the maximum ambient temperature is 31,4°C, the temperature in the chamber is 38,8°C, and in the collector – 52,2°C. Even in this case, the increase of the temperature is small – 7,4°C. The increase of the temperature values in the chamber and the collector are by 2°C compared to the case when the valves are open.

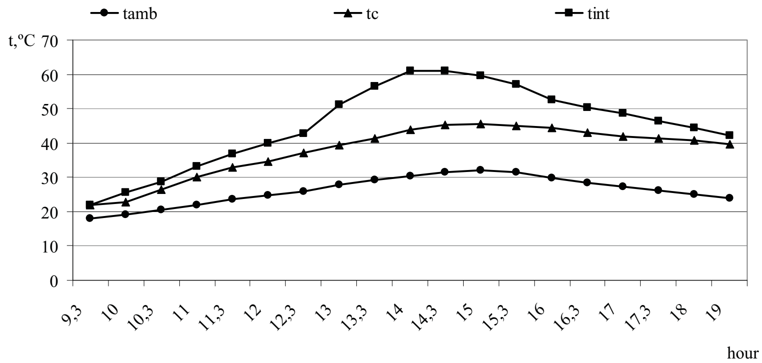


Fig. 6 Daily variation of the ambient temperature t_{amb}, the temperature inside the collector t_{int} and inside the chamber t_c when the damper-type valves are fully open and the collector is covered with a simple glass.

When the ambient temperature is 32°C, the temperature inside the chamber is 45,5°C, and in the collector is 61°C. The increase of the temperature value in the chamber compared to the ambient temperature is by 13,5°C.

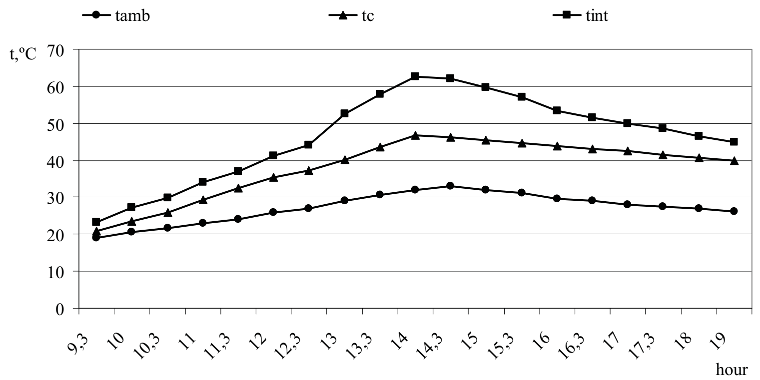


Fig. 7 Daily variation of the ambient temperature t_{amb}, the temperature inside the collector t_{int} and inside the chamber t_c when the damper-type valves are fully closed and the collector is covered with a simple glass

The variation of the temperature is approximately the same when the valves are closed. The ambient temperature is 32,9°C and the temperature in the chamber reaches 46,7°C. The value is increased by 13,8°C. In this modification, the maximum temperature in the collector is measured – 62,7°C.

Figures 8 and 9 show the comparison between the temperatures in the drying chamber when the collector is closed with a simple glass and K-glass, respectively when valves are closed (fig.8) and open (fig. 9).

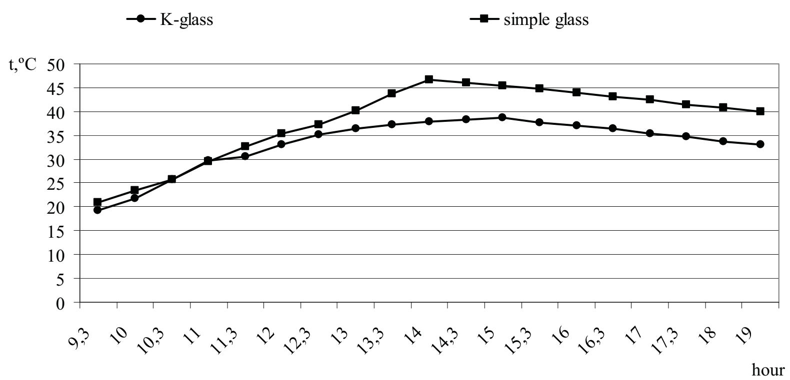


Fig. 8 Daily variation of the temperatures in the drying chamber when the collector is covered with simple glass and K-glass and the valves are fully closed

When K-glass is used for covering the collector, it is found out that the temperature in the drying chamber is lower by about 10°C. The reason for this is that the K-glass transforms the short waves in long waves and retains the heat in the space which it covers [4]. The glass lets in only part of the sun light (UV – 3%; visible light – 44%; IR – 53%), another part is reflected and a third part is absorbed [4]. The glass does not let waves which length is above 2500 nm, but absorbs a certain part of them. This imposes (having in mind the purpose of the glass) that the air is exhausted from the glazed unit and to fill it with gas – argon, krypton or xenon. In this way the glass is proof against breaking. On the other hand, the permeability of the glass is additionally reduced. The different companies guarantee reduction in the limits of (18…22) %.

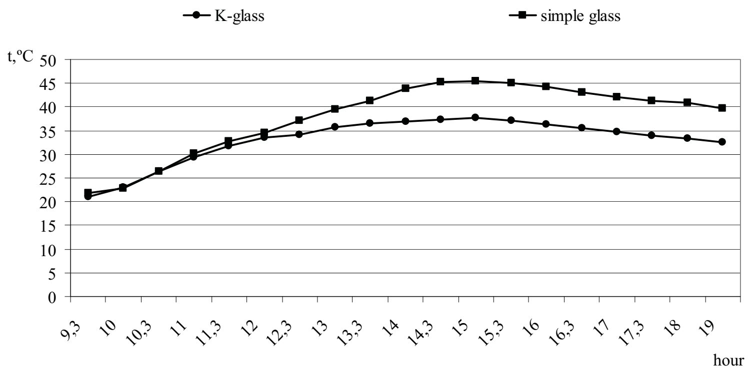


Fig. 9 Comparison between the temperatures in the drying chamber when the collector is covered with a simple glass and K-glass and the valves are fully open

CONCLUSION

The expected difference between the temperature in the drying chamber and the ambient temperature is not enough and this is due to the insulating capacity of the thermal shield and the absence of a thermal accumulator. During forthcoming tests, an appropriate thermal accumulator will be searched for.

The K-glass has better insulating quality but its filling with gas decreases the permeability with (18…22) % and leads to a lower temperature in the dryer.

REFERENCE

1. Dennis Scanlin, Indirect, through-pass, solar food Dryer, 1997;
2. Renewable energy world, volume 10;
3. www.utilitiesbulgaria.com.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.879.4
Izvorni znanstveni rad
Original scientific paper

EFFECT OF REACTOR SIZE ON COMPOSTING OF AGRICULTURAL WASTE

IVAN PETRIC[1], ALMIR ŠESTAN[2], INDIRA ŠESTAN[3]

[1]Department of Process Engineering, Faculty of Technology, University of Tuzla
Univerzitetska 8, 75000 Tuzla, Bosnia and Herzegovina, e-mail: ivan.petric@untz.ba
[2]Department of Chemistry, Faculty of Science, University of Tuzla, Univerzitetska 4
75000 Tuzla, Bosnia and Herzegovina
[3]Department of Physical Chemistry, Faculty of Technology, University of Tuzla
Univerzitetska *8, 75000 Tuzla, Bosnia and Herzegovina*

SUMMARY

The main objective of this study was to compare the performance of composting process of two important agricultural wastes in Bosnia and Herzegovina (poultry manure and wheat straw) in two reactors with different sizes (1 L and 32 L). The experiment was carried out under adiabatic conditions for 14 days. The effect of reactor size on the characteristics of composting process was monitored in terms of temperature, emission of carbon dioxide and ammonia, oxygen consumption, organic matter conversion, pH and electrical conductivity. The higher values of these characteristics were achieved in the large reactor than in the small reactor. The temperature in both reactors was maintained above 55°C for 2 days, which should be sufficient to maximize sanitation and to destroy pathogens.

***Key words**: Composting, reactor, agricultural waste, poultry manure, wheat straw.*

INTRODUCTION

In 2006 the total live poultry stock in Bosnia and Herzegovina was 12 731 564 birds (Federation of Bosnia and Herzegovina – 5 385 000 birds (Federal Office of Statistics, 2007a), Republika Srpska – 7 346 564 birds (Republika Srpska Institute of Statistics, 2007a)). On the other hand, in 2006 the total wheat production in Bosnia and Herzegovina was 219 441 t from harvested area 67 799 ha (Federation of Bosnia and Herzegovina – wheat straw 65 492 t with area harvested 20 015 ha (Federal Office of Statistics, 2007b);

Republika Srpska – wheat straw 153 949 t with area harvested 47 784 ha (Republika Srpska Institute of Statistics, 2007b). Therefore, poultry and wheat represent two important agricultural industries in Bosnia and Herzegovina generating large amount of manure and straw. Composting poultry manure with wheat straw could offer many environmental and economic benefits for the country like Bosnia and Herzegovina.

Organic fraction of this solid waste can be degraded either in non-reactor or reactor system. The advantages of the closed vessels or reactor systems over non-reactor systems are the better control of composting conditions and the emissions of air pollutants and odour, as well as shorter period for stabilization of organic waste (Briški et al., 2003).

Many studies of the composting process in reactors (laboratory or pilot-scale) with mixture of poultry manure and wheat straw have been reported in literature. According to our knowledge, none of these studies have been dealt in comparison of process performances with different reactor volumes.

Hence, the main motive and objective of this study was to evaluate the effect of two different reactor size on composting process of poultry manure and wheat straw through the monitoring of the main composting characteristics (temperature, emission of carbon dioxide and ammonia, oxygen consumption, organic matter conversion, pH and electrical conductivity).

MATERIALS AND METHODS

The organic solid waste for composting was composed of poultry manure and wheat straw. Before mixing with manure, the straw was cut on pieces 2.5 cm long. Manure and straw were manually mixed, in plastic boxes for 30 min, by hands, in order to achieve better homogenization of material. The experiment with same mixture ratios (manure to straw, 5.25:1 on dry weight, respectively) was performed with the following initial physic-chemical characteristics of the mixture: dry matter 30.89±0.43 (% ww), organic matter 80.22±0.66 (% dw), pH 7.40±0.04, electrical conductivity 3.10±0.02 (dS m^{-1}).

Laboratory-scale composting tests were conducted for 14 days in closed thermally insulated column reactors with effective volumes of 1 L (0.20 height x 0.08 internal diameter m) and 32 L (0.48 height x 0.30 internal diameter m). The schematic diagrams of an experimental laboratory-scale composting reactors are shown in Figure 1 and Figure 2. The reactors (1 L and 32 L) were filled with 0.353 kg and 12.522 kg of the compost mass, respectively. The experiment was used for comparison the performances of composting process in both reactors.

A thermos bottle (Pengo, Italia) was modified and used as small reactor. This modification included the rubber stopper with holes for inlet of air, for thermocouples, and for outlet of gas mixture (Figure 1). Reactor was additionally insulated with polystyrene foam. A large laboratory reactor (Figure 2), made of high-density polyethylene, was also used. This reactor was insulated with a layer of polyurethane foam (1 cm of thickness). A vertical rotating axis with blades mixing on intermittent schedule, fixed at perforated plate made of chrome, ensures the complete mixing of the composting mass. The reactor is equipped with a valve for dropping the leachate and condensate.

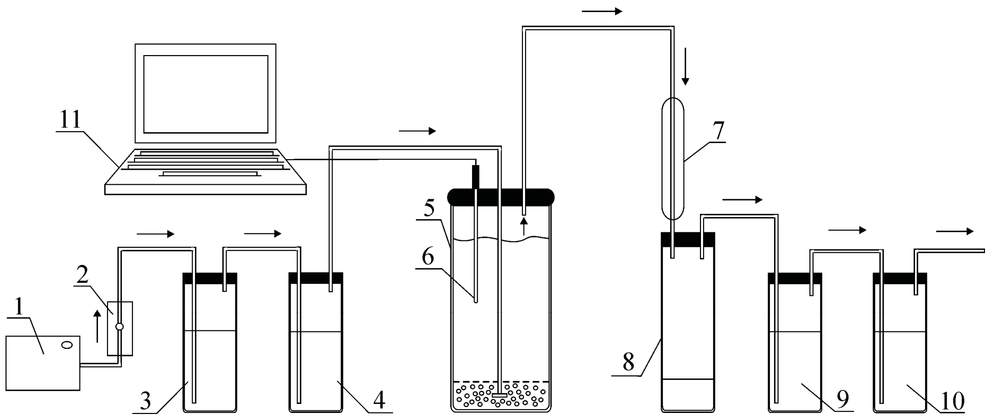


Figure 1 Schematic diagram of the small reactor
1. aquarium pump, 2. airflow meter, 3. gas washing bottle with solution of sodium hydroxide, 4. gas washing bottle with distilled water, 5. small reactor, 6. thermocouple, 7. condenser, 8. graduated cylinder, 9. gas washing bottle with solution of sodium hydroxide, 10. gas washing bottle with solution of boric acid, 11. laptop

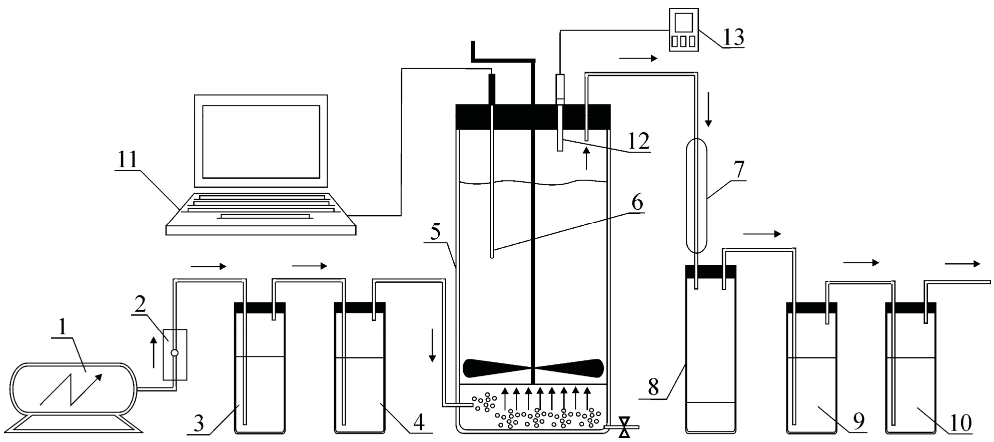


Figure 2 Schematic diagram of the large reactor
1. air compressor, 2. airflow meter, 3. gas washing bottle with solution of sodium hydroxide, 4. gas washing bottle with distilled water, 5. reactor, 6. thermocouples, 7. condenser, 8. graduated cylinder, 9. gas washing bottle with solution of sodium hydroxide, 10. gas washing bottle with solution of boric acid, 11. laptop, 12. sensor for carbon dioxide, 13. data logger for carbon dioxide)

Aquarium pump CX-0098 (Champion, China) was used to blow the air with a constant flow (0.9 L min^{-1} kg^{-1} OM) into small reactor, while an air compressor EURO 8/24 (Einhell, Germany) was used for constant aeration (0.9 L min^{-1} kg^{-1} OM) of the large reactor. Measurement of airflow was carried out using airflow meters (Valved Acrylic Flowmeter, Cole-Parmer, USA).

Before inlet to the reactor, the air had been introduced into solution of sodium hydroxide in order to remove traces of carbon dioxide. Then, air passed through the gas-washing bottle with distilled water in order to maintain the humidity at reactor inlet.

At outlet, the gas mixture passed through a condenser, a gas washing bottle with 1 M sodium hydroxide and a gas washing bottle with 0.65 M boric acid, in order to remove the condensate, carbon dioxide and ammonia, respectively.

Temperature was monitored by thermocouples type T (Digi-Sense, Cole-Parmer, USA), placed in the middle of the substrate. Thermocouples were connected through the acquisition module Temperature Data Acquisition Card Thermocouple CardAcq (Nomadics, USA) on a laptop. Automatic registration of data for temperature was performed over the whole period of the experiment, using special software (Nomadics, USA). The temperature in the laboratory was also measured.

For determination of carbon dioxide content, an aliquot volume of sodium hydroxide solution (used as a „trap“), with the indicator of phenolphthalein, was titrated by standard solution of 1 M hydrochloric acid. The difference in titration between blank and sampled probes was used for calculation of the mass of the “trapped” carbon dioxide.

For determination of ammonia content, an aliquot volume of boric acid solution (used as a „trap“), with the indicator of bromcresol green-methyl, was titrated by standard solution of 1 M hydrochloric acid. The difference in titration between sampled and blank probes was used for calculation of mass of the „trapped“ ammonia.

The gas washing bottles were changed daily for determination of carbon dioxide and ammonia.

Moisture content in the substrate was calculated from the difference between the masses before and after drying of samples in a dry oven at 105°C for 24 h (APHA, 1995). After cooling in a desiccator (30 min), the samples were incinerated at 550°C for 6 h, and then cooled again in a desiccator. The difference in the masses between dried and incinerated samples represents the mass of organic matter (APHA, 1995).

The loss of organic matter k is calculated from the initial and final organic matter contents, according to the Equation (1) (Diaz et al., 2003):

$$k = \frac{\left[OM_m(\%) - OM_p(\%)\right] \cdot 100}{OM_m(\%) \cdot \left[100 - OM_p(\%)\right]} \tag{1}$$

where OM_m is the organic matter content at the beginning of the process; and OM_p is the organic matter content at the end of the process.

pH and electrical conductivity were measured by using a PC 510 Bench pH/Conductivity meter (Oakton, Singapore) in aqueous extract, which was obtained by shaking the samples mechanically for 30 minutes with distilled water at a compost to water ratio of 1:10.

Suspension (10 g of sample and 100 mL of distilled water) was filtrated through the filter paper Whatman 42 Ashless Circles 125 mm Dia (Whatman, Great Britain) for 3 h.

The composting material was mixed only in the large reactor several times per day (for 15 min each time). After mixing, samples (about 50 g) were taken every day at the same time, from different places in the substrate (top, middle, bottom). The analysis of the fresh samples was performed immediately after taking them out of the reactor.

Each analysis was done in triplicate with calculation of the mean value. Each experiment was done in duplicate in order to reduce the experimental error.

RESULTS AND DISCUSSION

For the efficiency of composting in the reactor system it is necessary to know the reaction rate at which biodegradation occurs in the composting mass, and the extent of degradation achieved. Therefore, composting of poultry manure and wheat straw was closely monitored during 14 days and experimental results are presented in Figures 3-7.

There were three reasons why the large and the small reactor were used with the same mixture. The first reason was to discuss their different performances. The second reason was in the fact that the large reactor (with external insulation and daily mixing) provided better simulation of a full-scale composting than the small reactor. The third reason was that the small reactor did not allow taking the samples for analysis because of small amount of compost mass inside the reactor.

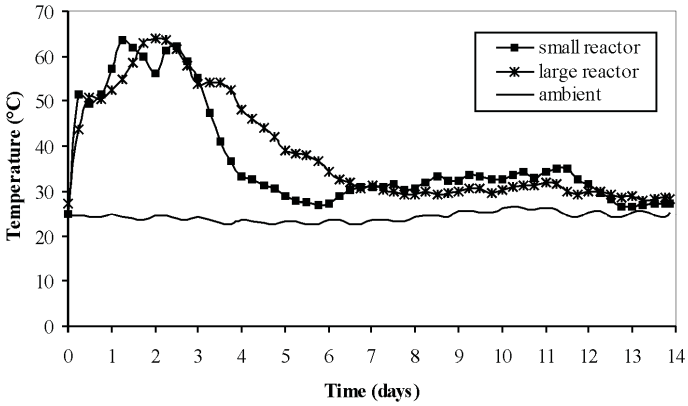


Figure 3 Evolution of temperature during composting process

Compost temperature rose rapidly above ambient temperature in both reactors (Figure 3). Temperature remained elevated longer in the large than in the small reactor. The surface area-to-volume ratio for the large and the small reactor were 0.15 and 0.55, respectively. The lower surface area-to-volume ratio of the large reactor would reduce conductive heat loss through the walls which is in agreement with literature data (Hogan et al., 1989; Petiot and de Guardia, 2004; Mason and Milke, 2005). The second temperature peak that occurred in the small reactor was possibly a result of delayed microbial growth in the lower layers of composting mixtures, either due to water leached from the top, or due to lower heat removal rate caused by predominance of smaller, constant aeration rate, or both. The lag period on temperature curve was not recorded because the original substrate was rich in microorganisms. Thus, after several hours the temperature in the composting mass started to rise due to intense biodegradation. The composting process reached the maximum temperature of 64.6°C after 2.1 days in the large reactor and 64.5°C after 1.3 days in the small reactor. The temperature in these reactors was maintained above 55°C for 2 days, which should be sufficient to maximize sanitation (Stentiford, 1996). According to Strauch and Ballarini (1994) only the thermophilic range of 55°C is sufficient to destroy pathogens.

The production of carbon dioxide is caused by mineralization of organic matter in the substrate (Bernal et al., 1998). Figure 4 shows the results of the carbon dioxide changes inside the reactors (measured by titration according to the above mentioned procedure). The produced carbon dioxide in the large reactor directly followed the temperature profile of substrate, with fluctuations caused by mixing and sampling. The mass of the produced carbon dioxide increased in both reactors proportionally to microorganisms' activity during the process. The greatest mass of carbon dioxide was generated during the first 3 days. After the third day, easily degradable organic compounds were degraded and the microbial activity (especially bacteria activity) decreased. Therefore, the amount of produced carbon dioxide was reduced. The relative high values for the mass of produced carbon dioxide from fifth to ninth day could be a sign that there was a degradation of hardly degradable organic compounds (cellulose, lignin). The differences in the rate of carbon dioxide evolution between the reactors were large during the first 9 days of the process, and after that they were very small.

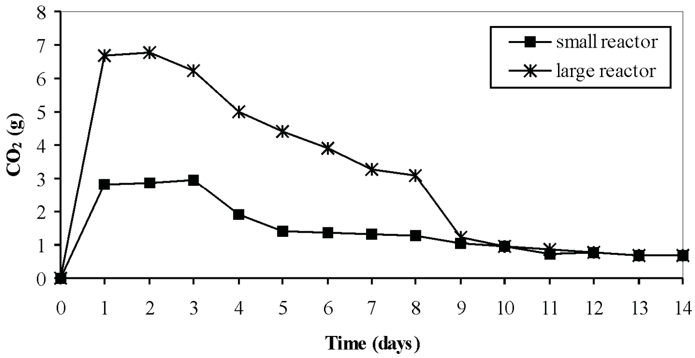


Figure 4 Evolution of carbon dioxide during composting process

The minimum concentration of oxygen (which means the maximum consumption of oxygen) was noticed in the exit gas mixtures from both reactors after the first day of the process (the small reactor 16.0 vol. %, the large reactor 11.7 vol. %) (Figure 5). From the seventh day to the end of the process, the profiles of consumed oxygen in both reactors were similar. Suler and Finstein (1977) reported that the oxygen concentration in the exit gas needs to be at least within 10-18% to prevent a decrease in metabolic activity based on carbon dioxide evolution. Therefore, the oxygen profiles in both reactors provided ideal conditions for microbial growth.

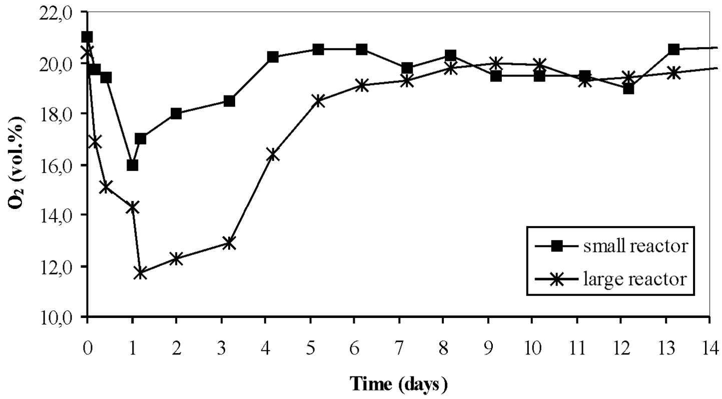


Figure 5 Evolution of oxygen during composting process

The increased emission of ammonia was observed in both reactors at the beginning of the process (Figure 6), which could be explained by great content of nitrogen in the initial mixture. The maximum emission of ammonia was observed from the small reactor after first day and from large reactor after the third day. From the tenth day to the end of the process, the profiles of generated ammonia in both reactors were similar.

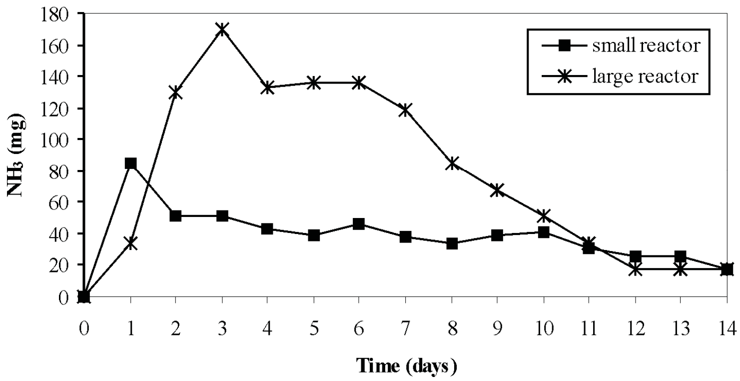


Figure 6 Evolution of ammonia during composting process

Ammonia represents even 98% of emission of nitrogen from composting material (Beck-Friis et al., 2001). The losses of nitrogen often reach up to 33% during the composting of poultry manure (Hansen et al., 1989). The straw decreased the moisture content of the mixture. Therefore, pores filled with air became greater, which made better conditions for degradation. As a consequence, modification of balance NH_4^+/NH_3 could have been expected. On the other hand the addition of straw decreased carbon to nitrogen ratio and temperature. The temperature decrease diminished the ammonia vapour pressure, so the ammonia remained more dissolved in the water solution of the composting material. The pH value influenced the ammonia concentration in compost air space by controlling the distribution of ammonia and ammonium concentration in the aqueous phase. The combination of temperature-pH effects on ammonia release is not quite clear and should be the aim of future studies on composting organic wastes.

Table 1 Physic-chemical characteristics of the compost (three measurements, mean value±standard deviation)

Reactor	Dry matter (%ww)	Organic matter (% dw)	pH	Electrical conductivity (dS m^{-1})
Small	20.17±0.63	70.40±0.65	8.71±0.06	2.62±0.08
Large	22.48±0.50	68.00±0.42	8.85±0.02	4.31±0.04

ww – wet weight; dw – dry weight

Experimental results at the end of 14-day experiment in dry matter, organic matter, pH and electrical conductivity during composting in 1 L and 32 L reactors, are presented in Table 1. The final value for dry matter content of the small reactor (20.17%) was lower than the corresponding value for the large reactor (22.48%). That means that the compost from the small reactor had a greater moisture content although it might be expected that the constant air flow in the small reactor may have enhanced cooling and drying of the composting mixture (especially at the bottom). It was observed that water condensation occurred under the top of both reactors leading to rewetting of the substrate. The degradation of organic matter was related to the loss of organic matter, which was, in turn, directly related to the microbial respiration (Paredes et al., 2002). The organic matter content of the materials decreased in both reactors during the process, but this reduction was greater in the large reactor (47.60%) than in the small reactor (41.36%). It can be explained by daily mixing of material in the large reactor. Periodic mixing of the composting mixture stimulated carbon dioxide production, redistributed substrate and water, and provide additional aeration. Mixing facilitated constant and prolonged oxygen utilization by microbial populations. Movement of the material aided aeration, introducing a fresh supply of air into the middle of composting mass where diffusion alone has been insufficient to maintain high oxygen and low carbon dioxide levels. Agitation assisted homogeneity of the composting mass, the uniformity of temperature, preventing overheating in the centre of mass, and cooling at exposed surfaces. The results with reduction of organic matter content are in an agreement with literature data (Kulcu and Yaldiz, 2005). The final pH values for both reactors were similar (small reactor 8.71, large reactor 8.85), but the final values for electrical conductivity were different (small reactor

2.62 dS m^{-1}, large reactor 4.31 dS m^{-1}). Lower value of electrical conductivity for the small reactor indicated smaller amount of available minerals than the corresponding value of electrical conductivity for the large reactor.

Evolution of pH and electrical conductivity in the large reactor are presented in Figure 7. The initial value of pH was 7.40, and final was 8.85. The maximum value was 8.86 (eighth day) and after that it had been maintained until the end of the process. The increase in pH was induced due to production of ammonia during ammonification and mineralization of organic nitrogen as a result of microbial activities (Mahimaraja et al., 1994). A decrease in pH on tenth day of composting was caused by the volatilization of ammoniacal nitrogen and the H^{+}-released as a result of microbial nitrification process by nitrifying bacteria (Eklind and Kirchmann, 2000). The large quantities of carbon dioxide that are given off during the composting process with sufficient aeration might also be responsible for the decrease in pH value, because evaporation of water and release of carbon dioxide led to the acidification of the mixture once buffering effect of the bicarbonate had diminished (Cáceres et al., 2006).

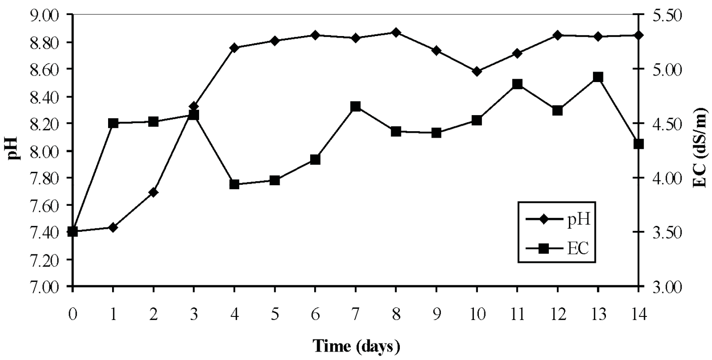


Figure 7 Evolution of pH and electrical conductivity during composting process

The EC value reflected the degree of salinity in the compost, indicating its possible phytotoxic/phyto-inhibitory effects on the growth of plant if applied to soil. Electrical conductivity values increased from 3.50 to 4.31 dS m^{-1} during the composting process. These high values could be due to the effect of the concentration of salts as a consequence of the degradation of organic matter (Campbell et al., 1997).

CONCLUSIONS

During composting of poultry manure and wheat straw, the higher values of all observed characteristics were achieved and maintained in the large reactor than in the small reactor. The temperature in both reactors was maintained above 55°C for 2 days, which should be sufficient to maximize sanitation and to destroy pathogens. The maximum temperature of 64.6°C was reached after 2.1 days in the large reactor and 64.5°C after 1.3 days in the small reactor. The greatest mass of carbon dioxide was generated during the first 3 days. The minimum concentration of oxygen (which means its maximum consumption) was noticed in the exit gas mixtures from both reactors after the first day of the process (the small reactor 16.0 vol. %, the large reactor 11.7 vol. %). The maximum emission of ammonia was observed from the small reactor after the first day and from large reactor after the third day. The reduction of organic matter content was greater in the large reactor (47.65%) than in the small reactor (41.36%). The final pH values for both reactors were similar (small reactor 8.71, large reactor 8.85), but the final values for electrical conductivity were different (small reactor 2.62 dS m^{-1}, large reactor 4.31 dS m^{-1}). The results indicated that an increase in reactor size (or surface area-to-volume ratio) enhance the process efficiency but ammonia loss and pH should be controled. The small reactor allow the temperature to stay in the thermophilic zone shorter than the large reactor, due to high heat losses through the external surface (even with good insulation).

ACKNOWLEDGEMENTS

This research was financially supported by the Federal Ministry of Education and Science of Bosnia and Herzegovina.

REFERENCES

1. American Public Health Association (APHA) (1995). Standard Methods for the Examination of Water and Wastewater. APHA, Washington, DC.
2. Beck-Friis B., Smårs S., Jönsson H., Kirchmann H. (2001). Gaseous Emissions of Carbon dioxide, Ammonia and Nitrous Oxide from Organic Household Waste in a Compost Reactor under Different Temperature Regimes. J Agric Engng Res 78(4): 423-430
3. Briški F., Horgas N., Vuković M., Gomzi Z. (2003). Aerobic composting of tobacco industry solid waste-simulation of the process. Clean Techn Environ Policy 5: 295-301
4. Cáceres R., Flotats X., Marfà O. (2006). Changes in the chemical and physicochemical properties of the solid fraction of cattle slurry during composting using different aeration strategies. Waste Manag 26: 1081-1091
5. Campbell A.G., Folk R.L., Tripepi R. (1997). Wood ash as an amendment in municipal sludge and yard waste composting processes. Compost Sci Util 5(1): 62-73
6. Diaz M.J., Madejon E., Lopez F., Lopez R., Cabrera F. (2003). Optimization of the rate vinasse/grape marc for co-composting process. Process Biochem 37: 1143-1150
7. Eklind Y., Kirchmann H. (2000). Composting and storage of organic household waste with different litter amendments. II: nitrogen turnover and losses. Biores Technol 74: 125-133
8. Federal Office of Statistics (2007a). Livestock and poultry slaughtered in abattoirs. Available at http://www.fzs.ba/Podaci/brojstoke2006.htm (Accessed 1 October 2008)
9. Federal Office of Statistics (2007b). Agriculture-Area harvested and cereal production. Available at http://www.fzs.ba/Podaci/poljoprivreda2006.htm (Accessed 1 October 2008)

10. Hansen R.C., Keener H.M., Hoitink H.A.J. (1989). Poultry manure composting: an exploratory study. Transactions of the ASAE 32(6): 2151-2158

11. Hogan J.A., Miller F.C., Finstein M.S. (1989). Physical Modeling of the Composting Ecosystem. Appl and Environ Microbiol 55(5): 1082-1092

12. Kulcu R., Yaldiz O. (2005). Composting dynamics and optimum mixture ratio of chicken manure and vineyard wastes. Waste Manage Res 23: 101-105

13. Mahimaraja S., Bolan N.S., Hedley M.J., Mcgregor A.N. (1994). Losses and transformation of nitrogen during composting of poultry manure with different amendments: an incubation experiment. Biores Technol. 47: 265-273

14. Martins O., Dewes T. (1992). Loss of Nitrogeneous Compounds during Composting of Animal Wastes. Biores Technol 42: 103-111

15. Mason I.G., Milke M.W. (2005). Physical modelling of the composting environment: A review. Part 1: Reactor systems. Waste Manag 25: 481-500

16. Paredes C., Bernal M.P., Cegarra J. (2002). Bio-degradation of olive mill wastewater sludge by its co-composting with agricultural wastes. Biores Technol 85: 1-8.

17. Petiot C., de Guardia A. (2004). Composting in a Laboratory Reactor: A review. Compost Sci & Util 12(1): 69-79

18. Republika Srpska Institute of Statistics (2007a). Number of livestock and poultry head. Avail. at http://www.rzs.rs.ba/Saopstenja/Poljoprivreda/BrojStokeIZivine06.pdf (Accessed 1 October 2008)

19. Republika Srpska Institute of Statistics (2007b). Early crops and fruits. Available at http://www.rzs.rs.ba/Saopstenja/Poljoprivreda/RaniUseviVoce07.pdf (Accessed 1 October 2008)

20. Stentiford E.T. (1996). Composting control: Principles and practice: In: DeBertoldi, M., Sequi, P., Lemmes, B., Papi, T. (Eds.), The Science of Composting. Chapman & Hall, pp 49-59

21. Strauch D., Ballarini G. (1994). Hygienic aspects of production and agricultural use of animal wastes. J. Vet Med 41: 176-228

22. Suler D.J., Finstein M.S. (1977). Effect of Temperature, Aeration and Moisture on CO_2 Formation in Bench-Scale, Continuously Thermophilic Composting of Solid Waste. Appl Environ Microbiol 33: 345-350

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.153.46:631.171
Pregledni rad
Review paper

THE REVIEW OF THE FEATURES OF MACHINE UTILIZATION IN FIELD CROP- AND VEGETABLE FARMING AND PLANTATION CULTIVATION

LÁSZLÓ MAGÓ

Hungarian Institute of Agricultural Engineering, Gödöllő
H-2100, Gödöllő, Tessedik s. u. 4., e-mail: laszlomago@fvmmi.hu

ABSTRACT

The present study is a comprehensive survey covering the analysis of the development of the machine stock and the use of the machines of field crop producing, field vegetable growing and plantation cultivating farms by the application of the means of computer-guided modelling. The characteristics of the machines demanded by the production of different plants are taken into account and special attention is paid to the application of machines with reasonable capacity and technical level in respect of cost by different farm sizes.

Our aim is to stipulate the range of farm size under which the development and operation of an own machine stock is not even with additional machine cost offering worth in the branches surveyed. By this the farm size limit under which the use of the logistically more defenceless lease work is reasonable in order to keep the cost of machine work at an acceptable rate will be defined. This limit varies from branch to branch. This way the fact that the mechanization of the individual branches is highly dependent from the farm size and the diversity of parameters effecting mechanization can be pointed out.

***Key words**: Mechanisation of different branches of plant production, mechanisation of different sized farms, machine fleet planning, machine utilisation, low cost machine fleet*

INTRODUCTION

Work done *by an efficiently developed machine system* is a significant condition of the fruitfulness of farming. The machine prices and the cost of their utilization are extremely high and all these result in extraordinarily high production costs. *Rational machine utilization* is a definitive factor of the efficiency of venture-farming. According to our experiences the machine stock of a venture and the way and rate of utilization of same are reserves which can substantially contribute to the increase of corporate income (**Takács Gy. - Takács** 2003). [9]

Contrary to former practice the concept of "optimal machine system" is not to be interpreted within the framework of corporate enterprise only but we are to find a solution for solving the mechanization problems and planning the machine utilization of *small and medium size* farms as well (**Fenyvesi et al.** 2003). The wide range of enterprise sizes characteristic nowadays and the great number of power and working machine types available are also to be considered. [2]

The planning of mechanization cannot be limited to determining the number of machines. There is a rightful demand for the determination and consideration of the economic parameters of the power and working machines of different types and performance categories developed by diverse enterprise sizes. The acquisition and afterwards use of valuable equipment necessitates well-grounded economic decisions.

Considering the shift-hour performance of the machines under given production circumstances an overall system for building up a machine system adapted to small, medium and large farm size can be developed. The *areal size limits and cost of the utilization* of self-owned power machines of different performance level and harvesting machines of diverse functions can be determined as well as the *number of shift-hours to be performed* which also effects the efficiency and cost of machine utilization. In case of power machine families representing different quality, resp. cost level the cost level of the given power machines carrying out the individual work operations at different farm sizes can be determined.

METHOD

The crop growing branches surveyed

The surveys can be conducted by *modelling* the machine working processes of agricultural production. In the case of field crop production a crop plan including cereal plants for human consumption, maize for animal breeding and for energy production purposes and oil seeds – as sunflower and the nowadays very popular crucifer - appropriate for human consumption and energy production as well and reflecting the special features of production in Hungary has been applied. Our calculations have been based on a crop plan including cereal plants, sweet corn, onion and root vegetables in case of field vegetable growing while in case of plantation cultivation the data of a vine growing farm have been taken into account. Depending on farm size the proportion of the crop area of the individual plants has been stipulated in view of the agronomical and production technological conditions.

The machine families applied, the parameters of model calculations

Basically the cheapest power machine families used in Hungary on the one hand and the ones with the highest possible investment cost demand available on the market of agricultural machinery on the other have been the subject of the survey. While in case machines with low historical cost the costs of machine utilization are low as well owing to the meagre amortization cost, a substantial amortization cost is to be calculated in case of high price power machines. In the latter case the price difference can be compensated by the lower specific fuel consumption due to the more modern construction, the easy handling, the quality of work done, and the ergonomically more advantageous design. The life expectancy of the high investment cost machines is also longer. This can, though, not easily be denoted in figures as the life expectancy of a lower cost machine can be lengthened several times by a low cost overall renewal. The spare part costs of these machines-equipment are mostly favourable and the costs of the additional repairs are also not considerable on the whole compared to the purchase price of a modern machine.

The basic figures of machine utilization have been determined with the help of the data base of the Hungarian Institute of Agricultural Engineering. [3]

The *model-calculations* have affected the determinative farm size points of machine stock development in a farm size range of 2-1000 ha depending on branch. On this basis we can come to statements affecting a wider segment of the agricultural property structure, resp. to conclusions concerning mechanization and machine utilization.

RESULTS

The conclusions arising from the results of the model calculations concerning the composition of the power machine system and the shift hour performance of the power machines

The composition of a machine system with minimal utilization cost by power machine categories depending on farm size in the different crop growing branches

The multi-purpose power machines have been classified according to *engine performance* during the survey, moreover the self-propelled grain harvesting machine *function* has also been considered. The composition of the power machine systems assigned to the individual areas has been determined by *power machine categories*. Under given machine working conditions as sowing structure and production technology characteristic of the special features in Hungary *regular coherences* can be stated considering the composition by categories of a *cost efficient power machine system* developing according to farm size.

In case of ***field crop production*** the power machine system applicable to the smallest farm size included in the survey is “built up” in case of tractors of the 40 kW performance ones minimally necessary for quality cultivation. Parallel with the growing of the territory first the performance level (from 30 ha on the use of 60 kW tractors is reasonable) and later also the number of the ***tractors*** composing the machine system grows. Thus from a farm size of 100 ha on the 40 and 80 kW performance tractors are *both* included in the machine system. From a farm size of 300 ha the role of the above mentioned power machines is taken over by 60 and 120 kW performance tractors the capacity of which is appropriate for the increasing labour demand. From a 500 ha farm size on the number of these tractors grows in the proportion of the increase of capacity demand.

It is worth mentioning that in case of large size farms the cost level of machine utilization can be decreased further by increasing the number of the applied power machine performance categories and by optimizing the allocation of operations among the machine combinations of different capacity (**Magó** 2002a, b). [4; 5]

It is also reasonable to apply tractor and trailer for solving ***transport*** tasks in order to increase utilization.

The use of an own minor capacity ***grain harvesting machine*** may become reasonable from a farm size exceeding 100 ha. From a farm size of 500 ha on a harvesting machine with a bigger throughput can be applied due to the great deal of machine work demand. According to calculations in a 1000 ha farm it is highly recommended to operate at least two grain combines (**Magó** 2008a). [6]

In case of ***field vegetable production*** a tractor of 60 kW performance is appropriate for small size farming, for quality cultivation and for the fulfilment of the individual harvesting functions. Together with the increase of farm size the performance level (from 30 ha on the use of 80 kW tractors is reasonable) and also the number of (the 40 kW auxiliary tractor appears) ***tractors*** composing the machine system grows. The 40 and the 80 kW performance tractors are already present *together* in the machine system from 50 ha on. At a farm size of over 200 ha the tasks of the power machine cultivation is done and the tugged harvesting machine is operated by are taken over by a 120 kW performance tractor, and the number of auxiliary tractors apt for fulfilling plant protection, nutrient supply and transport tasks grows, thus the capacity of the power machines is sufficient for the increasing labour demand.

The use of an own lower performance ***grain combine harvester*** for harvesting cereals ensuring crop rotation is reasonable in case of a property size of over 300 ha (**Magó** 2008b). [7]

In case of ***plantation cultivation*** the performance of the tractor applicable to the smallest farm sizes is 20 kW which is sufficient for the necessary cultivation works as well. In case of this farm size a further 45 kW power machine is needed for the operation of the vine harvesting machine taken by lease. The performance level (from 10 ha on the use of a 45 kW tractor is reasonable) and the number (from 50 ha on the necessary cultivation and harvesting works are already done by two power machines of equal performance level) of the plantation cultivating tractors grows together with the growth of the area.

The number of shift-hours performed subject to power machine category and farm size in the different branches of crop production

The number of shift-hours achievable by different farm sizes effects the composition by category of the power machine system. (Figure 1)

- In case of ***field crop growing*** considering the *smallest farm size* (**max. 50 ha**) the *utilization level* of the tractors is *low:* maximum 400-500 shift-hours annually.
- In case of *medium size farms* (**50-300 ha**) this quantity is *bigger*: 800-1400 shift-hours per year.
- In case of *large size farms* (**over 300 ha**) the performance (1000-1800 shift-hours a year) of the tractor categories is already significant.

A grain harvesting machine with rationally chosen capacity achieves *good* utilization by farm sizes ***over 300 ha*** with a shift-hour performance of about 300/year and an *acceptable* operational cost hereby (**Magó** 2008c). [8]

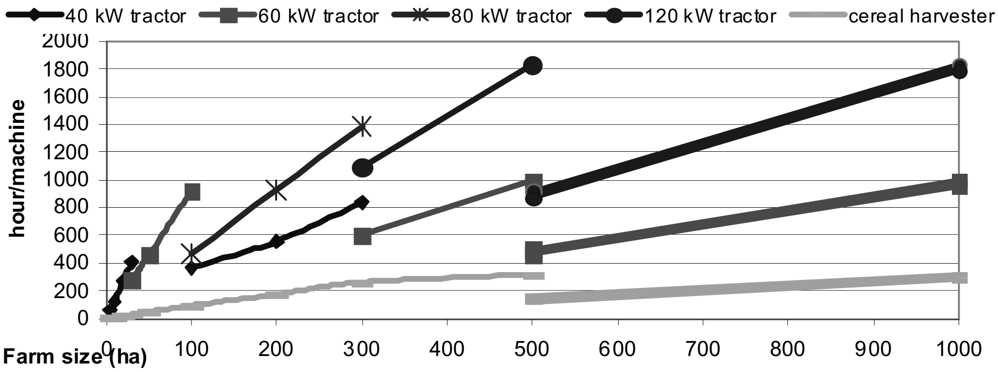


Figure 1 The shift-hour performance of power machine categories subject to farm size based on model calculations in case of field crop growing

The number of calculated shift-hours achievable in case of ***field vegetable growing*** subject to farm size is as follows:

- By the smallest farm size surveyed (**max. 20 ha**) a *low level of utilization* of tractors can be achieved: maximum 500 shift-hours a year.
- In case of *medium farm sizes* (**20-100 ha**) the number of shift-hours is already remarkable: 500-1000 shift-hours per year.
- In case of *large farm sizes* (**over 100 ha**) the tractor categories may already have a significant performance (1000-1800 shift-hours per year) (Figure 2)

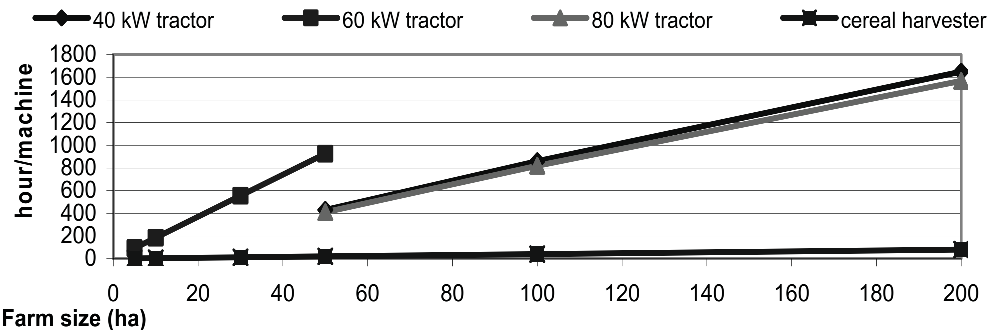


Figure 2 The shift-hour performance of power machine categories subject to farm size based on model calculations in case of field vegetable growing

The level of shift-hour performance by ***plantation cultivation***: (Figure 3)

- By the *smallest plantation sizes* surveyed (**max. 20 ha**) only a *low level of utilization*, maximum 600 shift-hours a year can be achieved even if a low capacity power machine is applied.
- In case of *medium and large size plantations* (**over 20 ha**) this quantity *grows* and the tractors may have a remarkable (600-1250 shift-hours annually) performance.

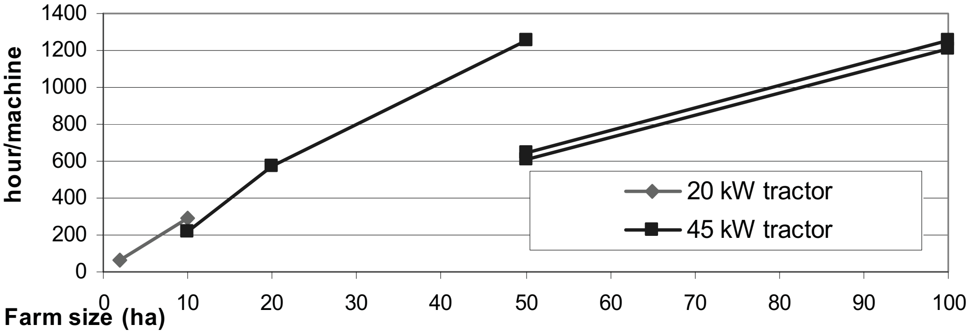


Figure 3 The shift-hour performance of power machine categories subject to farm size based on model calculations in case of plantation cultivation

The number of shift-hours per *unit of area decreases* with the increase of farm size. In case of ***field crop production*** on *small size farms* 10-15 shift-hour/ha/year is performed. In the size range of *30-300 ha* a shift-hour performance of 8-10/ha can be calculated, *from this size on* an annual figure of about ***6 shift-hours per hectare*** becoming constant with the realization of an *efficient labour plan* can be observed. (Figure 4)

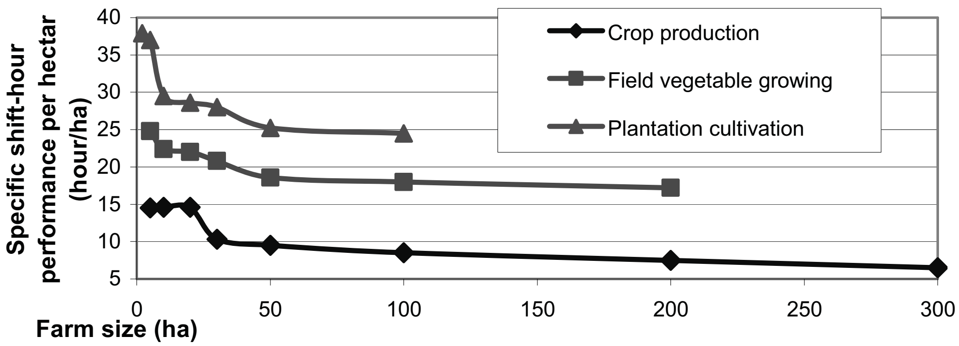


Figure 4 The total shift-hour performance of power machines subject to farm size in the different branches

In case of ***field vegetable growing*** by the *small farm sizes* 20-25 shift-hours per hectare per year are realized. In the size range of *30-200 ha* 18-20 sh/ha can be calculated but with the *increase of labour effectivity* even the favourable ***15 shift-hours per hectare*** performance can be achieved.

By ***plantation cultivation*** in case of *small farm sizes* 35-40 sh/ha can be achieved. In the size range of *10-50 ha* shift-hours per hectare are performed, *from this size range on* the still significant annual figure of ***24 shift-hours per hectare*** becomes constant.

The above figures are characteristic of the utilization of the low investment cost power machines and they alter a bit if high investment cost power machine families are used. The more up-to-date power machine-working machine connections need shorter time for executing their labour tasks and this is also reflected in the above mentioned specific index. In field crop production, for instance the utilization of the more expensive and higher technical level results in a benefit of 0,3-0,5 shift-hour per hectare annually. But presuming internal home work only this benefit is a disadvantage considering utilization as the annual shift-hour performance of the individual machines decreases and hereby their specific utilization cost increases.

It can be stated that the most machine working hour demanding branch for the cultivation of one hectare is the plantation cultivation, field vegetable growing comes next, and the last one in the row is the field crop production. Obviously farms producing grain and oilseeds have the lowest machine working hour input demand. With the growth of the farm size the specific number of machine working hours necessary for the cultivation of one hectare area decreases in each branch and the figures are nearly halved in case work is done under more favourable and more efficient large scale farming conditions with high performance machinery.

The great number of hours experienced by small farm sizes increases the living labour expenditure as well. Though for farm of this size category the application of mainly low performance machines is characteristic due to the limited level of machine utilization the general expenses and, therefore also the operational costs are high.

The analysis of machine utilization- and investment costs subject to farm size

The machine utilization costs

The above are also proved by Figure 5 which shows the lower and upper limit of machine utilization costs, resp. the most probable range of machine utilization costs of the different branches subject to farm size taking the application of low technical level power- and working machines as well as the expensive power machines representing the most modern technology into account.

In general terms we can say that the low level of utilization by the small size farms generates the dominance of fixed costs. Due to this fact the substantial differences between the amortization costs of cheap and expensive machines are also reflected in the cost of utilization. By medium size farms this tendency is already more moderate. By large farm sizes where the variable costs predominate in the cost structure of machine utilization owing to the notable shift-hour performance and the specific costs of fuel and wage costs are more favourable due to the fact that the machines are of a higher technical level and able to work more efficiently and with a better area performance the difference between the utilization costs of the cheap and the expensive power machines reduces, in some cases to the minimum.

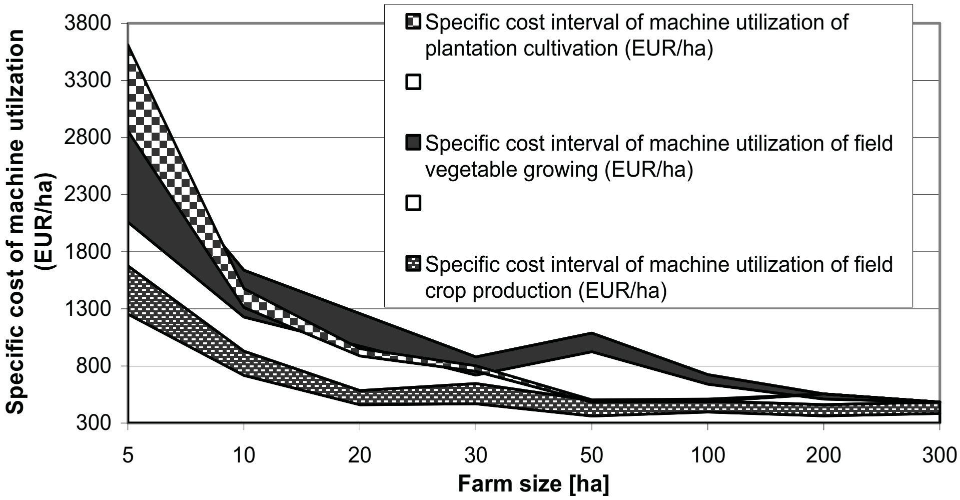


Figure 5 The interval of specific machine utilization costs in the different branches subject to farm size

Considering the above we can come to the conclusion that the variability of machine utilization cost tapers with the growth of farm size. In case of plantation cultivation where labour tasks are fulfilled by one or two nearby maximally utilized power machines by large farm size and machine harvesting is done by pulled harvester the cost interval gets quite narrow. Contrary to the above the maximal utilization of the self-propelled grain combine used in field crop producing and field vegetable growing farms can hardly be ensured even in case of large farm sizes and the high level of the operational costs of same tempers the "slimming" of the cost interval.

It can be stated that by the more working time demanding branches in case of large-scale farming the costs of machine utilization are less dependent on the technical and cost level of the appliances used and the machine costs assignable to the given area size and labour quantity can be determined more precisely.

The phases of increasing costs breaking the reducing tendency of machine utilization costs noticeable subject to farm size are attributable to the appearance of new higher performance machines at the given farm size. The capacity expansion of the machine stock is attached to the increase of machine performance. The arising idle capacity can be utilized by the further increase of the farm size and till then a local increase of fixed costs is characteristic of the machine utilization (**Magó** 2008a). [6]

Surveying the decreasing tendency of machine utilization costs parallel with the increase of farm size it is clear that in case of real small-scale farming the machine costs are several times, three or may be even six-seven times higher than the acceptable and economically reasonable level of the medium, but especially the large-scale farms. Consequently it can be stated that in spite of the reasonably chosen power machine capacity there is no technical solution which could acceptably solve the cost problem of farms smaller than about 16-20 ha in case of field crop production, 9-12 ha in case of field vegetable growing and 5-7 ha in case of plantation cultivation.

It must be pointed out that under the indicated farm size limits the development of an own machine stock is not economical if there is no lease-work possibility besides home labour whereby the machine utilization can be increased, the period of returning of machine investments can be shortened and a more fruitful farming can be achieved. (**Baranyai et al**. 2008). [1]

All the above can be even more specifically supported by demonstrating the specific costs of machine investment. By small farm sizes the specific costs of machine investment are obviously higher and their period of return is statutorily longer.

There is a possibility for the use of own machines also beneath the above mentioned farm sizes limits which do not ensure effective machine utilization. In this case the solution for the small-scale farms may be the operation of second-hand machines already over the amortization period which need close attention and are in many cases repaired by the owner personally (**Magó** 2008a, 2008c).[6; 8]

The machine investment costs

In respect of investment costs it is obvious that the increase of the number of own machines parallel with the increasing farm sizes effects the decreasing tendency of specific machine investment costs subject to farm size and local investment cost maximums arise on individual intervals. All this is by small farm sizes conspicuous. In the case of the three branches of crop production surveyed this phenomenon can be observed by different farm size each.

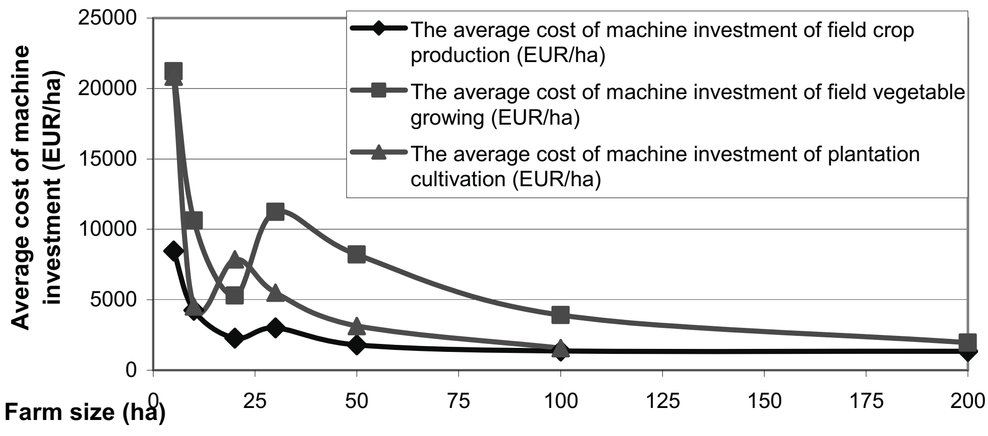


Figure 6 The conformation of the average rate of specific machine investment costs subject to farm size in the different branches of crop production

In the case of field crop production the change from the power machine used in small-scale farming to the higher performance tractor and the connecting working machines due to the increasing property size is reasonable by about 30 ha. The purchase of the pulled harvesting machine with several special functions leading to a substantial rise of specific investment costs is also due at a size of 30 ha in field vegetable growing. In case of plantation cultivation, however, the change of category and the purchase of the low capacity pulled harvesting machine can already take place at a property size of 20 ha due to the remarkable shift-hour performance which intensely effects the investment costs in this case as well. (Figure 6)

With the characterization of machine utilization and investment costs subject to farm size and with the phenomenon of *activating* the individual power machine categories we have dealt with in detail in our earlier essays (**Magó** 2008c). [8]

It can be stated here as well that one who intends to operate an own machine stock under the above mentioned size limits has to face a specific investment cost five to ten times higher than the acceptable cost level. If, however, one is forced to do that due to some production–technological pressure one has to try to decrease the specific costs of machine utilization by increasing machine utilization in order to keep the costs at an acceptable level.

CONCLUSION

It can well be demonstrated by the presented examples of the branches of plant production that while the investment of an own machine is not economical by small-scale production including the least machine labour per hectare demanding grains and oilseeds due to the low level of machine utilization already under 18 ha, the farm size limit of non-economical machine utilization is lower in case of field vegetable growing and plantation cultivation where the specific labour demand per unit of area is higher and the level of machine costs is already from 6-10 ha farm size on acceptable due to the better machine utilization.

Furthermore, the capacity of the machines assigned to the crop growing technologies applied in the latter branch is lower, their purchase price is mainly lower and this effects the machine cost level of small-scale farming in a more favourable way than the phenomena experienced in field crop production.

The aim of our research work and the exposition of its results are the professional support of the machine investment decisions and the machine utilization practice of the different size farms promoting hereby the creation of the conditions of fruitful farming and rational machine investment decisions.

In the present study we have tried to offer a general guideline considering a general crop plan and production technology characteristic of several branches with an overview of the composition of machine stock from the use of the lowest cost level to the highest technical level machinery, the machine demand and the utilization level of those together with investment and utilization costs which may serve as a basis and may open further research perspectives for the reduction of machine utilization costs both for the producers and for the professional organizations.

ACKNOWLEDGEMENT

The author would like to express his gratitude to the OTKA Fund for the financial support (F 60210).

REFERENCES

1. Baranyai Zs., Sípos N., Takács I.: (2008) Examination of Main Factors of Producers' Willingness to Cooperate in Hungarian Agriculture, Cereal Research Communications, Akadémiai Kiadó, Vol. 36: p. 723-726.
2. Fenyvesi L., Gockler L., Hajdú J., Husti I.: (2003) A mezőgazdaság műszaki fejlesztésének lehetséges megoldásai. Gazdálkodás, No. 5. 1-15 p.
3. Gockler L: (2007) The Purchase Price and Running Costs of Agricultural Machines in 2007, Mezőgazdasági Gépüzemeltetés 2007. No.1., Hungarian Institute of Agricultural Engineering. Gödöllő.
4. Magó L.: (2002a) Economically Reasonable Using of Different Power Machines According to the Farm Sizes, Hungarian Agricultural Engineering, Periodical of the Committee of Agricultural Engineering of the Hungarian Academy of Sciences, Vol. 15/2002. p. 79-82.
5. Magó L.: (2002b) „Selection of the Machinery Fleet by Integer Non-linear Programming", Innovation in the Agriculture and the Industry, International Conference on Agricultural Engineering Abstracts, Budapest, 30 June -4. July 2002. Vol. 2. p. 112-113.
6. Magó L.: (2008a) Low Cost Mechanisation on Small and Medium Size Plant Production Farms, Bulletin of Szent István University, Special Issue Part I., SZIE Gödöllő, p. 273-285.
7. Magó L.: (2008b) „Efficient Machine Utilisation in Small and Medium Size Field Vegetable Production Farms", Journal of Agricultural Machinery Science, Agricultural Machinery Association - Ege University, Bornova-Izmir, Turkey, 2008. Vol. 4., No. 1., p. 81-85.
8. Magó L.: (2008c) Cost Effective Mechanisation on Small and Medium Sized Farms, Agricultural and Biosystems Engineering for a Sustainable World, International Conference on Agricultural Engineering, AgEng2008, Hersonissos, Crete - Greece, 23-25 June 2008. Book of Abstracts p. 98-99. Full paper in CD issue.
9. Takácsné-György K., Takács I.: (2003) Az üzemméret és tőkehatékonyság összefüggései, a hatékonyságnövelés néhány alternatívája. In Birtokviszonyok és a méretgazdaságosság. A magyar mezőgazdaság nemzetközi versenyképessége NKFP-2003/4/32. Edit.: Szűcs I. Agroinform Kiadó. Budapest.. 99-169. pp.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.317.7:631.17
Stručni rad
Expert paper

ANALYSIS OF THE USE OF AUTOMATIC STEERING SYSTEMS FROM TECHNO-ECONOMICAL POINT OF VIEW

JÓZSEF HAJDÚ, LÁSZLÓ MAGÓ

Hungarian Institute of Agricultural Engineering, Gödöllő
2100 Gödöllő, Tessedik S. u. 4., E-mail: hajdu@fvmmi.hu

SUMMARY

The development of informatics applications and electronic data transmission, data processing made the establishment of precision agricultural production technologies and their rapid spread possible. This process was accelerated when the civil application of satellites previously used for military purposes was permitted. The accurate performance of the specific work operations within precision crop production by the set operating parameters may significantly improve efficacy. Since very little experience is available in this relation in Hungary the Hungarian Institute of Agricultural Engineering, Gödöllő, as the leader of the consortium, the KITE Agricultural Service and Trade Incorporated, Nádudvar, and Búzakalász Agriculture Service and Trade Incorporated, Kunszentmárton as members of the consortium have initiated a research and development project.

Key words*: Automatic steering systems, parallel tracing, auto tracing, tecno-economical analysis, machine costs.*

INTRODUCTION

One of the most difficult tasks for machine operators in the traditional arable crop production is to lay down a straight trace at the start of the work, which is easier to follow later. The proper joining of production lines may also prove to be problematic.

Agricultural machinery may be manoeuvred more accurately in the fields with the help of the recently available automatic steering systems and satellite navigation based steering systems.

With satellite navigation aid machinery, machinery groups in arable crop production technologies are able to perform their tasks with high cultivation accuracy, without cultivation skips, unreasonable cultivation overlapping, and territorial skips.

In the research phase the preliminary planning of movement maps concerning self-propelled machinery and tractor machinery groups, the optimalisation of trace and cultivation directions, the accurate performance of technological operations and the minimalisation of over cultivation (skips and unnecessary overlapping) were realized. The field measurements have proved that the amount of machinery work and energy expenditure may be decreased while production efficacy may be increased.

Our principal objective is to develop domestic economics and application conditions, the introduction and calculation of economic advantages in terms of parallel, trace following automatic steering systems.

METHODOLOGY

The economics analysis has been carried out by taking into consideration the arable land of our consortium member, the Búzakalász-Agrár Zrt. in Kunszentmárton along with the available machinery and applied technologies calculating with the actual performance and costs. The crop structure of the incorporation is based on three crops in the following proportion: 900 hectares of wheat, 600 hectares of sunflower, 100 hectares of corn, that is totalling 1600 hectares.

The technological demand of these crops has determined the composition and selection of machinery, machinery systems.

We have analysed:

- the change in field performance in case of machinery operations,
- the change in machinery productivity in case of complex production technology,
- the change in the value of machinery work used for the cultivation of one hectare,
- the performance of power engines in terms of yearly operating hours in the different steering modes,
- the amount of machinery work applied for the cultivation of one hectare.

The assessment of machinery operations has been divided into manual, parallel (trace following) and automatic steering modes.

RESULTS

Increase in field performance and productivity

In case of the three major operation groups the soil cultivation operations with the application of parallel steering show 3.1%, and 6% plus field performance increase with automatic steering as compared to manual steering. In case of sowing these numbers are 3,4 %, and 6,9 %, while in case of harvesting the figures are 1,7 and 4,9 %. (Figure 1).

By adding up the given operations the possible productivity increase within the complex technologies in case of wheat is 19% plus with parallel steering, 42% plus with automatic steering as compared to manually steered power engines. In case of corn production the figures show 7 % plus, 18 % plus increase, while in case of sunflower these are 6 % plus and 14% plus increase (Figure 2).

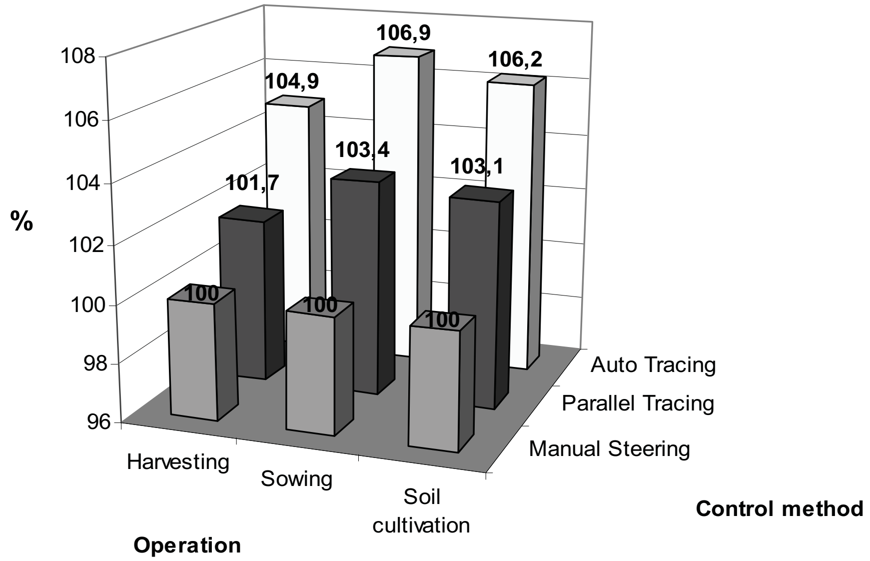


Figure 1 Field performance increase with parallel and automatic steering systems per work operation

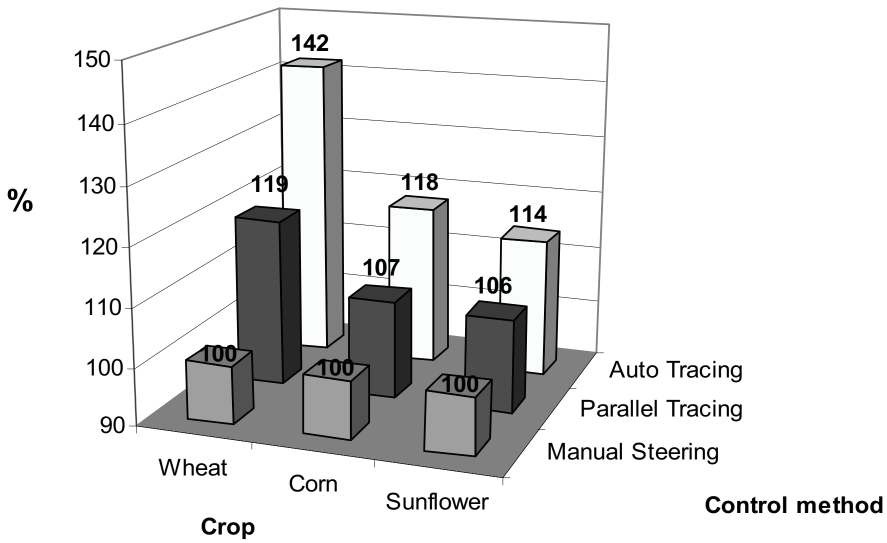


Figure 2 Field performance increase with parallel and automatic steering systems per production technology

The change of investment demands

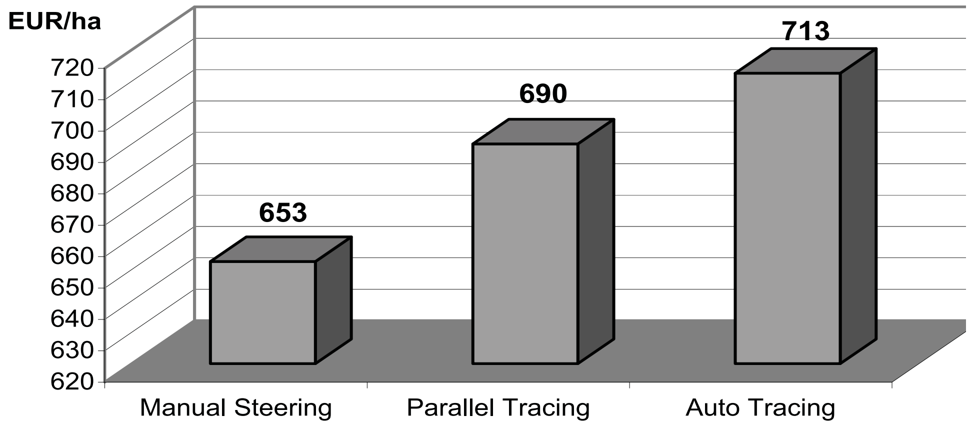


Figure 3 The change of specific machinery investment demands in case of parallel and automatic steering

On the basis of calculations done on a 1 hectare territory, the investment demand of machinery able to serve three crops increases costs with 9.375HUF/ hectare in case of parallel steering, while 15.000 HUF/ hectare in case of automatic steering as compared to manual steering. (Figure 3). The increase of productivity compensates the higher costs.

The change of specific machinery cost in terms of different crops

On the basis of the performed analysis the specific (calculated on one hectare) average cost of machinery work as compared to manual steering decreases by 4440 HUF/ hectare in case of parallel steering, and by 5621 HUF/ hectare in case of automatic steering, which means 9,19% and 11.92% savings. The highest savings may be reached within wheat production by the application of automatic steering - that is 12.47%; 5677 HUF/ hectare. In case of line cultures slightly less, however over 11% cost reduction may be realised (Figure 4).

Machinery work savings possibilities

The examined farm applies high capacity machinery and machinery work effective, operation reduced production technologies as compared to the Hungarian average, therefore it uses low, 3.17 operational hours machinery work on average for the cultivation of one hectare.

This specific machinery work volume may be reduced with an additional 7.9% by the application of parallel, and 11,1 % by the application of automatic steering systems (Figure 5). This means that when cutting edge technology and machinery are used less than 3 operational hours machinery works is needed for the cultivation of an hectare, which is a rather favourable value even in international comparison.

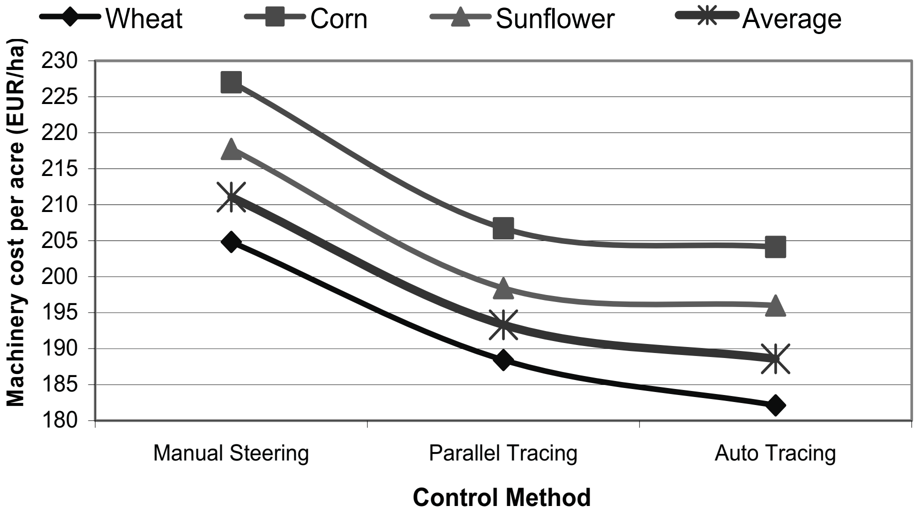


Figure 4 The change of machinery cost per hectare in terms of different crops when manual, parallel and automatic steering methods are applied

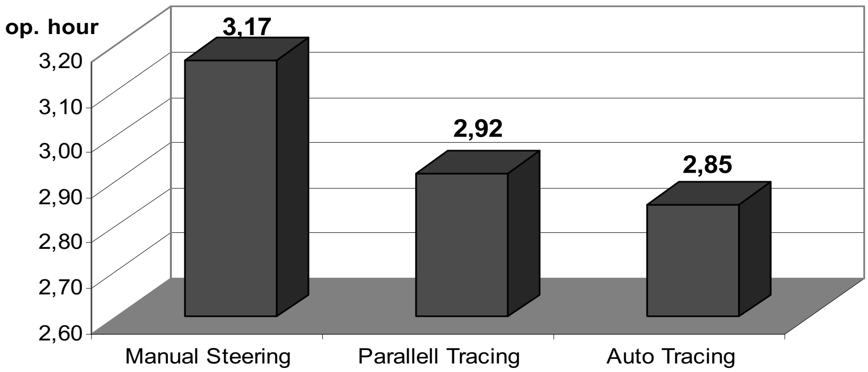


Figure 5 Operational hour performance per hectare in case of different steering methods in the examined farm

Reduction of machinery workload

The annual machinery workload of the power engines used in the farm may be significa-ntly – by 8-11% - decreased as a result of more accurate and effective operations. In favourable cases even 400-500 operational hours may be saved, which may result in the reduction of the number of machines, or the utilisation of machinery in leasing, rental contracts. By parallel steering machinery workload may be decreased with at least 400 operation hours, while automatic steering may result in even 512 hours savings in the 1600 hectare farm (Figure 6).

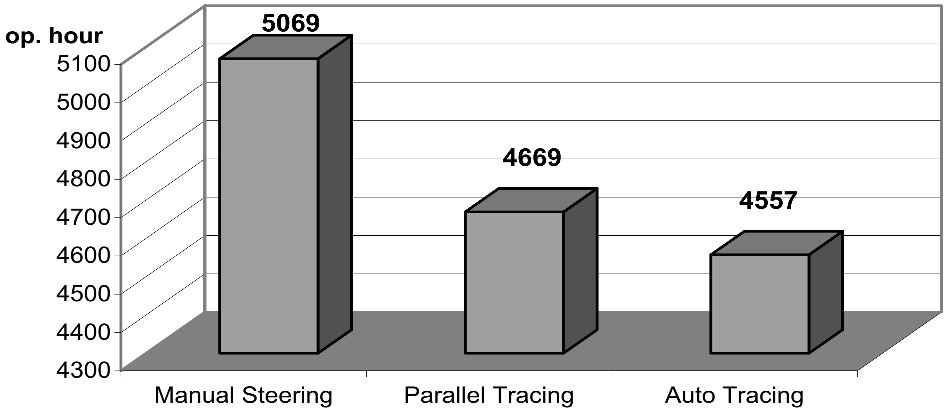


Figure 6 Annual operational hour performance of power engines in case of different steering methods in a 1600 hectare farm

PROPOSALS FOR THE UTILIZATION OF THE RESULTS

The widespread application of the results shall be proposed in the plant production sector of agriculture. The results of the farm having contributed in the realisation of the project have proved the benefits, which have encountered in the course of the examinations and measurements.

Primarily automatic steering solutions are to be advised, which ensure higher efficacy and cost reduction, furthermore are less demanding for the operator, who may concentrate better on the quality of work. Advances may be experienced in the quality of work, or possible loss may be reduced.

Remarkable benefits may be indicated particularly in case of bigger farms or more intensive machinery use, where machinery work per hectare expenditures may be decreased, while the efficacy of machinery work is increased, not to mention the better production results to be realised due to precision cultivation. The benefits may be measured in farms of 300-400 hectares, however the result are more notable in 4000-5000 hectares farms.

Another benefit of the automatic steering and machinery control systems is that they may be developed gradually or completed step by step in case of a given machinery fleet. The system may be developed into the direction of work machines from power engines implementing effective and precision production, which is regarded as the most advanced agricultural production technology nowadays.

REFERENCES

1. Földesi I.: (2005) Precíziós termelés, Őstermelő, 2005/2, 96-99 old.
2. Földesi I., Fekete, A., Kovács L.: (2006) Comparison of GPS-based automatic vehicle steering and navigation aid. Book of Abstracts of International Conference on Advances in Agricultural Technologies and their Economic and Ecological Impacts. Tel Aviv, May 8-10. 13-14.

3. Földesi I., Hajdú J., Magó L., Fekete, A., Deákvári J., Kovács L.: (2007) Automatic steering with GPS navigation aid. Agricontrol 2007. 2nd IFAC International Conference on Modeling and Design of Control Systems in Agriculture. Osijek, Croatia, 03.-05. September 2007. p. 207-210.

4. Hajdú J., Kelemen Zs., Magó L.: (2008) „Automatikus irányítás alkalmazásával elérhető géphasz-nálati költség csökkentés vizsgálata a szántóföldi növénytermelésben” MTA-AMB XXXII. Kutatási és Fejlesztési Tanácskozás, Gödöllő, 2008. január 22., 1. kötet, p. 150-154.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 633.11:633.15] (497.5)
Prethodno priopćenje
Preliminary communication

KRIVULJA JEDNAKOG PROIZVODA ZEMLJIŠNIH I NE-ZEMLJIŠNIH RESURSA U PROIZVODNJI PŠENICE I KUKURUZA U REPUBLICI HRVATSKOJ

MIROSLAV TRATNIK, RAMONA FRANIĆ, IVO GRGIĆ

Sveučilište u Zagrebu, Agronomski fakultet, Svetošimunska cesta 25,
10 000 Zagreb, Hrvatska, e-mail: mtratnik@agr.hr

SAŽETAK

Proizvodne mogućnosti nacionalnih poljoprivreda ili njezinih proizvodnji, mjere se kroz odnos raspoloživih zemljišnih i ne-zemljišnih ili kapitalnih resursa. Isto tako proizvodni potencijal poljoprivrede zavisi i o proizvodnoj kombinaciji tih dvaju resursa. Poljoprivrede istih zemljišnih i ne-zemljišnih resursa u kvantitativnom smislu, mogu postići iste razine proizvodnji uz različite, više ili niže razine njihovih kombinacija. Drugim riječima, razina kombiniranja među resursima u ostvarivanju iste proizvodne razine bit će definirana agrarnom politikom, odnosno mjerama poticaja.

Tako će poljoprivrede kapitalno niže opremljenosti (u razvoju i nerazvijene) svoju krivulju jednakog proizvoda (poljoprivrednu proizvodnju) i agrarnu politiku morati temeljiti na politici „rastrošnosti“ zemljišnih resursa, dok će one druge (višeg kapitalnog koeficijenta) svoju poljoprivrednu proizvodnju temeljiti na agrarnoj „zemljišno-štednoj“ politici.

U radu računamo funkciju jednakog proizvoda za pšenicu i kukuruz u Republici Hrvatskoj iz kombinacija distribucije korištenih zemljišnih i ne-zemljišnih resursa deriviranih količinom proizvodnje iz proizvodno-potrošne bilance (1983.-2006.). Matematički, funkcija jednakog proizvoda po tipu je istostrana hiperbola s asimptotama na koordinatnim osima zemljišnih i ne-zemljišnih resursa.

Svaki par točaka dva resursa na hiperbolnoj funkciji je kontinuirana kombinacija tehnoloških razina za istu razinu proizvodnje (Prema proizvodno-potrošnoj funkciji jednakog proizvoda Hrvatske za pšenicu i kukuruz iznose 1.230.300 tona (prema količinama izokvanti za razdoblje 1997.-2007.). U teoriji, kod istostranih hiperbola te su kombinacije asimptotski neograničene, dok su one u praksi nacionalnih poljoprivreda, skup određen prema "ukusu" nacionalnih agrarnih politika odnosno njihovih strategija rasta i razvitka.

Ključne riječi: *krivulja jednakog proizvoda, zemljišni i ne-zemljišni resursi, pšenica, kukuruz, samodostatnost.*

UVOD

Proizvodnja pšenice i kukuruza su najvažnije ratarske radno-ekstenzivne (kapital-intenzivne) kulture. Posebice se to uočava na krupnijim i specijaliziranim proizvodnim sustavima. Tehnološko-ekonomski gledano, oni troše relativno malo rada s visokom razinom kapitalne opremljenosti rada.

Zapravo, na makro-razini ekonomika nije ništa drugo nego umješnost kombiniranja korištenja ograničenih resursa ili njihovih agregata u cilju postizanja optimalnih rezultata na razini proizvodnji, grana i gospodarstva kao cjeline.

Danas to posebno dolazi do izražaja kada su svjetski trendovi održive poljoprivredne proizvodnje posebno izraženi u pogledu optimalnog korištenja neobnovljivih i ne-proizvodivih resursa kakvo je zemljište. Stoga je vrlo bitan izračun funkcije jednakog proizvoda i spoznaja o mogućim kontinuiranim (po funkciji modela) kombinacijama utrošaka zemljišnih i ne-zemljišnih resursa u toj proizvodnji, a za količinu nacionalne samodostatnosti u potrošnji pšenice i kukuruza.

Danas u svijetu postoje dva pristupa i razine tehnologije proizvodnje pšenice (Posebice se to odnosi na proizvodnju pšenice u dvije zemlje, Argentinu i Sjedinjene američke države kao najveće svjetske proizvođače pšenice.) i kukuruza. Tehnologije koje se temelje na raspoloživim velikim proizvodnim površinama (Argentina, Kanada, SAD) odnosno koriste zemljišno „rastrošnu“ tehnologiju (da bi osigurali samodostatnost i izvoz-krivulju jednakog proizvoda) i one koje koriste zemljišno reduktivnu tehnologiju. Rast prinosa po jedinici površine postaje tehnološko-ekonomski imperativ. Odabirom takovog koncepta u proizvodnji pšenice i kukuruza uvjetuje vođenje agrarne politike u zemlji koja će raspoloživu razinu ne-zemljišnih inputa uzeti kao nezavisnu varijablu, kombinirajući je s reduktivno raspoloživim zemljišnim inputom kao zavisnom varijablom a za razinu nacionalne bilančne samodostatnosti (jednakog proizvoda).

MATERIJAL I METODE

Podaci korišteni za modeliranje krivulje jednakog proizvoda oficijelni su podaci Državnog zavoda za statistiku Republike Hrvatske. Pri tome se kao jedna od nezavisnih varijabli ne-zemljišnog resursa koristila potrošnju mineralnog gnojiva u tonama dok su drugu varijablu zemljišnih resursa činile varijacije u požnjevenim površinama pod pšenicom i kukuruzom.

Temeljem ovih podataka izračunati su parametri jednostrane hiperbole koja je u grafičkom obliku krivulja izokvante, odnosno funkcija jednakog proizvoda, odnosno krivulja. Krivulja jednakog proizvoda (CEP) pokazuje alternativne kombinacije dvije vrste resursa koje će proizvesti istu količinu ukupnog proizvoda (Harold G. Halcrow, str. 75.,1980.). Svaki par točaka dva resursa na hiperbolnoj funkciji je kontinuirana kombinacija tehnoloških razina za istu razinu proizvodnje.

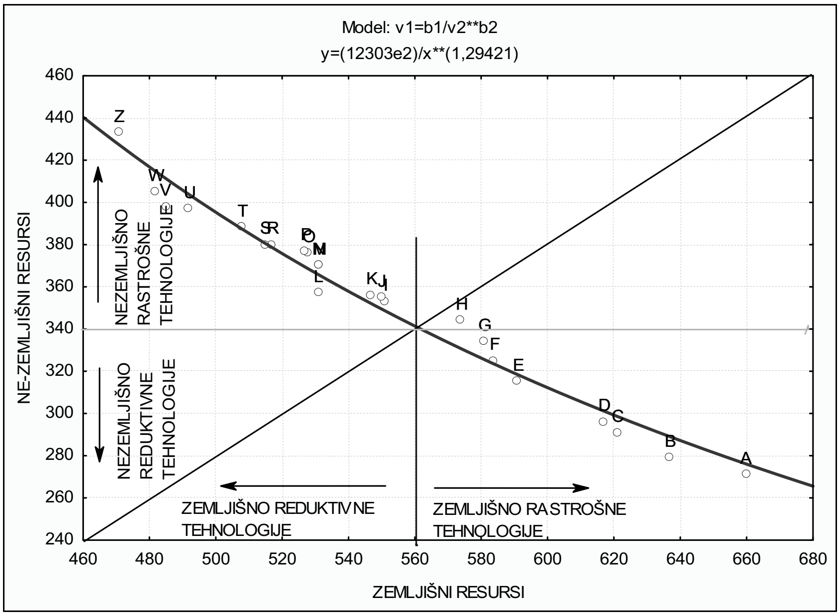
Pri izračunu vrijednosti parametara funkcije jednakog proizvoda na razini bilancirane nacionalne samodostatnosti pšenice i kukuruza koristila se je metoda ponderiranih najmanjih kvadrata (*Weighted Least Squares*) iz softwareskog paketa STATISTICA 7.0.

Izokvante prema definiciji su krivulje rjeđe pravci koji povezuju točke iste vrijednosti, u svakom trenutku, kontinuiranu i definiranu kombinaciju dviju nezavisnih varijabli. Dakle, u našem modelu nezavisne su varijable zemljišni i ne-zemljišni resursi koje je R. Hrvatska koristila u razdoblju 1997-2007., dok je zavisna varijabla konstanta hiperbole, odnosno vrijednost jednakog proizvoda od 1,23 milijuna tona.

Jednakostrana hiperbola kao zaglađeni funkcijski model jednakog proizvoda parametriran je korištenjem zemljišnih i ne-zemljišnih resursa odnosno potrošnje mineralnog gnojiva. Njezin je funkcijskih oblik:

$$\Psi = \frac{1.230.300}{X^{1,29421}}$$

Hrvatska je svoju funkciju izokvante jednakog proizvoda za pšenicu i kukuruz uprosječila na razini samodostatnosti od 1.23 milijuna tona. Ta se proizvodnja mogla postići diskretnom kombinacijom potrošnje mineralnog gnojiva kao ne-zemljišnog resursa u rasponu od 270 do 430 tisuća tona u tehnološko-ekonomskoj kombinaciji s zasijanom površinom od 470 do 680 tisuća požnjevenih hektara.



Grafikon 1 Izokvantna funkcija jednakog proizvoda u proizvodnji pšenice i kukuruza u Hrvatskoj

Kombinacija nezavisnih varijabli nije samo puka kombinacija utrošaka dva resursa izokvante nego kroz nju i određena tehnološka razina proizvodnje. U tom smislu je poznato, kako pojedine zemlje svijeta primjenjuju različite tehnološke kombinacije upotrebe resursa (sukladno agroekološkim uvjetima i ciljevima agrarne politike) za planiranu, proizvodno-potrošnu samodostatnu količinu. Takve se tehnološko-ekonomske kombinacije kreću od redukcije uporabe količine onog resursa kojega imaju ograničenog ili konkurentski uvjetovanog (potrošno reduktivnog) do onog kojeg pojedine zemlje imaju dovoljno i proizvodno-ekonomski zamjendbenog i poznatog kao potrošno rastrošne tehnologije proizvodnje, odnosno za onu proizvodnju koja je tržišno profitabilnija ili nacionalnom strukturom proizvodnje planirana.

REZULTATI I RASPRAVA

Ekonometrijski gledano krivulja jednakog proizvoda je istostrana hiperbola čije točke predstavljaju iste razine proizvodnje koja se može postići s različitim kombinacijama utrošaka resursa, a čijom uporabom su uvjetovane. U našem je modelu izokvanta jednakog proizvoda funkcijska konstante odnosno količine pšenice i kukuruza samodostatne u potrošnji Republike Hrvatske.

U zemljama svijeta koje primjenjuju zemljišno rastrošne tehnologije proizvodnje prinosi po jedinici proizvodne površine su relativno niski odnosno obrnuti kod zemljišno reduktivnih tehnologije. O tome nam svjedoči sljedeća tablica posebice u proizvodnji pšenice.

Tablica 1 Komparativni prikaz tehnoloških obilježja proizvodnje pšenice kroz prosječne prinose

Država	Aritmetička sredina $\bar{x}$	Standardna devijacija σ	Pouzdanost -95,0%	Pouzdanost +95,0%	t-vrijednost	p
SAD	2,76	0,19	2,62	2,89	45,9	0,0
Argentina	2,44	0,19	2,31	2,58	40,0	0,0
Hrvatska	3,98	0,49	3,63	4,33	25,7	0,0
Mađarska	3,91	0,67	3,43	4,39	18,3	0,0
Francuska	6,98	0,51	6,62	7,35	43,6	0,0
Češka	4,68	0,52	4,31	5,05	28,5	0,0

Izvor: Izračuni autora

Iz tablice je moguće, vrlo nedvojbeno, pročitati kako je proizvodnja pšenice u SAD-u i Argentini, velikih svjetskih proizvođača, obilježena niskim prinosima po jedinici površine od 2,44 odnosno 2,76 tona po ha s relativno stabilnim prinosima,σ_A=0,19 i σ_{Ar}=0,19. Takove tehnologije prepoznajemo u pojedinim zemljama kao zemljišno rastrošne, jer raspolažu s velikim proizvodnim površinama za postignuće razine nacionalne prehrambene i izvozne samodostatnosti.

S druge strane, zemlje europski proizvođači, uključujući i Hrvatsku sklonije su zemljišno reduktivnoj tehnologiji proizvodnje, a nacionalna samodostatnost često je vezana za agro-ekološki povoljne i manje povoljne proizvodne godine. Hrvatska bi s obzirom na prosječne prinose pšenice spadala u zemlje proizvođače pšenice, zemljišno rastrošne tehnologije proizvodnje, s niskim prosjekom prinosa od svega $\bar{x}$ = 3,98 t/ha iako po europskim proizvodnim karakteristika (ograničenih sjetvenih površina) pripadala bi krugu zemljišno reduktivnih tehnologija proizvodnje.

To sve se često iskazuje u čestim godišnjim oscilacijama samodostatnosti na nacionalnoj razini a za posljedicu ima vrlo velike prosječne godišnje oscilacije tržišnih cijena. S druge strane hrvatska agrarna politika ne poznaje i ne prakticira optimalnu kombinaciju zemljišnih i ne-zemljišnih tehnologija kako bi osigurala nacionalnu samodostatnost na pšenici i kukuruzu.

Sličnu tendenciju zemljišno raskošne tehnologije u proizvodnji pšenice pokazuje i Mađarska dok bi se za Češku Republiku i posebice Francusku moglo konstatirati kako primjenjuju kombinaciju kapitalno odnosno ne-zemljišno rastrošni tehnološko-ekonomski koncept.

Hrvatska je prema funkciji izokvante svoju samodostatnu nacionalnu proizvodnu razinu pšenice i kukuruza mogla postići s neutralnom kombinacijom zemljišnih resursa od 560.000 požnjevenih hektara i ne-zemljišnog resursa iskazanog kroz potrošnju mineralnog gnojiva od 340.000 tona. Svakako da se za istu razinu proizvodnje iz neutralne tehnologije mogla izvesti bilo koja diskretna kombinacija utrošaka ovih resursa.

ZAKLJUČAK

U tom smislu Hrvatska ima zemljišno rastrošnu ili ne-zemljišno reduktivnu tehnologiju proizvodnje pšenice i njoj korespondentnu agrarnu politiku. Isto se može reći i za proizvodnju kukuruza budući su problemi plasmana i cijena ovih temeljnih ratarskih proizvoda predmetom post-žetvenih prijepora vlade i proizvođača.

Godišnje proizvodne površine se indikativno ne planiraju jer se ne uvažava planiranje putem krivulje jednakog proizvoda barem za angažman zemljišta i mineralnog gnojiva kao ne-zemljišnog resursa. Ta su dva resursa visoko utjecajna u definiranju proizvodno-potrošne samodostatnosti na nacionalnoj razini. Prepuštanje laissez-faire (Jedan od vodećih načela kapitalizma. Ova doktrina zahtjeva da ekonomski sustav bude slobodan od vladine intervencije ili modernizacije i bude upravljan samo prema zahtjevima tržišta.) odluke proizvođačima koji proizvodne površine zasnivaju temeljem cijene iz prošle godine nije strateško upravljanje ovim segmentima proizvodnje u ratarstvu. To rađa stihijnost koja će utjecati na kretanje cijena sukladno agroekološkim uvjetima, a ne alternativnim kombinacijama prema zakonitostima krivulje jednakog proizvoda. Ekonometrijska egzaktnost ili objektivna indikativnost nisu bile „ideje“ vodilje agrarne politike u tom segmentu naše poljoprivrede.

LITERATURA

1. Neten, J., Wasserman, W., &Kutner, M.H. (1985): Applied linear statistical models: Regression, analysis of variance, and experimental designs. Homewood, IL: Irwin.
2. Harold G. Halcrow (1980): Economics of agriculture, McGraw-Hill, New York.
3. Harold Graham Halcrow (1998): The laws of my life, Published, H.G. Halcrow (Champaign, Ill)
4. Horn, R.V. (1993): Statistical Indicators for Economical Sciences; Cambrige University Press, Cambridge, CP2 1RP, UK
5. Robert S. Pindyck, Daniel L. Rubinfeld (2005): Microeconomics (5th Edition), McGraw-Hill, New York
6. Kazuo Sato (1975): Production Functions and Aggregation, North-Holand American Elsevier.
7. Tratnik, M., Ramona Franić, Kristina Svržnjak, Bašić, F. (2009): Lend rents as a criterion for regionalization-The case of wheat growing in Croatia; Land Use Policy,Vol. 26 No 1,
8. Tratnik, M., Grgić, I, Franić, Ramona (2008): Kolebljivost cijena voća i žita i ekonomska opravdanost infrastrukturnih objekata za čuvanje i hlađenje: pro et contra, Aktualni zadaci mehanizacije poljoprivrede / Silvio Košutić (ur.). – Zagreb, Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, 623-631, Opatija, Hrvatska

EQUAL PRODUCT CURVE OF LAND AND NON-LAND RESOURCES IN PRODUCTION OF WHEAT AND MAIZE IN THE REPUBLIC OF CROATIA

SUMMARY

Production potentials of national agricultural systems or their productions are measured by a ratio of available land and non-land or capital resources. Also, production potential of agriculture depends on production combination of these two resources. Agricultural systems of the same land and non-land resources in a quantitative sense, can achieve the same production levels at different, higher or lower levels of their combinations. In other words, the level of combination of the resources in achieving the same production level will be defined by agricultural policy measures, or – more specific – by measures of support.

So, agricultural systems with lower capital equipment (developing or undeveloped), will found their equal product curve (agricultural production) and agricultural policy on the policy of "prodigality" of land resources, while the other ones (of higher capital coefficient) will found their agricultural production on agricultural policy of saving (economical) land use.

The function of equal product for wheat and maize in the Republic of Croatia is calculated from distribution combinations of used land and non-land resour-

ces, derived by production quantities from the production-consumption balance sheets (1983-2006). Mathematically, the equal product function is equilateral hyperbola with asymptotes on co-ordinates of land and non-land resources.

Each pairs of dots of two resources on hyperbola function is a continuous combination of technological levels for the same level of production. Theoretically, in the case of equilateral hyperbola, those combinations are asymptotically unlimited, while those in national agricultural practices make a group determined by the "taste" of national agricultural policies, or their growth and development strategies.

Key words: *equal product curve, land and non-land resources, wheat, maize, self-sufficiency*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 338.2:631.164
Stručni rad
Expert paper

EUROPEAN RURAL DEVELOPMENT POLICY - IMPLICATIONS ON ROMANIA

ELENA TONEA, MONICA BUTNARIU

Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara,
elenatonea@yahoo.com

SUMMARY

The European rural development policy plays a major role in economic, social and territorial cohesion. It is based on the following principles: recognising the multifunctional role of agriculture, improving competitiveness, ensuring that environmental issues are taken into account, diversifying economic activity, conserving rural heritage.

***Key words**: Rural policy, agricultural investments, agricultural and forestry activities*

INTRODUCTION

The future of agriculture is closely linked to the balanced development of the countryside, which accounts for 80% of the area of Europe. Alongside the market support measures, the European rural development policy plays a major role, in Europe, as well as in Romania.

Only economically viable farms which comply with minimum standards regarding the environment, hygiene and animal welfare, and where the farmer possesses adequate competence, are eligible for romanian market.

The conditions relating to investment aid must be met at the date on which the individual decision granting aid is adopted. In EU, when investments are made in order to comply with new standards, farmers may be granted aid and a period of grace.

EU GUIDING ADVISES FOR AGRICULTURAL HOLDINGS

The aid for young farmers targets heads of holdings who are under 40 years of age, possess adequate competence and are setting up in farming for the first time.

Their holdings must be viable and comply with minimum standards regarding the environment, hygiene and animal welfare.

The aid consists either of a single premium of up to EUR 25,000, or an interest subsidy on loans taken on with a view to covering the costs of setting up. In such cases, the amount of the interest subsidy may not exceed the value of the single premium, except in the case of young farmers using agricultural advisory services, during a three year period, for which the ceiling is EUR 30,000.

SUPPORT FOR VOCATIONAL TRAINING

This kind of support it should improve the occupational skill and competence of farmers and other persons involved in agricultural and forestry activities, help them redeploy production in qualitative terms, apply production practices compatible with the upkeep and improvement of the landscape, protection of the environment and meet the standards applicable to hygiene and animal welfare, and manage their holdings better.

In Romania, improving processing and marketing of agricultural products will be followed by firms which are economically viable and which comply with minimum standards regarding the environment, hygiene and animal welfare; they may receive support for investments to improve the processing and marketing of agricultural products.

The goal is to increase the competitiveness and added value of agricultural products by improving their presentation, rationalising processing procedures and marketing channels, reorienting production to new outlets, applying new technologies, monitoring quality and health conditions, encouraging innovation and protecting the environment.

FORESTRY

Concernind the european forestry programmes, support may be granted to private individuals, municipalities and associations thereof who own woodland. Using that as an example in Romania such aid may contribute to:

- improving non-farm land: measures include afforestation, investments to enhance the value of forests and improve the harvesting, processing and marketing of forestry products, open up new outlets for forestry products, promote joint action by forest owners and assist the recovery of forestry production as a result of natural disasters or fire;
- afforestation of farm land: aid may be granted to cover the costs of planting and maintenance and to compensate farmers for income forgone;
- preserving woodlands, where their protective and ecological role is in the general interest and where the cost of preventive measures exceeds the income from silviculture, and maintaining fire breaks.

In the case of woodland classified as high or medium forest fire risk, the measures must comply with the national plans under the Community legislation on the protection of forests.

FACILITATING THE DEVELOPMENT AND STRUCTURAL ADJUSTMENT OF RURAL AREAS

Community support may also be granted to activities not covered by the above measures, but which contribute to converting and improving farming activities.

Such activities include land reparcelling, setting up farm advisory services, marketing high-quality agricultural products, development of key services in rural areas, renovation of villages and protection of heritage, promotion of tourism and craft activities, management of integrated rural development strategies by local partnerships, etc.

These measures are financed by the EAGGF Guarantee Section or Guidance Section, depending on their regional context.

The EAGGF Guarantee Section covers support for early retirement, less-favoured areas, agri-environment measures and afforestation of farmland. The other rural development measures are financed by the EAGGF Guidance Section in Objective 1 areas and by the Guarantee Section in regions not covered by Objective 1.

The Commission may extend the scope of the measures eligible for financial assistance from the EAGGF Guidance Section and propose the financing of studies relating to programming by the EAGGF Guarantee Section.

Lastly, the EAGGF also covers measures for the development and structural adjustment of rural areas relating to the renovation and development of villages, the protection and conservation of rural heritage, the diversification of farm activities and the improvement of infrastructure relating to the development of farming which are not financed by the European Regional Development Fund (ERDF).

Romanian rural development measures must be compatible with Community law and coherent with other Community policies. Such coherence is especially important in the case of the CAP provisions on the common market organisations and measures on quality and health in agriculture.

In addition, measures receiving financial assistance under this regulation may not receive aid under any other Community support scheme. Moreover, any measure which is incompatible with a specific condition laid down in this Regulation will not be eligible for support under other Community support schemes.

Rural development aid granted by the Member States must comply with the Community rules on State aids and the ceilings fixed by the Council in the agricultural regulations and directives (above such ceilings, national aids must be notified by the Member States and approved by the Commission) and with the Community rural development rules. Thus:

- State aids for investments that exceed the percentages laid down for Community aid are prohibited, except in the case of investments to improve the environment, hygiene and animal welfare in the general interest;
- aid to compensate for natural handicaps must always comply with the Community rules;

- agri-environment aid must comply with the Community conditions and limits, although these may be exceeded where necessary to properly cover the loss of income, additional costs, etc.

To ensure that all rural areas in the Community are covered by the rural development policy, the measures provided for in the regulation are included in the following multiannual programmes:

- Objective 1 programmes: measures financed by the EAGGF Guidance Section;
- Objective 2 programmes: measures relating to early retirement, less-favoured areas and areas subject to environmental constraints, agri-environment measures and afforestation of farm land;
- rural development programmes: all other measures.

Rural development programmes are based on plans drawn up by the Member States at the most appropriate geographical level for a seven-year period (2000-2006). These plans describe the current situation, the proposed strategy, the expected impact, the financial planning, the planned measures, including agri-environment measures, the necessary studies and technical measures, the competent authorities and the provisions required to implement the plan effectively.

The Member States must present their rural development plans to the Commission not later than six months after the entry into force of the regulation, and the Commission must adopt the final programmes within six months of their submission.

FINANCIAL PLANNINGS

The regulation on the financing of the common agricultural policy applies to rural development measures, except in the case of certain measures covered by Objective 2.

Now that financial planning has been included in the programming, the Commission fixes the initial allocations to the Member States, broken down by year, on the basis of needs and efforts to be undertaken. They can be adjusted in the light of actual expenditure and any expenditure reviews carried out by the Member States.

As example, the Community Initiative Leader+ is one of the programs which are promoting the implementation of integrated, original strategies for sustainable rural development. It focuses on local partnership and promotes networking in rural areas.

CONCLUSIONS

During next period, in Romania should be adopted detailed rules on the conditions for granting support, the calculation of allowances and the periods and conditions to be applied, as well as the implementing provisions for the rural development plans, the revision of programmes, financial planning, monitoring and evaluation and the coherence between rural development and the market organisations.

REFERENCES

1. Prisecaru, Petre (2005). Guvernanţa Uniunii Europene, Editura Economică, Bucureşti.
2. Vass, Andreea (2005). Protecţionismul European. Implicaţii asupra României, Editura Economică, Bucureşti.
3. www.europeana.ro

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 330.32:631.164.23
Stručni rad
Expert paper

HOW CAN BE SUSTAINABLE INVESTMENTS EFFICIENT FROM ECONOMICAL POINT OF VIEW

ELENA TONEA

Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara

SUMMARY

Investments are a present spending for a future gain either profit or other benefits (ecological, social, technical, skills etc.). The investments can be adapted to the change and made sustainable. This is not a fashion; it is a reality that already is present in well developed countries. The European developed countries are investing in their own economies on sustainable development basis and putting the foundation for a new economy based on information technology.

Key words: *Investments, efficiency, sustainability*

EFFICIENCY AND EFFECTIVENESS IN INVESTMENTS

The non-classical approach, based on sustainable investments and new economy, is necessary for Romania on its access to European Union economic integration. The efficiency means to do well what are you doing, at time and with optimum consume of resources human, material or financial. The economic efficiency of investments means to put in balance efforts (financial, human, technical etc.) with effects (gains as turnover, profit, production, services, products, impact on environment etc.).

For example, an investment in a building is efficient if the time of completing and the return on investment is full filed at the desired time without any time delays and resources over consumptions.

The efficiency coefficient help at the selection of a variant of a project investment from others taking as a base the ratio effects/ efforts there were seen as profit/ costs, for instance, or products made / optimum quantity consumed resources.

Effectiveness means to do the right thing, with the lowest consumption of resources human, material, technical or financial. In a practical way it means that an investment is effective if it is the most adequate for the purpose involved and it is done with the lowest (or optimum) consumption of resources. For example, an investment in a building is effective if the desired utility is full filed and the consumption of resources during using is the most appropriate.

INVESTMENTS AND SUSTAINABLE DEVELOPMENT IN ECONOMY AND AGRICULTURE

The concept of sustainable development has emerged in the seventies due to the general concern about the global environment, as a result of pollution and an increasing usage of sources for raw materials and energy. Sustainability means the rearrangement of technological, scientific, environmental, economic and social resources in such a way that the resulting heterogeneous system can be maintained in a state of temporal and spatial.

Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

As a result of the definitions of a sustainable development, a sustainable production can be an industrial activity resulting products that meet the needs and wishes of the present society without compromising the ability of future generations to meet their needs and wishes. As a consequence of this definition, a sustainable production will minimize the pollution of the global environment as well as the use of natural sources of raw materials and energy.

A possible way to reach these requirements is by a continuous improvement of industrial activities with respect to:

- reduction of energy usage of non-renewable energy sources,
- usage of recovered goods, parts and materials from discarded goods,
- sustainable product quality.

A sustainable production implies that all phases of the product are viewed with respect to the requirements, from the exploitation of raw material and energy sources until the recovery of materials. In the chain, the different industrial activities can be distinguished: exploration of raw material and energy sources, transformation of raw materials into materials, product design, transformation of materials into products, recovery of goods, parts and materials.

To arrive at sustainability for the complete chain, each activity of the chain should be sustainable. That means that three main activities of the chain have to be optimized: product design, transformation and recovery.

The product design determines the material and energy usage of a product during his entire life cycle and the percentage of recovery. During the transformation activity, material and energy usage is depicted by the used processes and systems, while this activity determines the product quality too. During recovery, the quantity and quality of recovered goods, parts and materials are determined by the processes and systems.

Product and production belongs to each other and are coupled on the technology: product-technology-production. Innovations are obtained by new technological opportunities while demand is dictated by the market.

ECO-DESIGN PRODUCTS AND INVESTMENTS

The product design is important for all activities in the chain in order to create an integral chain control with respect to a sustainable development. Almost all limitations are the result of the product design.

To create a sustainable investment, the choice of the materials and the way the product structure has been composed, are very important. Therefore the following activities should have a high priority for the product eco-design:

- minimal usage of virgin materials,
- minimal energy consumption during the production and usage periods,
- usage of materials which can be recovered easily,
- eco-design with easy to divide materials,
- easily disassembled or dismantled oriented product design,
- eco-design so that parts and the product have long life cycles.

The aim is to have the requirements with respect to sustainability from the beginning of the design phase, using concurrent engineering and concurrent economics.

The purpose of production is to enrich society through the production of functionally desirable, aesthetically pleasing, environmentally safe, economically affordable, highly reliable, top-quality products. Technical development has made it possible to attain high productivity rates which are essential for any society willing to enjoy high living standards.

In the past, it was tried to obtain an efficient organization in order to have a higher production output. But now the price pressure requires an efficient organization in order to reduce the cost price.

To be competitive, management has focused on reorganizations and transferring the production to low wages countries. Besides being efficient and producing with a high quality, product assortment, delivery time and the look of a product became very important.

A sustainable production system means that production system will have less impact to the environment, and it's end products as well, being characterized by: reduction of energy usage from non-renewable sources, closing the production chain by introducing recovery of the goods, parts and materials, increasing the sustainable product quality.

CONCLUSIONS

To transform an existing production system into sustainable Romanian investitures could follow some of the next strategies.

Total Excluding Strategy: is the situation in which it gives no market demand for the product, or the product doesn't full fill the sustainability requirements; this means that there are no economical-ecological reasons to maintain it.

Reconverting Strategy: is the situation in which it gives to a market demand for the products, or the products don't full fill the sustainability requirements and (the product) could be replaced on the market, with other types of products resulting from other types of technologies; in the mean time the technical facilities (machinery, equipment etc.) could be used in remodeling the process (in a sustainable way) for other (sustainable) end-products with other segment market destination.

Reconfiguration Strategy: is the situation in which it gives a market demand for the product at affordable price, but the product doesn't full fill the sustainability requirements, or the technological chain is not sustainable itself and there are not enough investment funds to finance the total replacing with a new one.

Total Replacing Strategy: is the situation in which already exists a market demand for the products, and because these are not sustainable, and the technology to produce them is not sustainable as well but there are enough money to buy another to full fill the sustainability requirements.

REFERENCES

1. Bran, F., 2002, *Ecosfera şi politicile ecologice*, Editura ASE, Bucureşti
2. Rojanschi, V., Bran, F., Grigore, F., 2004, *Elemente de economia şi managementul mediului*, Editura Economică, Bucureşti
3. Vasilescu, I., Românu, I., 2000, *Managementul investiţiilor*, Editura Mărgăritar, Bucureşti

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.798:635.9
Prethodno priopćenje
Preliminary communication

IMPROVING WORK PROCESSES IN PACKING HOUSES OF FLOWERS MIXED FARM

GAD VITNER[1], AVITAL BECHAR[2]

[1]Ruppin Academic Center, School of Engineering, Emek-Hefer, 40250, Israel
[2]Institute of Agricultural Engineering, ARO, Beit-Dagan, Israel
e-mail: gadiv@ruppin.ac.il

SUMMARY

The study investigates the work processes in a packing house of flowers mixed farm. These processes are labour intensive, and many workers involved in the various operations cause bottlenecks that affect costs and working efficiency.

The objectives of the present study were to improve work methods of flowers mixed farms growing a variety of cut flowers and green ornamentals, to increase productivity and to develop optimal work plans in order to maximize the total revenue.

The research was performed during the years 2007-2008 in a modern farm in the central part of Israel. The farm consists of 22 hectares, growing a range of cut flowers and green ornamentals during the various seasons: Ruscus, Aralia, Solidago, Aspidistra, Asparagus, Antirrhinum, Crocosmia, Matricaria, Lilium, Gomphrena and Hibiscus. Work studies and time measurements were performed in the various stages of sorting and packing. A computer simulation model was developed to find an optimal work plan to maximize revenue. Decision rules pending the proportion of waste and sales price were developed. It supported the decision whether or not to continue with the packing routine.

Simulation results showed that the optimal number of workers in the washing and cleaning work station is 4. It was found that waste proportion threshold for the Antirrhinum was 75% while 10% for the Ruscus.

Key words: *Packing House, Mixed Farm, Simulation, Work methods, Time studies, Productivity*

INTRODUCTION

The article is based on a study, conducted during the years 2007-2008 in a modern farm in the central part of Israel, that was aimed at increasing productivity. The objectives of the present study were to improve work methods of flowers mixed farms growing a variety of cut flowers and green ornamentals, to increase productivity and to develop optimal work plans in order to maximize the total revenue. The farm consists of 22 hectares, growing a range of cut flowers and green ornamentals during the various seasons: Ruscus, Aralia, Solidago, Aspidistra, Asparagus, Antirrhinum, Crocosmia, Matricaria, Lilium, Gomphrena and Hibiscus.

Work methods analysis is a commonly employed technique designed to improve productivity (Globerson, 2000), whereas the determination of standard times for agricultural work processes, such as harvesting or sorting, is essential to enable efficient labour management (Luxhoj and Giacomelli, 1990; Bechar *et al.,* 2007).

Finding the optimal solution for a given operational situation is a classic industrial engineering problem. By definition, optimal solutions (Taha, 2003) supply the best results, but implementing such optimal solutions can be complicated. The use of optimization in agricultural operations is not frequent due to the lack of complete databases, high variability and low accuracy of the operational, marketing and environmental parameters (Vitner *et al*., 2006).

The objectives of the present study were to improve work methods used on cut flowers mixed farm and to increase productivity in order to maximize total revenue.

METHODS

Farm data

Data were collected on a modern farm in the central part of Israel. The farm consists of 22 ha of various cut flowers and green ornamentals and employed 18 workers. Work studies and time measurements were performed during the various stages in the packing house. Layout (Fig. 1) and geometries of the packing houses were examined. The cut flowers under investigation were Ruscus, Aralia, Solidago, Aspidistra, Asparagus, Antirrhinum, Crocosmia, Matricaria, Lilium, Gomphrena and Hibiscus. The annual yield per hectare is in the range of 600,000-900,000 stems per crop type.

Packing house layout

The packing house consists of several workstations, where workers and materials flow according to the work stages, starting with the washing station and ending with the packaging station, as follows:

- Washing station.
- Sorting.
- Binding station.
- Packaging

Work methods

Work stages in the packing house were defined, and time measurements were taken. The packing house layout is illustrated in figure 1.

The branches are brought to the packing house by the tractor; branch piles are unloaded from the cart and transferred to the refrigerated room for temporary storage. The following processes are performed to accomplish the packaging:

- Transfer from refrigerated room to sorting station.
- Binding 10 stems with two rubber bands (one in the bottom and one at the top of the stem.
- Return to refrigerator for intermediate storage prior to packaging
- Packaging in containers
- Shipment

The sorting and binding station steps are as follows:

- Counting - groups of 10 stems
- Bundling - Binding is accomplished using two rubber bands.

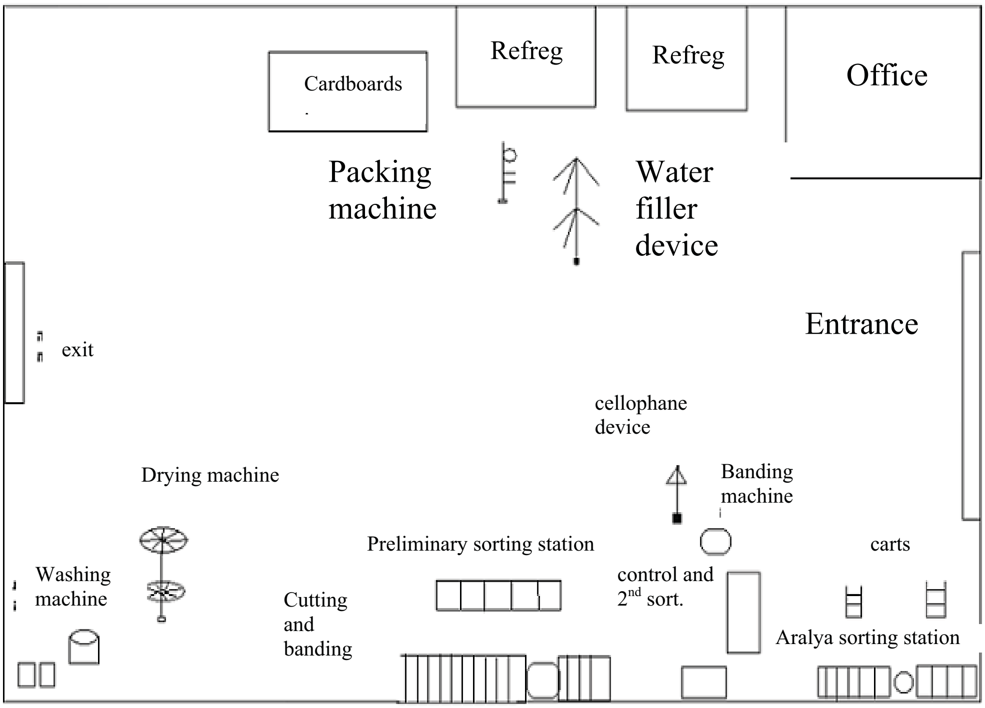


Figure 1 Packing house layout

Work and time measurements

In this research, work studies were performed by means of direct measurements and work sampling techniques (Barnes, 1980). Time measurements were made using work study software developed for handheld computers (Bechar *et al*., 2005).

RESULTS AND DISCUSSION

The results are based on data collected and measured on the farm under study. This farm represents a typical mixed flower farm production processes in the State of Israel. A Pareto analysis conducted showed that there are four major crop types which produce about 90% of the annual sales as follows: Ruscus (4 ha), Aralia (4 ha), Aspidistra (4 ha) and Antirrhinum (1 ha). Thus, the work studies and time measurements were focused on these types. The 2007 annual sales of the four major crop types are presented in Table 1.

Table 1 Annual sale of different crops flowers in 2007

Crop type	Number of Flowers
Ruscus	900,000
Aralia	800,000
Aspidistra	800,000
Antirrhinum	600,000

Time Studies

The major work elements for the studied crops and the related measured times are presented in Table 2.

Table 2 Time studies for major elements and the related proportions

	Ruscus		Aralia		Aspidistra		Antirrhinum	
	Time(s)	%	Time(s)	%	Time (s)	%	Time (s)	%
Binding 10 stems	3.2	50.08	12.48	83.48	2.86	52.58	3.95	44.17
Binding 50 stems	1.83	28.64	1.8	12.04	1.39	25.56	2.62	29.23
Washing	0.23	3.6	0.21	1.4	0.48	8.83	-------	------
Packing	0.65	10.17	0.46	3.08	0.71	13.04	0.79	8.85

Observing the measured time in Table 2 it can be seen that for the various crop types the binding stages contain most of the working cycle time: 73% for Antirrhinum, 77% for Aspidistra, 79% for Ruscus and 95% for the Aralia.

Waste

During the sorting process the workers conducted a visual inspection of the stems to verify the compliance with quality requirements. The following variables were examined: the length, the colour, the width and other visual defects. It should be mentioned that these examinations are somehow subjective and it depends on the experience of the worker. Figure 1 as an example, illustrates the measured proportion of waste for the Antirrhinum. A cost analysis was conducted to verify the break-even point for the rejection of a given batch. The waste threshold for the various crop types is presented in Table 3.

Table 3 Waste threshold for the studied crops

Crop type	Threshold (%)
Ruscus	10
Antirrhinum	75
Aspidistra	35
Aralia	21

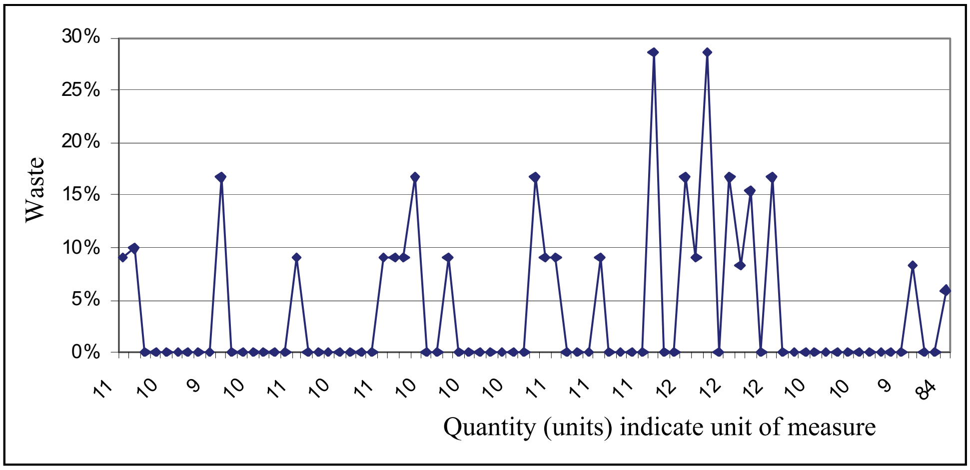


Figure 2 Measured waste proportion of Antirrhinum

Simulation

A simulation model, using the Arena package was developed. The development and validation of the model were conducted as required. The model is actually a mirror picture of the packing house layout and is a flowchart scenario based model (it is not an analytical model) supported by the Arena environment. The main scope of our study is the improvement of work processes in the packing house and not the technical details of the simulation. Thus we do not intend that this paper may be a platform for elaboration of the technical details. The main issue presented is the input/output variables and how it affects productivity.The model simulates the operations at the packing house. It enables to conduct sensitivity analysis ("what if" questions) in order to verify the productivity of various combinations of the relevant variables. The model uses the measured data (distributions of the work elements) achieved during the work study phase. The main goal is to verify the time per stem and hourly outcome per worker as a function, work pace, number of workers, proportion of waste and the size of orders. A validation process was conducted to verify that the model simulates the real life infrastructure. The simulation inputs were: the measured operating time per stem, the number of workers, waste proportion, order quantity. The calculated outputs of the simulation were: total working time per stem, flow time per stem in the packing house, load on workers, total number of stems per crop type.

All combinations of the different variables were calculated. The range and resolution of each variable are shown in Table 4. The simulation was conducted for each crop type.

Table 4 Simulation variables: range and resolution

Variable name	unit	range	resolution
Order quantity	No. of Flowers	500-5,000	1,000
Order quantity	No. of Flowers	5,000-50,000	5,000
Waste	%	0-100	10
Work pace	%	80, 100, 130	-----
Number of workers	worker	1-8	1

For example, a typical combination is: an order quantity of 15,000 flowers, waste proportion of 20%, work pace of 100% and number of workers 5.

The flow time for the various crops versus the number of workers is presented in figure 2.

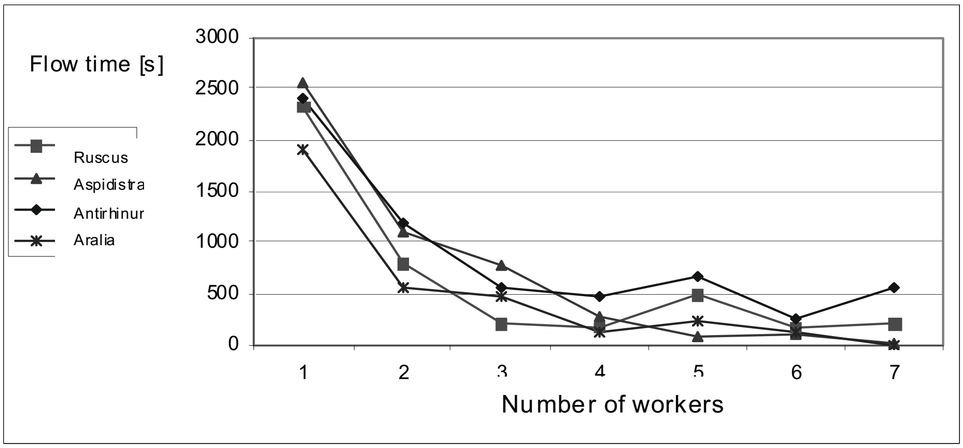


Figure 3 Flow time versus number of workers

The simulation results show that the optimal figure is 4 workers. There is a consistent decrease of the flow time while changing the number of workers from 1 worker to 4 workers.

CONCLUSIONS

The study investigated the yield of the various crop types flowing through the work stations in the packing house. In the work study phase it was found that most of the stations are loaded over 100% and that there are few bottlenecks. The simulation conducted a sensitivity analysis of the yield while introducing the proportion of waste and the market order quantities. Simulation results can support the farmer's decision on the optimal allocation of workers to the various work stations for a given crop type.

REFERENCES

1. Bechar, A., Dayan, D., Schmilowitch, S., Moskovitch, Y., Edan, Y., 2005, "A Pocket-Pc-Based Platform for Agricultural Work Study Measurement". Proceeding of The 35th International Conference on Computers and Industrial Engineering, pp. 269-274. Istanbul, Turkey.
2. Bechar, A., Yosef, S. Netanyahu, S. Edan, Y., 2007, "Improvement of Work Methods in Tomato Greenhouses Using Simulation", Transactions of the ASABE, vol. 50 no. 2, pp. 331-338.
3. Globerson, S.,2000, Operations Management and Performance Improvement, Cherikover Publishers Ltd., Tel-Aviv.
4. Luxhoj, T.J., Giacomelli, G.A., 1990. "Comparison of labour standards for a greenhouse tomato production system: a case study", International Journal of Operations and Production Management", vol. 10 no. 3, pp. 38-49.
5. Meyers F.E., Stewart, J.R., 2001, Motion and Time Study for Lean Manufacturing, 3rd ed. Prentice Hall, New Jersey.
6. Taha, H.A., 2003, Operations Research: An introduction, 7th ed., Prentice Hall, New jersey.
7. Vitner, G., Giller. A. and Pat, L., 2006, "A proposed method for the packaging of plant cuttings to reduce variability", Biosystems Engineering, vol. 93 no. 3, pp. 353-358.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.153.46:631.17
Prethodno priopćenje
Preliminary communication

REGIONALNI ASPEKTI OPREMLJENOSTI OBITELJSKIH POLJOPRIVREDNIH GOSPODARSTAVA POLJOPRIVREDNIM STROJEVIMA

IVO GRGIĆ[1], VLADIMIR LEVAK[2], RATKO MATIJA[3]

[1]Sveučilište u Zagrebu, Agronomski fakultet, Svetošimunska cesta 25, 10 000 Zagreb, Hrvatska, e-mail: igrgic@agr.hr
[2] Poljoprivredna zadruga JALŽABET, Suhodolska 21, 42 203 Jalžabet, Hrvatska
[3] Vugrovečka 44, 10 360 Sesvete, Hrvatska

SAŽETAK

Kao kandidat za punopravno članstvo u Europskoj uniji, Republika Hrvatska je harmonizirala nacionalnu statistiku sa statističkim standardima EU. Donošenjem nacionalne klasifikacije prostornih jedinica za statistiku usvojena je podjela Republike Hrvatske na tri statističke regije: Sjeverozapadna Hrvatska, Središnja i Istočna (Panonska) Hrvatska te Jadranska Hrvatska.

Između pojedinih regija značajne su razlike, a najviše se očituju u razini gospodarske razvijenosti. U usporedbi sa BDP po stanovniku EU-25, BDP Sjeverozapadne Hrvatske je 53,58%, Panonske 31,54% te Jadranske Hrvatska 39,66%.

U Panonskoj Hrvatskoj je 49,9% OPG Hrvatske sa 56,7% korištenog poljoprivrednog zemljišta. Sjeverozapadna Hrvatska ima 27,5% OPG te 28,8% korištenog poljoprivrednog zemljišta. Prosječna veličina OPG Panonske Hrvatske je 2,2 ha korištenog zemljišta, Sjeverozapadne 2,0 te Jadranske 1,2 ha.

Poljoprivredna mehanizaciji je uz kemizaciju i oplemenjivanje pokretač promjena u poljoprivrednoj proizvodnji. Od svoje pojave do danas traktori su ostali najvažniji poljoprivredni pogonski strojevi polivalentne namjene, stoga je postalo uobičajeno da se stupanj mehanizacije poljoprivrede mjeri i odnosom poljoprivrednih površina (ili jednog dijela poljoprivrednih površina) i broja traktora. Na brojnost i strukturu strojeva utiče gospodarska razvijenost područja, agrarna i proizvodna struktura, konfiguracija terena itd.

U Panonskoj regiji na jednoosovinski traktor dolazi 38,9 ha korištene poljoprivredne površine, na dvoosovinski 5,9 ha te na kombajn 138,6 ha. Znatno manje površine su u Sjeverozapadnoj Hrvatskoj (na jednoosovinski traktor 9,7 *ha, dvoosovinski 3,3 ha te na kombajn 117,7 ha). Kod Jadranske regije na jednoosovinski traktor je 2,4 ha, dvoosovinski 4,5 ha te na kombajn 261,3 ha.*

***Ključne riječi**: regija, obiteljsko poljoprivredno gospodarstvo, traktor, kombajn*

UVOD

Upravljanje regionalnim razvitkom vrlo je složen i aktualan problem današnjice (Črnjar 2001), a u Hrvatskoj je fenomen regionalnog razvitka i ravnoteže do sada nedovoljno obrađivan (Europska unija daje veliki značaj multidimenzionalnim regionalnim politikama. Hrvatska, kao budući EU član, mora izraditi komplementaran regionalni modela s obzirom na Uniju, Bogunović 2007.) (Filipić i Šimunović 1998). Donošenjem Nacionalne klasifikacije prostornih jedinica za statistiku (Narodne novine 35/07) usvojena je podjela Republike Hrvatske na tri statističke regije: Sjeverozapadna Hrvatska (Grad Zagreb, Krapinsko-zagorska, Zagrebačka, Varaždinska, Koprivničko-križevačka i Međimurska županija), Središnja i Istočna (Panonska - Virovitičko-podravska, Požeško-slavonska, Brod-sko-posavska, Osječko-baranjska, Vukovarsko-srijemska, Karlovačka, Sisačko-moslavačka i Bjelovarsko-bilogorska županija) Hrvatska te Jadranska Hrvatska (Dubrovačko-neretvan-ska, Splitsko-dalmatinska, Zadarska, Istarska, Šibensko-kninska, Ličko-senjska i Primor-sko-goranska županija).

Regionalni pristup gospodarskom razvitku posebice je bitan kod promišljanja poljoprivrednog razvitka. Hrvatska je zemljopisno, klimatski, pedološki, demografski, gospodarski i po drugim obilježjima heterogena država (U svijetlu skorog pristupanja Republike Hrvatske Europskoj uniji, trenutačna teritorijalna podjela Republike Hrvatske na općine, gradove i županije predstavlja prepreku za korištenje sredstava predpristupnih fondova Europske unije - Frajman-Jakšić, Nater i Pekanov 2007) te će postizanje željenih ciljevi razvitka ovisiti će i o uvažavanju regionalnih različitosti (Sadašnju gospodarsku situaciju Hrvatske karakterizira vrlo visoka razina koncentracije ukupne gospodarske aktivnosti u nekoliko centara te se, primjerice, samo u Gradu Zagrebu ostvaruje 30% ukupnog bruto domaćeg proizvoda, Lovrinčević, Mikulić i Budak 2004.) kao i korištenjem poredbenih prednost. Osim općih problema gospodarskog razvitka s kojim se susreće, u jednom dijelu Hrvatske naglašena je posljedica ratnih razaranja, prometne izolacije, gubitka demografskog potencijala (U suvremenom razvoju stanovništva Hrvatske prevladavaju nepovoljni depopulacijski demografski procesi - ukupna depopulacija, prirodna depopulacija i demografsko starenje, Živić D. 2007, te su ti procesi značajan remetilački čimbenik stabilnom i uravnoteženom regionalnom razvoju Republike Hrvatske, Živić 2007.), loše gospodarske strukture itd. (Kovačević 1998).

Agregatna poljoprivredna proizvodnja Hrvatske uvelike će ovisiti o uvažavanju njenih regionalnih različitosti čemu se mora prilagoditi kako ekonomska tako i agrarna politika u korištenju široke lepeze prihvatljivih mjera. U svemu tome posebno mjesto, zbog brojnosti i proizvodnih resursa te njihovog značenja u očuvanju ruralnog prostora, imaju obiteljska poljoprivredna gospodarstva koja su i širi predmet ovog rada.

U radu se na temelju određenja/obuhvata statističkih regija Hrvatske, a prema podacima Popisa poljoprivrede 2003. kvantificiraju osnovni poljoprivredni resursi obiteljskih poljoprivrednih gospodarstava (OPG) s posebnim naglaskom na njihovu opremljenost strojevima i opremom. Osnovni cilj rada je istražiti važnost pojedinih regija kod osnovnih poljoprivrednih resursa u vlasništvu OPG i to posebice poljoprivrednih strojeva te ukazati na osnovne probleme njihove uporabe.

METODE RADA I IZVORI PODATAKA

Predmet i cilj istraživanja odredili su metodologiju primijenjenu u radu. U radu su, na temelju Popisa poljoprivrede 2003. i razvrstaju hrvatskih županija u statističke regije, grupirani osnovni podaci za obiteljska gospodarstva te na taj način utvrđen regionalni razmještaj pojedinih proizvodnih resursa odnosno utvrđeno značenje pojedine regije. Kao osnovni izvor podataka korišten je Popis poljoprivrede 2003. godine.

REZULTATI I DISKUSIJA

Brojnost poljoprivrednih strojeva i razina njihove iskoristivosti ovisi o mnoštvu čimbenika kao što je broj gospodarstava (U ovome radu analiza se temelji na broju obiteljskih poljoprivrednih gospodarstava iz Popisa poljoprivrede 2003. godine (N=448.532). Obiteljsko poljoprivredno gospodarstvo je «ekonomska jedinica kućanstva koja se bavi poljoprivrednom proizvodnjom bez obzira na njenu namjenu, odnosno bez obzira na to jesu li proizvodi za tržište ili samo za vlastitu potrošnju - Statistički ljetopis RH, Metodološka objašnjenja, str. 248, 2007.) i njihova zemljišna prosječna veličina, struktura poljoprivrednih površina, poljoprivredna proizvodna struktura itd.

Posljednjih petnaestak godina u Hrvatskoj s jedne strane zamjetno je i daljnje usitnjavanje zemljišnog posjeda odnosno povećanje broja parcela (Osim promjene metodologije praćenja od Državnog zavoda za statistiku nazočno je smanjenje obradivih površina i zbog izgradnje komunalne infrastrukture-cesta i gospodarskih zona.), ali istovremeno i povećanje prosječne korištene površine kod manjeg broja obiteljskih gospodarstava (Prema Upisniku poljoprivrednih gospodarstava njihova prosječna korištena poljoprivredna korištena površina je oko 6 ha što je značajno iznad statističkog prosjeka Hrvatske.) što nam ukazuje na proces raslojavanja unutar posjedovne strukture OPG (Postoji određeni strah od mogućnosti prodaje poljoprivrednog zemljišta strancima i onima koji zemlju neće obrađivati, a domaći poljoprivrednici ističu da nemaju dovoljno zemljišta za obradu s obzirom na raspoloživu mehanizaciju i radnu snagu.).

Mnogi autori upozoravaju da je prosječno mala veličina (Postoje značajne primjedbe na postojeći Zakon o raspolaganju poljoprivrednim zemljištem u državnom vlasništvu jer se često ukazuje na nemogućnost dobivanja državnog zemljišta na korištenje koje je najčešće „uređeno" odnosno kvalitetnije od prosjeka.) i velika rascjepkanost posjeda (Prema Popisu poljoprivrede 2003. godine prosječno OPG sastoji se od 4,3 parcele ali je kod većih gospodarstva broj parcela znatno veći, ali prisutne su i velike regionalne razlike.) jedan je od glavnih ograničavajućih čimbenika napretka obiteljskih poljoprivrednih gospodarstava i razvitka cjelokupne hrvatske poljoprivrede i to posebice sa aspekta korištenja i iskoristivosti poljoprivrednih strojeva (Svržnjak 2001). Ovakvu agrarnu strukturu drugi autori ocjenjuju kao trenutak „za čvršći pristup restrukturiranju poljoprivrednih gospodarstava, posebno u pogledu proizvodne orijentacije i usklađivanja veličine posjeda s kvalitetom zemljišta, raspoloživom radnom snagom, mehanizacijom….“ (Zmaić, Petrač i Sudarić 2007). Za treće je put zemljišne konsolidacije postupak komasacije. „Komasacijom se rješavaju imovinsko-pravni odnosi na zemljištu, pitanje ekonomičnosti poljoprivredne proizvodnje, potrebe navodnjavanja ili odvodnje, problem staračkih poljoprivrednih domaćinstava i dr.“ (Ivković, Džapo i Dolanjski 2008).

Obiteljska poljoprivredna gospodarstva posjeduju većinu zemljišnih resursa Hrvatske (80% poljoprivrednih te 75% oraničnih površina). Panonska regija dominantna je po broju OPG (49,9%), broju osoba koji na njima žive (49,3%), površini korištene poljoprivredne površine (56,7%) te oranica i vrtova (67,2%) (Od godine 2005. došlo je do promjene metodologije praćenja poljoprivrednog zemljišta, vidi Statistički ljetopis RH, Metodološka objašnjenja, str. 246, 2007.). Po istim obilježjima na drugom mjestu je Sjeverozapadna regija (prosječno 28%) te onda Jadranska regija.

Tablica 1 Regionalni razmještaj OPG, površina i osoba na gospodarstvima

Regija	**Broj gospodarstava**	**Korištena površina ha**	**Oranice i vrtovi ha**	**Broj osoba**
Sjeverozapadna	27,5	28,8	28,1	28,7
Panonska	**49,9**	**56,7**	**67,2**	**49,3**
Jadranska	22,6	13,4	4,8	22,0
Ukupno OPG	448.532	869.195	602.183	1.485.647
Hrvatska		1.086.403	802.093	
% OPG (Hrvatska=100)		80,0	75,1	

Izvor: Preračunato prema podacima Popisa poljoprivrede 2003., DZS RH

Prosječno najveće poljoprivredne korištene površine su u Panonskoj regiji (2,2 ha/gospodarstvu), nešto manje u Sjeverozapadnoj te izrazito najmanja u Jadranskoj regiji (1,2 ha). Isto je i kod oranica (Panonska regija ima 1,8 ha/gospodarstvu, Sjeverozapadna 1,4 ha te Jadranska samo 0,28 ha po OPG). Postoje državni programi kojima se potiče okrupnjavanje zemljišta.

„Bogatstvo“ zemljištem očituje se i u poljoprivrednim površinama po osobi pri čemu je najbogatija Panonska regija (0,67 ha), zatim Sjeverozapadna (0,59 ha) te Jadranska (0,36 ha).

Velika vrijednost OPG očituje se i u gospodarskim objektima koji u konačnici značajno troškovno opterećuju poljoprivrednu proizvodnju. Osim silosa koji su u većini na velikim gospodarstvima/poslovnim subjektima (63,7% ukupnog kapaciteta) ostali gospodarski objekti su, preračunato preko kapaciteta, u većinskom vlasništvu OPG (tablica 2).

Tablica 2 Gospodarski objekti OPG po regijama

	Staje za krupnu stoku m^2-	**Objekti za svinje m^2-**	**Objekti za ovce i koze m^2-**	**Peradarnici m^2-**
Sjeverozapadna	37,4	33,2	10,6	34,7
Panonska	**48,6**	**61,7**	33,5	**42,4**
Jadranska	14,0	5,1	**55,9**	22,8
Ukupno OPG	3.603.069	4.421.019	935.715	2.140.524
Hrvatska	4.046.637	4.694.297	956.243	2.645.802
% OPG (Hrvatska=100)	89,0	94,2	97,9	80,9

Nastavak tablice 2

	Drugi objekti za držanje stoke m^2	**Objekti za strojeve m^2**	**Silosi m^3**	**Skladišta m^2**
Sjeverozapadna	**42,3**	43,1	47,1	42,2
Panonska	36,7	**44,8**	**47,7**	**46,7**
Jadranska	21,0	12,1	5,2	11,1
Ukupno OPG	2.615.736	3.906.248	625.990	5.340.068
Hrvatska	2.677.467	4.167.952	1.723.499	5.481.027
% OPG (Hrvatska=100)	97,7	93,7	36,3	97,4

Izvor: Preračunato prema podacima Popisa poljoprivrede 2003., DZS RH

«Revolucionarni» poticaj poljoprivredna proizvodnja je dobila prvo pojavom te poslije masovnom primjenom poljoprivrednih strojeva. Njihovom pojavom i uporabom mijenjaju se i odnosi na selu, gase se neki običaji vezani uz solidarno ispomaganje i zajednički rad, no, javljaju se neki novi oblici kroz udruživanje i zajedničko korištenje strojeva (Stojnović i Kantar 2008).

Većina traktora i kombajna Hrvatske je u vlasništvu OPG. Regionalni razmještaj odgovara konfiguraciji područja i proizvodnoj strukturi te su jednooosovinski traktori najprisutniji u Jadranskoj regiji (55,2%), a dvoosovinski (45,1%) i kombajni (58%) u Panonskoj regiji.

Na jednoosvinski traktor u Panonskoj regiji dolazi 38,9 ha korištenog poljoprivrednog zemljišta, u Sjeverozapadnoj 9,7 ha te u Jadranskoj samo 2,4 ha. Manje poljoprivredne korištene površine su koje dolaze na dvoosovinski traktor (Panonska 5,9 ha, Sjeverozapad-na 3,3 te Jadranska 4,5 ha). Kod kombajna (zbog specifičnosti njihove upotrebe) najveće površine su u Jadranskoj regiji (261,3 ha), zatim Panonskoj (138,6) te Sjeverozapadnoj 117,7 ha).

Tablica 3 Regionalni razmještaj traktora i kombajna

	Jednoosovinski traktori	**Dvoosovinski traktori**					**kombajni**
		ukupno	**do 40 kw**	**41-60**	**61-100**	**Preko 100**	
Sjeverozapadna	30,1	41,0	**43,6**	33,7	27,1	22,4	34,8
Panonska	14,7	**45,1**	41,0	**57,2**	**63,8**	**68,1**	**58,0**
Jadranska	**55,2**	13,9	15,4	8,9	9,2	9,6	7,3
Ukupno OPG	86.243	185.953	141.661	38.348	4.983	961	6.132
Hrvatska	86.536	189.887	142.531	39.642	6.091	1.623	7.023
% OPG (Hrvatska=100)	99,7	97,9	99,4	96,7	81,8	59,2	87,3

Izvor: Preračunato prema podacima Popisa poljoprivrede 2003., DZS RH

Prema nekim stručnjacima sadašnje stanje opskrbljenosti obiteljskih poljoprivrednih gospodarstava poljoprivrednom mehanizacijom nezadovoljavajuće je prvenstveno zbog velikog udjela rabljene i nefunkcionalne mehanizacije u prosjeku visoke dobi, a k tome tijekom srpske agresije i rata otuđeno je i uništeno između 18 i 20 tisuća traktora (Par i Njavro 2003).

Iz tablice 3 vidljivo je da značajan broj gospodarstava nema odgovarajuće strojeve i opremu te zbog toga moraju plaćati usluge korištenja tuđe mehanizacije. S druge strane, dobro opremljena gospodarstva često nemaju dovoljno raspoloživog zemljišta za racionalnu upotrebu mehanizacije (Filipović i sur. 2005) tj. imaju veliku angažiranu snagu traktora po ha poljoprivredne površine. Mnogi autori istraživali su problem korištenja strojeva i opreme na OPG. Tako Stojnović, Bošnjak i Kušec 2000. dolaze do toga da je „prosječna instalirana snaga 34,35 kW po traktoru, a starost 13, 88 godina, opskrbljenost priključnim strojevima i oruđima bila je 3,55 priključka po traktoru, a iskorištenost traktora je u prosjeku 164,5 radna sata godišnje".

Prema istraživanju Par i Njavro 2003 „prosječno jedan traktor dolazi na 6,95 hektara poljoprivredne površine odnosno na 4, 6 hektara obradive površine (2001.) što istraživana gospodarstva svrstava u red onih koji su primjereno opremljeni traktorima. Naime, prema podacima zastupljenosti raspoložive snage traktora po jedinici poljoprivredne površine na jedan hektar u SAD-u dolazi 1 kW, u Njemačkoj 1, 7 kW odnosno u Francuskoj 3,2 kW. Na anketiranim gospodarstvima ustanovljeno je da na jedan hektar rabljene (obradive) površine dolazi od 3, 9 do 6, 3 kW, što ukazuje na nedovoljnu iskorištenost traktora, a što je i najčešći razlog visokog udjela troškova traktora po jedinici proizvodnje u gospodarstvu". Velikoj i snažnoj poljoprivrednoj mehanizaciji problem su premale ukupne površine te veliki broj i premale parcele. Istodobno, na OPG vrlo često je nedovoljno znanje i sposobnost u korištenju poljoprivredne mehanizacije koja je sve skuplja i sofistiranija. Edukacija o radu sa mehanizacijom koju provode poljoprivredne savjetodavne službe i prodavači mehanizacije omogućuju svrhovitije korištenje mehanizacije.

Danas su glavna područja gospodarenja mehanizacijom pravilan izbor, racionalno korištenje, efikasno održavanje, te pravodobna zamjena tehnički istrošenih i ekonomski zastarjelih strojeva. Promjene uvjeta proizvodnje, zbog prirodnih, tehnoloških i tržišnih utjecaja, mijenjaju troškove i racionalnost korištenja pojedinih strojeva. Stoga se poljoprivredni proizvođači prilagođavaju promjenama i nastoje koristiti opremu koja se pokazala učinkovitom u uporabi, a što omogućuje snižavanje troškova poljoprivredne proizvodnje (Karić 1999). Jedan od načina boljeg korištenja strojeva je kroz mogućnost stvaranja „strojnih prstena“ radi učinkovitijeg korištenja mehanizacije.

Već duže razdoblje primjetno je tehnološko starenje traktora kod manjih obiteljskih gospodarstava zbog malog ulaganja u obnovu strojnog parka. To je izrazito kod visoko specijalizirane mehanizacije za obradu zemljišta, a naročito kod mehanizacije za trajne nasade. Velika su očekivanja da će se ulaskom Hrvatske u EU povećati mogućnost povoljnije nabavke suvremenije poljoprivredne mehanizacije iako i danas za nabavku nove poljoprivredne mehanizacije hrvatski poljoprivrednici dobivaju povrat kapitalnih ulaganja.

Po brojnosti, ali ne i po važnosti, kod OPG manje su prisutni drugi strojevi/linije kao što su linije za krumpir i šećernu repu, linije za krmno bilje, drugi strojevi za berbu, traktorske prikolice itd. (tablica 4).

Tablica 4 Regionalni razmještaj ostalih strojeva

	Linije za krumpir i šećernu repu, broj	**Linije za krmno bilje, broj**	**Ostali strojevi za berbu, broj**	**Traktorske prikolice, broj**	**Bačve i cisterne hl**
Sjeverozapadna	54,4	63,6	40,9	39,9	44,8
Panonska	32,6	32,2	54,4	44,9	27,4
Jadranska	13,1	4,2	4,7	15,2	27,8
Ukupno OPG	1.494	12.899	15.883	166.433	1.915.739
Hrvatska	1.799	13.096	16.252	169.975	2.653.216
% OPG (Hrvatska=100)	83,0	98,5	97,7	97,9	72,2

Izvor: Preračunato prema podacima Popisa poljoprivrede 2003., DZS RH

Općenito je prisutan nedostatak priključnih strojeva kod manjih gospodarstava (posjeduju samo traktor i nedovoljno priključaka) što se najčešće nadoknađuje posudbom od drugih gospodarstava.

ZAKLJUČAK

Usmjeravanje poljoprivrednog razvitka treba uvažiti regionalnu distribuciju osnovnih poljoprivrednih proizvodnih resursa. U tome po broju i značenju (proizvodnom i troškovnom) bitno mjesto zauzimaju poljoprivredni strojevi (traktori i kombajni). Njihova efikasnost odvija se u interakciji sa drugim poljoprivrednim resursima kao što je poljoprivredno zemljište (veličina, broj parcela), radna snaga, gospodarski objekti. Panonska regija dominantna je po broju OPG (49,9%), broju osoba koji na njima žive (49,3%), površini korištene poljoprivredne površine (56,7%). Većina traktora i kombajna Hrvatske je u vlasništvu OPG. Regionalni razmještaj odgovara konfiguraciji područja i proizvodnoj strukturi te su jednooosovinski traktori najprisutniji u Jadranskoj regiji (55,2%), a dvoosovinski (45,1%) i kombajni (58%) u Panonskoj regiji. Sadašnje stanje opskrbljenosti OPG poljoprivrednom mehanizacijom nezadovoljavajuće je prvenstveno zbog velikog udjela rabljene i nefunkcionalne mehanizacije u prosjeku visoke dobi, a vrlo često je prisutno nedovoljno znanje i sposobnost u korištenju poljoprivredne mehanizacije koja je sve skuplja i sofisticiranija.

LITERATURA

1. Bogunović A. (2007). Regionalna politika EU i Hrvatska, Ekonomska istraživanja (1331-677X) 17 (2004), 1; 58-73,
2. Črnjar M. (2001). Regionalno prostorno i okolišno planiranje u funkciji osmišljenog razvoja regije, u „Kakav regionalni razvitak treba Hrvatskoj“ ured. Sundać, Dragomir, Ekonomski fakultet Rijeka, ISBN: 953-6148-20-X
3. Državni zavod za statistiku (2008). Statistički ljetopis 2007. Zagreb: Državni zavod za statistiku.
4. Filipić P., Šimunović I. (1998). Regionalna struktura Hrvatske, u „Koncepcija regionalnog razvitka Hrvatske“, ured. Frochlich, Zlatan, Ekonomski fakultet Zagreb
5. Filipović D., Grgić Z., Par V., Tratnik M. (2005). Opremljenost hrvatskih poljoprivrednih kućanstava strojevima i opremom, Društvena istraživanja : časopis za opća društvena pitanja (1330-0288) 14 (2005), 3; 565-577
6. Frajman-Jakšić Anita, Nater Nataša, Pekanov Dubravka (2007). Mogućnosti financiranja razvoja lokalne i regionalne samouprave u Republici Hrvatskoj iz pretpristupnih fondova Europske unije, u „Financiranje razvoja i restrukturiranja gospodarstva“, ured. Matić, Branko ; Novak, Branko ; Marković, Branimir, Sveučilšte Josipa Jurja Strossmayera u Osijeku, Ekonomski fakultet, ISBN: 978-953-253-037-7
7. Ivković Mira, Džapo M., Dolanjski D. (2008). Komasacija zemljišta-preduvjet uspješne poljoprivredne proizvodnje, 43. hrvatski 3. međunarodni simpozij agronoma / Pospišil, Milan (ur.). - Zagreb : Agronomski fakultet, Zagreb , 2008. 61-65 (ISBN: 978-953-6135-67-7)., Opatija, Hrvatska, 18.-21. veljače 2008.
8. Karić M. (1999). Gospodarenje sredstvima mehanizacije u poljoprivredi, u Strategija razvitka poljoprivrede i prehrambene industrije istočne Hrvatske / Jakšić, Marijan ; Pekanov, Katarina (ur.). - Osijek : HGK, CROMAR, Hrvatsko društvo ekonomista , 1999. 109-130.
9. Kovačević D. (1998). Gospodarski razvitak hrvatskog Podunavlja, Kemija u industriji (0022-9830) 2 (1998), 48; 44-50
10. Lovrinčević Ž., Mikulić D., Budak Jelena (2004). Područja posebne državne skrbi u Hrvatskoj-razlike u regionalnoj razvijenosti i demografsko-obrazovne karakteristike, u knjizi Hrvatska na putu u Europsku uniju /ured. Teodorović, Ivan/, Ekonomski institut, Zagreb, ISBN: 953-6030-28-4
11. Nacionalna klasifikacija prostornih jedinica za statistiku, Narodne novine 35 od 2007
12. Par V., Njavro M. (2003). Opremljenost obiteljskih poljoprivrednih gospodarstava traktorima, Aktualni zadaci mehanizacije poljoprivrede : zbornik radova 31. međunarodnog simpozija iz područja mehanizacije poljoprivredeZagreb : Zavod za mehanizaciju poljoprivrede, Agronomski fakultet Sveučilišta , 2003. 31-39.

13. Stojnović M., Bošnjak J., Kušec V. (2000). Istraživanje iskorištenosti traktora na obiteljskim poljoprivrednim gospodarstvima, Actual tasks on agricultural engineering / Košutić, Silvio (ur.). – Zagreb, Opatija, Hrvatska, 01. - 04. 02. 2000.

14. Stojnović M., Kantar Sandra (2008). Neki socio-ekonomski aspekti uporabe poljoprivrednih strojeva u hrvatskim ruralnim sredinama, u Razvoj, identitet i okoliš, međuregionalni aspekti / Jerčinović, Silvije ; Kantar, Sandra ; Svržnjak, Kristina (ur.). - Križevci : Visoko gospodarsko učilište u Križevcima , 2008. 32-34 (ISBN: 978-953-6205-13-4).

15. Svržnjak Kristina (2001). Zemljišna politika u funkciji dinamičnog razvoja poljoprivrede, magistarski rad, Agronomski fakultet Sveučilište u Zagrebu

16. Zmaić K., Petrač B., Sudarić Tihana (2007). Ruralni razvoj Republike Hrvatske – mogućnosti i ograničenja u uvjetima tranzicije, u Globalizacija i regionalni identitet / Šundalić, Antun ; Petrač, Božidar (ur.). - Osijek

17. Živić D. (2007). Demografski aspekti regionalne/prostorne polarizacije Hrvatske, u „Globalizacija i regionalni identitet“, ured. Šundalić, Antun ; Petrač, Božidar, Ekonomski fakultet u Osijeku, Sveučilište J. J. Strosmayera u Osijeku, ISBN: 978-953-253-023-3

REGIONAL ASPECTS OF FAMILY FARMS AGRICULTURAL MACHINERY EQUIPMENT

ABSTRACT

As a candidate for a full-scale membership in European Union, Republic of Croatia harmonized its national statistics with EU statistic standards. According to National Classification of Areal Units, Republic of Croatia is divided on three statistical regions: North-West Croatia, Middle and East Croatia and Adriatic Croatia.

There are significant differences between regions, which can mostly be seen in economic development. Compared to EU GDP, GDP of North-West Croatia is 53.58%, for East Croatia 31.54% and for Adriatic Croatia 39.66%. East Croatia has 49.9% of family farms (FF) in Croatia, using 56.7% of agricultural land. North-West Croatia has 27.5% of FF using 28.8% land. The average size of FF in East Croatia is 2.2 hectares, in North-West Croatia is 2.0 ha and in Adriatic Croatia is 1.2 ha.

Actuators of changes in agricultural production are mechanization, chemisation and breeding. Tractors are still the most important machines due to their polyvalent purpose, therefore it became usual to measure the mechanization level by the ratio between land and number of tractors. Number and structure of machines is influenced by economic development of the region, agricultural and production structure, configuration of terrain etc.

In East Croatia, 38.9 ha of land come on every one axis tractor, 5.9 ha on every two axis tractor and 138.6 ha on one combine. North-West Croatia has significantly smaller ratios: 9.7 ha on one axis tractor, 3.3 ha on two axis tractor and 117.7 ha on combine. In Adriatic Croatia the numbers are: 2.4 ha on one axis tractor, 4.5 ha on two axis tractor and 261.3 ha on combine.

***Key words**: region, family farm, tractor, combine*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 628.8:631.234:635.64
Prethodno priopćenje
Preliminary communication

ENERGY ANALYSIS FOR GREENHOUSE AND OPEN FIELD TOMATO PRODUCTION

M. DJEVIC, ALEKSANDRA DIMITRIJEVIC

Department for Agricultural Engineering , Faculty of Agriculture Belgrade, Belgrade University, Nemanjina 6, 11080 Zemun, Serbia, mdjevic@agrif.bg.ac.rs, saskad@agrif.bg.ac.rs

ABSTRACT

The aim of this paper is to analyze energy patterns in open and greenhouse tomato production, since tomato is very important vegetable in human nutrition with tendency to be used whole year. Concerning the high energy consumption in greenhouse production a comparison with open filed tomato production was found to be interesting. Data used in the study were obtained from the experiment carried out on a private property 140 km south from Belgrade. In the study, energy values were calculated by multiplying the amount of inputs and outputs by the related energy conversion factors. The same tomato varieties were planted in open filed and in the greenhouse at the same time. The greenhouse used was gutter-connected double PE covered structure 21m wide and 250m long.

According to energy output (yield per m^2) parameters for estimating tomato production energy efficiency were calculated (energy input per kg of product, energy out/in ratio and energy productivity).

Key words: *Energy, greenhouse, open filed, tomato, energy input, energy output, energy efficiency.*

INTRODUCTION

Tomato is one of the most common vegetable used in human nutrition around the world. Tomato is used in fresh consumption, conserved in some way or as a material for food processing industry. It has high energy value and is rich in vitamins and minerals. It is also said that it is most profitable vegetable variety. It is grown on 2.5 million hectares and in Serbia region on, around 20.000 ha.

Tomato is grown in open filed as well as in greenhouses. Concerning the greenhouse production, tomato is still grown in non-heated greenhouses that enable two up to three week earlier harvesting compared to open filed production. In tomato is grown in heated greenhouses harvesting can start in April. The reasons why tomato is rarely grown in heated greenhouses can be high energy inputs for the production and higher investments in heating systems and high-yielding varieties.

Aim of this paper was to analyze energy use patterns in greenhouse and open filed tomato production in order to see whether greenhouse tomato production can be beneficiary or not and whether there are differences in energy consumption and energy efficiency in these two production systems.

MATERIAL AND METHOD

The same variety of tomato was grown in the open filed and in gutter-connected greenhouse. Gutter-connected plastic greenhouse (Figure 1) was covered with double PE folia. It was 21m wide and 250 m long. Inner folia was 50 µm thick and outside folia was 180 µm thick.

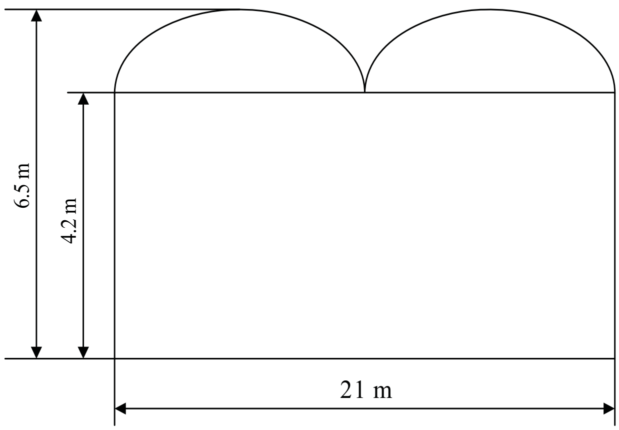


Figure 1 Greenhouse construction

The experiment was carried out at private property near Jagodina (Serbia) on 44° 1' 59" latitude and 21° 16' 30" altitude. Tomato production was evaluated regarding energy consumption, energy efficiency and energy productivity.

The method used for energy efficiency analysis (Ortiz-Cañavate [10], Djevic [12], Hatirli [2], Ozkan [3]) was based on energy input analysis (definition of direct and indirect energy inputs), energy consumption for given plant production and energy efficiency. On the basis of tomato production output and energy input, energy input/kg of product, energy out/in ratio and energy productivity were estimated as follows:

$$\text{Energy input/kg of product (EI)} = \frac{\text{energy input for production [MJ/ha]}}{\text{output [kg/ha]}} \tag{1}$$

$$\text{Energy out/in ration (ER)} = \frac{\text{energy value of production [MJ/ha]}}{\text{energy input for the production [MJ/ha]}} \tag{2}$$

$$\text{Energy productivity (EP)} = \frac{\text{production [kg/ha]}}{\text{energy input for the production [MJ/ha]}} \tag{3}$$

Energy inputs were calculated by multiplying material input with referent energy equivalent. Energy equivalents for different material inputs as well as for tomato output were obtained from different sources (Table 1).

Table 1 Energy equivalents for different input and output values used in greenhouse production

Input	Energy equivalent (MJ/unit)	Reference
Straw (kg)	16.47	[1]
Diesel fuel (l)	46.30	[10]
Technical systems (h)	13.06	[11]
Fertilizer (kg)		
Nitrogen	78.10	[10]
Phosphorus	17.40	[10]
Potassium	13.70	[10]
Fungicides (l)	168.00	[10]
Water (l)	0.009	[10]
Human labor (h)	1.96	[11]
Tomato (kg)	0.8	[2]

Information on energy input and energy output were entered into Excel spreadsheets and energy parameters were calculated based on equations 1 to 3.

Tomato was placed in the greenhouses in Jun 2008. and harvested from July 2008. In the open field 204 tomato seedlings were planted. In greenhouse number of plants was 14463. Both open filed and greenhouse tomato were grown on red mulch folia 25µm thick. Production technology was based on soil preparation with rotary hoe, fertilizer application prior to planting and, during the vegetation period application of fertilizers, fungicides and irrigation.

RESULTS AND DISSCUSION

Quantities of materials used in open filed and greenhouse tomato production are shown in tables 2 and 3 as well as their energy values. Based on total energy input, specific energy consumption was calculated.

Table 2 Energy consumption for open filed tomato production

Energy input	**Quantity**	**Total energy (MJ)**	**Share %**
Fuel (l)	1	47.8	4.77
Technical systems (h)	0.18	2.35	0.23
Fertilizers (kg)			
Nitrogen	3.75	295.13	29.43
Phosphorus	9.3	161.82	16.14
Potassium	14.1	193.17	19.27
Water (l)	10080	90.72	9.05
Human labor (h)	108	211.68	21.11
Total energy input (MJ)		954.87	100
Specific energy input (MJ/m^2)		15.91	

Table 3 Energy consumption for greenhouse tomato production

Energy input	Quantity	Total energy (MJ)	Share %
Fuel (l)	70	3346	9.85
Technical systems (h)	5.2	67.91	0.2
Fertilizers (kg)			
Nitrogen	55.23	4346.6	12.79
Phosphorus	42.77	744.2	2.19
Potassium	76.52	1048.32	3.08
Pesticides (kg)	0.58	115.42	0.34
Fungicides (kg)	3.26	299.92	0.88
Water (l)	1445400	13008.6	38.28
Human labor (h)	5616	11007.36	32.39
Total energy input (MJ)		33984.34	100
Specific energy input (MJ/m^2)		6.47	

Parameter that can be used to compare energy consumption for different greenhouse constructions is specific energy input, MJ/m^2. This parameter showed different values for open filed and greenhouse tomato production. Lower value was calculated for gutter connected greenhouses (6.47 MJ/m^2) compared to open filed production (16.71 MJ/m^2). It can be calculated that specific energy consumption in greenhouse tomato production was 59% lower than tomato production in the open filed.

The structure of energy inputs for the greenhouses can be seen in tables 2 and 3. It can be seen that in open filed tomato production highest share had indirect energy inputs. The share of fertilizers in total energy consumption was 64.84%, after that come labor with 21.11% share and water with 9.05%. Direct energy inputs are represented by fuel for technical systems and their share is 4.77% in total energy consumption. In greenhouse tomato production these relations are a bit different. Indirect energy inputs still have a higher share in total energy consumption but their structure is different. Energy used through water had a highest share of 38.28%. After that comes human labor with 32.39% and fertilizers with 18.06%. The share of direct energy input was 9.85%. The main reason for this low share is that greenhouse was not heated and only fuel consumption is considered as direct energy input. Reasons for these kinds of structures can be found in more labor intensive production in greenhouses and, generally more intensive tomato production in greenhouse.

Energy output was calculated based on energy value for tomato and obtained yield (Table 4). Higher specific energy output was obtained in gutter-connected greenhouse (19.02 MJ/m^2) and the lower in the open filed tomato production (16.32 MJ/m^2).

Table 4 Tomato yield and energy output in open filed and greenhouse

	Yield [kg]	**Energy output [MJ]**	**Specific energy output [MJ/m2]**
Open filed	1224	979.2	16.32
Gutter-connected greenhouse	124848	99878.4	19.02

Higher energy output was obtained in greenhouses as expected. For the open filed production measured tomato yield was 20.4 kg/m^2 while in the greenhouse this value was 23.78 kg/m^2. If energy output is calculated for m^2 it can be seen that in the greenhouse tomato had 15% higher energy output compared to open filed production. The reason for this can be searched in more uniform micro-climatic and production conditions in greenhouse compared to open filed production. Shading effect of the covering material could also be the reason why higher yield were obtained in greenhouse. There were a few days in July and August that had above average temperature for that period of year and it could be seen that in that period outside tomato was exposed to direct sunlight and this caused burn damage on tomato fruits.

Based on measured energy inputs and energy output, parameters for energy analysis were calculated (Table 5). It can be seen that different values were obtained for open filed and greenhouse tomato production regarding basic energy parameters.

Table 5 Parameters for energy analysis

Energy parameter	**Open filed**	**Gutter-connected greenhouse**
Energy input / kg of product (EI) [MJ/kg]	0.82	0.27
Energy efficiency (ER)	0.98	2.94
Energy productivity (EP) [kg/MJ]	1.22	3.67

The higher energy input per kg of product was calculated for open filed tomato production, 0.82 MJ/kg, and the lower value for this parameter was calculated for the greenhouse production, 0.27 MJ/kg. These values are directly influenced by yield and energy consumption which was in both cases on the greenhouse tomato side. If these values are compared it can be seen that for the greenhouse tomato production 67% less energy was needed for the obtained yield compared to open filed tomato production.

Concerning energy out / in ration, the higher value was calculated for the greenhouse, 2.94 and the lower value was obtained for open filed tomato production, 0.98. These values could be compared with other similar researches. Hatirli et al [2] reported that in the greenhouse tomato production this values varied from 0.7 up to 2.3 depending on size of the greenhouse holdings in Turkish region. Higher values presented in this paper, for Serbia region could be explained with larger greenhouse production area and with higher yield obtained.

If the energy productivity is analyzed it can be seen that greenhouse tomato production had better productivity compared to open filed production. If values are compared (Table 5) it could be seen that open filed tomato production was with 67% lower energy efficiency compared to open filed tomato production.

The next phase in research will be to compare tomato production in different greenhouse structures regarding energy consumption and energy efficiency in different production periods.

CONCLUSION

Tomato is very important vegetable variety in human nutrition around the world. It is grown in the open filed as well as in the greenhouses. The aim of this paper was to analyze whether there are differences in energy consumption and energy efficiency between these two production systems.

Based on input materials and tomato output energy parameters were determined. Results showed that specific energy consumption was lower for greenhouse production compared to open filed tomato production. Structure of energy inputs showed that indirect energy input had up to 90% share in total energy consumption. Greenhouse tomato had a higher yield and higher energy productivity. Open filed tomato production was found to be with higher energy input per kg of product and with lower output / input ratio.

ACKNOWLEDGEMENT

This paper presents results from national Project “Improvement and preservation of agricultural resources in the function of rational energy consumption and agricultural production quality preservation“. Project is financed by Ministry of Science and Environment Protection, Republic of Serbia, project number TR 20076.

REFERENCES

1. Enoch H.Z. A theory for optimalization of primary production in protected cultivation, I, Influence of aerial environment upon primary plant production, Acta Hort. 1978. 76:31-44.
2. Hatirli S. A., Ozkan B., Fert C. Energy inputs and crop yield relationship in greenhouse tomato production, Renewable Energy, 2006. 31: 427-438
3. Ozkan B., Fert C., Karadeniz F. Energy and cost analysis for greenhouse and open-filed grape production, Energy 2007. 32: 1500-1504.
4. Storck, H. (1977): Towards an Economic of Energy in Horticulture, Acta Hort. 1978. 76:15-30.
5. Hanan J.J. Greenhouses. Advanced Technology for Protected Cultivation, CRC Press, 1998.
6. Nelson, P. Greenhouse Operation and Management, 6th edition. 2003.
7. Stevens A. B., Stevens S. A., Albrecht M. L., Karen I. B. Starting a Greenhouse Bussinies. Cooperative Extension Service, 1994. Kanzas State University Manhattan, Kansas.
8. Badger P. C. Solid Fuels, CIGR Handbook, vol. 3. 1999. p. 248-288.
9. Ortiz-Cañavate J., Hernanz J.L. Energy Analysis and Saving in Energy for Biological Systems, CIGR Handbook, vol. 3. 1999. p.13-37.
10. Dimitrijević M., Đević M., Boretos M., Miodragović R. Design and Control Systems in Greenhouses, Technique Towards the 3rd Milenium; Haifa, Israel, 1999.
11. Đević M., Dimitrijević A.. Greenhouse energy consumption and energy efficiency, Energy efficiency and agricultural engineering 2005, International conference, Russe, Bulgaria (http://www.ru.acad.bg/baer/BugGHRad.pdf), 2004.
12. Momirović, N. Škola gajenja povrća, Specijalno Izdanje, Poljoprivredni list, 2003, p. 50-53.
13. Paradajz, Food and Agriculture Organisation of the United Nations, Belgrade, 2004.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 634.22:634.54:641.3
Izvorni znanstveni rad
Original scientific paper

PLUMS AND WALNUTS ADDITION INFLUENCE ON BREAD RHEOLOGICAL AND SENSORY PROPERTIES

DANIELA STOIN*, DIANA-VERONICA DOGARU, UIVAROSAN GABRIEL, MATEESCU CONSTANTIN, CAMELIA MOLDOVAN

Banat's University of Agricultural Sciences and Veterinary Medicine, Faculty of Food Processing Technology, Calea Aradului, 119, 300645, Timisoara, Romania
*email: mucetedaniela@yahoo.com

SUMMARY

Bread is one of the most necessary food products, of the most nourishing and wanted, and there are few regions on the globe in which bread is not known. Nowadays bread has become a food stuff so common, that when a slice of bread is being cut, nobody asks himself questions about it's history, about it' s production process.

Nowadays, we call bread the product obtained by baking a biologically fermented dough. From this definition it self accrues that bread is a product which requires a long evolution of the cereals way of use as foodstuff.

For establishing the bread quality, a special importance shows its chemical composition, because the substances that enter in its constitution serve to the obtaining of the energy necessary to the human body, to the formation of tissues and to regulate different processes of the human body.

Beside the chemical composition, the bread quality and alimentary use respectively, a large measure depends on a series of signs: flavor and taste, external appearance, crumb porosity and texture, breads' volume.

This paper belongs to a more complex study, one which aims to obtain some high nourishing value, bread assortments and improving it's rheological features with walnuts and plums addition, that successfully replace the ameliorative and dye substances used in bakery (e.g roasted malt extract). In this regard, sensory analysis and a series of rheological tests (compression and relaxation tests) have been performed on the 5%, 10% and 15% walnut and plums addition bread.

The experimental results have indicated that 10% and 15% walnut and plums addition, respectively, are the most adds visible to be used in bread processing, conclusion that comes off from the data obtained on all samples compression and *relaxation tests, from compression modulus correlation with walnut and plums content.*

Key words: *Bread, visco-elastic properties, compression, relaxation, nut, plum*

INTRODUCTION

Ever since the earlier times, bread was the main part of any persons' diet. As it is demonstrated by including it in Father's Prayer, bread represented the essential food, along history.

If nowadays bread is in a majority made of wheat, in the past, the rye, the barley-corn, the rice and the maize were used separately or mixed. But, as the life standard increased, the use of cereals (others than wheat) in the bread production decreased significantly. Consuming bread and its assortments were always related to tradition, customs and religious beliefs and, not in the last place, to consumer's income *(Lapusneanu et. al., 2001; Saseanu, 2005).*

On a national scale lately, a diversification of the bakery products developed by local customs, that regard products weights, shape, recipe, technologies and products flavour, but also by taking over the local consumers to some products from other countries. In this regard, there is an intense concern for improving bread and bakery products quality, essential criteria for our country to reach the standards and demands enforced by the European Union.

On an international scale, it entered into force that established the enrichment of all flour types (except the black one) with minimum calcium, iron and vitamin B_1 amounts, laws that also established the composition and the permitted additives in bread and flour.

The healthy effect of the bread and bakery products on the health of the population is very important if we mention the variety of these products in the daily diet, starting from the cereals consumption for breakfast, to the paste, bakery and pastry products, that never miss from any consumer's meal *(Simatos et. al., 1995; Scanlon et. al., 2001).*

The diet issue is one of the most important matters of the contemporary society. During the past years, a very important role is given to diet-illness relation, hoping that a „diet - health" tactic will be elaborated.

Since bread is an essential food, daily consumed by the population, its and all its assortments production has been a main concern of the Romanian society *(Saseanu, 2005).*

Starting from these observations, the aim of this paper consisted in obtaining some high nourishing value bread assortments and the improvement of its rheological features (texture) with walnut and plum addition. In this regard, sensory analysis and a series of rheological tests (compression and relaxation tests) of the 5%, 10% and 15% walnut and plum addition bread were performed.

The use of kernel and plums as supplement in classic bread processing is justified starting from this complex structure. The kernel is rich in fats (50-70%), proteins (15-25%), antioxidants (melatonin, rheolo ellagic acid, gammatocopherol, carotenoides and poliphen-olic compounds), vitamins (E, B_1, B_2, B_3, B_5, B_6, folic acid), mineral salts (magnesium, potassium, copper, iron, zinc). Plums are rich in vitamins A, B, C, B_1, B_2, PP, in sulphouros, phosphoros, Mn, Mg, Na and K (300 mg/ 100 g fresh fruits) *(Marranca, 2003; Terry et. al., 2001).*

These fruits bring the appetite to normal, lighten the intestinal transit, stimulate the liver, determine the umoral detoxification and refresh the organism. Have antifeverish, antihelmitic, depurative, laxative, nourishing, nervous stimulating, detoxifying and decongestive properties, producing the tissues relaxation and diminishing the inflammations *(Kirk et. al., 2002).*

The influence of walnuts and plums content on rheological properties of bread crumb was studied. Rheological characterization was made by compressive loading tests and relaxation tests. To obtain the Young modulus of dough at low values of Cauchy strain the compressive test was used *(Mateescu, 2001; Dogaru et. al., 2004).* Also, relaxation test was used *(Gamero et. al., 1993; Steffe et. al., 1996).*

MATERIAL AND METHODS

Bread obtaining technological method

The technological method for obtaining the walnut and plums supplement bread was the classical one. The fabrication recipe was the following one: flour 450 g (white and black 2:1), water-56%, yeast-1.6%, salt-2% and different walnut and plums supplement: 5% (22g), 10% (44g) and 15% (66g). Similarly, a control bread sample without walnut and plums supplement was performed. For the entire process of obtaining bread, the ALASKA BM 2000 apparatus was used. The optimum parameters for the technological process were: *mixing* 30 minutes, *fermentation* 130 minutes, *baking* 50 minutes.

The walnut and plums supplemented bread quality evaluation

The bread obtained after the above described method was submitted to the sensory exam, following: the external appearance, crumb porosity and texture, flavor, taste, microbial alteration signs and impurities presence *(according to STAS 91-83 „ Bread, loaf products and bakery specialties Analysis methods”).*

From the so obtained bread, a slice of about 3 cm was cut for rheological features evaluation. The slice was cut after 2 hours of room temperature storage. From this slice, samples were taken with a cylinder 3 cm long and 2 cm in diameter. Further, compression and relaxation tests were performed. For each bread assortment, 3 times each were performed. For the experimental study, a compression JTL Janz apparatus was used. The so obtained samples were compressed with a constant speed to 120 seconds, the compression force being read at every 5 seconds. After the 120 seconds the compression was stopped and began the bread crumb relaxation force reading, at every 5 seconds, too, until the value repeated 3 times in succession. At the third consecutive reading begins the reading performed at every 10 seconds until the value repeats 3 times in succession. The obtained data were interpreted in the ORIGINI 7.0 program. Two replicates were analyzed and averaged.

RESULTS AND DISCUSSION

The walnut and plums supplemented bread quality appreciation requires sensory tests and rheological measures correlation.

Walnut and plums supplemented bread sensory evaluation

The bread obtained according to the paragraph 1, showed the following sensory features (table 1) which are in accordance with STAS 91-83.

Table 1 Walnut and plums supplemented bread sensory features

Sensory features	
Product's shape	- volume in proportion with weight, increased with 10-30%;
Crust - aspect - color	 - shiny, well developed surface, thin crust with slights cracks (1-2mm); - golden yellow, characteristic to the analyzed assortment;
Crumb - kerfs - color - consistency	 - homogeneous texture, with no impurities; - the crumb is dark colored, characteristic to the analyzed assortment; - elastic, when easy pressed accrues to the initial shape, well baked crumb;
Taste and flavor	-pleasant, aromatic, characteristic to well baked product;
Microbial alteration signs	- upon bursting no mucilaginous filaments are formed.

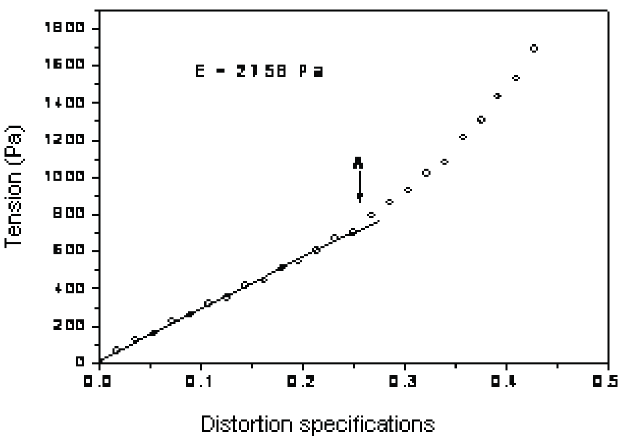


Figure 1 Compression curve for the control bread sample (o). Solid line- linear regression curve for small distortions

Walnut and plums supplemented bread rheological tests

Compression curves obtained, $\tau = f(\varepsilon)$, express the dependence of compression stress τ by Cauchy strain ε (Steffe et. al., 1996). Graphically, the compression curve for the witness sample is showed in figure 1. As it can be observed, there is a sigmoid dependence, being similarly with compressive stress-strain curves obtained for rye bread (Mateescu, 2001; Swyngedau et. al., 1991). From the slope of the first part of the experimental curve (ε_c <0.2) the compression modulus or Young modulus (E) was calculated. It was ascertained that the bread crumb is not uniform.

That is why, the rheological characteristics obtained from the compression curve (compression modulus and the mechanical work needed for 12 mm compression) are very different. The obtained values for E and L for all three samples, and the average values too, are showed in table 2. The force relaxation curve is graphically showed in figure 2.

Table 2 Rheological features of the control sample crumb, calculated from the compression and relaxation curves, respectively

Witness	**E (Pa)**	**L (J/kg)**	F_e	A_1	**λ (s)**
Sample 1	2758	0.771	0.777	0.215	18.41
Sample 2	9125	1.610	0.741	0.248	38.76
Sample 3	4490	1.135	0.798	0.183	13.29
Medium values	5458 ± 1900	1.172±0.243	0.772 ± 0.016	0.215 ± 0.018	23.5 ± 7.7

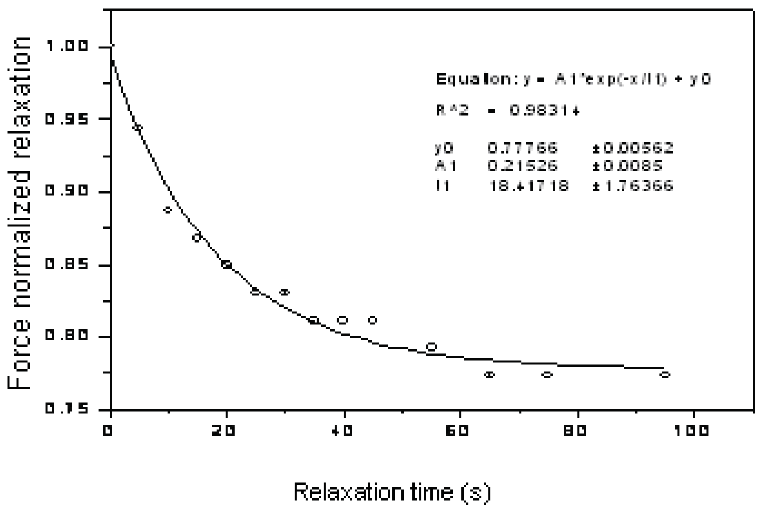


Figure 2 Force relaxation curve, for the control bread sample (o).Solid line- calculated relaxation curve

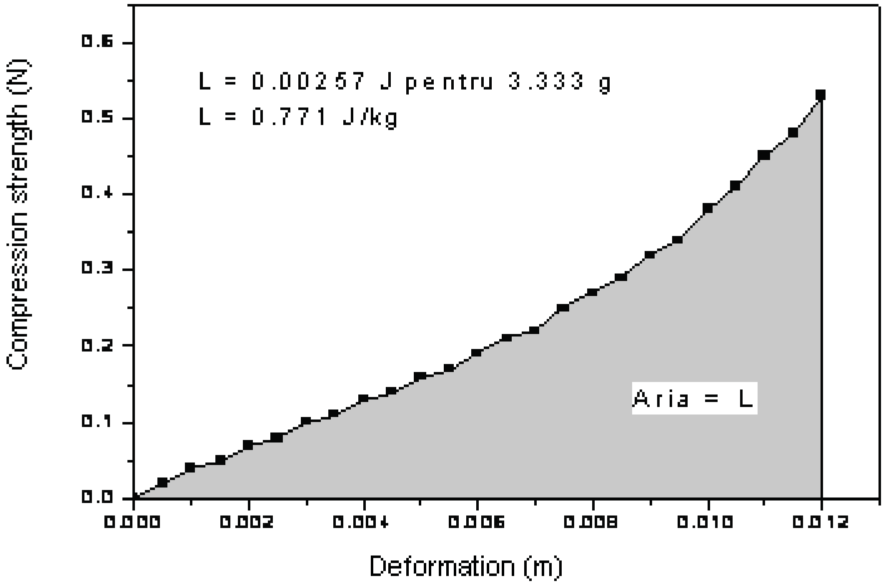


Figure 3 The calculation manner of the mechanical work needed for a 12 mm distortion of the control bread sample

Control 2: E = 9125 Pa

Equation: y = A_1*exp (-x/t1) + y0

R^2 = 0.99158

y0 0.74162 ±0.00438

A_1 0.24766 ±0.00515

t_1 38.76224 ±2.1948

The relaxation test is a static procedure used to characterize visco-elastic properties of the studied bread crumb. The obtained relaxation data could be excellent fitted by equations that were derived from generalized Maxwell model, consisting of two parallel Maxwell elements connected in parallel with a spring (Steffe et. al., 1996):

$$F(t) = F_e + A_1 \cdot \exp\left(-\frac{t}{\lambda_1}\right) + A_2 \cdot \exp\left(-\frac{t}{\lambda_2}\right) \quad (1)$$

In this relation Fe (equilibrium force) represents the value of relaxation force at high values of time (t), A_1 and A_2 are the initial values of force on Maxwell elements, λ_1 and λ_2 are relaxation times for dough. A way to overcome some of the difficulties of the Maxwellian models is to normalize and linearize the experimental force relaxation curves using an empirical equation proposed by Peleg (Steffe et. al., 1996):

$$\frac{F_{(o)} \cdot t}{F_{(o)} - F_{(t)}} = k_1 + k_2 \cdot t \tag{2}$$

where F(o) is the force at time zero, F(t) the force after time t, 1/k1 is related to the initial stress decay rate, and1/k2 to a hypothetical asymptotic level of stress not relaxed at long time constants (Gamero et. al., 1993).

The calculated data from the 1st order experimental fit for the 3 witness samples are shown in table 2, also. From the data presented, it can be seen that the corresponding values to E and L are very different due to the crumb without homogeneity. In exchange, the obtained values for the normalized equilibrium force (Fe) are close to one another and represent about 77% of the initial force. On the other side, the relaxation time (λ) and the difference between the initial force and the equilibrium force (A1) are different.

Table 3 Rheological features of the control walnut and plums supplemented bread sample, calculated from the compression and relaxation curves, respectively

Sample	**Procent (%)**	**E (Pa)**	**L (J/kg)**	F_e	A_1	**λ (s)**
Control	0	5458 ± 1900	1.172±0.243	0.772 ± 0.016	0.215 ± 0.018	23.52 ± 7.70
Walnut	5	5025 ± 1330	0.990±0.205	0.766 ± 0.011	0.230 ± 0.008	33.6 ± 3.9
	10	2288 ± 544	0.651±0.127	0.746 ± 0.017	0.238 ± 0.014	22.12 ± 1.02
	15	1971 ± 480	0.519±0.114	0.739 ± 0.022	0.248 ± 0.020	22.31 ± 3.40
Plums	5	3590 ± 953	0.800±0.160	0.766 ± 0.007	0.223 ± 0.005	26.88 ± 2.88
	10	2744 ± 584	0.764±0.079	0.748 ± 0.019	0.234 ± 0.019	28.59 ± 5.02
	15	4876 ± 588	0.801±0.096	0.763 ± 0.006	0.219 ± 0.009	29.84 ± 0.93

In table 3, the average values of all rheological characteristics obtained at different concentrations of the walnut and plums content in bread are showed. It can be seen the influence that the walnut and plum content has on all studied rheological characteristics. Also, it can be ascertained the same evolution type for E, L, Fe and A1, that is they decrease with the increase of walnut and plum concentration in bread. In exchange, A1 (the difference between the initial force and the equilibrium force) increases with the walnut and plums concentration increase, and the relaxation time varies.

The graphical dependence on between the compression modulus and the walnut and plums content from figures 4 and 6 emphasizes the following: a 10% or 15% walnut and 10% plum, respectively, ensures the best elasticity for the bread crumb. Also, from table 3 there can be seen that these walnut and plums percents added in bread are the best in order to obtain bread with good rheological features. Because the compression modulus and mechanical work evolution are the same (see table 3), the correlation between these two measures was graphically presented (figures 5 and 7). From the graphical representation, in both cases it can be seen a relative good linear correlation, so, the linear correlation factor in the case of walnut supplement is R=0.9743, and in the case of plums supplement is R=0.887.

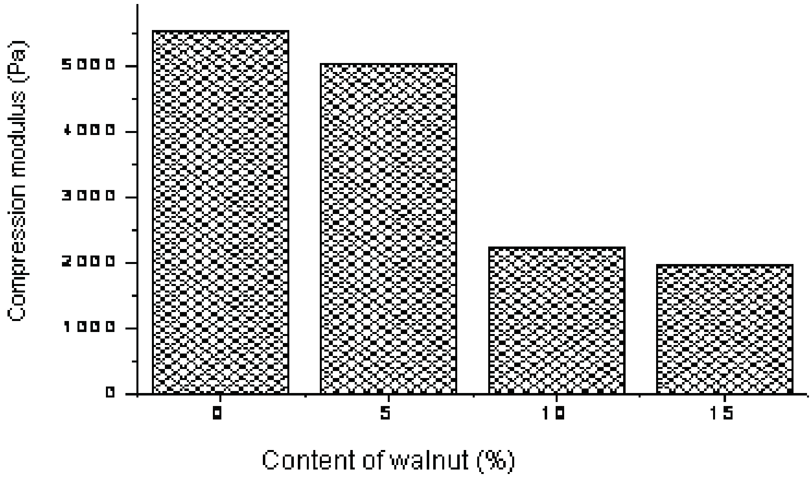


Figure 4 The walnut content influence on the crumb compression modulus

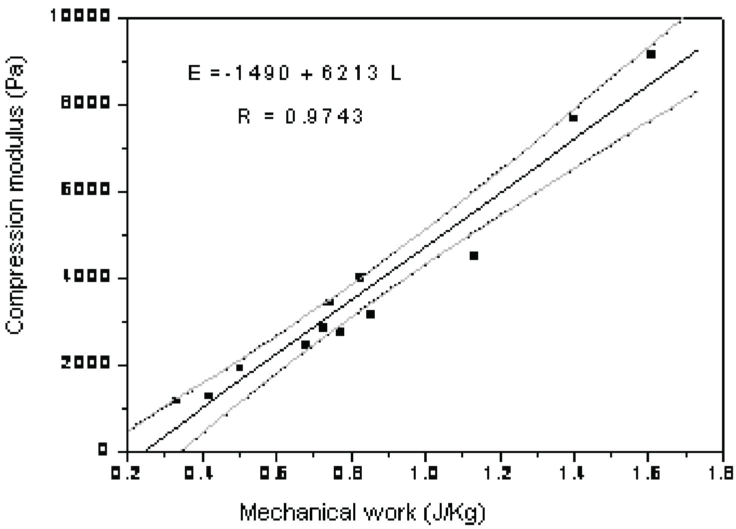


Figure 5 Correlation between the compression modulus and the mechanical work needed for a 12 mm bread crumb compression

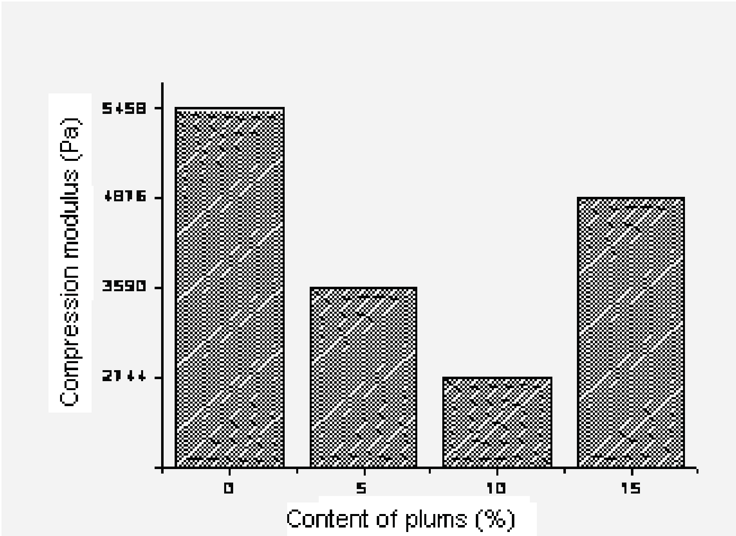


Figure 6 The plums content influence on the compression modulus of the bread crumb

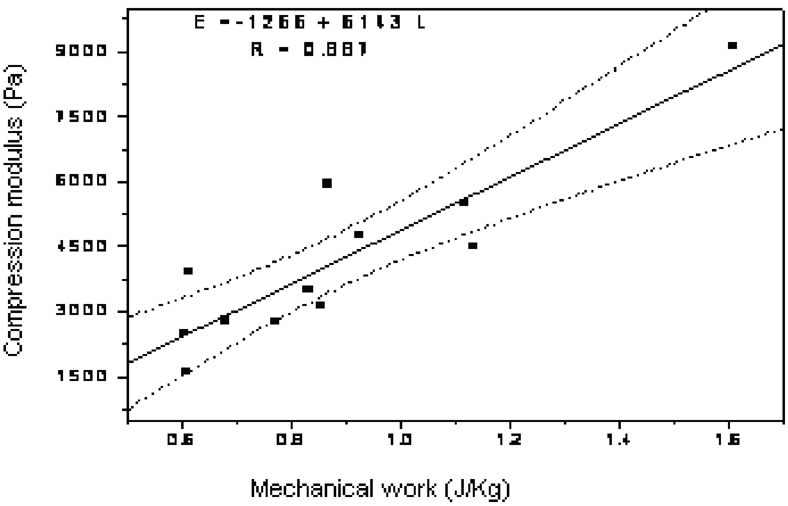


Figure 7 Correlation between the compression modulus and the mechanical work needed for a 12 mm bread crumb compression

Figure 8-13 are presented curves of compression and relaxation adequate sample 2 of bread with the addition of 10% walnut and plums respectively.

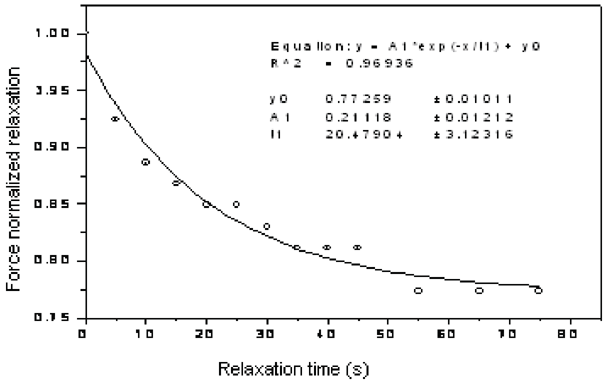


Figure 8 Compression curve for bread sample 2 with 10% walnut

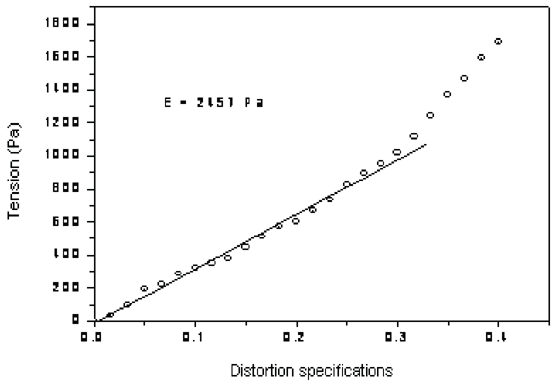


Figure 9 Relaxation force curve for bread sample 2 with 10% walnut

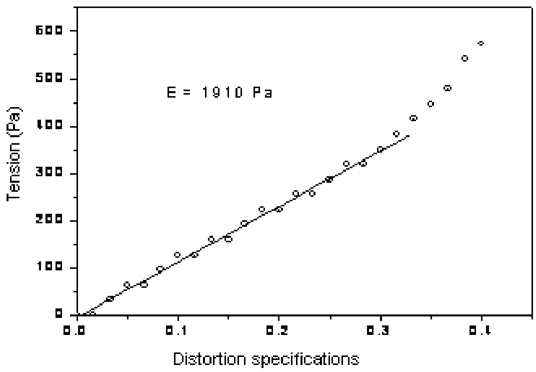


Figure 10 Compression curve for bread sample 2 with 15% walnut

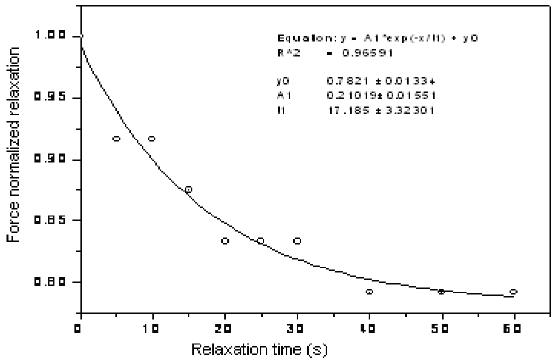


Figure 11 Relaxation force curve for bread sample 2 with 15% walnut

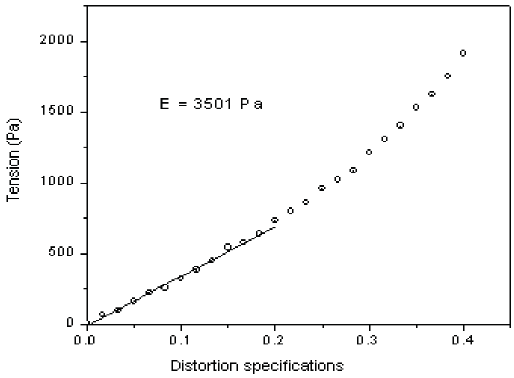


Figure 12 Compression curve for bread sample 2 with 10% plums

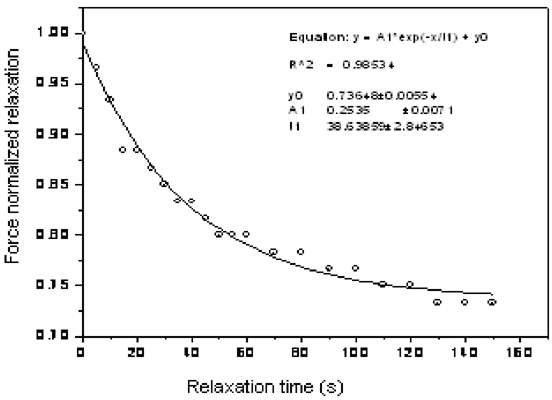


Figure 13 The relaxation force curve for bread sample 2 with 10% plums

CONCLUSIONS

By walnut and plums supplement in the bread obtained with the classical method, results a bread assortment both high nutritional valuable as a result of the proteins, fats, vitamins and mineral salts contribution brought by these, and with improved rheological features, represented by the remarkable porosity, elasticity and flavor.

The walnut and plums supplement in bread may successfully replace the ameliorative and coloring substances used in bakery (e.g the grounded malt extract).

These supplements use in the bread obtaining process causes also, the prolongation of the its validity term as a result of the natural sugars and organic acids.

REFERENCES

1. Dogaru, D., Tamasesc, A.M., Mateescu, C., (2004), Mechanical properties of bread crumb. (I). Compression. Sci. Res. Agroalim. Process and Technol., X(1), 31-38
2. Gamero, M., Fiszman, S.M., Duran, L., (1993), Stress relaxation of fruit gels. Evaluation of models and effects of composition. J. Food Sci., 58(5), 1125- 1134
3. Kirk, O., Borchet, T.V., Fuglsang, C.C., (2002), Industrial enzyme applications. Current Opinion in Biotechnology, 13, 345–351
4. Lăpuşneanu A., Lăpuşneanu S., (2001), Drumul pâinii în istoria Dobroge, Editura Dobrogea, Constanța, 21-26
5. Marranca B., (2003) „A Slice of Life"- Contemporary writers on food-by, The Overlook Press, Peter Mayer Publishers Inc., US, 229
6. Mateescu C., (2001), Reologia produselor agroalimentare, Vol. I, Editura Eurostampa, Timişoara, 90-120
7. Săseanu S., (2005) „*Strategii manageriale în industria de panificație*", Matrix Rom, Bucureşti, 86-125
8. Scanlon, M. G., Zghal, M. C., (2001), *Bread properties and crumb structure*, Food Res. Int.
9. Simatos D., Blond G., Perez J., (1995), *Food preservation by moisture control; fundamentals and applications*, Editori Barbosa-Canovas G.V., Welti-Chanes J., *Basic physical aspects of glass transition,* ISOPOW Pract. II, 3 – 31
10. Steffe, J.F., (1996), Rheological Methods in Food Processing Engineering. 2nd ed., Freeman Press, East Lansing, MI 48823, USA
11. Swyngendau, S., Nussinovitch, A., Roy, I., Peleg, M., Huang, V., (1991), Comparison of four models for the compressibility of breads and plastic foams. J. Food Sci., 56(3), 756-759
12. Terry, P., Terry, J.B., Wolk, A., (2001), Fruit and vegetable consumption in the prevention of cancer: an update. *J. Intern. Med.* 250, 280-290
13. STAS-ul 91-83
14. http://oror.essortment.com/historybread-rdyd.htm
15. www.botham.co.uk/bread/history2.htm

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.53.011:635.615
Izvorni znanstveni rad
Original scientific paper

A STUDY OF FRICTION CHARACTERISTICS OF DIFFERENT VARIETY WATERMELON SEED AT DIFFERENT MOISTURE CONTENT

ONDER KABAS, AZIZ OZMERZI

Nuts Research Institute, Giresun/Turkey
Akdeniz University, Agriculture Faculty, Department of Farm Machinery, Antalya/ Turkey

SUMMARY

An experimental arrangement was developed to determine the static and dynamic coefficient of friction of two varieties of watermelon seed (crimson sweet, galaxy and shimal F1). The static and dynamic friction against three surfaces (galvanized steel, plywood and rubber sheet) were measured at a moisture range from 4.12 to 49.25, from 4.97 to 44.62 and 4,08 to 42.33 % (w.b.) for Crimson sweet, Galaxy and Shimal F1, respectively.

Knowledge of the coefficient of friction of seeds is useful in the design of handling equipment, silo and conveyor, sorting and separating of seeds. At all moisture contents, rubber sheet showed the highest friction coefficient, followed by plywood sheet, and galvanized sheet. The increase in friction coefficient with moisture content was the largest for Crimson sweet watermelon seed on galvanized surface, followed by Shimal F1 and Galaxy on galvanized sheet and plywood surface, respectively. Crimson sweet variety had the highest friction on all frictional surfaces at all moisture levels.

Key words: *Watermelon, moisture content, friction*

INTRODUCTION

Watermelon (*Citrullus lanatus*), as a member of the Cucurbitaceous family, the watermelon is related to the cantaloupe, squash and pumpkin, other plants that also grow on vines on the ground. Watermelons can be round, oblong or spherical in shape and feature thick green rinds that are often spotted or striped. They range in size from a few pounds to upward of ninety pounds. The leading commercial growers of watermelon include China, Turkey, Iran and the United States. Watermelon is not only great on a hot summer day; this delectable thirst-quencher may also help quench the inflammation that contributes to conditions like asthma, atherosclerosis, diabetes, colon cancer, and arthritis.

Static and dynamic friction coefficient of crops on different surfaces for example rubber, glass, plywood, galvanized sheet are very important by design parameters for design of handling, sorting, cleaning, transporting and storage facilities such as conveyor belt, bins and silos.

Some researchers have worked on some physical properties of watermelon seeds which they have reported to be moisture dependent, but limited studies have been done on friction coefficient. Different techniques can be used for measuring physical properties. Previously, some researchers (Mohsenin 1986) investigated the reasons of variation in the coefficient of friction values of biological materials.

The experimental results showed that sliding surface, moisture content, velocity, normal pressure, temperature, humidity and testing technique affected friction values. Therefore, specific conditions should be considered while determining the coefficient of friction values of agricultural products. Zhang et al. (1994) used a Wykeham Farrace shear box apparatus to determine grain friction of wheat. Kabas et al. (2007) used inclined surfaces to measure static coefficient of friction and a rotary disc for dynamic coefficient of friction of cowpea seed. Schaper and Yaeger (1992) used an instron to measure the frictional force between material and surfaces. A rotary disc was used to measure static and dynamic coefficient of frictions of chickpea seeds (Akinci et al. 2002).

The objective of the study was to investigate the effect of moisture content on static and dynamic coefficient of friction of three varieties watermelon seed against three surfaces at different levels of moisture content.

MATERIALS AND METHODS

Material

The watermelon seeds (crimson sweet, galaxy and shimal F1) were used for all the experiments in this study. The seeds were obtained from the local market in Antalya, Turkey. The watermelon seeds were kept in cooled bags for transport to the laboratory. The seeds were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt and chaff as well as immature and damaged seeds. The initial moisture content of seeds was determined by using a Standard method (ASAE, 1994). The remaining material was packed in a hermetic vessel and kept in cold storage until use and during study.

Method

The seed samples of the desired moisture levels were prepared by adding the amount of distilled water as calculated from the following relationship (Balasubramanian, 2001):

$$Q= W_i(M_f-M_i) / (100-M_f) \tag{1}$$

Where: Q is the mass of water to added in kg; W_i is the initial mass of the sample in kg; M_i is the initial moisture content of the sample in % w.b. and M_f is the final moisture content of the sample in % w.b. The moisture content of seeds was determined by the standard method at the time of each experiment.

The static coefficient of friction was determined for three different structural materials, namely, galvanized, rubber and plywood sheet. For this measurement one end of the friction surface was attached to an endless screw. The seed was placed on the surface and it was gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the seed started sliding over the surface, then using the tangent value of that angle the coefficient of static friction was found (Fig. 1). Gezer et al. (2002), Nimkar and Chattopadhyay (2001), Kabas et al. (2007) have used similar methods.

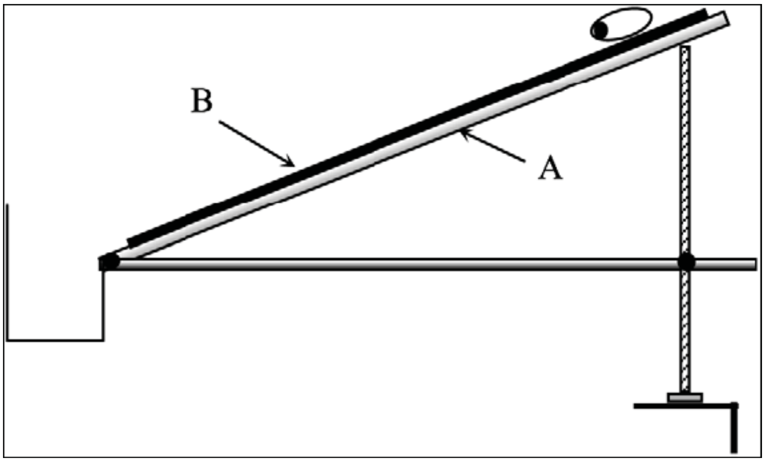


Fig 1 Static coefficient of friction apparatus: (A) tilting surface; (B) test surface sheet.

The dynamic coefficients of frictions of watermelon seeds different moisture contents were measured using a friction device (Fig. 2). The device developed by Tsang-Mui-Chung, Verma, and Wright (1984) and improved by Chung and Verma (1989) has three main components which are a stationary sample container with its support shaft, a driving unit with rotating disc and the data acquisition system. The samples were placed on the rotating surface and the torque necessary to restrain the sample was measured by the data acquisition system. This torque was used to determine the static and dynamic coefficients of friction using the following equation (Chung & Verma, 1989)

$$\mu = T_m / (wq) \tag{2}$$

Where; μ is the dynamic coefficient of friction, T_m the measured torque, q the length of the torque arm and w is the sample weight on the rotating surface. The average value of the torque during the rotation of the disc was used to calculate the dynamic coefficient of friction.

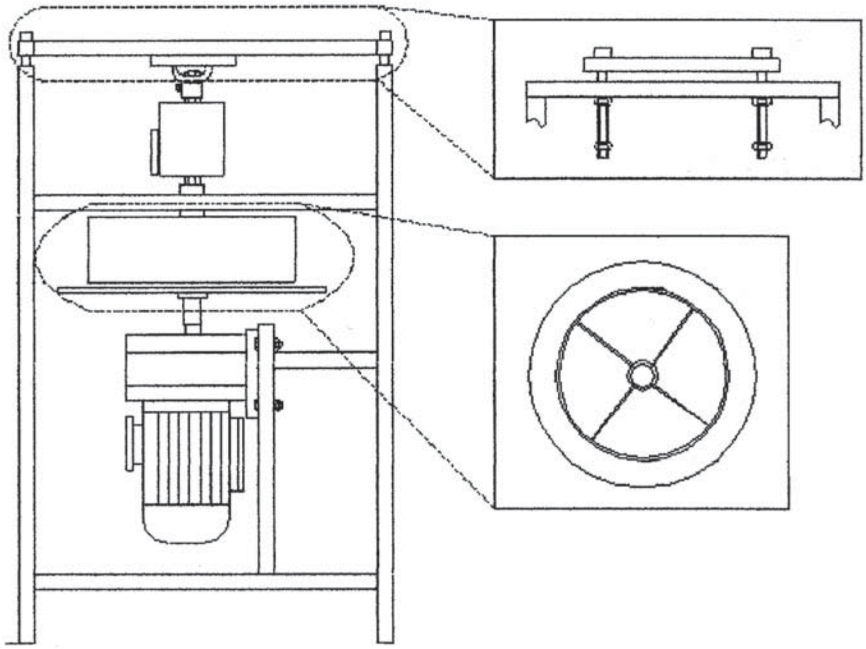


Fig 2 Dynamic friction measuring device system

RESULT AND DISCUSSION

Relationship between values of static and dynamic coefficient of friction against various surfaces (rubber, galvanized sheet, plywood) and moisture content for various types of watermelon samples is given in Table 1.

Table 1 Relationship between coefficient friction and moisture content of various watermelon seeds

Coefficient of friction	Crimson sweet		Galaxy		Shimal F1	
	Model	R^2	Model	R^2	Model	R^2
Static						
Galvanized	y=0,014x+0,3276	0,954	y=0,0099x+0,3296	0,985	y=0,0129x+0,2914	0,948
Plywood	y=0,012x+0,3883	0,989	y=0,0124x+0,3891	0,938	y=0,0081x+0,3937	0,881
Rubber	y=0,0077x+0,6298	0,932	y=0,0102+0,4555	0,976	y=0,0089x+0,5381	0,986
Dynamic						
Galvanized	y=0,0118x+0,2343	0,954	y=0,0085x+0,2374	0,996	y=0,0108x+0,2083	0,954
Plywood	y=0,0102x 0,2758	0,984	y=0,0105x+0,2766	0,952	y=0,007x+0,2825	0,904
Rubber	y=0,0072x+0,4592	0,947	y=0,009x+0,3350	0,978	y=0,0081x+0,3972	0,976

The static and dynamic coefficient of friction for different varieties of watermelon seeds with various surfaces at different moisture content are presented in Fig. It was observed that the coefficient of friction increased with increase in moisture for all the surfaces. Increase in friction coefficient with moisture content maybe explained by increased cohesive force of wet seeds with the structural surfaces, since the surface becomes stickier as moisture content increases. The same result was reported by Konak et al., (2002), Akinci et al., (2004), Kabas et al., (2007).

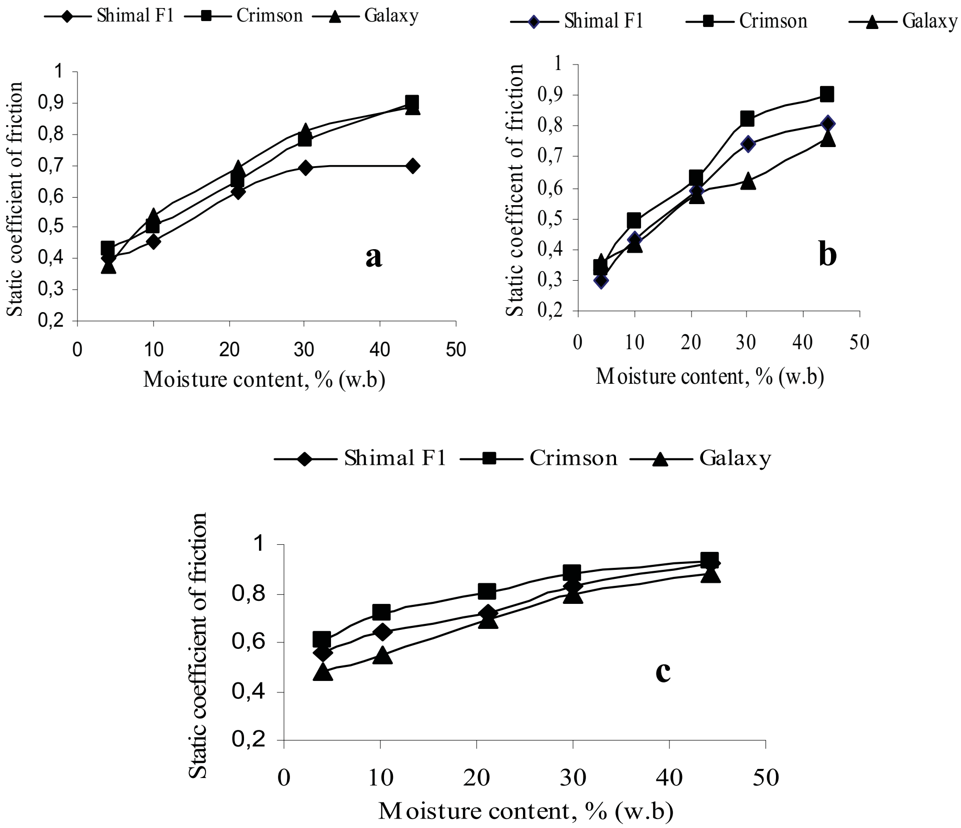


Fig 3 Static coefficient of friction of watermelon seeds on diffirent surfaces a-galvanized, b- plywood, c-rubber,

Figure 3 show that the highest static coefficient of friction for crimson sweet on rubber surfaces and it has the highest static coefficient friction on all surfaces. Also, the lowest value on static friction for Shimal F1 on galvanized sheet and galaxy has the lowest static coefficient friction on plywood and rubber surfaces.

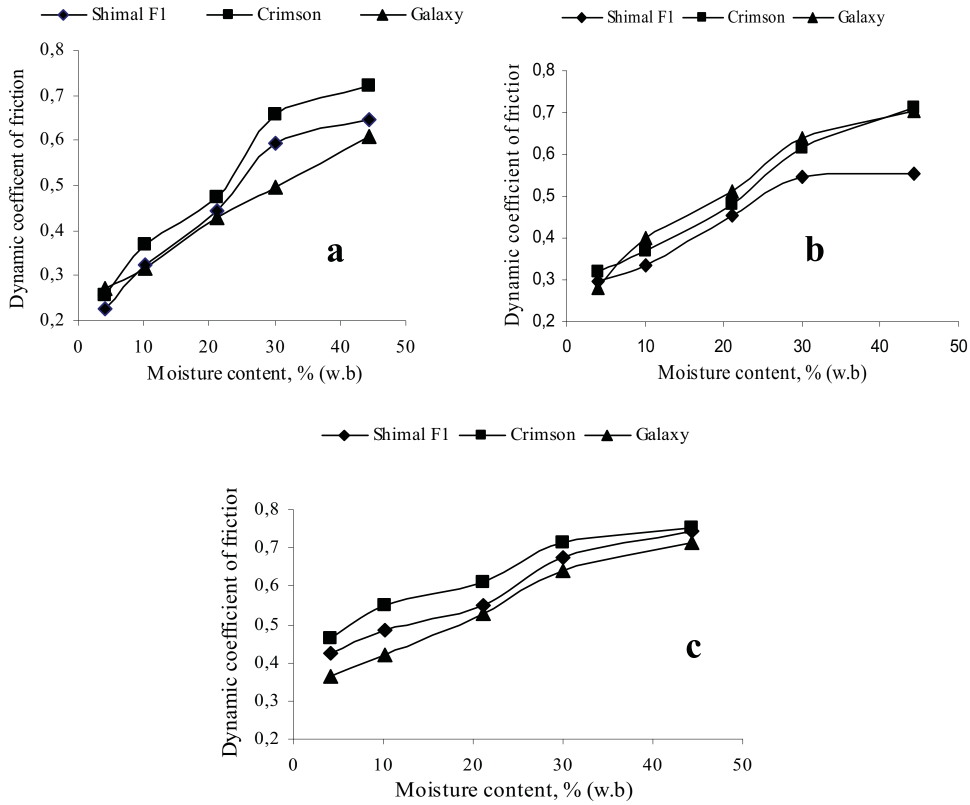


Fig 4 Dynamic coefficient of friction of watermelon seeds on diffirent surfaces a-galvanized, b- plywood, c-rubber,

The dynamic friction coefficient of friction is lower than static coefficient of friction. The crimson sweet has the highest dynamic coefficient of friction on all friction surfaces and observed highest value for its on rubber surfaces. Values of dynamic friction of coefficient are changing from 0,255 to 0,755. Also, the lowest value on dynamic friction for Shimal F1 on galvanized sheet and galaxy has the lowest dynamic coefficient friction on plywood and rubber surfaces.

CONCLUSION

1. It is evidenced that the increase in moisture content of watermelone seeds linearly increased the dynamic and static friction coefficient on three surfaces.
2. The static coefficient of friction varied from 0,340 to 0,930, 0,360 to0,89 and 0,300 to 0,92 for crimson sweet, galaxy and shimal F1, respectively, depending on the surfaces and different moisture content between 4.08% and 40,33 % w.b. Besides, the coefficient of dynamic friction varied from 0,255 to0,753, 0,270 to 0,713 and 0,225 to 0,745.

3. Among the surfaces tested, determined that rubber has the highest coefficient of friction for all watermelons seeds varieties which has followed by plywood and galvanized sheet.

REFERENCES

1. Akinci I., Ozdemir F., Topuz A., Canakci M. (2004). Some Physical and Nutritional Properties of Juniperus Drupacea Fruits. Journal of Food Engineering. 65 (3), 325-331.
2. ASAE.1994. ASAE Standards S352.3-moisture measurement-ungrounded grains and seeds.In: ASAE Standards 1994, 469 St. Joseph, MI
3. Balasubramanian D. (2001). Physical properties of raw cashew nut. J. Agric. Eng. Res.78, 291-297.
4. Chung J. H., Verma L. R. (1989). Determination of friction coefficients of beans and peanuts. Transactions of the ASAE, 32(2), 745–750.
5. Gezer I., Hacıseferogulları, H., Demir F. (2002). Some physical properties of Hacıhaliloglu apricot pit and its kernel. Journal of Food Engineering, 56, 49–57.
6. Kabas O., Yilmaz E., Akinci I., Özmerzi A. (2007). Some physical and nutritional properties of cowpea seed (*Vigna sinensis* L.). Journal of Food Engineering. 79, 1405–1409.
7. Konak M., Çarman K., Aydin C. (2002). Physical properties of chick pea seeds. Biosystems Engineering. 82(1), 73-78
8. Mohsenin, N. N. 1986. Physical properties of plant and animal materials, 2nd edition. Gordon and Breach Science Publishers.
9. Nimkar, M. P., Chattopadhyay, K. P. (2001). Some physical properties of gren gram. Journal of Agricultural Engineering Research. 80(2),183–189.
10. Schaper . L., Yaeger E.C. (1992). Coefficients of friction of Irish potatoes. Tranactions of the ASEA. 35(5): 1647-1651.
11. Tsung-Mui-Chung M., Verma L. R., Wright, M. E. (1984). A device for friction measurement of grains. Transactions of the ASAE, 27, 1938–1941.
12. Zhang Q., Britton M.G., Kieper R.J. (1994). Interactions between wheat and a corrugated steel surface. Transaction of ASAE. 37(3): 951-956.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 635.132:664.844
Stručni rad
Expert paper

MECHANIC PROPERTIES OF CARROT ROOT

MILENA JANČIĆ, MILIVOJ RADOJČIN

Faculty of Agriculture, 21000 Novi Sad, Trg Dositeja Obradovića 8

SUMMARY

The carrot root, which is breeded for fresh use, must contain a lot of high quality characteristics. The quality is refer to physics, chemicals and mechanics characteristics.

As it was wished to get the high quality carrot root, breeding technology was very special. It was taken on mini bars, and analized a number of years as an excellent technology. After breeding process, the roots were brought in the laboratory. There were analized physics characteristics: mass, volume, lenght, dencity and sphericity. The variation coefficient of physics characteristics was positive, and the results were shown the uniform in the sample (Jancic M. 2007.). That was important for demands of market.

The measurements of mechanics characteristics of carrot root are got from the instrument, which is constructed in the laboratory ´Biosistemic engineering´, at Agriculture University in Novi Sad. (Karadzic B. Babic M. Radišic S. 2006). This insrument contains three main components: platform, which is stationary, sounder with cylindrical end, and system for data converter.

The small cubical samples of carrot root were pressed by the sounder of this instrument. Mechanic hardness was defined by precise cell for measurement – force converter. The results were given by sensor and RS 232 port, and delivered to PC – computer. The data were kept in Excel – files.

The instrument was constructed to define the relation between force – deformation. The pressure force curve clearly showed quality textural charasteristics of carrot root. The root sample is in solid state till the force reach the value of critical tension. Then the sample is changing in fluid state, i.e. desintegrated state. The diagram tension – relative deformation is based on the force values, relative deformation, tension and sample cross section values. The modul of elasticity for each sample was given by linear aproximation results from diagram tension – relative deformation and Hook´ s law. The results of variation coefficient and elasticity modul were uniform in the carrot root sample.

The instrument, which is constructed for mechanical characteristic measurements, has a great use in analyses mechanical characteristics of machine materials as in analyses mechanical characteristics of agriculture materials. The instrument has use in analyses of fruit and vegetables hardness in a process of dehidration.

At the begining of this work, it was known that the machine materials have precisely fixed critical tension value, and it is always the same in production of that material. The carrot and other agriculture products are made of natural cells and their mechanical hardness may vary. In the carrot root sample, in this production, the values of variation coefficient and elasticity modul were uniform.

***Key words**: carrot root, mini bars, constructed instrument for mechanical hardness, elasticity modul.*

INTRODUCTION

The technology of mini bars is a great opportunity for breeding carrot for fresh use. Carrot consumers have high requirements about root shape. The root has to be long, straight and uniform shape. When is wished to get these roots, the idea was to breed carrot on mini bars. That breeding method gave better soil conditions for growing carrot.

The shape was not branched, and roots were uniform in mass, volume, lenght, sphericity and dencity. (Jancic M. 2007.)

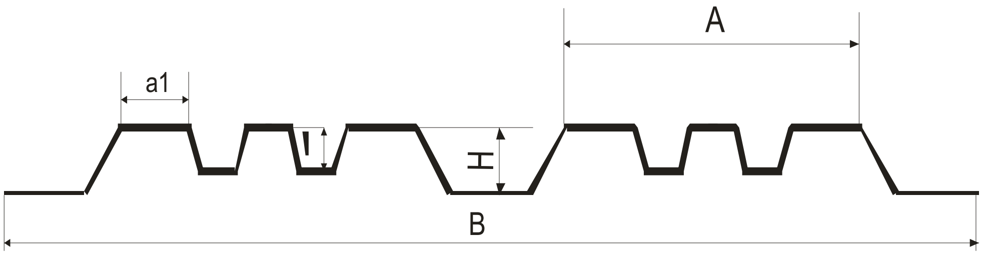


Fig. 1 Schematic description of soil after getting bars
(H_1 – hight of mini bar; a_1 - width of mini bar top; B – working area of machine;
A – width of one bar; H – hight of bar)

Mechanical characteristics of agriculture products

The agriculture products are analized in pressure, flexing, removal, and stretching like as machine construction materials. The instruments for mechanical meassurements are not universal, and are constructed for each group of similar materials, because the agriculture materials are different in shape, dimensions and mechanical hardness.

In analyses of agriculture materials it is found dependence between deformation and force. In the figure 2. it is shown the general example of deformation – force dependence for agriculture materials.

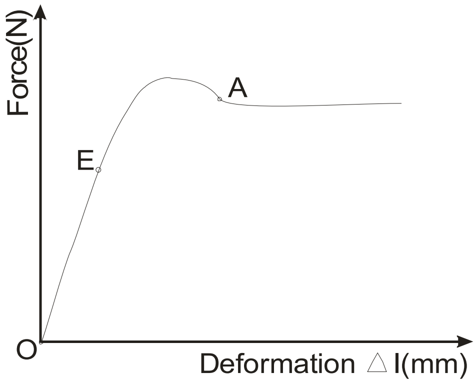


Fig. 2 The diagram deformation – force

At the low strain, the material has plastic deformation. This is the elasticity area till point E. In that area is defined Hook´s law. After the E – point, the material has both elastic and plastic deformation. The strained material is in solid state till the point A, where the material reaches the critical tension. At that moment material change the solid state into fluid state. After point A, the material has characteristics of fluid.

Elasticity modul

In the area of elasticity deformation, while the material has characteristics of solid state, it is defined elasticity modul. Elasticity modul is a coefficient of proportionality critical tension (stress) and relative deformation.

Hook´s law:

$$E = \frac{\sigma}{\frac{\Delta l}{l}} \qquad (N / mm^2)$$

where is: E - elasticity modul, σ - critical tension, Δl - stretching from deformation, l – lenght of the sample, Δl/l - relative deformation of sample, σ – is proportional of the force and cross section of sample.

$$\sigma = F / P \qquad (N / mm^2)$$

METHODS

Instrument description

The measurements of root mechanical hardness, in a test of pressure, are done by the instrument, which is constructed in laboratory ´Biosistemic engineering´, at Agriculture University in Novi Sad. (Karadzic B. Babic M. Radišic S. 2006). The most of these instruments contains three main components: platform, which can be stacionary or removable, sounder with cylindrical end, and sistem for acquisition data, i.e. sensors for force and movement, PLC or PC with acquisition card and software.

The instrument is based on 16 – bits processor and precise optics encoder, which measure the movement of sounder. The hardness of products are defined by precise measure cell – force transducer. On this instrument, the sounder is manual working with mechanism of lever. The sounder is pressed the cubical sample of carrot root. The cubes were 8 mm x 8 mm x 8 mm dimensions. In the further development of this instrument, it is planed to replace the sounder manual work into electromotor work, because it can eliminate the mistakes of operater measurements.

The measurement system contains: rotation encoder, lever with measurement tapes, PLC with interface.

The results are delivered to PC computer by RS 232 port, and data are kept in Excel – files.

As a position sensor it is used incremental optics encoder AINS 41.

Optics encoder is contained: discs, light source and light detectors. Disc is luminous and made of plastic. On it´s periphery, it is placed the ring on which are thick unluminous equidistant markers.

The light detector is the marker reader. This reader makes series of impulses while the disc is rotating. In equidistant moments microcomputer stops counting, reads data from counter and the counting is again continued.

The force transducer with measurement tapes contains elastic element which converts the force into elastic deformation.

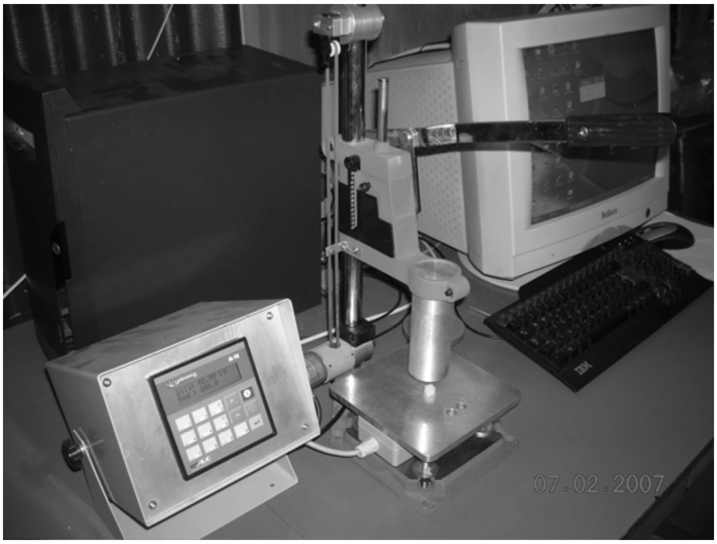


Fig. 3 Original instrument for mechanical biomaterial analysis (Karadzic, B. et al. 2006)

The sensor has two ovals opening connected with flat cutting. The element is with one end attached with base, and on the other end is placed the platform for fruit. The measurement range of force is + / - 200 N, with resolution 0,1 N. The impulses processing are done by micro PLC. Micro PLC has operator panel, which contains LCD – display and numeric keyboard for easier comunication between operator – machine. The results are delivered by RS 232 port and then software makes analyses and visualizes data.

The platform is used in a test of many nutritional products and inedible products.

The main use of this instrument is measuring the product hardness.

The instrument is constructed to measure dependence force – deformation. While the operator moves lever by hand, the instrument automatic enters data of the pair values - force F and deformation Δ l.

The biomaterial is in solid state till it reaches the critical tension σ. Then the material change it´s state in fluid state (Babic M. 2003.). All samples in the force test, are defined dimensions a, b, c, with the accuracy of 0,1 mm.

Based on automatic entered data, the software forms tables. In that tables are columns for force values, deformation, sample cross section (P = a x b), the lenght of sample (c), tension (σ) and relative deformation (Δ l / c). These values are used to form the diagrams tension – relative deformation for each sample.

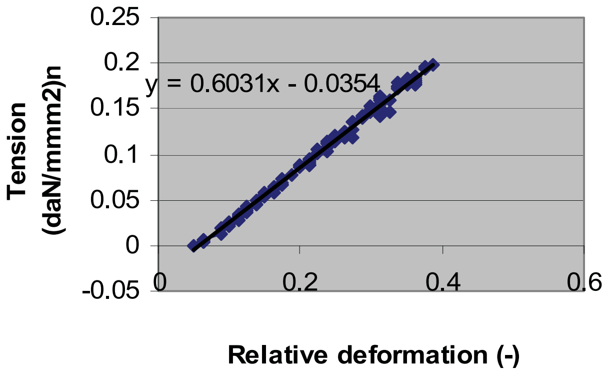


Fig. 5 The diagram of linear aproximation of tension – relative deformation

The elasticity modul is given by the linear aproximation of the results from diagram tension – deformation, and Hook´s law. The elasticity modul is a proportional coefficient of critical tension and relative deformation (Hook ´s law):

$$E = \sigma / (\Delta l/c) \qquad (N/mm^2)$$

where is: E - elasticity modul, σ - critical tension, Δl - stretching from deformation, Δ l/c - relative deformation

RESULTS AND DISCUSION

After harvesting, carrot roots were brought to the laboratory and there were measured physics characteristics of carrot root. The coef. variation results of sphericity and density were shown, that the carrot roots in these characterisitcs have been just ideal, and the results of mass and volume were in range of statistic´s no significant variation. (Jancic M. 2007.)

The hardness analyses of carrot root brought positive statistics results. Average of elasticity modul was E = 6,02324 N / mm^2, standard deviation σ = 0,779948, and variation coefficient Cv =12,94897 %. The variation coefficient result was in range of statistic´s no significant variation.

Tab. 1 Results of elasticity modul

The number of sample	**E – elasticity modul N/mm^2**
1	6,982
2	5,586
3	4,389
4	5,641
5	6,238
6	6,196
7	6,883
8	6,526
9	5,332
10	5,333
11	5,068
12	4,860
13	6,290
14	6,031
15	6,124
16	5,649
17	6,348
18	6,695
19	6,554
20	7,872
21	6,259
22	5,711
23	6,605
24	6,483
25	4,926

Tab. 2 Statistics values of elasticity modul

	Average (N/mm^2)	**St.dev**	**Variation coefficient %**
Elasticity modul	6,02324	0,779948	12,94897

CONCLUSIONS

The new method of land cultivation have been satisfied for carrot root breeding and getting regulary shaped root.

There was no significant variation in the variation coefficient results of physics characteristics.

The mechanical characteristics of carrot root were meassured by constructed instrument for mechanical biomaterial analysis (Karadzic, B. et al. 2006).

The instrument has use in analyses of mechanical characteristics of machine materials, as in analyses mechanical characteristics of agriculture materials.

The results of variation coefficient of root hardness and elasticity module were in range of statistic´s no significant variation, what is excellent for agriculture material.

Experimental analyses of physics characteristics and mechanical characteristics gave positive results and all production of carrot root has got good placement at market.

REFERENCES

1. Babic Lj. Babic M. Drying and storage, Faculty of agriculture, Novi Sad
2. Babic M. Physical characteristic of agriculture material, Faculty of agriculture, Novi Sad
3. Bajkin A. (1994). The machines in vegetable breeding. University of Novi Sad, Faculty of agriculture, Novi Sad
4. Bajkin A. Ponjican O. Jancic M. (2007). The influence of combine working parts on carrot root quality. In XI Congr for Process technic and energetic in agriculture, Novi Sad
5. Bajkin A. Jancic M. Ponjican O. (2006). Mechanical harvesting root crop, potato and bulbed vegetables. In: VII Congr Vegetable breeding today Vol 7. Novi Sad, Serbia, pp 36 – 41.
6. Bajkin A. Ponjičan O. Orlovic S. Somer D. (2005). The machines in horticulture breeding., University of Novi Sad, Faculty of agriculture, Novi Sad
7. Hadzic V. Belic M. Nesic Lj. (2004). Pedology. Faculty of agriculture, Novi Sad
8. Jancic M. (2008). Producing on mini bars as a condition for getting regular shape of carrot root (comparation of two breeding methods on different mini bars) Proceedings of the`36. Internacional Symposium on Agricultural Engineeering´ 2008– Actual Tasks on Agricultural Engineering, Opatia

9. Karadzic B. Babic M. Radisic S. (2006). The meassurement system for hardness definition of agriculture products. Review for Process technic and energetic in agriculture Vol 10 (5), pp 162 – 165.

10. Lazic B. Djurovka M. Markovic V. Ilin Z. (1998). The vegetables. University of Novi Sad, Faculty of agriculture, Novi Sad

11. Mohsenin N. (1980). Physical Properties of Plant and Animal Materials, Gordon and Breach Science Publisher, New York – London – Paris

12. Ponjican O. Bajkin A. Jancic M. (2006). Exploation parametres of mini bar machine. In X Congr. Actual problems of agriculture machines Agriculture technic

13. Radomirovic D. Bajkin A. Jancic Milena Zoranovic M. (2006). Rotation cinematics of rotary with opposite workig organs. Review of machine, tractors and keeping machines Vol 11 (5), pp 62 – 67

14. Todorovic J. Lazic B. Komljenovic I. (2003). Crops and vegetables guidebook, Grafo – Mark, Laktasi

15. www.agricolaitaliana.com

16. www.dewulf.be

17. www.masitaly.com

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 664.4
Izvorni znanstveni rad
Original scientific paper

RESEARCHES REGARDING THE POSSIBILITIES OF OBTAINING ENRICHED BREAD WITH SELENIUM AND ZINC

CAMELIA MOLDOVAN*, CRAINICEANU EUGENIU, DANIELA STOIN, DIANA-VERONICA DOGARU, NICOLETA HADARUGA, DELIA DUMBRAVA

Banat's University of Agricultural Sciences and Veterinary Medicine,
Calea Aradului nr. 119, Timisoara, RO-300645; *e-mail: camelia.clep@gmail.com

SUMMARY

Selenium and zinc are known as essential biominerals for animal/human organism. They are found in some enzymes - superoxid-dismutase, charbonic-anhydrase, lactic-dehydrogenase, glutation-peroxidase, etc. - which are very important for metabolic processes [2].

The major selenium and zinc sources are the cereals. Because in our civilization the cereal cultures are intensive, Se and Zn contents are more and lower. Thus, it is necessary the supplementation with these in food [13, 14]. Because the Romanian soil is poor in Se, the cereals can not accumulate optimal contents of Se and, in consequence, the cereals consumption (in different forms) does not contribute to the optimal equilibrium of the minerals needed by human body [9]. One possibility to establish of mineral equilibrium consist in food nutritional value enrichment, for instance in bread – where the chemical composition does not satisfy the nutritional needs of the human body.

The aim of this work was to enrich the bread, which was obtained by classic process, by adding active organic selenium (Se-methyonine) and zinc gluconate, respectively by bran ads, as the best long-term strategy to prevent the deficiency of Se and Zn to human population, nevertheless to prevent the apparition of some colon cancer types – by adding food fiber (bran).

Some sensorial and physical-chemical characters were studied to the bread made with the ads mentioned above. By sensorial point of view Se / Zn enriched bread didn't present major changes comparing with the without any enrichment bread. The studied physical-chemical parameters were: moisture, acidity, ash, porosity and elasticity module. The studies revealed higher acidity values for the bread with more bran content, and the same results for the bread enriched with Se. Idem the moisture. The higher porosity was found at Zn enriched bread, the *lowest porosity at bread with Se, but the without any enriched bread value was intermediate of these.*

***Key words**: bread, germ, bran, flour, enrichment, selenium, zinc*

INTRODUCTION

Selenium and zinc are essential biominerals in metabolic processes of animal body, being found in numerous enzymes. Selenium is a vital micronutrient for the proper cell function. Se is a component of glutathione peroxidase (EC 1.11.1.9, GSHPx). Recommended dietary intake is determined by health authorities, being typically situated at 60 - 80 μg per day for adults [16]. To maintain nutritional equilibrium the adult needs 50-200 Se μg per day [15].

Recent scientific research demonstrates that maintaining optimal levels of selenium within human body may improve the function of immune system, helps repairing and increase cell resistance to damages, defends against damages caused by free radicals, toxins and pollutants; helps protection against specific degenerative diseases and improves the functionality of body's systems. Scientific research suggests that around 230 μg of selenium each day for men and around 130 μg each day for women will provide optimal nutrition and disease prevention [16].

The selenium level in food depends to the natural differences between essential foods and selenium availability in environment. Se availability may be influenced by human activities. A great number of works reported selenium content in food. Several examples of these are presented below (as mg/kg): 0.4 to 1.5 in liver, kidney and seafood; - 0.1 to 0.8 in cereals and cereal products; 0.1 to 0.4 in muscles; 0.1 to 0.3 dairy products; 0.1 in fruits and vegetables (Oelschlager and Menke, 1969; Morris and Levander, 1970; Schroeder et all., 1970; Suchkov, 1971; Arthur, 1972; Millar and Sheppard, 1972; Ferretti and Levander, 1974; Sakurai and Tsuchiya, 1975; Abutalybov et al., 1976; Bieri and Ahmad, 1976; Kasimov et al., 1976; Olson et al., 1978, quoted by EHC 58, 1986) [13].

Zinc content in animal body is low – around 2.5 g, but it's role is essential. Zinc is necessary in over 200 chemical reactions in animal organism, being especially involved in protein synthesis. This element has antioxidant properties, being important for respiration, endocrine system, immunity, reproduction [14, 17]. Specialists recommend a daily intake of 14 mg in men and 12 mg in women. Though Zn is in many foods (e.g.: fish, seafood, meat, eggs, cereals, dry vegetables), deficiency frequently appear in peoples.

The reason of that is coffee, tea, alcohol consum, smoking and stress - which exhaustion of Zn reserves, and the processing of food - especially cereals for pasta and bread – which causes decreasing of zinc content.

Major symptoms of Zn deficiency consist in: dry skin, digestive perturbance, acneea, difficult healing, frail, spoted or exfoliated nails, hair losses. Here are some Zn levels in food: liver – 9 mg, weat germ – 7 mg, integral bread – 5 mg, beef meat, yolk of egg, duck liver – 4 mg, soy – 3 mg, dry been, lentil, pea, fish, crustaceea – 2-2.5 mg. There is recommended the association of Zn with Se in anti-ageing products for skin [17].

Selenium and zinc deficiencies, as well as other minerals, usually appear in the conditions of soil carency, but also as a consequence of poverty. Fertilising practices with Se or Zn for the soil may substantially improve the content of vegetal food with Se and Zn and afterwards - on the trophic chain – the mineral content for animal food. The improvement of food practices remains an optimal and durable strategy having the major aim to mentain the mineral intake in people, by including Zn and Se supplements in daily diet. This method involves certaines measures: ensuring of bioavailability of rich Zn and Se diet within the whole year; the access of every consummer at these products; increasing of food request and offer for food products with Se and Zn [15].

Selenium and zinc bioavailability depends to chemical form and antagonism and sinergism relations [15].

The bread is a suitable food to be enriched with Se and Zn. There is known that white bread contains 1.5% fiber and a lot of Zn is lost by refination, while the black bread contains 3.5% fiber and the Graham bread contains 5.8% fiber.

In the specialised literature there are known several cases of Se enrichment. There was even patented „bread with Se" [18]. The use of zinc-enriched bread was found to be an economical and already accessible method to eliminate zinc deficiency and prevent further occurrence. [2, 6, 7, 11, 18]. The effects of supplementation with Se wheat bread on Se concentrations, GSHPx activities and related enzymes in the prevention of lipid peroxidation were studied by Thomson (1985).

The sensorial parameters of bread would strongly influence consumer's choices. Together with these parameters, the texture remains a very important component of bread quality. This work presents several sensorial and physical-chemical parameters of bread enriched with Se and Zn [1, 3, 4, 5, 8, 10, 12].

METHODS

We prepared bread by the traditional method [1] using different wheat flour: pure weat flour (p.w.f.) 000 Dobrogea and mixtures from (p.w.f.) 000 Dobrogea with: p.w.f. 650 Boromir, p.w.f. 480 TIP, whole flour, p.w.f. BL 550, bran I, bran II, bran with germ in ratio 1:1. These mixtures are presented in Table 1. Yeast, salt and water in all bread samples were added in the same proportion. The three types of bread were made: without any enrichment, enriched with Se, respectively, enriched with Zn (see table 1). The Se and Zn were introduced in the stage of mixing the dough. All the bread samples were baked at the same temperature and in the same forms. After their cooling, the breads were analyzed for the following parameters:

- moisture by termobalance method at 106ºC;
- acidity by titration with NaOH 0.1 N in presence of fenoftaleina, and it was calculated with formula: $A = \frac{V_{NaOH} \cdot 0.1}{m_{sample}} \cdot 100$;

- porosity by formula: $P = \frac{V - \frac{m}{\rho}}{V} \cdot 100$, where P = porosity of bread crumb (%), V = volume of crumb cylindrical sample (m^3), m = weight of crumb cylindrical sample (g), ρ = density of flour (g/cm^3). The density of flours was made by ratio between weight and volume; [3, 4]. We cut up a bread cylinder; we calculated its volume and weighed it.

- elasticity module by formula: $E = \frac{\tau}{\varepsilon}$, where: E - elasticity (Young) modulus (Pa), τ - compression tension - stress (Pa), ε - linear specific deformation (strain). The compression tension was calculated by formula: $\tau = \frac{F}{S}$, where F = compression force (N) and S = sample surface (m^2). Specific deformation was calculated with formula: $\varepsilon = \frac{\Delta x}{x_0}$, where Δx - descendent length of piston ($\Delta x = v \cdot t$) and x_0 - initial height of samples (m) [4, 8].

RESULTS AND DISCUSSION

The sensorial characteristics of analyzed samples were not very different to the control samples, except the bread with selenium, which had a little pungent and the smell persisting around 8-12 hours after baking. The supplement of selenium caused a difficult evaporation of the water from bread, comparing with the control samples and the zinc supplemented bread. In consequence, the bread with Se had a higher final weight. The porosity of Se bread samples was lower, independent to the flour type. The results of this study are presented in table 1.

The results regarding moisture show a higher value on samples with bran and germ on the hand, on the other hand a high value was registered at bread samples with selenium. The volume of the bread samples with bran and germ was smaller than the rest of the samples. The samples with zinc always showed lower values for moisture. We observed an increase of water content in bread with selenium adds.

Acidity values were higher at bread samples with selenium and bran / germ comparing with other samples.

Porosity value was lower in the case of bread samples with bran and germ. Any direct correlation of porosity with selenium and zinc was found, but it was remarked indirect correlation between moisture and porosity. The higher porosity values were registered in bread samples obtained from p.w.f.; the porosity values decreased by increasing the bran content. Porosity of bread with zinc adding registered highest values.

Bread with selenium or zinc has a soft texture in comparison with normal bread. The aspect of stress curve in bread control ("1") was similar in all three kinds of bread (fig. 4a, b, c). Young modulus was higher in the case of simple bread (“1”) comparing with the bread sample “1+Se” respectively “1+Zn”.

Table 1 Results of analyzed parameters of bread samples

Flour type	Sample	Moisture (%)	Ash (%)	Acidity (acidity degrees)	Porosity (%)
1 p.w.f. 000 Dobrogea	1	11.41±0.62	0.6212±0.006	0.557±0.02	71.12435±2.099
	1+Se	12.33±0.94	0.6320±0.035	0.556±0.03	74.11368±1.949
	1+Zn	11.15±0.74	0.6324±0.034	0.579±0.03	77.47022±1.709
2 p.w.f. 000 Dobrogea + p.w.f. 650 Boromir	2	12.54±0.24	0.6941±0.003	0.507±0.01	78.93408±3.854
	2+Se	12.96±0.26	0.6888±0.026	0.517±0.03	77.9831±5.402
	2+Zn	12.52±0.31	0.6949±0.00	0.500±0.23	77.52336±2.429
3 p.w.f. 000 Dobrogea + p.w.f. 480 TIP	3	12.47±0.54	0.7396±0.027	0.398±0.03	79.01278±3.427
	3+Se	13.43±0.53	0.7412±0.05	0.420±0.02	77.89244±4.143
	3+Zn	12.56±0.73	0.7403±0.09	0.385±0.18	81.69204±0.497
4 p.w.f. 000 Dobrogea + whole flour	4	12.82±0.62	1.3142±0.046	0.955±0.14	68.29103±1.251
	4+Se	13.94±0.44	1.3201±0.04	0.975±0.06	72.16362±1.004
	4+Zn	12.90±0.53	1.3244±0.037	0.978±0.02	70.58991±0.021
5 p.w.f. 000 Dobrogea + p.w.f. BL 550	5	10.95±0.98	1.1532±0.039	0.499±0.04	71.75542±0.294
	5+Se	12.18±0.69	1.1530±0.004	0.459±0.13	72.20235±0.683
	5+Zn	11.27±1.34	1.1611±0.201	0.538±0.03	70.51151±3.253
6 p.w.f. 000 Dobrogea + bran I	6	13.92±0.96	1.4023±0.016	1.526±0.02	55.24704±2.857
	6+Se	14.81±1.34	1.4112±0.014	1.550±0.04	58.69594±3.416
	6+Zn	13.86±1.20	1.4045±0.032	1.625±0.1	62.07988±3.233
7 p.w.f. 000 Dobrogea + bran II	7	13.95±0.74	1.4109±0.09	1.335±0.03	58.23476±2.451
	7+Se	15.04±1.51	1.4118±0.024	1.808±0.16	59.60266±1.113
	7+Zn	14.23±1.38	1.4113±0.05	1.329±0.06	56.20533±1.246
8 p.w.f. 000 Dobrogea + bran with germ	8	14.25±1.34	1.3422±0.173	1.755±0.02	63.89722±3.224
	8+Se	14.86±0.63	1.3391±0.032	1.878±0.04	66.62401±0.463
	8+Zn	14.28±1.52	1.3415±0.046	1.688±0.12	61.77712±2.442

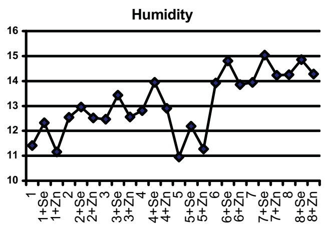


Fig. 1 Moisture of the bread samples

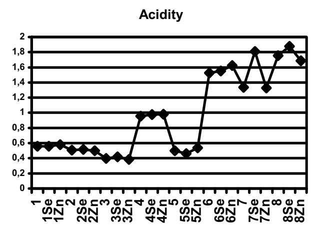


Fig. 2 Acidity of the bread samples

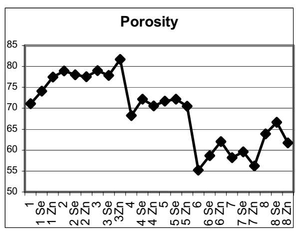


Fig. 3 Porosity of the bread samples

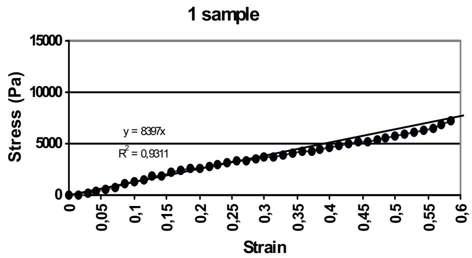


Fig. 4a Young modulus for bread from "000 Dobrogea" p.w.f.

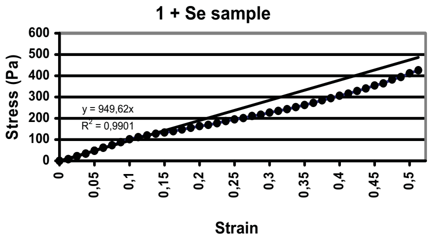


Fig. 4b Young modulus for bread from "000 Dobrogea" p.w.f. with selenium

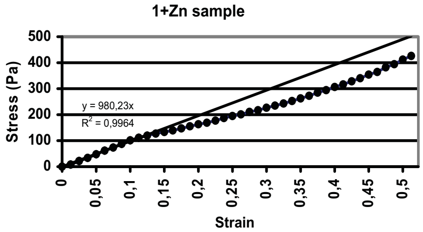


Fig. 4c Young modulus for bread from "000 Dobrogea" p.w.f. with zinc

In the case of bread obtained from mixture of "000 Dobrogea" p.w.f. + "650 Boromir" p.w.f., the adding of Se or Zn determined an increase of Young modulus. The elasticity has almost equal values with control bread samples, and the same situation was for Se / Zn adds bread samples ("2+Se" and "2+Zn"). The stress curve was similar to added samples but different with the control samples ("2").

The highest elasticity modulus value in bread obtained from mixture of "000 Dobrogea" p.w.f. + "480 TIP" p.w.f. was remarked on control bread samples ("3"). The aspect of stress curve in this sample presents similitude with the bread sample with Zn. The Young modulus for selenium bread registrated an intermediary value.

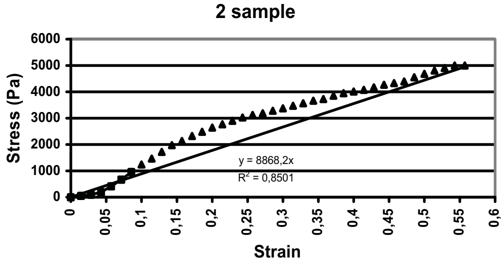


Fig. 5a Young modulus for bread from "000 Dobrogea" p.w.f. + "650 Boromir" p.w.f.

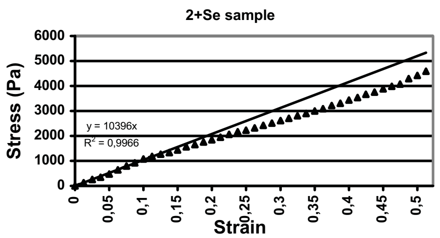


Fig. 5b – Young modulus for bread from "000 Dobrogea" p.w.f. + "650 Boromir" p.w.f with selenium

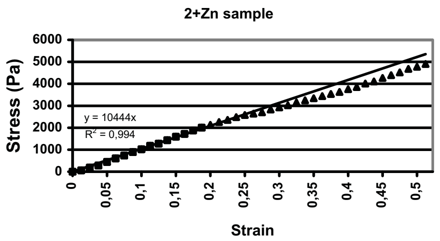


Fig. 5c – Young modulus for bread from "000 Dobrogea" p.w.f. + "650 Boromir" p.w.f with zinc

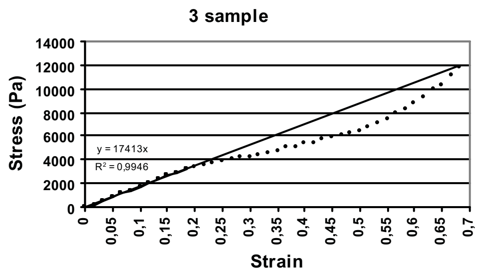


Fig. 6a Young modulus for bread from "000 Dobrogea" p.w.f. + "480 TIP" p.w.f.

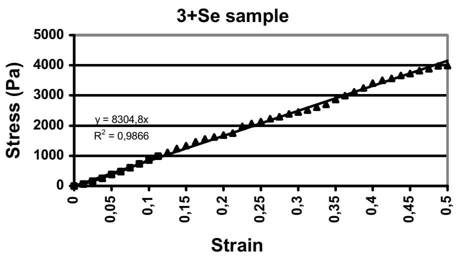


Fig. 6b Young modulus for bread from "000 Dobrogea" p.w.f. + "480 TIP" p.w.f +Se

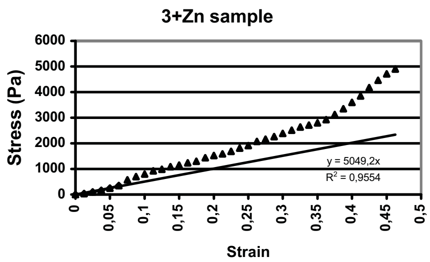


Fig. 6c Young modulus for bread from "000 Dobrogea" p.w.f. + "480 TIP" p.w.f + Zn

The similitudes of stress curve aspect were observed in bread sample obtained from mixture of "000 Dobrogea" p.w.f. + whole flour with adding of Se / Zn.

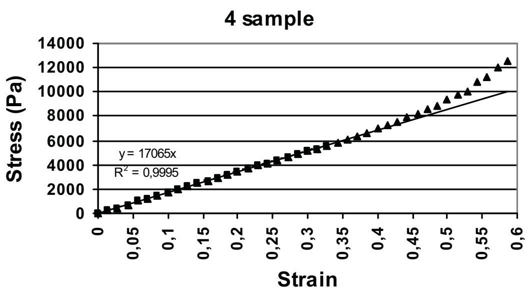


Fig. 7a Young modulus for bread from “000 Dobrogea” p.w.f. + whole flour

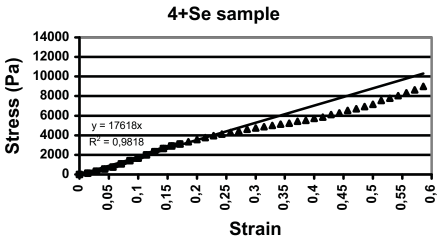


Fig. 7b Young modulus for bread from “000 Dobrogea” p.w.f. + whole flour + Se

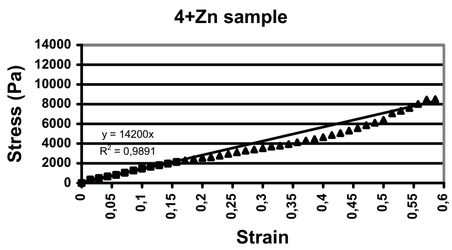


Fig. 7c Young modulus for bread from “000 Dobrogea” p.w.f. + whole flour + Zn

For bread obtained from mixture of “000 Dobrogea” p.w.f. + BL 550 p.w.f. the highest value of Young modulus was remarked in control bread sample (E=26323), following elasticity value of zinc added bread sample (E=17537) respectively selenium added bread (12633).

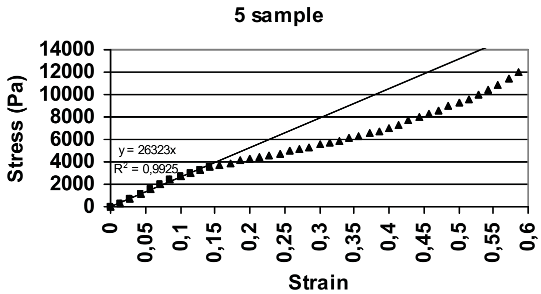
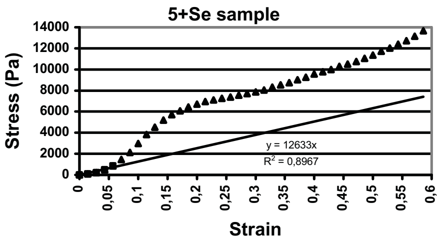


Fig. 8a Young modulus for bread from “000 Dobrogea” p.w.f. + BL 550 p.w.f.



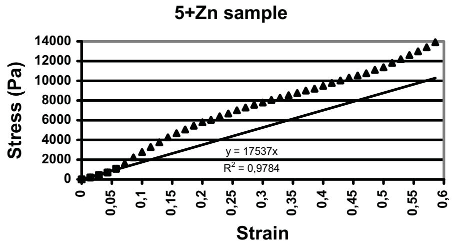


Fig. 8b Young modulus for bread from "000 Dobrogea" p.w.f. + BL 550 p.w.f. + Se

Fig. 8c Young modulus for bread from "000 Dobrogea" p.w.f. + BL 550 p.w.f.+ Zn

The presence of food fiber (bran I / bran II) determined an increase of elasticity modulus in "6" bread sample obtained from mixture of "000 Dobrogea" p.w.f. + bran I. The bread texture with bran was more firm. The aspect of stress curve is similar for all samples ("6", "6+Se" and "6+Zn").

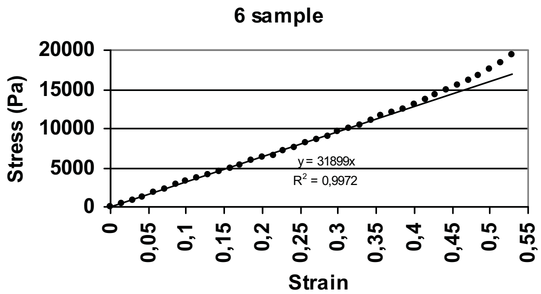
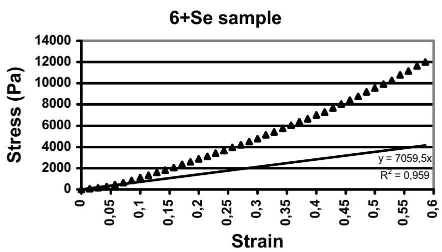


Fig. 9a Young modulus for bread from "000 Dobrogea" p.w.f. + bran I



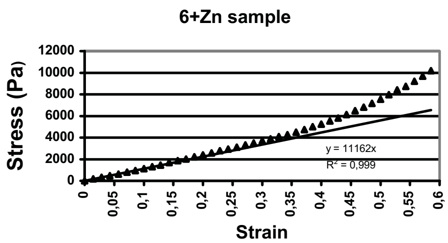


Fig. 9b Young modulus for bread from "000 Dobrogea" p.w.f. + bran I + Se

Fig. 9c Young modulus for bread from "000 Dobrogea" p.w.f. + bran I +Zn

In the case of bread obtained from mixture of “000 Dobrogea” p.w.f. + bran II, the Young modulus registered similar values for bread with adding of selenium and zinc. It was observed a similar aspect of stress curve for these three samples.

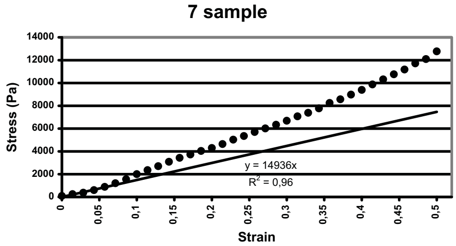


Fig. 10a Young modulus for bread from “000 Dobrogea” p.w.f. + bran II

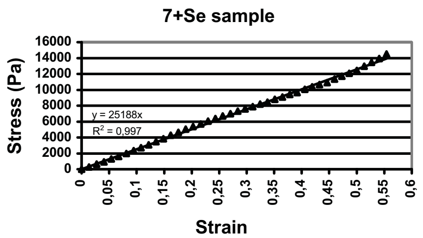


Fig. 10b Young modulus for bread from “000 Dobrogea” p.w.f. + bran II + Se

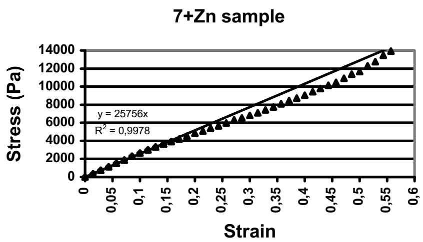


Fig. 10c Young modulus for bread from “000 Dobrogea” p.w.f. + bran II +Zn

Mixing the flour with bran and flour with germ conducted to bread with similar values of elasticity modulus, either in bread samples with Se/Zn, or in control bread sample. The aspect of the stress curves for these samples was analogous.

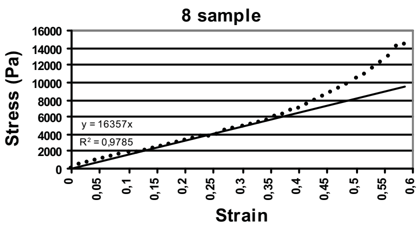


Fig. 11a Young modulus for bread from “000 Dobrogea” p.w.f. + bran and germ

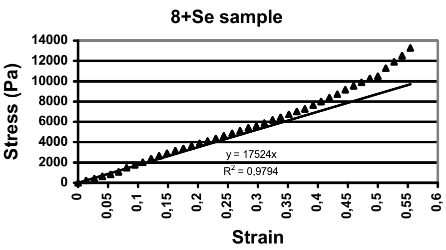


Fig. 11b Young modulus for bread from "000 Dobrogea" p.w.f. + bran II + Se

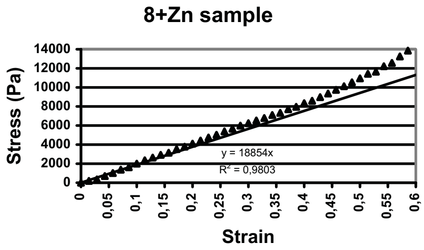


Fig. 11c Young modulus for bread from "000 Dobrogea" p.w.f. + bran II +Zn

CONCLUSIONS

1. Sensorial characteristics of zinc enriched bread samples were not very different to the control sample;
2. Bread samples with selenium adding have a light pungent smell which disappears in 8-10 hours after baking; selenium adding may be proper used in the flavoured bread with spices or volatile oil (e.g. bakerolls with onion, garlic etc.);
3. No influences of selenium or zinc supplements over the bread volume were noticed;
4. The adding of selenium in bread leads to a difficult vaporisation of water;
5. No correlations between the bread acidity and selenium or zinc adds were found;
6. Higher values for acidity were signaled at the samples with bran or germ adding (food fiber);
7. A reversed correlation was established between the water content of the samples and their porosity;
8. Elasticity modulus was not correlated with the selenium or zinc adding;
9. Bran and germ did not improve the volume, the texture and the crumb aspect, but they gave flavour and pleasant taste to the crumb;
10. The decrease of the bread volume was determined by the reduced content of the gluten from dough meaning also the decrease of retaining the gas resulted from fermentation;
11. The fiber better retains the water in the bread, therefore the bread degradation will be delayed;
12. The presence of the fiber (in the conditions of the competition for water inside the dough) leads to insufficient hidratation of the glutenic proteins, with the consequence of a lower rate of glutenic net;
13. In the conditions of higher water content in the dough with fiber, the baking is recommended at lower temperature, but with a longer duration;
14. The fiber adding determines the incresing of the freshness period and diminish the degradation rate of the bread.

REFERENCES

1. Bordei Despina, Fotini T., Toma Maria, (2000) Ştiinţa şi tehnologia panificaţiei, Editura Gir.
2. Chatt A, Dietary intake of zinc and selenium in Turkey, Journal of Radioanalytical and Nuclear Chemistry, Volume 249, Number 1, July 2001, pp. 33-37(5)
3. Gluba T, ObraniakA., Estera Gawot-Młynarczyk, The effect of granulation conditions on bulk density of a product, Physicochemical Problems of Mineral Processing, 38 (2004) 177-186.
4. Hădărugă Nicoleta, Hădărugă D., (2008) Controlul calităţii produselor alimentare de origine vegetală, Ed. Eurostampa, Timişoara.
5. Hibberd, G.D., Parker N.S., (1985) Measurements of the compression properties of bread crumb. J. Texture Studies, 16, 97-110.
6. Khalil Mona M., Bioavailability of zinc in fiber-enriched bread fortified with zinc sulphate, Molecular Nutrition & Food Research, Volume 46 Issue 6, Pages 389 – 393, 2004 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim
7. Kiliç I; Ozalp I; Coskun T; Tokatli A; Emre S; Saldamli I; Köksel H; Ozboy O, The effect of zinc-supplemented bread consumption on school children with asymptomatic zinc deficiency. Journal of pediatric gastroenterology and nutrition 1998;26(2):167-71).
8. Mateescu C., Dogaru Diana, (2001) Sci, Res. Agroalimentary Proc. Technol., volume VII, 247-252.
9. Stăncioiu V. – Rolul fiziologic al elementelor minerale în organismul animal, Ed. Tehnică, Bucureşti, 1981.
10. Steffe J.F., (1996) Rheological methods in Food Engineering, 2nd edition, Freeman Press, East Lansing, MI 48823, USA.
11. Thomson CD, Ong LK , Robinson MF, Effects of supplementation with high-selenium wheat bread on selenium, glutathione peroxidase and related enzymes in blood components of New Zealand residents, American Journal of Clinical Nutrition, by The American Society for Clinical Nutrition, Inc., Vol 41, 1015-1022, 1985. http://www.ajcn.org/cgi/content/abstract/41/5/1015
12. van Vliet T., Janssen A.M., Bloksma A.H., Walstra P., (1992) Texture Stud., 23 439-460.
13. *** EHC (Environmental Health Criteria) 58, International Programme on Chemical Safety, World Health Orgnization, Geneva, 1987.
14. *** EHC (Environmental Health Criteria) 221, International Programme on Chemical Safety, World Health Orgnization, Geneva, 2001.
15. *** - www.agir.ro/buletine/119.pdf
16. *** - www.laucke.com.au/health/GoldenWholemeal.htm
17. *** - http://sanatate.jurnalul.ro/articole/88063/
18. *** - http://www.freepatentsonline.com/4057649.html

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 638.135
Izvorni znanstveni rad
Original scientific paper

HPLC COMPARATIVE ANALYSIS OF POLYPHENOLIC CONTENT OF PROPOLIS AND BLACK POPLAR FOLIAR BUD EXTRACTS

CAMELIA PEEV[1], LAURIAN VLASE[2], CRISTINA DEHELEAN[1], CODRUTA SOICA[1], STEFANA FEFLEA[1], ERSILIA ALEXA[3]

[1]University of Medicine and Pharmacy „Victor Babeş” Timişoara, Faculty of Pharmacy, Timişoara, P-ta Eftimie Murgu nr.2, 300041

[2]University of Medicine and Pharmacy “Iuliu Hatieganu” Cluj-Napoca, Faculty of Pharmacy

[3]University of Agronomy- Banatul, USAMVB, Timisoara

ABSTRACT

Propolis is a resinous mixture that bees - Apis mellifera collect from tree buds, sap flows, or other botanical sources. It is well documented that in the temperate area all over the world, the main source of bee glue is the resinous exudate of poplar buds, mainly from the black poplar - Populus nigra.

In modern phytotherapy (gemmotherapy), foliar buds are considered as an important source for the preparation of vegetal pharmaceutical products. The buds are used as fresh material, which is uncommon for classical phytotherapy, yet very often used for the newest vegetal types of extracts (gemmotherapy, homeopathy).

The polyphenols accumulate in young vegetal organs, especially in the epidermis of young leaves, the cuticula of leaves and buds. Polyphenols are known in therapy for their antioxidant effect, their capacity to reduce the noxious effect of the free radicals in the living organisms, for the anti-inflammatory effect, the proapoptotic activity in cancer cells, as dermal protective agents against the deleterious effect of UVB radiation (caffeic acid) as chemo-preventive compounds (caffeic acid, apigenin, kaempferol) and the antifungal activity (hyperoside, luteolin). Preparations of propolis are not standardized, nevertheless very popular in practice.

The present study consists of a comparative analysis of polyphenols and flavonoids in methanol extracts of the fresh foliar buds of Populus nigra L. and in the harvested propolis, using the HPLC technique. The experiment was carried out using an Agilent 1100 HPLC Series system (Agilent, USA) equipped with *degasser G1322A, quaternary gradient pump G1311A, autosampler G 1311A. Non-hydrolyzed and hydrolyzed extracts were analyzed. Nineteen of the most spread chemical compounds found in vegetal extracts have been used as standards. In the non-hydrolyzed samples of Populus nigra foliar buds, eight types of polyphenols were identified, in different quantities: caftaric acid (1,30 mg/100 g), caffeic acid (27,76 mg/100 g), p-coumaric acid (35,12mg/100 g), ferulic acid (6,08 mg/100 g), quercetin, luteolin, kaempferol and apigenin, while in propolis there were found five types of polyphenols, also in different quantities: caftaric acid (159,00mg/100 g), caffeic acid (2.549,47mg/100 g), p-coumaric acid (1.163,59 mg/100 g), ferulic acid (872,14 mg/100 g) and sinapic acid (1.474,93 mg/100 g).*

From the 19 standard substances used in the experiments, ten polyphenolic compounds have not been identified in the foliar buds extracts of Populus sp. and propolis: gentisic acid, chlorogenic acid, cichoric acid, hyperoside, isoquercitrin, rutoside, myricetin, fisetin, quercitrin, patuletin.

The significant increased concentration of caffeic acid, p- coumaric acid and sinapic acid in propolis may suggest the recommendation of its introduction in the natural extracts, as chemo-preventive, antitumoral, topical protective agents.

***Key words**: Polyphenolic compounds, foliar buds, HPLC, poplar, propolis.*

INTRODUCTION

Foliar buds are considered as a representative source in the modern phytotherapy (gemmotherapy) for the preparation of vegetal pharmaceutical products. The fresh vegetal product is frequently used in the newest vegetal extracts (gemmotherapy, homeopathy), but rarely found in the classical phytotherapy. [1, 2].

Propolis is a resinous mixture that bees *(Apis mellifera)* collect from tree buds, sap flows, or other botanical sources. Bees collect resins from trees such poplar and conifers. It is well documented that in temperate areas all over the world, the main source of bee glue is the resinous exudate of the buds of poplar trees, mainly the black poplar *(Populus nigra)* [2, 3].

Scientific literature data show that the European type of propolis contains the typical phenolic compounds found in poplar buds: flavonoid aglycones(flavones and flavanones), phenolic acids and their esters; it also is composed by 50% resin, 30% wax, 5% pollen, 10% essential oils and 5% various organic compounds. It is well known as a fungistatic, antimicrobial and vulnerary agent [3].

The polyphenols are secondary products of the vegetal metabolism. They accumulate in young organs, especially in the epidermis of the young leaves, the cuticula of leaves and buds [4, 5]. Polyphenols are known in therapy for their antioxidant effect, their capacity to reduce the noxious effect of the free radicals in the living organisms [6, 7], the anti-inflammatory effect, the induction of apoptosis in cancer cells, the anticancer activity and as topical protective agents against the deleterious effect of UVB radiation (caffeic acid) [8], for their the chemo-preventive activity (caffeic acid, apigenin, kaempferol) [9, 10] and nonetheless for the antifungal activity (hiperoside, luteolin) [11] and hepato-protective activity (caffeic acid, ferulic acid) [7].

Poplar species belong to the *Populus* genre*,* the *Salicaceae* family. The vegetal products mostly used as fitotherapeutic remedies are the buds from the black poplar (*Populus nigra* L.) and the trembling poplar (*Populus tremula* Michx.) [12].

Traditionally these vegetal products are used for several affections: bladder inflammation, common cold, diarrhea, liver disorders, rheumatism and stomach problems. Poplar ointment, made from the buds of the poplar tree was formerly a common hemorrhoid remedy, but has now unfairly fallen into almost complete oblivion. The drug is derived from the fresh, crushed buds and can be used to make very helpful hemorrhoid ointments and suppositories. In addition poplar buds have a decongestant, anti-itching and calming effects due mainly to its tannin content [5, 6, 7].

In the resinous material of the foliar buds of poplar trees there have been identified several types of compounds: flavonic derivates (crizol, tectocrizol, apigenol), flavonolic derivates (galangine, izalpinine, quercetol, kempherol and others), flavonones (pinocembrine, pinostrobine), phenolic compounds (cafeic acid, dimethylcafeic acid, izoferulic acid and their esthers), fat acids, aliphatic alcohols and terpenic structures(bisabolol) [5, 6].

The present study presents the analysis of polyphenols and flavonoids in the methanol extracts of the fresh foliar buds and in propolis, using the HPLC technique. Nineteen of the most spread chemical compounds found in plant extracts have been used as standards [13, 14].

MATERIAL AND METHODS

Natural material

The black poplar (Populus nigra L.) foliar buds of were harvested in March 2006, from the wild flora of the Cluj district, Romania. The vegetal material was positively identified at the Department of Pharmaceutical Botany, Faculty of Pharmacy, “Victor Babeş” University of Medicine and Pharmacy Timişoara, and voucher specimens were deposited in the Herbarium of this institution. The propolis was purchased by the Apiculture Department of Zootechnical University, Cluj-Napoca. The sample consists of five different series dating from 2006.

Sample preparation

A. The foliar buds were extracted with absolute methanol in a ratio of 1gram fresh foliar buds to 10 mL solvent, for 24 hours at room temperature. For the HPLC analysis, the extracts were diluted 10 times with methanol and filtered through a 0.5 μm filter (Sartorius). The injection volume was 5 μL.

The liquid sample of propolis was obtained by dissolving 1 gram in 10 mL methanol.

B. Hydrolysis of the glycosilated compounds to free polyphenols was realized by heating 0.5 mL of plant extract with 1 mL of 2N HCl at 80^0C (water bath) for 40 minutes. The solution was completed to 10 mL with methanol and filtered through a 0.5 μm filter (Sartorius).

Apparatus and chromatographic conditions

The experiment was carried out using an Agilent 1100 HPLC Series system (Agilent, USA) equipped with degasser G1322A, quaternary gradient pump G1311A, autosampler G 1311A. For the separation, a reverse-phase analytical column was employed (Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 μm particle); the temperature was set to 48°C. The detection of the compounds was performed using a G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min). The chromatographic data were processed using a ChemStation software from Agilent, USA.

The mobile phase was a binary gradient prepared from methanol and buffer solution. The buffer solution was prepared by dissolving potassium dihydrogen phosphate (40 mM) in water and the pH was adjusted to 2.3 with 85% orthophosphoric acid. The elution started with a linear gradient, beginning with 5% methanol and ending at 42% methanol, for 35 minutes; isocratic elution followed for the next 3 minutes with 42% methanol. The flow rate was 1 mL min^{-1} and the injection volume was 5 μL. All solvents were filtered through 0.5 μm filters (Sartorius) and degassed through ultrasonication.

Identification and quantitative determination of polyphenols

The compounds were detected at 330 nm (the acids) and at 370 nm (the rest of the flavonoids). Retention times were determined, with a standard deviation ranging from 0.04 to 0.19 min (n=5 repeated analysis at concentration of 10 μg mL^{-1}) (Table 1). Quantitative determinations were performed using an external standard method. Calibration curves in the 0.5–50 μg mL^{-1} range with good linearity ($R^2 > 0.9993$, 1/response weighting scheme) for a five point plot were used to determine the concentration of polyphenols in plant samples.

All compounds were identified in samples by comparison of their retention times with respect to standards. Precision and accuracy were checked with a standard solution containing each phenolic compound in a concentration of 10 μg mL^{-1}, five sample replicates. The precision (RSD, n=5) varied between 0.92 and 4.84%, and the accuracy (n=5) between –3.26 and 6.54%. Considering as validation criteria for precision and accuracy a value not higher than 15% ; according to guidelines for bioanalytical method validation [15], the method is precise and accurate.

Chemicals

Methanol of HPLC analytical-grade, 85% orthophosphoric acid, potassium dihydrogen phosphate, and hydrochloric acid of analytical-grade were purchased from Merck (Germany). The standards were: caffeic acid, chlorogenic acid, p-coumaric acid, kaempferol, apigenin, rutoside, quercetin, quercitrin, isoquercitrin, myricetin, fisetin, hyperoside from Sigma (Germany), ferulic acid, sinapic acid, gentisic acid, patuletin, luteolin from Roth (Germany); cichoric acid, caftaric acid from Dalton (USA). Methanol stock solutions (100 g mL^{-1}) of the above standards were prepared and stored at 4^0C, protected from daylight; they were appropriately diluted with double distilled water before use, as working solutions.

RESULTS AND DISCUSSIONS

The chromatogram of the standard phenolic compounds and their corresponding retention times (t_R) are presented in Figure 1 and, respectively Table 1. The chromatographic conditions are described in the section Material and Methods.

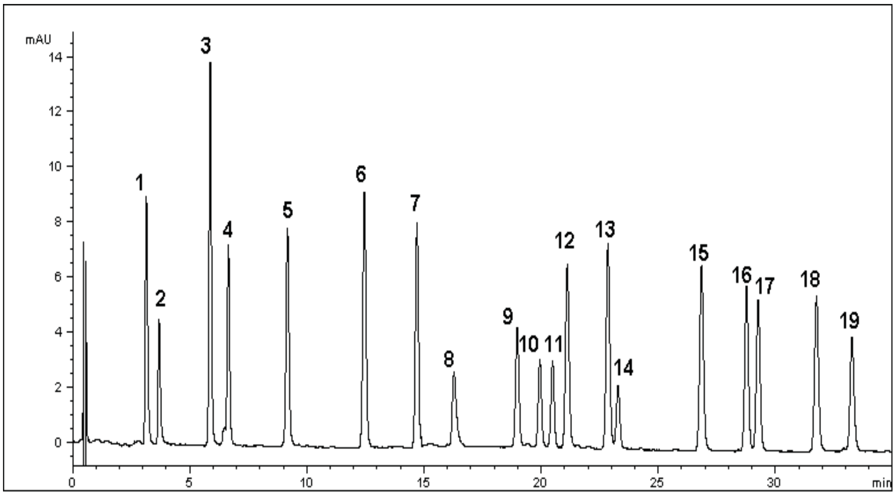


Figure 1 HPLC Chromatogramme of the standard mixture; Conditions: Agilent 1100 HPLC Series system (Agilent, USA); column - Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 µm particle); the work temperature - 48°C; G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min); sample volume - 5µL; 1-Caftaric acid; 2-Gentisic acid; 3- Caffeic acid; 4-Chlorogenic acid; 5-p-Coumaric acid; 6-Ferulic acid; 7-Sinapic acid; 8-Cichoric acid; 9-Hyperoside; 10-Isoquercitrin; 11-Rutoside; 12-Myricetin; 13-Fisetin; 14-Quercitrin; 15-Quercetin; 16-Patuletin; 17-Luteolin; 18-Kaempferol; 19-Apigenin

Table 1 Retention times of polyphenolic compounds

Peak nr.	**Phenolic compound**	**$t_R \pm$ SD (minutes)**	**Peak nr.**	**Phenolic compound**	**$t_R \pm$ SD (minutes)**
1	Caftaric acid	3.34 ± 0.06	11	Rutoside	20.76 ± 0.15
2	Gentisic acid	3.83 ± 0.07	12	Myricetin	21.13 ± 0.12
3	Caffeic acid	6.12 ± 0.04	13	Fisetin	22.91 ± 0.15
4	Chlorogenic acid	6.83 ± 0.05	14	Quercitrin	23.64 ± 0.13
5	p-Coumaric acid	9.48 ± 0.08	15	Quercetin	27.55 ± 0.15
6	Ferulic acid	12.80 ± 0.10	16	Patuletin	29.41 ± 0.12
7	Sinapic acid	15.00 ± 0.10	17	Luteolin	29.64 ± 0.19
8	Cichoric acid	15.96 ± 0.13	18	Kaempferol	32.48 ± 0.17
9	Hyperoside	19.32 ± 0.12	19	Apigenin	39.45 ± 0.15
10	Isoquercitrin	20.29 ± 0.10			

t_R – retention time; SD – standard deviation, (n=5 repeated analysis at concentration of 10 µg mL-1)

Figures 2 and 3 present the HPLC chromatograms *Populus nigra* foliar buds extracts before and after the hydrolysis.

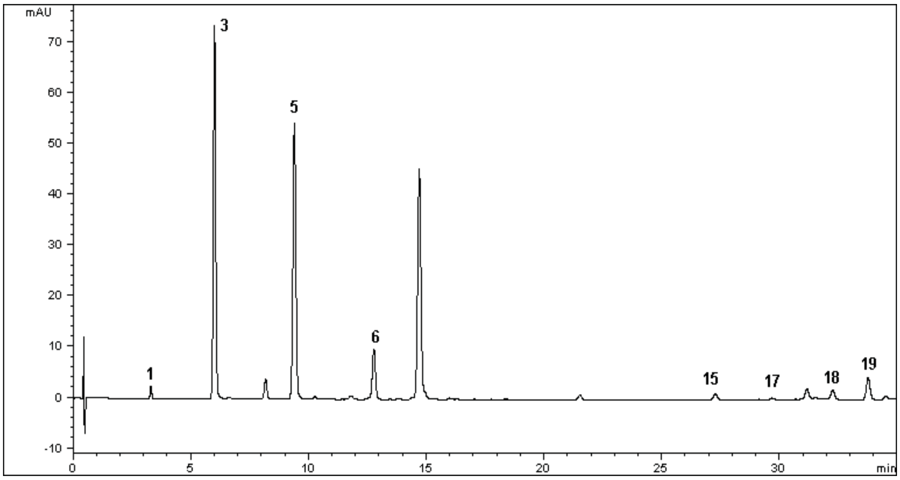


Figure 2 HPLC chromatogram of a non-hydrolyzed *Populus nigra* foliar buds extract; Conditions: Agilent 1100 HPLC Series system (Agilent, USA); column - Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 µm particle); the work temperature - 48°C; G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min); sample volume - 5µL

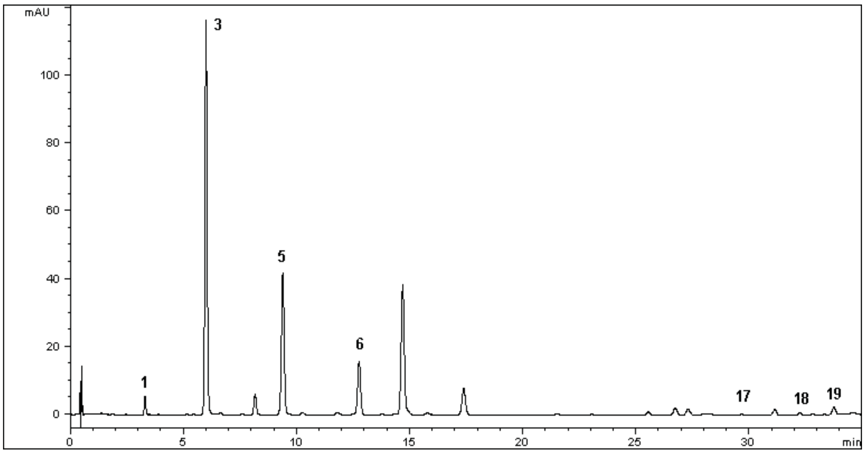


Figure 3 HPLC chromatogram of a hydrolyzed *Populus nigra* foliar buds extract; Conditions: Agilent 1100 HPLC Series system (Agilent, USA); column - Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 µm particle); the work temperature - 48°C; G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min); sample volume - 5µL

Figures 4 and 5 present the HPLC chromatograms Propolis extracts before and after the hydrolysis.

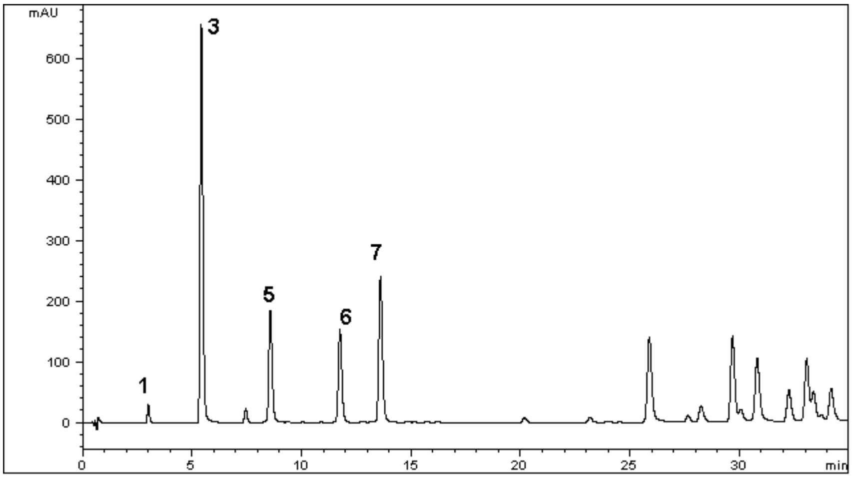


Figure 4 HPLC chromatogram of a non-hydrolyzed *Propolis* extract: Conditions: Agilent 1100 HPLC Series system (Agilent, USA); column - Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 µm particle); the work temperature - 48°C; G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min); sample volume - 5µL

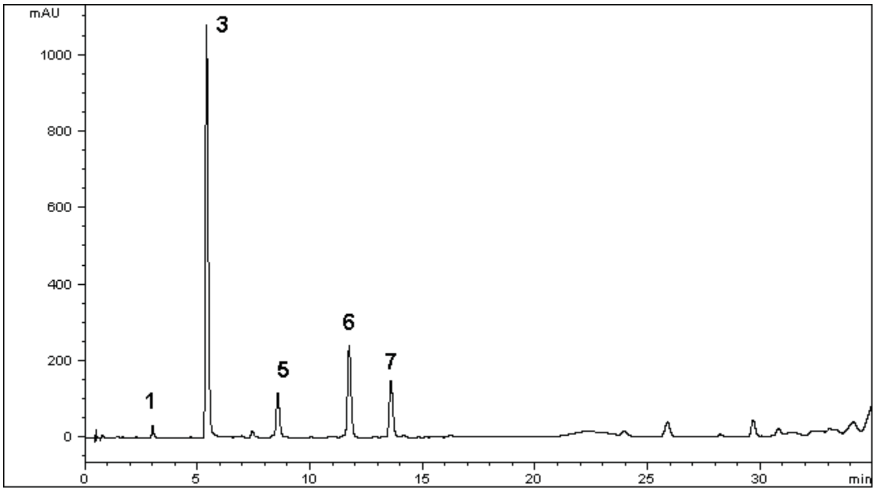


Figure 5 HPLC chromatogram of a hydrolyzed *Propolis* extract; Conditions: Agilent 1100 HPLC Series system (Agilent, USA); column - Zorbax SB-C18 100 x 3.0 mm i.d., 3.5 µm particle); the work temperature - 48°C; G1316A UV detector at 330 nm (until 17 min) and 370 nm (from 17 min until 35 min); sample volume - 5µL

The content in polyphenolic compounds of foliar buds of *Populus nigra* L. and propolis before and after the hydrolysis are presented in Table 2.

Table 2 The content in polyphenolic compounds of *Populus nigra* and *Propolis* (mg/100 g)

Polyphenols	*Populus nigra*		*Propolis*	
	NH	H	NH	H
Caftaric acid	1.30	2.57	159.00	134.47
Gentisic acid	–	–	–	–
Caffeic acid	27.76	42.89	2549.47	3967.30
Chlorogenic acid	–	–	–	–
p-Coumaric acid	35.12	26.73	1163.59	717.61
Ferulic acid	6.08	9.10	872.14	1325.14
Sinapic acid	–	–	1474.93	876.36
Cichoric acid	–	–	–	–
Hyperoside	-	–	-	–
Isoquercitrin	-	–	_	–
Rutoside	–	–	–	–
Myricetin	–	–	–	–
Fisetin	–	–	–	–
Quercitrin	–	–	–	–
Quercetin	1.06	-	–	-
Patuletin	–	–	–	–
Luteolin	0.58	0.36	–	–
Kaempferol	1.74	0.85	–	-
Apigenin	6.16	2.76	–	–

NH – non-hydrolyzed sample; H - hydrolyzed sample

Eight compounds have been found in the *Populus nigra* foliar buds extracts: caftaric acid, caffeic acid, p-coumaric acid, ferulic acid, quercetin, luteolin, kaempferol and apigenin in the non-hydrolyzed samples and 7 compounds: caftaric acid, caffeic acid, p-coumaric acid, ferulic acid, luteolin, kaempferol and apigenin in the hydrolyzed samples.

The *Propolis* extract has presented five polyphenolic compounds: caftaric acid, caffeic acid, p-coumaric acid, ferulic acid and sinapic acid in the non-hydrolyzed samples, and in the hydrolyzed sample. Caffeic acid and ferulic acid are contained in higher concentrations in the hydrolised sample (3967.30 mg/100 g and 1325.14 mg/100 g) compared to those in the non-hydrolised one (2549.47/ mg/100 g and 872.14 mg/100 g). This indicates that these compounds are found in propolis both under free and conjugated forms.

Sinapic acid was found only in the propolis sample, while quercetin, luteolin, kaempferol and apigenin were detected only in the foliar bud extracts of the poplar tree. The concentration of poliphenolic compunds is much higher in the case of propolis extract, compared to that of the foliar buds.

Ten polyphenolic compounds have not been detected in the analyzed extracts, neither in the non-hydrolyzed samples nor in the hydrolyzed ones: gentisic acid, chlorogenic acid, cichoric acid, hyperoside, isoquercitrin, rutoside, myricetin, fisetin, quercitrin, patuletin. It is possible to be completely absent or to be found in extremely small quantities, impossible to detect in the conditions of our experiment.

The significant increased quantities of caffeic acid (3967.30 mg/100 g), p- coumaric acid (1163.59 mg/100 g) and sinapic acid (1474.93 mg/100 g) in propolis may suggest the recommendation of their introduction in natural chemo-preventive, antitumoral extracts, provided for topical protection against the deleterious effect of UVB radiation.

The difference between the polyphenolic content suggests that their analysis could be helpful. In order to apply them in therapeutics it is very important to identify the main compounds and their ratio. The analysed vegetal species are important because of polyphenolic content, aspect that suggests their antioxidant properties. HPLC analysis is a proper method for to identify the polyphenols.

CONCLUSIONS

A comparative screening of the polyphenolic composition was done for the foliar buds of the black poplar and for the European type of propolis, using HPLC method and 19 standards.

Polyphenolic compounds have been identified in the methanolic extracts of *Populus nigra* L., and in the non-hydrolyzed and hydrolyzed samples of propolis.

Qualitatively and quantitatively, the hydrolyzed samples contain a higher number, respectively concentration of polyphenolic compounds. The propolis contains only five of the polyphenolic structures considered as standards, but they are present in significant quantities. Meanwhile in the foliar buds of the black poplar there were determined a number of eight polyphenolic compounds.

From the 19 standards used in the experiments, a number of 10 polyphenolic compounds have not been identified neither in the foliar buds extracts of *Populus sp.* nor in the propolis: gentisic acid, chlorogenic acid, cichoric acid, hyperoside, isoquercitrin, rutoside, myricetin, fisetin, quercitrin, patuletin.

REFERENCES

1. PITERA F., Compendio di Gemmoterapia Clinica, Editore de Ferrari, 2000, p.302.
2. HEINRICH M., BARNES J., GIBBONS S., WILIAMSON E., Phytotherapy and pharmacognosy, Edinburg- London- New York, 2004, p.226.
3. V.Bankova, Recent trends and important developments in propolis research, Evid.Based Complement. Altern. Med. 2:29-32, 2005.
4. HARBORNE J.B., MABRY T.J., MABRY H., The flavonoids, Chapman and Hall, London 1975, p. 63.
5. BRUNNETON J., Pharmacognosie, Editions Tec& Doc, Paris, 1999, p.395.
6. HUNNIUS, Pharmazeutisches Worterbuch, Walter de Gruyter- Berlin- New York 1998, p.1126.

7. STĂNESCU U., MIRON A., HĂNCIANU M., APROTOSOAIE C., Plante medicinale de la A la Z, Editura Gr.T.Popa, Iaşi, 2004, p. 451-455.

8. STANIFORTH V., CHIU L., YANG N., Carcinogenesis, 2006, 27, nr. 9, p.1803.

9. TARAPHDAR A., ROY M., BHATTCHARYA M., Current Science, 2001, 80, nr.**11**, p.1387.

10. M.Kampa, V. Alexaki, G.Notas, Antiproliferative and apoptotic effects of selective phenolic acids on human breast cancer cells, Breast Cancer Res.6(2), 63-74, 2004

11. ABAD M., ANSUATEGUI M., BERMEJO P., Active antifungal substances from natural sources, Arkat, Mardrid, 2006, p.116.

12. CIOCÂRLAN V., Flora ilustrată a României. Pteridophyta şi Spermatophyta, Editura Ceres, Bucureşti, 2000, p. 74.

13. BUCUR, VLASE L., FODOREA C., ISTUDOR V., Revista de Chimie, 2006, **57**, 2, p.189.

14. DEHELEAN C., VLASE L., PEEV C., ANTAL D., SOICA C., Revista de Chimie, 2006, **57**, 8, p. 862.

15. U. S. DEPARTMENT OF HELATH AND HUMAN SERVICES, Food and Drug Administration, Center for Drug Evaluation and Research. Guidance for Industry. Bioavailability and Bioequivalence studies for orally administered drug products-general considerations, July 2002.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 663.81
Prethodno priopćenje
Preliminary communication

RESEARCHES REGARDING THE DETERMINATION OF ORGANIC ACIDS IN FRUITS JUICE

DIANA VERONICA DOGARU, DANIELA STOIN,
NICOLETA-GABRIELA HADARUGA, T.I. TRASCA, I. JIANU

Banat`s University of Agricultural Sciences and Veterinary Medicine, Faculty of Food Processing Technology, Calea Aradului no. 119, RO- 300645, Timisoara, Romania
diana25_dv@yahoo.com

ABSTRACT

The importance of consuming fruits and vegetable, as well as their products is well known[1]. A high-performance liquid chromatographic (HPLC) separation method has been used for the simultaneous determination of organic acids in juices and drinks. Besides HPLC method has been used an enzymatic method for determination of organic acids. These methods could also be used to evaluate the authenticity, spoilage or micronutrient contents of juices.

Organic acids are widely distributed in fruits and vegetables. They are also used extensively as acidulants in the manufacturing of beverages, fruit and vegetable drinks or juices [4,5,6,7]. The principal acids used to enhance beverage flavors are citric, tartaric, fumaric and phosphoric acids. Citric acid is the most widely used acid while malic and tartaric acid are important natural compounds of fruits that are used along with fumaric acid in fruit-flavored drinks [2,3]. In addition, benzoic acid is widely used as a preservative in fruit drinks and juices because the pH imparted by natural and added acids is not sufficient to ensure long-term microbial stability.

The content of organic acids in fruit juices not only influences their flavor but also their stability, nutrition, acceptability and keeping quality. Therefore, it is important to be able to precisely determine acids content for quality control purposes, as well as for meeting various laws and regulations and for labeling purposes.

The purpose of this study is to separate, identify and quantify common organic acids in a variety of juices and beverages using RP-HPLC [8,9,10] and enzymatic tests, which will identify compounds not only by their retention times but also their individual spectra. This will not only provide more nutritional data for a juice or beverage but also an indicator of microbial spoilage such as an *increase in lactic acid content indicating lactic acid bacteria spoilage and the authenticity of the juices[11,12].*

Key words: *fruit juice, food analysis, organic acids*

INTRODUCTION

Organic acids are widely distributed in fruits and vegetables. They are also used extensively as acidulants in the manufacturing of beverages, fruit and vegetable drinks or juices. The principal acids used to enhance beverage flavors are citric, tartaric, fumaric and phosphoric acids. Citric acid is the most widely used acid while malic and tartaric acid are important natural compounds of fruits that are used along with fumaric acid in fruit-flavored drinks. In addition, benzoic acid is widely used as a preservative in fruit drinks and juices because the pH imparted by natural and added acids is not sufficient to ensure long-term microbial stability.

The content of organic acids in fruit juices not only influences their flavor but also their stability, nutrition, acceptability and keeping quality. Therefore, it is important to be able to precisely determine food acids present for quality control purposes, as well as for meeting various laws and regulations and for labeling purposes.

The purpose of this study is to separate, identify and quantify common organic acids and phenolic compounds in a variety of juices and beverages using RP-HPLC method which will identify compounds not only by their retention times but also their individual spectra.

This will not only provide more nutritional data for a juice or beverage but also an indicator of microbial spoilage such as an increase in lactic acid content indicating lactic acid bacteria spoilage and the authenticity of the juices.

METHODS

Apple juice obtaining

We were taken 5 samples of apple juice, as follows: there were chosen 3 cultivars of apples cultivated in our country (garden apples) and imported ones Jonathan, Red Delicious and Golden. The apple juices were notated as follows:

- JI apple juice from imported Jonathan apples
- JG apple juice from garden Jonathan apples
- RI apple juice from imported Red Delicios apples
- GI apple juice from imported Golden apples
- GR apple juice from garden Golden apples

We tried to determine main compounds which come as substrat or as reaction products. We determined the quantity of organic acids during such an enzymatic process. The samples are from the 3 apple cultivars used: *Jonathan, Red Delicious and Golden,* garden cultivated in our country and imported and buyed on the market. The juices were obtained from fruits by squeezing them with a juice maker obtaining apple juice with pulp, from which were prepared the samples for injection.

Juices were kept at 4 °C before analysis. Fruit juice was centrifuged at 5000 rpm for 10 min. Fruit drinks were filtered through a 0.45-mm membrane filter and injected directly into the RP-HPLC.

Chromatographic analysis

RP-HPLC (reversed phase-high performance/pressure liquid chromatography), chromatographic analysis was realized with a Agilent 1100 apparatus. Optimum efficiency of separation was obtained using the following analysis conditions: *column*: Zorbax SB-C18, 250 x 4.6 mm x mm, 5 µm particle diameter; *UV wavelengh*: 215 nm; *mobile phase*: acetonitrile, acidulated water (pH = 3) with phosphoric acid 48:52; *temperature*: 25^0C; *flow* 0.3 mL/min; *injected volume*: 20 µl.

In order to quantify bioactive compounds from apple juice (organic acids), standard solutions of malic, acetic, lactic, citric and cafeic acid were prepared Chromatografic analysis were realized in the same conditions with apple juice.

RESULTS AND DISCUSSION

On the base of standard curve obtained for malic, acetic, lactic, citric, cafeic acid, concentrations of those acids in analysed samples were determined. Apple juice from GI cultivar (*Golden import*) presented 11 peaks determined through HPLC from which 4 were identified with standards. Thus, the most concentrated was malic acid (concentration 1.65 mg/100mL), then acetic acid (concentration 0.31 mg/100mL), lactic acid (concentration 0.27 mg/100mL) and cafeic acid (concentration 0.0027 mg/100mL) (table1).

Table 1 Characteristics of GI apple juice

No. Crt.	Retention time (min)	Area	A%	Identified compound with standard (mg/100mL)	Compound
1	3.374	182.7	9.87	-	Unidentified
2	3.536	599.1	32.36	-	Unidentified
3	**3.703**	**575.4**	31.08	1.65	**Malic acid**
4	3.791	90.5	4.89	-	Unidentified
5	3.907	51.8	2.80	-	Unidentified
6	4.341	46.1	2.49	-	Ascorbic acid
7	**4.509**	**210.4**	11.37	0.27	**Lactic acid**
8	**6.393**	**68.2**	3.68	0.31	**Acetic acid**
9	**10.434**	**5.8**	0.31	0.0027	**Cafeic acid**
10	12.202	17.1	0.92	-	Unidentified
11	13.185	4	0.22	0.0049	Quercetine
		1851.1	100		

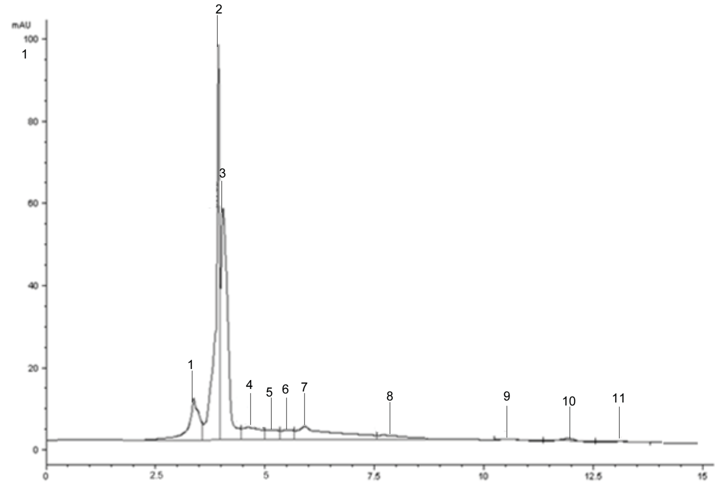


Figure 1 HPLC chromatogram of GI apple juice

Table 2 Characteristics of JI apple juice

No. crt.	Retention time (min)	Area	Identified compound with standard (mg/100mL)	Compound
1	1.8	8.2	-	Unidentified
2	2.068	26.2	-	Unidentified
3	2.589	52.4	-	Unidentified
4	2.722	1150.9	-	Unidentified
5	**3.721**	**473.3**	1.36	**Malic acid**
6	3.849	132.7	-	Unidentified
7	3.904	9.1	-	Unidentified
8	4.311	13.9	-	Ascorbic acid
9	**4.66**	**136.9**	0.18	**Lactic acid**
10-11	**6.455**	**25.7**	0.26	**Acetic acid**
12	7.285	12.9	-	Unidentified
13	8.319	28.4	-	Unidentified
14	8.946	26.4	-	Unidentified
15	**9.497**	**30.6**	1.61	**Citric acid**
16	**10.417**	**106.4**	0.0487	**Cafeic acid**
17	11.945	145.5	-	Unidentified
18	13.157	25	0.0307	Quercetine
19	19.241	4.7	-	Unidentified

Apple juice (obtained) from imported Jonathan cultivar (JI) presented 18 peaks and we identified 5 organic acids (table 2). From those, the biggest concentration had citric acid (1.61 mg/100mL), then malic acid (concentration 1.36 mg/100mL), acetic acid (concentration 0.26 mg/100mL), lactic acid (concentration 0.18 mg/100mL) and cafeic acid (concentration 0.0487 mg/100mL). Figure 2 presents the HPLC chromatogram of JI apple juice.

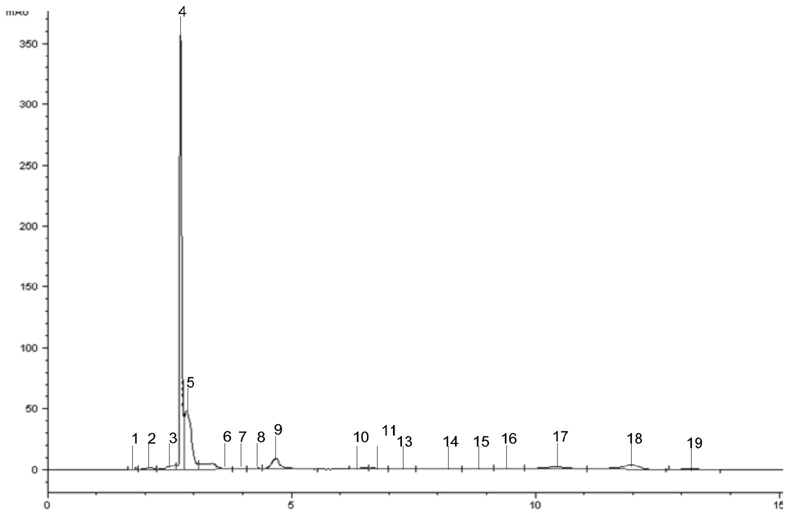


Figure 2 HPLC chromatogram of JI apple juice

Table 3 Characteristics of RI apple juice

No. crt.	Retention time (min)	Area	Identified compound with standard (mg/100mL)	Compound
1	1.736	2.6	-	Unidentified
2	1.922	8	-	Unidentified
3	2.004	12.3	-	Unidentified
4	2.996	22	-	Unidentified
5	3.507	57	-	Unidentified
6	**3.774**	**417.4**	1.20	**Malic acid**
7	**4.626**	**8.6**	0.01	**Lactic acid**
8	**6.405**	**12.9**	0.25	**Acetic acid**
9	11.775	1.9	-	Unidentified

The RI apple juice sample presented the smallest number of peaks, 9, (table 3). From those peaks we identified malic acid (concentration 1.20 mg/100mL), acetic acid (concentration 0.25 mg/100mL) and lactic acid (concentration 0.01 mg/100mL). Figure 3 presents the HPLC chromatogram of RI apple juice.

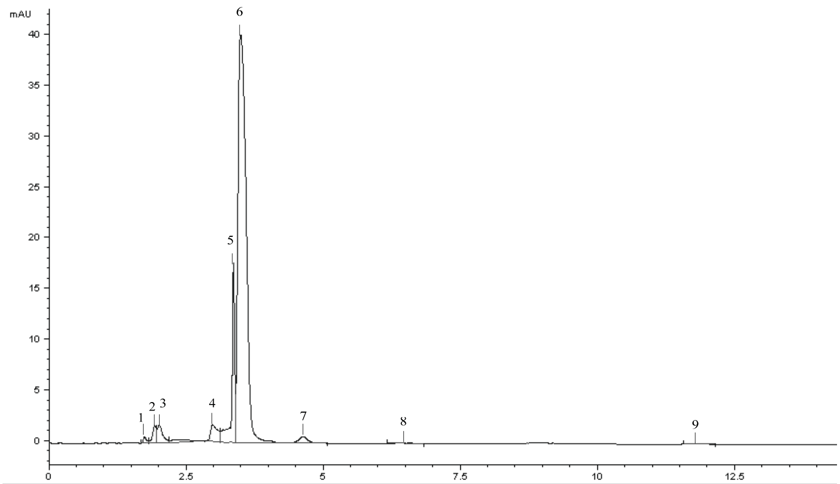


Figure 3 HPLC chromatogram of RI apple juice

The GG (Golden garden) sample presented 24 peaks, the biggest number of peaks of all analysed samples (table 4). Among these were identified the 5 organic acids identified with standards. Malic acid had the highest concentration (10.69 mg/100mL), followed by citric acid (concentration 2.58mg/100mL), lactic acid (concentration 0.48 mg/100mL), acetic acid (concentration 0.46 mg/100mL) and the lowest concentration was for cafeic acid (0.0043 mg/100mL). The HPLC chromatogram of GG apple juice is presented in figure 4.

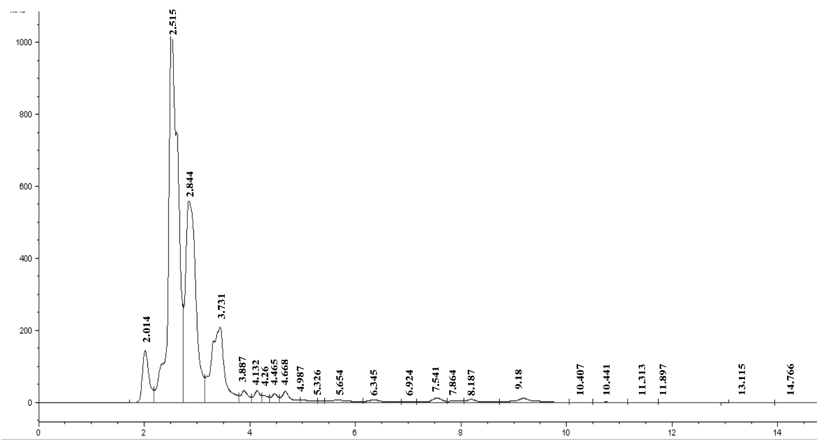


Figure 4 HPLC chromatogram of GG apple juice

Table 4 Characteristics of GG apple juice

No.crt.	**Retention time (min)**	**Area**	**Identified compound with standard (mg/100ml)**	**Compound**
1	2.014	1295.6	-	Unidentified
2	2.515	133352.2	-	Unidentified
3	2.844	7754.4	-	Unidentified
4	**3.731**	**3724.4**	**10.69**	**Acid malic**
5	3.887	333.4	-	Unidentified
6	4.132	296.9	-	Unidentified
7	4.26	165.2	-	Ascorbic acid
8	4.465	210.1	-	Unidentified
9	**4.668**	**368.6**	**0.48**	**Acid lactic**
10	4.987	128.2	-	Unidentified
11	5.326	44.3	-	Unidentified
12	5.654	247.4	-	Unidentified
13	**6.345**	**202.6**	**0.46**	**Acid acetic**
14	6.924	47.3	-	Unidentified
15	7.541	219	-	Unidentified
16	7.864	99.8	-	Unidentified
17	8.187	174.7	-	Unidentified
18	**9.18**	**358.7**	**2.58**	**Acid citric**
19-29	**10.407**	**94.6**	**0.0433**	**Acid cafeic**
21	11.313	31.8	-	Unidentified
22	11.897	45.2	-	Unidentified
23	13.115	26.1	0.0320	Quercetine
24	14.766	20.6	0.0128	Kaempferol

The chromatogram for JG sample presented 22 peaks, and were identified with standards 6 organic acids: malic acid (concentration 15.09 mg/100mL); citric acid (concentration 1.94 mg/100mL); lactic acid (concentration 0.54 mg/100mL); acetic acid (concentration 0.40 mg/100mL); cafeic acid (concentration 0.0117 mg/100mL) (table 5).

Table 5 Characteristics of JG apple juice

No.crt	Retention time (min)	Area	Identified compound with standard (mg/100ml)	Compound
1	2.018	852.4	-	Unidentified
2	2.511	13935.5	-	Unidentified
3	2.866	13724.6	-	Unidentified
4	**3.719**	**5256.9**	**15.09**	**Malic acid**
5	3.916	327.5	-	Unidentified
6	4.163	284.9	-	Unidentified
7	4.292	151.1	-	Ascorbic acid
8	4.502	212.6	-	Unidentified
9	**4.702**	**412.8**	**0.54**	**Lactic acid**
10	5.702	191	-	Unidentified
11	**6.411**	**148**	**0.40**	**Acetic acid**
12	7.325	16.3	-	Unidentified
13	7.598	199	-	Unidentified
14	7.951	113	-	Unidentified
15	8.278	99.9	-	Unidentified
16	**9.293**	**142.7**	**1.94**	**Citric acid**
17	**9.525**	**25.5**	**0.0117**	**Cafeic acid**
19	10.414	14	-	Unidentified
20	11.477	23.1	0.0283	Quercetine
21	13.619	4.9	-	Unidentified
22	14.505	5.8	0.0036	Kaempferol

Table 6 Characteristics of all apple juice samples

No	Cod	Sample	Malic acid (mg/100ml)	Lactic acid (mg/100ml)	Acetic acid (mg/100ml)	Citric acid (mg/100ml)	Cafeic acid (mg/100ml)
Retention time (min)			3.7	4.5	6.3	9.2	10.4
1	GI	Golden imported	1.65	0.27	0.31	-	0.0027
2	JI	Jonathan imported	1.36	0.18	0.26	1.61	0.0487
3	RI	Red delicious imported	1.20	0.01	0.25	-	-
4	GG	Golden garden	10.69	0.48	0.46	2.58	0.0433
5	JG	Jonathan garden	15.09	0.54	0.40	1.94	0.0117

CONCLUSIONS

Apple juice contains a variety of organic acids and phenolic compounds such as malic acid, ascorbic acid, chlorogenic acid and flavonoids. Measurements of organic acids and phenolic compounds are useful for labeling purpose as well as for the determination of the authenticity of the juice.

In this work, RP-HPLC method is presented for the simultaneous separation and determination of organic acids in apple juices. Six non-phenolic acids were eluted. The established method was successfully used to measure a variety of organic acids in fruit juices and drinks. This method could also be used to evaluate the authenticity, spoilage or nutrient contents of juices.

REFERENCES

1. C.A. Rice-Evans, N.J. Miller, G. Pagana, Free Radic. Biol. Med. 20 (1996) 933.
2. M.T. Huag, R.C. Smart, C.Q. Wong, A.H. Conney, Cancer Rec. 48 (1988) 5941.
3. H. Hayatsu, S. Arimoto, T. Negishi, Mutat. Res. 202 (1990) 1678.
4. B. Vennat, A. Pourrat, H. Pourrat, D. Gross, P. Bastide, J. Bastide, Chem. Pharm. Bull.36 (1988) 828.
5. T.J. Barden, M.Y. Croft, E.J. Murby, R.J. Wells, J. Chromatogr.A 785 (1997) 251.
6. F. Ahmet Ayaz, A. Kadiolu, M. Reunanen, J. Agric. Food Chem. 45 (1997) 2539.
7. F. Kvasnicka, M. Voldrich, J. Chromatogr. A 891 (2000)
8. B. Fernandez de Simon, J. Perez-Iizarbe, T. Hernandez, C. Gomez-Cordoves, I. Estrella, J. Agric. Food Chem. 40 (1992) 1531.
9. A. Escarpa, M.C. Gonzalez, J. Chromatogr. A 830 (1999) 301.
10. H. Chen, Y.G. Zuo, Y.W. Deng, J. Chromatogr. A 913 (2001 387.
11. C. Tricard, M.H. Salagoity, P. Sudraud, Ann. Falsif. Expert Chim. Toxicol. 79 (1986) 303.
12. R.S. Singhal, P.R. Kulkarni, D.V. Rege, Handbook of Indices of Food Quality and Authenticity, Woodhead, Cambridge 1997.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 632.95.024:633.1
Stručni rad
Expert paper

RESEARCHES REGARDING THE ORGANOCHLORINE PESTICIDES OF THE CEREAL PRODUCTS AND FODDER FROM THE WEST PART OF ROMANIA

ERSILIA ALEXA[1], MARINELA SBURLEA[2], DANIELA STOIN[1], MIHAELA MALAESTEAN[2]

[1]Banat's University of Agricultural Sciences and Veterinary Medicine,Timisoara, Romania
[2]Residues Determination Laboratory Timisoara, Romania
e-mail: ersilia_alexa@yahoo.com

SUMMARY

The use of organochlorine pesticides has had multiple advantages, but it also has the disadvantage of low degradability, both chemically and biologically in living organisms and environment, due to a very high bio-concentration potential, lipophilicity and remarkable stability towards atmospheric agents. The accumulation of pesticide residues in plant foods consists of either the direct contact with the plant by sprinkling, or those diffusion from soil in plants as a result of the pesticides administration on the soil surface. In this case, the amounts that reach aboveground plant parts are very small, but those who remain in the edible roots and in the tubers are significant.

Although most of the organochlorine pesticides are forbidden to be administrated in Romania since 1988, at present being allowed for use only those with γ-HCH base for seeds treatment, still they are used unlawfully by the farmers.

In this paper, the organic-chloride pesticides (HCH, DDT derivate products and methabolites) load in cereals and fodder, during a two years period: 2006 and 2007, in the western area of Romania, was aimed. The analysis method used is AOAC 970.52 – Organochlorine pesticide residues gas chromatographic method. The experimental results indicated that the residual load with α-HCH and β-HCH isomers, increases in the following order: maize, wheat, fodder. The DDT and Lindane are situated in the range of undetectable limits or in the minim detection limit (LMD)-maximum admitted limit (LMA) domain, did not occur any contamination with these organochlorine compounds in neither of the analysed matrices. Also, a tendency of decrease of HCH and DDT isomers residues was found in time.

***Key words**: Organochlorine compounds, HCH, DDT, cereals, fodder*

INTRODUCTION

The insecticides are pesticides used for insect's destruction. The organochlorine insecticides (OCI) belong to the following structures: diphenilethane (DDT) and ciclohexane (HCH) halogenates derivates, policiclical (aldrine, dieldrine, chlorinedane, heptachlor) and terpenical (toxaphene) halogenates derivates.

The large use of the organochlorine pesticides had and still does exhibit multiple advantages, but some disadvantage must be emphasyzed. The organochlorine derivates exhibit low degradability, both chemically and biologically in living organisms and environment, due to a very high bio-concentration potential that characterizes many of the compounds.

Sequelly a soil, vegetation, water permanent load is realized, due to the periodical and repeated treatments and to the these increasing accumulations. Ingested by the animals, through the polluted or treated fodder, they are retained in the animals fatty tissue (liposoluble) or excreted in milk and eggs. This way, they determine a general pollution of the food, where, due to the stability, are long time preserved. Because of this, their use started to be limited, being replaced, wider and wider, with organophosphorical compounds [1]. Despite this, there are countries in which significant amounts of HCH or DDT isomers residues in cereal products can be found that exceed about 58 and 73% of the samples analysed [4-5].

The chlorine pesticides had been used for the first time in Romania in 1948.The first products were mainly on DDT basis, but there had been used others based on chlorinedane, dieldrine, endrine, aldrine, heptachlor and toxafene. All of these products have been imported, except those based on DDT and heptachlor, which were locally made. After 1988, these kinds of products had been forbidden by the authorities to be used in Romania.

The mentioned substances were being used as powders, granules or liquids, on large agricultural areas, on meadows and lucerne crops.

Starting with 1965 the DDT pesticides had not been layer on the meadows and lucerne crops. At the present, the only chlorine insecticides used in Romania are those based on lindane, used for seede treatment, but this is not on the list of forbidden substances of the Stockholm Agreement [3].

The studied organochlorine insecticides (DDT and HCH isomers) belong to the Persistent Organic Contaminants (mentioned as POC). These compounds are chemical substances that remain in the environment for long periods, toxic for humans and wild organisms and they accumulate in fatty tissues, are volatile and have a global circulation through the atmosphere and the oceans and seas waters [6].

MATERIAL AND METHOD

The analysis method used is the AOAC 970.52 - *Organochlorine and organophosphorus pesticide residues*. *General multiresidues method* of organochlorine pesticides residues determination from the animal food products and fodder by gas chromatography [6].

The determined compounds were: hexachlorciclohexane isomers, alpha – hexachlorciclohexane (α - HCH), beta - hexachlorciclohexane (β - HCH), gamma – hexachlorciclohexane (γ - HCH) - Lindane, as well as the p,p' - dichlor-diphenile-trichlor-ethane (p,p' - DDT).

The mean recovery values ranged from 85-90%. The liniar dynamic range of the detector response was checked. The average correlation coefficient was 0,923. The limit of detection (LMD) are based on signal to noise ratios of 3:1 and were 0.005 ppm for α-HCH, 0.002 ppm for γ-HCH, 0.01 ppm for β-HCH and 0.03 ppm for DDT.

Samples were taken from counties belonging to the west part of Romania, Arad County (AR), Salaj County (SJ) and Bihor County (BH)

RESULTS AND DISCUSSION

The experimental results regarding the content of the organochlorine insecticides determinate in maize, wheat and fodder samples, during 2006 and 2007, as well as the analyzed samples number, are presented in Tables 1 and 2.

Table 1 The content of organochlorine insecticides in maize, wheat and fodder, in 2006

County/year	n	Residues	Number of positive samples			Number of undetectable samples		
			Wheat	Maize	Fodder	Wheat	Maize	Fodder
AR 2006	12	α-HCH	1	-	2	4	12	10
		Lindane	-	-	-	12	12	12
		βHCH	-	-	-	12	12	12
		DDT	-	-	-	12	12	12
BH 2006	9	αHCH	-	-	-	9	9	9
		Lindane	-	-	-	9	9	9
		βHCH	-	-	1	8	5	8
		DDT	-	-	-	9	9	9
SJ 2006	21	αHCH	1	-	-	20	20	20
		Lindane	-	-	-	21	21	21
		βHCH	-	-	9	21	21	12
		DDT	-	-	-	21	21	21

* MAL – maximum admitted limit; ** LMD – Limit of detection

The obtained experimental results regarding the HCH and DDT residues content in cereals and fodder, indicate the exceeding of the maximum admissible limits (according to *EPA Seeks Public Comment, 2006*) only for the alpha and beta HCH isomers in wheat and fodder samples, in 2006.

Table 2 The content of the organochlorine insecticides in maize, wheat and fodder, in 2007

County/year	No. of analised samples	Residues	Number of positive samples			Number of undetectable samples		
			Wheat	Maize	Fodder	Wheat	Maize	Fodder
AR 2007	10	αHCH	-	-	-	8	9	10
		Lindane	-	-	-	10	10	10
		βHCH	-	-	2	6	3	4
		DDT	-	-	-	10	10	10
BH 2007	16	αHCH	-	-	-	16	16	16
		Lindane	-	-	-	16	16	16
		βHCH	-	-	-	16	16	16
		DDT	-	-	-	16	16	16
SJ 2007	33	αHCH	-	-	-	24	11	29
		Lindane	-	-	-	31	14	18
		βHCH	-	-	1	27	19	26
		DDT	-	-	-	33	33	33

* MAL – maximum admitted limit; ** LMD – Limit of detection

In wheat, it is found an exceed of 8 3 % (∝HCH) of the samples analyzed in Arad county and 4.7% (∝HCH) of the samples in SJ, while in BH county no contents of (∝HCH) were recorded above the maximum admitted limit. 58.3% of the total wheat analyzed samples in Arad county regarding the (∝HCH) content, is situated in the range of detectable values, but without exceeding MAL, with values in the range of 0.005-0.02 ppm.

The (βHCH) isomer was found above the maximum admitted limit (0.01 ppm), in one fodder sample taken from BH county, while the samples taken from SJ county had exceeded MAL in proportion of 42.8%

The maize samples did not record high values at none of the analyzed parameters, so the obtained values had situated in proportion of 44.4% between the LMD and MAL, in the case of the samples from BH county and respectively 4.7% in the samples from SJ county.

DDT and Lindane (gamma HCH) residues, in all of the analyzed samples, had not been detectable, situating themselves below MDL, both the fodder and the cereal samples.

In 2007 (table 2) the analyzed sample load with organochlorine pesticides residues, decreases in comparison with 2006, the alpha HCH isomer does not record positive values, above MAL, at neither of the analyzed matrices. Most of the samples that are found with values of the alpha HCH parameter exhibit values below MDL of 0.005 ppm. The samples taken from SJ county, show values regarding the alpha HCH indicator in proportion of 66.6% for maize, 27.2% for wheat and 12.1% for fodder, in the DML-MAL domain, without exceeding the maximum admitted threshold of 0.02 ppm.

The beta HCH isomer remains for 2007, the only compound that records positive samples, above MAL of 0.01 ppm at fodder, but these values are found again in a small number of samples (1 sample taken from SJ county and 2 samples from AR county).

The gama HCH isomer and DDT do not record positive values, for none of the analyzed matrices.

From the point of view of the analyzed counties, BH county records the lowest values regarding the organochlorine pesticides, most of them being below MDL.

CONCLUSIONS

The experimental results regarding the residual load of HCH and DDT isomers in the wheat, maize and fodder samples taken from counties of the West of Romania, lead to the following conclusions:

- From the point of view of the analyzed matrices, the residual load increases in the following order: maize, wheat, fodder;
- Among the HCH analyzed isomers, beta HCH shows the greatest incidence of reappearing under the residual form in the cereal products;
- DDT and lindane situate in the range of undetectable values or in the MDL-MAL, unexisting any contamination with these organochlorurated compounds in neither of the analyzed matrices, no matter the area where they come from;
- The county with the maximum residual load is AR county followed by SJ, while BH county shows minimum values regarding the organochlorine pesticides residues;
- A decreasing tendency of the HCH isomers residues in time is established, the percents of the samples declared positive being lower in 2007 than in 2006.

REFERENCES

1. Alexa E., *Contaminants in vegetable products*, Ed. Eurobit, Timisoara, 2003
2. Alexa E., *Pesticides and their remanence*, Ed. Eurobit, Timisoara, 2003
3. Cadariu A., *Proiectul Internațional de Eliminare a POP, Raportul de Țară privind Poluanții Organici Persistenți,* 2003
4. Toteja GS, Mukherjee A, Diwakar S, Singh P, Saxena BN , *Residues of DDT and HCH pesticides in rice samples from different geographical regions of India: a multicentre study*, Food additives and contaminants 20 (10): 933-939 OCT 2003
5. ***AOAC Official Methods Analysis, 1997.
6. ***EPA Seeks Public Comment, Lindane and Other HCH Isomers--EPA Risk Assessment Fact Sheet, 2006

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 543.3:628.1
Stručni rad
Expert paper

STAGNATED WATER QUALITY MONITORING FOR THE SUSTAINABLE DEVELOPMENT OF THAT RESOURCES

MONICA BUTNARIU, DANIELA STOIN, CORNELIA CHEȚ, OTILIA COTUNA, CARMEN PAIAN

Banat's University of Agricultural Sciences and Veterinary Medicine – Timisoara, Calea Aradului, No. 119, 300645, Timisoara, Romania, Chemistry and Vegetal Biochemistry Department, e-mail: monicabutnariu@yahoo.com

SUMMARY

The study want to evaluate the chemical and physical quality of stagnated water and rains water from Timisoara City for obtaining a batter view of the health state of the living creatures from Timis – Bega hydro graphic pool.

The main objective of the study is to establish the water samples quality for ecological rehabilitation and the impact of different human activities on rains water qualities for recycling in natural circuit or for a possible use form.

The samples for this study were analyzed and tested according by national norms and standards approved by the Standards Association from Romania (A.S.R.O.).

The study and water quality evaluation analysis and literature dates about the elements and the standards from the field led to the next conclusions: rains water tested from the area near the city of Timisoara has high concentrations of nitrates and nitrites in limits of the III – rd Quality Class, fact that confirms the existence of an pollution with N compounds in atmosphere; the organic charge of rains water CCO – Mn presents values between 5.43 mgO$_2$/L and 8.56 mgO$_2$/L, corresponding to the II – nd Quality Class.

The purpose of water resources management is rational use by maintenance and value of meteoric water.

***Key words**: water, monitoring, chemical and physical characteristics, pollution*

INTRODUCTION

Water, beside to air and soil are fundamental for the progress of human society. That natural resource is considered to be a constitutive part of Earth that represents the vital functions, impossible to replace in the biological and economical life of our society. Concerning that sources of water developed a diversity of bio systems, even the human society was attracted on that areas. The developing of the human society was dependent by the access of water, and the biggest and dynamic human societies were dependent by the proximity of the water resources and its quality. (The Council; Adams 2000).

Romania promises to implement the 2000/60/EC, approved by European Parliament and European Union Council in 23 of October 2000, in the same time with the member states of European Union that has in our days an advanced position concerning the levels that should to be followed on the process. To help that happening, under the coordination of International Comity for the protection of Danube (ICPDR), our country cooperates with the others Danubian countries for realizing till 2009 of the Management pool planning on Danube. That document represents a unitary vision about the activities of sustainable care on Danubian waters. (Low about potable water quality from 2002).

The Directive offers European Comity, the member's states and the candidates to membership the possibility to cooperate to form partnerships based on the presences of all interested parts to protect interior waters and all the other waters by preventing the pollution at the source and establishing a mechanism to control all pollution sources. The first Directive about water establish the dead line when the waters should reach the minim point of quality, by reducing the emissions from human, industrial and agricol activities. (Burtică 2000; Water Frame Directive 2000).

The adopting of the water care decision – is based on the knolidge in real time of characteristic parameters and knolidges about the investigated areas (rivers, lakes, underwater, wastewaters), investigation environments (water, sediments/masteries in suspension, biota) and monitories' elements (biologic, hydro – morphological, physical and chemical).

In water quality concerning is always the necessity of realizing a new concept of monitoring system about waters (the idea hepled by laws), for define «*ecologic quality*» of «*suspension water – sediment – materials*» like a «*bio – chemical entity*». (Butnariu 2004; Wasserwirtschaft 1996)

Water waste (swamps, stagnated waters) belongs to the surface waters, the parameters followed being comparated with the *Normative about reference objects for classifying surface waters quality, Annex 6.11at Implementation planning at the Directive76/464/CEE and directives „daughters" about pollution caudated by certain dangerous substances thrown in aquatic environment of the Community*. (Journal of environmental 1997)

In general the potential cause of reaching the limit values at pollutants can be: natural causes, point pollutions, diffusion pollutions and the biggest pollution potential on pollution sources belongs to the homes domains, chemical industries, economical agents, extractive industries and metallurgic industry. (Ricci 1996). Defused pollution is about the pollutants entries on aquatic environment, being harder to identified and controlled. Here is included agricol pollution, solids and liquids masteries from atmosphere. The diffuse sources are including the pollutions caudated by the products/materials consumed by industry or population. (Blas 1992; Schneider 1996).

Because in data base existing for Timis – Bega pool was proved that the town of Timisoara is the most important source of point pollution there are missing about the data bases about stagnated water quality and rain waters, the main objective of this study being to evaluate the waters from physical and chemical point of very, the quality of stagnated waters and rain waters on different places in Timisoara. (Butnariu 2005; Water Journal from 1990).

Monitoring systems for surface waters and under waters, in the European Directive on waters are represented in 7 under systems, that has lake new thing another two systems (the transitional water system and the system of modified and manmade waters) as:

- Subsystem of transitional waters;
- Underwater subsystem;
- Natural lakes subsystem;
- Rivers subsystem;
- Sea waters subsystem;
- Man made and modified waters subsystem;
- Wastewater subsystem. (Chiarle 2000; Riedel 1994)

According to the directive in waters field the national monitoring system of water quality is formed by 3 types of monitoring: surveillance monitoring, operational monitoring and investigation monitoring.

Surveillance monitoring is used for the evaluate of waters from pools or hydro graphic pool, emerging information’s for: impact evaluation validation procedures, efficient project of monitoring programs, evaluation of changes on long periods of time for the impact of atrophic activities on waters. (Manahan 1986)

Operational monitoring should to be realisated for all water bodies by evaluating the impact or by surveillance monitoring, being identified with high risk of not be in the same direction with the environmental objectives. Operational monitoring has the purpose to establish the aquatic ecosystems that present the risk of not caring the environmental objectives and to evaluate any state changes on aquatic ecosystems, changes from measurements programs. (Butnariu 2007; Infoterra 1993).

Investigation monitoring should be dun for the: identify the causes of increase limits from quality standards on environment, for certify the causes that a quantity of water can’t reach environmental objectives and for the impact of accidental pollution. (Năstase 1981; Memento Technique de l’eau 1989)

Today, the monitoring activity answers to the First Directive and others European Directive from water field, by studding some aspects from surveillance monitoring. (Standards. Norms. Legi; Burden 2002)

METHODS

Standards about natural wastewater quality contain today approximate 30 indicators and the most used are:

- Dissolved oxygen content that is the most important way to appreciate river water quality because it determinates the possibility of aquatic life development in normal limits; the existence of a deficit indicates an intense biological activity because of it high impurity state;
- Chemical consume of oxygen (CCO) represents a global parameter of organic pollutant substances concentration; until then the chemical consume of oxygen is much higher that the value of biochemical consume of oxygen after five days (CBO_5), the water is considered toxic and the phenomena of self purifying will not be happening;
- Biochemical consume of oxygen after five days (CBO_5) represents a global parameter directly proportional with concentrated biodegradable pollutants from inside of water.

Another indicator of water quality is: NH_4^+, iron content Fe^{2+}, Fe^{3+} and water pH.

Table 1 Indicators of water quality and standards accepted for the analyses

No.	Quality indicator	U.M.	Analyses method
1	Hydrogen ions concentration (pH)	unit. pH	pH- SR ISO 10523 / 97
2	Conductivity	μS/cm	Electric conductivity - SR EN 27888 / 1997
3	Alkalinity	mval/dm^3	Alkalinity- SR ISO 9963 -1 / 97
4	Calcium (Ca^{2+})	mg/dm^3	Calcium - STAS 3662 -90 and SR ISO 7980 /97
5	Magnesium (Mg^{2+})	mg/dm^3	Magnesium- STAS 6674 / 77and SR ISO 7980 / 97
6	SO_4^{2-}	mg/dm^3	STAS 8601-70
7	Cl^-	mg/dm^3	Cl^-- SR ISO 9297 / 2001
8	NO_2^-	mg/dm^3	NO_2^- - SR ISO 6777 / 1996
9	NO_3^-	mg/dm^3	SR ISO 7890-2:2000; SR ISO 7890-3:2000 SR ISO 7890/1-98
10	NH_4^+	mg/dm^3	SR ISO 5664:2001 SR ISO7150-1/2001
11	O_2 dissolved	mg/dm^3	O_2 dissolved - SR EN 25813 / 2000
12	Chemical consume of oxygen- method with permanganate of potassium (CCO-Mn)	mg O_2/dm^3	CCO-Mn - SR EN ISO 8467 / 2001
13	Chemical consume of oxygen- method with $K_2Cr_2O_4$ (CCO-Cr)	mg O_2/dm^3	CCO-Cr - SR ISO 6060 / 1996
14	Biochemical consume of oxygen at five days (CBO_5)	mg O_2/dm^3	CBO_5 - SR EN 1899-2/2002

According to the normal values of the indicators of quality, the receptor waters can be speared in three categories:

- Water from the I category, represent waters used for alimentation and salmonides growth;

- Waters from the II category are the best for notation and fish growing;
- Waters from the III category are the best for aquatic natural flora and animals, for technological use and for irrigations. (Techniques. Sciences. Methods 1988)

The samples for study were tested respecting the national standards approved by A.S.R.O. in Table no 1.

RESULTS AND DISCUSSION

Irrational exploitation of water resources (on surface and below) and the man made changes on natural flux turn back sooner or later, direct or indirect against human communities by: drying pools, phreatic water small level, or the opus of it perturbing the supplies of water, food or even take to the disappearance of a whole community.

Similarly, the activity of human will damedge water quality and will pollute them. The pollution can be multiple and different: casnic pollution (deversing on soil or in surface waters of dejections), urban pollutions, industrial and agricol pollutions.

All that are introducing directly of indirectly, a physical agent (suspension material), chemical (chemical elements or compounds), or biologic (germs), unwanted and novice for water and their uselessly or accidental, punctual in time or well localize or can be hard to find. This is the way to explain the pollution with nitrites and nitrates from surface waters. The sources of waters became impossible to use as potable.

It is important to control the quantity of water consummated and the quality of it. Self clean of waters is one of the most important problems. The content of chemicals from rain waters is dependent of atmospheric pollutants.

The quality of rain waters in cities is an indicator of chemical pollution of that area and the study in the city of Timisoara in 2007 shown us the existence of a major pollutant in atmosphere. The quality of water from rains varieties according to geographical factors and humans.

Table 2 The physical and chemical characteristics of rain waters samples

Quality indicator	**U.M.**	**Water sample**				
		1	2	3	4	5
pH	unit. pH	6.38	6.62	5.21	5.26	5.49
Conductivity	μS/cm	16.30	17.00	61.00	44.50	21.50
Ammonia (N-NH_4^+)	mg/L	0.00	0.00	0.00	0.00	0.00
Calcium (Ca^{2+})	mg/L	30.80	36.20	42.00	18.50	36.40
CCO-Mn	mgO_2/L	5.95	5.92	8.80	8.20	5.43
Clorures (Cl^-)	mg/L	22.76	14.18	16.45	11.40	10.64
Magnesium(Mg^{2+})	mg/L	18.20	10.10	37.60	24.06	15.60
Nitrates (N-NO_2^-)	mg/L	0.05	0.10	0.10	0.10	0.05
Nitrites (N-NO_3^-)	mg/L	5.00	5.00	5.00	5.00	5.00
Sulphates (SO_4^{2-})	mg/L	0.00	0.00	50.00	50.00	50.00
TOC	mgC/L	4.02	4.002	6.62	5.42	4.56

Evaluation of water quality from rains in Timisoara offers information's on the possibly to reintroduce it in the global circuit in nature.

The physical and chemical characteristics of rain waters samples in five places are presented in Table 2.

The values about water quality from rains were compared with "Normativul privind obiectivele de referinţă pentru clasificarea calităţii apelor de suprafaţă" No. 1146 from 27.03.2002.

The rains called and meteoric waters contain impurities that can be find even in the quality characteristics of water. From the analysis of sample points from Timisoara there are the next conclusions:

pH – of rains so between 5.0 – 6.62, medium or slightly acid, according to the natural waters classification depending on pH – (table 3) rain waters characterization from Timisoara is slightly acid (pH between 5 – 6.4).

Table 3 Classification of natural waters according to pH

No.	Water type	pH value
1	Oxidant waters	3
2	Acid waters	3 – 5
3	Slightly waters	5 – 6.4
4	Neural waters	6.5 – 7.5
5	Slightly basic water	7.6 – 8.5
6	Alkaline waters	8.6 – 9.5
7	Strong alkaline	9.5

The quantity of nitrates varieties and is higher on big rains as a result of N oxidation from air because of the electrical discharge in atmosphere.

N oxides from atmosphere are from natural and atrophic sources: the natural source is represented by the decompounds of the organic materials and electrical discharge in atmosphere by the formation of the different species like (N_2O, NO_2. *etc*.), that oxides rich in atmosphere and from anthrop sources like angens with internal burning and centrals.

Rain waters from Timisoara have high concentrations of nitrites and nitrates in limits of the III class of quality, fact that confirms the existence of pollution in atmosphere with N compounds.

Organic charge of water from rains exprimated in CCO – Mn presents values between 5.43 mgO_2/L – 8.56 mgO_2/ L, corresponding to the II quality class.

The purpose of the water resources management is rational use and stocking and use of meteoric waters.

For this purpose there is a technical possibility to retain waters from rains in reservors like under grown pools and then be used for different needs of humans, irrigations, and the excess can be filtered in soil to a ring in filtering.

CONCLUSIONS

Comparing all the values of the characteristics of quality from "*Normativul privind obiectivele de referință pentru clasificarea calității apelor de suprafață la Planul de Implementare a Directivei 76/464/CEE" and "directivele fiice*" about the pollution causated by certain dangerous substances discharged on water results:

- pH – of water is slightly acid;
- organic charge of water exprimated in CCO – Mn has the value of 8.56 mgO_2/L. value included in the II class of quality;
- salinitati and durity of water are included in the I class of quality;
- N from nitrates ($N - NO_2^-$) and nitrites ($N - NO_3^-$) corresponds to the III class of quality;

If water is an finite and vulnerable source that needs rules for establishing the human priorities then needs to respect environment protection and rational use of water resources. The communities should to aware of the obligation that they have concerning water resources. The objectives of a well administration of aquatic ecosystems referring to users requests, the optimization of aquatic resources use and a well knowledge of all the problems and their consequences on long or short therm of atrophic actions on environment.

REFERENCES

1. Adams.V. D. (2000). Water ∝Wastewater Examination Manual. Lewis Publishers
2. Blas W. R. (1992). River water Quality Ecological Assessment and Control. Belgia. 453
3. Burden F. R. (2002). Environmental Monitoring Handbook. McGraw-Hill. New York.
4. Burtică G., Pode R., Pode V., Vlaicu I. Negrea A., Micu D., (2000). Tehnologii de tratare a efluentilor reziduali. Editura Politehnica. Timisoara
5. Butnariu M. (2004). Chimie analitica si instrumentala. Ed. Orizonturi Universitare. Timisoara. I.S.B.N. 973 – 638 – 136 – 6
6. Butnariu M. (2007). Chimie analitica si analiza instrumentala – notiuni teoretice si practice. Editura Mirton. Timisoara, 35;
7. Butnariu M. Goian M. (2005). Metalele grele din solurile Banatului si biomonitorizarea lor. Ed. Orizonturi Universitare. Timisoara. I.S.B.N. 973 – 638 – 179 – X, Nature Science Collections
8. Chiarle. M. Ratto. M. (2000). Water Research. Vol.34. 2971–2978
9. Manahan S.E. (1986). Quantitative Chemical Analysis. Brooks / Cole Publishing Company. Monterey. California.
10. Năstase V., (1981). Poluarea unor surse de apa cu unele substante chimice. Rev. Med. Chem., No. 2. Iasi.
11. Ricci O., (1996). Techniques. Sciences. Methods, vol. 4. 249
12. Riedel E., (1994). Anorganische Chemie. – Auflage. Berlin – New York; de Gruyter

13. Schneider S.H., (1996). Water resources. In Encyclopaedia of Climate and Weather. Oxford University Press. New York. vol. 2
14. ***Infoterra. (1993). Metode de tratare a apei. Caiet de traduceri. Romania Water & Waste Treatment. Vol. 36. No. 11.30. 23.
15. ***Journal of environmental Engineering. (1997). 123. No. 4.
16. ***Legea calitatea apei potabile (2002). No.458/
17. ***Memento Technique de l'eau. (1989). Degremont. Lavoisir Tec – Doc. vol. 1.2. Paris.
18. ***Revista Agentiei de apa. (1990). Adour Garonne. No. 45. 29
19. ***Standarde. Norme. Legi si alte acte de reglementare privind protectia mediului
20. ***Techniques. Sciences. Methods. (1988). No. 4 and 9. 243 – 246
21. ***The Council of the European Communities water for human consumption. 80. 778. EEC. 183
22. ***Wasserwirtschaft (1996). 86. no.12
23. *** Water Frame Directive (2000)./60/EC

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.223.66:636.4.083.14
Izvorni znanstveni rad
Original scientific paper

INDOOR CLIMATE IN PIGSTIES WITHOUT LITTER AND WITH DEEP LITTER IN WINTER

O. SADA, B. REPPO

Institute of Technology, Estonian University of Life Sciences; Kreutzwaldi St. 56;
51014 Tartu, Estonia, e-mail: oliver.sada@emu.ee; boris.reppo@emu.ee

SUMMARY

Pig keeping on deep litter and without litter using liquid manure systems is becoming widely practiced in large reconstructed and newly built pigsties. As animal keeping technologies have an impact on the productivity of animals, service life of buildings and efficiency of tending performed, it is necessary to study working environment and indoor climate of pigsties. In order to find out the impact of outdoor climate and different methods of animal keeping on indoor climate during wintertime, the air temperature, relative humidity, air velocity and contents of oxygen, carbon dioxide and ammonia were measured on a daily basis at the height of 1.5 m above the pigsty floor and also at the height of 0.1, 0.5, 1.5 and 2.0 m above the places where pigs were tended (pens and tending passages) in pigsties with deep-litter (800 fattening pigs) and with liquid manure system (650 young pigs). Simultaneously, outdoor air temperature and relative humidity were measured. Data Logger equipment with relevant sensors and Gas Monitor Pac III were used for studying the parameters of indoor climate. HygroLog equipment was used for measuring the temperature and relative humidity of outdoor air. Measurement results were statistically processed by using computer programmes AMR Win Control, HW3 and MS Excel.

It turned out that the numerical values of indoor climate parameters of pigsties were affected by animals keeping methods and tending works performed. Outdoor climate had greater impact on indoor climate in a pigsty with insufficient insulation. The content of carbon dioxide in the air at the height of pigs in pig pens was 0.19% and the content of ammonia was 28-39 ppm, which was remarkably higher than standard limit. The content of ammonia measured in human working zone above the tendering passage exceeded standard limit. Daily measured mean ammonia content was lower in pigsty, where deep-litter keeping of animals was applied and higher in pigsty without litter, where floor heating was used. It appeared that heating of pigsty of fattening pigs needs to be more *efficient during winter in order to improve humidity parameters and ventilation of harmful gases during tendering.*

***Key words**: Working environment, temperature, relative humidity, oxygen, carbon dioxide, ammonia, air velocity, keeping technology, outdoor climate*

INTRODUCTION

The quality of human work environment and surroundings of pigs depends on indoor climate of pigsties. We need to know the resistance of humans and animals, applicable technologies, equipment and premises to indoor climate. The indoor climate of buildings for keeping animals is affected by various factors: applicable tending technology, systems for providing animals with forage, water and removal of manure and outdoor climate (Mothes, 1976; MWPS-33, 1989; Kender et al., 1998; Sada and Reppo, 2006).

Building of large pigsties with deep litter and without litter, which use liquid manure removal systems, has become a wide practice nowadays. Enlargement of pigsties is accompanied with problems regarding the achievement of the required indoor climate of the working environment (the increase of air humidity, contents of carbon dioxide and ammonia in winter, overheating of premises in summer, etc.) and problems on European level, such as the ethical production quality and assurance of acceptable odour in ambient air.

Research on pigsties has mostly been focused on the air temperature, relative humidity, air velocity and – to certain extent – gas composition (Mothes, 1976; Tuunanen and Karhunen, 1986; Karhunen, 1994), providing a basis for designing ventilation systems for relevant premises. Generally, such research has been carried out in small pigsties for up to 500 pigs and in customized laboratories (Tuunanen and Karhunen, 1986). Gas composition, its variation on a daily basis and its dependence on applicable animal-keeping methods and technologies have been studied to a lesser extent.

Due to extensive building of big deep-litter pigsties and pigsties without litter, which use liquid manure systems, it has become necessary to study indoor climate in pigsties. For the purpose of finding out the impact of winter outdoor climate and different pig-keeping methods on indoor climate of the building, the temperature, relative humidity and air velocity and contents of oxygen, carbon dioxide and ammonia were measured on daily basis in the pigsty and also in places where pigs were tended (pig pens, tending passage) in different air layers in deep-litter and liquid manure system pigsties. Parallel to observation of animal behaviour the pig-tender's activities were chronologically portrayed and outdoor air temperature and relative humidity were measured. Data Logger equipment with relevant sensors and computer programme AMR Win Control were used for studying indoor climate, content of ammonia was measured using Gas Monitor Pac III equipment and computer programme HW3, outdoor air temperature and relative humidity were measured with Rotronic Logger equipment.

MATERIAL AND METHODS

Indoor climate was studied in pigsties for 800 fattening pigs and 650 young pigs, which are hereinafter referred to as Pigsty A and Pigsty B (Table 1). Pigsties are standard-design buildings made of silicate bricks and reinforced concrete. Fattening pigs and young pigs were fed with dried fodder delivered by automatic conveyor from automatic feeders. Roxcell device was used both in Pigsty A and Pigsty B. In Pigsty A fattening pigs were kept on straw litter (ca 50 pigs per pen), where manure was removed with shovel-loader after replacing the fattening pigs in the pen. In Pigsty B liquid manure system was used, where manure from pens, with ca 20 young pigs each, was drained into a channel below the grated floor, leading to pump-room, where it was pumped to manure storage. Bite-type device were used as drinkers. Ventilation was regulated by automatic forced ventilation.

Table 1 Data on pigsties

Item	Pigsty A	Pigsty B
Number on pigs	800 fatlings (25-100 kg)	650 young pigs (15-50 kg)
Way on handling	Deep-litter	Liquid manure system
Ventilation	Compulsion ventilation	Compulsion ventilation
Air flow control	Automatically	Automatically
Heating	Missing	Floor water heating
Fodder delivery	Dry food automatic system Roxcell	Dry food automatic system Roxcell
Manure disposal	With tractor	Liquid manure, with flow for the pumping station
Drinkers	Bite-type	Bite-type
Litter	Straw	Missing

The methods of the study were based on the Health Protection Act TKNE-5/1995 of the Republic of Estonia (https://www.riigiteataja.ee...25048; Veinla, 1987) and Finnish advisory opinion (Karhunen, 1992; Tuunanen, 1986), according to which the numerical values of indoor climate parameters of work environment can be measured at the standard heights of 0.1 and 1.0 metres in case of animals in pigsty and at the height of 1.5 m in case of human workplace. In order to study daily changes in indoor climate of pigsties conditioned by outdoor climate, animal keeping technologies, technological processes performed, activities of the tender and animal behaviour; the air temperature, relative humidity, air velocity and contents of oxygen, carbon dioxide and ammonia were measured on a daily basis at the interval of 60 seconds at the height of 1.5 m from the floor of the pen in the centre of the pigsty in winter (27.01-4.02.2007). For the purpose of determining numerical values for indoor climate parameters in the air zones of humans and animals in upright position and animals in lying position, these parameters were measured at the heights of 0.1, 0.5, 1.5 and 2.0 m from the floor with the interval of 10 seconds during one minute each. Measurements were taken (29.01-4.02.2007) during tending works in the central part of pigsties within the entire cross-section of premises (in tending passages, pens) and diagonally at the ends of the pigsties. Indoor climate parameters were measured at 8 locations both in Pigsty A and in Pigsty B. Simultaneously outdoor air temperature and relative humidity were measured daily. ALMEMO Data Logger 8990-8 equipment with relevant sensors was used for studying the indoor climate.

Air temperature and relative humidity were measured with AMR-manufactured sensor FH646-1 with measurement area -20…+80°C (measuring accuracy 0.01°C) and 5...98% (measuring accuracy 0.1%). Oxygen sensor FY 9600-O_2 and ZA9000–AK2K were manufactured by AMR and their measurement area was 0-100% and measuring accuracy was 0.01%. Carbon dioxide content was measured with sensor FY A600-CO_2 with measurement area 0…2.5% and measuring accuracy 0.01%. Air velocity was measured using thermo-anemometer FHA645TH2 with measurement area 0...2.0 $m \cdot s^{-1}$ and resolution 0.001 $m \cdot s^{-1}$. Ammonia content was measured with Gas Monitor Pac III equipment manufactured by Dräger Safety AG &Co KGaA, its measurement area was 0...250 ppm and measuring accuracy 1 ppm. HygroLog device manufactured by Rotronic and HygroClip S sensor were used for measuring outdoor temperature and relative humidity (measurement area -40…+85°C and 0...100%, accuracy ±0.3°C and ±1.5%, respectively). Measurement results were analysed by using computer programmes AMR WinControl, Pac III Software 3.nn, HW3 (Dräger, 2001; AHLBORN, 2007). Statistical processing of the research data by using computer program AMR WinControl made possible to determine the min, max and mean values of indoor climatic parameters; standard deviation (s.d.) standard error of mean (s.e.) were determined by program MS Excel (Kiviste, 1999).

RESULTS AND DISCUSSION

Study results (Figures 1 and 3; Table 2) reveal that mean daily temperatures measured in the pigsties were 12.38 (s.d. 0.466) and 25.08°C (s.d. 0.485), whereas the outdoor temperature was 0.91 (s.d. 0.871) and 0.28°C (s.d. 0.289) respectively (Figure 2, Table 2).

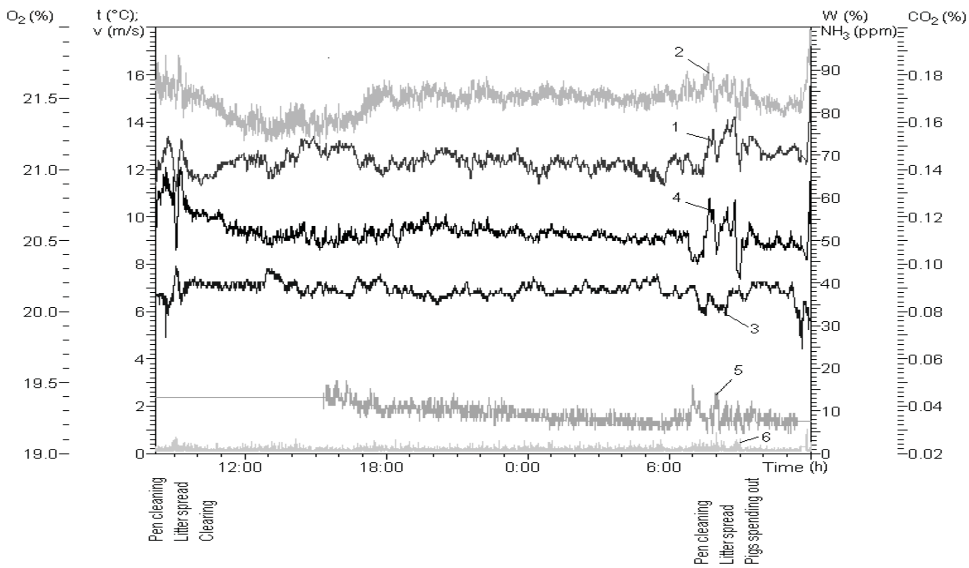


Figure 1 Daily change of numerical values of indoor climate parameters in Pigsty A: 1– temperature, 2–relative humidity, 3–oxygen, 4–carbon dioxide, 5–ammonia, 6–air velocity

Mean relative humidity in pigsties was 82.63 (s.d. 3.145) and 88.42% (s.d. 4.817) respectively, which exceeded recommended limits during 24 hours in Pigsty A and Pigsty B (Figures 1 and 3; Table 2). Air humidity was somewhat lower in the afternoon before tending works in Pigsty A with higher temperature of outdoor air (Figure 2). Relative air humidity in Pigsty B increased during tending works (Figure 3) despite higher outdoor temperature and lower humidity.

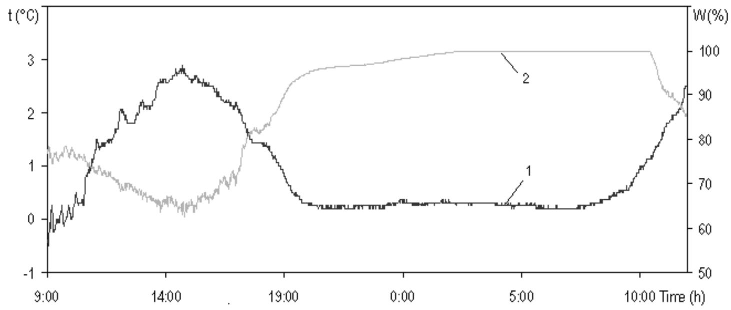


Figure 2 Daily changes in outdoor temperature (1) and relative humidity (2) near Pigsty A.

Table 2 Indoor and outdoor climate parameter values of pigsties

Measured parameters	Min	Max	Mean	*s.d.*	*s.e.*
		Pigsty A			
Temperature, t (°C)	11.10	14.20	12.38	0.466	0.008
Relative humidity W (%)	72.8	93.4	82.63	3.145	0.038
Oxygen O_2 (%)	19.80	20.32	20.15	0.051	0.001
Carbon dioxide CO_2 (%)	0.09	0.14	0.11	0.005	0.0001
Ammonia NH_3 (ppm)	4.0	17.0	8.89	2.083	0.024
Air velocity v (m/s)	0.082	0.927	0.15	0.057	0.001
Outdoor temperature t_1 (°C)	-0.4	2.9	0.91	0.871	0.021
Outdoor relative humidity W_1 (%)	76.9	100.0	88.45	13.049	0.321
		Pigsty B			
Temperature, t (°C)	24.20	26.10	25.08	0.485	0.013
Relative humidity W (%)	79.8	98.7	88.42	4.817	0.126
Oxygen O_2 (%)	17.48	20.00	18.75	0.832	0.022
Carbon dioxide CO_2 (%)	0.15	0.29	0.19	0.028	0.001
Ammonia NH_3 (ppm)	12.0	32.0	18.07	2.698	0.031
Air velocity v (m/s)	0.102	0.238	0.12	0.010	0.0003
Outdoor temperature t_1 (°C)	-0.4	0.9	0.28	0.289	0.007
Outdoor relative humidity W_1 (%)	79.4	96.1	88.28	3.833	0.097

Mean content of carbon dioxide in the air of pigsties was 0.11 (s.d. 0.005) and 0.19% (s.d. 0.028), respectively. During tending works and due to excitement of pigs the content of carbon dioxide in the air increased to 0.29% in Pigsty B (Table 2; Figure 3), which was higher than recommended (CIGRI, 1984; Liiske, 2002). The content of oxygen in the indoor air diminished when the animals were awake and breathed more actively (Figure 3).

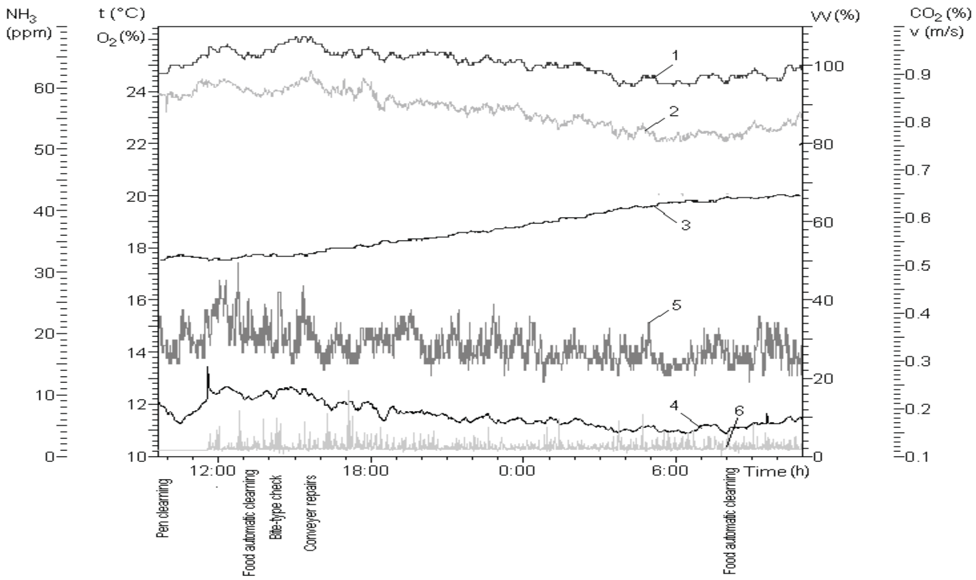


Figure 3 Daily change of numerical values of indoor climate parameters in Pigsty B: 1–temperature, 2–relative humidity, 3–oxygen, 4–carbon dioxide, 5–ammonia, 6–air velocity.

Mean ammonia content measured in the pigsties was 8.89 (s.d. 2.083) and 18.07 ppm (s.d. 2.698) (Table 2), thus in the allowed limits (20 ppm) set out in standards (http://www.riigiteataja.ee...73153).

It was discovered, that in pigsties the formation of air temperature, the concentrations of relative humidity and gases differs in different air zones (altitudes) of keeping pigs and tending places. Figures 4 and 5 give the mean numerical values of indoor climatic parameters obtained both in Pigsty A and B as a result of measurements in four pig pens and in four tending passages at different altitudes.

The indoor climate quality of the pig keeping environment and its influence upon the productivity of pigs has been studied in laboratories (climatic chambers) with limited number of pigs or in real operating pigsties, which is more complicated due to the multitude of different factors. As large pigsties have been operated, where the pigs are kept on deep litter in unheated premises or in pigsties with heated floors, using liquid manure system, the present study envisaged its goal in investigating the correspondence of the numerical values of indoor climate parameters of these pigsties to the pig-keeping standard norms in winter. The mean numerical values of daily parameters are dealt with. The pigs' daily gain (meat-forming) is a steady process independent of hourly climate fluctuations, which conditions can be restored round the clock.

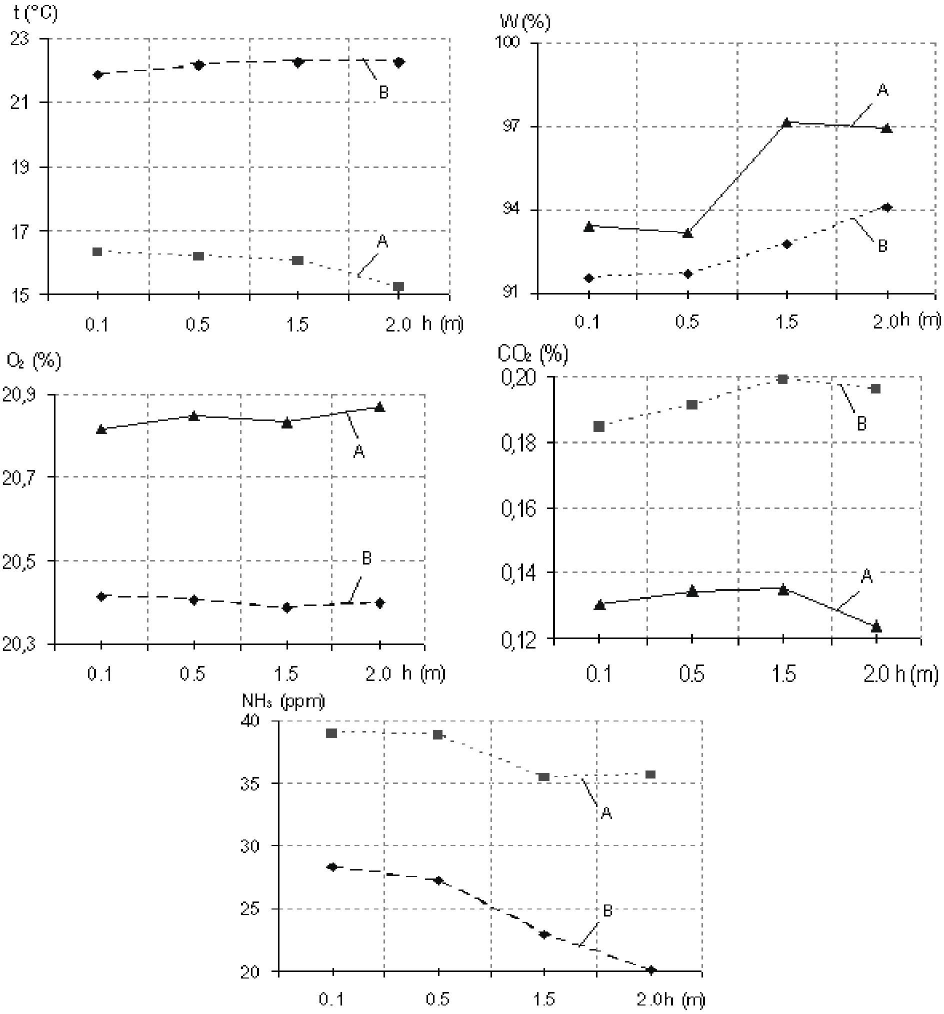


Figure 4 Mean numerical values of the indoor climate parameters in Pigsties A and B measured in pens in different heights of air zones

Also the formation of such indoor climate parameters as temperature, relative humidity and gas content in different air zones (altitudes) by pig-keeping and in human workplaces was of interest. Indoor air temperature, relative humidity and ammonia content were major parameters affecting the indoor climate of animal-keeping premises (MWPS, 1989; Kender et al., 1998; Reppo et al., 2003). Recommended minimum indoor air temperature for fattening pigs and young pigs was 7-15°C, maximum temperature 25-27°C and optimal temperature 15-22°C depending on the age and live weight of animal. The daily temperature variation in pigsties should not exceed 2-3°C (CIGR, 1984; Rosti, 1988; Maatalouden…, 1990; Tuuna-nen and Karhunen, 1984). Recommended relative humidity was between 60-80%, also 60-

85% (Brent, 1991), but should not exceed 85%, because in that case other indicators of microclimate have also deteriorated (Veinla, 1987). Excess moisture generated drip water, mould and fungi at the structures of the building. Low air humidity content (less than 55%) can cause drying of oral mucous membrane of animals and generate dust in the premises (Mothes, 1976; Veinla, 1987).

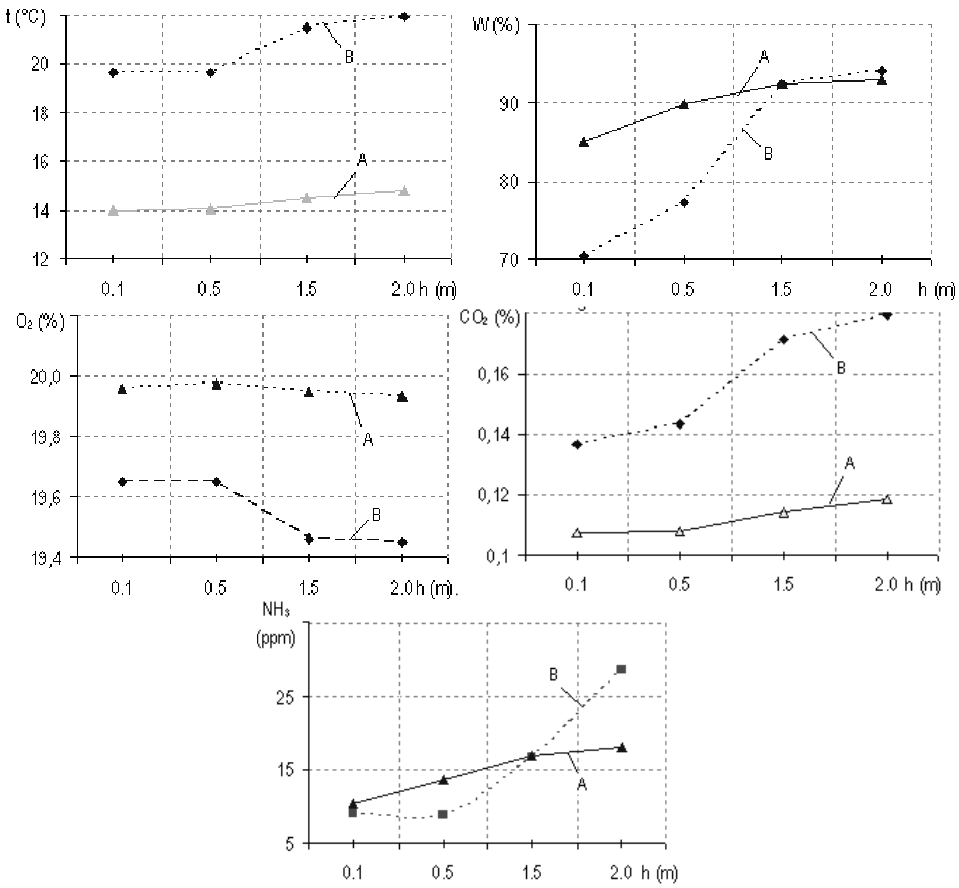


Figure 5 Mean numerical values of the indoor climate parameters in Pigsties A and B measured in tending passages in different heights of air zones.

In case of low outdoor temperature measured at Pigsty A -0.4-(+2.9)°C the indoor temperature was between 11.1-14.2°C during 24 hours, which still remained in lower limits of the norms for fattening pigs (Maatalouden…, 1990). The lower the air temperature (as compared to optimal temperature) the worse the fattening or growth results (CIGR, 1984; Liiske, 2002). In order to prevent such deterioration the pigsty needs to be heated.

Daily measurements of indoor climate in winter revealed that indoor air temperature was more homogeneous and higher in Pigsty B with better insulation of walls and ceilings, well-functioning ventilation system, floor heating and manure removal via drainage channel (Figure 3). The mean relative air humidity in pigsties was 82.63 and 88.42%, exceeding the recommended norms (Figure 1 and 3, Table 2).

From the investigation of Pigsty A indoor climate it is obvious (Figures 1 and 2) that the influence of outdoor temperature and relative humidity on the indoor climate is considerable. Animal respiration and the processes occurring on the surface of manure cause the generation of carbon dioxide and ammonia, which are considered harmful gases (Rosti, 1988). The sources of reference and standards provide different information concerning the concentration limits of carbon dioxide. According to German researcher Mothes (1976) the maximum allowed concentration of carbon dioxide is 0.35% in the air zone of animals and 0.50% in human work zone, whereas pursuant to Finnish data (Maatalouden..., 1990) human evaluation of air deteriorates already in case of concentration of 0.1% and ventilation is necessary in case of 0.25%. Pursuant to the occupational health and safety requirements the carbon dioxide content of 0.50% is considered harmful for human (Seppänen O and Seppänen M, 1998). Pursuant to the standards applicable in the Republic of Estonia (http://riigiteataja...73153, 2002) the content of carbon dioxide allowed in the air of human environment is up to 0.50%.

Daily measurement showed that the carbon dioxide mean concentration in the pigsties air was 0.11 and 0.19%, increasing during tending works in Pigsty A to 0.14 % and in Pigsty B to 0.29%, corresponded by simultaneous decrease of air oxygen (Figures 1 and 3). According to Jürgenson (1949) in winter we have to cope with the carbon dioxide concentration higher than 0.17%, but if possible, it should be lower than 0.17%.

The information also varies in case of the highest concentration of ammonia in the air. Allowed concentration of ammonia in the air is up to 20 ppm in the European Union (CIGR, 1984). Estonian standards (http://riigiteataja.ee...73153, 2002) and authors (Tuunanen and Karhunen, 1984) refer to 20 and 25 ppm as the allowed average standard limit in the air inhaled in human working zone. The data provided by several authors (Mothes, 1976; Einberg, 2001; Pals et al., 2003) reveal that the air emission of ammonia in the premises used for animal keeping depends on the handling of manure, air temperature and relative humidity. It was observed that the emission of ammonia from the manure was higher in the case of high temperature and high relative humidity of the indoor air.

The study also revealed, that due to higher indoor temperature in Pigsty B the daily average ammonia content (18.1 ppm) was higher than in Pigsty A (8.9 ppm), but due to proper ventilation (average air velocity 0.12 and 0.15 $m \cdot s^{-1}$ respectively) virtually remained within the allowed standard limits (Table 2).

During tending works when the pigs were awake, moving around, treading the manure and carrying it around, the air emission of ammonia increased. Therefore it is necessary to increase ventilation in pigsties during tending works, especially when cleaning the pig pens.

While the indoor climate daily mean numerical values (excl. relative humidity) of the pigsties were practically within the norms (Table 2), then the measured values obtained in pig pens and tending passages (at the tender's working zone) at different altitude levels showed variations from the daily mean, the values of relative humidity and ammonia content actually exceeded the recommended values (Figures 4 and 5).

The study of indoor climate parameters in pig pens (Figure 4) revealed that in Pigsty A the temperature was higher at the surface of deep-litter when measured at the height of pigs (+16.4°C) than at the height of 2.0 m (+15.2°C). In Pigsty B, where young pigs were kept on water-heated concrete floor, the indoor air temperature fluctuations in different height zones were smaller. The carbon dioxide concentrations (0.13 and 0.19%) in both pigsties at the height of pigs were within the norms. As the pigs were awake (as also during the tending work), it caused considerable relative humidity and the carbon dioxide together with steam evaporated, thus affecting the oxygen content in the air upper layers of the room (Figure 4).

The research confirms that ammonia emission is dependent on the relative humidity of the work area, with the rise in the relative humidity percentage the ammonia content in the air also increases. It was observed (Einberg, 2001), that ammonia emission was rather high at dungy surfaces, especially high at the surface of liquid manure. It is maintained (Karhunen, 1992), that the ammonia content is higher in the air layers under the pigsty ceiling. Our research proves that the ammonia content is higher in the lower air layers because of the vicinity of origination. High ammonia content was measured in lower air layers in pig pens in Pigsty A, yielding a mean of 39.0 ppm at the height of 0.1 m (Figure 4). Partial transfer of drinking water to the rest area and insufficient straw supply caused an increase in relative humidity and air emission of ammonia. As the density of ammonia (0.7714 kg/m^3) makes it lighter than air (1.2928 kg/m^3), it goes up, but is well-soluble in water vapours by neutral reaction and is reduced in higher air layers (Mothes, 1976).

It appeared that the air temperature measured in tending passages was higher in Pigsty B, controlled by the water-heated concrete floor (Figure 4).

Higher air layers of tending passage in Pigsty B also showed higher content of carbon dioxide, thus removing oxygen from these layers, whereas the air temperature and contents of carbon dioxide and oxygen remained within standard limits. At the same time at the height of 1.5-2.0 m and high percentage of relative humidity the content of ammonia in the air was non-permissibly high (30 ppm), indicating the need to reconsider ventilation.

CONCLUSIONS

In the course of the study, in winter the indoor air temperature, relative humidity and air velocity, contents of oxygen, carbon dioxide and ammonia were measured during 24 hours at the height of 1.5 m above the pig pens and also in the pig pens and tending passages at the heights of 0.1, 0.5, 1.5 and 2.0 m in pigsties with deep litter and liquid manure removal system. Data Logger equipment, relevant sensors and computer programme AMR WinControl, Pac III Software 3.nn, HW3 were used for the study. In addition to the research of the indoor climate, simultaneously the outdoor air temperature and relative humidity measurements were also taken at the pigsties.

It turned out that the numerical values of the indoor climate parameters of pigsties were affected by the methods of animal keeping and tending works. Outdoor climate had greater impact on indoor climate in a pigsty with insufficient insulation. Mean outdoor temperatures were between 0.91 and 0.28°C. Mean air temperatures in pigsties were 12.38 and 25.08°C, thus remaining within the limits allowed for keeping animals. Measured relative humidity, 82.63 and 88.42%, exceeded recommended values. Air temperature was lower in a deep-litter pigsty, which was less insulated and more ventilated ($0.15\ m \cdot s^{-1}$). According to the study results the temperature measured at the height of animals in pigsties for fattening pigs and young pigs was 16.2-16.4 and 21.9-22.2°C, respectively.

Daily mean carbon dioxide contents in pigsties were 0.11 and 0.19%, but increased to 0.29% during tending works in Pigsty B with liquid manure system. Mean measured ammonia contents in pigsties were 8.89 ppm and 18.07 ppm, but increased to 32 ppm in Pigsty B during cleaning and tending works. Measurements at different altitudes in pig pens and tending passages revealed their difference from pigsties' daily mean and, in case of air relative humidity and ammonia content, exceeded the recommended values. It appeared that in order to improve the humidity conditions and gas composition of air in pigsties, more efficient ventilation is required in winter.

REFERENCES

1. AHLBORN. Issue 2007/2008. Product Catalog. Measuring instruments and sensors.
2. Brent G. (1991). Housing the pig. Farming Press, UK.
3. CIGR (1984). Report of working group on climatization of animal houses. SFBIV, Aberdeen.
4. Dräger Safety AG & Co KGaA, July 2001, 2nd edition. Lübeck.
5. Einberg G. (2001). Ventilation and the stable climate – a factor of animal wellbeing and production. Thesis for Licentiate of Engineering, Stockholm.
6. http://www.riigiteataja.ee/ert/act.jsp?id=73153, (2002). Töökeskkonna keemiliste ohutegurite piirnormid, eRT.
7. https://www.riigiteataja.ee/ert/act.jsp?id=25048, (1995). Tööruumide mikrokliima tervisekaitsenormid ja -eeskirjad TKNE, 5.
8. Jürgenson L. (1949). Lauda soojamajandus ja õhustus. RK Teaduslik Kirjastus, Tartu.
9. Karhunen J. (1992). Kaasut ja pöly elainsuojiea imanvaihdoissa. Vakolan Tiedote, 52. Painorateri OY.
10. Karhunen J. (1994). Itkupinta-tuloilmalaitteen vaikutus eläinsuojassa. Agricultural research centre of Finland. Vakolan Tiedote*,* 52/92, Vakola.
11. Kender T., Arulepp M., Veermäe I. (1998). Measurement of ammonia concentrations in the air of livestock building with the aid of ammonium selective electrochemical sensor. Transactions of the Estonian Academic Agricultural Society, **7**: 35-38.
12. Kiviste A. (1999). Matemaatiline statistika MS Excel keskkonnas. GT Tarkvara OÜ, Tallinn, Estonia.
13. Liiske M. (2002). Mikrokliimaseadmed. EPMÜ, Tartu, Estonia.
14. Maatalouden tuotantorakennusten ilmastointi ja lämmitys. (1990). Neste Air-IX Espoo.
15. Mothes E. (1976). Stallklima. Leistungsfaktor der Tierproduktion. Kolos, Moskva.
16. MWPS-33 (1989). Naturalventilating Systems for Livestock Housing. First Editions. Midwest Plan Service.

17. Pals A. (2003). Loomapidamistehnoloogiate mõju lehmalauda sisekliimale. Magistriväitekiri, Tartu.

18. Reppo B., Mikson E., Pajumägi A., Miljan J. (2003). Indoor climate of uninsulated cowsheds during wintertime. The 31st International symposium, Actual tasks on agricultural engineering, pp. 307-316, Opatija.

19. Rosti S. (1988). Sianhoito. Mäntan Kirjapaino OY, Helsinki.

20. Sada O., Reppo B. (2006). Handling technologies impact on the pigsty quality. Proceedings 5th International Scientific Conference Engineering for rural development, pp. 114-119. Jelgava.

21. Seppänen O., Seppänen M. (1998). Hoone sisekliima kujundamine. Koolibri, Tallinn.

22. Tuunanen J., Karhunen J. (1984). Dimensioning of ventilation in animal houses. Scientific report of Vakola 39, Vihti.

23. Tuunanen J., Karhunen J. (1986). Fan powered extraction and natural ventilation in animal houses. Scientific report of Vakola 44, Vihti.

24. Veinla V. (1987). Farmide mehhaniseerimine. Valgus, Tallinn.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 637.116
Stručni rad
Expert paper

ANALYSIS OF MOST FREQUENT ERRORS DURING THE INTRODUCTION OF MILKING ROBOT IN SLOVENIA

D. STAJNKO, M. LAKOTA, B. MURŠEC, P. VINDIŠ

University of Maribor, Faculty of Agriculture and Life Sciences, Vrbanska 30, 2000 Maribor, Slovenija, e-mail: denis.stajnko@uni-mb.si

ABSTRACT

In the present work, errors occurred when milking by the "Delaval VMS" robot, were studied on the cattle herd of 60 milk cows in Dravograd, Slovenia. Before the observation ten cows were selected from database that were most often noted by the computer as incompletely milked. As reported by control milk computer three most important reasons for incomplete milking were: the cow is restless and it is kicking, an udder for milking was not found and unexpectedly low milkiness.

At the beginning of the observation on January 30, 2008, nine cows were still incompletely milked, for which the kicking was the reason for three cows, inability to find an udder with four cows, and unexpectedly low milkiness with two cows. One cow was fully milked.

After manual setting of udder positions, five cows were still incompletely milked at the end of second observation on February 15, 2008. The unrest and kicking were the reasons with two cows, inability to find an udder with tree cows. Five cows were fully milked.

In the last observation on May 30, 2008, after replacement of the camera lens mounted on the robotic arm, eight cows was fully milked and two cows were again incompletely milked due to inability to find an udder. Statistical analysis of multiple observations showed that the reason for incomplete milking was damaged lens of the camera mounted on the robotic arm, due to the hard water being used for washing out the equipment. Unfortunately, two cows could not adapt to the robot milking and had to be culling out.

Keywords: *robot, cow, milking, error, quality*

INTRODUCTION

The ideas about fully automating the milking process were generated in the mid seventies due to the growing costs of labor. Rossing et al. (1985) concluded it was possible to milk the cows in a concentrate feeder, which was the first step towards the milking robot. The second was the development of automatic cluster removers. Further on in the early eighties, automation in milking parlours was expanded with the development of milk yield recording equipment and sensors to detect udder health problems. The final step in the automation development seemed to be the development of automatic teat cup attachment systems, which led to a fully automated automatic milking system (AM-system).

However, it took almost a decade to convert the techniques for locating teats and attaching teat cups to fully integrated and reliable automatic milking systems. The first milking robots were installed on commercial dairy farms in the Netherlands in 1992. The breakthrough of automatic milking came at the end of the nineties.

An AM-system consists of six main modules: milking stall, teat detection system, robotic arm device for attaching the teat cups, teat cleaning system, control system including sensors and software.

Changing over from a milking parlour to automatic milking usually lead to big changes for both herdsman and cow and can cause stress to both. With automatic milking, the milking process does not require permanent supervision anymore. However, this does not mean that the hours spend on traditional milking will be spared. New labor tasks arise with the implementation of automatic milking in the farm; control and cleaning of the AM-system, twice or three times a day checking of attention lists including visual control of the cows and fetching cows that exceeded maximum milking intervals. On average a 10% reduction in total labor demand is reported compared with the conventional milking system with twice milkings per day (De Koning, 2001). The biggest change however, is the change in the character of the labor. Instead of mainly handwork during milking, the herdsman has to check several times per day attention lists from the computer of the AM-system.

The impact on the cows also, can be big. The AM-system might not be suitable for all cows, because of udder shape and teat position or behavior. Nevertheless, the culling rate of cows, because they are not suitable for automatic milking, is estimated to be less than 5-10%. More important is the introduction period, cows should be handled quietly and consistent, to learn them to adapt themselves to the new surrounding and milking system. For this reason all AM-systems are equipped with concentrate dispensers. In the transition from conventional to automatic milking, cows have to learn to visit the AM-system at other times than before. Special attention is needed and in the first weeks, human assistance will be necessary.

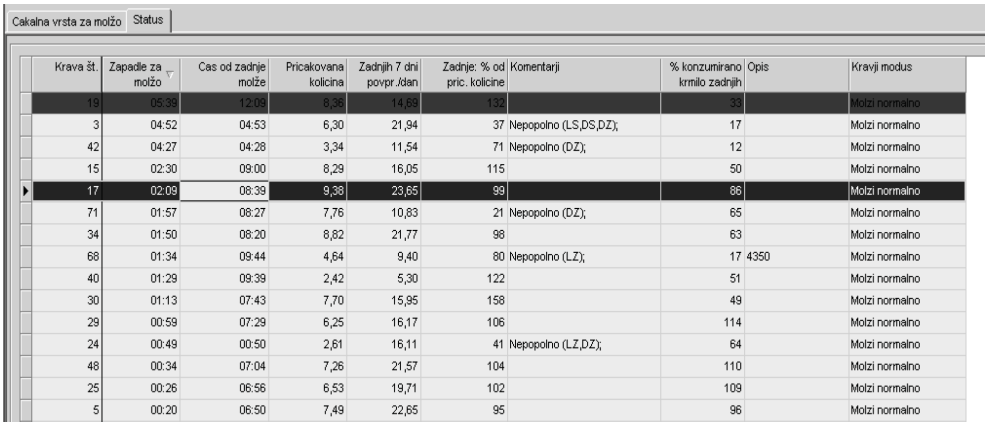
METHODS

Experiment features

In September 2006 the automatic milking system "Delaval VMS" was introduced on the farm Klančnik, Dravograd, as the forth one in Slovenia. The herd consisted of 60 Holstein-

Frisien cows, which were already milked in the fish-bone parlour system. In the first four months after the installation the herd and the owner had to learn, how to use the new system. However, one year after the introduction of AM ten cows were still steadily reported to be incompletely milked.

After analyzed the computers reports on January 30, 2008 (Figure 1) the following was stated: three cows were incompletely milked because of kicking, inability to find an udder was found with four cows, unexpectedly low milkiness with two cows and one cow was already reported as properly milked.


Cakalna vrsta za molžo | Status

Krava št.	Zapadle za molžo	Cas od zadnje molže	Pricakovana kolicina	Zadnjih 7 dni povpr./dan	Zadnje: % od pric. kolicine	Komentarji	% konzumirano krmilo zadnjih	Opis	Kravji modus
19	05:39	12:09	8,36	14,69	132		33		Molzi normalno
3	04:52	04:53	6,30	21,94	37	Nepopolno (LS,DS,DZ);	17		Molzi normalno
42	04:27	04:28	3,34	11,54	71	Nepopolno (DZ);	12		Molzi normalno
15	02:30	09:00	8,29	16,05	115		50		Molzi normalno
17	02:09	08:39	9,38	23,65	99		86		Molzi normalno
71	01:57	08:27	7,76	10,83	21	Nepopolno (DZ);	65		Molzi normalno
34	01:50	08:20	8,82	21,77	98		63		Molzi normalno
68	01:34	09:44	4,64	9,40	80	Nepopolno (LZ);	17	4350	Molzi normalno
40	01:29	09:39	2,42	5,30	122		51		Molzi normalno
30	01:13	07:43	7,70	15,95	158		49		Molzi normalno
29	00:59	07:29	6,25	16,17	106		114		Molzi normalno
24	00:49	00:50	2,61	16,11	41	Nepopolno (LZ,DZ);	64		Molzi normalno
48	00:34	07:04	7,26	21,57	104		110		Molzi normalno
25	00:26	06:56	6,53	19,71	102		109		Molzi normalno
5	00:20	06:50	7,49	22,65	95		96		Molzi normalno

Figure 1 The computer front panel with the milking status of each cow
('Nepopolno' - incompletely milked cow)

Since the milking robot continuously reported the same unmilked teats of particular cow, it was suggested to adjust the robot hand on each of four teats for all nine cows and started monitoring the milking process in the first observing term till February 1, 2008. It was assumed that the reasons for errors would be detected visually by researchers during the automatic milking of selected cows.

However, due to the unsatisfied results of milking after next four days, the robot hand was adjusted for the second time on February 5. From those settings till February 15, each cow was watched at least 10 times during the milking procedure, so the results of the computer reports can be compared accurately.

The results of testing at the end of this particular period did not satisfied the farmer neither the researching team again, thus additional causes for mistakes during milking were looking for. After consulting the Delaval service team, the substitute camera lens (Figure 2) was mounted on the robotic arm due to the obscure of visibility caused by the calcium in the hard water. The second probe period began on March 28 and lasted till May 28, 2008.

For monitoring the above described parameters a kind of interview data sheet was created in which all the actions were written and later compared with the computer data in a statistical analysis of multiple observations by the SPSS 14.0 software.

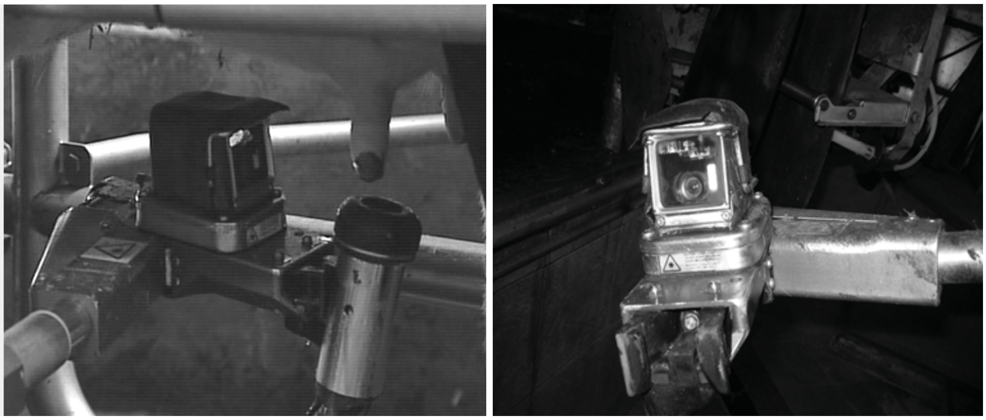


Figure 2 A camera lenses at the robotic arm

RESULTS

The initial computer data base for ten cows that were incompletely milked is presented in Table 1. As my be seen on January 30, for three cows kicking was the reason for being reported as unmilked, inability to find an udder with four cows, and unexpectedly low milkiness with two cows. One cow was fully milked. The first results of the new position of new robot hand could be seen already in the following days, since another two cows were reported as completely milked.

The results of the second observations are written in the Table 2. As may be seen on February 15, after settings the udder positions manually for the second time, five cows were fully milked. Another half of the group was still incompletely milked.

Table 1 First observation of the herd

Date	Kicking	Udder not found	Unexpected low milkiness	Completely
January 30 2008	3	4	2	1
January 31 2008	3	4	0	2
February 1 2008	4	3	0	3

The unrest and kicking were the reasons with two cows, inability to find an udder with three cows, while no cow was reported as unexpectedly low milkiness. It is known and obviously detected in the experiment that the position of udder and afterward the teats was changing significantly during the lactation of the selected cows, thus a farmer should check out those particular cows and adjust the robot hand frequently as was the case prior the experiment.

Table 2 The second observation after adjustment of robot hand

Date	Kicking	Udder not found	Unexpected low milkiness	Completely
February 5 2008	2	2	1	5
February 11 2008	3	2	1	4
February 15 2008	2	3	0	5

The results of the last observation series, after replacement of the camera lens mounted on the robotic arm, are presented in the Table 3. On May 30 only two cows were again incompletely milked, while the other eight was reported to be fully milked. The unrest and kicking together with inability to find an udder were the reasons which appear in the last observing period most frequently. Additional precise analysis of the computer reports clearly showed, that the same cows were steadily unrest and therefore the robot hand was unable to find the teats also after several attempts. Therefore, it was concluded at the last day of the third period that those two animals would have to be cull out from the herd. Whenever compared with other 58 cows, the culling rate of the cows in this particular herd is 3.3%, which corresponds quite well with the reports of De Koning (2001)

Table 3 Results of the third observation after replacement of camera lens on the robot hand

Date	Kicking	Udder not found	Unexpected low milkiness	Completely
May 26 2008	1	1	1	7
May 28 2008	2	1	0	7
May 30 2008	0	2	0	8

CONCLUSSIONS

The six month lasting observation on the milk farm 'Klančnik', Slovenia, showed that the introduction of automating milking with robot is a long lasting process, since it took almost one and a half year to figure out and fixed the main reason for unmilked cows. The farmer and the herd faced the same problem in our country as previously reported from the Netherlands experiences. It was proved that the robot milking system was not suitable for all cows, because of the udder shape and teat position or in most cases bad unrest behavior. Although a precise adjustment of the robot hand solved the majority of cows being reported as incompletely milked, there were still animals, which could not survive the new technology. The bed tempered character were the main reason for two cows of the particular farm to be cull out from the herd.

ACKNOWLEDGMENT

The authors are gratefully acknowledged to the family Kogelnik, the owners of the milking farm 'Klančnik' for friendly hospitability and patience during all the experiment period.

The authors also acknowledge the vital contributions made by Milena Hartman, B.S. student at the Faculty of Agriculture and Life Sciences in Maribor.

REFERENCES

1. Koning, C. de, (2001) Automatic milking; chances and challenges: in: A.Rosati, S. Mihina, C. Mosconi (editors), Physiological and Technical Aspects of Machine Milking, pp 131-140, ICAR TS 7, Rome, Italy
2. Rossing, W, A.H. Ipema and P.F. Veltman (1985). The feasibility of milking in a feeding box. IMAG Research Report 85-2, Wageningen, The Netherlands.

ANALIZA NAJČEŠĆIH POGREŠKA PRILIKOM UVOĐENJA AUTOMATSKE MUŽNJE ROBOTOM U SLOVENIJI

SAŽETAK

U priloženom radu na primjeru mliječne farme sa 60 krava muzara kod Dravograda (Slovenija) izložene su najčešće greške koje su se pojavile tijekom uvođenja robota "Delaval VMS". Nakon polugodišnjeg uhodavanja stada i samog vlasnika u sustav robotske mužnje, iz kompjuterske baze podataka odabrano je 10 krava koje su stalno bilježene kao nepotpuno pomuzene. Najčešća tri razloga za pogreške tijekom mužnje bila su: nemirna krava- skače, vime nije pronađeno, neočekivano niska mliječnost. Na početku našeg pokusa 30. siječnja, 2008., od deset krava jedna je bila potpuno pomuzena, dok je devet krava bilo javljano kao nepotpuno pomuzenih od čega; 3 krave zbog nemira i skakanja, 4 zbog nemogućnosti pronalaženja vimena, 2 zbog neočekivano niske mliječnosti.

Na kraju drugog perioda promatranja 15. veljače 2008., nakon ručnog podešavanja pozicije vimena kod svake od deset krava, pet ih je bilo potpuno pomuzenih dok je za ostalih pet ponovo javljano da su nepotpuno pomuzene; od čega su bile 2 nemirne ili su skakale, kod 3 robotska ruka nije našla vime, a kod jedne je bila neočekivano niska mliječnost.

Tridesetog svibnja završava drugo razdoblje promatranja mužnje nakon što se promijenilo staklo leće na kameri robotske ruke. Osam krava je potpuno pomuzeno dok se kod dvije još uvijek javlja problem zbog nepronalaženja vimena koje je zapravo posljedica nemira i skakanja tijekom mužnje. Statistička analiza događaja pokazala je kako je glavni razlog pogreški na farmi krava 'Klančnik' zapravo bilo zaprljano staklo leće robotske ruke koju je prouzrokovala vrlo tvrda voda kojom se pere robot nakon svake mužnje. Nažalost dvije krave nikako se nisu naučile novoj tehnologiji pa su nakon završetka laktacije izdvojene iz stada.

***Ključne riječi**: robot, krava, mužnja, pogreške, kvaliteta*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 636.2.06
Prethodno priopćenje
Preliminary communication

CALCULATION OF CATTLE BODY MASS ON THE BASIS OF ALOMETRIC MEASUREMENTS

M. BRUS, M. JANŽEKOVIČ, D. STAJNKO

University of Maribor, Faculty of Agriculture, Vrbanska 30, 2000 Maribor, Slovenia
e-mail: marjan.janzekovic@uni-mb.si

ABSTRACT

For establishing the body mass of living animals it is possible to use various mechanical and digital weighing devices. An alternative possibility was researched by using measuring implements. We were testing over 30 fattened animals. During experiment the bulls were weighed by electronic weighing device EC 2000. The trunk length (d) and the chest size (o) were measured simultaneously. The body mass (T) was calculated according to the equation: $T = o \times d / 50$. It was found out that the body mass of 240 - 290 kg calves was established with the accuracy between 0.44 kg and 2 kg by calculating on the basis of measurements without the weighing device. The results showed that the calculation is very accurate with certain body mass, when the animal's frame is of rectangular shape and the body structure in the front and the rear part is almost equally deep. The measurements of the chest size were not precise enough in all development stages. Therefore also the trunk size in the middle of the body and the size in the rear part should be included into the equation for increasing the reliability of the estimates. Introduction of those new points of measurements will improve the accuracy of calculation of the body mass also for the animals which phonotypical feature is in cylindrical shape during the period of growth.

Key words: *cattle, weighing, body dimensions*

INTRODUCTION

The body frame, size and length are in positive relation to intensity and capacity of meat production. Only the animals with sufficient body frame and with well muscled top - quality body parts can be successfully fattened to high body mass. With frequent establishing of the body mass the raisers can follow up the development of the animals, particularly the growth of young animals. The most reliable information about the body mass of cattle can be obtained by weighing the animals. Frequently, however, the raisers do not have available the weighing devices. For this reason, they can resort to approximate establishing of the body mass on the basis of the animal's chest size. However, the information acquired is less accurate than the one obtained by weighing. The differences are affected by the breed type, satiety of the animal, manner of feeding and even tightness of the tape during measuring [9, 10].

The tabular values were prepared on the basis of more than 50 years of practice and experience of the German-Austrian schools of agriculture for establishing the body mass without the weighing device. The data in tables are valid, if the cattle is normally raised. If the animals are measured before the transport, they may have lost 4 - 5 % of the body mass [7, 11].

The chest size as a basis for the determination of the body mass of living cattle is increased close behind the shoulder-bones. During measuring the animal must stand with the legs placed parallel and the head should be kept normally. After the measurement has been taken, the body mass is read according to the table. It is taken into account that the determination of the body mass on the basis of the chest size is only approximate.

The body mass is one of highly important indicators of the development of the young animal, therefore it is very important to follow it up. Accurate data on the body mass are obtained by weighing with the use of various weighing devices, such as the spring ordinary weighing devices or more modern electronic weighing devices. In our researches the electronic weighing device EC 2000 produced by the maker Tru-test was used [1]. Since the animals cannot be often weighed, the individual body parts are measured alternatively. Usually, measuring of the chest size suffices. However, as much as the calves deviate from the optimal body development, the establishing of the body mass deviates. In order to calculate the body mass more accurately, it is necessary to consider also the trunk length in addition to the chest size. To increase the accuracy of calculation of the body mass, it is appropriate to complete the formula by covering in the measurements also the size of the middle and rear part, since, thus, the back width is considered [2].

In our research the calculation of the body mass of young fattened bulls the measuring tape, the Lydtin's rod and the electronic weighing device were used. On the basis of measurements of the trunk length and chest size the body mass was calculated and the accuracy of the calculation in individual stages of weighing was analyzed.

Accuracy of the body mass measurements based only on the chest size measurement has proved to be insufficient, since the deviations between the weighed mass and the calculated mass were too high. Therefore, our primary aim was to reach the accuracy of calculation of the body mass of fattened animals on the basis of the measurements of the body length and chest size in comparison with the results of simultaneous weighing of animals on the electronic weighing device EC 2000.

MATERIAL AND METHODS

In the years 2004 and 2005 a group of 30 young bulls was studied. On the first weighing the young bulls were moved from the quarantine barn into the barn for fattening, where 10 animals were placed together into the group boxes. The groups were formed according to the body mass and the animals remained together until the end of the test. A plan of 5 weighing was made, starting from housing at average age of 135 days at the average body mass of 182.70 kg. At the same time also the trunk length, the chest size, the withers height and the croup height were measured. Those measurements were performed during all five stages of weighing. After first weighing we calculated the difference between weighted mass and calculated mass (equation 1) and animals selected to the three groups per 10 animals which were in different boxes. In the first group were animas with the lowest difference in the third group were animals with the highest difference and in the second group were the rest animals (Figure 1).

For collecting of data the measurements and the weighing were repeated every 2 months after housing. Testing of the bulls ended with the average age of 382 ± 12.69 days and with the average body mass at fifth weighing of 485.33 ± 40.85 kg followed by weighing prior to slaughter.

For the determination of the body measurements the formula followed [12] was used:

$$T = \frac{o \times d}{50} \quad (1)$$

where:

T...body mass (kg)

d...trunk length from the middle of withers to tail root (cm)

o...chest size measured at 3 cm behind the elbow joint (cm)

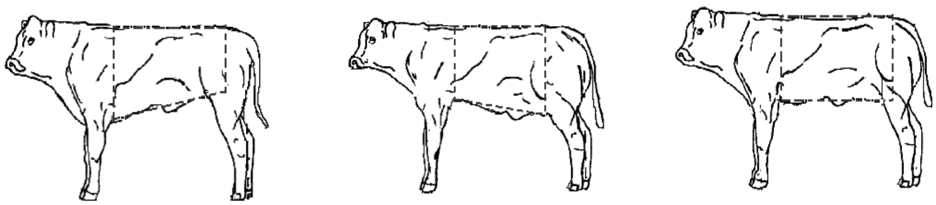


Fig. 1 Different types of body shape a) animal with dipper chest region; b) animal with shallow chest region; c) animal with rectangular shape of body [2]

Weighing

In review of literature for the last 20 - 30 years, the authors were not concerned about the determination of the mass on the basis of the body dimensions, since they were of the opinion that the weighing devices were more accurate and available to anyone. For following up the mass, particularly in intensive raising, the spring and/or electronic weighing devices were purchased. Thus, for weighing the birth mass the weighing device of at least 1 kg accuracy and for further weighing the weighing device of at least 2 kg accuracy are to be used.

At the beginning and during weighing we had to check that animals were fully on the platform. Beside, we had to ensure that the underside of the platform or crate was kept clear of dirt, stones and clear of any obstruction, and that the installation was level. After weighing we stored the indicator in a cool dry place (Figure 2).

The total capacity of weighing device is 2000 kg. The resolution was set to 0.5 kg (fine mode 0.1 kg) Accuracy ±1 % or 2 resolutions with Tru-Test load bars connected. Power supply was 12 V DC powered by adaptor or vehicle battery.

Fig. 2 The animal stands on a platform. The entrance and exit gates are not connected to the platform and therefore are not weighed

At the beginning load bars were installed under the platform on a firm, level surface and prevent platform movement. Then we connected load bar cables to the indicator and ensured that they would not be walked on, chewed by animals or squashed in any way. The indicator automatically calibrated itself to Tru-Test load bars.

The applied Tru-Test aluminum cattle platform is a unique, registered design product with many inherent advantages. It is manufactured from high quality marine grade aluminum which ensures lightweight and resistant to corrosion. The weld-free folded design has a number of advantages. Firstly, a weld-free construction may contribute to a longer life as weld points are often a point of weakness on more conventional designs. Secondly, the folded design is strong and very stiff along the length of the platform, which helps to ensure accurate weighing.

The load bars were mounted beneath the platform. The 'hoof' width (width on which the animal stands) of the platform, crate, crush or squeeze chute was not wider than the length of the load bars [1].

The Tru-Test weighing system (Figure 3) consists of a microprocessor controlled indicator (keyboard/display unit) and one or more load bars. The load bars are fitted beneath a platform or crate to hold the animal and they transmit the weight signal to the indicator. The indicator displays the weight and, through the keypad, provides control over the processing facilities of the scale.

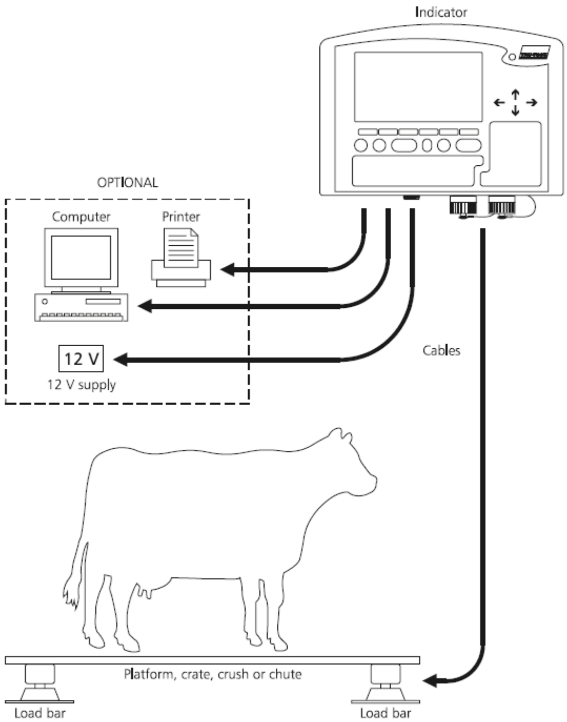


Fig. 3 The weighing system [1]

Tru-Test indicators automatically identify and calibrate to the load bars we connected. The Tru-Test indicators operated with the complete range of Tru-Test load bars. This was a standard calibration.

Measuring

For measuring of animals the following devices were used (Figure 4):

- Lydtin's rod,
- measuring tape - meter,
- compasses.

Most measurement were taken by means of 117 cm long hollow Lydtin's rod. The hollow houses a 1 m long thinner extractable rod. Both rods are marked with a centimetre scale. The beginning and the end of certain body dimension are taken by two foldable arms, which can be moved vertically on the rod. The Lydtin's rod can measure: the height of the withers, the croup height, the body length, the croup length, the chest width, the haunch width and the chest depth. The measuring tape was 2 m long and made of linen or metal and serve to measure the chest size. There are certain differences between the body masses stated by individual authors. The compasses are metallic and ensure measuring of up to 60 cm length [7, 8].

Fig. 4 Lydtin's rod, measuring tape – meter and compasses

Statistics

Collected data were statistically processed by statistical package SPSS 12.01. for Windows [15]. The parameters of the basic statistics were calculated and the differences between the calculated and weighed masses of animals were compared by independent t-tests [13].

RESULTS

As seen from the table 1, the calculation of the body mass on the basis of measurement overestimates the body mass on the first weighing. As indicated by the 13.51% deviation ($p \leq 0.05$) the chest size in relation to the rear part of the body is well developed on very young animals. During the second weighing it was found out that the differences were minimal, i.e., 0.06%. During that period the growth of bones is very intensive and the calculation implies the body shape which is most similar to the rectangle. During the third weighing the difference of 5.84% was established ($p \leq 0.05$) between the calculated and weighed mass, however, the ratio changed in favor of the weighed body mass. It was found out that the body measurements and the calculation did not cover completely the development of the body. The chest size and the trunk length increased slower than filling of the rear part so that the body mass was underestimated. Further, it can be seen that during the fourth and, afterwards, fifth weighing the body measurements, such as the size and the length, the build-up and filling of the body and the latter was underestimated as well, since the calculation of the mass did not take into account 10.62% and/or 11.03%, of body weight, which leads to significant difference between the masses ($p \leq 0.05$).

The development of the weighed body mass of bulls is shown in figure 5. During the first weighing the body mass was lower than the body mass calculated according to the measurements of the chest size and length. The measurement of the body mass was much more accurate during the second weighing, where it approached the 0.06% difference. Figure 8 also shows that the body mass deviated more and more, when the growth of the animal's body was slowed down and built-up of meat in the middle and rear part starts. It can also be seen that the calculation of the body mass on the basis of measurements was a linear value which, within 240 to 290 kg, coincides with the actually weighed body mass by means of the electronic weighing device.

Table 1 Representation of consecutive measurements

		Measurement 1		**Measurement 2**		**Measurement 3**		**Measurement 4**		**Measurement 5**	
Group		Mass[1] (kg)	Measure[2] (kg)	Mass (kg)	Measure (kg)	Mass (kg)	Measure (kg)	Mass (kg)	Measure (kg)	Mass (kg)	Measure (kg)
1	$\bar{x}$	171,10	205,69	247,00	251,33	316,56	295,65	379,78	351,93	461,50	402,97
	N	10,00	10,00	9,00	9,00	9,00	9,00	9,00	9,00	8,00	8,00
	SD	12,84	16,92	18,64	11,06	25,83	24,20	37,98	28,66	34,61	34,91
2	$\bar{x}$	188,70	214,24	270,00	264,25	338,11	320,84	421,56	378,91	497,00	404,82
	N	10,00	10,00	10,00	10,00	9,00	9,00	9,00	9,00	9,00	9,00
	SD	14,64	16,80	23,78	19,19	33,31	13,07	38,21	27,32	41,04	36,45
3	$\bar{x}$	188,30	202,24	264,44	266,00	332,78	313,32	412,38	352,12	497,57	400,39
	N	10,00	10,00	9,00	9,00	9,00	9,00	8,00	8,00	7,00	7,00
	SD	11,29	16,91	21,84	17,95	34,56	21,34	54,93	30,89	43,55	26,57
Total	$\bar{x}$	182,70[a]	207,39[b]	260,82	260,66	329,15[a]	309,94[b]	404,27[a]	361,33[b]	485,33[a]	402,91[b]
	N	30,00	30,00	28,00	28,00	27,00	27,00	26,00	26,00	24,00	24,00
	SD	15,06	17,08	23,06	17,26	31,65	22,10	46,02	30,65	41,73	31,95
Difference (%)*		+ 13.51%		- 0.06%		- 5.84%		- 10.62%		- 11.03%	

* Weighed mass is 100%; [1]weighing mass; [2]calculated mass

The results of own research showed that the calculation was very accurate with certain body masses, when the frame of the animal was rectangular and/or when the body structure in the front and rear part was almost equally deep. It means that the measured mass of bulls and the weighed mass deviated for a little. Of course, also the weighing devices have allowable deviations (± 1%), but that deviation was negligible and did not affect the results importantly. It was founded that it was possible to establish the body mass of the cattle accurately as well.

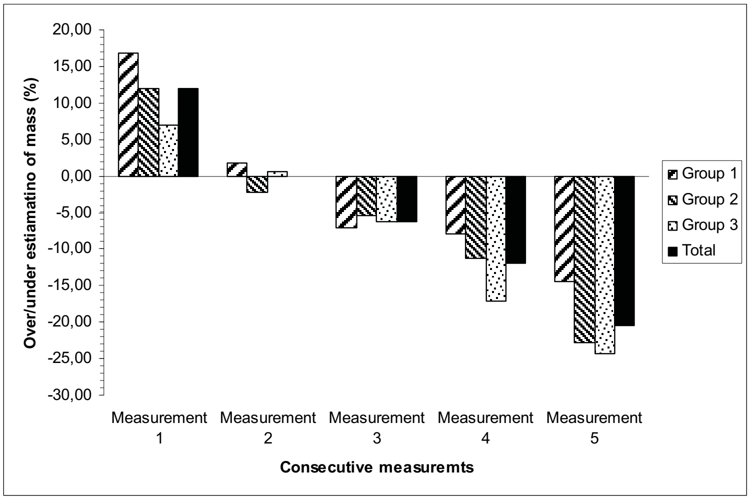


Fig. 5 Comparison of body masses obtained by weighing and calculation in test period

In figure 5 are represented results of over estimated calculated mass (+ part of the y ax) and under estimated mass (- part of the y ax) of bulls in comparison to the weighted mass. At the first measurement we over estimate mass for all bulls but for first group least of all. By the second measurement there was no significant difference among weighted and calculated mass for bulls. For measurements 3, 4 and 5 we see that all calculated masses for bulls were underestimated. The smallest average error was for the first group (-2,19%) than for second group (-5,93%) in than for the third group for -8,02%. In total the calculated mass was underestimated for 5,34%

CONCLUSIONS

The growth of the animals based on the calculation from the difference of masses between two measurements considerably influences the economy of animal fattening. When studying the influences of the growth and age of animals on the basis of the body mass during the studied period, the following conclusions can be conducted:

1. It has been proved that all body parts of the cattle during the measurements did not grow simultaneously and equally. During the second weighing, when the body shape was most rectangular, the deviations were minimum, i.e., only 0.06%.
2. When the body form was most rectangular, the accuracy of calculation on the basis of measured body parts was the greatest (group one).
3. The formula used for calculation would have to be complemented with the data of measurements of the trunk size in the middle of the body and the size in the rear part of the body, because the animals at certain age did not develop in the chest part, but its body filled in the back side. This shows last three measurements in all groups with non linear rise of under estimated calculated mass of bulls.

4. On small farms the cost of purchase of the digital weighing device would be too great in comparisons with its production of cattle breeding thus, measuring of the chest size at 3 cm behind the elbow joint, in the middle of the trunk (behind the last rib), and measuring of the size in the rear part of the body and the trunk length from the middle of the withers to the tail root are more appropriate.

REFERENCES

1. User's guide EC 2000, Tru-Test Limited, 2003, Auckland, New Zealand, 4.
2. M. Cepon, M. Klopcic, K. Potocnik, S. Zgur, P. Dovc, Technical rules and description of methods for measuring and calculating production and other properties and methods for predicting genetic values for pure breed reproductive cattle in Slovenia, Biotechnical Faculty, Zootechnical department, Domžale (2006) 78.
3. M. Janzekovic, B. Mursec, I. Janzekovic, Development of noninvasive method of measuring of heart rate in cattle, Proceedings of the 4th DAAAM International Conference on Advanced Technologies for Developing Countries, Slavonski Brod, Vienna DAAAM International, 2005, 523-528.
4. U. Zuperl, F. Cus, M. Milfelner, Fuzzy control strategy for an adaptive force control in end-milling, Journal of Materials Processing Technology, 2005, vol. 164-165, 1472-1478.
5. A. Ploj, B. Mursec, F. Cus, U. Zuperl, Characterization of machines for processing of waste materials, Journal of Materials Processing Technology 175 (2006) 338-343.
6. M. Janzekovic, B. Mursec, I. Janzekovic, Techniques of measuring heart rate in cattle, Technical Gazete 13 (2006) 31-37.
7. H. Kräußlich, Tierzuchtungslehre. Verlag Eugen Ulmer, Stuttgart (1994) 175-182.
8. M. Cepon, M. Janzekovic, M. Klopcic, K. Potocnik Dappled cattle breeding programme in Slovenia. Association of societies of dappled cattle of Slovenia, Ljubljana (2004) 11-16.
9. M. Janzekovic, B. Mursec, F. Cus, A. Ploj, I. Janzekovic, U. Zuperl, Use of machines for liquid manure aerating and mixing, Journal of Materials Processing Technology 162-163 (2005) 744-750.
10. S. Kogel, J. Utz, Wie gut eigenen sich Fleckviehbullen fur Gebrauchskreuzungen. Tierzuchter 40 (1988) 385-388.
11. N. Kunzi, G. Stranzinger, Allgemeine Tierzucht. Verlag Eugen Ulmer Stuttgart (1993) 66-90.
12. N. C. Kadunc, Tests and demonstrations in physiology, Faculty of Veterinary Science, Ljubljana (1993) 38-39.
13. D. J. Sheskin, Parametric and nonparametric statistical procedures, Chapman and Hall/CRC, USA (2000) 32-33.
14. M. Kirchgessner, Tierernährung. DLG Verlag (1997) 582.
15. SPSS 12.0 statistical procedures companion, New York, Prentice Hall, 2003.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 664.65.05
Prethodno priopćenje
Preliminary communication

CONTRIBUTIONS CONCERNING THE SYNTHESIS AND ANALYSIS OF THE KNEADING RAM-SHAPE ARM MECHANISM

BARBU GRECU, GHEORGHE VOICU, VICTOR MOISE, GEORGE ADÎR

University „Politehnica" of Bucharest
e-mail: ghvoicu_2005@yahoo.com; victor.moise@yahoo.com;

ABSTRACT

The paper presents the technological process of the dough kneaders, which imitates manual kneading, hit by hand, as well as the synthesis and kinematic analysis of its kneading arm. There are established the trajectory, velocities and accelerations of the head of the kneading arm, the parameters that influence the homogenization – kneading process. By taking into account of these analyses, it is established, also, the connection between the parameters of the ram-shape kneading arm, so that the trajectory of the tracing-point T has a certain configuration.

Key words: *dough, kneading ram-shape, mechanism, synthesis*

INTRODUCTION AND LITERATURE REVIEW

The scope of dough kneading is to achieve the homogenization of all ingredients of the recipe in an unitary mixture, with certain physical – chemical and technological characteristics, that lead to obtain proper finished products.

The principle of manual dough kneading has represented the base for achieving of the first dough kneading units, used in bakery units. There are, also, today, kneading units that copy so well the manual kneading by using both arms or that one with beating.

The mechanical system of the ram-shape arm kneading unit, used in the dough kneading process by beating, it is achieved by 2 subsystems: a cylindrical tank with rotational movement and a 4 - bars mechanism with movement in the longitudinal plane of the tank (Fig. 1) [1].

The end-user element of the mechanism is the connecting rod 2, whose constructive shape is demanded by the necessity to drive a tracing-point T of the connecting rod, on a given curve inside the tank and whose shape is depicted by the segments (a'b'), (b'c'), (c'a').

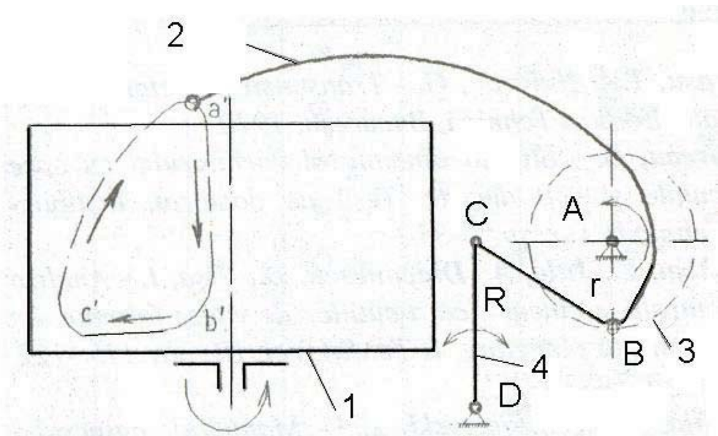


Fig. 1 The theoretical scheme of the beating type kneading unit
1.rotational tank; 2.beating type kneading arm; 3.action wheel (eccentric); 4.swing lever

THE EQUATION OF THE CONNECTING ROD CURVE OF THE KNEADING MECHANISM

The curve on which has to move the tracing-point T, is established by the demands of the kneading technological process. Thus, at the lower part, the connecting rod must move on a horizontal direction, parallel to the inferior surface of the tank, as close as possible to this one, to detach the dough from the bottom of the tank and to drive it in the homogenization process. At the central part of the tank, the connecting rod has to move on a descending vertical direction, producing compression and shearing in the dough and the withdrawal of the connecting rod from the dough, about the external part of the tank, must be done on a curve that has to allow a continuous connection between the horizontal and vertical zones of the connecting rod curve. In this zone, the dough is liable to complex stresses of elongation, torsion and shearing [1].

Generally, the tracing-point T describes a trajectory called *connecting rod curve*, given by a 6 degree function. The positioning equations of the tracing-point T include the variable dimensional and geometrical parameters (fig. 2) and appear like this [2,3,4]:

$$\begin{aligned} x &= r\cos\varphi + a\cos\alpha = k + R\cos\Phi + b\cos\beta \\ y &= r\sin\varphi + a\sin\alpha = h + R\sin\Phi + b\sin\beta \end{aligned} \tag{1}$$

where: r = AB; a = BT; b = CT; R = DC; $k = x_D - x_A$; $h = y_D - y_A$

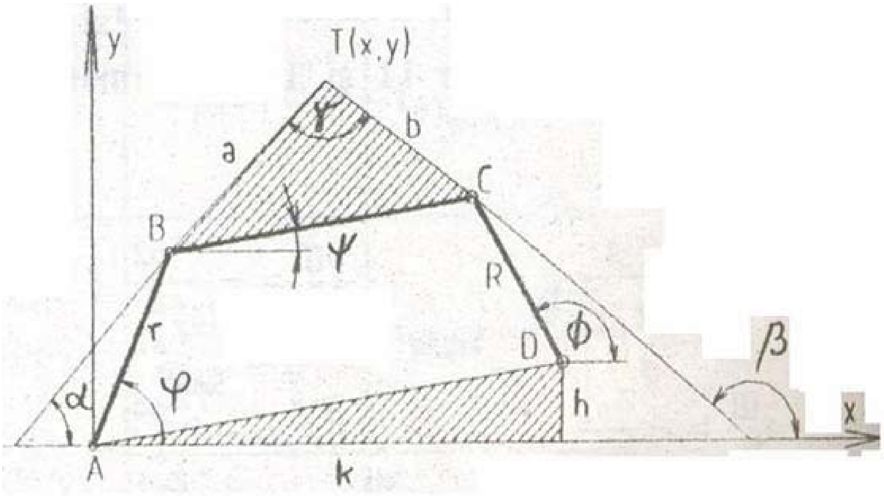


Fig. 2 The structural scheme of the ram-shape kneading mechanism

By eliminating the variable geometrical parameters, it is obtained the connecting rod curve, under the implicit shape:

$$U^2 + V^2 = W^2 \tag{2}$$

where:

$$U = \frac{1}{2}\begin{vmatrix} C_1 & B_1 \\ C_2 & B_2 \end{vmatrix}; \quad V = \frac{1}{2}\begin{vmatrix} A_1 & C_1 \\ A_2 & C_2 \end{vmatrix}; \quad W = \frac{1}{2}\begin{vmatrix} A_1 & B_1 \\ A_2 & B_2 \end{vmatrix}$$

The coefficients (A_1, B_1, C_1) and (A_2, B_2, C_2) have the expressions:

$$\begin{cases} A_1 = 2ax \\ B_1 = 2ay \\ C_1 = x^2 + y^2 + a^2 - r^2 \end{cases} \tag{3}$$

$$\begin{cases} A_2 = 2b[(x-k)\cos\gamma - (y-h)\sin\gamma] \\ B_2 = 2b[(y-h)\cos\gamma - (x-k)\sin\gamma] \\ C_2 = (x-k)^2 - (y-h)^2 + b^2 - R^2 \end{cases} \tag{4}$$

By using the transformations:

$$\begin{vmatrix} X \\ Y \end{vmatrix} = \begin{vmatrix} \cos\gamma & \sin\gamma \\ -\sin\gamma & \cos\gamma \end{vmatrix} \begin{vmatrix} x \\ y \end{vmatrix} \tag{5}$$

$$\begin{vmatrix} K \\ H \end{vmatrix} = \begin{vmatrix} \cos\gamma & \sin\gamma \\ -\sin\gamma & \cos\gamma \end{vmatrix} \begin{vmatrix} k \\ h \end{vmatrix} \tag{6}$$

$$Z = \begin{vmatrix} K & H \end{vmatrix} \begin{vmatrix} X \\ Y \end{vmatrix} = \begin{vmatrix} k & h \end{vmatrix} \begin{vmatrix} x \\ y \end{vmatrix} \tag{7}$$

$$\Lambda = \begin{vmatrix} K & -H \end{vmatrix} \begin{vmatrix} X \\ Y \end{vmatrix} = \begin{vmatrix} k & -h \end{vmatrix} \begin{vmatrix} x \\ y \end{vmatrix} \tag{8}$$

$$L^2 = \begin{vmatrix} K & H \end{vmatrix} \begin{vmatrix} K \\ H \end{vmatrix} = \begin{vmatrix} k & h \end{vmatrix} \begin{vmatrix} k \\ h \end{vmatrix} \tag{9}$$

$$\begin{cases} A^2 = a^2 - r^2 \\ B^2 = b^2 - R^2 + L^2 \\ C^2 = A^2 + B^2 \end{cases} \tag{10}$$

It is obtained:

$$U = b(x^2 + y^2 + A^2)(Y - H) - ay(x^2 + y^2 + B^2 - 2Z) \tag{11}$$

$$V = -b(x^2 + y^2 + A^2)(X - K) + ax(x^2 + y^2 + B^2 - 2Z) \tag{12}$$

$$W = 2ab\left[A\cos\gamma - (x^2 + y^2 - Z)\sin\gamma\right] \tag{13}$$

The connecting rod curve includes 9 dimensional parameters of the mechanism, namely:

$$f(x, y, r, R, a, b, \gamma, x_A, y_A, x_D, y_D) = 0 \tag{14}$$

These 9 parameters are established by imposing the condition that the tracing-point T passes thru 9 points of the fixed plane, where this point is moving.

DIMENSIONAL SYNTHESIS AND KINEMATIC ANALYSIS ASPECTS OF THE RAM-SHAPE KNEADING MECHANISM

In the synthesis problem of the mechanism there are taken into consideration the tank dimensions (diameter D, height H), because the base joints are placed outside the tank, as well as the working space of the swing lever.

By choosing r = 1 and axis Ox at H / 2 distance from the tank base, by using a change of the system against the rotational axis of this one, there were established the relative dimensions: BC = 2.53; DC = 1.86; BT = 5.6; x_D = 2.26; y_D = 1.86; $\gamma = 180^0$; b = 0.

The Cartesian coordinates of the tracing-point T, established by the relations:

$$\begin{aligned} X_T &= r\cos\varphi + BT\cos\Psi = X_1 + X_2 \\ Y_T &= r\sin\varphi + BT\sin\Psi = Y_1 + Y_2 \end{aligned} \tag{15}$$

allow to draw the connecting rod curve (Fig. 3).

The velocities and accelerations parameters of the point T, are established by the relations [2, 3, 4]:

$$\begin{cases} v_T^x = -\omega_1 Y_1 - \omega_2 Y_2 \\ v_T^y = -\omega_1 X_1 - \omega_2 X_2 \end{cases} \tag{16}$$

$$\begin{cases} a_T^x = -\omega_1^2 X_1 - \omega_2^2 X_2 - \varepsilon_2 Y_2 \\ a_T^y = -\omega_1^2 Y_1 - \omega_2^2 Y_2 - \varepsilon_2 X_2 \end{cases} \tag{17}$$

where:

$$\omega_2 = -\frac{AB\sin(\varphi-\Phi)}{BC\sin(\Psi-\Phi)}\omega_1$$

$$\varepsilon_2 = \frac{-AB\cos(\varphi-\Phi)\omega_1^2 - BC\cos(\Psi-\Phi)\omega_2^2 + DC\omega_3^2}{BC\sin(\Psi-\Phi)} \tag{18}$$

By considering ω_1 = 1, there are obtained the numerical values of the transmitting functions of velocity and acceleration, with the diagrams depicted in fig.3,b, respectively, fig.4.

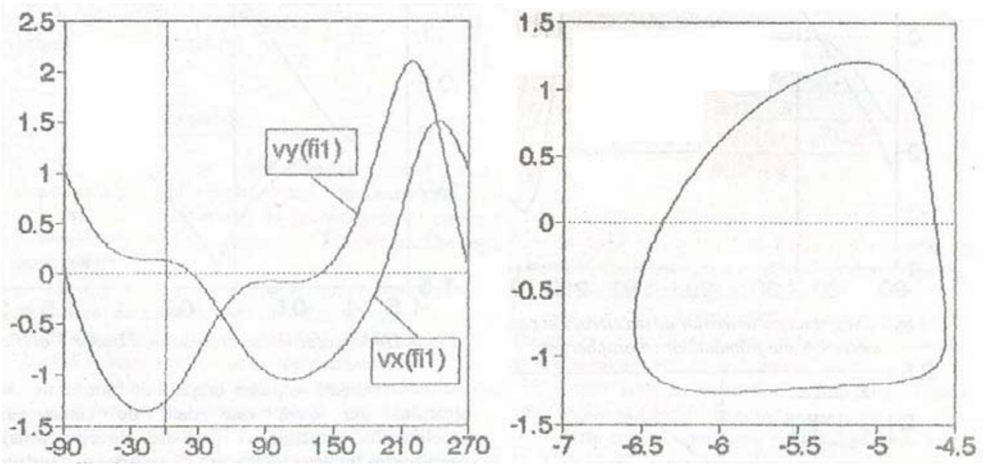


Fig. 3 The connecting rod curve of the kneading mechanism (a); diagram of velocity parameters (b)

By analyzing the diagram from fig. 3, it is established that the trajectory of the point T of the mechanism satisfies, so close, the demands initially imposed, so, the kneading unit can achieve a proper technological process.

To obtain that all the dough mass be subjected to the homogenization and kneading process, the tank of the kneading unit is rotating around its vertical axis with some speed, which can be between 10 – 20 rot / min (and even higher).

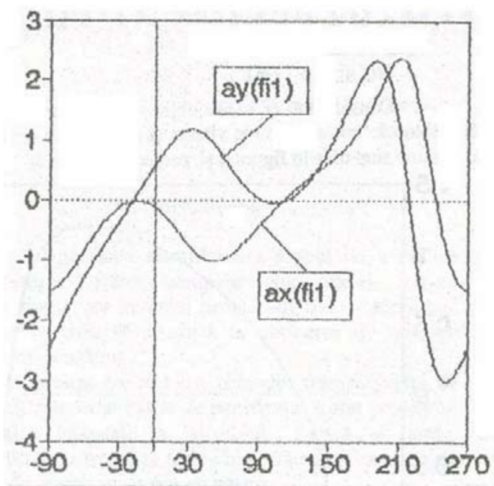


Fig. 4 Diagram of acceleration parameters for the ram-shape arm kneading mechanism

To achieve the imposed trajectory of the head of the kneading arm (tracing - point T), its speed must have a hodograph $v^y(v^x)$, similar to that one depicted in fig.5,a. The analysis of the velocities values of this point (fig. 4 and fig. 6), shows that these ones are located between the limits 0 – 1.5 on horizontal direction and between 0 – 2.1 on vertical direction (relative values), values imposed, also, by changing the direction of the movement of the arm along the trajectory.

The same time, the action of the kneading arm upon the dough from the tank, is given by the characteristics of accelerations of point T (value, direction, sense), when it covers the trajectory imposed by the constructive and functional parameters of the kneading mechanism.

In fig. 5,b is presented, graphically, the hodograph of accelerations of point T, $a^y(a^x)$, with values that satisfy the initially imposed demands.

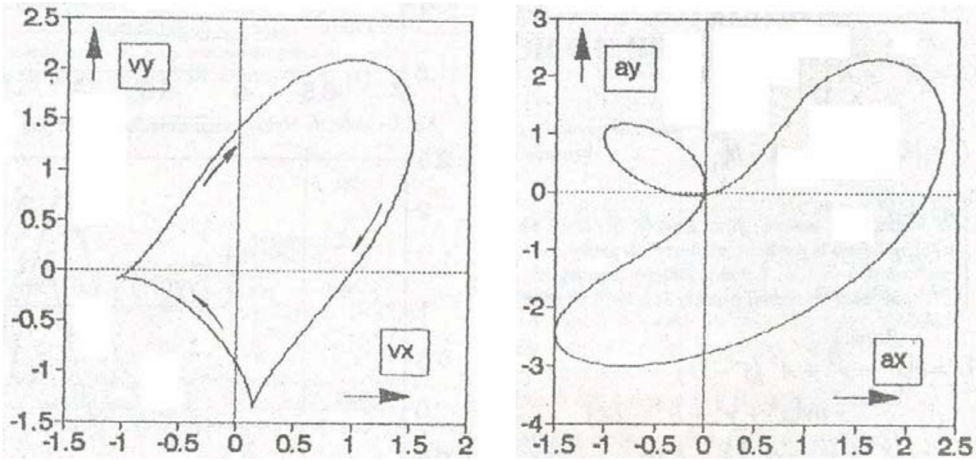


Fig. 5 The hodograph of velocities for the tracing-point T of the connecting rod (a); the hodograph of accelerations for the point T of the ram-shape kneading mechanism (b)

The diagrams from fig. 5, present the relative values of accelerations of point T, which take into consideration the correspondence relations between dimensions, velocities and accelerations of the constitutive elements of the mechanism. These values are placed in the limits 0 – 2.36 on horizontal direction and between 0 – 3.0 on the vertical direction. It is noticed that for those 3 typical points of the connecting rod, correspond 3 intervals of the rotation angle of the leading element, namely:

$$(a^{'}b^{'}) \to (-90^{o};23^{o});(b^{'}c^{'}) \to (23^{o};193^{o});(c^{'}a^{'}) \to (193^{o};270^{o}) \qquad (19)$$

CONCLUSIONS

From the kinematic analysis and synthesis of the ram-shape kneading mechanism (with beating), can be established its constructive characteristics, so that the whole surface of the tank pass, during one rotation, through the action zone of the arm and, in this way, the entire dough from the tank be subjected to some complex stresses of deformation (elongation-compression), torsion, shearing, that lead finally to obtain adequate quality products. To achieve the demands imposed by the technological process (the detachment of the dough from the tank bottom and from its walls, its stress and deformation, together with the homogenization of the ingredients of the mixture: flour, water, salt, yeast etc and the absolute hydration of the flour), the head of the kneading arm must have a well established trajectory, as well as the best velocities and accelerations.

The connecting rod curve of the tracing-point T, established in this paper, approximates very well the trajectory that has to be covered by the end of the kneading arm, trajectory demanded by the necessities of the working process.

The working space of the elements of the ram-shape kneading mechanism are outside the tank, for this purpose being imposed, also, the curvilinear shape of the connecting rod 2.

The results obtained allow, also, to establish some ascertaining relations of the mechanism dimensions, by comparison with the tank dimensions.

REFERENCES

1. Giurcă, V. – Tehnologia şi utilajul industriei de panificație, vol. I şi II, Univ. Galați, 1980

2. Hartenberg, R., Denavit, J. – Kinematic Synthesis of Linkages, Mc Graw – Hill Book Company, New York, 1964

3. Pelecudi, Chr., Grecu, B. – Sistematizarea prin polinoame de puteri a curbelor de bielă la mecanismele patrulatere, SYROM'85, vol. I – 2, Bucureşti, 1985

4. Pelecudi, Chr. – Precizia mecanismelor, Ed. Academiei, 1975

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.9:622.647.2:631.374
Stručni rad
Expert paper

FATIGUE ANALYSIS OF THE MOUNTED TRANSPORT BOX BASED ON FINITE ELEMENT METHOD

DENIZ YILMAZ, H. KURSAT CELIK, MEHMET TOPAKCI, IBRAHIM AKINCI

Akdeniz University, Faculty of Agriculture, Dept. of Agricultural Machinery
Antalya-TURKEY, e-mail: dyilmaz@akdeniz.edu.tr

ABSTRACT

Mounted transport box is generally used for transporting and lifting of the fertilizer and soil in orchard or greenhouses. Mounted transport box can be get into motion from three point linkage unit of tractor. It works under the different kind of reaction forces because of its loading and operating condition in agricultural fields. Hence, sometimes, some problems as plastic deformations or fractures can be seen on the mounted transport box. In this study, 3-Dimensional (3D) parametric solid modeling was generated and finite element stress analysis was performed for the mounted transport box, which is widespread used and was manufactured as 1000 kg transport capacity and turn over. According to the results of finite element stress analysis, safety number of cycles of the mounted transport box was investigated. Finally, it was presented that the analysis outputs of the stress analysis, safety factors and fatigue analysis results based on simulation. In the static FEA, maximum load was assumed as 1000 kg and maximum equivalent (Von Misses) stress magnitude was obtained as 260.225 MPa. Safety factor of 1.086 was obtained for entire model according to static FEA results.

***Key words**: CAD, CAE, Finite Element Method, Fatigue, Agricultural Machinery*

INTRODUCTION

Transport box used in agriculture has been used for transporting and lifting of the fertilizers and soils in horticulture or greenhouses. It has been generally preferred in Ege and Mediterranean region of Turkey in which fruit and vegetables farming are of notable density. Its body is fairly simple and useful from the standpoint of design and manufacturing technique. Transport box manufactures in Turkey are mainly small scale manufactures. Annual transport boxes productions are approximately 1000 number per a year for these manufactures. Transport box, used in rough fields, runs some failures during the unsuitable loading and wrong exertion are applied. These failures depend on fatigue assembly or others conditions which are done by user.

Fatigue may occur even if the amplitude of repeated stresses is smaller than static tensile strength or yield strength. The fatigue limit is described as the number of cycles to failure. The fatigue limit is also little affected by mean stress and when the mean stress is lower than elastic limit. However, when the mean stress is large, to a certain degree, the fatigue limit is affected by the mean stress and is low.

Despite the fact that most engineers and designers are aware of fatigue and that a vast amount of experimental data has been generated on the fatigue properties of various metallic and non metallic materials, fatigue failures of engineering components are still common. A number of factors influence the fatigue life of a component service. The use of calculations and simulations is a key feature of modern design process. Several properties such as stress, strength and stiffness, durability, handling ride comfort and crash resistance can today be numerically analyzed with varying levels of accuracy. Development time can be shortened by ensuring that some or rather all of these properties fulfill prototype is being built. Accordingly calculations based on fatigue life and loading histories permit structures and components to be optimized for durability without the need for expensive and time consuming testing of series of prototypes. Thus designs can be obtained that are less conservative than those based on traditional criteria such as maximum load or stress for a series of standard load cases (Fermer and Svensson 2001, Omid et al. 2008).

The usage of Finite Element Analysis (FEA) for calculating stress and strain is a well established procedure in analyzing fatigue and determining longevity. Numerical methods have been using to solve complicated problems in different engineering disciplines. In mechanical design process, one of the most used numerical methods is Finite Element Method (FEM). The method can be used nearly all somewhat different engineering field together with developing technologies and computers. In addition, using these applications is very important in agricultural mechanization system design (Celik et al. 2008).

The FEM method was developed more by engineers using physical insight than by mathematicians using abstract methods. It was first applied to problems of stress analysis and has since been applied to other problems of continua. In all applications, the analyst seeks to calculate a field quantity: in stress analysis, it is the displacement field or the stress field; in thermal analysis, it is the temperature field or heat flux; in fluid flow, it is the stream function or the velocities potential function; and so on. Results of greatest interest are usually peak values of either the field quantity or its gradients.

The FEM is a way of getting a numerical solution to a specific problem. A FEA does not produce a formula as a solution, nor does it solve a class of problems. Also, the solution is approximate unless the problem is so simple that a convenient exact formula is already available (Cook 1995).

MATERIAL AND METHOD

The transport box used in the test was manufactured by a local manufacturer company; a 1000 kg maximum load capacity as overturn with backward was considered. The box was connected to the tractor three hitch points. Up and down movements are providing with a tractor hydraulic control unit. It consists of root, vertical and horizontal chassis. Pin of the hydraulic connections and unloading unit of box are on the vertical chassis. Back cover hinged with two points as opening to the right side. Cover is locked on the box. Some technical features of the transport box were given in Table 1.

The transport box was modeled as 3D and Solid Works 3D parametric design software was used in solid modeling process. Tractor connection and original 3D solid model of transport box was shown in Figure 1.

Table 1 Some technical features of the transport box

General features	Unit
Tool	
Width [mm]	1100
Length [mm]	1300
Total height [mm]	1050
Weight [kg]	186
Box	
Height [mm]	400
Volume [m^3]	0.400
Three hitch points (Category)	II
Roof height [mm]	860

After 3D modeling operation of transport box, FEA was carried out for determining stress distribution on transport box. Operation condition of transport box was simulated in the analysis. As boundary conditions; tractor three hitch points were assigned as cylindrical supports (it means that just tangential movement is free for each point) and load was applied inside-bottom face of transport box (maximum load of 1000 kg was assumed). The FEA was generated as 3D, linear, static and assumption of isotropic material properties. AISI 1023 Carbon Steel obtained in Cosmosworks material library was assumed as material of transport box. The material properties and its S-N (Stress-Number of Cycles to fatigue) curve were given in Figure 2 (Cosmosworks 2006).

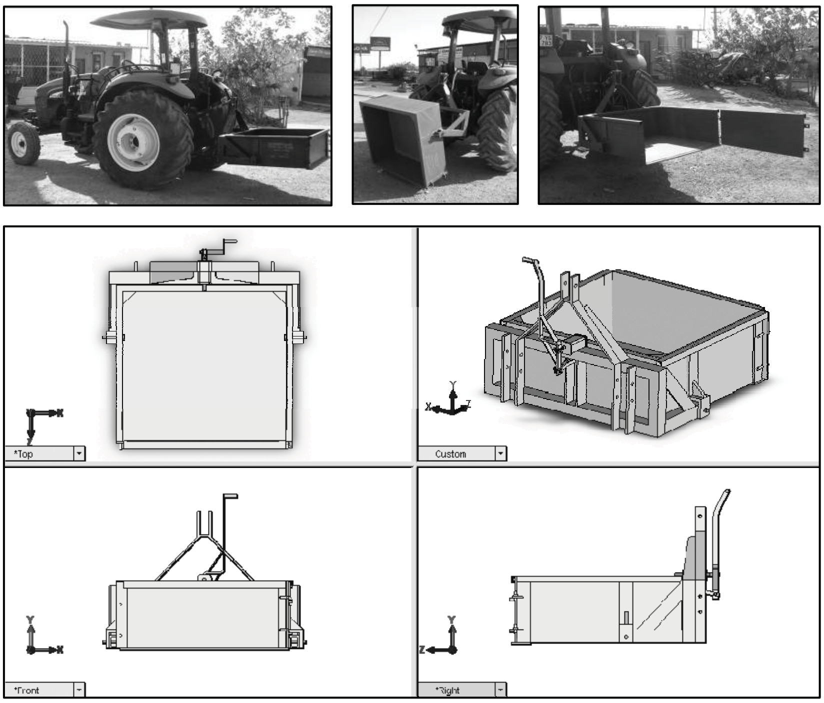
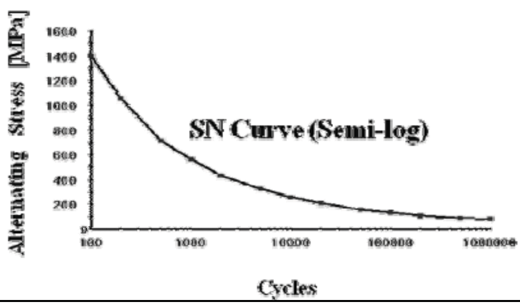


Figure 1 Tractor connection and 3D solid model of transport box

Mechanical Properties of 1023 Carbon Steel		
Young's Modulus	[GPa]	205
Tensile Ultimate Strength	[MPa]	425
Yield Strength	[MPa]	282
Poisson Ratio	[-]	0.29
Density	[kg/m³]	7858



Cycles	Alternating Stress [MPa]
100	1400.0
200	1060.0
500	717.5
1000	567.2
2000	437.4
5000	328.0
10000	259.6
20000	211.8
50000	157.2
100000	136.0
200000	112.7
500000	92.2
1000000	85.4

Figure 2 Material properties of transport box

CosmosWorks (Commercial FEA software) was used for the FEA analysis of the transport box. In the meshing procedure, second order (high order) solid tetrahedral elements were used. 150487 nodes and 76024 elements were obtained in total for the mesh construction. After solving process equivalent (Von Mises) stress distribution on transport box was obtained. According to the results of FEA, maximum stress of 260.225 MPa was determined. If the maximum stress value can be compared with yield strength of material, it can be said that there is no failure because of plastic deformation. The maximum value was under the yield stress point of material (in the static, linear assumption). In addition of the stress results safety working coefficient of the transport box was calculated and minimum safety factor of 1.086 was obtained for entire solid model. The safety factor was calculated according to the equation of "$\sigma_{(Yield\ Limit)}/\ \sigma_{(max)}$" Where the $\sigma_{(max)}$ is maximum equivalent stress from simulation and $\sigma_{(Yield\ Limit)}$ is yield strength point of material as MPa (Cosmosworks 2006). The boundary conditions, mesh construction and the outputs of the FEA result were shown in Figure 3.

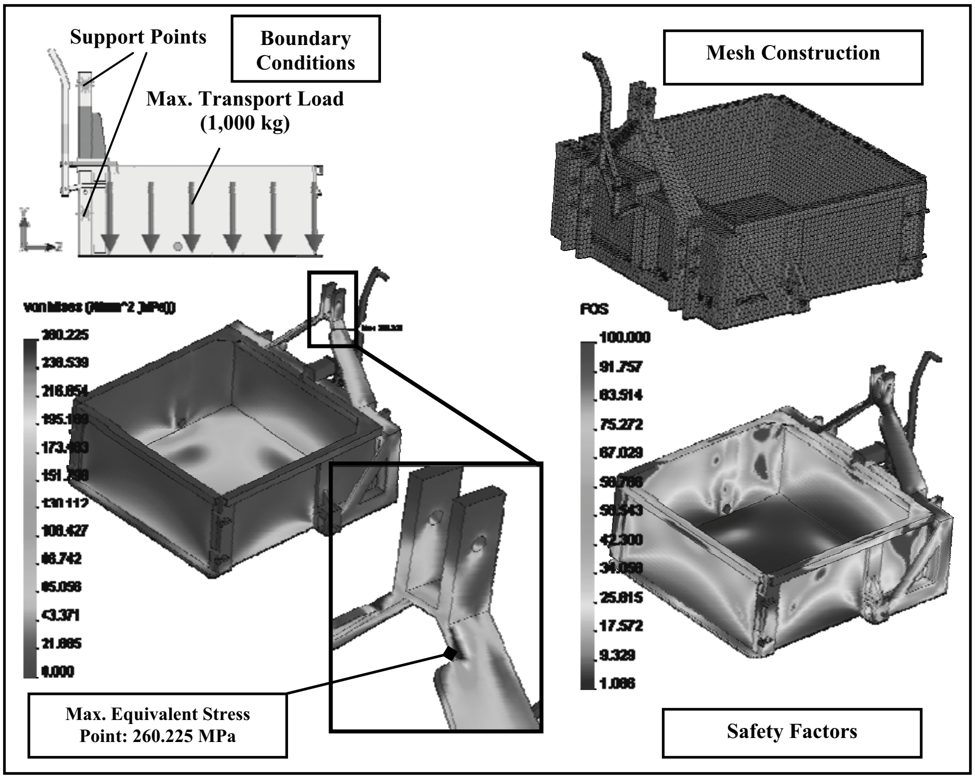


Figure 3 FEA process of transport box

Fatigue is the prime cause of the failure of many objects, especially those made of metals. Linear and nonlinear structural studies do not predict failure due to fatigue. They calculate the response of a design subjected to a specified combination of restraints and loads. If the analysis assumptions are observed and the calculated stresses are within the allowable limits, it can be concluded that design is safe for this combination of loads regardless of how many times the load is applied.

Results of static studies are used as the basis for defining a fatigue study. The number of cycles required for fatigue failure to occur at a location depends on material, composition, and type of loading (Cosmosworks2008 2007).

Fatigue of metals has been studied for 150 years (Bannantine et al. 1989). Three primary fatigue analysis methods are presented in the literature. These are the stress-life approach, the strain-life approach, and the fracture mechanics approach. These methods have their own region of application with some degree of overlap between them. The understanding of any one of these methods provides a technique which may be used to perform a fatigue analysis. However, it is the insights gained from understanding of all three methods which allow the engineer to choose the method or methods that are most appropriate for the given problem.

In general, it has been observed that the fatigue process involves the following stages: (1) crack nucleation, (2) short crack growth, (3) long crack growth, (4) final fracture (Lee et al. 2005).

Based on the stress magnitudes and the expected number of cycles needed to cause the damage, fatigue can be divided into the following two basic groups.

High Cycles Fatigue: Where the magnitudes of alternating stresses are moderate and cause none or small levels of plastic deformations in the material. The parts loaded in this manner are assumed to resist a high number of loading cycles (from 1000 to 10^6 cycles) before the fatigue failures. The method used to describe high cycle fatigue is referred to as a stress-life (S-N) based approach. (The Cosmosworks commercial FEA software is operating based on this approach in the fatigue analysis).

Low Cycles Fatigue: The alternating stresses have higher magnitudes, causing significa-nt plastic deformations. Due to the high stress levels, parts subjected to the repetitive loading tent to fail under a relatively small number of cycles, hence the name low cycle fatigue. The strain-life based approach suitable for the description of this class of problems (Cosmosworks2008 2007).

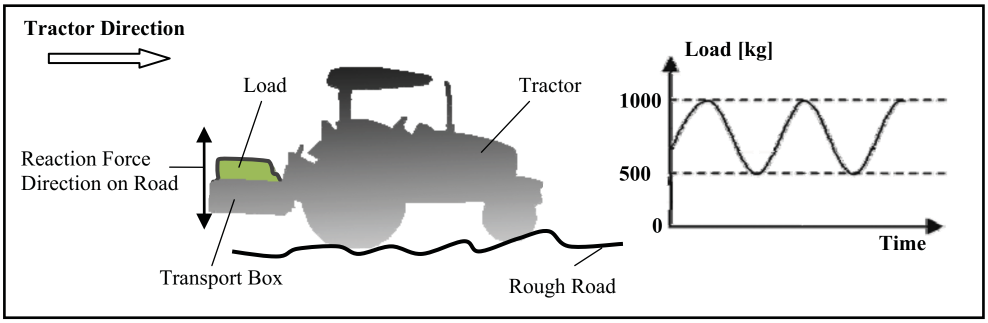


Figure 4 Loading case of the transport box for fatigue events

In the fatigue events, loading histories can be defined as two cases which are constant amplitude loading and variable amplitude loading. In the fatigue analysis simulation of the transport box, constant amplitude loading case was assumed and the rough road condition was simulated. In the fatigue events assumption, transport box was repetitive loaded between 1000 and 500 kg due to rough road condition and the design life of 10^6 cycles was assigned. Loading case of the transport box for fatigue events was shown in Figure 4.

RESULTS AND DISCUSSIONS

After definition of the fatigue events for transport box, solving process was run in the software. Damage plot, life plot and biaxiality plot were obtained. Damage plot shows the percentage of the life of the structure consumed by the defined fatigue events. The damage factor, also called usage factor, represents the ratio of the consumed life of the structure. Failure due to fatigue occurs when the damage factor reaches 100%. According to damage plot, damage of 122.2% was determined on near the upper hitch point of the transport box. It means that failure due to fatigue will be occurred according to defined fatigue events for transport box.

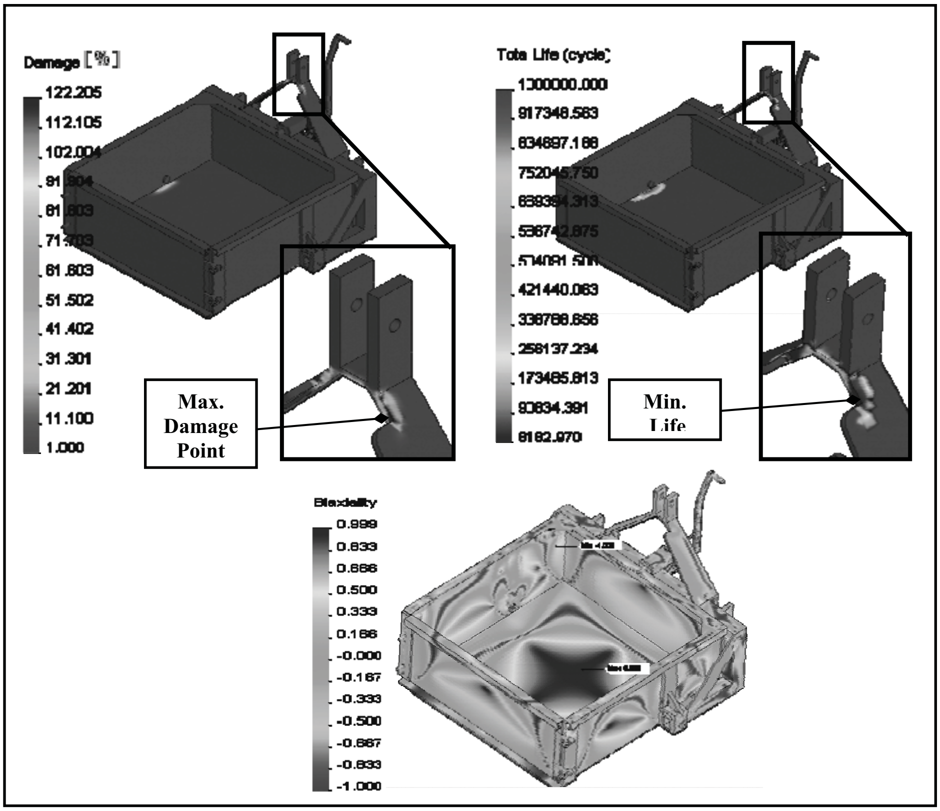


Figure 5 Plots of the fatigue analysis

Life plot shows the number of cycles (for constant amplitude event studies) that causes fatigue failure at each location. The plot is based on S-N curves and the alternating stress at each location. Cycles of 8182.97 were obtained at the max. stress point of the construction in the analysis, The fatigue failure will be concluded at the location of this cycles.

Biaxiality; the ratio of plots the smaller alternating principal stress (ignoring the alternating principal stress nearest to zero) divided by the larger alternating principal stress. The value of –1.0 indicates pure shear, and the value of 1.0 indicates pure biaxial state. This plot can help designers to determine a fatigue strength reduction factor for the study. According to biaxiality plot, range of the value was determined between -1.0 and 0.999. Plots of the fatigue analysis were shown as damage plot, life plot and biaxiality plot in the Figure 5.

CONCLUSIONS

Within this study, it is focused on a sample Computer Aided Engineering (CAE) application for design application and analysis of agricultural machinery system. Today, developing technologies, computers and design software allow us generating more effective designs in the interested areas. For the complex problems, technical calculations also can be realized by software which was integrated with numerical methods. Because of these important points, to usage of CAE application is very important for design progress of the agricultural mechanization system.

Transport box which is used in agricultural fields was used as an example for this study. Depended to original dimension of the transport box, its 3D solid model was modeled by parametric design software. Then its static FEM stress analysis was realized by commercial FEM software. Based on static FEA results, a fatigue analysis was realized according to defined fatigue events. As a basic result, static FEA results did not point any failure but fatigue events showed that there was damage on the structure. CAE application also can help designer to prevent their design from unpredicted failure cases. Some points can be summarized for this study such as follow:

1. In the static FEA, maximum load was assumed as 1000 kg and maximum equivalent (Von Misses) stress magnitude was obtained as 260.225 MPa. It is lower than yield strength point of material. It can be said that there is no failure due to plastic deformation under static loading case.
2. According to yield strength point of material safety working coefficient was calculated. Safety factor of 1.086 was obtained for entire model according to static FEA results.
3. In the fatigue events of transport box, it is assumed that the structure was operated under repetitive loading (constant amplitude loading) case the repetitive loading case was between 500 kg and 1000 kg.
4. Although static FEA could not show failure, fatigue analysis results presented damage ratio of 122.2% on the structure.
5. As minimum number of cycles for the all structure, 8182.97 cycles was obtained for transport box.

REFERENCES

1. Bannantine, J., A., Comer, J., J., Handrock, J., L. (1989). Fundamentals of metal fatigue analysis. Publication of prentice hall, ISBN-10:013340191X, ISBN-13: 9780133401912, pp 272, USA
2. Celik H.K., Yilmaz D., Akinci I. (2008). Structural stress analysis under the static load of a tractor mounted lifting apparatus. CIGR-2008 International Conference of Agricultural Engineering, Iguassu Falls City, Brazil, CD version.
3. Cook R., D. (1995). Finite element modeling for stress analysis. Univesity of Wisconsin-Madison, Publication of John Willey & Sons Inc., ISBN 0-471-10774-3, pp 320, USA
4. Cosmosworks (2006). On-line user's guide, Solidworks Software Corp. USA
5. Cosmosworks2008 (2007). Fatigue analysis theory. Solidworks Software Corp. Document number: PMTO181-ENG, pp 224, USA
6. Fermer M., Svensson H. (2001). Industrial experienced of FE-based fatigue life predictions of welded automotive structures. Fatigue Fract Eng Mater Structures 24: 489-500.
7. Lee Y., Pan J., Hathaway R., Barkey M. (2005). Fatigue testing and analysis –theory and practice. Publication of Elsevier Inc., ISBN: 0-7506-7719-8, pp 402, USA
8. Omid M., Mahmoodi E., Mıraee A. (2008). Fatigue analysis of connecting rod of universal tractor in the finite element code ANSYS. 10 th International Congress on Mechanization and Energy in Agriculture, Antalya, Turkiye. pp 326-329

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.979.2:631.361.85
Pregledni rad
Review paper

POWER CALCULUS ELEMENTS FOR OIL PRESSES

S. ST. BIRIS[1], M. MANEA[1], G. PARASCHIV[1], V. VLADUT[2], S. BUNGESCU[3]

[1] "Politehnica" University of Bucharest, Romania, [2] INMA Bucharest, Romania,
[3] "Politehnica" University of Timisoara, Romania

SUMMARY

Mechanical continuous presses are the most commonly used machines for the pressing of oleaginous materials in oil industry. These presses have the following advantages: continuously working, high working capacity, operate without major shocks and vibrations, easy adjustment of the working pressures, etc. Available theoretical elements of functional and power calculus for these machines are quite limited, relying mainly on simple formulas containing some correction coefficients whom values are empirically obtained, from experiments. Processes and phenomena that occur during the pressing process of the oleaginous materials are very complex. This paper contains a theoretical model regarding the power necessary to operate an oil press. The necessary components to power the press are: the power needed to transport the material along the pressing chamber, the power required to press the oleaginous material, the power needed to overcome the friction between the screw spire and the material, the power needed to push the material from the press through the exhaust cylinder head. In this paper there are presented diagrams that show the influence of various constructive and functional parameters on the pressing process.

Key words. *Continuous mechanical press, pressing, power, mathematical model, wine industry, oil industry*

INTRODUCTION

Due to the advantages it presents (continuous operation, high working capacity, run without high shocks and vibrations, working pressures which can be easily adjusted, etc.) the mechanical continuous presses are the most used in food industry, especially for pressing the grapes in wine industry and the oily material in oil industry.

The theoretical elements of a functional calculus, as well as of the power necessary for operating the press are actually rather poor, being based especially on simple formulas containing some correction coefficients, whose value is empirically obtained from experiments. This is due to the complexity of the processes and phenomena taking place during pressing, such as: material transport, proper pressing, overcoming the frictions between auger and material, pushing the material through the slot at the end of the pressing chamber.

In figure 1 is shown a representative mechanical continuous press with variable auger diameter and pitch, used for pressing the oily material in oil industry, which can reach pressures up to 40 MPa in the pressing chamber.

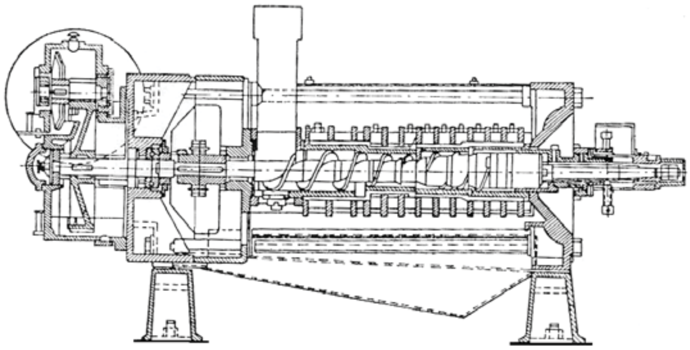


Fig. 1 Mechanical Continuous Press Used in Oil Industry

THEORETICAL ELEMENTS

Functional calculus elements

Pressure ratio (representing the reduction of the material subdued to pressing) is calculated by the relation [1]:

$$\boxed{\varepsilon = \frac{V_i - V_f}{V_i}} \tag{1}$$

where: V_i –represents the initial volume of the material, [m^3] and V_f–the final volume, [m^3].

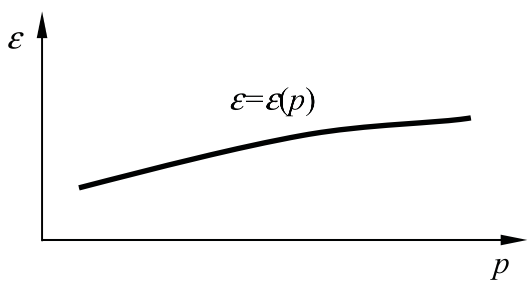


Fig. 2 Variation of the pressure ratio depending on pressure

The value of the pressure ratio is directly proportional to the press working pressure, having a variation, as that one shown in figure 2.

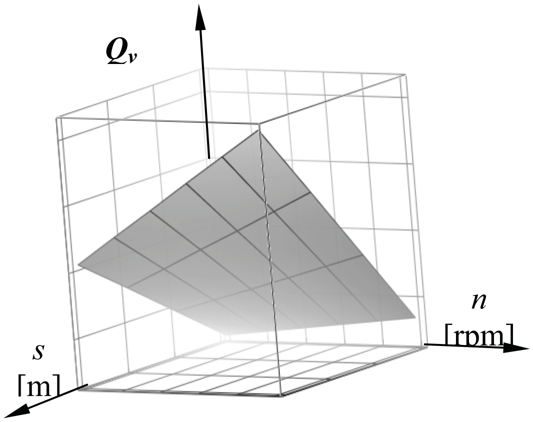


Fig. 3 Variation of the press flow rate depending on the auger rotational speed and the spire pitch

Press volume flow rate can be evaluated by using the relation [2]:

$$Q_v = V_{te} \cdot (1-\varepsilon) \cdot n \cdot k \cdot 60 \quad [\mathrm{m^3/h}] \tag{2}$$

where: V_{te} – represents the theoretical volume of material displaced by the auger spire during a complete rotation, in the exhaust area [$\mathrm{m^3}$]; n – the auger rotational speed, [$\mathrm{min^{-1}}$]; k – coefficient taking into account the material flowing back through the spire extremities, as well as the incomplete feed with material, (k=0,2÷0,35).

The theoretical volume of the material displaced by the auger spire is calculated by the relation:

$$V_{te} = \frac{\pi}{4} \cdot (D^2 - d^2) \cdot (s - \delta) \quad [\mathrm{m^3}] \tag{3}$$

where: s – represents the auger spire pitch [m]; δ – thickness of the auger spire, [m]; D – outer diameter of the auger spire, [m]; d – inner diameter of the auger spire (of the auger shaft), [m].

By replacing in relation (2) the expression of the theoretical volume given by the relation (3), it results the expression of the press volume flow rate under the form (see Figure 3):

$$\boxed{Q_v = \frac{\pi}{4} \cdot (D^2 - d^2) \cdot (s - \delta) \cdot (1-\varepsilon) \cdot n \cdot k \cdot 60} \quad [\mathrm{m^3/h}] \tag{4}$$

Calculus of the power necessary to operate the press

The power necessary to operate the press can be evaluated by using the relation:

$$\boxed{P_p = \frac{P_{tr} + P_{pres} + P_{fr} + P_{cap}}{\eta_{tm}}} \text{ [kW]} \tag{5}$$

where: P_{tr} – represents the necessary power for transporting the material from the feeding chamber to the exhaust head, [kW]; P_{pres} – necessary power for pressing the material, [kW]; P_{fr} – necessary power for overcoming the frictions between the auger spire and the material, [kW]; P_{cap} – necessary power for pushing the material through the exhaust space in the press, [kW]; η_{tm} – mechanical transmission yield (output).

Necessary power for transporting the material

Taking into account the calculus relations of the slow helical conveyors it can be written the expression of the necessary power for the proper transporting of the material along the auger:

$$\boxed{P_{tr} = \frac{F_r \cdot v}{1000}} \text{ [kW]} \tag{6}$$

where: F_r – represents the force resisting to the material advancing along the press auger, [N]; v – mean speed by which the material moves along the press auger, [m/s].

The resistant force F_r is given, on one part, by the phenomenon of outer friction between the material and the walls of the pressing chamber, and, on the other part, by the phenomenon of outer friction of the material subdued to pressing. The value of this force can be calculated by the expression:

$$\boxed{F_r = q \cdot l \cdot g} \text{ [N]} \tag{7}$$

where: g – represents the gravity acceleration , [m/ s^2]; q – the linear load (mass per linear meter of material in the press, [kg/m]; l – length of pressing chamber, [m].

The expression of the linear load, q, can be written:

$$\boxed{q = S \cdot \psi \cdot \gamma = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot \psi \cdot \gamma} \text{ [kg/m]} \tag{8}$$

where: ψ – represents the coefficient of admission for the press section; S – area of the cross section of the pressing chamber, [m^2], γ – density of the transported material [kg/m^3].

By replacing into the relation (7) it results:

$$\boxed{F_r = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot \psi \cdot \gamma \cdot l \cdot g} \text{ [N]} \tag{9}$$

It results the necessary power for transporting the material along the pressing chamber:

$$\boxed{P_{tr} = \frac{F_r \cdot v}{1000} = \frac{\pi \cdot (D^2 - d^2) \cdot \Psi \cdot \gamma \cdot l \cdot g \cdot v}{4 \cdot 1000} = \frac{\pi \cdot (D^2 - d^2) \cdot \Psi \cdot \gamma \cdot l \cdot g \cdot s \cdot n}{4 \cdot 1000 \cdot 60}} \text{ [kW]} \quad (10)$$

Necessary power for pressing the material

The mechanical work done for pressing the material (L_{pres}) results from the expression of the equivalent tension (stress) σ, which appears inside the pressing chamber as a result of applying on the cross surface (*S*) of the pressing chamber an equivalent pressing force (F_{pres}), so that it may be produced a reduction of the volume occupied by the material, from the initial value, V_i to the final value, V_f, as it is also shown in figure 4. Thus the equivalent tension (stress) in the pressing chamber can be expressed:

$$\sigma = \frac{F_{pres}}{S} = \frac{F_{pres} \cdot \Delta l}{S \cdot \Delta l} = \frac{L_{pres}}{\Delta V} = \frac{L_{pres}}{V_i - V_f} \text{ [Pa]} \quad (11)$$

Taking into account the relation (1), it results:

$$V_f = V_i \cdot (1 - \varepsilon) \quad (12)$$

and from the relations (11) and (12) it is obtained the expression of the mechanical work done for pressing the material:

$$L_{pres} = \sigma \cdot (V_i - V_f) = \sigma \cdot [V_i - V_i \cdot (1 - \varepsilon)] = \sigma \cdot \varepsilon \cdot V_i \text{ [J]} (13)$$

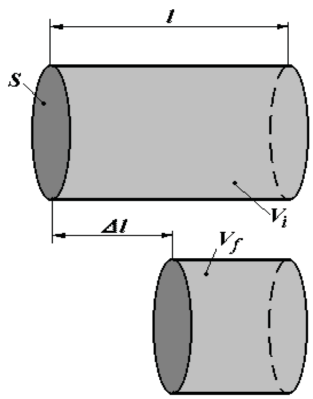


Fig. 4 Variation of the material volume in the pressing process

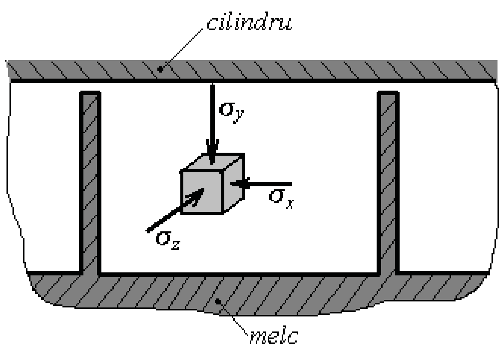


Fig. 5 Elementary volume of material subdued to the pressing process

For determining the value of equivalent tension (stress) σ, it is considered an elementary volume of material subdued to pressing, evenly loaded on each section, as in figure 5, which, the pressing process, moves only on the longitudinal direction of the press (direction *x*). In these conditions it may by written:

$$\begin{cases} \sigma_y = \sigma_z \\ \sigma_x = p \end{cases} \tag{14}$$

where: *p* [Pa] - represents the pressure performed by the auger, which is exerted on the material.

It is considered that the tensions (stresses) on the direction *y* and *z* appear due to the pressure oriented to the direction of material displacement, respectively:

$$\sigma_y = \sigma_z = \beta \cdot \sigma_x \tag{15}$$

where: β - represents the coefficient of the side pressure.

Taking into account the relation (15), it results:

$$\sigma_x + \sigma_y + \sigma_z = p \cdot (1 + 2 \cdot \beta) \tag{16}$$

As the materials subdued to the pressing process in the food industry also contain a certain percentage of liquid substance (oil, must, etc.), it can be considered that the hydrostatic pressure law remains valid, respectively:

$$\sigma = \frac{\sigma_x + \sigma_y + \sigma_z}{3} = \frac{p \cdot (1 + 2 \cdot \beta)}{3} \tag{17}$$

It results the expression of the mechanical work necessary for pressing the material:

$$\boxed{L_{pres} = \frac{1 + 2 \cdot \beta}{3} \cdot p \cdot \varepsilon \cdot V_i} \ \text{[J]} \tag{18}$$

respectively, the expression of the necessary power for pressing the material:

$$P_{pres} = \frac{F_{pres} \cdot v_{pres}}{1000} = \frac{F_{pres} \cdot \dfrac{\Delta l}{\Delta t}}{1000} = \frac{F_{pres} \cdot \Delta l}{1000 \cdot \Delta t} = \frac{L_{pres}}{1000 \cdot \Delta t} \tag{19}$$

where: F_{pres} – represents the pressing force [N]; v_{pres} – the pressing speed, [m/s]; Δt – the time interval when the reducing of the material volume is performed from the initial value V_i to the final value V_f, [s]. The value of this time interval can be calculated depending on the rotational speed [min^{-1}] of the press auger, respectively:

$$\Delta t = \frac{60}{n} \tag{20}$$

Taking into account the relations (18), (19) and (20), it results the expression of the necessary power for pressing the material:

$$\boxed{P_{pres} = \frac{L_{pres} \cdot n}{1000 \cdot 60} = \frac{(1 + 2 \cdot \beta) \cdot p \cdot \varepsilon \cdot V_i \cdot n}{3 \cdot 1000 \cdot 60}} \text{ [kW]} \tag{21}$$

In reality, in the case of food industry presses, the value of the pressure, p, is not constant along the auger, having a variation which can be as that shown in figure 6.

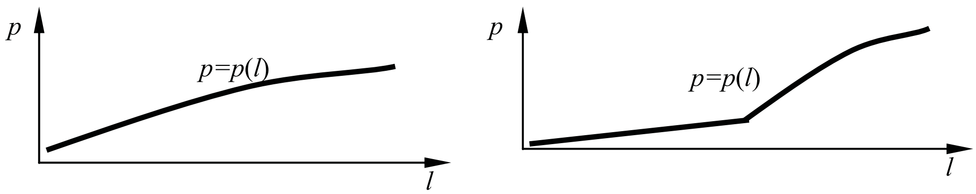


Fig. 6 Pressure variation along the pressing chamber

Power necessary for overcoming the frictions between the auger spire and material

In order to calculate the necessary power for overcoming the frictions between the auger spire and the material it is necessary that first to calculate the friction torque (moment), which appears on the spire surface when it comes into contact with the material. For the calculus of this friction torque (moment) it is first taken into consideration an elementary ring, dr, situated on the auger spire on the radius r (Figure 7) and for the auger length suitable to a pitch, s it is determined *the normal force* exerted on the elementary ring:

$$dN = p \cdot dS = p \cdot 2 \cdot \pi \cdot r \cdot dr \tag{22}$$

The value of *the friction force* which appears on the surface of the elementary ring is calculated by the relation:

$$dF_f = \mu \cdot dN = \mu \cdot p \cdot 2 \cdot \pi \cdot r \cdot dr \tag{23}$$

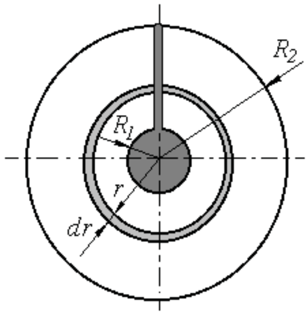


Fig. 7 Elementary ring on the auger spire

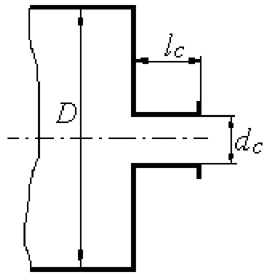


Fig. 8 End of the pressing chamber

The expression of the friction torque (moment) at the surface of the elementary ring is:

$$dM_f = r \cdot dF_f = \mu \cdot p \cdot 2 \cdot \pi \cdot r^2 \cdot dr \qquad (24)$$

which, by integration, for the whole active cross surface of the auger spire, suitable to a length equal to a pitch, *s*, leads to:

$$M_f = \int_{R_1}^{R_2} \mu \cdot p \cdot 2 \cdot \pi \cdot r^2 \cdot dr = 2 \cdot \mu \cdot p \cdot \pi \cdot \int_{R_1}^{R_2} r^2 \cdot dr = 2 \cdot \pi \cdot \mu \cdot p \cdot \left. \frac{r^3}{3} \right|_{R_1}^{R_2} \qquad (25)$$

respectively:

$$\boxed{M_f = 2 \cdot \pi \cdot \mu \cdot p \cdot \frac{R_2^3 - R_1^3}{3}} \text{ [Nm]} \qquad (26)$$

It results the expression of the necessary power for overcoming the friction between the auger spire and the material:

$$\boxed{P_{fr} = \frac{M_f \cdot n}{9550} = \frac{2 \cdot \pi \cdot \mu \cdot p \cdot \left(R_2^3 - R_1^3\right) \cdot n}{3 \cdot 9550}} \text{ [kW]} \qquad (28)$$

Power necessary for pushing the material through the exhaust space

For pushing the material through the exhaust space from the end of the pressing chamber the power is consumed:

$$P_{cap} = \frac{F_c \cdot v_{cap}}{1000} = \frac{F_c \cdot \dfrac{\Delta l_c}{\Delta t}}{1000} = \frac{F_c \cdot \Delta l_c}{1000 \cdot \Delta t} = \frac{L_c}{1000 \cdot \Delta t} = \frac{L_c \cdot n}{1000 \cdot 60} \text{ [kW]} \qquad (29)$$

where: F_c – resistant force to material pushing through, the head of the pressing chamber, [N]; v_{cap} – the material speed through the head of the pressing chamber, [m/s]; l_c – length of exhaust canal, [m].

The necessary mechanical work for pushing the material through the exhaust space (Fig. 8) for the end of the pressing chamber L_c is calculated:

$$L_c = F_c \cdot l_c = p \cdot A_c \cdot l_c = p \cdot \frac{\pi \cdot d_c^2}{4} \cdot l_c \quad [\mathrm{J}] \tag{30}$$

It results the expression for the calculus of power P_{cap}:

$$P_{cap} = \frac{p \cdot \pi \cdot d_c^2 \cdot l_c \cdot n}{4 \cdot 1000 \cdot 60} \quad [\mathrm{kW}] \tag{31}$$

APPLICATION

On the basis of the mathematical model developed in this study, in figure 9 it is shown the variation of the component parts of the power necessary for operation in the case of a press from the oil industry.

The main data taken into consideration for modelling are: the variable auger rotational speed (n=15÷40 min^{-1}), the variable pressure inside the pressing chamber (p=50·10^5÷200·10^5 Pa), the diameter of the pressing chamber (D=200 mm), the diameter of the auger shaft (d=100 mm).

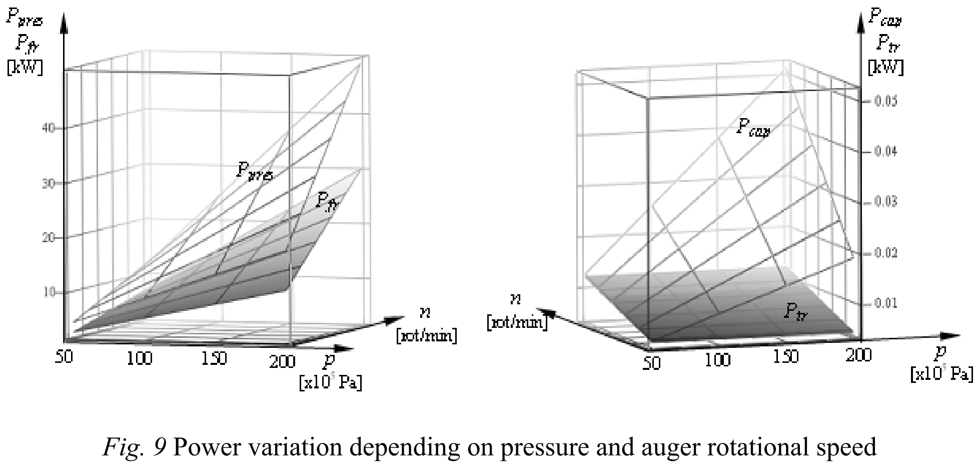


Fig. 9 Power variation depending on pressure and auger rotational speed

CONCLUSIONS

The mathematical model which was created in this paper permits the high precision determination of the functional parameters and of the necessary power for operating the presses in food industry.

In figure 9 it can by noticed that the necessary power for the proper pressing P_{pres} is the highest, being followed by the necessary power for overcoming the frictions between the auger spire and the material subdued to pressing P_{fr}. The values for the power necessary to push the material through the exhaust space P_{cap} and for the material transport through the pressing chamber P_{tr} are much lower than those for the presses P_{pres} and P_{fr}, being possible to be even neglected.

REFERENCES

1. Biriş S.Şt., 2002, Optimization by Using the Finite Elements Method of the Pressing Chamber Walls at the Mechanical Continuous Press for Wine Preparation TPV-3,5, Volume of the Jubilee Session of Scientific Communications - Achievements and Perspectives in the Biotechnical Systems Engineering, ("ISBTeh-2002"), June 7^{th}÷8^{th}, 2002, U.P. Bucharest, page. 200÷203.
2. Ioancea L., Dinache P., Popescu Gh., Rotar I., 1986, Machinery, Implements and Installations in Food Industry, Ceres Publishing House, Bucharest 1986, page 130÷147.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC
621.979.2:631.361.85
Izvorni znanstveni rad
Original scientific paper

STUDIES REGARDING THE USE OF FINITE ELEMENTS METHOD FOR THE WORKING PROCESS MODELING OF THE OIL PRESSES

S. ST. BIRIS, M. MANEA, E. MAICAN, N. UNGUREANU, L. TOMA

"Politehnica" University of Bucharest, Romania

SUMMARY

Processes and phenomena that appear in the pressing chamber during the working process of mechanical continuous oil presses are very complex and difficult to mathematically describe. The active element of mechanical continuous presses is the screw. During the working process, the pressure in the pressing chamber is not constant. The pressure is smaller in the oleaginous material feed zone and increases as approaches the discharge area of the pressing chamber. Optimization requires that in the feed zone the volume of the pressing chamber to be higher, the diameter and the screw spire pitch to be higher, and toward the exit from the pressing chamber the volume of the pressing chamber to be lower, respectively the screw pitch to be smaller. Finite elements method (FEM) is currently the most advanced engineering tool for numerical calculus and mathematical modeling. Using various FEM analysis programs the distribution of stresses and strains both in the screw and in the oleaginous material subjected to the pressing process can be studied. Using a two-dimensional (2D) analysis model, the distribution of tensions and strains in both the screw and the oleaginous material subjected to the pressing process can be studied in the strain state plane.

Key words. *Continuous mechanical press, pressing, mathematical model, oil industry, finite element method*

INTRODUCTION

Screw presses, hydraulic presses, roll presses and mills, juice-extractors, juice reamers, collapsible-plate and frame-filter presses are some of the equipments used for expression processing (Khan and Hanna, 1983). "Extraction" is the process of separating a liquid from a liquid-solid system with the use of a chemical. There has been some confusion in the literature between the operations of "expression" and "extraction". The latter word has been used quite loosely to designate either operation (Gurnham and Mason, 1946). This tendency has been so extensive that the distinction between the two terms appears to be disappearing from the literature. The term ”extraction” is also used for mechanical oil expression.

Vegetable oils are examples of liquid-solid mixtures which can be recovered from either operation of expression and extraction or with a combination of the two processes.

The oil can be obtained from oilseeds by three methods: full pressing (using high pressure screw presses), direct solvent extraction of oilseeds and a combination of these two methods, known as “pre-pressing” (oilseeds are initially pressed in a low pressure screw press followed by solvent extraction).

The type of extracting system used to separate the oil depends primarily on the seed’s oil content. Screw pressing is generally used for materials exceeding 20% oil content. Solvent extraction is preferred for oilseeds like soybean or pre-pressed cakes of other oilseeds having an oil content of less than 20%.

In figure 1 it is presented a small capacity mechanical continuous press, with two exhaust ends, for oil industry.

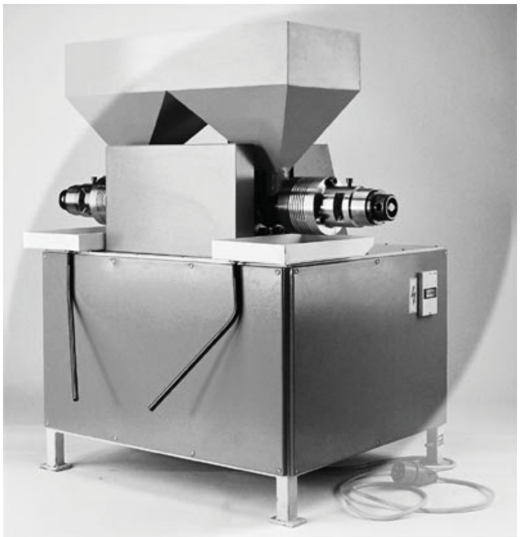


Fig. 1 Screw oil press PU-50U

Vadke et al. (1988) developed a theoretical model for expression of vegetable oil. Mrema and McNulty (1985) used the experimental data from unidirectional pressing to predict the output of the commercial screw press.

Shirato et al. (1978) developed an analysis for the case of continuous pressing in a screw press and presented a mathematical model which could calculate the rate of expression of liquid from a solid-liquid mixture of clay and water passing through a press. They considered a mixture where liquid was not enclosed within the solid particles, so that the material parameters average coefficient of consolidation (c) and the coefficient of volume change (m_v) could be determined independently of pressing conditions. Their model required prior knowledge of feed rate and pressure profile along the screw shaft which is not generally available. Hence, the model could not be practically applied to the screw pressing of the oilseeds.

Several models (Carley et al. 1953; Squires 1958; Shirato et al. 1965; Booy 1967; Oliveira 1992) are available for the case of a screw extruder, a machine similar to screw press except for the different provision for out flow of liquid. In screw presses the flow of expressed oil is through very fine spacing provided between barrel rings along the screw length. The extruders have only one opening at the end of the barrel from which the extrudate leaves the barrel through a die. The pressure profile in screw presses are similar to those found in extruders (Tadmor and Klein 1970; Harper 1981). However, these models were basically developed for extrusion of plastics and foods and they may need certain modifications prior to their application to stimulate the screw pressing of oilseeds.

Vadke et al. (1988) developed a model via superimposition of filtration analysis on screw extrusion theory to calculate the press throughput and residual oil content in press cake for a given press geometry and physical properties of oilseed.

During oil expression, oilseeds are progressively compressed to physically expel the oil. Initially, an oilseed is in a three phase system: air, oil and solid oilseed particles. As the compression begins, entrapped air escapes and rearrangement of the seeds/particles takes place. The volume of the voids decreases. As compression proceeds, individual seeds are squeezed into the inter-particle spaces with a concomitant loss of their initial geometry and flow of oil from inside of the cells to the inter-particle voids present in the system. At this stage the sample approximates an almost saturated two phase system consisting in the voids of the former. The fluid (oil), as well as the solids present in the oilseed is assumed to be incompressible during the process of consolidation.

In practice, this assumption of incompressibility of solids is not appropriate the oilseed particles for two reasons. First, the degree of saturation of oilseed samples, with an oil content of 20-45%, is actually much less than unity. Hence, the initial pore pressure in the vegetable oilseed sample is much lower than that for a saturated medium. Mrema and McNulty (1980) reported pore pressure values as low as 0,4% of the total applied stress in the case of oilseeds, in contrast with a typical pore pressure value of 20% of the total applied stress for saturated soils (Terzaghi, 1943). Hence, the stress carried by the solid particles of oilseeds is much higher than that for the soils. Second, the oilseeds particles are biological materials made of small plant cells which hold different constituents (oil globules, proteins, carbohydrates, fiber and ash). Under sustained application of mechanical pressure over time, these solid constituents which are basically chemical chains of different natures, are compressed and are likely to deform. The oil globules present inside the cell walls are ruptured to coalesce into droplets which tend to flow. The expressed oil is eventually squeezed out through a tortuous path in the cake body under sustained stress over time. On the contrary, the soil particles are made of uniform and single constituent solids. The water is held between these particles rather than being present inside each particle. These particles are more likely to rearrange and compress rather than deform, although under certain conditions high deformations in the soils solids may also occur (Ortigao, 1995).

THEORETICAL ELEMENTS

The uniaxial compression of a solid-liquid mixture has been extensively studied. Terzaghi's (1943) theory of consolidation for saturated soils, Kormendy's (1964, 1975) theory of pressing and the expression theory proposed by Shirato et al. (1970, 1971, 1979) are some of the major theories used to develop mathematical models for this purpose. While Terzaghi's theory has been specifically used for expression of oil from oilseeds, Kormendy's theory has been generally applied to pressing of comminuted fruits. Shirato et al. (1970) developed a mathematical analysis for the expression of liquid from clay-water systems to a stage where it was possible to accurately predict the liquid flow rate for a variety of pressing conditions.

Kormendy (1974), in an analysis of one-dimensional pressing problem, introduced the pressing coefficient which was almost equivalent to the consolidation coefficient (c) proposed by Terzaghy (1943), but different from it in certain aspects. While the pressing coefficient and consolidation coefficient had the same dimensions as those of diffusivity, the value of the consolidation coefficient could not be taken as constant in the case of comminuted fruits, because of very large deformations (the volume of the pressed material decreases up to one-fifth of the original one). Hence, a variable consolidation coefficient needed to be considered while applying this theory for the compression of products involving large deformations. The modified consolidation coefficient defined by Shirato (1965) differs only in constant factors from the pressing coefficient.

For a material to show high pressability, Kormendy (1974) found that the material must have both a well-deformable solid phase and low resistance of flow between the solid and liquid phases. Thus, Kormendy (1974) found that an optimum grade of comminution existed for fruits.

Kormendy (1964) also showed that the time to reach a definite percentage yield of the liquid phase was proportional to the square of initial thickness of the pressed cake and thereby, demonstrated that pressing apparatuses with small initial cake thickness are advantageous.

Although several different theories are available for predicting the oil expression from oil-bearing materials, most of the models reported so far have employed the Terzaghy's theory of consolidation for uniaxial compression (Mrema and McNulty, 1985; Singh and Singh, 1991; Sivala et al., 1991). The only model available for a screw press (Vadke, 1987) employed the superimposition of filtration analysis on screw extrusion theory to calculate press throughput and residual oil content in press cake for a given geometry and physical properties of oilseed.

The axial flow of a non-Newtonian fluid in an extruder was presented by Shirato et al. (1983):

$$Q_x' = \frac{\pi \cdot D \cdot W_0 (H_d - \delta) N \cdot cos\,\theta_\alpha \cdot f_d}{2} - \left(\frac{H^3 \cdot W \cdot f_{pd} \cdot f_{ps}}{12 \cdot n \cdot \mu_{sm}} \right) \frac{dP}{dX} \tag{1}$$

$$f_d = 1 - (0.487 \cdot n^2 - 0.948 \cdot n + 0.972) H_d / W \tag{2}$$

$$f_{ps} = 1 - (0.949 \cdot n^2 - 1.87 \cdot n + 1.59) H_d / W \tag{3}$$

$$f_{pd} = 0.98 \quad \text{(for the region of interest in this study)} \tag{4}$$

were: f_d - is the shape factor for drag flow (dimensionless), f_{ps} - shape factor for pressure flow (dimensionless), f_{pd} - correction factor for pressure flow (dimensionless), D - barrel diameter (m), W_0 - flight width (m), $H_d -$ flight depth (m), $\delta -$ clearance between shaft flight and barrel surface (m), $N -$ speed of the shaft rotation (r/min), $\theta_\alpha -$ helix angle (degrees), $n -$ power law index for semi-solid (dimensionless), $\mu -$ viscosity (Pa s), $P_s -$ pressure exerted by the shaft (Pa), $X -$ distance along the worm channel (m).

Combining the material balance across a small section of the barrel with the basic filtration equation, the following equation was obtained:

$$\frac{dQ_x^t}{dX} = \left[\frac{\pi \cdot D \cdot P}{\alpha_s \cdot \mu_1 \cdot m_s} \right] \frac{\rho_l}{\rho_{sm}} \tag{5}$$

where: $d -$ choke opening (m), $m_s -$ mass of the solids in worm channel per unit area of barrel (kg/m^2), $\alpha_s -$ specific filtration resistance (m/kg), $X -$ refers to direction of worm channel (referred to as axial direction), $\rho -$ density (kg/m^3), $sm -$ refers to semi solid mass (oil-solid mixture), $l -$ refers to liquid phase (oil).

Equations (4) and (5) could be used to evaluate the throughput and the oil expression rate provided the pressure developed in the press was known.

The active element of mechanical continuous presses is the screw (Fig. 2).

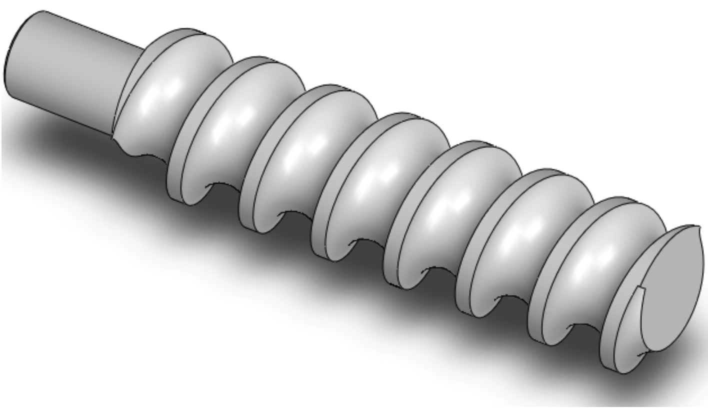


Fig. 2 The screw of PU-50U mechanical oil press

The equations of a helix, wound on a tapered shaft is given by:

$$\begin{cases} x = (R + s \cdot l)\cos\theta \\ y = (R + s \cdot l)\sin\theta \\ z = (R + s \cdot l)\cot\alpha \end{cases} \tag{6}$$

x, y, z are the shaft axes.

The length S of the helix curve defined by x, y, z, according to Hildebrand (1977), is:

$$S^2 = x^2 + y^2 + z^2 \tag{7}$$

where x, y and z are as defined in equation (1) above, respectively.

Hence

$$\left[\frac{dS}{d\theta}\right]^2 = \left[\frac{dx}{d\theta}\right]^2 + \left[\frac{dy}{d\theta}\right]^2 + \left[\frac{dz}{d\theta}\right]^2 \tag{8}$$

where

$$\begin{cases} \dfrac{dx}{d\theta} = (R + s \cdot l)\sin\theta \\ \dfrac{dy}{d\theta} = (R + s \cdot l)\cos\theta \ (9) \\ \dfrac{dz}{d\theta} = (R + s \cdot l)\cot\alpha \end{cases}$$

i.e.

$$\left[\frac{dS}{d\theta}\right]^2 = (R + s \cdot l)^2\left[\sin^2\theta + \cos^2\theta + \cot^2\alpha\right] = (R + s \cdot l)^2\cos^2\alpha \tag{10}$$

or

$$\frac{dS}{d\theta} = (R + s \cdot l)\cos ec\alpha = \frac{R + s \cdot l}{\sin\alpha} \tag{11}$$

or

$$S = \frac{R + s \cdot l}{\sin\alpha}\int_{\theta_2}^{\theta_1} d\theta \tag{12}$$

i.e.

$$S = \frac{R + s \cdot l}{\sin\alpha}(\theta_2 - \theta_1) \tag{13}$$

if θ_1=0º and α=17º, then (13) becomes

$$S = 3.4203(R + s \cdot l)\theta_2 = 3.4203(R + s \cdot l)n \cdot \pi \tag{14}$$

According to Stephens (1970) screw length S is given by:

$$S = 2 \cdot \pi \cdot R \cdot n \cdot sec\,\alpha \tag{15}$$

The volume of the spiral space between the crest of the screw and the inside of the barrel can be found from:

$$V = B \cdot S \cdot h = S \cdot h \cdot \pi \cdot D \cdot tan\,\alpha \tag{16}$$

But the mass flow rate per hour, M=screw capacity and the volumetric rate flow V is given by:

$$\dot{V} = \frac{\dot{M}}{\rho} \quad [\mathrm{m^3/h}] \tag{17}$$

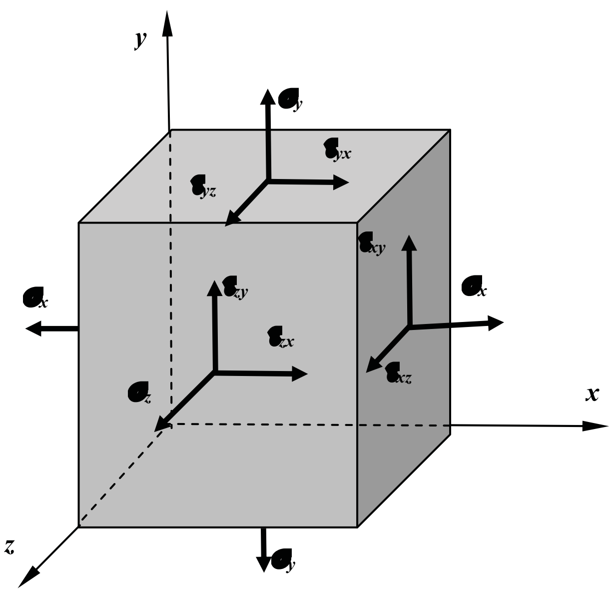


Fig. 3 Stress tensor components

Figure 3 show the stress state in the oleaginous material subjected to the pressing process, of an infinitely cubic element, which can be written in a matrix, termed the matrix of the stress tensors [8].

$$T = \begin{Vmatrix} \sigma_x & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_y & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_z \end{Vmatrix} \tag{18}$$

The relation between the specifical stresses and strains is given by the constitutive law known as Hooke's generalised law, stated by the ecuations:

$$\begin{cases} \varepsilon_x = \frac{1}{E}\cdot\left[\sigma_x - \upsilon\cdot\left(\sigma_y+\sigma_z\right)\right] & \gamma_{yz} = \frac{1}{G}\cdot\tau_{yz} = \frac{2\cdot\left(1+\upsilon\right)}{E}\cdot\tau_{yz} \\ \varepsilon_y = \frac{1}{E}\cdot\left[\sigma_y - \upsilon\cdot\left(\sigma_x+\sigma_z\right)\right] & \gamma_{zx} = \frac{1}{G}\cdot\tau_{zx} = \frac{2\cdot\left(1+\upsilon\right)}{E}\cdot\tau_{zx} \\ \varepsilon_z = \frac{1}{E}\cdot\left[\sigma_z - \upsilon\cdot\left(\sigma_x+\sigma_y\right)\right] & \gamma_{xy} = \frac{1}{G}\cdot\tau_{xy} = \frac{2\cdot\left(1+\upsilon\right)}{E}\cdot\tau_{xy} \end{cases} \tag{19}$$

where the three material constants are: E – Young's modulus, G – shear modulus, υ - Poisson's ratio.

For isotropic materials, the relation between these constants, is:

$$G = \frac{E}{2\cdot(1+\upsilon)} \tag{20}$$

The modulus of elasticity (E) of the oleaginous material can be determined at discrete vertical stresses, during the oedometer test, using the equation [5]:

$$E = E'\cdot\frac{1-\upsilon-2\cdot\upsilon^2}{1-\upsilon} \tag{21}$$

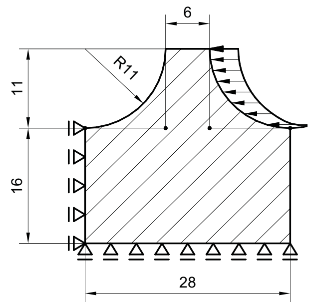
where E' is the oedometer modulus of the sample.

MATERIAL AND METHODS

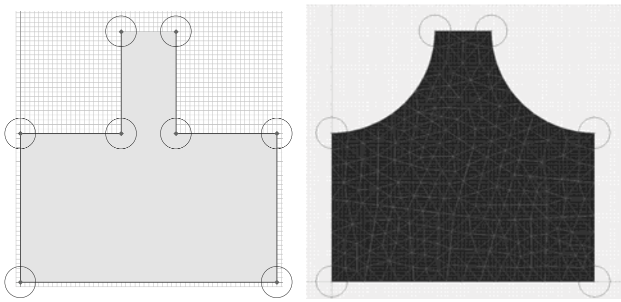
For the analysis using finite elements method (FEM) were developed two plane strain models. The first model is part of the screw with constant diameter, constant pitch and constant helix thickness (Fig. 4.b). The second model describes a screw, as the one presented in figure 2, having the same geometrical caracteristics but with variable helix thickness (Fig. 4.c). It was comparatively studied the stresses distribution, both in the screw and in the oleaginous material, corresponding to the discharge area of the pressing chamber, where the pressure reaches the highest value.

The screw is made of steel ($E = 2{,}1\cdot10^5$ MPa, υ=0,3), and the oleaginous material – sunflower – has the internal friction angle ϕ = 28,5°, apparent cohesions C = 4,48 kPa, Poisson's ratio values υ = 0,28-0,33, modulus of elasticity E = 5000-7000 kPa.

The structural nonlinear analysis was made on the ideal model, which was considered the oleaginous material as if it were homogeneous and isotropic material. It was used the COSMOS/M 2.95 Programme and QuickField Student Programme for FEM modelling, and the results can be visualised in the figures 5 to 9.



a)



b) c)

Fig. 4 Analysis models for the screw

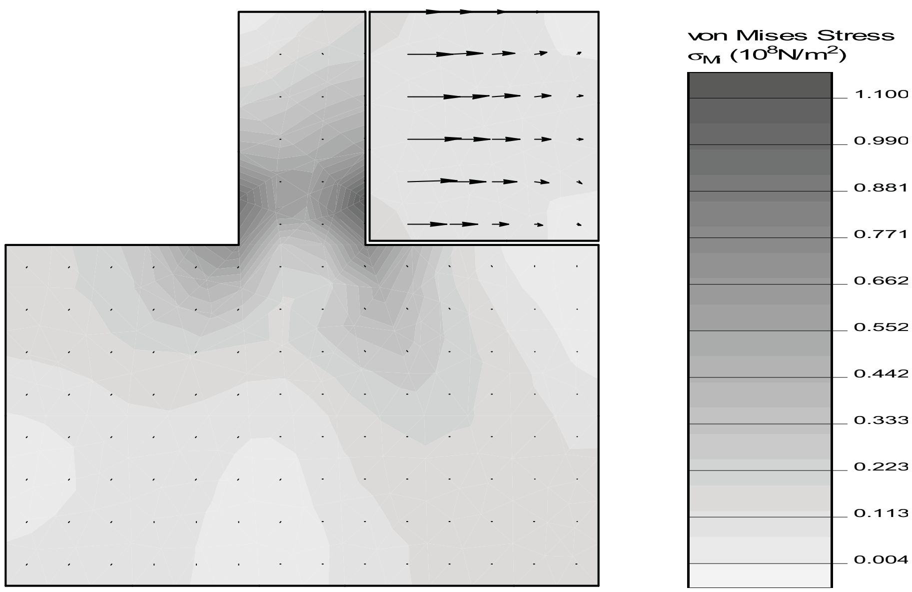


Fig. 5 Stresses distribution in the first screw type and in the oleaginous material

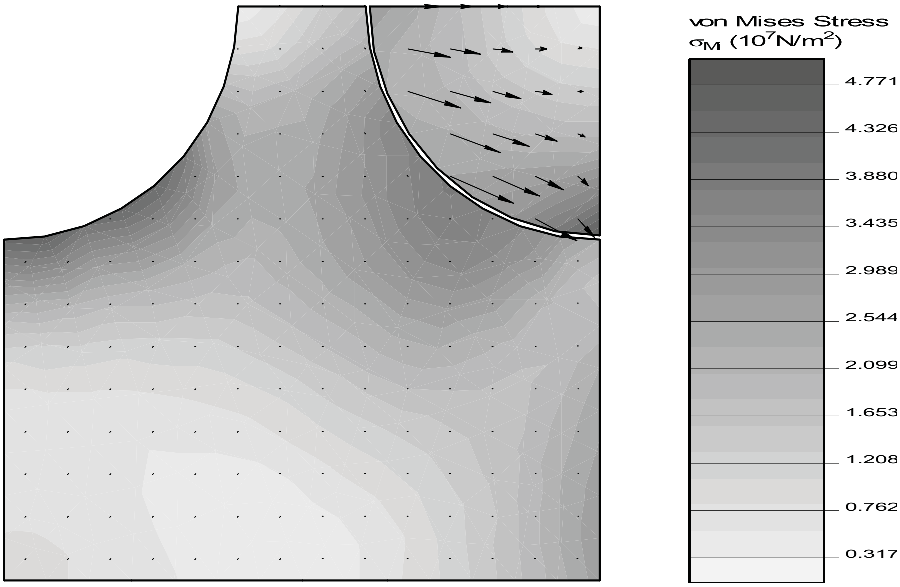


Fig. 6 Stresses distribution in the second screw type and in the oleaginous material

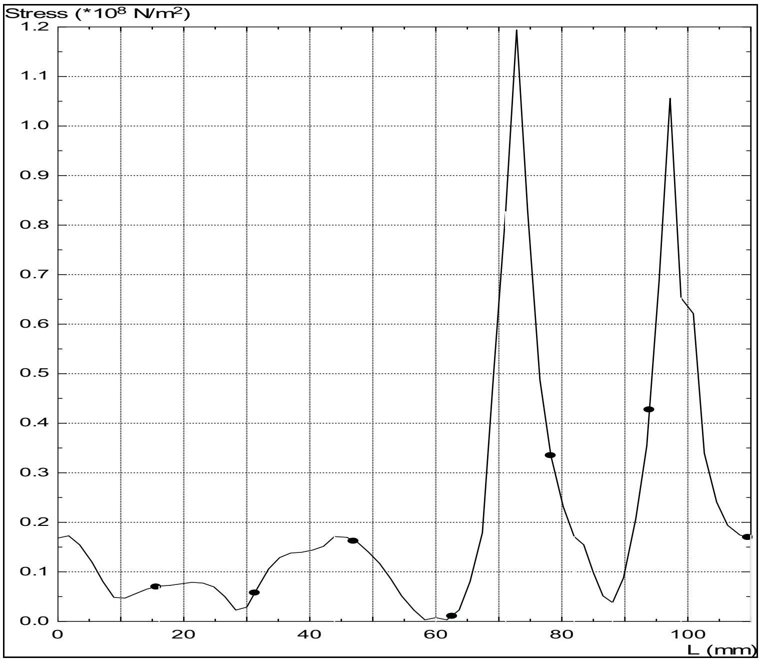


Fig. 7 Graphical distribution of the stresses on the edge of the first screw type

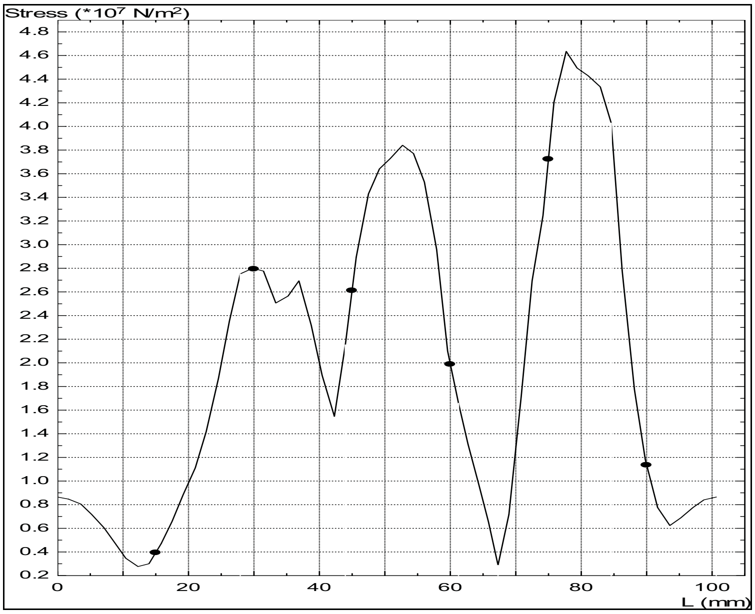


Fig. 8 Graphical distribution of the stresses on the edge of the second screw type

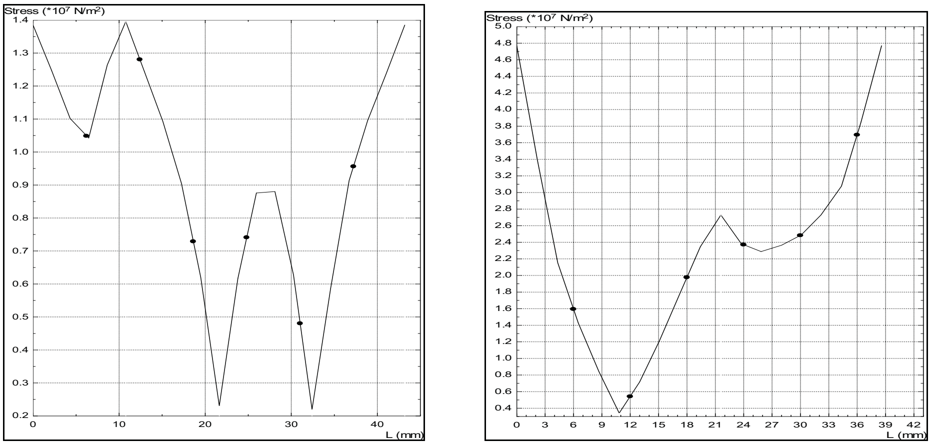


Fig. 9 Graphical distribution of the stresses on the edge of the oleaginous material for the first, respectively the second screw model

CONCLUSIONS

1. The Finite Element Method is in present the most advanced mathematical tool which can be used for the working process modeling of the oil presses. For mathematical modeling the oleaginous material is considered as a homogeneous and nonlinear.

2. As it can be seen, by comparing figures 5 and 6, in case of the screw with constant helix thickness the equivalent stresses are higher, up to 80-90 MPa, unlike the screw with variable helix thickness where the equivalent stresses, for the same working conditions, are less than 40-45 MPa. Also, in the first case, on the oleaginous material is exerted an more uniformly distributed pressure in the whole volume and a stronger flow of the material on axial direction.
3. By comparing the graphics presented in figures 7 and 8 it can be observed that the stress distribution for the variable screw thickness it is more suitable than for constant thickness helix screw, due to the fact that the differences between the maximum and minimum stresses values are smaller. Hence, based on the stress distribution, the second model, presented in figure 6, is better.
4. By comparing the graphics presented in figure 9 it can be observed that the oleaginous material subjected to the pressing process in case of the first model the stresses are more uniformly distributed, in the whole volume, although the values of the equivalent stresses are smaller.
5. It is necessary to elaborate 3D FEM analysis model that takes into account all the friction forces that are developed between the oleaginous material and the screw helix, respectively the pressing chamber walls.
6. It is also necessary to elaborate an 3D complex FEM analysis model that takes into account the fact that the oleaginous material subjected to pressing has variable weight, due to the liquid phase (oil) separation during the pressing process. At present, these models are still studied, being necessary extensive experimental researches to validate these models.

REFERENCES

1. Amalia Kartika I., Pontalier P. Y., Rigal L., 2006, Extraction of sunflower oil by twin screw extruder: Screw configuration and operating condition effects. Bioresource Technology, Vol. 97, pg. 2302-2310.
2. Bargale P.C., 1997, Mechanical oil expression from selected oilseeds under uniaxial compression. Doctoral Thesis. University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
3. Bredeson D. K., 1983, Mechanical extraction. Journal of American Oil Chemists Society, Vol. 60(2), pg. 211-213.
4. Hamzat, K. O., Clarke B., 1993, Prediction of oil yield from groundnuts using the concept of quasi-equilibrium of oil yield. Journal of Agricultural Engineering Research, Vol. 55, pg. 79-87.
5. Moya M., Ayuga F., Guaita M., Aguado P., 2002, Mechanical properties of granular agricultural materials. Transactions of the ASAE, Vol. 45(5), pg. 1569-1577.
6. Oyinlola A., Ojo A., Adekoya L. O., 2004, Development of a laboratory model screw press for peanut oil expression., Journal of Food Engineering, Vol. 64, pg. 221-227.
7. Singh J., Bargale P. C., 2000, Development of a small capacity double stage compression screw press for oil expression. Journal of Food Engineering, Vol. 43, pg. 75-82.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.67:626.8
Izvorni znanstveni rad
Original scientific paper

STRUCTURAL OPTIMIZATION WITH FEM IN AGRICULTURAL ENGINEERING: A CASE STUDY FOR IRRIGATION PLUMBING ELEMENT

H. KURSAT CELIK, MEHMET TOPAKCI, IBRAHIM AKINCI

Akdeniz University, Faculty of Agriculture, Dept. of Agricultural Machinery
Antalya-TURKEY, e-mail: hkcelik@akdeniz.edu.tr

ABSTRACT

Machine manufacturing fields are improving to itself together with developing technologies. Especially, developed computers and software, which are interested in designing of machine elements, have very important role for obtaining to optimum parameters of design of products. Numerical techniques and optimization methods are used in the interested fields if the analytical techniques are insufficient. Today's design software, which integrated numerical techniques and optimization methods are very useful to obtain solution for effective designs, which are generated in virtual screen. It is inevitable progress that designing and manufacturing of agricultural mechanization systems by using these kind of virtual screen applications. In this study, a sample-plumbing element, which is used in agricultural irrigation, was modeled as three-dimensional and parametric. Operating conditions of system were evaluated then a study was built on determining of optimum thickness and body length by referenced finite element stress analysis results of plumbing element. Consequently, it is focused that three-dimensional parametric modeling, finite element analysis and optimization applications on designing of agricultural mechanization systems-devices and a study was carried out about determining to optimum thickness and body length of a sample plumbing element.

Key words: *Parametric Design, Finite Element Analysis, Agricultural Irrigation*

INTRODUCTION

Agricultural irrigation has biggest proportion in usage area of water in the world (Cakmak, 2002). The water, that is necessary for agricultural production, is provided by naturally or irrigation techniques in agricultural fields. In general, irrigation is defined as the artificial application of water to the soil usually for assisting in growing crops (Kanber, 2002). Water, as a fluid is controlled (guided) by using hydraulic systems in agricultural fields. The fluid control is provided via plumbing systems and hydraulic equipments. The water must be pressured and it must be elevated according to the level of water source and type of its applications in the agricultural fields. The water pressure has to be provided in the system for transferring and distribution of water (Ozmerzi, 2001). The pumping systems are used if water source is lower or far away than irrigation area for transferring of water. Generally, members of a pumping system can be classified in three main groups. These are pumps for provide to movement of water, an engine for pump and plumbing elements (pipes, fittings, connection parts, control system equipments, e.c) (Tezer, 1970).

Hydraulic systems and hydraulic pumps have been using for long time in the interested areas. It can be seen that various type of hydraulic pumps, which are designed for different operating conditions of hydraulic systems in the working areas. Especially, Positive displacement hydraulic pumps are used for provide to high pressures in the operating areas for hydraulic power transfer (Basaran, 1986). For this reason, positive displacement hydraulic pumps are operated under the high pressures hence the high pressure is transferred to plumbing elements. The plumbing elements must be designed according to its operating conditions and it must be durable enough to avoid any failure because of high pressure. Otherwise plastic deformations, cracks and breaking failures can be occurred on the plumbing elements in course of time.

Agricultural production industry is improving itself together with technology in its each progression. Especially, today, developed computers and software, which are used for designing of machine elements, are take place in designing of agricultural mechanization systems. In the product design area, some of these applications are three-dimensional (3D) solid modeling and finite element method applications. Designers can simulate and determine optimum parameters of their designs helping with computers and software which is also integrated optimization techniques in virtual screen.

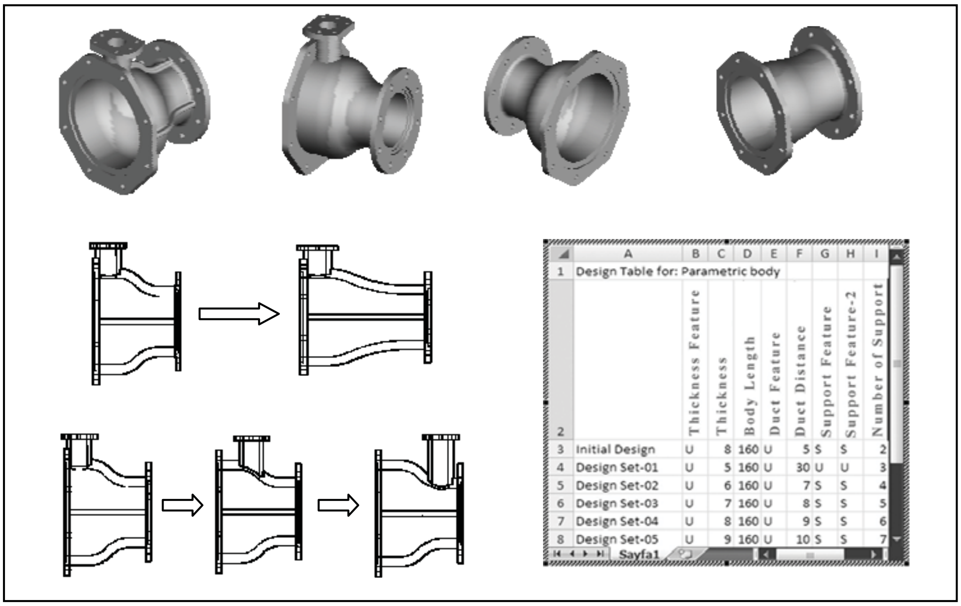
In this study, a sample plumbing element which is used in agricultural irrigation was modeled as 3D and parametric. Many models (configurations), which have different parameters and geometries, can be obtained by parametric modeling. A commercial finite element code was used for simulate to stress distribution of the plumbing element under defined boundary conditions. It was observed that stress distributions as 3D in the simulation. An optimization study was carried out for determining to optimum wall thickness and body length of the plumbing element referenced by equivalent stress values and deformations, which were obtained from the simulation.

MATERIALS AND METHODS

3D Parametric Modeling of the Plumbing Element

Visual evaluations and geometrical analysis are very important for designers. 3D models of products can be evaluated easily in virtual screen. In the procedure, if it is necessary, design parameters of products can be changed without any time losses, and design errors which can not be seen in design progress, can be determined easily. Before the virtual applications, evaluating process had been carried out in prototype process. Therefore, time-cost losses were increasing.

Solidworks 3D parametric design software was used for 3D solid modeling of the plumbing element. The solid model was defined with different components (passage, belt, flange, main body). Design parameters (design variables) were assigned to each other using equations. Different configurations of plumbing element which were defined with different parameters can be obtained by changing specific parameters in all parameters of existed solid model. “Design Table” function was used in design software to obtain different configurations. In this function, specified parameters transferred in to excel file and different configurations of 3D model can be created automatically in the design software by changing specified parameters (Celik H.K, 2006). Obtained different-sample configurations of 3D model can be seen in Figure.1.



	A	B	C	D	E	F	G	H	I
1	Design Table for: Parametric body								
2		Thickness Feature	Thickness	Body Length	Duct Feature	Duct Distance	Support Feature	Support Feature-2	Number of Support
3	Initial Design	U	8	160	U	5	S	S	2
4	Design Set-01	U	5	160	U	30	U	U	3
5	Design Set-02	U	6	160	U	7	S	S	4
6	Design Set-03	U	7	160	U	8	S	S	5
7	Design Set-04	U	8	160	U	9	S	S	6
8	Design Set-05	U	9	160	U	10	S	S	7

Figure 1 Different configurations of 3D solid model and design table function

Finite Element Analysis

Finite element analysis was performed for initial design of parametric model after modeling operation. Ansys Workbench commercial finite element code was used for stress analysis of the plumbing element. In this study, some assumptions are generated which are below.

Assumption 1: Fluid is in static case and it applies pressure inside face of the wall of plumbing element as 60 bar (daN/cm^2).

Assumption 2: Plumbing element was manufactured as grey cast iron

(Elastic Modulus: 110 GPa, Poission rate: 0.28, Yield stress: 151 MPa) (Ansys software, 2006).

Assumption 3: Design parameters for initial design were defined as; body length: 150 mm, diameter of fluid input: 160 mm, diameter of fluid output: 90 mm, wall thickness: 10 mm.

In the analysis, the plumbing element was fixed at its own screw holes, both assembly faces were supported as frictionless support (It means that just for normal direction of degree of freedom is zero) and maximum pressure was applied to inside face of the wall of the plumbing element. The Analysis was generated with assumptions of 3-dimensional, static, linear, and isometric material properties. Element type of Solid 187 (10-Node Tetrahedral Structural Solid) was used in the finite element structure of the model. Nodes of 24342 and element number of 13246 were obtained in totally. Maximum equivalent stress (Von Misses) of 51.03 MPa and maximum displacement of 2.44 e-2 mm were obtained after simulation (Figure 2).

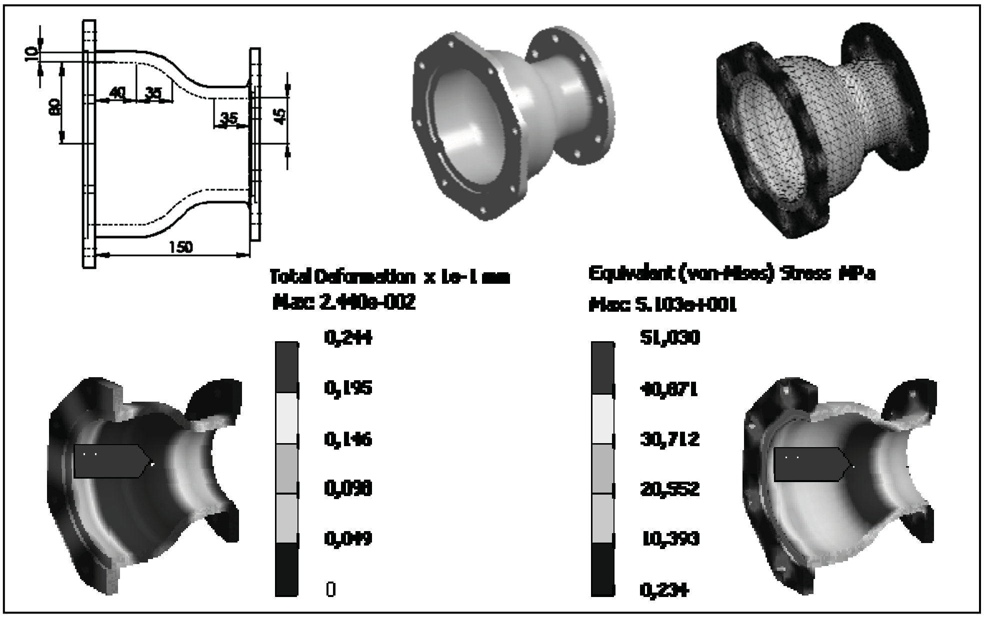


Figure 2 Finite element analysis for initial design

Optimization

Today, rivalry is increasing between manufacturing companies, and it appears such a factor for generate more efficient designs of products. Today, it is not enough that generate good working designs. Designed products should work not only without any failure but also economic, ergonomic, easy manufacturing and suitable for serial manufacturing. It means that designs should give maximum or minimum outputs depend on their input parameters.

In this point, optimization methods can be useful for designers. Mathematical meaning of optimization is obtaining conditions, which give maximum or minimum magnitude of a function (Figure 3), (Rao, 1996).

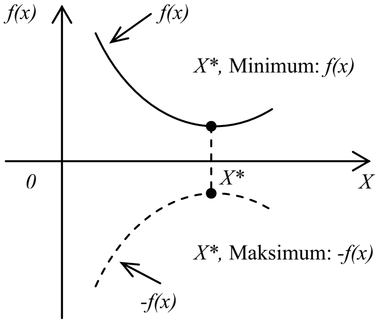


Figure 3 Curve of optimization

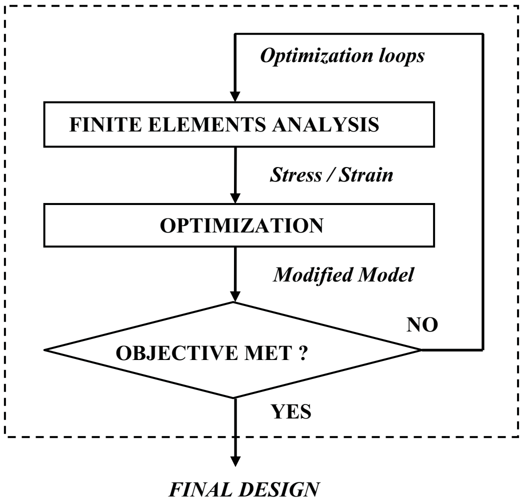


Figure 4 Basic optimization procedure

In the engineering, many different kind of objective functions can be defined under defined boundary conditions for get optimum parameters of the function. These can be defined as minimizing of costs, maximizing of profits, i.e. There are three constituent in an optimization problem. These are design parameters, design constraints and objective function (Sipahi, 2004). There is an iteration procedure in optimization. In this procedure, design parameters are changed depend on design constraints until meeting with objective function. Basic optimization work flow has been shown in Figure 4 (Haubler et al, 2001).

There is not seen any plastic deformation if stress values, which are obtained from simulation of plumbing element, are evaluated according to yield stress point of material.

Displacement values are also in the acceptable values of the plumbing element. As it seen, stress values are a quite bit under the yield point of material. It means that an optimization study can be carried out about determining of optimum wall thickness and optimum body length of plumbing element for optimum stress distribution, gain of weight and suitable geometry.

Ansys-Designxplorer module was used for optimization study about determining optimum wall thickness and optimum body length of plumbing element. Method of "Design of Experiment" (DOE) was based in the module. DOE method is a technique which is used for determining of sample design sets based on analysis results of initial design in the optimization (Ansys Product, 2005). Analysis results, which are depended on predefined initial design parameters, are used for defining the sample design sets and these design sets form a design curve (Figure 5). Another finite element analysis is generated for each design sets. Defined work flow for Designxplorer was applied in order as below;

1. Transmitting the study, which have defined input and response parameters, in to Designxplorer interface.
2. Generating of design curve and design sets.
3. Determining of optimum design set according to objective function.

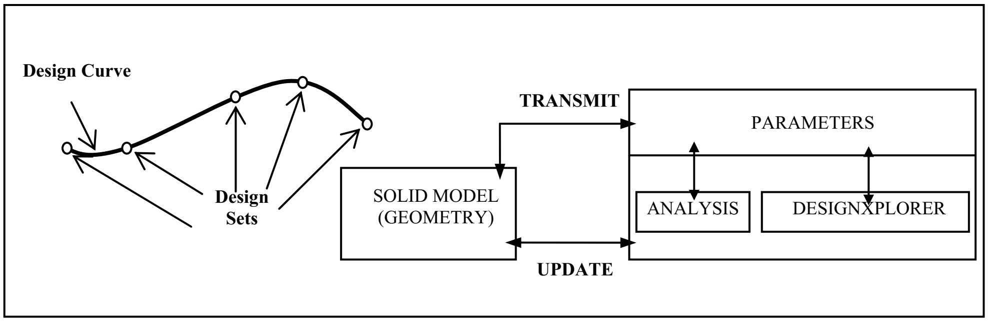


Figure 5 Design sets, design curve, and Designxplorer work flow diagram

Many parameters have been used to generate solid model. But, its all parameters have not been used in the optimization study. Input parameters (design variables) were assigned as thickness and body length. Response parameters were assigned as maximum equivalent stress, maximum displacement and total mass of model. Assigned design variables and design constraints were presented in Table 1.

Table 1 Design variables and design constraints

Design Variables			Initial Design Values	Design Constraints
Wall Thickness	(t)	[mm]	10	$2 \leq t \leq 14$
Body Length	(L)	[mm]	150	$125 \leq L \leq 245$

Numbers of nine design sets have been generated as automatically by optimization module. Then, solutions of pre-defined response parameters have been obtained according to these design sets. Values of the parameters have been presented in Table 2. In addition, variations of response parameters with design variables were presented as three-dimensional graphics in Figure 6. In this way, the values of body length and wall thickness can be compared with the values of equivalent stress, displacement and body mass. As it seen in the graphics, if the values of thickness increase, the values of mass increase but, the values of equivalent stress and displacement decrease.

Table 2 Values of design variables and response parameters

Parameters		**Design Set 1**	**Design Set 2**	**Design Set 3**
Body Length	[mm]	185	125	245
Wall thickness	[mm]	8	8	8
Mass	[kg]	7,7831	6,67	9,0363
Equivalent. Stress (max.)	[MPa]	58,598	63,738	56,395
Displacement (max.)	[mm]	3,2494e-2	3,0063e-002	3,4472e-2
Parameters		**Design Set 4**	**Design Set 5**	**Design Set 6**
Body Length	[mm]	185	185	125
Wall thickness	[mm]	2	14	2
Mass	[kg]	3,655	12.273	3.3894
Equivalent. Stress (max.)	[MPa]	237,68	39.433	269.64
Displacement (max.)	[mm]	0,15623	1.917e-2	0.15519
Parameters		**Design Set 7**	**Design Set 8**	**Design Set 9**
Body Length	[mm]	245	125	245
Wall thickness	[mm]	2	14	14
Mass	[kg]	3.9533	10.236	14.571
Equivalent. Stress (max.)	[MPa]	222.31	40.772	40.178
Displacement (max.)	[mm]	0.15862	1.5948e-2	2.0812e-2

Following part of the study, “Goal Driven Optimization” (GDO) approach was used that is conducted in the Designxplorer module. Values of the design variables were evaluated by this approach according to definitions and objective function for design. GDO is an approach which is used for determining to the optimum values of design parameters in the generated design sets (Ansys product, 2006).

Objectives, constrains and priorities have been defined according to objective function, after created design sets. The objective function was assigned as minimum wall thickness for the plumbing element. In addition, desirable values of body length (one of the design variable), equivalent stress, displacement and mass (response parameters) have been defined. Desired definition of the all parameters was presented in Table 3. Candidate design sets which were obtained from Designxplorer GDO approach were presented in Figure 7 and they were evaluated. These results are occurred by software iterations according to all desired definitions.

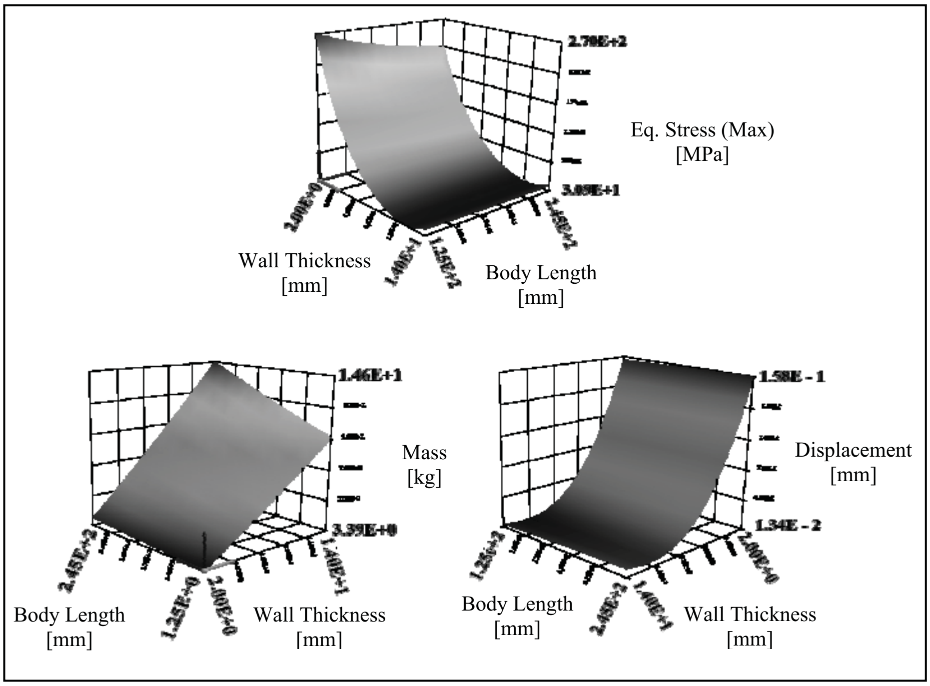


Figure 6 Variations of response parameters with design variables; 3D-graphics

Table 3 Definitions of GDO approach for Objective function

Parameters		Lowest Limit	Upper Limit	Target Value	Desired Value	Importance
Wall Thickness (t)	[mm]	2	14	-	Near Lowest Value	High
Body Length (L)	[mm]	125	245	-	-	-
Mass (m)	[kg]	-	-		-	
Eq. Stress (max)	[MPa]	-	-	145	Near Target Value	High
Displacement (max)	[mm]	-	-	-	-	-

Candidate Designs

Parameter		Candidate A		Candidate B		Candidate C	
Body Length	(L)	244.58	-	219.62	-	192.74	-
Wall Thickness	(t)	3.8693	★★	3.9162	★★	4.0802	★★
Body Mass	(m)	5.484 kg	-	5.2693 kg	-	5.1219 kg	-
Eq. Stress(max.)		145.75 MPa	★★★	146.81 MPa	★★★	145.48 MPa	★★★
Displacement(max.)		0.10372 mm	-	0.1019 mm	-	9.7117e-002 mm	-

Figure 7 Candidate designs and response parameters after GDO approach

Equivalent stress values which were obtained from optimization study were evaluated by referenced yield point of plumbing element's material. Optimum values has been accepted which exists in design set-1 for all design parameters and response parameters. (Figure 7). Design variables have been updated by referenced design set-1. Updated data were re-checked for suitability control on the solid model geometry and Ansys simulation was re-generated for agreement of operating condition with optimization results. All parameters, which were generated before and after optimization study, were presented in Table 4.

Table 4 Values of the Parameters initial design and final design

			Initial design (Before Optimization)	**Final design (After Optimization)**
Wall Thickness	(t)	[mm]	10	3.8693
Body Length	(L)	[mm]	150	244.58
Mass	(m)	[kg]	8.3690	5.4840
Eq. Stress (max.)		[MPa]	51.03	145.75
Displacement (max.)		[mm]	2.44 e-2	1.0372 e-1

RESULTS AND CONCLUSIONS

In this study, three-dimensional parametric solid modeling technique was used for 3D modeling of a sample plumbing element which is used in agricultural fields, and its different geometry configurations have been created using this application. A sample model was selected in the all configurations then its finite element simulation was carried out according to assumed boundary conditions of the plumbing element. Results of the simulation pointed that an optimization study could be carried out. An optimization study was generated on determining of optimal wall thickness and body length of the plumbing element. Final design results was compared with initial design results and some points was presented as below

1. Wall thickness was reduced after optimization study as 6.3071 mm ($t_{optimum}$=3.8683 mm).
2. 2.885 kg was gained against first body weight ($m_{optimum}$=5.4840 kg).
3. Optimal body Length obtained as 244.58 mm after optimization study ($L_{initial}$=150 mm).
4. Maximum equivalent stress value was obtained as 145.75 MPa in final design. If this value compare with initial design stress value, it is seen that stress value has increased but it was also under the yield point of material. Because of that it can be said that this value can be acceptable ratio of design.
5. Maximum displacement value was obtained as 1.0372e-1 mm. It is also over the initial design's displacement value but they are very small values that means it is not affected on probable any design failures by plastic deformations.

In this optimization study, objective functions were focused on optimal wall thickness and optimal body length. However, a sample study carried out about agricultural machine-device design using Computer Aided Engineering applications. Especially, it will be not only very useful that using these applications on machine agricultural elements-devices which are operated under high pressure and high loading conditions but also gaining of cost and time. However, one of the care point is setting of all parameters and interpreting of simulation results correctly. Besides of this point, material properties of design, all working and boundary conditions and desired working life must be considered carefully. The best way can be said that designers should evaluate their own designs according to standards of machine element and they should carry out their design analysis again on final design. These kinds of applications can be applied on many kinds of different agricultural mechanization systems and it can be very successful to obtain optimum design parameters of products.

REFERENCES

1. Ansys Workbench Products Release Notes for V.10.0, (2005)
2. Ansys Workbench software, (2006). Ansys Workbench Material Library
3. Basaran A. (1986). Comparing of Manufactured Helical and Spur Gear Pump's Characteristics, Msc Thesis, Anadolu University, Inst. of Natural and Applied Sciences, Eskişehir-Turkey (In Turkish)
4. Cakmak B. (2002). Assessment of Irrigation System Performance in Irrigation Associations, Kızılırmak Basin, KSU J. Science and Engineering 5(2) (In Turkish)
5. Celik H.K. (2006). Stress Analysis of Gear and Pump's Housing in Gear Pumps Using Finite Element Method. Msc. Thesis, Kocaeli University, Inst. of Natural and Applied Sciences, Kocaeli-Turkey (In Turkish)
6. Haubler P. Emmrich D., Müller O., Iizhöfer B ., Nowicki L., Albers A. (2001). Automated Topology Optimization of Flexible Components in Hybrid Finite Element Multibody Systems Using Adams. 16. European ADAMS Users's Conference 2001 Institute of machine design, University of Karlsruhe, Germany
7. Kanber R. (2002). Irrigation, Cukurova University, Faculty of Agriculture Press, Publication No: 174, Textbook No: A-52, Adana-Turkey (In Turkish)
8. Ozmerzi A. (2001). Mechanization of Garden Plants, Akdeniz University, Faculty of Agriculture, Publication No: 76, Antalya, 146. (In Turkish)
9. Rao S. S. (1996). Engineering Optimization-Theory and Practice, third edition, Purdue University, ISBN 0-471-55034-5, India
10. Sipahi E. (2004). Design Optimization of Foot Valve Components with Ansys. Msc. Thesis, Dokuz Eylül University, Inst. of Natural and Applied Sciences, İzmir-Turkey (In Turkish)
11. Tezer E. (1970). Textbooks and Application notes of Branch of Agricultural Machinery and Devices, Ankara University, Faculty of Agriculture, Ankara-Turkey (In Turkish)

36. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.94:628.16
Izvorni znanstveni rad
Original scientific paper

NUMERICAL SIMULATION AND EXPERIMENTAL COMPARATIVE STUDY OF SEPARATION PROCES IN HYDROCYCLONES WITH DIFFERENT SHAPES OF THE CONE

GEORGE IPATE, TUDOR CASANDROIU

Depart. of Biotechnical Systems, University “Politehnica” of Bucharest, Romania

SUMMARY

This paper describes the results of a study on Computational Fluid Dynamics (CFD) to analyse the complex and multiphase flow behavior in new hydrocyclones with different geometrical shape of conical body using a standard k-ε model, and experimental validation of efficiency separation results. Using these model in a steady-state way led to results that were in good agreement with experimental results. The CFD and experimental research here presented for the hydrocyclone has challenged a number of key understandings of the hydrocyclone flow field and of the particle separation mechanism within. The paper will focus on the issues of efficiency separation model equations, of the role of geometrical shape models, and instabilities present in the flows, with strong interactions between the hydrocyclone geometry and operating parameters, creating a strong turbulent behaviour. These equations can be used to predict the performance of hydrocyclones and make the proper selections, but have their limitations due to the specific system on which the correlation development was based.

Key words: *Hydrocyclones, solid-liquid separation, CFD simulation, separation efficiency, comparative study*

INTRODUCTION

Hydrocyclones are widely used in the treatment of waste water streams from poultry processing from remove feathers, sand and grit, fatty solids, and other wastes. They are essentially a passive device with a short residence time, which makes them easy to run. A review of earlier simplified models for the so-called dilute flow separation in the hydrocyclone, i.e. for relatively small solid concentrations, can be found in a book by

Svarovsky (1981). Mathematical models based on fluid mechanics involving simplifying assumptions have clarified some aspects of the hydrocyclone vortex-flow problem was developed by Monredon et all (1992). Numerical calculations of the separation of suspensions with different particle size distribution in the hydrocyclone computing by Dueck (1999) show that feed solid concentration affects the separation parameters of the hydrocyclone. However the fact that they treat particle-laden flows means that wear and its minimization is a major problem.

The main goal of the paper was to create a computer model of a cyclone separator unit operation. This model allows the user to either design a new cyclone or rate the performance of an existing cyclone. There are many calculation options available to the user. Additional options, such as series cyclones and dip leg sizing, can be incorporated into the model to increase the usefulness of the simulation. Another major goal of the project is to evaluate the performance of the computer model. This was done using experimental investigations and industrial cyclone data. The literature examples were used to produce performance curves on graphs.

METHODS

In this study a commercial CFD (Computational Fluid Dynamics) package called Ansys is applied to build a computational model and calculate results. Computational Fluid Dynamics is the technique which solves problems involving fluid flow by means of computer-based simulation.

Numerical model

Mathematical model of the coupled fluid flow in the hydrocyclones is based on the classical continuity, momentum and turbulent kinetic energy equations.

Lagrangian Tracking Implementation. Particle transport modeling is a type of multiphase model, where particulates are tracked through the flow in a Lagrangian way, rather than being modeled as an extra Eulerian phase. The full particulate phase is modeled by just a sample of individual particles. The tracking is carried out by forming a set of ordinary differential equations in time for each particle, consisting of equations for position, velocity and masses of species. These equations are then integrated using a simple integration method to calculate the behavior of the particles as they traverse the flow domain. The following section describes the methodology used to track the particles.

Integration. The particle displacement is calculated using forward Euler integration of the particle velocity over time step, δ t.

$$x_i^n = x_i^0 + v_{pi}^0 \cdot \delta t \tag{1}$$

Where the superscripts *o* and *n* refer to old and new values respectively and v is the particle velocity. In forward integration, the particle velocity calculated at the start of the time step is assumed to prevail over the entire step. At the end of the time step, the new particle velocity is calculated using the analytical solution to (Eqn. 3):

$$v_p = v_f + (v_p^0 - v_f)\exp(-\frac{\delta t}{\tau}) + \tau \cdot F_{all}(1 - \exp(-\frac{\delta t}{\tau})) \tag{2}$$

The fluid properties are taken from the start of the time step. For the particle momentum, $\varphi 0$ would correspond to the particle velocity at the start of the time step. In the calculation of all the forces, many fluid variables, such as density, viscosity and velocity are needed at the position of the particle.

Momentum Transfer. The forces acting on the particle which affect the particle acceleration are due to the difference in velocity between the particle and fluid and due to the displacement of the fluid by the particle. The equation of motion for such a particle was derived by Basset, Boussinesq and Oseen for a rotating reference frame:

$$\frac{\pi d^3 \rho_p}{6}\frac{dv_p}{dt} = \frac{1}{8}\pi\rho_f d^2 C_D \left|v_f - v_p\right|\left(v_f - v_p\right) + F_b - \frac{\pi d^3}{6}\left(\rho_p - \rho_f\right)\omega\times(\omega\times R) - \frac{\pi d^3 \rho_p}{6}\omega\times v_p \tag{3}$$

where d is the particle diameter, v is velocity, ρ is density, CD is the drag coefficient, Fb is the buoyancy force due to gravity, ω is the rotational velocity, is a vector directed from the axis of rotation, subscript f refers to the fluid and the subscript p refers to the particle. The term on the left-hand side is a summation of all of the forces acting on the particle expressed in terms of the particle acceleration. In this form, the equation of motion has particle acceleration terms on both sides of the equation and would require solution by an iterative method.

- *Term I* is the drag force acting on the particle:

$$F_D = \frac{1}{8}\pi\rho_f d^2 C_D \left|v_f - v_p\right|\left(v_f - v_p\right) \tag{4}$$

- *Term II* is the buoyancy force due to gravity, which for a spherical particle is given by:

$$F_b = \frac{\pi d^3}{6}\left(\rho_p - \rho_f\right)g \tag{5}$$

Where g is the gravitational acceleration.

- Term III is the centripetal force, present only in a rotating frame of reference:

$$F_{centripetal} = -\frac{\pi d^3}{6}\left(\rho_p - \rho_f\right)\omega\times\left(\omega\times R\right) \tag{6}$$

- Term IV is the Coriolis forces, present only in a rotating frame of reference:

$$F_{coriolis} = -\frac{\pi d^3 \rho_p}{3}\omega\times v_p \tag{7}$$

Where v_p is the particle velocity, ω the angular velocity of the rotating frame and *r* is the vector from the axis of rotation to the current particle position.

Geometrical model

In order to ease comprehension, we will call the hydrocyclones with different geometrical ratios, H1_1, H1_2, H2, H3, H4 and H5, respectively. The geometrical dimensions used in the construction of each centrifugal separator are in Table 1 and figure 1. In the this stage of work a parametric three-dimensional geometrical model of the six hydrocyclones whit different geometrical characteristics and cone sections, was designed. For this purpose a CAD-type software (called Solid Works), capable of designing even very complex geometrical objects, was applied (figure 2). Geometry transferred from Solid Works to CFD package preprocessor is much more flexible and accurate then that created with preprocessor itself.

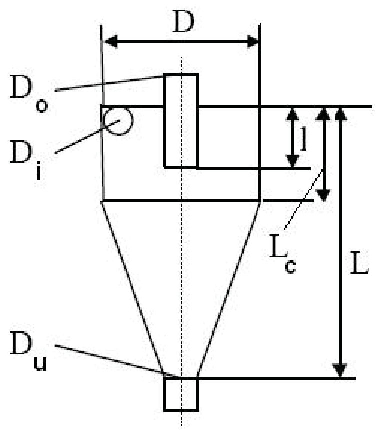


Figure 1 Conventional hydrocyclone dimensions

Table 1 Geometrical characteristic of hydrocyclones

Hidrociclon	**D [mm]**	**D_i/D**	**D_o/D**	**D_u/D**	**l/D**	**L/D**	**L_c/D**
H 1_1	70	0.2	0.28	0.11	1	2.86	0.93
H 1_2	70	0.2	0.28	0.11	0.86	2.86	0.93
H 2	70	0.2	0.28	0.11	0.71	2.57	1.21
H 3	64	0.22	0.31	0.13	0.93	3.13	1.53
H 4	67	0.21	0.3	0.12	0.96	3.16	1.42
H 5	66	0.21	0.3	0.12	0.94	3.26	2.20

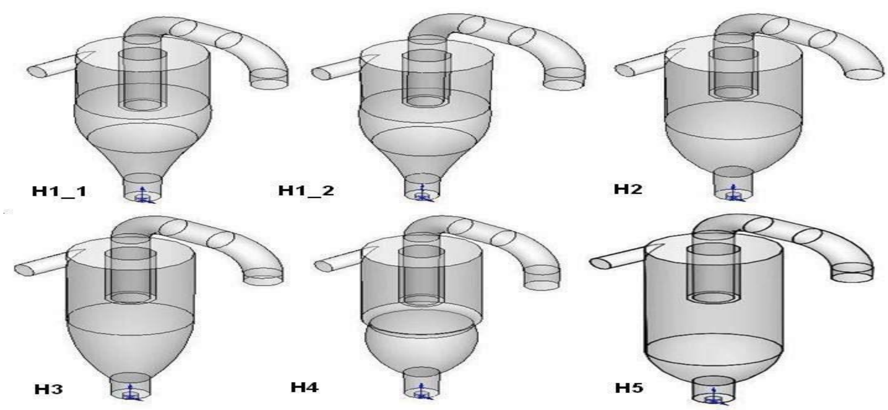


Figure 2 Geometrical shape of hydrocyclones 3D

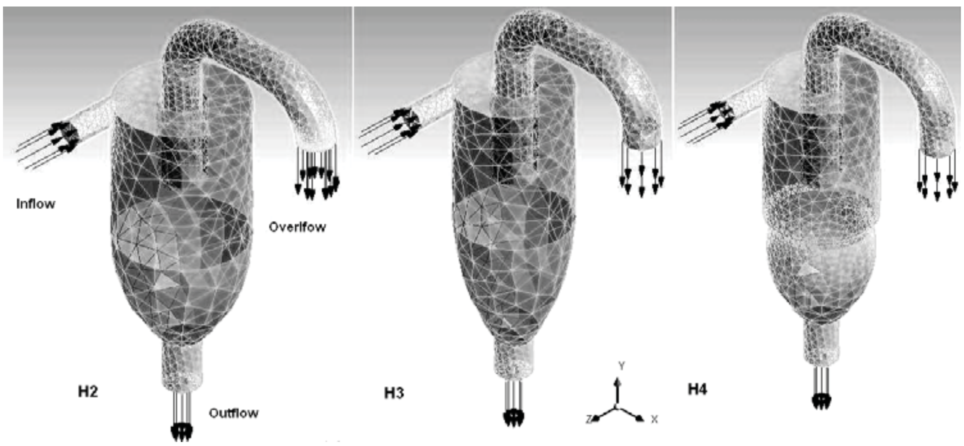


Figure 3 Triangular structure grid of hydrocyclones

The main parameter is the hydrocyclone diameter D. This is the inside diameter of the cylindrical feed chamber. The size of the vortex finder equals 0.71-1D. The next section is the conical sections, typically referred to as the cone section. The termination of the cone section is the apex orifice and the critical dimension is the inside diameter at the discharge point.

CFD Experiments

In this part of our work CFD package Ansys was used to study only the hydrodynamic behavior of a liquid-solid flow in a hydocyclone. Concerning low volume fractions of a solid phase the Eulerian-Eulerian multiphase model and the standard k-ε turbulence model were used. The steady-state problem formulation was used to simulate the start-up of the apparatus. Many types of computational grid was used. It was unstructured triangular grids (Fig. 3) with 2693-3522 nodes, and 7594-15978 tetrahedron-elements. The workstation used for all simulation was Notebook Dell Inspiron-1501, 799 MHz, 500 MB RAM. Convergence was assumed to be reached when no further changes in the interesting happened, and never before the residuals decreased to 10^{-3}.

A mixture of fluid and particles is fed tangentially into the upper or larger diameter part of the hydrocyclone whit different cone sections. The resulting spinning effect forces solids to the wall of the device and they exit from the bottom or apex of the cone, while the cleaned liquid and fine particles exits at the top.

CFD simulation of given multiphase system were computed for different mixture volumetric concentration in range between 0.57-1.25 %. Water was used as a continuous primary phase. The material were used as a solid phase, it was all sands with densities of 2650 kg/m^3. Particles were considerated small spheres with distribution of diameter in range of 5 to 320 μm (figure 4).

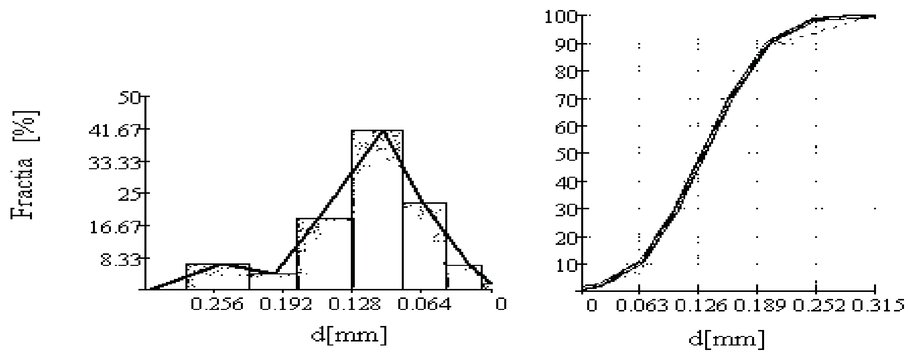


Figure 4 Granulometric distribution curves of solid particles

Separation efficiencies

The total efficiency ET is defined as the mass fraction of solids recovered in the underflow (equation 8). The fraction of fluid that is discharged in the underflow is called flow ratio R_f. Therefore, R_f is the minimal efficiency at which a separator will operate even if no centrifugal action takes place.

$$ET = \frac{M_{su}}{M_s} \tag{8}$$

The reduced total efficiency ETR, also called centrifugal efficiency, is the separation efficiency taking into account only those particles that will be separated due to the centrifugal field. Hence, ETR does not consider the particles that are "separated" due to the flow ratio. The reduced total efficiency is defined by Eqn. (9).

$$ET_R = \frac{ET + R_f}{1 + R_f} \tag{9}$$

Where: ET_R – reduced total efficiency, non-dimensional; ET – total efficiency, non-dimensional; R_f – flow ratio, non-dimensional.

RESULTS AND DISCUSSION

The flow chart shown below illustrates the general solution procedure. The solution of each set of equations shown in the flow chart consists of two numerically intensive operations. In Fig. 5 we present the effect of mixture concentration on reduced cut size diameters for the hydrocyclones.

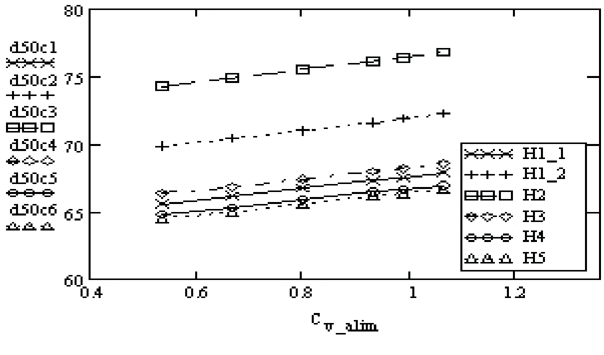


Figure 5 Reduced cut size diameters d50c

In Fig. 6, 7 are shown general velocity profiles for different outlet size to particle diameter ratio. This geometrical parameter is very important for proper apparatus operation. If this value is smaller than 5 μm there is high possibility that the doming can occur and the particle flow in the cell can be blocked. In agreement with published data the descending particle velocity is increasing with growing outlet size to particle diameter ratio (d_{50c}/d). In other words smaller particles move faster. In comparison with experimental data the computed velocities are approximately at the same level.

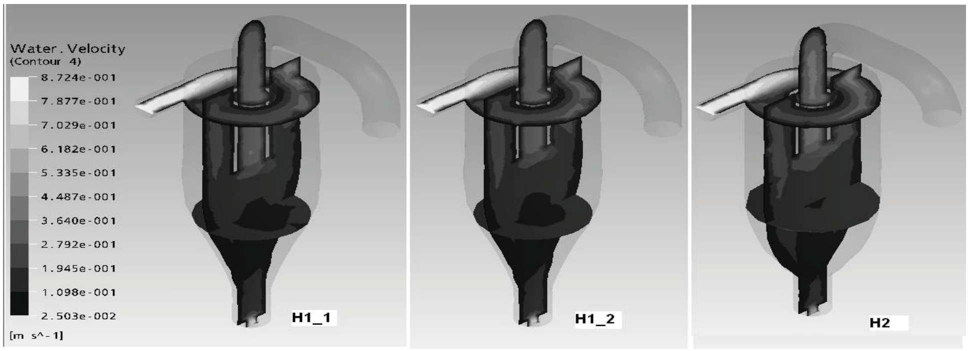


Figure 6 The water velocity profiles in hydrocyclones H1_1, H1_2 and H2

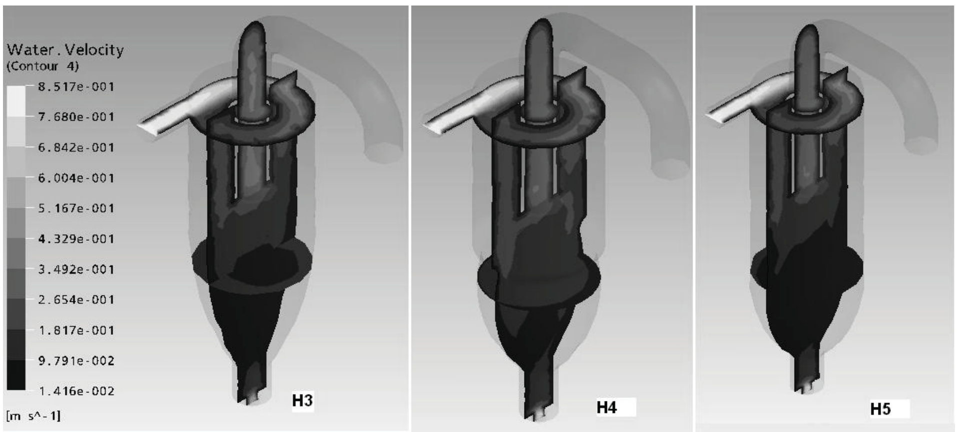


Figure 7 The water velocity profiles in hydrocyclones H3, H4 and H5

CFD Experiments

In this part of our work CFD package Ansys was used to study only the hydrodynamic behavior of a liquid-solid flow in a hydocyclone. Concerning low volume fractions of a solid phase the Eulerian-Eulerian multiphase model and the standard k-ε turbulence model were used. The steady-state problem formulation was used to simulate the start-up of the apparatus. Many types of computational grid was used. It was unstructured triangular grids (Fig. 3) with 2693-3522 nodes, and 7594-15978 tetrahedron-elements. The workstation used for all simulation was Notebook Dell Inspiron-1501, 799 MHz, 500 MB RAM.

Convergence was assumed to be reached when no further changes in the interesting happened, and never before the residuals decreased to 10^{-3}.

A mixture of fluid and particles is fed tangentially into the upper or larger diameter part of the hydrocyclone whit different cone sections. The resulting spinning effect forces solids to the wall of the device and they exit from the bottom or apex of the cone, while the cleaned liquid and fine particles exits at the top.

Fig. 8, 9 documents effect of water inlet velocity on particle flow in the distribution of sand velocity. In accordance with experiments the computed particle velocity increases with increasing inlet flow rate. In this case the difference between simulation and experiment is more slightly. Experiments also show that for the higher particle density, the effect of inlet flow rate is smaller. The effect of polydispersion of particulate phase is just the same. Figs. 6, 7, 8 and 9 show examples of the results from the CFD analysis, all of them apply for the operating inlet velocity condition at 1.463 m/s.

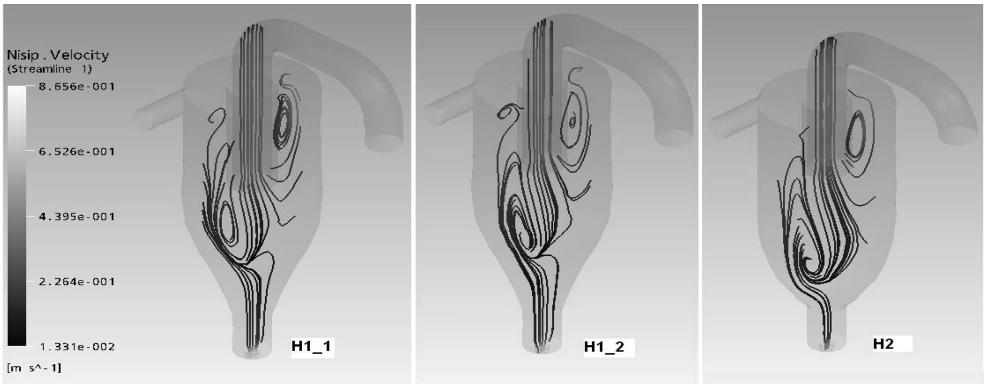


Figure 8 Sand streamlines in plane XY (z=0) for hydrocyclones H1_1, H1_2 and H3

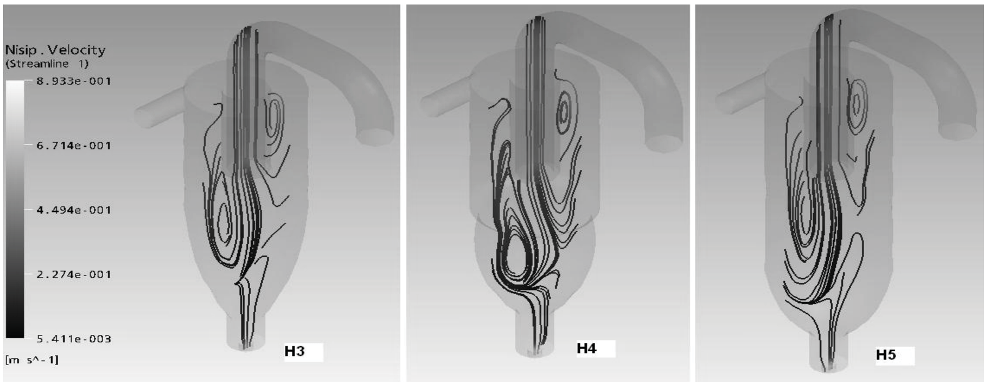


Figure 9 Sand streamlines in plane XY (z=0) for hydrocyclones H3, H4 and H5

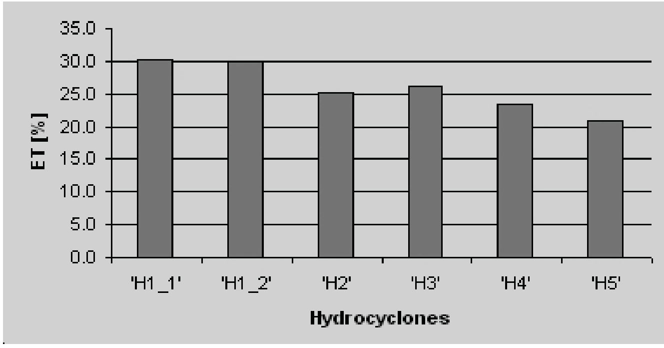


Figure 10 Total efficiency of hydrocyclones

The experimental data of total efficiency, contained in Table 2 agree with the observations done about the influence of the tangential velocity on the particle separation. They are in accordance with the results presented in Fig. 7. In the same operational conditions of the hydrocyclone H5, the hydrocyclone H1_1 had a larger amount of collected solids in the underflow stream.

Table 2 Experimental data of total efficiency and reduced total efficiency

Total Efficiency ET - exp				**[%]**		**Total Reduced Efficiency ET_r- e**				**[%]**	
H1_1	H1_2	H2	H3	H4	H5	H1_1	H1_2	H2	H3	H4	H5
28.390	28.153	21.343	21.257	26.207	18.387	22.089	21.827	17.461	17.923	20.869	15.123
37.201	31.053	28.935	27.223	25.045	17.636	27.386	24.045	22.360	21.322	19.986	14.781
23.987	29.015	29.253	28.286	22.663	17.299	19.164	21.814	22.523	22.037	18.763	14.153
27.593	30.768	28.346	31.602	17.182	24.501	21.428	23.023	21.956	24.335	14.748	19.092
32.330	33.297	23.740	25.594	25.977	20.316	24.103	24.987	19.031	20.082	20.714	16.373
32.229	28.228	20.135	23.349	23.859	27.424	23.937	21.931	16.723	18.750	18.988	20.784

Figure 11 also shows that the actual recovery curve does not decrease below a certain level. This indicates that a certain amount of material is always recovered to the underflow in concordance whit Kawatra (2005).

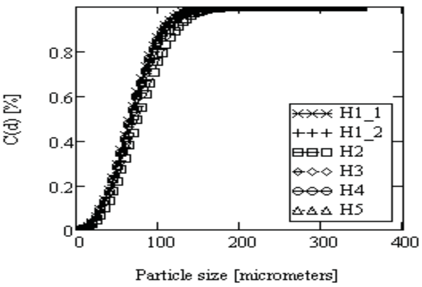


Figure 11 Cumulative distribution curves

If a comparison is made between the minimum recovery levels of solids to the liquid that is recovered, they are found to be equal. Therefore it is assumed that a percent of all size fractions reports directly to the underflow as bypassed solids in equal proportion to the liquid split. As the d_{50c} point changes from one application to another, the recovery curves shift, along the horizontal axis.

Table 3 Distance between each pair of group means

gmdist					
0	1.9879	1.6631	8.5639	5.7209	12.835
1.9879	0	3.6708	18.139	9.4327	9.7527
1.6631	3.6708	0	7.3717	2.4442	7.2337
8.5639	18.139	7.3717	0	5.8761	23.98
5.7209	9.4327	2.4442	5.8761	0	6.6433
12.835	9.7527	7.2337	23.98	6.6433	0

A multivariate analysis of variance (MANOVA) was be used to test the influence of variables in changes in the performance the separation process in hydrocyclones whit different geometrical shapes of cone. The ***gmdist*** field measures the distances between each pair of group means and is presented in table 3. As might be expected, the multivariate distance between the hydrocyclones H5 and H1_1 (12.835) is larger than the difference between more closely spaced geometry hydrocyclones (1.663 and 1.987). The diagrams that show clusters of the groups formed using the distances between their means is presented in figure 12.

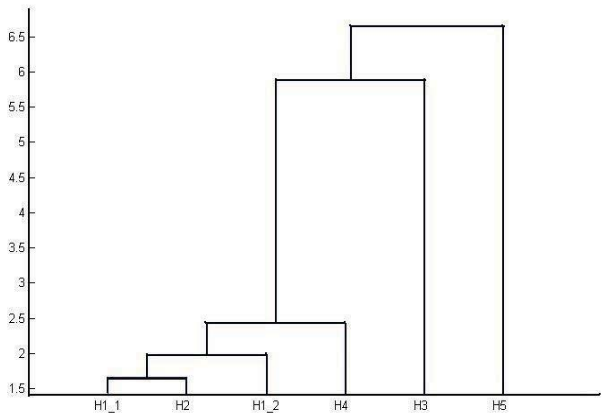


Figure 12 Diagram of the distances between group means

The parabola type of cone part could increase the separation efficiency, separation sharpness, cut size and capacity, and decrease the energy loss coefficient and flow split.

CONCLUSIONS

Simulation captured important trends in influence of system parameters (particle size and density, inlet velocity of carrier phase) on particle velocity. Numerical results also show that type and shape of computational grid are not elementary parameters.

According to the experimental data and the fluid dynamic simulations, we were able to conclude, in the comparative study between the hydrocyclones whit different geometrical shapes of cone that the separation process in hydrocyclones resulted in changes in the performance of those separators.

The results in this study are valuable for understanding the behaviors of particle motion in the separation process inside hydrocyclones, and provide some valuable information for finding some effective way to improve the separation performance in the hydrocyclone.

REFERENCES

1. Dueck J., Matvienko O., Neeße Th. (1999) Numerical calculations of the separation of dense suspensions with different particle size distribution in the hydrocyclone, In Proceedings of the 9th Workshop on Two-Phase-Flow Predictions, M. Sommerfeld M. (eds), Merseburg, pp 194-202
2. Ipate G., Casandroiu T. (2007). Computer simulation of liquid-solid separation - hydrocyclone whit two conical sections. Modelling and optimization în the machines building field, MOCM-14, Romanian Technical Sciences Academy, 2:160-167
3. Ipate G., Casandroiu T. (2007), Numerical study of liquid-solid separation process inside the hydrocyclones whit double cone sections, Scientific Bulletin of U.P.B., 69: 19-28
4. Ipate G., Casandroiu T. (2007). A three-dimensional simulation of separation proces in hydrocyclones whit different generatrix of the cone. Proc Symposium "Engineering and Management of Sustainable Development in Agriculture, Transports and Food Industry", INMATEH-III, Bucharest, 25:168-176
5. Kawatra S. K. (2005). Optimization of Comminution Circuit Throughput and Product Size Distribution by Simulation and Control Final Technical Report
6. Monredon T.C., Hsieh K.T. Rajamani R.K. (1992). Fluid flow of the hydrocyclones: an investigation of the devices dimensions, International Journal of Mineral Processing 35: 65-83
7. Svarovsky, L. (1981). Solid-liquid Separation. Butterworths, London

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.37:634.1
Prethodno priopćenje
Preliminary communication

SYNTHESIS OF THE DRIVING MECHANISM USED TO MANUFACTURE THE MACHINES FOR FRUIT TREE DIGGING PITS

VICTOR MOISE, BARBU GRECU, GHEORGHE VOICU, ILEANA DUGAESESCU

University POLITEHNICA of Bucharest, Splaiul Independentei, no.313, 060032, Bucharest, Romania, e-mail: victor.moise@yahoo.com; ghvoicu_2005@yahoo.com

SUMMARY

The mechanisms of machines for digging pits have the role to lead a tracing point on the vertical direction. To avoid the damage of the machine during the working, the deviation of the tracing point from the vertical direction must be in the assessed limits.

In this paper we present the kinematic synthesis of the elements dimension of the driving mechanism, which represents the basis for the achievement of the digging machine. To write the necessary equations for the accomplishment of the kinematic synthesis of the mechanism, we used the methods of mechanisms theory. Usually, in the mechanisms synthesis appears the systems with a great number of nonlinear equations, whose solving are used the adequate numerical methods.

***Key words**: numerical methods, digging machines, tree digging*

INTRODUCTION

The machines for fruit tree digging pits have the role to move a tracing point on the vertical direction. In practice, are used different mechanisms by their help obtaining precise mathematical curves [1, 2, 7, 14]. Some of these mechanisms contain a great number of elements, in which case it can be a disadvantage from constructive point of view. Therefore, for the most part, we carry out the synthesis of other mechanisms with a low number of elements, which can be approximate certain known curves. The curves approximation it is made for certain number of data points. The number of the positions of a tracing point of the mechanisms (the point of the curve approximation) is made by the complexity of the used mechanism. Thus, the more independent number of contours of the used mechanisms is greater the number of the imposed positions of the tracing point is bigger, as shown in the following paragraph.

MATERIAL AND METHOD

There are two methods that can be used to write the equations: synthesis method for curves approximation and synthesis method for guiding a segment belonging to a driving rod. Following, the two methods will be briefly presented.

Plane mechanisms' synthesis for curve approximation

The kinematics scheme for a complex mechanism is given in figure 1. The tracing point ***T*** occupies ***p*** positions. Data regarding the unknowns and the number of equations that can be written must be determined, in order for the system to be consistent and determined.

For the beginning, the data regarding the unknowns will be discussed. In the mechanisms' synthesis for the approximation of a given curve, both constant and variable data appear.

The unknown constant data are:

a) $n_1 = n$, number of elements;

b) $n_2 = 4(N-1)$, the number of parameters to be attached to the initial contour of (N – 1) independent contours (N is the mechanisms' independent contours);

c) $n_3 = 3$, number of parameters necessary for base positioning;

d) $n_4 = 2$, number of parameters necessary to position a point on an element;

e) $n_5 = -C_t$, number of parameters which are eliminated due to the insertion of C_t translation couple.

In order to identify the variable parameters, let's consider p positions of the tracing point, which means p positions of the mechanism. In this case there are:

f) $n_6 = m \cdot p$, variable data. These parameters are the angles made by the vectors attached to the mechanism's elements with the OX axes, as well as the variable parameters in the translation couples (if they exist).

From the mechanisms structure [1, 2, 7, 8, 10, 11, 12, 14] it is a matter of knowledge that: $n = 2N + M + 1$, $m = 2N + M$, where M is the mechanism's degree of mobility.

The total number of unknowns is:

$$Unknowns\_No = n_1 + n_2 + n_3 + n_4 + n_5 + n_6 = 6N + M + 2 - C_t + 2N \bullet p + M \bullet p. \quad (1)$$

In order to establish the equations number, it is considered that:

a) a mechanism with N independent contours, whereby $2N$ scalar equations are resulting; for the p mechanism's positions $2N \cdot p$ equations result;

b) for the $OABTO$ contour (fig.1), a vector equation is written; when projected on the OXY coordinate system's axes, this equation leads to two scalar equations. If p mechanism's positions are considered, there are resulting $2p$ scalar equations.

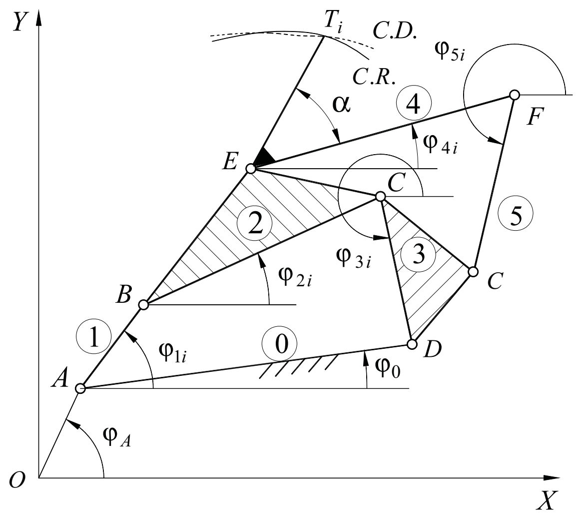


Figure 1 Complex mechanism with articulated rods

The total number of equations is:

$$Eq\_Number = 2N \cdot p + 2p\,. \tag{2}$$

From the compatibility conditions it is found that:

$$Unknowns\_No = Eq\_Number, \tag{3}$$

which means:

$$p = \frac{6N + M + 2 - C_t}{2 - M}\,. \tag{4}$$

Depending on the mechanism's degree of mobility, equation (4) gives the number of positions the tracing point T can occupy:

$$M = \begin{cases} 1, \text{results } p = 6N + 3 - C_t; \\ 2, \text{results } p = \infty. \end{cases} \tag{5}$$

From equation (5) one can notice that $p = \infty$ for $M = 2$ mechanism's mobility, which means that the tracing point T can occupy an infinity number of positions in the mechanism's region of operation, which was expected.

If $n_6 = (m-1)p$ is considered in the equations-unknowns balance, then equation (3) leads to:

$$p = \frac{6N + M + 2 - C_t}{3 - M} . \tag{6}$$

For different values of the mobility degree, different relations are attained, which help to calculate the maximum number of positions of the tracing point T:

$$M = \begin{cases} 1, \text{results } p = 3N + \frac{3}{2} - \frac{C_t}{2}; \\ 2, \text{results } p = 6N + 4 - C_t; \\ 3, \text{results } p = \infty. \end{cases} \tag{7}$$

Synthesis of guiding mechanisms

In case of guiding mechanisms synthesis, besides the positions of the tracing point T, the relative positions between the segments T_1Q_1 and T_iQ_i are required (fig. 2):

$$\theta_i = \varphi_{ni} - \varphi_{n1},\ i = \overline{2, p} . \tag{8}$$

One can notice that (p-1) equations (corresponding to the relative angles θ_i) are added to those $2N \cdot p + 2p$ written for curve approximation. From the compatibility condition (*Unknowns Number = Equations Number*) results:

$$6N + M + 2 - C_t + 2N \cdot p + M \cdot p = 2N \cdot p + 2p + (p-1) . \tag{9}$$

The number of positions that can be occupied by a segment of the driving rod can be determined from equation (9):

$$p = \frac{6N + M + 3 - C_t}{3 - M} . \tag{10}$$

If different values are given to the degree of mobility in equation (10), then:

$$M = \begin{cases} 1, \text{results } p = 3N + 2 - \dfrac{C_t}{2}; \\ 2, \text{results } p = 6N + 5 - C_t; \\ 3, \text{results } p = \infty. \end{cases} \tag{11}$$

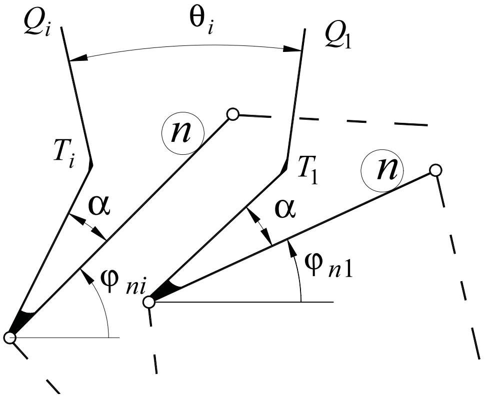


Figure 2 The θ_i relative angles

In equation (10) one can notice that, if $M = 1$ and the number of translation couples is odd, an unknown must be imposed. If $M = 3$, then the number of positions is infinite, which was expected

The number of the positions given in the relations (4), (6) and (10) is modified if we establish certain dimensions by the project theme.

NUMERICAL EXAMPLE

There is the directing mechanism, given in figure 3, used at the achievement of a machine for fruit tree digging pits. It is required to determine the mechanism dimensions, thus the tracing point *T* (see figure 2) to be approximate with a straight line.

For the writting the necessary equation of mechanisms'synthesis is used the contours method. Thus, the independent contours ABCEA, ABFG and ABTA can be written the vectorial equations:

$$\begin{aligned} &\overline{AB} + \overline{BC} = \overline{AE} + \overline{EC}; \\ &\overline{AB} + \overline{BF} = \overline{AG} + \overline{GF}; \\ &\overline{AB} + \overline{BT} = \overline{AT}. \end{aligned} \tag{12}$$

As part of the vectorial equation (8) there are presented constant and variable parameters. The constant parameters are: XE, XG, YG, AB, BC, BF, FG, BT. The variable parameters are the angles $\varphi_{1i}, \varphi_{2i}, \varphi_{4i}, \varphi_{5i}$ and S_{4i} in the D prismatic couple.

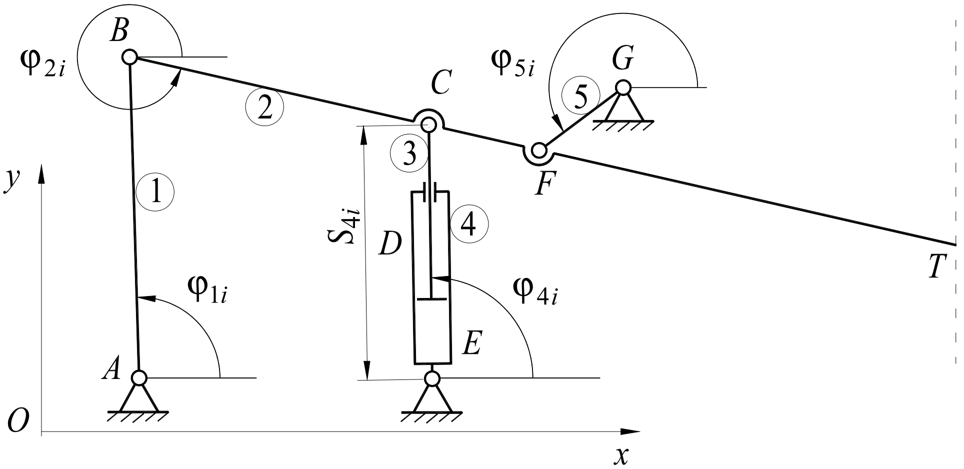


Figure 3 The kinematic scheme of the mechanism

By projecting equations (8) on the xOy coordinate system's axes are obtained the scalar equations:

$$\begin{cases} AB\cos\varphi_{1i} + BC\cos\varphi_{2i} - S_{4i}\cos\varphi_{4i} - XE = 0; \\ AB\sin\varphi_{1i} + BC\cos\varphi_{2i} - S_{4i}\sin\varphi_{4i} = 0; \\ AB\cos\varphi_{1i} + BF\cos\varphi_{2i} - FG\cos\varphi_{5i} - XG = 0; \\ AB\sin\varphi_{1i} + BF\sin\varphi_{2i} - FG\sin\varphi_{5i} - YG = 0; \\ AB\cos\varphi_{1i} + BT\cos\varphi_{2i} - XT_i = 0; \\ AB\sin\varphi_{1i} + BT\sin\varphi_{2i} - YT_i = 0; \\ i = \overline{1, p}\ . \end{cases} \tag{13}$$

Equalling the number of the equations with the number of unknowns, results $8 + 5p = 6p$ so we obtain $p = 8$, that imposes 8 positions for the tracing point *T*.

The equations (13) represent a system with 48 nonlinear equations and 48 unknowns. The solving of nonlinear equations system (13) is made by using the gradient method [3, 4, 5, 6, 9, 13]. The number of the equations system (13) being great, the determination of the value of the functional matrix elements can be done by the numerical method.

For the positions of the tracing point *T* presented in table 1, we obtain the dimensions of the mechanism elements and the positions of the frame joints (table 2).

Table 1 The positions of the tracing point T

$XT_i, i = \overline{1,8}$	2.352	2.352	2.352	2.352	2.352	2.352	2.352	2.352
$YT_i, i = \overline{1,8}$	0.223	0.363	0.503	0.643	0.783	0.923	1.063	1.203

Table 2 The dimensions of the mechanism elements and the positions of the frame joints

XE	**XG**	**YG**	**AB**	**BC**	**BF**	**FG**	**BT**
0.569944	0.783524	0.787194	0.784537	0.554568	0.608553	0.255711	2.435267

CONCLUSIONS

Using adequate numerical methods, we can do the synthesis of each mechanism for the curve approximation. The number of the assessed points depends on the mechanism indepe-ndent contours number, therefore the synthesis equation systems must be compatible and determined. The obtained curve deviation refers to the known curve depends of the used solving method and of the computer system performance.

REFERENCES

1. Artobolevski, I.I., *Theorie des mecanismes et des machines*. Editions Mir, Moscou, 1977.
2. Artobolevski, I.I., *Teoria mecanismelor şi a maşinilor*. Editura Tehnică, Bucureşti, 1955
3. Bakvalov, N., *Methodes numeriques*, Editions Mir, Moscou 1976
4. Chapra, S.C., Canale, R., *Numerical methods for engineers*, Second edition, McGraw-Hill, Inc., New York, 1988
5. Demidovitch, B., Maron, I., *Elements de calcul numeriques*, Editions Mir, Moscou, 1976
6. Dorn, W.S., Mc Cracken, D.D., *Metode numerice cu programe în FORTRAN*. Editura Tehnică, Bucureşti, 1976
7. Manolescu, N., Kovacs, Fr., Orănescu, A., *Teoria mecanismelor şi a maşinilor*. Editura Didactică şi Pedagogică, Bucureşti, 1972
8. Moise, V., Simionescu, I., *Mecanisme plane cu bare articulate*. Editura Printech, Bucureşti 1999
9. Moise, V., Maican, E., Moise, Şt.I., *Metode numerice. Teorie şi aplicaţii*. Editura Printech, Bucureşti, 2004
10. Moise, V., Simionescu, I., Ene, M., Neacşa, M., Tabără, I.A.: *Analiza mecanismelor aplicate*. Editura Printech, Bucureşti, 2007
11. Pelecudi, Chr.: *Precizia mecanismelor*. Editura Academiei R.S.R., Bucureşti, 1975
12. Pelecudi, Chr., Maroş, D., Merticaru, V., Pandrea, N., Simionescu, I.: *Mecanisme*, Editura Didactică şi Pedagogică, Bucureşti, 1985
13. Salvadori, G.M., Baron, L.M.: *Metode numerice în tehnică.* Editura Tehnică, Bucureşti, 1974
14. Simionescu, I., Moise, V.: *Mecanisme*. Editura Tehnică, Bucureşti, 1999

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 636.085.625:636.5.084.1
Stručni rad
Expert paper

TESTING OF PELLETING EFFICIENCY, QUALITY AND EFFECT OF PELLETED FEED ON BROILER PERFORMANCE

MENTOR THAQI, ILIR ZENELAJ, FATMIR JAKA

Faculty of Agriculture, University of Pristina, Kosovo, mentorth@hotmail.com

ABSRACT

The positive effects of pelleting: improved feed efficiency, improved digestibility, higher feed density, no feed ingredient separation, decreased feed wastage, better bacteriological quality, improved growth. Disadvantages of pelleting: investment in equipment, maintenance cost, risk from destruction of some vitamins, amino acids, enzymes. A new pelleting facility in Kosova was investigated on pellet efficiency and quality and effect of pelleted feed on broiler performance.

Trial 1 included the influence of horizontal barrel conditioner speed on pelleting efficiency and quality. If mash material speed in the conditioner was 8.19 kg/min, mash temperature after mixing with steam was 81^{o}C, capacity 438 kg/h, durability index 88.9, pelleting efficiency 150kw/t, pelleting cost was 6€/t. When speed was 16.63 kg/min at 71^{o}C, capacity 997 kg/h, durability index 72.3, pelleting efficiency 71kw/t, pelleting cost decreased to 3€/t. At maximum speed of 28,45 kg/min at 50^{o}C, capacity 1,707 kg/h, durability index 48, pelleting efficiency 46kw/t, pelleting cost decreased to 1,94€/t.

Trial 2 included the effect of mash and steam pelleted feed on broiler performance. The average feed consumption of 300+300 broilers after 44 days was 5.20 kg/bird when pelleted feed was used compared with 5.54 kg/bird of mash, feed consumption of pelleted feed was 0.34 kg/bird less than mash, or 6.18%, cheaper feeding with pellets was € 0.13. Weight per bird was higher at pellet feeding with 2.65 kg/bird compared with mash feeding of 2.53. The difference on weight for pellet feeding was 0.12 kg/bird or 4.35% and difference in Euro was 0.23€/bird. Conversation ratio for pelleted feed was 1.96 compared with 2.19 at mash feed.

***Key words**: Pelleting, Pellet durability index, Feed consumption, Bird weight, Conversation ratio*

INTRODUCTION

Feed constitutes about 60-70 per cent of the total cost of broiler production. Various physical feed forms, mash or pellet can directly influence the broiler performance and cost of production of broiler meat. In Kosovo broilers are generally fed with mash diets, until the new pelleting facility started with operations in 2007. Currently around 20% of broilers are fed with pellet diets, and other 80% with mash diets. Pelleting is a process of transformation of a soft, often dusty feed into a hard pellet accomplished by compression, extrusion and adhesion. The advantage in using pellets is handling and storage and a little waste in feeding. Other positive effects of pelleting are improved feed efficiency, improved digestibility, no feed ingredient separation, better bacteriological quality, and improved growth. Disadvantages of pelleting are investment in equipment, maintenance cost, risk from destruction of some vitamins, amino acids, enzymes.

The pelleting of poultry rations improves weight gain and feed efficiency when compared with unprocessed mash diets. This improvement in performance is partly due to increase of feed intake. Birds fed pellets also use less energy for feeding therefore the energy available for growth is increased. This positive response can be achieved if the pellet is of good quality. A diet with good pellet quality has high pellet durability and a low level of fines. Durability is the pellet ability to remain intact during handling and transportation. Low durability results in breakdown and the accumulation of fine particles in the feed. The accumulation of fine particles will give poorer growth.

Many authors reported that pellets had better-feed efficiency up to six-week age of birds Asha Rajini *et al*. (1998a,b). Moran (1990) observed that pelleting of feed improves the body weight of poultry. Bolton and Blair (1977) reported that feed intake of broilers is up to 10 per cent greater with pellets compared with mash. But McAllister *et al. (2000)* reported no significant differences in live weight gain between birds fed on mash diet and those given complete pelleted diets.

The study evaluated the technical characteristics of new pellet mill, testing a pellet quality of broiler feed and the influence of barrel conditioner speed on pelleting efficiency and quality. The pellet quality was presented through the durability index. Feed manufacturing practices have significant effect on pellet durability. Except raw material composition, grinding of raw materials and conditioning of feed are regarded as the most influential factors affecting pellet durability (Behnke, 1996).

This study also compared the effect of feeding mash and pellet feeds on growth rate, feed efficiency and other productive characters of broiler trying to find out the most economic and suitable form of feed.

MATERIALS AND METHODS

Trial 1 included pelleting efficiency and quality of broiler feed. This study was carried out at JAZI Company that is located in Gjakova, Kosovo. JAZI Company is one of the main feed producers in Kosovo that supplies its products to most parts of the country and also in regional countries.

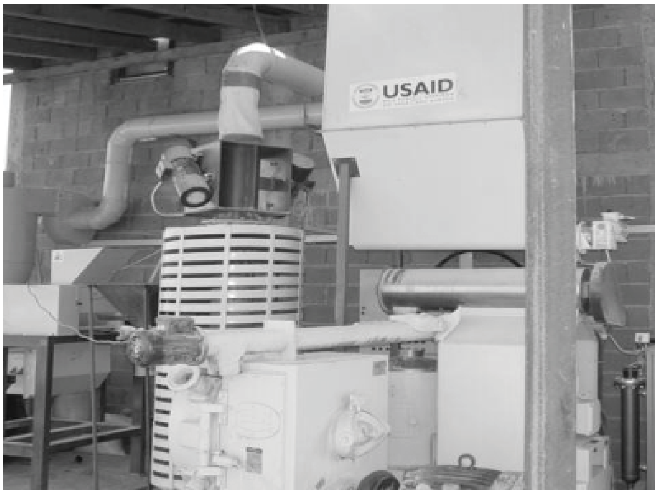


Photo 1 Pelleting feed mill line

The new pelleting feed mill line (Photo 1) has a pellet mill with a capacity of 1.500 kg/h run by 30 kw main motor. This production line is manu-factured by Metal-Matik Company located in Beocin, Serbia. Die pres of 6mm was used at this pellet mill during the production and also when we test a pellet efficiency and quality. Pellet mill utilizes two rollers within the pelleting chamber.

The pellet mill conditioner is the blending mechanism for adding steam to the feed. The conditioner consists of a chamber with an agitator to blend additives into the feed. There are two connections in the conditioner for pipes for the inputs of liquids.

Photo 2 Adjustment of mash material speed in conditioner

During conditioning, feed mill particles absorb steam making it more pliable for pelleting, also enabling gelatinization of feed components. To obtain the best results form steam addition, the conditioner paddles of the shaft are easily adjustable. There is a mechanism to adjust the mash material speed in conditioner that influenced pelleting production rates and quality of pelleted feed (Photo 2).

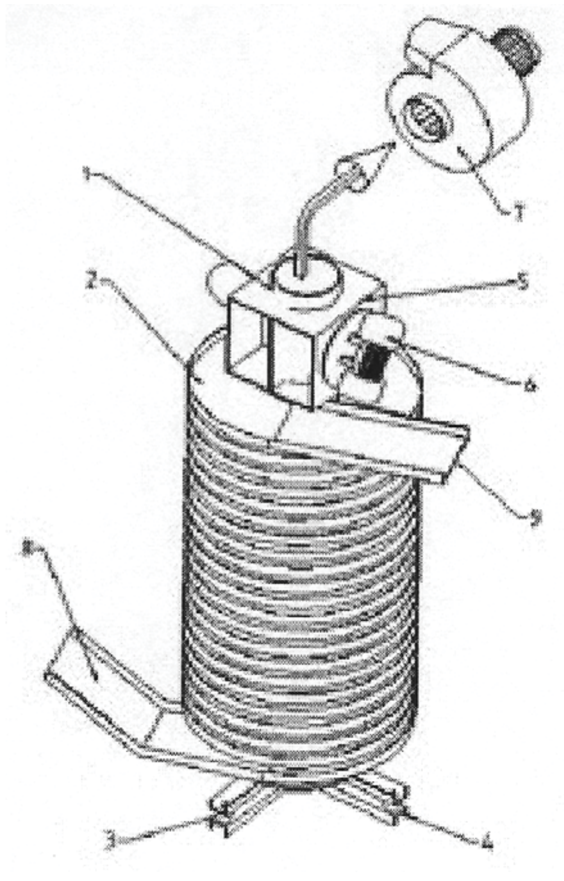


Figure 1 Vertical pellet cooler

The vertical cooler SH 1500/600 with a capacity of 1,5 t/h (figure 1), has a simple design, requires little maintenance and low energy cost. Pellets are directed in the bottom part of the cooler. As the pellets flow through, they are exposed to high velocity air which cools and dries them. The air is drawn through the pellets via a fan connected to the center section. Under the influence of vibration, material moves by spiral upwards at the top spirals to the discharger. Pellet discharging is with a smooth, constant flow that is very good for feeding crumble rolls.

Photo 3 Crumbles for feeding broilers

Crumbler DVS 2500 was used to break pellets into smaller particles (Photo 3) for feeding of broilers from the first to day 44. The crumbler with capacity of 2,5 t/h, has two cast hardened rolls which are corrugated. The rolls are mounted on anti-fiction bearings which are bolted at a steel frame to guaranty proper alignment of the rolls, keeping them in parallel. The level of grinding is regulated by changing the gap between the rolls.

The formed and crumbled pellets are screened to remove oversized particles and fines. As this plant is producing two diameters of products, it has a screener with two decks.

Testing of pellet durability: Pellet need to be durable enough to withstand numerous mechanical conveying and still have a high quality. Pellet durability is determined by tumbling a test sample for ten minutes at 50 rpm in a box of 300mm x 127mm. A sample of pellets (500 gram) immediately after cooling, after tumbling for 10 minutes, was removed, sieved and the percent of whole pellets was calculated. Pellet durability is defined as:

$$\text{Durability} = \frac{\text{Weight of pellets after tumbling}}{\text{Weight of pellets before tumbling}}$$

Composition of the experimental diet: Feed provided from 1 to 44 days of age was formulated to nutritionally support optimal performance of broilers (Table 1). The same composition of diet was used for the mash and pelleted feed.

Table 1 Broiler feed (mash and crumbled pellet) offered from 1 to 44 days of age

Composition Ingredients	**Starter**	**Grower**	**Finisher**
Corn	60.00	60.8	60.8
Soybean mill	37.75	18.0	18.0
Wheat bran	-	6.00	6.00
Fat	1.00	-	-
Limestone	-	5.00	10.00
Sacox	1.25	-	-
Clinacox	-	1.25	1.25
Total	100.0	100.0	100.0

Trial 2 included the effect of mash and steam pelleted feed on broiler performance. This study was carried at Aves Prom poultry farm that is located in Mitrovica, Kosovo.

Photo 4 Ross 308 broilers researched in this work

Six hundred Ross 308 (Photo 4) one-day-old chicks were divided in two groups and half of them fed with mash and half with crumbled pellets. Mash and pelleted feed provided to chicks from the first day until the day 44 was starter, grower and finisher.

RESULTS AND DISCUSSION

Trial 1 included the influence of horizontal barrel conditioner speed on pelleting efficiency and quality. The mash material was passed through the conditioner in three different speeds, from lower to higher speed. When mash material speed in the conditioner was 8.19 kg/min, mash temperature after absorbing steam was 81oC, production rate 438 kg/h, durability index 88.9, pelleting efficiency 150 kw/t, pelleting cost was 6€/t. When speed was 16.63 kg/min at 71oC, production rate 997 kg/h, durability index 72.3, pelleting efficiency 71kw/t, pelleting cost decreased to 3€/t. At maximum speed of 28,45 kg/min at 50oC, production rate 1,707 kg/h, durability index 48, pelleting efficiency 46kw/t, pelleting cost decreased to 1,94€/t. The results of barrel conditioner speed effect on pelleting efficiency and quality are given in table 2.

Table 2 The effect of barrel conditioner speed on pelleting efficiency and quality

Mash speed in conditioner kg/min	**Mash temperature °C**	**Capacity kg/h**	**Durability index %**	**Pelleting efficiency kw/t**	**Pelleting cost Euro**
8.19	81	438	88.9	150	6.00
16.63	71	997	72.3	71	3.00
28.45	50	1,707	48.0	46	1.94

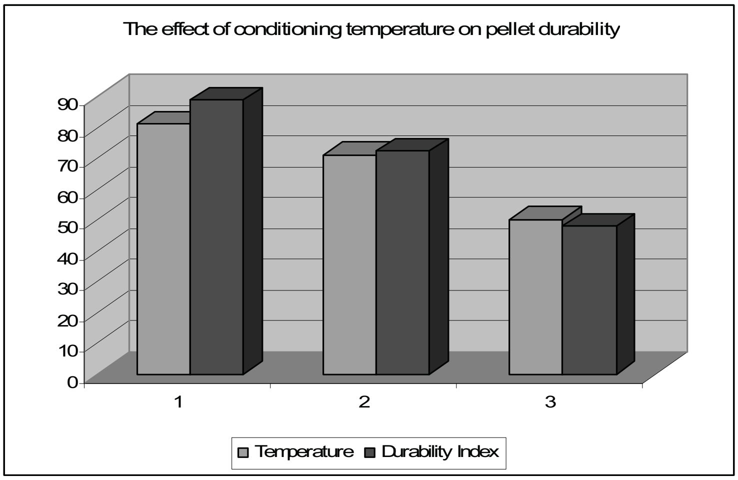


Fig 2 The Effect of Conditioning Temperature and Time on Pellet Durability

Response in weight gain and feed efficiency of birds fed pelleted diets is substantially improved when the diet is of good pellet quality, high pellet durability and low levels of fines. The mash speed in barrel conditioner had the direct impact on pellet mill capacity and durability index. The durability index of first mash speed (88.9) and second mash speed (72.3) shows a good pellet quality, but the third mash speed durability index (48.0) shows low and not satisfied pellet durability and high levels of fines. Reduction in pellet durability and hardness is a result of a lack of particulate binding due to a short time when mash material passed through the conditioner.

The high production rate at maximum speed of barrel conditioner does not justify the high quality of pellet. As poor pellet quality results in the occurrence of fines which have a negative effect on feed intake, reducing live-weight and increasing FCR, the maximum mash material speed in conditioner it is not recommended. The effect of conditioning temperature and time on pellet durability is presented at figure 2.

Trial 2 included the effect of mash and steam pelleted feed on broiler performance.

Different growth performance parameters average feed consumption, body weight gain, broiler price were presented in the Table 3.

Table 3 Effect of mash and pellet feeding on broiler performance

Feed form	Total feed consum kg	Feed/bird kg	Total weight kg	Weight/bird kg	Conversion ratio
Mash	1,600,867	5.54	731,268	2.53	2.19
Pellet	1,501,967	5.20	764,509	2.65	1.97

Feed consumption: The higher feed consumption of 300+300 broilers after 44 days were at broilers fed with mash (5.54 kg/bird) compared with broilers fed with pellets (5.20 kg/bird). Feed consumption of pelleted feed was 0.34 kg/bird less than mash, or 6.18%. This result shows cheaper feeding with pellets for € 0.13/bird compared with mash diets.

The result is similar to Jensen *et al*. (1962) who observed that chickens fed with mash and pelleted diets consumed approximately the same quantity of diet, but pellet-fed birds spent less time in the act of consuming meals. Recent studies using modern strains of commercial broilers have reported similar responses in feeding behavior (McKinney and Teeter, 2003). It could then be concluded that the increased growth rate of birds fed pelleted diets is accounted for by a reduction in energy expenditure during meal consumption. Reddy *et al*. (1961) observed that chicks fed pellets spent approximately 4% of their day in the act of consuming feed compared with 15% for mash-fed birds.

Compared with observation of above mentioned authors, this result is different from results presented by Bolton and Blair (1977) who reported that pellet consumption is higher for 10 per cent with crumble or pellets than with mash. Bertechini *et al*. (1992) also reported that pelleted diets consumption is higher compared with mash diets. If this observation is correct, the high rate of feed wastage at group fed with mash (that was not investigated at this work) could be the reason for higher mash feed consumption.

Body weight: The highest body weight was observed in group fed with pellets (2.65 kg/bird) compared with group fed with mash (2.53 kg/bird). The difference on weight was 0.12 kg/bird or 4.35% and difference in Euro was 0.23€/bird. This result agreed with Munt *et al*. (1995) and Preston *et al*. (2000) who showed poorer performance of mash fed birds than birds fed on crumble and pellet.

Feed conversion ratio (FCR): The higher (2.19) FCR value was observed in mash group, which indicated low feed conversion efficiency. FCR value was lower in group fed with pellet (1.96). Similar results were obtained by Reece *et al.*(1986) and Asha Rajini *et al.* (1998) who reported that pelleting increases feed conversion.

CONCLUSIONS

The barrel conditioner speed of mash material had a direct effect on conditioning time, pelleting efficiency and quality. As the conditioning time and temperature was increased, the pellet durability increased. When mash material was passed through the conditioner in lower speed, higher temperature (81^{o}C) due to higher conditioning time effected on high pellet durability index (88.9), however the pellet production rate was low (438 kg/h) and pelleting cost was high (6€/t). At medium speed, low conditioning time and temperature (71^{o}C), pellet durability index decreased (72.3), production rate increased (997 kg/h) and pelleting cost decreased (3€/t). At maximum speed, lower conditioning time and temperature (50^{o}C), durability index was very low (48), production rate was higher (1,707 kg/h) and cost lower (1,94€/t). In order to realize a benefit in broiler performance fed pellets, and high production rate, the medium speed of mash material at barrel conditioner is a recommended option of authors for this pellet mill line. High pellet quality that has direct effect on broiler performance can not be sacrificed by high production rates from feed mills.

Pelleted feed resulted in higher broiler performance compared to mash feed. The feed consumption was higher (6.18%) at broilers fed with mash (5.54 kg/bird) compared with broilers fed with pellets (5.20 kg/bird). The highest body weight (4.35%) throughout all growing period was observed in group fed with pellets (2.65 kg/bird) compared with group fed with mash (2.53 kg/bird). Feed conversion ratio was higher (2.19) in group fed with mash, compared with group fed with pellet (1.96), which indicated higher feed conversion efficiency at pellet group.

REFERENCES

1. Asha Rajini, R., R. Kumararaj, D. Narahari, R. Ravindran, and K. Sundaresan, 1998b. Influence of season, form of feed, dietary energy, age and sex on carcass traits of broilers. Ind. J. Poult. Sci., 33: 346-348.
2. Asha Rajini, R., S. Thanabalan, D. Narahari and R. Kim, Hyoung Ho and Chung, Yuen Hoo, 1996. Effects of Kumararaj, 1998a. Influence of season, form of feed and dietary energy levels on broiler performance. Ind. J. Poult. Sci., 33: 36-41.
3. Behnke, K. C. 1996. Feed manufacturing technology: current issues and challenges. Animal Feed Science and Technology, Vol. 62, pp 49-57.
4. Bertechini, A.G., H.S. Rostagno, J.B. Fonseca and A.I.G. Oliveira, 1992. Effect of environmental temperature and physical form of diet on performance and carcass quality of broiler fowl. Poult. Abst., 18: 3066.
5. Bolton, W. and R. Blair, 1977. Poultry Nutrition. Ministry of Agriculture, Fisheries and Food. Bulletin 174 (London, H.M.S.O.).
   eating patterns and rate of passage of birds fed pelleted and unpelleted diets. Poult
6. Jensen, L.S., 2000. Influence of pelleting on the nutritional needs of poultry. Asian–Aus. J. of Anim. Sci. 13:35-46.
7. Jensen, L.S., L.H. Merrill, C.V. Reddy, and J. McGinnis, 1962. Observations on
8. McAllister, A., K.J. McCracken and F.A. Magee, 2000. Influence of grinding, rolling and pelleting on the nutritional value of grain sorghums and yellow corn for broilers. World's Poult. Sci. J., 56: 215-222.
9. McKinney, L.J., and R.G. Teeter, 2003. Caloric value of pelleting and the consequential creation of nutritional dead zones. Poult. Sci. 82 (Suppl. 1):S109.
10. Moran, E.T., Jr., 1990. Effect of pellet quality on the performance of meat birds. Poult. Abst., 16: 2875.
11. Munt, R.H.C., J.G. Dingle and M.G. Sumpa, 1995. Growth, carcass composition and profitability of meat chickens given pellets, mash or free choice diet. Br. Poult. Sci., 36: 277-284.
12. Preston, C.M., R.J. Mc Cracken and A. Mc Allister, 2000. Effect of diet form and enzyme supplementation on growth, efficiency and energy utilization of wheat based diets for broilers. Br. Poult. Sci., 41: 324-331.
13. Reddy, C.V., L.S. Jensen, L.H. Merrill, and J. McGinnis, 1961. Influence of pelleting on metabolizable and productive energy content of a complete diet for chicks. Poult. Sci. 40:1446.
14. Reece, F.N., B.D. Lott and J.N. Deaton, 1986. Effects of environmental temperature and corn particle size on response of broilers to pelleted feed. Poult. Sci., 65: 636-641.
15. Sci. 41:1414-1419.

Annex 1 Data Recording at Broiler Feed Trial

Total Number of Broilers 300 + 300 (600 Broilers)												
Mortality			Feed Consumption						Weight Gain			
Day	Broiler Fed Pellets	Broiler Fed Mash	Consum. Bird/day Pellets	Consum. Bird/day Mash	Total Daily Consum Pellets	Total Daily Consum Mash	Total Kg/phase Pellets	Total Kg/phase Mash	Gain Kg/day/ /bird Pellets	Gain Kg/day/ /bird Mash	Total Kg/phase Pellets	Total Kg/phase Mash
1	299	299	0.012	0.012	3.588	3.588	3.588	3.588	0.010	0.010	2.99	2.99
2	299	298	0.014	0.014	4.186	4.172	7.774	7.760	0.011	0.011	6.279	6.268
3	299	298	0.016	0.016	4.784	4.768	12.558	12.528	0.012	0.012	9.867	9.844
4	299	298	0.019	0.019	5.681	5.662	18.239	18.190	0.013	0.013	13.754	13.718
5	298	296	0.021	0.021	6.258	6.216	24.497	24.406	0.014	0.014	17.926	17.862
6	296	296	0.026	0.027	7.696	7.992	32.193	32.398	0.016	0.015	22.662	22.302
7	296	296	0.031	0.033	9.176	9.768	41.369	42.166	0.019	0.017	28.286	27.334
8	296	296	0.034	0.036	10.064	10.656	51.433	52.822	0.022	0.019	34.798	32.958
9	296	296	0.038	0.039	11.248	11.544	62.681	64.366	0.026	0.022	42.494	39.47
10	295	294	0.041	0.044	12.095	12.936	74.776	77.302	0.029	0.027	51.049	47.408
11	294	294	0.047	0.050	13.818	14.700	88.594	92.002	0.032	0.031	60.457	56.522
12	294	294	0.051	0.054	14.994	15.876	103.588	107.878	0.035	0.033	70.747	66.224
13	294	293	0.054	0.062	15.876	18.166	119.464	126.044	0.037	0.036	81.625	76.772
14	293	292	0.060	0.070	17.580	20.440	137.044	146.484	0.041	0.041	93.638	88.744
15	*292*	*291*	*0.069*	*0.076*	*20.148*	*22.116*	*157.192*	*168.600*	*0.046*	*0.046*	*107.07*	*102.13*
16	291	291	0.075	0.081	21.825	23.571	21.825	23.571	0.047	0.047	120.747	115.807
17	290	291	0.080	0.087	23.200	25.317	45.025	48.888	0.049	0.048	134.957	129.775
18	290	291	0.086	0.093	24.940	27.063	69.965	75.951	0.051	0.050	149.747	144.325
19	290	291	0.090	0.097	26.100	28.227	96.065	104.178	0.053	0.051	165.117	159.166
20	290	291	0.094	0.103	27.260	29.973	123.325	134.151	0.055	0.052	181.067	174.298
21	290	291	0.100	0.110	29.000	32.010	152.325	166.161	0.057	0.054	197.597	190.012
22	290	291	0.106	0.116	30.740	33.756	183.065	199.917	0.059	0.056	214.707	206.308
23	290	291	0.112	0.122	32.480	35.502	215.545	235.419	0.061	0.058	232.397	223.186
24	290	291	0.116	0.130	33.640	37.830	249.185	273.249	0.063	0.060	250.667	240.646
25	289	291	0.120	0.137	34.680	39.867	283.865	313.116	0.067	0.062	270.03	258.688
26	289	290	0.126	0.143	36.414	41.470	320.279	354.586	0.070	0.065	290.26	277.538
27	289	289	0.141	0.150	40.749	43.350	361.028	397.936	0.073	0.067	311.357	296.901
28	289	289	0.148	0.157	42.772	45.373	403.800	443.309	0.077	0.070	333.61	317.131
29	289	289	0.152	0.160	43.928	46.240	447.728	489.549	0.079	0.073	356.441	338.228
30	289	289	0.157	0.166	45.373	47.974	493.101	537.523	0.081	0.075	379.85	359.903
31	289	289	0.162	0.170	46.818	49.130	539.919	586.653	0.083	0.081	403.837	383.312
32	289	289	0.167	0.176	48.263	50.864	588.182	637.517	0.089	0.083	429.558	407.299
33	289	289	0.173	0.183	49.997	52.887	638.179	690.404	0.090	0.086	455.568	432.153
34	*289*	*289*	*0.186*	*0.193*	*53.754*	*55.777*	*691.933*	*746.181*	*0.092*	*0.089*	*482.156*	*457.874*
35	289	289	0.210	0.216	60.690	62.424	60.690	62.424	0.096	0.090	509.9	483.884
36	289	289	0.214	0.221	61.846	63.869	122.536	126.293	0.098	0.092	538.222	510.472
37	289	289	0.217	0.230	62.713	66.470	185.249	192.763	0.099	0.093	566.833	537.349
38	289	289	0.220	0.237	63.580	68.493	248.829	261.256	0.099	0.096	595.444	565.093
39	289	289	0.224	0.239	64.736	69.071	313.565	330.327	0.099	0.097	624.055	593.126
40	289	289	0.227	0.241	65.603	69.649	379.168	399.976	0.098	0.096	652.377	620.87
41	289	289	0.233	0.244	67.337	70.516	446.505	470.492	0.098	0.096	680.699	648.614
42	289	289	0.236	0.245	68.204	70.805	514.709	541.297	0.098	0.095	709.021	676.069
43	289	289	0.238	0.249	68.782	71.961	583.491	613.258	0.096	0.095	736.765	703.524
44	*289*	*289*	*0.240*	*0.252*	*69.360*	*72.828*	*652.851*	*686.086*	*0.096*	*0.096*	*764.509*	*731.268*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.22
Izvorni znanstveni rad
Original scientific paper

THE INFLUENCE OF SUPPLY SPEED OF THE MINCING MACHINES FOR CHOPING RAW MATERIALS ON THE ENERGY SPECIFIC CONSUMPTION

BUDUI COSTIN

University of Agricultural Sciences and Veterinary Medicine from Iaşi,
Aleea Mihail Sadoveanu nr. 3, Iaşi-700490, Romania.

SUMMARY

The supply speed with fodder of the mincing machine it was adjusted by a gear box situated between the electric engine and the feeding rollers. The machine feeding with corn stalks have in view in permanent the ampermeter indication so that the electric engine to function in a normal load regime without overweight. We draw the variation curves of the energy consumption (E) and specific energy consumption (q) in function of supply speed (v_a = 0.123; 0.239; 0.420; 0.607; 0.737; 1.290 m/s). Even if the E = f (v_a) carriage curves is increasing with the supply speed (v_a) enlargement, the variation curves of the specific energy consumption q = f (v_a) are decreasing because the enlargement of the energy consumption it is smaller than work capacity. The bigger values of the specific energy consumption at small supply speeds are explained by the fact that the mincing length done at these speeds is very small.

Key words: *energy, supply; machines; chopping; fodder.*

INTRODUCTION

Supply equipment has as goal to press the fodder layer, to introduce it in a continuous way with a constant speed in chopping apparatus and to keep that fodder during the chopping process. Fodder which is placed on the conveyer is taken by the supplying and uniformity mixing mills which are toothed, embattled or jagged, which assures a suitable successive compression. Peripheric speed of the supplying mixing mills is establish so that to assure a continuous pass of the fodder from supplying conveyer in the mincing equipment and to avoid its bottomed in front of the knives.

MATERIAL AND METHOD

High consumption claimed by the mincing machines and equipments for raw fodder chopping put in light the necessity of chopping this fodders which are very necessary for ruminants, due to their rich content in cellulose and due to their price, respectively of the final product harvested from animals. This is the reason why scientific research must be focused to find ways to reduce the specific energy consumption at raw fodders' mincing. In the process of cutting through sliding, the geometry of the cutting edge of the knives has a very important influence and also a great importance. Mincing process was tracked on a laboratory stand designed and realized by the author (figure 1). The stand for studying the chopping of raw fodders has the following parts:

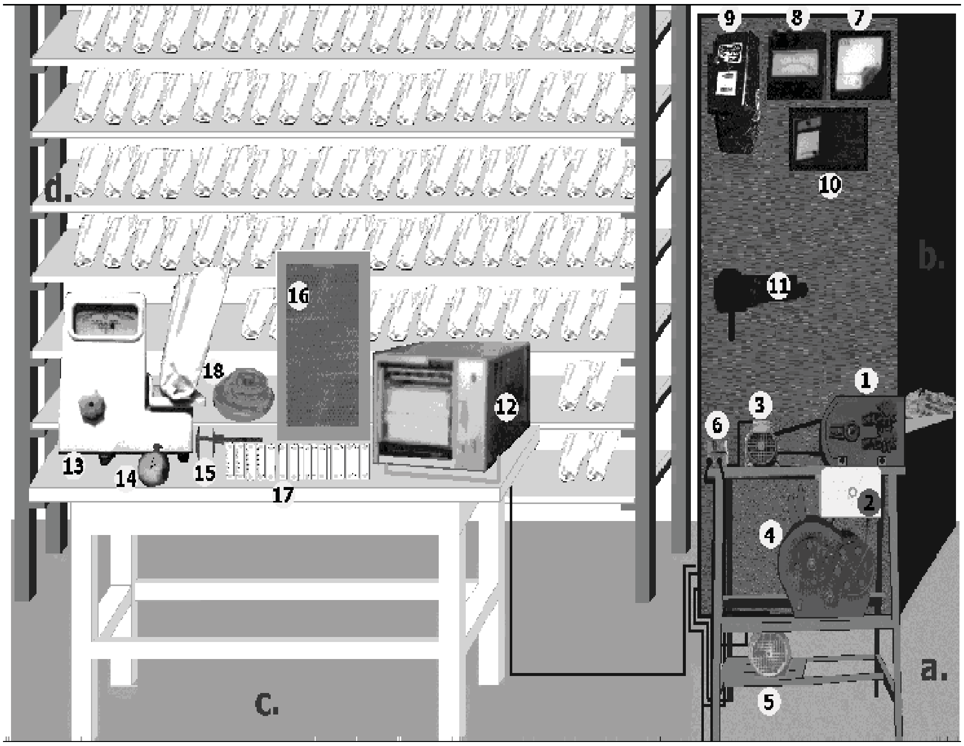


Figure 1 Stand for chopping process
a. Mincing machine for chopping raw fodders: 1 - mincing machine, 2 - drawer for collecting the chopped fodder, 3 - electric engine, 4 - gear box, 5 - electric engine which action the supply mixing mills, 6 - AC-3 automatic switches; b. Case with electric and electronic equipment: 7 – wattmeter, 8 – ampermetre, 9 - three phase electric counter, 10 - electronic tachymeter (10), 11 - general switch; c. Working table: 12 - ''Wattreg-1'' recording wattmeter, 13 - weighing machine for fodder samples, 14 - chronometer, 15 - sliding callipers, 16 - sieve for sifting the samples of chopped fodder, 17 - set of knives which equip chopping drum, 18 - wheels for trapezoidal belts; d. bookstand

Mincing machine for chopping raw fodders (figure 2) which is formed by: mincing machine (1), drawer for collecting the chopped fodder (2), electric engine (3) which action the drum (tambour) with knives for mincing, gear box (4) which adjust the rotation of the supply mixing mills, electric engine (5) which action the supply mixing mills and AC-3 automatic switches for the two electric engines.

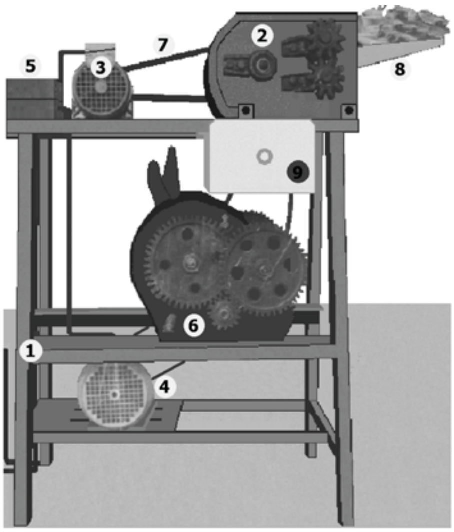


Figure 2 Mincing machine for chopping raw fodders (side front view)
1 - frame; 2 – mincing machine; 3 – electric engine for action of drum (tambour) with kinives; 4 – electric engine for action of supply mixing mills (cylinders); 5 - AC-3 automatic switch; 6 – gear box; 7 – trapezoidal belt transmission; 8 – supplying conduct; 9 – drawer for collecting of chopped fodder

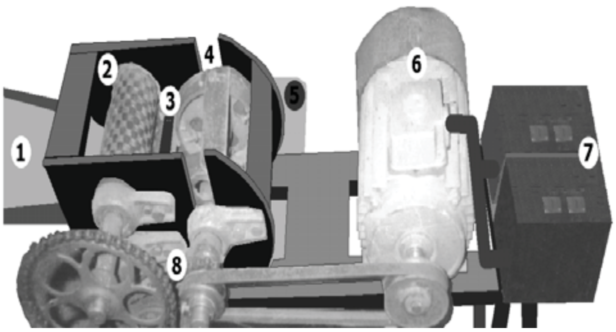


Figure 3 Mincing machine (upper view)
1 – supplying conduct; 2 – supplying cylinders (mixing mills); 3 – counter knife; 4 – tambour (drum) with knives; 5 – drawer; 6 – electric engine; 7 - AC-3 switches; 8 – trapezoidal belt transmissions

Mincing machine is formed from the following spare parts (figure 3): supplying conduct (1), two supplying and uniformity mixing mills (cylinders) (2), counter-knife (3), drum (tambour) with helicoidally knives (4) and drawer (5) for collecting the chopped fodder. Supplying conduct (1) is made from steel plate with a 0.4 mm thickness and is involved in arranging the fodder samples which will be chopped. Cylinders (mixing mills) for supplying and uniformity (2) have the role to introduce, in an uniform layer, the raw fodders into the mincing equipment and to keep the fodders' stems for their chopping by the knives of the mincing drum. Are made from steel and covered at the external part with rubber. They have an adjustable rotation due to the Northon gear box, for obtaining different chopping lengths.

Counter knife (3) is presented under the form of an steel plate (OLC-65) with two cutting edge shaped at 70^0, for being able to be mounted in two distinct position after one of the edge is out of work. Also the counter knife presents two width orifices for its mounting on machines frame and for adjustment of the distance between knives and counter knife. Have the role to assure the support of the fodder layer during chopping. Tambour with helicoidally knives (4), together with the counter knife form the chopping equipment of the fodders' mincing machine. Present a straight shaft made from steel, on which are mounted two flanges (disks), and on those are mounted, through two M8 screws at both ends, the four helicoidally knives. The same screws serve also for adjusting the distance between knives and counter knife, due to the width orifices of the knives. The whole rotor is supported on two radial bearings with two rows of balls. The knives are also made from quality laminated steel OLC-65 and the shape and dimensions are presented in figure 4.

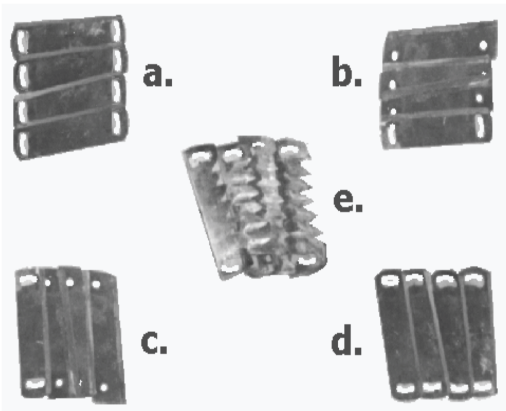


Figure 4 Sets of experimental knives: a, b, c, d – helicoidally knives with straight cutting edge; e – helicoidally toothed knives (specials)

Were used two types of knives as follow: **a; b; c;** and **d –** helicoidally knives with straight cutting edge (smooth), four sets of four knives with different sharpening angle; **e –** helicoidally knives with toothed cutting edge, a set of four knives.

The knives present width orifices for fixing screws of them on the two flanges (disks). Tambour rotation was kept constant, n = 1210 rot/min.

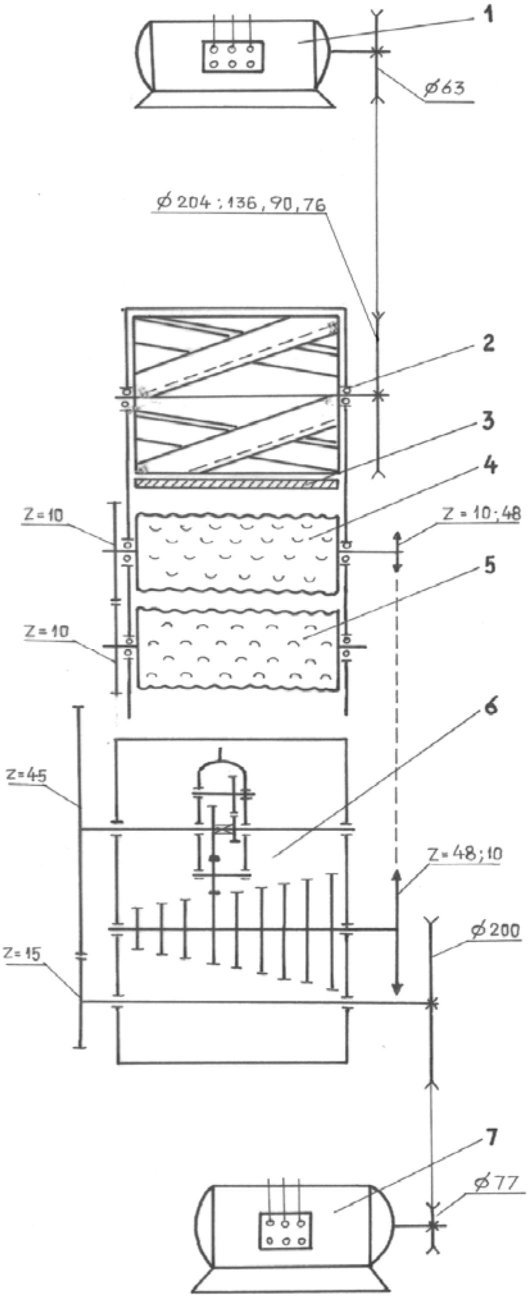


Figure 5 Cinematic scheme of the mincing machine for fodders: 1. – electric engine; 2. – mincing tambour; 3. – counter knife; 4. – upper supplying mixing mill; 5. – bottom supplying mixing mill; 6. – Northon gear box; 7. – electric engine of gear box

To modify the supplying speed was used a gear box placed between electric engine and mixing mills. *Gear box* (6) presented in figure 5 is Northon type and have also the role to adjust the rotation of the cylinders (mixing mills) and to offer a good placement of fodder layer, obtain in this way different chopping lengths and working capacities on working hour. Were obtained the following supplying: V_a = 0.123; 0.239; 0.430; 0.607; 0.737 and 1.290 m/s. Machine supplying with corn stalks and cobs was realized tracking permanently the indication of the ampermeter (In = 2.25 A), so the electric engine to function in a normal working regime, avoiding its overheating. In figure 5 is presented the cinematic scheme of the mincing machine for fodders.

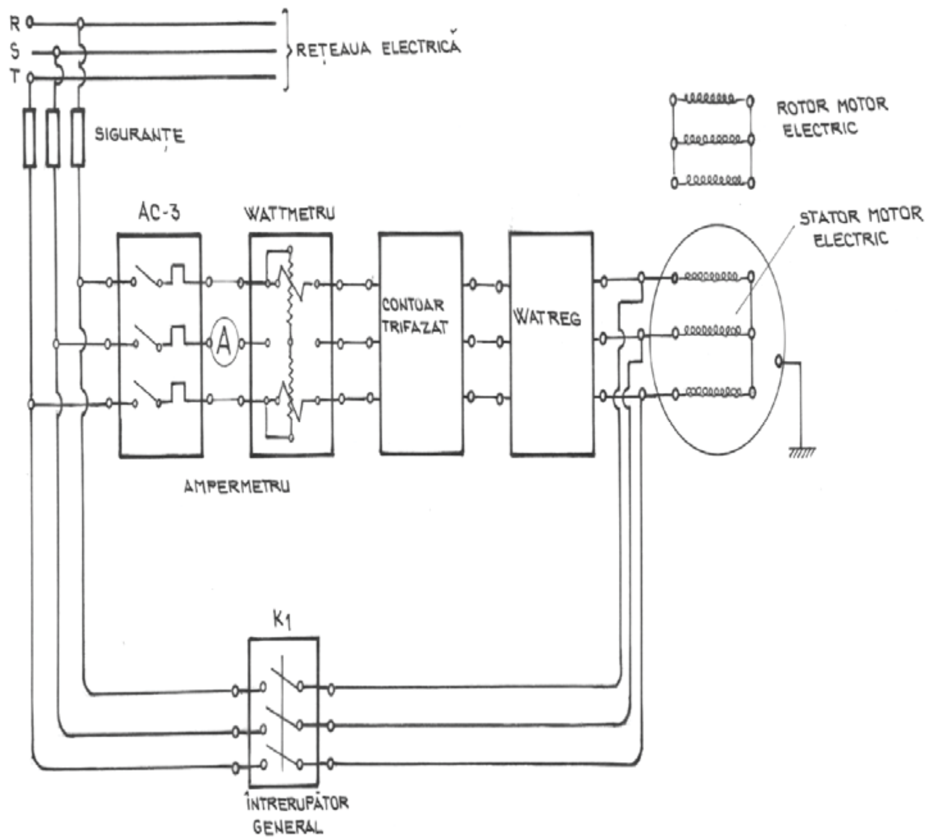


Figure 6 Block electric scheme of the testing stand

Case with electric and electronic equipment (figure 1) for measuring the energetic indexes**,** which have: wattmeter (7) for measuring the absorbed power by the electric engine which action the tambour with knives, ampermetre (8) for tracking a uniform supply of the chopping apparatus (measures the intensity of the current absorbed by the engine), three phase electric counter (9) for measuring the energy consumption of the engine, electronic tachymeter (10) for measuring the rotation of the tambour with chopping knives and of the supply mixing mills, general switch (11) which connect and disconnect the control and measurement apparatus. In figure 6 is presented the block electric scheme of the stand for experimental tests.

Working table (figure 1) have: ''Wattreg-1'' recording wattmeter (12), weighing machine for fodder samples (13), chronometer (14) for recording the chopping time of a fodder sample, sliding callipers (15) for measuring the length of the fragments of chopped fodder stems, sieve (16) for sifting the samples of chopped fodder, set of knives (17) which equip chopping drum, wheels (18) for trapezoidal belts which are successive mounted on the shaft of the chopping for rotation modifying.

Bookstand (figure 1) for placing the bags with chopped fodder samples obtained at different research variants.

RESULTS AND DISCUSSIONS

Table 1 Values of the indexes determine for different values of rotation of the chopping drum

Rotation of chopping drum, n (rot/min)	**Supply speed, v_a (m/s)**	**Determine indexes**		
		Working capacity, Q (kg/h)	**Consumed energy, E (kWh)**	**Energy specific consumption, q (kWh/t)**
451	0.123	10.405	0.212	20.374
	0.239	20.475	0.337	16.459
	0.430	36.855	0.387	10.473
	0.607	52.027	0.395	7.592
	0.737	63.170	0.431	5.398
	1.290	109.186	0.207	1.895
676	0.123	10.405	0.225	21.624
	0.239	20.475	0.393	19.194
	0.430	36.855	0.549	14.896
	0.607	52.027	0.572	10.994
	0.737	63.170	0.568	8.991
	1.290	109.186	0.327	2.994
1022	0.123	10.405	0.236	22.681
	0.239	20.475	0.427	20.854
	0.430	36.855	0.667	18.097
	0.607	52.027	0.806	15.491
	0.737	63.170	0.865	13.693
	1.290	109.186	0.928	8.499
1210	0.123	10.405	0.239	22.969
	0.239	20.475	0.440	21.489
	0.430	36.855	0.703	19.074
	0.607	52.027	0.879	16.495
	0.737	63.170	0.966	15.292
	1.290	109.186	1.015	9.296

After the done research the following indexes were determine:

- working capacity, Q (kg/h);
- consumed energy, E (kWh);
- energy specific consumption, q (kWh/t).

The obtained dates are recorded in table 1, and after them the q = f (v_a) and E = f (v_a) functions' curves were drawn.

In figure 7, are draw the curves of q = f (v_a) and E = f (v_a) functions for all the four rotations of the tambour with chopping knives, n = 451; 676; 1022; 1210 rot/min.

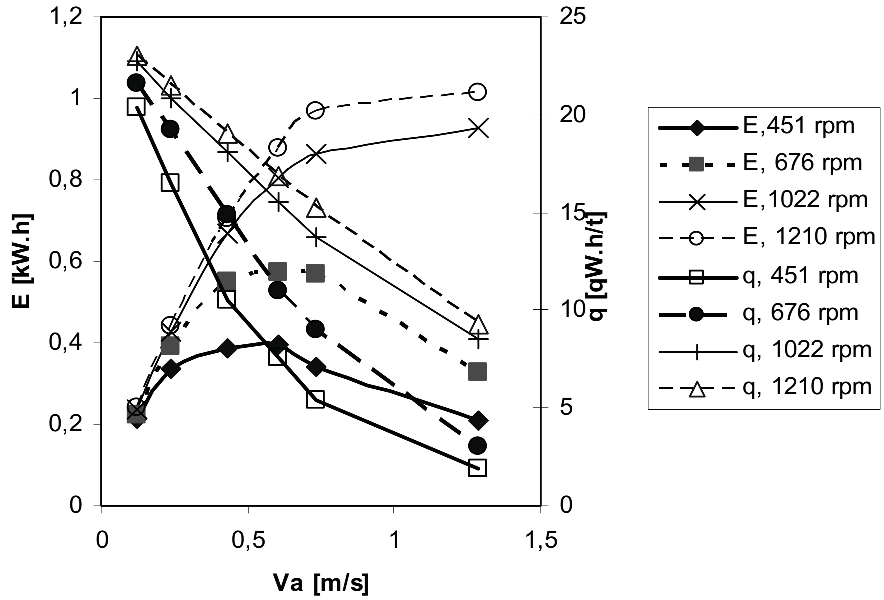


Figure 7 Variation of energy consumption (E) and energy specific consumption (q) function of supplying speed (v_a), for $\delta = 0.5$; U = 16 - 18%; $\beta = 10^0$; $\tau = 25^0$; n – different values

CONCLUSIONS

Higher values of energy specific consumption (q=22.969; 22.681; 21.624; 21.489; 20.854; 20.374; 19.194 kW) are recorded at low supply speeds (v_a = 0.123; 0.239 m/s), respectively at low working capacities (Q=10.405; 20.475 kg/h) and could be explained by the fact that chopping length realised at these speeds is very small (l_t = 4.090; 7.949 mm), while at high supply speeds increase a lot chopping length (l_t = 20.188; 24.512; 42.904 mm), working capacity increase and the energy consumption have a significant decrease.

We must establish the supply speed of the mincing machine for raw fodders function of chopped fodder length required by animals and function of the aggregates which realize mixing and distribution of forage, having permanently in view energy specific consumption which increase the cost price of fodder and at the same time the one of the husbandry product harvested from animals.

REFERENCES

1. Budui C. (2000). *Studies regarding modernization of the machines for fodders processing.* (in Romanian).Doctorate thesis. University of Agricultural Sciences and Veterinary Medicine ″Ion Ionescu de la Brad″ from Iaşi, Romania.
2. O'Dogherty M. J. (1982). *A review of research on forage chopping.* Journal of Agricultural Engineering Research.
3. Neculăiasa V. (1995). *Procese de lucru de lucru la maşinile agricole de recoltat.* Editura A92. Iaşi, Romania.
4. Persson S. (1987). *Mechanics of cutting plant material*. St. Joseph, MI, ASAE.
5. Taşcă Gr., Budui C. (1997). *Cercetări experimentale privind acționarea electrică a utilajelor pentru tocarea furajelor fibroase şi grosiere*. Lucrări ştiințifice, Seria Zootehnie, UŞAMV Iaşi, Romania.
6. Ziablov V.A. (1989). *Osnovâ teorii tehnologhiceskovo proțesu rezania i rejuscih apparatah kormoprigotovitelnâh maşinâ.* Traktorâ i seliskohoziaistvenâe maşinâ, nr. 9, Moskva.

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.563.2:635.31:664.844
Prethodno priopćenje
Preliminary communication

UTJECAJ PROCEDURA SUŠENJA NA BOJU I SPOSOBNOST REHIDRACIJE DIVLJE ŠPAROGE *ASPARAGUS MARITIMUS* L.

IBRAHIM MUJIĆ[1], STELA JOKIĆ[3], MILAN MARTINOV[2], DARKO VELIĆ[3], ŽELJKO PRGOMET[1], SLAVICA DUDAŠ[1], KATARINA RONČEVIĆ[1]

[1]Sveučilište u Rijeci, Rijeka
[2]Fakultet tehničkih nauka, Novi Sad,
[3]Prehrambeno-tehnološki fakultet, Osijek

SAŽETAK

Svježe šparoge dobivaju na popularnosti zbog svoje jedinstvene teksture i okusa, ali one su izuzetno kvarljivo povrće. Zbog toga je cilj istraživanja bio da se sušenjem omogući dugoročno očuvanje i prođa ovog povrća. Divlje šparoge koje se uzgajaju na području Jadranskog mora bile su sušene u komornoj sušari na različitim temperaturama sušenja 50, 60 i 70 °C i liofilizacijom na –40 °C, a zatim su rehidrirane. Boja osušenog materijala i omjer rehidracije odabrani su kao glavne karakteristike kvalitete.

Najbolji omjer rehidracije je postignut kada su uzorci sušeni liofilizacijom na –40 °C. Na temelju boje i omjera rehidracije, optimalno je konvektivno sušenje na 60 °C. Rehidracija i izgled osušene šparoge su dva važna fizikalna čimbenika kojima je potrebno posvetiti posebnu pozornost pri projektiranju ili odabiru postupka sušenja.

Ključne riječi*: metoda sušenja, divlje šparoge, boja, rehidracija*

UVOD

Asparagus maritimus L. rijetka je vrsta divljih šparoga koja raste u mediteranskom području i morfološki je slična *A. Officinalis*. Svježe šparoge dobivaju na popularnosti zbog svoje jedinstvene teksture i okusa (Lau et al. 2000). U nekim zemljama, šparoge su korištene, dugo vremena, kao biljni lijek protiv raka. Šparoga sadrži flavonoide (uglavnom rutin) i druge fenolne spojeve koji posjeduju jaka antioksidativna svojstva (Nindo et al. 2003). Zelena šparoga je izuzetno kvarljivo povrće. Svježe ubrane šparoge brzo propadaju što vodi do kratkog vijeka trajanja od 3-5 dana poslije branja pri normalnom rukovanjem na sobnoj temperaturi (An et al. 2008). Vrlo kratk rok trajanja šparoga uglavnom se odnosi na njihove visoke respiratorne aktivnosti koje se nastavlja nakon berbe (Albanese et al. 2007). Dehidracija, tj. sušenje, šparoga osigurava dugoročno očuvanje i prođu ovom proizvodu. Danas, sigurnost i kvalitetu hrane, u prvom redu očuvanje aktivnih sastojaka na koje su snažno usmjereni istraživači, proizvođači, tehnolozi i potrošači (Vadivambal & Jayas 2007). Dobra kvaliteta ocjenjuje se po svježini, očekivanom izgledu, okusu i teksturi. Prehrambene sigurnosne karakteristike uglavnom su definirane zakonima – tj. postoje definirane granice nepoželjnih nečistoća, kemijskih spojeva, teških metala i količine mikroorganizama. Promjene u kvaliteti koje se mogu pojaviti u bilo kojem proizvodu za vrijeme sušenja, su promjene u njegovim optičkim svojstvima (boja, izgled), senzorskim svojstvima (miris, okus, aroma) i strukturnim svojstvima (gustoća, poroznost, specifični volumen, svojstva teksture, itd.). Korelacija između promjene boje i gubitka aktivnih sastojaka (Müller 1992) potvrđena je na mnogim medicinskim i aromatičnim biljem. Rehidracijska svojstva, omjer rehidracije i rehidracijski kapacitet važne su karakteristike mnogih proizvoda, vezane uz njihove kasnije pripreme za potrošnju (Krokida & Maroulis 2000). Proizvodi s visokim rehidracijskim kapacitetom su ukusniji i zadržavaju njihov svježi izgled. Dominantan postupak očuvanja divljih šparoga, trenutno je prirodno sušenje u sjeni, propuhom ili prisilnim protokom zraka. Najveći nedostatak ovog postupka je očekivano veća količina mikroba i drugih nečistoća uzrokovanih kukcima, pticama, itd.

Konvektivno sušenje, uglavnom koristeći komorne sušare, također se naširoko koristi, posebno od strane malih proizvođača. Ovaj proces može ukloniti nedostake prirodnog sušenja. Sušenje na željenu razinu i postizanje ravnotežnog sadržaja vlage (Krokida & Marinos-Kouris 2003) iznimno je teško. Više je vjerojatno da će doći do pod- ili nad- sušenja. Posljedica pod sušenja, sa sadržajem vlage većim od ravnotežnog, rezultira u višem broju mikroba (Martinov et al. 2007). Ovaj postupak mogao bi rezultirati nepoželjnim smanjenjem aktivnih sastojaka i nepodesnim rehidracijskim karakteristikama. Liofilizacija je proces dehidracije tijekom kojeg je voda uklonjena sublimacijom leda iz smrznutog materijala. Dok led sublimira, sublimaciona granica, koja počinje na površini materijala, povlači se i ostaje porozna ljuska osušenog materijala. Isparena voda se transportira kroz porozan sloj osušenog materijala. Liofilizacija je najbolji način za sušenje hrane, ako se promatra kvaliteta konačnog proizvoda. Očuvanje većine početnih svojstava sirovog materijala, kao što su izgled, okus, boja, aroma, tekstura, biološka aktivnost i sl., čini liofilizaciju jednim od najboljih načina sušenja. Proizvod također zadržava prvobitni oblik i dimenzije. Dakle, rehidracijska svojstva proizvoda su dobra. Međutim, snaga tlaka pare u liofilizacija vrlo je mala u odnosu na konvencionalne metode sušenja. To uzrokuje da za sušenje treba više vremena, što rezultira relativno visokim troškovima sušenja. Iz tog razloga, liofilizacija će vjerojatno biti ekonomski opravdana samo za skuplja povrća, poput gljiva ili paprika (George & Datta 2002)

Znanja o utjecaju sušenja na svojstva hrane mogu se učinkovito koristiti za stvaranje novih atributa kvalitete i novih funkcionalnosti za konačne proizvode (Lewicki 2006). Nekoliko studija je provedeno kako bi se istražile karakteristike sušenja A. Officinalis (May et al. 1997; Nindo et al. 2003; Strahm & Flores 1994). Međutim, čini se da nema objavljenih radova o sušenju divljih šparoga (Asparagus maritimus L).

Cilj ovog istraživanja bio je ispitati utjecaj različitih postupaka sušenja, konvektivno sušenje, liofilizaciono sušenje i prirodno sušenje, na kvalitetu osušenih divljih šparoga.

Boja osušenog materijala, rehidracija matrijala nakon sušenja i rehidracijski kapacitet odabrani su kao glavne karakteristike kvalitete.

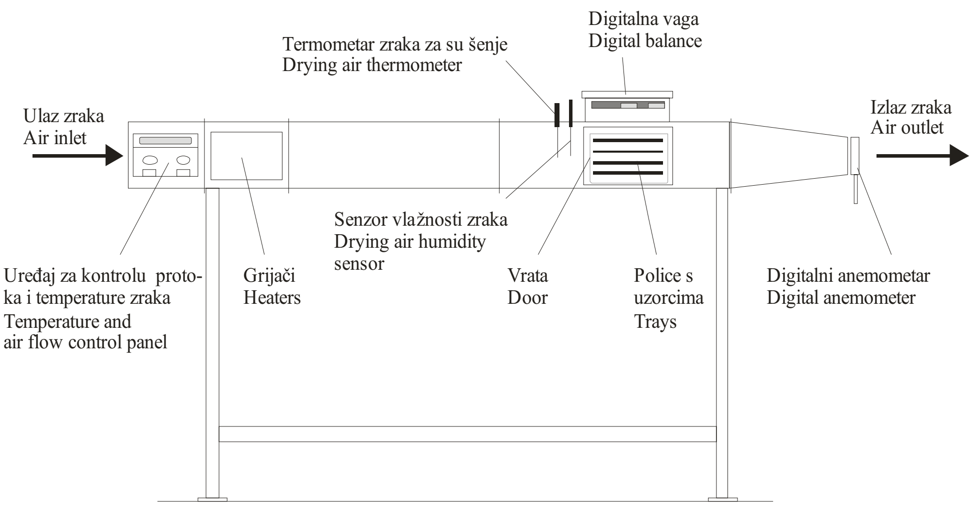
MATERIJAL I METODA

Svježi materijal

Svježe divlje šparoge (*Asparagus maritimus* L.) nabavljene su sa područja Jadranskog mora i pohranjene na +4 °C. Nakon stabilizacije na sobnoj temperaturi, šparoge su izrezane na dužinu od 10 cm. Sadržaj suhe tvari i boja svih uzoraka mjerene su prije i nakon sušenja.

Postupci sušenja

Konvektivno sušenje. Uzorci šparoga sušeni su u pilot komornoj sušari (UOP 8 Trake za kosu, Armfield, Velika Britanija) (Slika 1). Sušara radi na termogravimetrijskom principu. U sušari je omogućena kontrola temperature i brzine protoka zraka. Temperature sušenja, za ne-tretirane uzorke šparoga, varirle su od 40, 50, 60 i 70 °C. Sušara je radila sa brzinom zraka od 2,75 ms^{-1}. Zrak je strujao paralelno horizontalnim površinama za sušenje uzoraka. Proces sušenja je započeo kada su ostvareni potrebni uvjeti za sušenje. Pedeset uzoraka šparoga bilo je raspoređeno na tacne i postavljeno u tunel sušare, neposredno poslije toga mjerenja su započela. "Testo 350" sonde, smještene u komoru sušare, korištene su za praćenje relativne vlažnosti i temperature zraka (± 0,5 °C). Brzina protoka zraka je mjerena svakih pet minuta s digitalnim anemometrom (Armfield, Velika Britanija) smještenim na kraju tunela. Dehidracija je trajala dok potrebni sadržaj vlage od oko 8% (vlažna baza) nije postignut.



Slika 1 Laboratorijska sušnica korišćena za konvektivno sušenje

Fig. 1 Laboratory dryer used for convective drying

Liofilizacija. Uzorci šparoga bili su smrznuti na –20 i –40 °C i zatim liofilizirani u urjeđaju za liofilizaciju (LIO-10P, Kambic d.o.o. Slovenija) na 0,5 mbar tijekom primarnog i 0,03 mbar tijekom sekundarnog sušenja. Tijekom primarnog sušenja temperatura je iznosila –5 °C i bila kontinuirano povećavana do +20 °C tjekom sekundarnog sušenja. Princip temperaturne razlike (temperatura uzorka / temperatura police) je korištena za određivanje kraja primarnog sušenja.

Prirodno sušenje. Uzorci šparoga bili su ravnomjerno raspodijeljeni na tacne i sušeni su u hladu na maksimalnim dnevnim temperaturama zraka od oko 22 °C, i minimalnim noćnim temperaturama od oko 9 °C. Svaki sat mase uzoraka mjerene su na digitalnom mjerilu dok nije bio postignut potreban sadržaj vlage.

Određivanje sadržaja suhe tvari

Sadržaj suhe tvari uzoraka šparoga određen je sušenjem mlijevenih uzoraka (~ 10 g) za 24 h do konstantne mase na 105 ± 0,5 °C. Analize su rađene pomoću tri uzorka za svaku kategoriju i prosječni sadržaj suhe tvari (w_{db}), izražen u postocima (%) bio je izračunat pomoću sljedeće jednadžbe:

$$w_{db}(\%)=\left(\frac{m_2}{m_1}\right)\cdot 100 \tag{1}$$

gdje je m_1, masa uzoraka šparoga prije sušenja (g), a m_2 masa uzoraka šparoga nakon sušenja (g).

Mjerenja boje

Boja svježih, suhih i rehidriranih uzoraka mjerena je koristeći Chromameter CR-400 (Minolta). Šparoge su mlijevene u mlinu za kavu da bi se dobio fini prah. Analize vrijednosti boje su rađene dvadeset puta za svaki svježi i osušeni uzorak šparoga. Tri parametara, L (svjetlina), *a* (crvenilo) i *b* (žutilo), korišteni su za proučavanje promjena u boji. L se odnosi na svjetlinu uzoraka u rasponu crna = 0 do bijela = 100. Negativna vrijednost, *a* označava zelenu, dok pozitivna vrijednost ukazuje crveno-ljubičastu boju. Pozitivano b označava žutu, a negativno plavu boju. Kut nijanse, definiran kao $h° = \tan^{-1}$ (b / a) izračunat je iz *a* i *b* vrijednosti i izražava se u stupnjevima: 0° (crven), 90° (žut), 180° (zelen), 270° (plav). Ukupna razlika u boji (ΔE) je izračunata kako slijedi:

$$\Delta E=\sqrt{\left[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2\right]} \tag{2}$$

$$\Delta L = L - L_0 \qquad \Delta a = a - a_0 \qquad \Delta b = b - b_0 \tag{3}$$

gdje L_0, a_0 i b_0 označavaju parametare boje uzoraka svježe šparoge. Uzorci svježe šparoge korišteni su kao referentni, i veći ΔE predstavlja veću promjenu boje u odnosu na referentni materijal.

Ocjena rehidracionog omjera

Rehidracijski kapacitet korišten je kao obilježje kvalitete osušenog proizvoda (Velić et al. 2004) izražen preko rehidracijske stope - RR (Lewicki 1998). Oko 2 g (± 0.01 g) osušenih uzoraka smješteno je u laboratorijsku posudu od 250 ml (dvije analize za svaki uzorak), 150 ml destilirane vode dodato je i posuda je bila pokrivena i zagrijana do ključanja u roku od 3 min. Sadržaj laboratorijske posude zatim je lagano kuhan 10 minuta, a potom hlađen. Ohlađen sadržaj filtriran je 5 min pod vakumom i potom izvagan. Dehidracioni omjer je izračunat kao:

$$RR=\frac{W_r}{W_d} \tag{4}$$

gdje je Wr osušena masa (g) rehidriranog uzorka, i Wd je masa suhog uzorka korištenog za rehidraciju.

REZULTATI I DISKUSIJA

Promjene boje

Izmjerene karakteristike boje svježeg materijala bile su: L 23.1, *a* –4.2 i *b* 8.7. Kut nijanse svježeg materijala bio je 115.7°.

Djelovanje različitih postupaka sušenja i temperatura, na karakteristike boja sušenih i rehidriranih uzoraka šparoga, pokazalo se kao značajano što je prikazano u tab. 1 i tab. 2. Karakteristike boja su prikazane na sl. 2 i sl. 3.

Tablica 1 Parametri boje šparoge sušene različitim postupcima i temperaturama

Table 1 Color parameters of asparagus dried using different procedures and temperatures

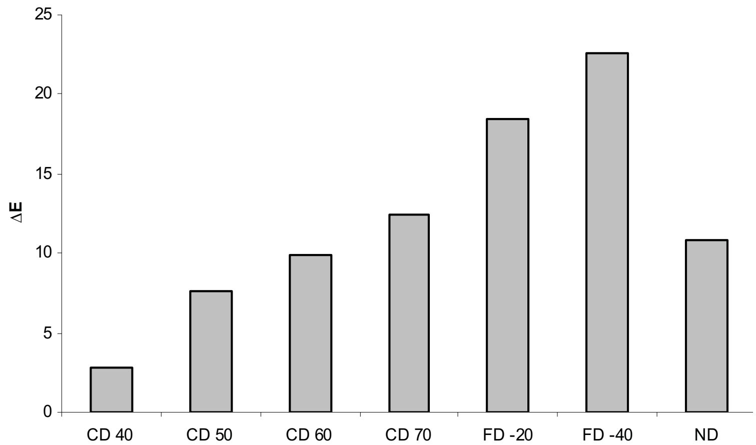
Postupak sušenja	**Temp. (°C)**	**L***	**a***	**b***	**h°**	**ΔE**
Konvektivno, convective	40	24,5	–2,5	7,0	109,9	2,8
	50	30,5	–2,5	8,5	106,2	7,7
	60	31,0	–2,5	8,5	106,1	9,8
	70	33,3	–2,7	9,9	105,3	12,4
Zamrzavanje, freeze	–20	40,9	–5,4	13,5	111,6	18,5
	–40	44,6	–7,1	14,9	115,5	22,6
Prirodno, natural	18	31,4	–3,4	10,4	108,0	10,8

Tablica 2 Parametri boje uzoraka rehidriradne šparoge

Table 2 Color parameters of rehydrated asparagus samples

Postupak sušenja,	**Temp. (°C)**	**L***	**a***	**b***	**h°**	**ΔE**
Konvektivno, convective	40	24,8	–3,8	10,1	110,8	3,4
	50	26,9	–4,3	11,7	110,3	5,2
	60	25,8	–3,4	10,8	107,4	5,8
	70	25,2	–2,1	10,5	101,1	8,2
Zamrzavanje, freeze	–20	31,0	–2,5	13,5	100,6	10,3
	–40	30,0	–4,7	13,7	109,0	14,9
Prirodno, natural	18	26,0	–2,6	11,1	103,4	5,5

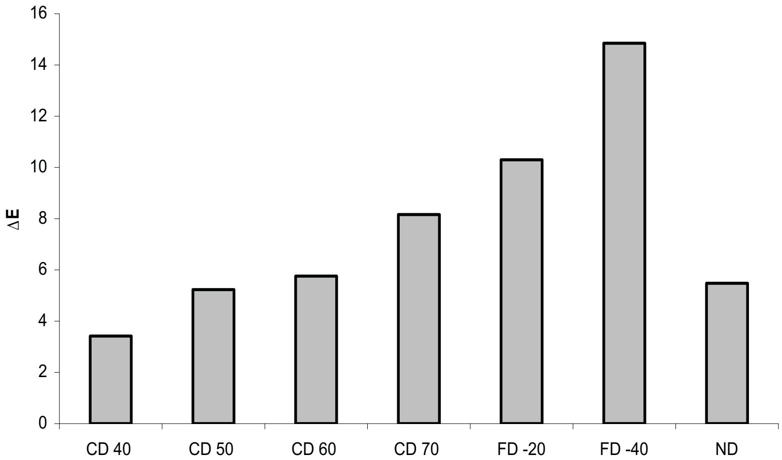
Vrijednosti ΔE rehidriranih uzoraka sušenih konvektivno varirale su od 3,4 do 8,2, dok su vrijednosti ΔE rehidriranih uzoraka sušenih liofilizacijom varirale su od 10,3 do 14,9. Vrijednost ΔE prirodno sušenih uzoraka je bila 5.5. Rehidrirani konvektivno sušeni uzorci na –40 °C imali su najveću vrijednost kuta nijanse, 110,8 °, dok su rehidrirani liofilizirani uzorci rezultirali sa najvećom ukupnom promjenom boje u odnosu na rehidrirane konvektivno i prirodno osušene uzorke.



CD – konvektivno sušenje, convective drying; FD – sušenje zamrzavanjem, freeze drying; ND – prirodno sušenje, natural drying

Slika 2 Promjena boje uzoraka (ΔE) osušene šparoge u ovisnosti od postupka i temperature sušenja

Fig. 2 Color difference (ΔE) of dried asparagus samples vs. different drying procedures and temperatures



CD – konvektivno sušenje, convective drying; FD – sušenje zamrzavanjem, freeze drying; ND – prirodno sušenje, natural drying

Slika 3 Promjena boje uzoraka (ΔE) rehidrirane šparoge u ovisnosti od postupka i temeperature sušenja

Fig. 3 Color difference (ΔE) of rehydrated asparagus samples vs. different drying procedures and temperatures

Postupak sušenja ima značajan utjecaj na boju šparoge, ali i temperatura sušenja vrlo je važan faktor. U slučaju konvektivnog sušenja povećanje temperature sušenja uzrokuje višu promjenu boje i rezultira tamniju boju. Izmjereno smanjenje vrijednosti kuta nijanse znači pad u intenzitetu zelenih i povećanje žutih nijansi, što je u korelaciji sa smanjenjem ukupnog sadržaja klorofila.

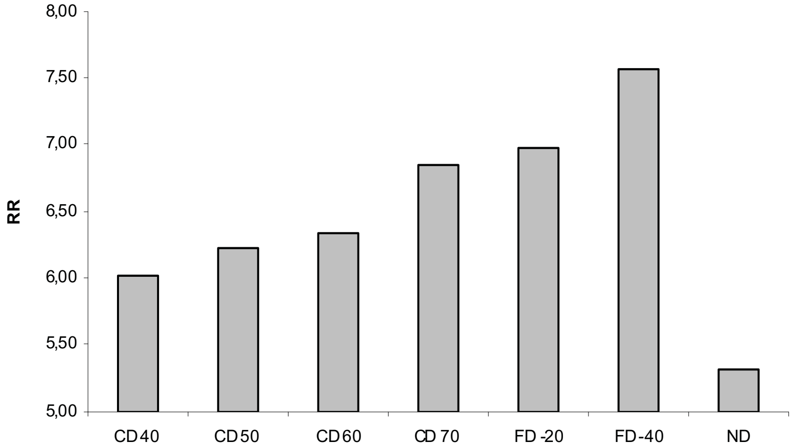
Rehidracijske karakteristike

Postupak sušenja imalo je značajan utjecaj na rehidracijske karakteristike uzoraka šparoga (slika 4). U slučaju konvektivnog sušenja, s povećanjem temperatura sušenja, rehidracijski omjer za netretirane uzorke šparoga također se povećao. To može biti zbog činjenice da je stopa uklanjanja vlage, na višim temperaturama sušenja vrlo brza i uzrokuje manje smanjenje osušenih uzoraka. Rehidracijski omjer za prirodno osušene uzorke bio je najniži. Liofilizaciono sušenje na –40 °C postiglo je najviši rehhidracijski omjer.

Konvektivno sušenje na temperaturama manjim od 45 °C rezultira višim brojem mikroba. (Martinov *et al.* 2007). To znači da temperatura sušenja treba biti iznad te razine. Prethodne studije potvrdile su da viša temperatura sušenja rezultira nižim unosom energije (Müller 1992). Zbog toga i vrlo slične karakteristike boja materijala sušenog na 50 i 60 °C, optimalna temperatura u tom slučaju je 60 °C.

Potrošači odabiru hranu u supermarketima na osnovi, prije svega, vizualne percepcije, a često je to jedina direktna informacija primljena od proizvoda. Ali za prehrambenog tehnologa, ne samo boja, već i rehidracijski kapacitet osušenih uzoraka jednako je važan.

Svojstva kao što su rehihidracijski kapacitet i boje rehidriranih uzoraka su važniji, naročito ako se sušena šparoga koristi, primjerice, u instant juhama.



CD – konvektivno sušenje, convective drying; FD – sušenje zamrzavanjem, freeze drying; ND – prirodno sušenje, natural drying, ND – svježi material, non dryed material

Slika 4 Koeficijent rehidracije (RR) svježe i sušene šparoge za različite postupke i temperature sušenja

Fig. 4 Rehydration ratio (RR) of non-treated asparagus samples vs. different drying procedures and temperatures

ZAKLJUČCI

Očito je da konvektivno sušenje šparoga rezultira u najnižoj promijeni boje svježeg materijala. Najbolje karakteristike boja postignute su sušenjem na temperaturi od 40 °C. Budući da se očekuje smanjenje broja mikroorganizama, sušenjem na temperaturama preko 45 °C, kao što je slučaj s drugim kulturama, temperatura sušenja trebla bi biti iznad ove razine, iako bi to trebalo biti potvrđeno tijekom budućih istraživanja. Također je poznato da povećanje temperatura sušenja rezultira u smanjenju vremena sušenja i specifičnog energetskog unosa. Zbog toga, i mala razlika u karakteristikama boje dobivenih sušenjem na 50 i 60 °C, predstavlja bolji ukupni rezultat.

Rehidracijske karakteristike liofiliziranih šparoga znatno su bolje u odnosu na druge metode, pri čemu su najbolji rezultati postignuti za –40 °C.

Potrošači preferiraju vidljive kvalitete, tj. boju proizvoda. Za neke uporabe, kao što je juha, rehidracijske karakteristike bi trebale imati dominantnu ulogu. To znači da, proizvođači hrane trebaju odlučiti o metodi sušenja u skladu s konačnom uporabom šparoga.

Buduća istraživanja trebala bi se baviti utjecajem sušenja na druge karakteristike kvalitete divlje šparoge, npr. sadržaj aktivnih sastojaka i broj mikroorganizama. Utjecaj ekonomskih parametara različitih postupaka sušenja treba takođe uzeti u razmatranje.

REFERENCE

1. Albanese D., Russo L., Cinquanta L., Brasiello A., Di Matteo M. (2007): Physical and chemical changes in minimally processed green asparagus during cold-storage. Food Chemistry 101: 274–280
2. An J., Zhang M., Wang S., Tang J. (2008): Physical, chemical and microbiological changes in stored green asparagus spears as affected by coating of silver nano particles-PVP. LWT 41: 1100–1107
3. Arora S., Bharti S., Sehgal V.K. (2006): Convective drying kinetics of red chillies. Drying Technology 24: 189–193
4. George J.P., Datta A.K. (2002). Development and validation of heat and mass transfer models for freeze-drying of vegetable slices. Journal of Food Engineering 52: 89–93
5. Krokida M.K., Maroulis Z.B. (2000). Quality changes during drying of food materials, In Drying Technology in Agriculture and Food Sciences, Science Publisher, Inc., 61-98
6. Krokida M.K., Marinos-Kouris D. (2003). Rehydration kinetics of dehydrated products. Journal of Food Engineering 57: 1–7
7. Lau M.H., Tang J., Swanson B.G. (2000). Kinetics of textural and color changes in green asparagus during thermal treatments. Journal of Food Engineering 45: 231-236
8. Lewicki P.P. (1998). Some remarks on rehydration of dried foods. Journal of food Engineering, 36: 81–87.
9. Lewicki P.P. (2006): Design of hot air drying for better foods. Trends in Food Science & Technology 17: 153–163
10. Martinov M., Oztekin S., Müller J. (2007). Drying. In: Oztekin, Martinov: Medicinal and Aromatic Crops, Harvesting, Drying, and Processing. Haworth Food & Agricultural Products Press, Binghamton, NY, 85-129
11. May B.K., Shanks R.A., Sinclair A.J., Halmos A.L., Tran V.N. (1997). A study of drying characteristics of foods using a thermogravimetric analyser. Food Australia 49: 218-220
12. Mcminn W.A.M., Magee T.R.A. (1996). Air drying kinetics of potato cylinders. Drying Technology 14: 2025-2040
13. Müller J. (1992). Trocknung von Arzneipflanzen mit Solarenergie. (Dissertation), Ulmer Verlag, Stuttgart
14. Nindo C.I., Sun T., Wang S.W., Tanga J., Powers J.R. (2003). Evaluation of drying technologies for retention of physical quality andantioxidants in asparagus (*Asparagus officinalis, L.*). Lebensm.-Wiss. u.-Technol. 36: 507–516
15. Strahm B.S., FLORES R.A. (1994). Dehydration of low-grade asparagus. Drying Technology 12: 903-921
16. Vadivambal R., Jayas D.S. (2007). Changes in quality of microwave-treated agricultural products—a review. Biosystems engineering 98: 1–16
17. Velić D., Planinić M., Tomas S., Bilić M. (2004). Influence of airflow velocity on kinetics of convection apple drying. Journal of Food Engineering 64: 97-102

THE INFLUENCE OF DRYING PROCEDURES ON THE COLOR AND REHYDRATION ABILITY OF *ASPARAGUS MARITIMUS* L.

SUMMARY

Fresh asparagus is gaining popularity due to its unique texture and flavor but they are also an extremely perishable vegetable. Because of that the aim of this research was to dry those vegetable to provides long term conservation and marketability.

Wild asparagus that have been grown in area of the Adriatic Sea were dried in tray drier at different drying temperatures 50° C, 60° C and 70° C and in freeze-dried equipement at –40° C and then rehydrated. The color of dried material and rehydration ratio are selected as the main quality characteristics of wild asparagus.

The best rehydration ratio were achieved when samples were freeze dried at –40° C. Based on color and rehydration ratio convective drying at 60° C presents an optimum.

The rehydration and appearance of dried asparagus are two important physical factors that need special attention when designing or selecting a drying procedure.

Key words: *Drying method, wild asparagus; color, rehydration*

37. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.22.628.8
Prethodno priopćenje
Preliminary communication

THE PARAMETERS OF NATURAL VENTILATION SYSTEM OF ANIMAL SHED

BRONIUS KAVOLELIS, ROLANDAS BLEIZGYS, JONAS CESNA

Lithuanian University of Agriculture
LT-53362 Akademija, Kaunas reg., LITHUANIA, e-mail: bkavolelis@mei.lt,
Rolandas.Bleizgys@lzuu.lt, Jonas.Cesna@lzuu.lt

SUMMARY

In designing a natural ventilation system for animal shed it is necessary to assess the ventilation induced by thermal buoyancy and wind forces during different seasons and under different animal housing conditions.

By applying analytical and experimental research a methodology was prepared to establish the ventilation intensity caused by thermal buoyancy and wind and the data on thermal buoyancy and wind values and their relationship achieved. The innovation of the methodology can be described by the fact, that a simple equation was formed to calculate the air speed in inlet and outlet openings, a mathematical expression of thermal buoyancy and wind ratio achieved and the required inlet opening area to let fresh air in compared with the outlet opening area to let polluted air out was substantiated to ensure all polluted air be removed through a rooftop aperture in winter. It was calculated that the average air speed in the rooftop aperture of a typical cold-type cowshed is 1.3 m/s (when there is no wind, this speed decreases down to 0.3 m/s), thermal buoyancy and wind ratio is 0.27 and in order to have all polluted air removed through the rooftop aperture in winter the inlet opening area in the walls must not exceed 40% of the rooftop aperture area.

The accuracy of the prepared methodology was tested under natural conditions of animal shed operation, when the distance between air inlet openings and outlet was 6.5 m. During the investigations indoor and outdoor temperatures, air speed in the outlet and wind speed were measured. During the experiments the difference of the indoor and outdoor temperatures varied from -2 to +16 ^{o}C and air speed in the outlet – from 1.2 to 1.9 m/s. The analytical results reflect the mean values of experimental data under natural conditions of operation rather accurately. The difference between the experimental and calculated air speed values in the outlet opening was insignificant and was within 0-8% range.

Key words*: natural ventilation, thermal buoyancy, wind, ratio, parameters*

INTRODUCTION

Of late years it is stressed that natural ventilation of buildings can save a lot of energy, CO_2 emissions are reduced, therefore, a natural ventilation system is environmentally friendly (Allocca, *et all*, 2003). A natural ventilation system is by half cheaper compared with the one of mechanical ventilation and maintenance makes only one third of the maintenance of the mechanical ventilation system. If natural ventilation is not sufficient, fans have to be installed for mechanical ventilation to complement the natural one.

The study of airflow through building openings has been the subject of papers by a number of authors. Natural ventilation is induced by thermal buoyancy and wind. At least two methods have appeared in the literature to combine the effects of wind with thermal buoyancy (Natural ventilation…,2008). One method superimposes wind and thermally induced pressure differences across openings, and use Bernoulli's equation to develop expressions for the speed as a function of vertical position in the opening. An alternative method – is to calculate the natural ventilation due to thermal buoyancy and wind separately and then combine them using the equation: square of total air flow rate is equal to the sum of squares of air flow rates induced by thermal buoyancy and wind forces.

It is proposed that the intensity of natural ventilation in premises is determined by many factors such as wind speed, direction and its turbulence, the size of ventilation openings and their location, heat sources, thermal conduction of outer walls, solar irradiance, etc. However, the most important thing is to evaluate ventilation induced by thermal buoyancy and wind speed (Li et all, 2001). Gravitational pressure is usually smaller that wind pressure, therefore, wind induced ventilation is also greater. However, it is difficult to forecast as wind speed and direction change regularly.

The objectives of this study were: first to work out of a methodology for establishing ventilation intensity induced by thermal buoyancy and wind at designing an animal shed ventilation system, than to test the methodology in production situation of animal shed. The analytical and experimental investigations were applied.

OBJECTS AND METHODS

Natural ventilation is induced by thermal buoyancy and wind (*Figure 1*). Due to thermal buoyancy air comes through the openings in both side walls of a building and is removed thought the aperture installed above. Wind forces air to come through the openings of one side wall and the air is removed thought the higher opening and through the openings of the opposite side wall.

Having solved the fundamental flow equations was developed following equations.

Air speed in inlet (Index 1) and outlet (Index 2) opening $v_{1(2)}$, m/s,

$$v_{1(2)} = C_{d1(2)} \sqrt{\frac{gH\,\Delta t}{T_{o(i)}} + v_v^2 \frac{k_1 - k_2}{2}}\ . \tag{1}$$

where

$C_{d1(2)}$ – air discharge coefficient for inlet or outlet opening;

g – gravitational acceleration, m/s^2;

H – height from midpoint of air inlet opening to air outlet opening, m;

Δt – difference between indoor and outdoor temperature, ^{o}C;

$T_{o(i)}$ – thermodynamic indoor or outdoor temperature, K;

v_v – wind speed, m/s;

k_1, k_2 – coefficient of wind pressure on wall near inlet and outlet opening.

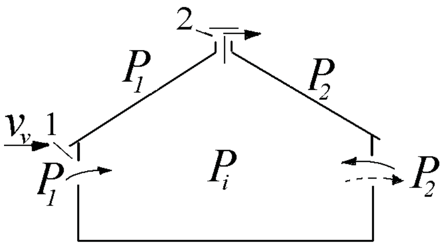


Figure 1 Schematic view of the animal building with inlet (1) and outlet (2):
P_1, P_2, P_i – wind pressure on the windward wall, leeward wall and indoor building

When T_i=283 K and k_i=0.7, k_2=-0.3 (Albright, 1990) equation (1) is simplified

$$v_{1(2)} = 0.19 C_{d1(2)} \sqrt{H \Delta t + 14 v_v^2} \quad (2)$$

Ratio of ventilations intensities induced by thermal buoyancy and wind

$$\eta = 0.27 \frac{\sqrt{H \Delta t}}{v_v}. \quad (3)$$

The experiments were carried out in pigsty with fattening pigs. Number of pigs is 600. In the pigsty animal were grown from 30 kg up to 110 kg. A pig stall was scattered with straw. The room width was 18 m, length – 60 m, and height – 3.5 m. The pigsty was oriented in a longitudinal south – north axis. The pigsty was naturally ventilated. Clean air flows in the pigsty through the gaps (inlet) of 30 mm width at the top of longitudinal wall boards, and the polluted air is removed through the one chimney (outlet). The distance between inlet and outlet (top of the chimney) was 6.5 m. Total area of in inlet in winter was 3 m^2. When the average outdoor temperature increased over 5^{o}C, the windows were opened. Cross-sectional area of chimney was 4 m^2.

During the experiments the measures of air speed at outlet, wind speed, temperature of indoor and indoor were carried out. Speed of air and temperature were measured by instrument ALMEMO 2290-3. The values of air speed gained were analysed statistically and compared with results calculated according to equation (2).

RESULTS AND DISSCUSION

Measuring results are given in *Figure 2*. The investigations carried out from July to December. During the experiments the air flow in the outlet was stable. The outdoor air temperature varied from -7 to +24 ^{o}C, and indoor air temperature was 9 – 22^{o}C. Thus temperature difference between indoor and outdoor air was from -2 to +16^{o}C The average wind speed varied from 3.6 to 4.2 m/s and was higher in cold season, i.e., when the indoor and outdoor temperature difference was higher. Air speed in the outlet v_2 m/s, and the dependence on the indoor and outdoor temperature difference Δt, ^{o}C, are expressed by the following regression dependence

$$v_2 = 0.042\Delta t + 1.25 \quad R^2 = 0.45, \tag{4}$$

when Δt = -2 – 16 ^{o}C, and v_v = 3.6 – 4.2 m/s

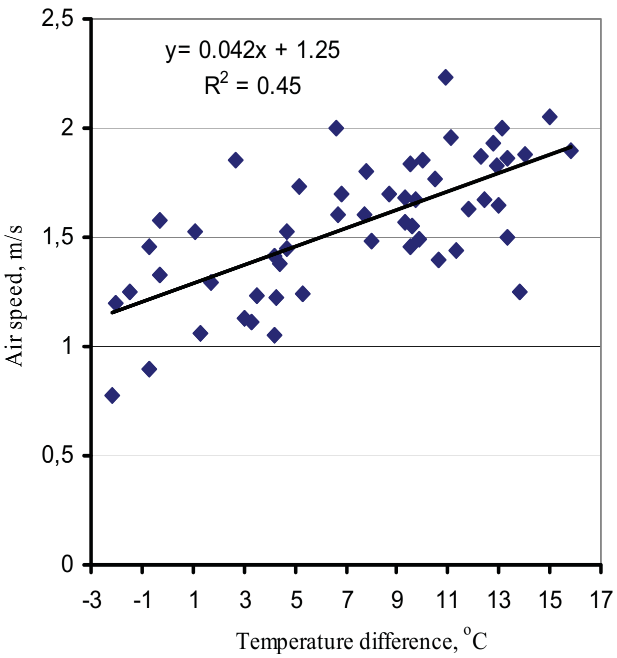


Figure 2 Experimental dependence of air speed in outlet on indoor – outdoor temperature difference; The distance between air inlet and outlet is 6.5 m and wind speed – 3.6-4.2 m/s

In warm season, when indoor and outdoor temperatures were even (Δt=0°C), air speed in the outlet was 1.15 m/s. In cold season, when indoor and outdoor temperature difference increased up to 16°C and wind speed increased from 3.7 to 4.2 m/s, air speed in the outlet increased up to 1.92 m/s, i.e., 1.5 times.

When the air speed in the outlet is known, the required total area of outlets

$$A_2 = \frac{\Sigma Q_o}{c\rho_i v_2}\left(\frac{\varepsilon + x\eta I}{\Delta t} - x_o\right), \tag{5}$$

where

ΣQ_o – total heat of the animals flow rate, kW;

c – specific heat capacity of air, kJ/(kg.K);

ε – ratio of sensible and total animal heat;

x_o – total module of heat losses through building partitions (walls, roof, floor and foundations), 1/K;

x – partial module of heat losses through building walls and roof, 1/K;

η – coefficient that evaluates solar irradiance, m^2. K/W (about 0.022 m^2. K/W);

I – average density of sun energy flow towards the building surface, W/ m^2;

Δt – permissible difference between indoor and outdoor air temperature, °C.

CONCLUSIONS

The key data to design a natural ventilation system for an animal shed were substantiated. They can be summarized as follows: The ratio of thermal buoyancy and wind was established and the methodology was prepared to forecast ventilation intensity based on the calculations of air speed in inlet and outlet openings. The equation was formed to calculate the ratio of size inlet and outlet areas. The accuracy of the methodology was approved by experimental research under natural conditions of barn operation. The difference between the experimental and calculated air speed values in the outlet opening was insignificant and was within 0-8% range. According to the analytical and experimental research results it was calculated that in a typical animal shed air speed in the aperture of the rooftop was 1.3 m/s (when there is no wind, this speed decreases to 0.3 m/s), ratio ventilation rate of thermal buoyancy and wind forces – 0.27; and in order to have all air removed through the rooftop aperture in winter, the area of inlets in the walls does not have to exceed 40% of the rooftop aperture area.

REFERENCES

1. Albright L.-D. (1990). Environment control for animals and plants. An ASAE Textbook. No 4, Michigan, 453 p.

2. Allocca C., Chen Q., Glicksman L. R.(2003). Design analysis of single – side natural ventilation. Energy and Buildings, 35(8): 785-795.

3. Li Y., Delsante, A. (2001). Natural ventilation induced by combined wind and thermal forces. Building and Environment, 36 (1): 59-71.

4. Natural ventilation - Foster and Down. Model 1/24/2008, 57 p. Available from internet http://www.conceptmodel.org/nh3/documents