UDC 631

ISSN 1333 - 2651

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

AAESEE

EurAgEng

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

Actual Tasks on Agricultural Engineering

OPATIJA, CROATIA, 22. - 26. FEBRUARY 2010

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

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

ZBORNIK RADOVA

38. MEĐUNARODNOG SIMPOZIJA IZ PODRUČJA MEHANIZACIJE POLJOPRIVREDE

OPATIJA, 22. - 26. veljače 2010.

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, Vinko Duvnjak, Goran Fabijanić, Dubravko Filipović, Zlatko Gospodarić, Igor Kovačev, Đuro Banaj, Robert Zimmer, Rajko Bernik, Viktor Jejčić, Miran Lakota, Tomaž Poje
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), Rameshwar Kanwar (USA), 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.

SPONZORI – SPONSORS

MINISTARSTVO ZNANOSTI, OBRAZOVANJA I ŠPORTA REPUBLIKE HRVATSKE

SAME DEUTZ-FAHR ŽETELICE
ŽUPANJA

INA
ZAGREB

MESSIS
ZGREB

AGROGROM
SAMOBOR

POLJONOVA
SESVETE

E u M AGROTEC
WEILHEIM-TECK
DEUTSCHLAND

STEPCO
VELIKA GORICA

AGROMARKETING
ZAGREB

PREDGOVOR - PREFACE

Usprkos gospodarskoj krizi globalnih razmjera, uz doduše skromnije ukupne troškove, ali 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, te međunarodnih udruga Poljoprivredne tehnike (EurAgEng, CIGR, AAAE i AAESEE) uspjeli smo organizirati 38. Simpozij "Aktualni zadaci mehanizacije poljoprivrede". Ovaj 38. po redu Zbornik sadrži 45 rada od čega : Belgija, Bosna i Hercegovina, Bugarska, Češka, Latvija i Turska po (1), Italija i Mađarska (2), Estonija i Hrvatska (3), Srbija (5), Slovenija (10) i Rumunjska (14) radova. Zahvaljujemo se svim sponzorima koji su svojom potporom omogućili održavanje ovog 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.

P.S. Iskrena hvala našem dragom prijatelju i kolegi prof. dr. Robertu Zimmeru za stalnu i predanu potporu struci i ovom simpoziju.

In spite of global economic crisis and its heavy burden, 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 and finally world known associations for agricultural engineering (EurAgEng, CIGR, AAAE and AAESEE) enabled organiser to carry out 38th symposium "Actual tasks on Agricultural Engineering". This proceedings contains 43 papers among them are: Belgium, Bosnia and Herzegovina, Bulgaria, Czech Republic, Latvia and Turkey with (1), Hungary and Italy (2), Croatia and Estonia (3), Serbia (5), Slovenia (10) and Romania (14) papers. We would like to thank authors, reviewers, participants and especially sponsors for their contribution to organise the symposium. We especially emphasize sponsoring of Ministry of Sciences and technology of Republic of Croatia who support us for 15 years. Finally we wish all participants, our colleagues pleasant time, weather and company during symposium.

P.S. Sincere thanks to our friend and colleague prof. dr. Robert Zimmer for his continuous and devoted support to profession and this symposium.

Chief Editor

Prof. dr. sc. Silvio Košutić

Zagreb, siječanj-January 2010.

SADRŽAJ – CONTENTS

D. De Wrachien, S. Mambretti 11
Usmjeravanje probojnog vala brana: 2D, dvofazni model slojevitog i neslojevitog nanosa hiperkoncentriranih tokova
Dam-break wave routing: a 2D, two phase model for mature and immature debris and hyper-concentrated flows

G. Dragomir, S. Dragomir, C.E. Tureac 27
Kvaliteta ispusnih voda u donji tok Dunava, te troškovi opskrbe pitkom vodom
Water quality discharged into the lower Danube and the costs associated with drinking water supply

B. Ogrizović, J. Simić 37
Uloga i značaj poljoprivredne savjetodavne službe AP Vojvodine
The role and importance of agricultural advisory service of AP Vojvodina

I. Grgić, V. Levak, Đ. Žutinić, M. Zrakić 49
Hrvatska poljoprivreda sa stanovišta ruralnih žitelja
Croatian agriculture from the view of the rural population

C. Tuerac, G. Dragomir, G. Aurica 59
Optimizacija združenih proizvodnih grana u poljoprivredi oblasti Iasi, Rumunjska s ciljem povećanja profitabilnosti
Optimization of production branches joint in agricultural Iasi county, from Romania in order to increase their profitability

T. Poje 67
Stanje traktorske tehnike u Sloveniji
State of tractor pool in Slovenia

Z. Mileusnić, M. Đević, R. Miodragović, M. Bozic 75
Utjecaj različitih trakcijskih sustava traktora u obradi tla
The influence of different traction systems on tractors use in tillage

R. Rosca, I. Tenu, P. Carlescu, D. Cazacu, V. Vlahidis 85
Vrednovanje modela superelipse za određivanje dodirne površine pneumatik-tlo
Evaluation of the super ellipse model for the tire-ground contact patch

D. Stajnko, M. Lakota, B. Muršec, P. Vindiš, J. Rakun 93
Utjecaj različitih sustava upravljanja kotača traktora na klizanje pri košnji na poprečnom nagibu
The influence of different steering system on wheel slip at simulation of mowing on a steep slope

V. Moise, S.St. Biris, B. Grecu, N. Ungureanu, L. David, G. Paraschiv........................ 99
Određivanje minimalne veličine poljoprivrednog posjeda s ciljem određivanja profitabilne traktorske "flote"
Determination of the minimum surface of an agricultural farm from which a certain power range of tractors become profitable

V. M. Muraru, P. Cardei, I. Pirna, C. Muraru-Ionel, R. Sfiru 111
Mehaničko zagađivanje poljoprivrednog tla
Mechanical pollution of agricultural soil

G. Paraschiv, B. Grecu, V. Moise, G. Adir, P. Voicu 121
Funkcijska analiza mehanizma ravnjača tla
The functional analysis of the mechanism of the soil leveling machine

G. Paraschiv, M. L. Toma, G. Musuroi, S. St. Biris, G. Voicu..................................... 131
Istraživanje realizacije hidrauličkog sustava s automatskim nadzorom –upravljanjem položaja poljoprivrednih strojeva spram površine tla
Research regarding the realization of a hydraulic system with automatic control of the agricultural machine position towards soil

T. Susam, M. Rustu Karaman, F. Er, I. Iseri 143
Nadzor varijabilnosti sadržaja Fe i Zn na specifičnoj plantaži jabuka primjenom prostornih GIS karti-predložaka
Monitoring of site specific Fe and Zn variability on the apple area using the GIS based spatial pattern maps

V. M. Muraru, P. Cardei, C. Muraru-Ionel, I. Pirna, I. Tenu 151
Kartiranje svojstava tla spektrofotometrijom
Soil properties mapping using spectrophotometry

P. Cardei, V.M. Muraru, R. Sfiru, V. Herea, C. Muraru-Ionel.................................. 163
Tehnika mješovitog "softwarea" za istraživanja okolišnih-ekoloških problema
Mixed techniques software for environment problem investigation

J. Cepl, P. Kasal, H. Souckova 175
Nove tehnološke mogućnosti gnojidbe krumpira
New possibilities for technology of potato fertilization

Đ. Banaj, V.Tadić, B. Vujčić, J. Lukinac 183
Procjena pokrivenosti lisne površine u voćnjaku jabuka pomoću vodoosjetljivih papirića
Method of evaluation leaf area coverage in apple orchard with water sensitive papers

J. Rakun, P. Berk, T. Paripovič, P. Lepej, M. Lakota, D. Stajnko **191**
Selektivni nanos fitofarmacevtskih sredstev z uporabo pametnega robota
Selective pesticide spraying with the help of an autonomous robot

S. Benni, D. Torreggiani, V. Corzani, F. Cuttin, P. Tassinari, S. Galassi **201**
Objekti vinogradarsko-vinarskog imanja: Analiza meta dizajna za određivanje prostornog rasporeda
Wine-growing and producing farm buildings: Meta-design analysis for the definition of spatial layouts

J. Kafashan, P. Van Liedekerke, H. Ramon, B. Tijskens **211**
Model prstenova u simulaciji transporta rasutih biomaterijala
A multi-ring model to simulate particle-based systems in biomaterials transport

M. Jančić... **219**
Oprema i certifikacija centra za doradu sjemena
Equipment and certification of seed processing centre

G. Dinaburga, D. Lapinš, J. Kopmanis **225**
Vrednovanje utjecaja nekontroliranih čimbenika na razvoj i urod ozime pšenice
Evaluation of effect of unregulated factors on development and yield of winter wheat

K. Beres, I. Husti.. **235**
Efekti odnosa strojeva i bilja na gubitke i profitabilnost (Primjer proizvodnje graha zrnaša)
The effects of the relationship between machine and plant on the losses and profitability (Based on the example of dry pea harvesting)

M. Đević, A. Dimitrijević **245**
Energetska učinkovitost uzgoja rajčice na polju i u zaštićenom prostoru
Energy efficiency of the open field and greenhouse tomato production

Z. Radan, R. Zimmer, R. Matić, D. Zimmer **255**
Poljoprivredna tehnika u uzgoju mrkve
Agricultural machinery in carrot production

B. Veselinov, D. Adamović, M. Martinov, M. Golub **261**
Istraživanje mehaničkog ubiranja cvata Nevena različitog međurednog razmaka
Investigation of mechanical harvest of marigold flowers for different row distances

L. Kais, J. Olt **271**
Strojevi u plantažnoj proizvodnji grmolike borovnice na iscrpljenim tresetištima
Low-bush blueberry machine cultivation technology in plantations established on milled peat fields

G. Adir, B. Grecu, L. David, G. Voicu.. **281**
Kompjuterizirana obrnuta kinematika 3R manipulatora bala
The computerized reverse kinematics of the 3R manipulator in the stacking process of bales

A. Kuut, J. Olt **291**
Primjena bioetanola kao standardnog goriva
Use of bioethanol fuel as regular fuel

M. Lakota, P. Berk, D. Stajnko, P. Vindiš, B. Muršec **299**
Uporabnost Jatropha (*Jatropha curcas* L.) rastlinskega olja za proizvodnjo biodizla v Sloveniji
*Using of Jatropha (*Jatropha curcas *L.) vegetable oil in biodiesel production*

P. Vindiš, B. Muršec, D. Stajnko, M. Lakota **307**
Simulacijski model pridelave in predelave energetskih rastlin v bioplin
Simulation model of energy crops growing and their utilization as substrate for biogas

B. Muršec, P. Vindiš, M. Lakota, D. Stajnko **317**
Laboratorijsko testiranje koruznih hibridov za bioplin
Laboratory testing of maize hybrids for biogas

R. Bernik, A. Zver **325**
Proizvodnja bioplina iz tropa
Biogas production from grape marcs

T. Poje **335**
Zakonski okviri za proizvodnju bioplina i prodaju električne energije u Sloveniji
Legal framework for biogas production and selling electricity in Slovenia

V. Jejčič, T. Poje **345**
Mogućnost upotrebe biomase iz poljoprivrede za energetske svrhe u Sloveniji
Utilization possibilities of biomass from agriculture as an energy supply in Slovenia

L. Mago, J. Hajdu, L. Fenyvesi **355**
Određivanje i usporedba potencijala produkcije biomase iz poljoprivrede u Mađarskoj
Determination and comparison of biomass potential from agriculture in Hungary

N. Mihailov **365**
Prikaz prosječne mjesečne sunčeve radijacije za grad Rousse, Bugarska
Monthly profile of the solar irradiation at Rousse, Bulgaria
G. Ipate, T. Casandroiu, G. Voicu, M. Tudosie **371**
Eksperimentalna studija reoloških svojstava prirodnih sokova povrća
Experimental study on rheological properties of natural vegetable juices

F. Mariasiu, N. Burnete **383**
Utjecaj kondicioniranja vanjskom energijom na fizikalne značajke biogoriva
The influence of external energy conditioning on biofuels physical properties

M. Salkić, A. Selimović, H. Keran **391**
Spektrofotometrijsko određivanje L-askorbinske kiseline korištenjem kalijevog tiocijanata kao stabilizatora
Spectrophotometric determination of L-ascorbic acid using potassium thiocyanate as a stabilizer

G. Voicu, T. Casandroiu, C. Tarcolea, E.M. Tudosie, P. Voicu **399**
Eksperimentalno istraživanje fizikalnih karakteristika proizvoda od pšenične meljave
Experimental research on the physical characteristics of products obtained from wheat milling

C. Budui **411**
Promjene funkcije sile rezanja promjenom kuta noževa uređaja za sitnjenje grube krme
Variation of the cutting force function of cutting angle of the knives from mincing device of the breaking machines for rough fodders

P. Berk, J. Rakun, M. Lakota, D. Škorjanc, M. Ocepek **419**
Regulacija temperature v vzrejališču pujskov z uporabo mehke odločitvene logike
Temperature regulation in piglets production with decision-making through fuzzy logic

O. Sada, B. Reppo **429**
Troškovi rada i radno opterećenje u uzgoju svinja za tov
Working time expenses and degree of difficulty of fatlings tending

D. Tucu, D. Mnerie **439**
Optimiranje opskrbe obnovljivom energijom
Optimization of renewable energy supply

D. Tucu, A.-G. Golîmba, D. Mnerie **447**
Dizajn integriranog strugala i rukohvata
Grippers design integrated in handling system destinated to agriculture mechanization

D. Tucu, A.-G. Golîmba, T. Slavici **455**
Fuzzy metode u optimiranju investiranja obnovljive energije
Fuzzy methods in renewable energy optimization investments

D. Mnerie, D. Țucu, I. Balcu, G. V. Mnerie, M. Mirică **463**
Proizvodnja bio-etanola iz celuloznih strugotina
Bio-ethanol from cellulose sweepings

IN MEMORAM **473**

KOMERCIJALNE PORUKE **475**
COMMERCIAL NOTES

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 627.4
Izvorni znanstveni rad
Original scientific paper

DAM-BREAK WAVE ROUTING: A 2D, TWO-PHASE MODEL FOR MATURE AND IMMATURE DEBRIS AND HYPER-CONCENTRATED FLOWS

D. DE WRACHIEN[1], S. MAMBRETTI[2]

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

ABSTRACT

It is commonly accepted that debris and hyper-concentrated flows resulting from a sudden collapse of a dam (dam-break) can be described by means of the De Saint Venant (SV) equations. During the last century much effort has been devoted to the numerical solutions of these equations, mainly driven by the need for accurate and efficient solvers for the discontinuities in dam-break problems.

In this paper, 1D and 2D two-phase models are proposed to predict the triggering, mobilising and stopping processes of both mature (non-stratified) and immature (stratified) dam-break debris and hyper-concentrated flows. The models are based on mass and momentum conservation equations for both liquid and solid phases. The McCormack-Jameson scheme was employed for the solution of the equations written in a conservative law form

The validate the models, comparisons have been made between their predictions and laboratory tests concerning flows of water and homogeneous granular mixtures in a uniform geometry flume reproducing dam-break waves. Agreements between computational and experimental results are considered very satisfactory, mainly for mature (non- stratified) debris flows, which embrace most real cases. To better predict immature (stratified) flows, the models has been improved in order to feature, in a more realistic way, the distribution of the particles within the mixture.

Key words: *dam-break, debris and hyper-concentrated flows, rheological behaviour of the mixtures, two- phase modelling.*

INTRODUCTION

In this paper a 2D two – phase model for debris flow propagation is proposed. SV equations, modified for including erosion / deposition processes along the mixture path, are used for expressing conservation of mass and momentum for the two phases of the mixture. The scheme is validated in 1D for dam-break problems comparing numerical results with experimental data. Comparisons are made between both wave depths and front propagation velocities obtained respectively on the basis of laboratory tests and with predictions from the numerical model proposed by McCormack – Jameson (McCormack, 1969; Jameson, 1982).

In order to analyze stratified (immature) flow – the solid/liquid mixture is present in the lower layer, while only water is present in the upper one – the model has been improved by taking into account mass and momentum conservation equations for each phase and layer. Momentum conservation equations describe energy exchanges between the two phases in the same layer and between layers, while mass conservation equations describe mass exchange between the layers (Mambretti et al., 2007, 2008). Moreover, to simulate the propagation on alluvial fans, the model was further improved to allow 2D simulations of mixtures of liquid and solid phases.

THEORETICAL APPROACH

Debris flow resulting from flash floods such as 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; Bechteler et al., 1992; Aureli et al., 2000).

Numerical treatments of such equations, generally, require schemes capable of preserving discontinuities, possibly without any special shift (shock – capturing schemes). Most numerical approaches have been developed in the last two or three decades, that include the use of finite differences, finite elements or discrete / distinct element methods (Asmar et al., 1997; Rodriguez et al., 2006).

1D Governing Equations

The 1D approach for unsteady debris flow triggered by dam – break is governed by the SV equations. This set of partial differential equations describes a system of hyperbolic conservation laws with source term (S) and can be written in compact vector form as:

$$\frac{\partial \mathbf{V}}{\partial t} + \frac{\partial \mathbf{F}}{\partial s} = \mathbf{S} \tag{1}$$

where:

$$\mathbf{V} = \begin{pmatrix} A \\ Q \end{pmatrix} \qquad \mathbf{F} = \begin{pmatrix} Q \\ \frac{Q^2}{A} + g \cdot I_1 \end{pmatrix} \qquad \mathbf{S} = \begin{pmatrix} 0 \\ g \cdot A \cdot (i - S_i) + g \cdot I_2 \end{pmatrix}$$

with $A(s,t)$: wetted cross – sectional area; $Q(s,t)$: flow rate; s: spatial coordinate; t: temporal coordinate; g: acceleration due to gravity; i: bed slope; S_i: bed resistance term or friction slope, that can be modelled using different rheological laws (Rodriguez et al., 2006).

The pressure force integrals I_1 and I_2 are calculated in accordance with the geometrical properties of the channel. I_1 represents a hydrostatic pressure form term and I_2 represents the pressure forces due to the longitudinal width variation, expressed as:

$$I_1 = \int_0^h (H-\eta)\cdot\sigma(s,\eta)\cdot d\eta \qquad I_2 = \int_0^h (H-\eta)\cdot\frac{\partial\sigma}{\partial s}\cdot d\eta \tag{2}$$

where H: water depth; η : integration variable indicating distance from the channel bottom; $\sigma(s,\eta)$:channel width at distance η from the channel bed, expressed as:

$$\sigma(s,\eta) = \frac{\partial A(s,\eta)}{\partial\eta} \tag{3}$$

To take into account erosion / deposition processes along the debris flow propagation path, which are directly related to both the variation of the mixture density and the temporal evolution of the channel bed, a mass conservation equation for the solid phase and a erosion / deposition model have been introduced in the SV approach. Defining the sediment discharge as:

$$q(s,t) = E\cdot B \tag{4}$$

with E: erosion / deposition rate; B: wetted bed width, the modified vector form of the SV equations can be expressed as follows:

$$\frac{\partial\mathbf{V}}{\partial t} + \frac{\partial\mathbf{F}}{\partial s} = \mathbf{S} \tag{5}$$

where:

$$\mathbf{V} = \begin{pmatrix} A \\ Q \\ c_s\cdot A \end{pmatrix} \qquad \mathbf{F} = \begin{pmatrix} Q \\ \dfrac{Q^2}{A} + g\cdot I_1 \\ c_s\cdot Q \end{pmatrix} \qquad \mathbf{S} = \begin{pmatrix} q(s,t) \\ g\cdot A(i-S_i) + g\cdot I_2 \\ E\cdot c_*\cdot B \end{pmatrix}$$

with c_s: volumetric solid concentration in the mixture; $c*$: bed volumetric solid concentration.

Two Phase Mathematical Model

In the present work granular and liquid phases are considered. The model includes two mass and momentum balance equations for both the liquid and solid phases respectively. The interaction between phases is simulated according to Wan and Wang hypothesis (1984). The system is completed with equations to estimate erosion/deposition rate derived from the Egashira and Ashida (1987) relationship and by the assumption of the Mohr – Coulomb failure criterion for non cohesive materials.

Mass and momentum equations for water can be expressed in conservative form as:

$$\frac{\partial Q_l(s,t)}{\partial s}+\frac{\partial(c_l\cdot A(s,t))}{\partial t}=0 \tag{6}$$

$$\frac{\partial Q_l}{\partial t}+\frac{\partial}{\partial s}\left(\beta\cdot\frac{Q_l^{\,2}}{c_l\cdot A}\right)=g\cdot c_l\cdot A\cdot\left(i-J-\frac{\partial H}{\partial s}\right)-F \tag{7}$$

with $Q_l(s,t)$: flow discharge; c_l: volumetric concentration of water in the mixture; β: momentum correction coefficient that we will assume to take the value $\beta=1$ from now on; J: slope of the energy line according to Chézy's formula; i: bed slope; F: friction force between the two phases.

According to Wan and Wang (1984), the interaction of the phases at single granule level f is given by:

$$f=c_D\cdot\frac{\pi\cdot d_{50}^{\,2}}{4}\cdot\frac{\rho_l\cdot(v_l-v_s)}{2}\cdot|v_l-v_s| \tag{8}$$

with c_D: drag coefficient; v_l: velocity of water; v_s: velocity of the solid phase; d_{50}: mean diameter of the coarse particle; ρ_l: liquid density.

Assuming grains of spherical shape and defining the control volume of the mixture as:

$$V_c=B\cdot H\cdot\cos\vartheta\cdot ds\approx B\cdot H\cdot ds \tag{9}$$

with ϑ: channel slope angle, which holds for low channel slopes, the whole friction force F between the two phases for the control volume can be written as:

$$F=\frac{3}{4}\cdot c_D\cdot\rho_l\cdot(v_l-v_s)\cdot|v_l-v_s|\cdot\frac{c_s}{d_{50}}\cdot H\cdot B\cdot ds \tag{10}$$

Mass and momentum conservation equations for the solid phase of the mixture can be expressed as:

$$\frac{\partial(c_s\cdot A)}{\partial t}+\frac{\partial Q_s}{\partial s}=E\cdot c_*\cdot B \tag{11}$$

$$\begin{aligned}\frac{\partial Q_s}{\partial t}+\frac{\partial}{\partial s}\left(\beta\cdot\frac{Q_s^{\,2}}{c_s\cdot A}\right)&=-g\cdot\frac{\rho_s-\rho_l}{\rho_s}\cdot c_s\cdot\left(1+i^2\right)\cdot\frac{\partial H}{\partial s}\cdot A+F+\\&+g\cdot\frac{\rho_s-\rho_l}{\rho_s}\cdot c_s\cdot\left(i^2-1\right)\cdot tg\delta\cdot A+g\cdot\frac{\rho_s-\rho_l}{\rho_s}\cdot c_s\cdot A\cdot i\end{aligned} \tag{12}$$

with $Q_s(s,t)$: discharge of the solid rate; ρ_s: solid phase density.

According to Ghilardi et at. (1999) and to Egashira and Ashida (1987), the bed volumetric solid concentration c* was assumed to be constant and the erosion velocity rate E a function of the mixture velocity U:

$$E = U \cdot k_E \cdot tg(\vartheta_f - \vartheta_e) \tag{13}$$

with k_E: coefficient equal to 0.1 according to experimental data (Egashira and Ashida, 1987; Gregoretti, 1998; Ghilardi et al., 1999; Gregoretti, 2000).

Positive or negative values of E correspond to granular material erosion or deposition, respectively.

ϑ_f and ϑ_e represent the energy line and the bed equilibrium angles, respectively, expressed as (Brufau et al., 2001):

$$\vartheta_f = arctg\left[\frac{J}{\cos\vartheta}\right] \tag{14}$$

$$\vartheta_e = arctg\left[\frac{c_s \cdot (\rho_s - \rho)}{c_s \cdot (\rho_s - \rho) + \rho} \cdot tg\phi\right] \tag{15}$$

where the debris flow density is defined as:

$$\rho = (\rho_s - \rho_l) \cdot c_s + \rho_l \tag{16}$$

and ϕ is the static internal friction angle. U is defined as follows:

$$U = c_s v_s + c_l v_l \tag{17}$$

For J the Takahashi (1991) equation has been chosen, according to the dilatant fluid hypothesis developed by Bagnold (1954):

$$J = S_i = \frac{U^2}{\left(\frac{2}{5 \cdot d_{50}} \cdot \frac{H}{\lambda}\right)^2 \cdot \frac{1}{a_b \cdot sen\,\delta} \cdot \left[c_s + (1 - c_s) \cdot \frac{\rho_l}{\rho_s}\right] \cdot g \cdot R} \tag{18}$$

with S_i: friction term and R: hydraulic radius given by:

$$R = \frac{A}{P} \tag{19}$$

where P is the wetted perimeter.

The quantity λ (linear concentration) depends on the granulometry of the solids in the form:

$$\lambda = \frac{c_s^{1/3}}{c_m^{1/3} - c_s^{1/3}} \tag{20}$$

where c_m: maximum packing volume fraction (for perfect spheres $c_m = 0.74$); a_b: empirical constant.

With regard to the momentum conservation equation (12) all its terms have been evaluated considering only the fraction of volume actually occupied by grains and ignoring the erosion / deposition velocity.

Extension to two layers (immature debris flow)

Debris flows are categorized as stratified or immature whenever the solid/liquid mixture is present in the lower layer, while only the water is present in the upper one (figure 3).

Assuming h_{mx} and h_{cw} as the depths of the mixture and of the clear water respectively, the total depth of the debris flow h_{df} is equal to:

$$h_{df} = h_{mx} + h_{cw} \tag{22}$$

while the maturity degree d_m is assessed as the ratio:

$$d_m = \frac{h_{mx}}{h_{df}} \tag{23}$$

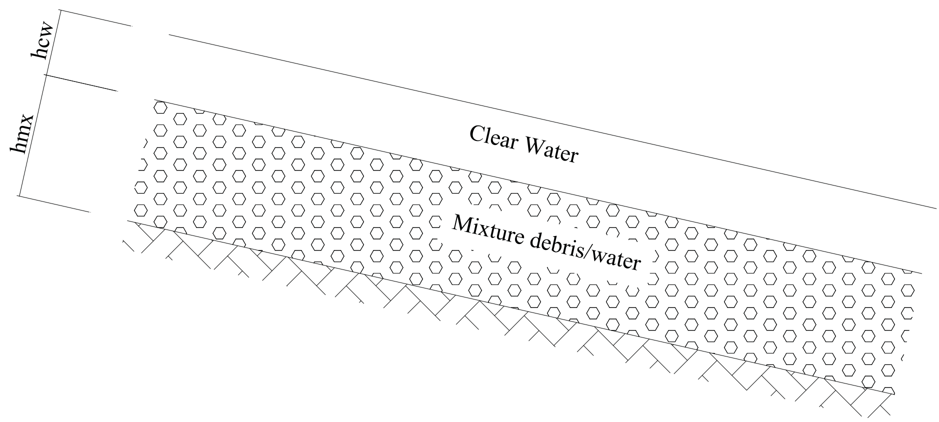


Figure 1: scheme of the immature (stratified) debris flow

Larcan et al (2006) has suggested – on the basis of laboratory experiments – to distinguish mature and immature debris flow by means of a criterion based on mixture velocity and concentration.

The experimental tests showed that in the first phase the flow is stratified; then, usually, it becomes mature, because the velocities and the concentrations are quite high. Finally, the tail of the wave is characterised by low velocities, due to the fact that the solid phase tends to deposit, and thus the flow becomes again stratified.

Mass and momentum equations for clear water can be expressed in conservative form as:

$$\frac{\partial Q_{cw}(s,t)}{\partial s} + \frac{\partial A_{cw}(s,t)}{\partial t} = 0 \tag{24}$$

$$\frac{\partial Q_{cw}}{\partial t} + \frac{\partial}{\partial s}\left(\beta \cdot \frac{{Q_{cw}}^2}{A_{cw}}\right) = g \cdot A_{cw} \cdot \left(i - J_{cw} - \frac{\partial H_{cw}}{\partial s} - J_{two\ layers}\right) \tag{25}$$

The resistance term J_{cw} can be assessed on the basis of bank shear stress, while the slope of the energy line, $J_{two\ layers}$, due to the lower layer, according to Chézy's formula, is expressed as:

$$J_{two\ layers} = \frac{n^2 \cdot (V_{cw} - V_{mx})^2}{R^{4/3}} \tag{26}$$

being n the Manning's number and V_{mx} the velocity of the lower layer. The drag force $T_{two\ layers}$ between the higher layer and the lower one, can be expressed as:

$$T_{two\ layers} = g \cdot A_{cw} \cdot J_{two\ layers} \tag{27}$$

In the same ways as (6) and (7), these equations can be expressed as:

$$\frac{\partial Q_{l,mx}(s,t)}{\partial s} + \frac{\partial (c_{l,mx} \cdot A_{mx}(s,t))}{\partial t} = 0 \tag{28}$$

$$\frac{\partial Q_{l,mx}}{\partial t} + \frac{\partial}{\partial s}\left(\beta \cdot \frac{{Q_{l,mx}}^2}{c_{l,mx} \cdot A_{mx}}\right) = g \cdot c_{l,mx} \cdot A_{mx} \cdot \left(i - J_{mx} - \frac{\partial H_{mx}}{\partial s}\right) - F + c_{l,mx} \cdot T_{two\ layers} \tag{29}$$

$T_{two\ layers}$ is opposite in sign with respect to (29) due to the fact that the higher layer, with greater velocities, exerts a drag force to the mixture.

Likewise (11) and (12), mass and momentum equations can be expressed as:

$$\frac{\partial (c_{s,mx} \cdot A_{mx})}{\partial t} + \frac{\partial Q_{s,mx}}{\partial s} = E \cdot c_* \cdot B \tag{30}$$

$$\begin{aligned} \frac{\partial Q_{s,mx}}{\partial t} + \frac{\partial}{\partial s}\left(\beta \cdot \frac{{Q_{s,mx}}^2}{c_{s,mx} \cdot A_{mx}}\right) &= -g \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot c_{s,mx} \cdot \left(1 + i^2\right) \cdot \cdot \frac{\partial H_{mx}}{\partial s} \cdot A_{mx} + F + \\ &+ g \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot c_{s,mx} \cdot \left(i^2 - 1\right) \cdot tg\delta \cdot A_{mx} + g \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot c_{s,mx} \cdot A_{mx} \cdot i + c_{s,mx} \cdot T_{two\ layers} \end{aligned} \tag{31}$$

The SV equations for 1D two – phase unsteady debris flow can be expressed in compact vector form as follows:

$$\frac{\partial \mathbf{V}}{\partial t} + \frac{\partial \mathbf{F'}}{\partial s} + C \cdot \frac{\partial \mathbf{F''}}{\partial s} = \mathbf{S} \tag{32}$$

where, for a rectangular section channel and for a completely mixed fluid:

$$\mathbf{V}=\begin{pmatrix} c_l\cdot A \\ c_s\cdot A \\ Q_l \\ Q_s \end{pmatrix}\qquad \mathbf{F'}=\begin{pmatrix} Q_l \\ Q_s \\ \dfrac{Q_l^{\,2}}{c_l\cdot A} \\ \dfrac{Q_s^{\,2}}{c_s\cdot A} \end{pmatrix}\qquad \mathbf{F''}=\begin{pmatrix} 0 \\ 0 \\ \dfrac{1}{2}\cdot g\cdot\dfrac{A^2}{B} \\ \dfrac{1}{2}\cdot g\cdot\dfrac{\rho_s-\rho_l}{\rho_s}\cdot\left(1+i^2\right)\cdot\dfrac{A^2}{B} \end{pmatrix}$$

$$\mathbf{S}=\begin{pmatrix} 0 \\ E\cdot c_*\cdot B \\ g\cdot c_l\cdot A\cdot(i-J)-\dfrac{3}{4}\cdot c_D\cdot(v_l-v_s)^2\cdot\dfrac{c_s\cdot A}{d_{50}} \\ g\cdot c_s\cdot A\cdot\dfrac{\rho_s-\rho_l}{\rho_s}\cdot\left[\left(i^2-1\right)\cdot tg\delta+i\right]+\dfrac{3}{4}\cdot c_D\cdot\dfrac{\rho_l}{\rho_s}\cdot(v_l-v_s)^2\cdot\dfrac{c_s\cdot A}{d_{50}} \end{pmatrix}$$

$$\mathbf{C}=\begin{pmatrix} 0 & 0 & c_l & c_s \end{pmatrix}$$

and for a stratified (immature) flow:

$$\mathbf{V}=\begin{pmatrix} A_{cw} \\ c_{l,mx}\cdot A_{mx} \\ c_{s,mx}\cdot A_{mx} \\ Q_{cw} \\ Q_{l,mx} \\ Q_{s,mx} \end{pmatrix}\qquad \mathbf{F'}=\begin{pmatrix} Q_{cw} \\ Q_{l,mx} \\ Q_{s,mx} \\ \dfrac{Q_{cw}^2}{A_{cw}} \\ \dfrac{Q_{l,mx}^{\;\;2}}{c_{l,mx}\cdot A_{mx}} \\ \dfrac{Q_{s,mx}^{\;\;2}}{c_{s,mx}\cdot A_{mx}} \end{pmatrix}\qquad \mathbf{F''}=\begin{pmatrix} 0 \\ 0 \\ 0 \\ \dfrac{1}{2}\cdot g\cdot\dfrac{A_{cw}^2}{B} \\ \dfrac{1}{2}\cdot g\cdot\dfrac{A_{mx}^2}{B} \\ \dfrac{1}{2}\cdot g\cdot\dfrac{\rho_s-\rho_l}{\rho_s}\cdot\left(1+i^2\right)\cdot\dfrac{A_{mx}^2}{B} \end{pmatrix}$$

$$\mathbf{S} = \begin{pmatrix} 0 \\ 0 \\ E \cdot c_* \cdot B \\ g \cdot A_{cw} \cdot (i - J_{cw}) - \dfrac{n^2 \cdot (V_{cw} - V_{mx})^2}{R_{cw}^{4/3}} \\ g \cdot c_{l,mx} \cdot A_{mx} \cdot (i - J_{mx}) - \dfrac{3}{4} \cdot c_D \cdot (v_{l,mx} - v_{s,mx})^2 \cdot \dfrac{c_{s,mx} \cdot A_{mx}}{d_{50}} + \\ \qquad c_{l,mx} \cdot g \cdot A_{mx} \cdot \dfrac{n^2 \cdot (V_{cw} - V_{mx})^2}{R_{cw}^{4/3}} \\ g \cdot c_{s,mx} \cdot A_{mx} \cdot \dfrac{\rho_s - \rho_l}{\rho_s} \cdot \left[(i^2 - 1) \cdot tg\delta + i \right] + \dfrac{3}{4} \cdot c_D \cdot \dfrac{\rho_l}{\rho_s} \cdot (v_{l,mx} - v_{s,mx})^2 \cdot \\ \qquad \dfrac{c_{s,mx} \cdot A_{mx}}{d_{50}} + c_{s,mx} \cdot g \cdot A_{mx} \cdot \dfrac{n^2 \cdot (V_{cw} - V_{mx})^2}{R_{cw}^{4/3}} \end{pmatrix}$$

$$\mathbf{C} = \begin{pmatrix} 0 & 0 & 0 & 1 & c_l & c_s \end{pmatrix}$$

Extension to 2D.

This model can be easily extended to 2D, by taking into account the mass and momentum equations for both the solid and liquid phases and by considering the force exchanges between the two phases and between the upper and the lower layers.

The equation in compact form can be expressed as

$$\frac{\partial \mathbf{V}}{\partial t} + \frac{\partial \mathbf{E}}{\partial x} + \frac{\partial \mathbf{F}}{\partial y} = \mathbf{S} \tag{33}$$

where

$$\mathbf{E} = \mathbf{E}' + \mathbf{c}_1 \cdot \mathbf{E}''$$
$$\mathbf{F} = \mathbf{F}' + \mathbf{c}_2 \cdot \mathbf{F}''$$

$$\mathbf{U} = \begin{vmatrix} h_{cw} \\ u_{cw} \cdot h_{cw} \\ v_{cw} \cdot h_{cw} \\ c_l \cdot h_{mx} \\ u_{mx} \cdot c_l \cdot h_{mx} \\ v_{mx} \cdot c_l \cdot h_{mx} \\ c_s \cdot h_{mx} \\ u_{smx} \cdot c_s \cdot h_{mx} \\ v_{smx} \cdot c_s \cdot h_{mx} \end{vmatrix} \qquad \mathbf{E}' = \begin{vmatrix} u_{cw} \cdot h_{cw} \\ u_{cw}^2 \cdot h_{cw} \\ u_{cw} \cdot v_{cw} \cdot h_{cw} \\ u_{mx} \cdot c_l \cdot h_{mx} \\ u_{mx}^2 \cdot c_l \cdot h_{mx} \\ u_{mx} \cdot v_{mx} \cdot h_{mx} \\ u_{smx} \cdot c_s \cdot h_{mx} \\ u_{smx}^2 \cdot c_s \cdot h_{mx} \\ u_{smx} \cdot v_{smx} \cdot c_s \cdot h_{mx} \end{vmatrix}$$

$$\mathbf{E}'' = \begin{vmatrix} 0 \\ \frac{1}{2} \cdot g \cdot h_{cw}^2 \\ 0 \\ 0 \\ \frac{1}{2} \cdot g \cdot h_{mx}^2 \\ 0 \\ 0 \\ \frac{1}{2} \cdot g \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot (1 + i_x^2) \cdot h_{mx}^2 \\ 0 \end{vmatrix} \qquad \mathbf{c}_1 = \begin{bmatrix} 0 & 1 & 0 & 0 & c_l & 0 & 0 & c_s & 0 \end{bmatrix}$$

$$\mathbf{F}' = \begin{vmatrix} v_{cw} \cdot h_{cw} \\ u_{cw} \cdot v_{cw} \cdot h_{cw} \\ v_{cw}^2 \cdot h_{cw} \\ v_{mx} \cdot c_l \cdot h_{mx} \\ u_{mx} \cdot v_{mx} \cdot c_l \cdot h_{mx} \\ v_{mx}^2 \cdot c_l \cdot h_{mx} \\ v_{smx} \cdot c_s \cdot h_{mx} \\ u_{smx} \cdot v_{smx} \cdot c_s \cdot h_{mx} \\ v_{smx}^2 \cdot c_s \cdot h_{mx} \end{vmatrix} \qquad \mathbf{F}'' = \begin{vmatrix} 0 \\ 0 \\ \frac{1}{2} \cdot g \cdot h_{cw}^2 \\ 0 \\ 0 \\ \frac{1}{2} \cdot g \cdot h_{mx}^2 \\ 0 \\ 0 \\ \frac{1}{2} \cdot g \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot (1 + i_y^2) \cdot h_{mx}^2 \end{vmatrix}$$

$$\mathbf{c}_2 = \begin{bmatrix} 0 & 0 & 1 & 0 & 0 & c_l & 0 & 0 & c_s \end{bmatrix}$$

$$
\mathbf{S} = \left|
\begin{array}{l}
0 \\
g \cdot h_{cw} \cdot \left[i_x - J_{cwx} \right] \\
g \cdot h_{cw} \cdot \left[i_y - J_{cwy} \right] \\
0 \\
- \frac{3}{4} \cdot c_D \cdot \frac{c_s \cdot h_{mx}}{D} \cdot (u_{mx} - u_{smx})^2 + g \cdot h_{mx} \cdot \left[i_x - J_{mxx} \right] \\
- \frac{3}{4} \cdot c_D \cdot \frac{c_s \cdot h_{mx}}{D} \cdot (v_{mx} - v_{smx})^2 + g \cdot h_{mx} \cdot \left[i_y - J_{mxy} \right] \\
E_x + E_y \\
\frac{3}{4} \cdot c_D \cdot \frac{\rho_l}{\rho_s} \cdot \frac{c_s h_{mx}}{D} \cdot (u_{mx} - u_{smx})^2 + \\
\quad + g \cdot c_s \cdot h_{mx} \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot \left[i_x - (1 - i_x^2) \cdot \tan \phi' \right] + \\
\quad + g \cdot \frac{\rho_l}{\rho_s} \cdot J_{mxx} \cdot c_s \cdot h_{mx} \\
\frac{3}{4} \cdot c_D \cdot \frac{\rho_l}{\rho_s} \cdot \frac{c_s \cdot h_{mx}}{D} \cdot (v_{mx} - v_{smx})^2 + \\
\quad + g \cdot c_s \cdot h_{mx} \cdot \frac{\rho_s - \rho_l}{\rho_s} \cdot \left[i_y - (1 - i_y^2) \cdot \tan \phi' \right] + \\
\quad + g \cdot \frac{\rho_l}{\rho_s} \cdot J_{mxy} \cdot c_s \cdot h_{mx}
\end{array}
\right|
$$

being u and v the velocities along the x and y axes, respectively.

Numerical treatments of such equations, generally, require schemes capable of preserving discontinuities, possibly without any special shift (shock – capturing schemes). Most numerical approaches have been developed in the last two or three decades, that include the use of finite differences, finite elements or discrete / distinct element methods (Asmar et al., 1997; Rodriguez et al., 2006).

Whatsoever solver adopted, at each time-step the degree of maturity has to be assessed, in order to choose the appropriate terms to incorporate in the SV equations.

EXPERIMENTAL RESULTS AND MODEL CALIBRATION

Validation of the 1D model

To validate the model, comparisons have been made between its predictions and experimental results carried out at the Hydraulic Laboratory of the Politecnico di Milano. Numerical solutions of the SV equations are based on the well-known McCormack-Jameson predictor-corrector finite difference scheme (McCormack 1969; Jameson 1982).

The 1D tests were performed with flows of water and homogeneous granular mixtures in a uniform geometry flume reproducing dam-break waves (Larcan et al., 2002; 2006). The experimental set-up consisted of a loading tank (dimensions 0.5 *m* x 0.5 *m* x 0.9 *m*) with a downstream wall made of sluice gate, a pneumatic control device and a very short opening time (0.3 *s*).

The mixture flowed in a 6 *m* long channel of square section (0.5 *m* x 0.5 *m*) and adjustable slope. To enable camera recordings, one of the flume lateral walls contained glass windows.

Experimental tests were performed by changing the channel slope, the bottom roughness (smooth bottom made of galvanised plate or rough bottom covered with an homogeneous layer of gravel, with d_{50} = 0.005 *m*), the solid material characteristics (plastic material: $\rho = 1168\, kg/m^3$, d_{50} = 0.003 *m*; or gravel: $\rho = 2621\, kg/m^3$, d_{50} = 0.005 *m*) and the volumetric concentration of the mixture.

Recordings were made with a Sony Digital Hand cam, model DCR – TRV32 E camera, which had an acquisition velocity of 25 frames per second, and were electronically elaborated.

To take into account different behaviours of the flow, the experimental data have been compared with the predictions of three rheological laws included in the one phase model (called “Water”, “Fix Bagnold” and “Mobile Bagnold” depending on the resistance law adopted) and with those of the two phase model.

Comparisons show good agreement on the general shape that includes a steep front immediately followed by the maximum wave height and a decrease in flow depths down to an asymptotic value reached at the stoppage

Validation of the 2D model

More difficult was to set-up a flume for collecting data regarding 2D wave propagation. At the Hydraulic Laboratory of the Politecnico of Milano, a simpler set-up was utilized. The devise consisted of a loading tank, a flume and a downstream plain (dimensions 1.0 *m*x1.0 *m*), with adjustable slope and roughness.

In the experimental tests carried out (Figure 2) no recording of the propagation wave was performed, but only a survey of the characteristics of the deposited solid material.

Moreover, a computer program was developed to handle the recording of the images and the following data processing phase. This program will be integrated in the 2D code for SV wave propagation.

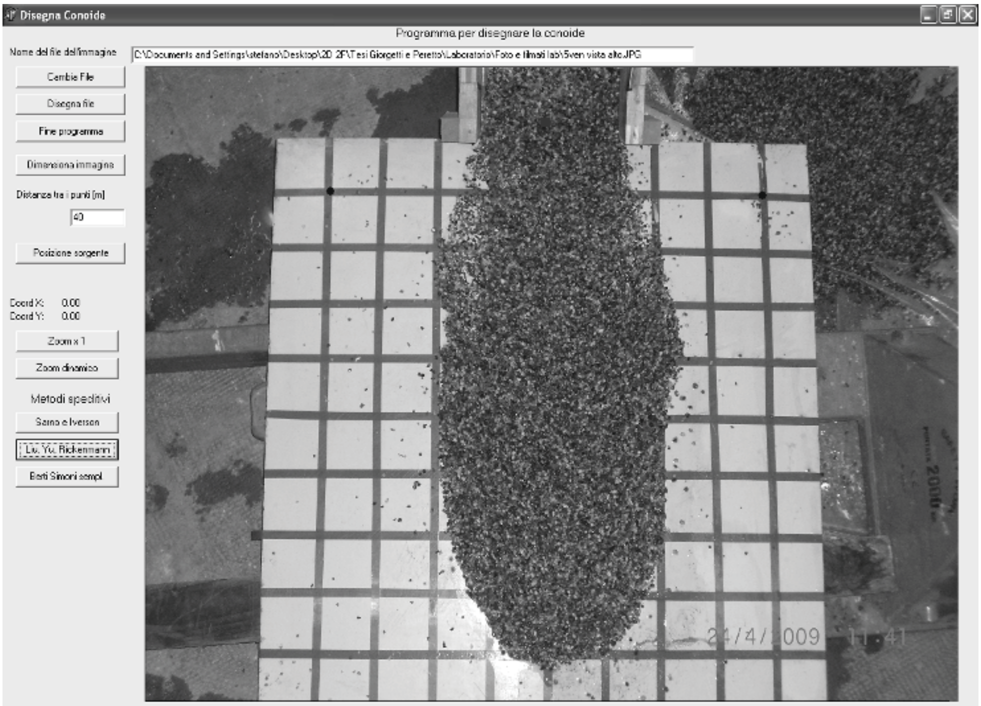


Figure 2: Experimental set-up for 2D debris flow propagation studies

CONCLUSIONS

Achieving a set of debris flow constitutive equations is a task which has been given particular attention by the scientific community during the second half of the last century.

In this context, the present paper describes the main features and characteristics of a numerical model suitable to solve the SV equations, modified for including two-phase debris flow phenomena, and able to assess the depth of the wave and the velocities of both the liquid and solid phases of no-stratified (mature) flow, following dam-break events.

The model is based on mass and momentum conservation equations for both liquid and solid phases. The McCormack-Jameson two-step explicit scheme with second order accuracy was employed for the solution of the equations, written in a conservative-law form. This technique was applied for determining both the propagation and the profile of a debris flow wave resulting from the instantaneous and complete collapse of a storage dam. Different experimental cases of dam-break situations in a square section channel have been considered for the purpose of comparing results.

Agreements between computational and experimental results regarding both wave front-advance and stage hydrographs are considered very satisfactory.

To widen the reach of the proposed model an essential improvement has been outlined in the paper. This improvement will render the model suitable to predict stratified (immature) flow by taking into account mass and momentum conservation equations for each phase and layer. Momentum conservation equations describe energy exchanges between the two phases in the same layer and between layers, while mass conservation equations describe mass exchanges between layers.

Moreover, a 2D, two-phase extension of the model has been proposed to predict the triggering mobilising and stopping processes of both mature (non-stratified) and immature (stratified) debris flows, and pertinent laboratory tests feasible to assess the efficiency and reliability of the updated model have been carried out.

Within this ground, in order to analyse reverse goading (sorting), when the solid phase is composed of non-homogeneous material, the model should be further improved, in order to feature the distribution of the material of different size of the solid phase: larger size material positioned in the front and in the top of the wave, and finer ones in the bottom and in the tail.

REFERENCES

1. 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
2. Aureli F., Mignosa P., Tomirotti M., “Numerical simulation and experimental verification of dam – break flow with shocks” *Journal of Hydraulic Research*, 2000, 38, pp. 197 – 216
3. 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
4. Bechteler W., Kulisch H., Nujic M., “2D dam – break flooding wave: comparison between experimental and calculated results” *Floods and Flood Management*, Ed. Saul, Dodrecht, 1992
5. Bellos V., Sakkas J.G., “1D dam – break flood propagation on dry bed” Journal of Hydraulic Engineering, 1987, ASCE 113(12), pp. 1510 – 1524
6. Brufau P., Garcia – Navarro P., Ghilardi P., Natale L., Savi F., “1D Mathematical modelling of debris flow” *Journal of Hydraulic Research*, 38, 2001, pp. 435 – 446
7. Egashira S., Ashida K., “Sediment transport in steep slope flumes”, Proc. of RoC *Japan Joint Seminar on Water Resources*,1987
8. 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
9. Garcia Navarro P., Saviròn J.M., “McCormack methods for numerical simulation of 1D discontinuous unsteady open channel flow” *Journal of Hydraulic Research*, 1992, 30(1), pp. 313 – 327
10. Ghilardi P., Natale L., Savi F., “Two mathematical models simulating a real-world debris-flow”, Proc.IAHR Symposium on *River, Coastal and Estuarine Morphodynamics*, Genova, 1999
11. Gregoretti C., “Fronte di debris-flow. Composizione e celerità”, *L’acqua* n. 6, pp. 29-39, 1998

12. Gregoretti C., “Stima della velocità massima del fronte di una colata detritica che si propaga in un alveo torrentizio”, Idra 2000

13. Jameson A., “Transonic airfoil calculation using the Euler equations” *Numerical Models in Aeronautical Fluid Dynamics*, Ed. P.L. Roe, 1982, Academic Press, New York

14. Larcan E., Mambretti S., Orsi E., “Leggi di resistenza al moto nelle colate di detriti conseguenti al crollo di dighe. 1. Apparato sperimentale e primi risultati.” Proceedings on *28° Convegno di Idraulica e Costruzioni Idrauliche*, Potenza, 16 – 19 settembre 2002 (in Italian)

15. Larcan E., Mambretti S., Pulecchi M., “A procedure for the evaluation of debris flow stratification.” Proceedings of the 1st International Conference on *Monitoring, Simulation, Prevention and Remediation of Dense and Debris flow* Eds. Lorenzini, Brebbia and Emmauouloudis, 7 – 9 giugno 2006, Rhodes, Greece

16. Mambretti S., Larcan E., De Wrachien D., “Debris flow and dam – break surges: Experimental analysis and two – phase modelling” *Quaderni di Idronomia Montana*, 27, pp. 447 – 462, 2007

17. Mambretti S., Larcan E., De Wrachien D., “Theoretical and experimental analysis of debris flow: Rehology and two – phase modelling” (in press) Irrigation and Drainage, 2008

18. McCormack R.W., “The effect of viscosity in hypervelocity impact cratering” *AIAA Paper*, 1969, 75-1

19. Rodriguez C., Blanco A., Garcia R., “Comparison of 1D debris flow modelling approaches using a high resolution and non – oscillatory numerical scheme on the finite volume methods”, Proceeding of the *1st International Conference on Monitoring, Simulation, Prevention and Remediation of Dense and Debris Flow*, Eds. Lorenzini and Brebbia, Rhodes, 2006

20. Takahashi T. “Debris flow” International Association for Hydraulic Research, Balkema, Rotterdam, 1991

21. Wan Z., Wang Y., “Hyper – concentrated flow” International Association for Hydraulic Research monograph, The Netherlands, 1984

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 556.3:628.1
Stručni rad
Expert paper

WATER QUALITY DISCHARGED INTO THE LOWER DANUBE AND THE COSTS ASSOCIATED WITH DRINKING WATER SUPPLY

GEORGETA DRAGOMIR, ŞTEFAN DRAGOMIR, CORNELIA-ELENA TUREAC

University of Galati, Romania
E-mail: gretadragomir@yahoo.com, doromir_dragomir@yahoo.com, cornelia_tureac@yahoo.com

SUMMARY

This paper presents a complex analysis of lower Danube river (Galati area) water quality and the costs of drinking water pollutant elimination. In the context of sustainable development the problem of water pollution has become of a great importance, especially because of ensuring a healthy environment (water, air and soil) for the future generations. In the present conditions, a good life standard of people means to develop clean environment for human activities. Following this idea the drinking water parameters have to be all the time within normal range. For Galati town the main water source is Danube river. Quantities and diversity of polluted substances discharged into the sewerage system and than in Danube river have been increasing continuously. The water cleaning facilities are very expensive and the cost of potable water for population grows up progressively. All those factors determine a continuous pressure on the water quality in the lower Danube river in Galati town area. Galati town is a medium size in Romania with about 400,000 inhabitants and considerable quantities of drinking water have to be provided daily (about six billion liters). A solution for the costs of water cleaning reduction is to diminish the quantities of pollutant substances discharged by diverse users and to do that, monitoring of all pollution inputs from agriculture, industry and other human activities is necessary.

Key words: *monitoring system, sewerage network, hydrological basins and quality standards*

INTRODUCTION

One of the most important problems for the Galati district is to ensure good parameters every day for drinking water for human activities. For that it is necessary to use advanced cleaning technologies to processing approximately six billion liters of water, daily. This cleaning [1] - that means waste water treatment mechanical, chemical and biological - necessity big and complexes installation. These equipments (pump, filter, settling basins, cleaning substances, pipes and other), are very expensive but in the some time are necessary for sustainable development for life and activities in Galati areal.

In that moment, after the measurement made and results recorded we observe big values of specifically indicators by comparing with accepted standards. The cause is the agricultural intensive (the drainage of pesticides in ground waters and than the discharge in the main river in area like: Siret, Prut and Danube rivers), the industrial activities (that discharge the polluted agents in a old and deteriorate sewerage network) and human activities by important quantities of house hold waste, that was evacuate in same old sewerage of town network, concomitant with population grow up).

It is necessary to develop and use new and performing systems, like membrane technologies [2] to make a high cleaning of waste water and to give the possibility for human to consume drink water without pollutants.

The modern monitoring from point of view costs and quality of drinking water in the areal of low Danube (Galati district area contained between Danube, Siret and Prut rivers), is important because the life level of human resource depend for the first of water and air quality and not for the last the soil quality.

A multitude of digital devices exists to respond to the demand of methods requiring less time, less manpower and less financial effort, because of hardware and sensor technologies development.

Such instruments provide accurate on-line estimations for more important (human health) water parameters and collect more samples giving a complex dimension of the water quality status and evolution in hydrological basins of Prut and Danube.

The specialists may collect and estimate the quantities of polluted substances. The research team must have the ability to understand and assimilate the information’s about water quality.

Monitoring water quality demands reliable methods not only for use within distinct countries, but also allowing exchange of environmental information from one country to another.

Furthermore, rules, regulations and administrative laws are put in force in many countries, including Romania with Governmental Directive (H.G. nr. 188 / 2004).

In our country has develop a system to following the environmental quality approach to standard setting and establishing the limits on levels of pollutants in the water.

Water quality standards provide the obligatory framework through physical, chemical, biochemical, radiological and microbiological methods, as well as sampling methods and terminology, to obtain standardized information with an important communication role in supplying answers concerning trends of the macro-regional environmental conditions.

The objectives of the study aims:

- Locating points of water pollution in the Lower Danube Galati;

- Determination of contaminants from wastewater discharged into the river Danube;
- Quantitative evaluation of contaminants;
- Selecting appropriate equipment for neutralizing contaminants from wastewater;
- Achieving an integrated evaluation and monitoring of sources of water pollution in the Danube Galati in order to improve water quality;
- Reduce of drinking water costs.

RESEARCH, EXPERIMENT AND METHODS

The main methods used:

- Field observation and investigation of pollution sources and areas of waste water discharge in the River Danube near Galati town;
- Location and use of photoelectric cells for analysis in the infrared spectrum of water discharged;
- Using flow meters to determine precisely the amount of polluted water on each point of discharge;
- Experiments and chemical analysis to determine the main chemicals that pollute;
- Economic calculations to determine the cost of drinking water

For the first we made a location of Galati area and water sources. The geographical coordinates of the envisaged area (Galați district) are: 28 ^{0} 01' E and 45^{0}25' N.

Galati district is located in the eastern extremity of Romania, on Covurlui Plain, at 3km down- stream of Danube - Siret junction and about 10km upstream of Danube – Prut junction.

Main surface water resources are Danube River, Siret River and Prut River. The Danube River is bounding the region on 20 km, between the junctions with Siret River and Prut River.

Galati city is situated at a junction point of five geographical units Danube floodplain, Macin Mountains, Baragan Plain, the Low Siret Plain and the Covurlui Plain.

Galati City is surrounded by two water accumulation: Brateş lake (area of 24 km^2) in the East of the City and Catuşa Lake situated in the West of the city. Backwater appears at big flow rates on Danube, both on Siret and Prut extending upstream about 30 km.

Dissolved oxygen in Danube water is continuously depleting, which has determined an incipient process of diminishing the oxygen of Danube Delta waters and the extinction of several valuable fish species (example, sturgeon).

Geographical position of Galati City at the “gates” of Danube Delta imposes better and efficient treatment of wastewaters discharged in the Danube River.

In present, wastewaters are directly discharged in the Danube River through six effluent-discharge zone and one points in the Siret River, just upstream the Galati City.

Other towns that discharge polluted water in emissary (river DANUBE and his affluent) without treatment are: Bucuresti, Craiova, Turnu Severin, Giurgiu, Calarasi, Braila, Tulcea, Sulina).

In Romania, wastewater treatment stations process [4], cover a percent of 72%, in especially for the towns inside the country. But we must mention that Galati town is situated near the border with Moldavia Republic (9 Km. distance) and Prut River is natural border.

Flow rates and discharged wastewater volumes from the evacuation points of Galati City by using sewage network make part in our research.

In this table we recorded the estimate volume of polluted water, in cubic meters, that was discharged in every day, in five important points distributed throughout the city of Galati.

Table 1 Zone of discharge for wastewater around of Galati town

No.	Point of waste discharging	Volumes of polluted water daily discharged, m^3	Name of the effluent
1.	Micro 21	6,8	In Siret River and than in Danube river
2.	Ferryboat sector	103,5	In Danube River
3.	Freedom point	7,6	In Danube River
4.	Danube waves	21,0	In Danube River
5.	Confluence of Prut-Danube	6,9	In Danube River (pumping conditioned by seaside level)

The total flow discharged by public canalization systems is in a greatest quantity and the water quality of Danube and Prut is considered in the II and III category.

Multi-yearly average flow rate of Danube and Prut = 6 300 $m^3 s^{-1}$. Minimum value = 1 740 $m^3 s^{-1.}$ Maximum value > 15 000 $m^3 s^{-1.}$

We observe in the next table that the most dangerous indicators of quality are overcome.

We show recorded parameters for water samples collected from Danube (like example we show the measurement recorded in the ferryboat sector, position no.2 from table no.1, in August 07, 7.30 hour p.m.) in August-September 2009 in the Galati town area and we compare with acceptable level (National quality standards NTPA 001).

The most dangerous pollutants for human health are (table no. 2): ammonia nitrogen, synthetic detergents, cyanide, phosphates and we see that the overcome is about 3 to 8 times higher like normal accepted in National quality standards NTPA 001.

Table 2 Measurement of quality water indicators

No.	Indicator	NTPA 001 Maximum acceptable level	Recorded	u. m.
1	Temperature	25	28	^oC
2	pH	6,5 – 8,5	7,8	unities pH
3	Suspension in water	35	300	mg / l
4	CBO_5	20	300	mg / l
5	CCO - Cr	125	500	mg / l
6	Ammonia nitrogen, $NH_4^{\ +}$	2	30	mg/l
7	Nitrogen total, N	10	14	mg / l
8	Sulphides and H_2S	0,5	1,2	mg /l
9	Phosphorus	1,0	5	mg /l
10	Synthetic detergents	0,5	26	mg /l
11	Substances extractable	20	30	mg /l
12	Total iron ion, Fe^{2+}, Fe^{3+}	0,5	-	mg /l
13	Total Cyanide	0,1	1,6	mg /l
14	Nickel, Ni^{2+}	0,1	1,2	mg /l
15	Chromium trivalent, Cr^{3+}	1,0	1,8	mg /l
16	Chromium hexavalent, Cr^{6+}	1,0	1,1	mg /l
17	Copper, Cu^{2+}	0,1	1,5	mg /l
18	Chlorides, Cl	500	584	mg /l
19	Phosphates, PO_3^-	1	3,2	mg /l

SOLUTIONS AND MEASURES ADOPTED

To investigate potential issues in improving the quality of life for residents of Galați City and surrounding region and reducing pollution levels in the Danube River and its downstream locations by implementing an automated monitoring system of water parameters [4], which integrates satellite images, in-situ measurements and that use informational fluxes, GPS and GIS technology.

The measures proposed to implement an integrated monitoring of pollution sources in the Danube River Galati:

- To design the hardware, communication and software infrastructure of such informational decisional system;
- To establish the points from where we collect water samples and control sections that existing in the monitoring plan for that work;

- To program and to test a Control Process Interface in Lab view and to manage DAQ Process;
- To develop a GIS Project for the Galați Sector of Danube River using Autodesk Land Desktop, Raster Design and CAD Overlay.

The monitoring system by satellites network (RTK), needs one minute to initialize on frequency receiver/DGPS immediately and her accuracy of cm in high.

RTK must have own base station in 20 km range and specifics instrument connection.

A specialized computer controls the system who have instruments and devices for coupling at measuring interface, based on real time information about quantity of diverse substance dissolved in water samples.

Statistical Processing permits a better interpretation of the parameters evolution according to specialist's will is performing. Data acquisition for water parameters developing, permit to compare the pollution waters water parameters at precisely time periods and than the environmental authority must to take the measures for eliminate the polluted source.

ECONOMICAL APPROACH

The Galati town cleaning installations has the capacity to cleaning the water for population inside but the costs are very high. If in 2007 year the cubic meter of drinking water was 0.8 euro in 2009 a cubic meter of drinking water is 1.1 euro.

Advanced wastewater treatment is often viewed as having a low priority and / or cost prohibitive by comparing with the other utilities, their owners and their customers have other objectives.

In general, these objectives include the provision of services viable drinking water supply and waste water-collecting, maintaining a positive financial balance and reasonable charges.

Often there are opportunities for water and sewerage companies in the lower basin of the Danube to organize the operation and provide services more efficiently.

A previous presentation highlighted some of the reforms in the tariff and to the management and tariff reforms that, if appropriate implementation, would increase the economic efficiency of utility companies. Furthermore, when water and sanitation operators demonstrate adequate management, character forward, holders of these companies and customers will be more willing to accept higher charges as part of the price payable to the public water system has a modern, of economically sustainable and environmentally friendly.

Both developments will help in the transformation of advanced treatment in a more attractive and feasible option for water and sewerage companies.

Operating a water cleaning system

As part of its management of water supply system, a community must consider various solutions for cost recovery, or to decide what methods will be used to finance the construction started and then regular maintenance and repairs of water supply system.

First, the community must take into account different sources of water available and different technologies of water supply [3]. Then it must to calculate the costs of construction, cleaning equipments, the maintenance for them and each other variable in this complex process.. Next step is to determine how to obtain resources to cover expenses. Construction or rehabilitation of a system of existing water supply is one of the issues, whose costs must be considered. The second issue is the expenditure required for operation, maintenance and repair system.

Building a cleaning water system [5] can be considered as a cost capital investment. Overall cost is calculated as a single, globally. In contrast, current costs are a series of charges that include operating costs such as fuel or lubricants, maintenance costs, costs to protect against vandalism and repair costs and replacement of damaged items. Instead, operating and maintenance costs (to cover costs of repair and maintenance, and fuel) may entail the establishment of user charges and / or some form of charging for community residents. Many international donor agencies can procure the necessary funds to cover capital costs for system construction, but will not sponsor operating expenses.

A model separating them for the low income community is given below:

Capital costs for building a water system may be covered from various sources, such as a government subsidy, a donation from an international donor, and / or fundraising through small donations of residents and philanthropists, sometimes even a loan. In contrast, running costs should be covered by a combination of consumption tax (the water being sold at a symbolic rate), and / or a standard fee for all residents.

Elements of calculation of the price of water and sanitation in Galati town

Calculation assumptions:

For the population is considered that the water delivered is 100% and from that 75% is the drinking water consumed. For the remaining customers is considered that the water delivered 100%, 100% is the drinking water consumed, except for those consumers that, by their specific activity, the water will be returned entirely to the sewer (food industry, railw-ay transport shipping), for which the quantity of waste water evacuated will be established under contract as a drinking water consumption of 10 cubic meters, population has to be paid the value of 7.5 cubic meters of waste water. For the same consumption of drinking water, other types of customers have paid the equivalent value of 10 cubic meters of waste water.

Meteoric water quantity calculation is based on the amounts channeled surfaces of buildings constructed. The monthly water overflows to the public, public institutions and organizations are calculated as: (area constructed x 0.3 x channeled rainwater drain rate) / 12 months."0.3" represents the specific rate based on the annual amount of meteoric water circulated by the National Institute of Meteorology and Hydrology.

Calculation of rain water for household and pool area of 100 square meters built in residential area: (100 x 0,3 x 0,75) / 12 = 1,88 lei (inclusive T.V.A.) / month or 0.43Euro/month.

Calculation of rain water for a 4 storey block with a built area, channeled of approximately 250 square meters (roof area) (250 x 0,3 x 0,75) / 12 = 4,69 lei/month (1.09 euro/month).

By dividing at 15 (number of flats) we obtain: 4,69 lei / 15 = 0,31 lei/flat/month (0.07 euro/flat/month).

In a ten-storey block this value is lower.

Is used this formula: (area occupied x 0.5 x tariff for public service rainwater drainage) / 12. For a built area of 100 square meters channeled we obtain: (100 x 0.5 x 0,75 is sewage rate) / 12 = 3,13lei (including VAT) / mc or 0.72 euro. "0.5" represents the specific rate established for economic agents. The amount above is added the cost of purification of waste water = 1,58 lei (with VAT) / square meters (0.36 euro). For rainwater and sewage costs = 0,80 lei (with VAT) / square meters (0.18 euro).

In conclusion we can see that for economic agents the drinking water is most expensive with 23%, by comparing with the costs of drinking water delivery for inhabitant (consumers) at their home. In these cost we include the tariff for public service of rainwater drainage and sewage costs.

CONCLUSIONS

One important exercise when it calculates various technology options for water supply system of a community is to examine and compare the costs and benefits of each.

For each type of water supply system considered, should make a list of actual costs. These include both capital costs and the operating time. It is important to estimate exactly the number of people who will benefit directly from that facility. Have excluded persons belonging to the community but live too far from the location chosen in order to benefit from the water. Then, based on total capital and operational costs, divided by the number of people served, will make an estimate of costs per capita.

This procedure may be an important factor to consider when evaluating different technologies [6] and water sources for choosing the best. The surgery must be made by the community and not for the community.

Operational costs per head to be compared with any proposed fees or prices at which water can be sold. To ensure transparency, these calculations must be made hand of any member of the community, and any existing or potential donor. Calculation of financial benefits of a water supply system is far more difficult.

On the other hand the monitoring system need for the first to ensure some location in the Galati district and a good link with GPS system that allows automated the correlation with water quality data. Water quality data can be collected at the sampling points established in the monitoring plan by using the Satellites network.

This automated monitoring integrated system must to give information for decisional support and for the measurement that can be taking.

In conclusions we can say that is necessary to respect the standards concerning qualitative and quantitative aspects of Danube, Prut and Siret river in the Galati sector and on long-term the effects of water quality deterioration, has influence on the Danube Delta ecosystems.

REFERENCES

1. Berné, F., Cordonnier, J. (1991), Tratement des eaux*,* Ed. Technip, Paris.
2. Cornelissen, E. R., Sijbers, P., Berkmortel, H., Koning, J., De Wit, A., De Nil, F., Van Impe, J. F. (2001), Reuse of leachate waste-water using membranes technology and reverse osmosis**.** Published in Membrane Technology, Vol. 2001, Issue 136, Pp 6-9.
3. Degrémont, G., (1991), Water Treatment Handbook, vol. 2, Lavoisier Publishing, Paris
4. Dunea, D., Moise V. (2004) Automated monitoring potential for water quality assessments in the Galați sector of Danube River, in Conference volume The Danube and Europe-Integrated Space Applications in the Danube Basin, Mamaia, Romania.
5. Lvovich, M.I., White, G.F. (1990), Use and transformation of terrestrial water in systems, in The Earth as Transformation by Human Action, global and regional changes, Edited by B.L.Turner a.o., Cambridge Press, pp. 235-252.
6. Robescu, D., Robescu, Diana (1996), Procedee, instalații şi echipamente pentru epurarea apelor, Litografia UPB, Bucureşti.

38. SIMPOZIJ
AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.15:659.23
Stručni rad
Expert paper

ULOGA I ZNAČAJ POLJOPRIVREDNE SAVETODAVNE SLUŽBE AP VOJVODINE

*B. OGRIZOVIĆ; ** J. SIMIĆ

*PSS Sombor d.o.o. Sombor
**Pokrajinski Sekretarijat za poljoprivredu, vodoprivredu i šumarstvo

SAŽETAK

U radu je istaknuto mesto i uloga Poljoprivredne stručne službe AP Vojvodine u agrarnoj politici Republike Srbije. Prikazom modela organizovanosti, načinom delovanja, zadacima službe i njenim pripremama da odgovori izazovima današnjeg savetodavnog rada na pokrajinskon nivou, dat je presek aktuelnog trenutka u delovanju službe. Poseban deo posvećen je edukaciji savetodavaca. Očekuje se da će i u narednom periodu više pažnje biti posvećeno savetodavstvu i sektoru korisnika, odnosno farmerima, s obzirom na to da se uskoro očekuje uredjenje odnosa u ovoj oblasti donošenjem Zakona o poljoprivrednim stručnim službama na nivou Republike Srbije.

Ključne reči: *poljoprivreda, savetodavna služba, savetodavci*

UVOD

Proizvodna politika u poljoprivredi, kao rezultat ciljeva agrarne politike limitirana je prirodnim uslovima, stepenom društvenog i ekonomskog razvoja, nacionalnim interesima, medjunarodnim tržištem itd. Metodi pomoću kojih se ostvaruju odredjeni ciljevi agrarne politike zemlje su brojni i raznovrsni. U okviru administrativnih mera (zakonski propisi o kontroli plodnosti zemljišta, zaštiti bilja, semenarstvu, selekciji stoke, poljoprivrednim stručnim službama, standardima i kontroli kvaliteta, obaveznoj primeni zootehničkih mera, itd), kao i organizacionih mera (organizacija rada Ministarstva za poljoprivredu, šumarstvo i vodoprivredu, organizacija rada Pokrajinskog sekretarijata za poljoprivredu, vodoprivredu i šumarstvo, i njihovih pratećih službi), predvidjeni su okviri rada Poljoprivrednih savetodavnih službi. Nakon osnivanja ovih službi 1991. godine i donošenja uredbe o funkcionisanju službi bilo je više pokušaja da se poboljša njihov rad.

METOD RADA

U radu su korišćeni publikovani zakonski propisi, oni koji su u nacrtu, a koji se odnose na normativnu regulaciju rada Poljoprivrednih stručnih službi, s aspekta potreba države i AP Vojvodine.Konsultovana je i odredjena literatura o nastanku, razvoju i ciljevima delovanja Poljoprivredne savetodavne službe Vojvodine.

DISKUSIJA

Jedan od važnijih segmenata u sprovodjenju agrarne politike svake države jesu i poljoprivredne savetodavne(stručne) službe. One bi trebalo da budu instrumenti države koji direktno, na terenu, utiču na sprovodjenje mera države podizanjem obima i kvaliteta proizvodnje i prenosom novih znanja krajnjim korisnicima. Država ovakvim službama poverava i odredjeni nivo kontrolno-inspekcijskih zadataka u vezi sa sprovodjenjem odredjenih mera u okviru specifičnih proizvodnji na terenu. Naravno, osnovni cilj je povećanje poljoprivredne proizvodnje i upoznavanje korisnika usluga s novim tehnologijama i proizvodnim procesima.

U pripremi je i javnoj raspravi novi Nacrt Zakona o obavljanju savetodavnih i stručnih poslova u oblasti poljoprivrede. Ovim zakonom uređuju se uslovi i način obavljanja savetodavnih i stručnih poslova u poljoprivredi koje obavlja poljoprivredni savetodavac. Detaljno se definišu pojmovi licenca i Registar poljoprivrednih savetodavaca, usavršavanje poljoprivrednih savetodavaca, planiranje razvoja savetodavnih poslova u poljoprivredi i druga pitanja od značaja za savetodavne poslove u poljoprivredi. U čl. 2 Nacrta definisani supojmovi: licenca, poljoprivredni savetodavac, primenjena istraživanja u poljoprivredi, registar poljoprivrednih savetodavaca, savetodavni poslovi u poljoprivredi, stručni poslovi u poljoprivredi (izveštajno – prognozni poslovi, utvrđivanje kvaliteta i analiza plodnosti zemljišta, stručni pregledi u proizvodnji semena i sadnog materijala, laboratorijske analize i testiranje biljaka biljnih proizvoda i propisanih objekata radi utvrđivanja štetnih organizama, mere selekcije u stočarstvu i drugi poslovi iz svih oblasti poljoprivrede. Čl 5 predviđa da savetodavne poslove može da obavlja malo privredno društvo i preduzetnik ako ispunjava uslove propisane ovim zakonom i propisima donetim na osnovu njega. Drugim rečima, zakon priznaje postojanje i privatnih (stručnih) savetodavnih službi. Poslovi iz ove oblasti će se poveravati na osnovu odluke nadležnih organa.

U skladu sa "Službenim glasnikom" RS 6/02 o prenosu odredjenih ingerencija na AP Vojvodinu donet je Pravilnik o organizaciji i radu pokrajinske Poljoprivredne savetodavne službe. Donošenjem ovog akta 22.03.2006. godine faktički su stvoreni uslovi za početak rada pokrajinske Poljoprivredne službe. Dotadašnja republička stručna služba je već i do tada obavljala odredjene poslove za pokrajinski sekretarijat. Svečanim proglašenjem 29.06.2006. godine, održanim u Izvršnom veću Vojvodine zvanično je promovisana služba, njeni ciljevi i rezultati dotadašnjeg rada. Osnovni cilj donošenja ovog pravilnika je povećanje prisutnosti savetodavaca na terenu kod poljoprivrednih proizvođača.

Pre osnivanja službe potencijalni savetodavci prošli su Program edukacije savetodavaca u organizaciji Centra za edukaciju i ruralni razvoj Poljoprivrednog fakulteta u Novom Sadu, koji je obuhvatao: 1. Metode pojedinačnog i grupnog rada i 2. Edukaciju edukatora.

Šta je to novo u odnosu na prethodni period, predvidjeno pravilnikom?

Do donošenja Pravilnika u realizaciji osnovnih programa savetodavnog rada učestvovali su svi inženjeri poljoprivrede koji se bave osim savetodavnim radom i drugim poslovima definisanim Zakonom o poljoprivrednoj stručnoj službi.

Nakon donošenja Pravilnika o organizaciji i radu poljoprivredne savetodavne službe Vojvodine, definisano je 66 savetodavaca, koji će učestvovati u ostvarivanju Programa. Kriterijumi odabira savetodavaca bili su: raspoloživa sredstva Pokrajinskog sekretarijata za poljoprivredu, vodoprivredu i šumarstvo, biografije i prethodno zalaganje savetodavaca.

Delokrug rada savetodavne službe Vojvodine

Osnovni zadatak savetodavne službe je povećanje dohotka na gazdinstvu, usmeravanje ruralnog razvoja lokalne zajednice, očuvanje prirodnih resursa i životne sredine, podsticanje pojave i razvoja asocijacija proizvodjača poljoprivrednih proizvoda. Rad poljopivredne savetodavne službe ogleda se, pre svega, u pružanju sledećih usluga:

- Stručni saveti o tehnološkim i komercijalno – tržišnim aspektima poljoprivredne proizvodnje,
- Edukacija proizvodjača o naučno – tehničkim dostignućima u poljoprivrednoj proizvodnji,
- Izvođenje ogleda – *kontrola*
- Rad sa odabranim gazdinstvima – *kontrola*
- Rad s udruženjima, odnosno asocijacijama – *kontrola*

Metodi rada koje savetodavci primenjuju u svom radu su:

- Individualni rad s proizvodjačima,
- Grupni rad s proizvodjačima
- Mediji, odnosno davanje stručnih saveta i informacija posredstvom medija.

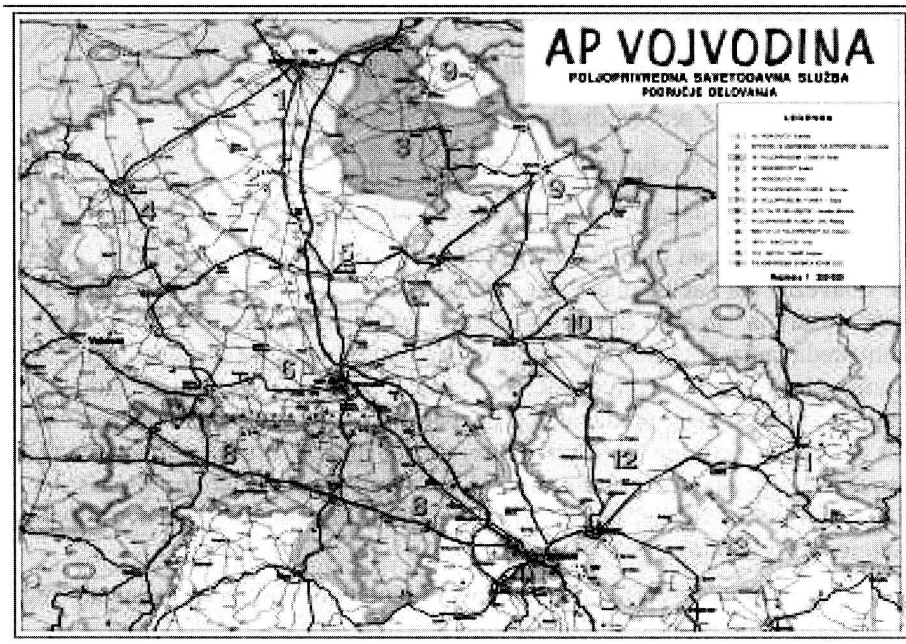
Kad su u pitanju grupni metodi rada savetodavca, tokom zimskog perioda, svaki savetodavac je obavezan da sačini plan rada i da ga sprovodi u delo. Svaki savetodavac pravi plan, koji dostavlja do 20. decembra tekuće godine Sekretarijatu koji obuhvata broj planiranih predavanja koja se organizuju u odredjenoj sredini (naseljenom mestu). Posle ostvarivanja plana svaki savetodavac je dužan da dostavi izveštaj o temama i broju učesnika, mestu izvodjenja, predavačima i zapažanjima. Status stanica pri osnivanju je bio takav da su sve regionalne poljoprivredne stanice bile u društvenoj svojini. Danas su transformacijom sve stanice postale društva sa ograničenom odgovornošću sa većinskim vlasništvom Republike Srbije, izuzev jedne koja je u privatnom vlasništvu i dve gde je u pitanju akcionarski kapital.

U momentu osnivanja Savetodavnu službu Vojvodine činilo je 13 jedinica – regionalno odredjenih. Raspored teritorije na kojoj deluju pojedine službe prikazan je na sl. 1.

Tab. 1 Raspored savetodavaca prema regionalnim službama

Tab. 1 Disposition of advisors in the regional service centers

Rednibroj No	Poljoprivredna stručna služba Agricultural advisory service	Broj ang. savetnika Number of employed advisors
1	"Agrozavod"AD Subotica	3
2	DP "Zavod za unapredjenje poljoprivrede" Bačka Topola	4
3	"Institut za poljoprivredu"AD Zrenjanin	7
4	"Poljoprivredna stanica" D.O.O. Kikinda	5
5	DP "Poljoprivredna stanica " Senta	4
6	DP "Institut Tamiš" Pančevo	7
7	DP "Agrozavod" Vršac	4
8	"Poljoprivredna stanica" D.O.O. Kovin	3
9	DP "Agroinstitut" Sombor	7
10	DP "Poljoprivredna stanica" Novi Sad	7
11	DP "Agrozavod" Vrbas	4
12	PI "Dr Petar Drezgić" Sremska Mitrovica	7
13	DP "Poljoprivredna stanica" Ruma	4



Sl. 1 Područje delovanja

Pic. 1 Area of activity

Svaka stanica u svojoj sistematizaciji trebalo je da predvidi radna mesta savetodavca, kao i posebnu organizaciju u okviru službe – sektor ili odeljenje koje se bavi isključivo savetodavnim radom. Pokrajinski sekretarijat ima pravo da osniva i nove službe, a utvrdjuje područja koja pokrivaju savetodavci. Savetodavci mogu biti stručnjaci iz različitih oblasti za koje se ukažepotreba. Sekretarijat donosi konačnu odluku o broju i profilu angažovanih savetodavaca,a postoji i mogućnost za postojanje "specijalaca"za pojedine oblasti proizvodnje. Osim odredjenih 66 savetodavaca za teritoriju Vojvodine, i ostali zaposleni u stručnim službama treba da pomažu savetodavnom radu. Pri osnivanju u strukturi savetodavaca u savetodavnoj službi radilo je: 22 ratara, 18 zaštitara, 18 stočara, 2 voćara, 2 agronoma za uredjenja voda, 2 mehanizatora i 2 agroekonomista. Broj tada angažovanih savetodavaca u regionalnim centrima dat je u tab. 1.

Ko može da bude savetodavac?

Osoba sa završenim Poljoprivrednim fakultetom ili neki drugi fakultet po potrebi, a da se pri tome bavi savetodavnim radom, najmanje sa 80% svog radnog vremena. Savetodavac je dužan da prati najnovija naučna i stručna dostignuća. Savetodavac takođe treba kvartalno da podnosi izveštaj o svojim aktivnostima putem tipologije – modela za dostavljanje izveštaja o sopstvenom radu, gde se evidentiraju sve aktivnosti za dati period, prihvaćenih od Pokrajinskog sekretarijata za poljoprivredu, vodoprivredu i šumarstvo. U svom radu savetodavac je obavezan da se pridržava prihvaćenih normi ili u protivnom može da izgubi mesto savetodavca.

Tokom delovanja službe kontinuirano se sprovodi edukacija iz različitih oblasti putem: kurseva, seminara i konferencije savetodavaca Poljoprivredne savetodavne službe APV (obavezni za sve savetodavce). Oblasti edukacije su: metodologija savetodavnog rada,standardi kvaliteta, modeli udruživanja, novi trendovi i tehnologije proizvodnje, principi organske proizvodnje i drugo. Ostvareni su kontakti sa savetodavnim službama :Slovenije, Slovačke, Holandije, Danske

Saradnici savetodavaca – odabrana gazdinstva i udruženja

Kriterijumi za izbor gazdinstava s kojima će se obavljati savetodavni rad prihvaćeni su od Sekretarijata. To bi trebalo da budu uzorna gazdinstva (optimalna organizacja, visok nivo proizvodnje, kvalitet proizvoda i ekonomičnost proizvodnje, tržišno orijentisana, mala gazdinstva s intenzivnom proizvodjom). Broj odabranih gazdinstava – po jednom savetodavcu je 50 gazdinstava. Niko do sada nije precizno definisao pojam uzorna gazdinstva.

Finansiranje savetodavnog rada:

Iz posebnog programa se finansira edukacija savetodavaca studijskim putovanjima, medijska promocija savetodavne službe, rad sa udruženjima i opremanje savetodavne službe. Ukupna suma izdvojena za osnovne oblasti delovanja iznosila je 2006 god. 84.225.000 din, + 24.825.000 za edukaciju savetodavaca, podolšanje softvera, pomoć udruženjima i projekte od posebnog značaja,što ukupno čini 109.050.000 din odnosno po tada važećem deviznom kursu oko 1.380.000 €.

Radom službe rukovodi Pomoćnik Pokrajinskog sekretara za poljoprivredu, vodoprivredu i šumarstvo uz pomoć Saveta za poljoprivredno savetodavstvo, koji donosi odluke, rukovodioca službe i Programskog odbora koji sačinjavaju savetodavci i saradnici –

zaposleni u sekretarijatu, a ima savetodavni karakter. Značajnu ulogu u radu poloprivredne savetodavne službe ima Centar za ruralni razvoj koji sačinjavaju saradnici s Poljoprivrednog fakulteta Novi Sad, a po čijim projektima se odvijaju osnovni pravci delovanja same službe.

Pokrajinski Sekretarijat za poljoprivredu, vodoprivredu i šumarstvo kreira, finansira i prati realizaciju i kvalitet sprovođenja godišnjih programa mera za unapređenje poljoprivrede putem savetodavnog rada poljoprivrednih stručnih službi.2007 god. Savetodavna služba APV za realizaciju godišnjeg progrma angažuje 73 savetodavca(70 +3 specijalizovana),za realizaciju ovog programa utrošeno je 112.225.000 dinara.2008 god. Broj savetodavaca koji učestvuju u realizaciji godišnjeg programa rada se penje na 80, a za njegovo sprovođenje utrošeno je 120.000.000 dinara. 2009 god. Planirano je angažovanje 90 savetodavca za realizaciju programa i utrošak 169.213.530 dinara , međutim rebalansom budžeta za rad ovih savetodavaca opredeljeno je svega 98.213.530 dinara(izmene i dopune programa se ponovo usvajau od strane Izvršnog veća APV). Svake godine održava se Seminar savetodavaca AP Vojvodine, koji ima zadatak da edukuje savetodavce, a na godišnjoj Konferenciji savetodavaca analizira se rad svake službe i predlažu rešenja za unapređenje procesa savetodavnog rada.

I po Nacrtu zakona o obavljanju savetodavnih i stručnih poslova u oblasti poljoprivrede i predviđa se nadležnost AP Vojvodine za rad Poljoprivredne savaetodavne službe, ali proces treba da definišu drugi zakonski i podzakonski akti.

Proces razvoja savetodavnih službi je složen i dugotrajan i sve su zemlje, naročito zemlje "u tranziciji", kroz ovaj proces sa manje ili više teškoća prošle. U tom se smislu, Srbija – Vojvodina nalaze u pocetnim fazama formiranja moderne institucije savetodavstva u poljoprivredi, a koje treba da adekvatno odgovori na potrebe poljoprivrede u tranziciji. Ovaj proces je multidimenzionalan i veoma složen. U Vojvodini, prvi (i teški) koraci su učinjeni. Jedan od tih koraka je i Tipologija saveta i usluga, kojom se na određen način nastoji ispratiti savetodavni rad stručnjaka iz stanica, kao i uspostaviti analitička osnova za dalje planiranje razvoja savetodavstva, kao i analize dobrih i loših iskustava.

Razvoj poljoprivredne savetodavne službe AP Vojvodine od osnivanja do danas

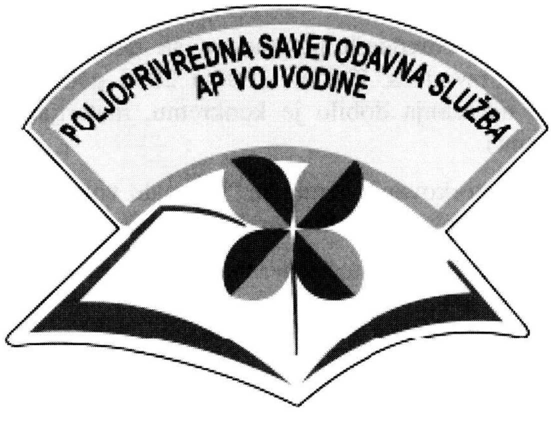
Sadašnji nivo organizacije obuhvata više službi, prikazano u tabeli 2.

Poljoprivrednu savetodavnu službu AP Vojvodine prati prepoznatljiv logotip na: kolima, radnim prostorijama, opremi savetodavaca, propagandnom materijalu, flajerima i brošurama. Portal Poljoprivredne savetodavne službe APV funkcioniše na sledećoj adresi: www.polj.savetodavstvo.vojvodina.gov.rs a obezbeđuje komunikaciju između savetodavaca, Sekretarijata i proizvođača o aktuelnim dešavanjima u radu službe, uredbama, subvencijama i podsticajima, praćenju različitih događaja i dešavanja. Daje savete i preporuke vezane za poljoprivrednu proizvodnju i suzbijanje bolesti i štetočina, a obezbeđuje informacije i iz ostalog delokruga rada. Oktobra 2008 godine u okviru dopune Portalu Poljoprivredne savetodavne službe APV puštena je prva SMS poruka prema korisnicima:" Za korak ispred – Naše znanje, vaša prednost" koja je predstavila novi vid rada, a služi za komunikaciju sa odabranim domaćinstvima i funkcioniše na različitim nivoima (služba–proizvođač, savetodavac–proizvođač, Sekretarijat-služba, savetodavac- savetodavac). SMS poruke prima oko 1.500 odabranih domaćina. Radi poboljšanja efikasnosti i kvaliteta rada savetodavaca na terenu Sekretarijat je službama u poslednje 4 god. omogućio nabavku :22 automobila, 13 računara i 20 lap top računara, 6 štampača, 2 video bima, 13 fotoaparata, 13 GPS uređaja za prikupljanje i pozicioniranje podataka prilikom uzorkovanja zemljišta. Druga oprema koja je nabavljena: sonde za uzorkovanje zemljišta, aparat za brzu analizu mleka, aparat za određivanje azota (Nitraček), pokretne meteorološke stanice – Metosi, mikroskopi, digestor, inoviran je i osposobljen radni prostor za savetodavce.

Tab. 2 Organizacione jedinice – savetodavni sektori

Tab 2 Organizational units - advisory sectors

Red.br. No	Organizacione jedinice – savetodavni sektori Organizational units - advisory sectors
1	**Novi Sad,** savetodavni sektor PSS "Poljoprivredna stanica" d.o.o. Novi Sad
2	**Vršac,** savetodavni sektor " PSS Vršac " d.o.o. Vršac
3	**Bačka Topola,** savetodavni sektor "PSS Bačka Topola" d.o.o. Bačka Topola,
4	**Kovin,** savetodavni sektor "Poljoprivredna stanica Kovin" d.o.o. Kovin
5	**Ruma,** savetodavni sektor "PSS Ruma" d.o.o.Ruma
6	**Sombor,** savetodavni sektor " PSS Sombor" d.o.o. Sombor
7	**Pančevo,** savetodavni sektor PDS Instituta "Tamiš" Pančevo
8	**Senta,** savetodavni sektor "PSS Senta" d.o.o. Senta
9	**Subotica,** savetodavni sektor "Agrozavod" ad Subotica
10	**Vrbas,** savetodavni sektor "PSS Vrbas" d.o.o. Vrbas
11	**Zrenjanin,** savetodavni sektor "PSS Zrenjanin" d.o.o. Zrenjanin
12	**Kikinda,** savetodavni sektor " PSS Kikinda" d.o.o. Kikinda
13	**Sremska Mitrovica,** savetodavni sektor " PSS Sremska Mitrovica" d.o.o. Sremska Mitrovica,
14	**"Enološka stanica",** "PSS Enološka stanica" d.o.o. Vršac



Sl. 1 Amblem Poljoprivredne savetodavne službe AP Vojvodine

Pic. 1 Emblem of Agricultural Advisory Service of AP Vojvodina

Osnovni program rada obuhvata rad sa odabranim domaćinstvima (svaki savetodavac prati 50 gazdinstava u periodu od 3 godine.), a ostvareni su sledeći rezultati:

- Saradnja ostvarena sa 3.114 odabranih domaćinstava (za koje postoji baza podataka -Karton gazdinstva).
- Za saradnju sa njima 74 savetodavca tokom 2008. utrošilo je 35.458 sati rada, pri 14.813 obilazaka ovih domaćinstava i dali 35.508 saveta, različite vrste.

Benefit koji odabrano gazdinstvo ima :

- Minimum 4 obilaska godišnje, besplatna analiza i preporuka za plodnost zemljišta, pomoć i savet za dobijanje subvencija, edukacija preko predavanja i jednodnevnih kurseva. Učešće na sajmovima u zemlji i inostranstvu,dobijanje besplatnih brošura i informacija,do povoljnijih kamata kod dobijanja kredita
- Pružanje savetodavnih usluga ostalim poljoprivrednim proizvođačima (u 2008. godini - savetodavci su na ovu vrstu rada utrošil 17.314 sati, pri čemu su dali 7.297 saveta).
- Edukacija poljoprivrednih proizvođača tokom zimskih meseci, u okviru organizovanih predavanja po naseljenim mestima(u 2008. godini je održano ukupno 1.184 predavanja na nivou cele Vojvodine).
- Putem masovnih edukacija poljoprivrednih proizvođača (radio i TV i štampe) objavljeno je i saopšteno tokom 2008.g. preko 2.657 različitih informacija vezanih za poljoprivrednu proizvodnju od značaja za proizvođače.
- U okviru programa istraživanja putem postavljanja "demo ogleda" radi provere naučnih činjenica u praksi savetodavci su tokom 2008.g . postavili 3.419 ogleda na sopstvenim parcelama ili imanjima poljoprivrednih proizvođača vezanih za sortiment,đubrenje i upotrebu pesticida.
- Savetodavci iz zaštite bilja učestvuju u praćenju kretanja štetnih organizama i daju različite preporuke za njihovo suzbijanje. Tokom 2008. godine je dato 1.235 različitih izveštaja i saopštenja.
- Rad na prikupljanju određenih parametara sa terena i podsticanju udruživanja poljoprivrednih proizvođača. Tokom 2007 i 2008 god.osnovano je više od 150 udruženja, a 86 udruženja dobilo je konkretnu, materijalnu pomoć ili pomoć u edukaciji ili opremi).
- Akcija besplatnog uzorkovanja zemljišta:"Uz malo volje plodno polje" (u proteklih 6 godina analizirano preko 100.000 uzoraka zemljišta),
- Program mera za unapređenje stočarstva (selekcijske mere u stočarstvu),

Kadrovska struktura savetodavaca u 2009 godini

- 87 inženjera poljoprivrede od kojih su:
- 3 doktora nauka,
- 6 magistara

od čega: 28 inženjera ratarstva i povrtarstva, 21 inženjera stočarstva, 26 inženjera zaštite bilja, 3 inženjera voćarstva i vinogradarstva, 4 inženjera poljoprivredne mehanizacije, 1 inženjera za uređenje voda, 4 agroekonomista (od kojih su 3 mlađa savetodavca), 1 ekonomista, 1veterinar i 1 inženjer informatike zadužen za održavanje Portala, ukupno čini 90 savetodavaca (3 specijalizovana).

Organizovano je učešće Poljoprivredne savetodavne službe na Poljoprivrednom sajmu u Novom Sadu i Zrenjaninu zajedno sa Sekretarijatom i za tu svrhu pripremljen je materijal: 10 raličitih flajera (4 na 6 jezika nacionalnih manjina i engleskom jeziku), Agropodsetnik, Registar savetodavaca i drugo, Portal dopunjen vremenskom prognozom, korigovana Tipologija savetodavnih usluga, održane edukacije za savetodavce i poljoprivredne proizvođače o konzervacijskom sistemu obrade zemljišta i čuvanju i pakovanju povrća,ispitan kvalitet i bezbednost sorti pšenice roda 2009 god. sa odabranih domainstava iz cele Vojvodine i urađen projekat uspostavljanja prognozno izveštajnih poslova na nivou AP Vojvodine.

Poslovi po kojima se prepoznaje savetodavna služba:

To su u prvom redu obaveštavanje javnosti putem medija o stanju useva na terenu i merama koje treba preduzeti u određenim kritičnim momentima, informisanje poljoprivrednih proizvođača o podsticajnim sredstvima, kreditima i subvencijama koje daje država. Prezentovanje dobijenih rezultata putem "demo-ogleda" poljoprivrednim proizvođačima, pružanje pomoći lokalnim zajednicama u sagledavanju raspoloživih resursa radi očuvanja životne sredine i usmeravanje razvoja ruralne sredine i preduzetništva na selu, davanje informacija i saveta vezano za organsku i integralnu proizvodnju i druge aktuelne informacije, neposredno i putem flajera i brošura.

Šta se planira u perspektivi:

U prvom redu to je reorganizacija Poljoprivredne savetodavne službe APV – sektorska podela rada sa izradom plana i strategije razvoja svakog segmenta Službe (na osnovu potreba poljoprivrednih proizvođača), do kraja 2009 god. predviđa se izmena Pravilnika o organizaciji i radu Poljoprivredne savetodavne službe APV. Uvođenje sistemskih ogleda na nivou cele službe, kao i mikroogleda na nivou pojedinačnih službi radi provere naučnih činjenica u praksi, sektorsko odvajanje savetodavnih poslova na nivou službi (na osnovu novog zakona koji je u proceduri), uspostavljanje i jačanje određenih sektora unutar Poljoprivredne savetodavne službe: sektor integralne i

organske proizvodnje (razdvojiti i jačati svaki pojedinačno), agroekonomski sektor donosi svoj program i kreće u realizaciju, mehanizatori usaglašavaju metodologiju koja će se propagirati na nivou službe, a intenzivno će se raditi na pojačanju i razvijanju međugranične i regionalne saradnje. Možda i najznačajnija delatnost bi bila osposobljavati kadar za pisanje projekata za predpristupne fondove EU. Naravno svakom savetodavcu predstoji polaganje državnog ispita i uspostavljanje licence da bi se mogao baviti savetodavnim radom.

Šta su ograničenja za dalji razvoj savetodavnog rada.

U prvom redu to je neizvesna visina budžetskih sredstava za funkcionisanje ovakvog servisa u perspektivi, a sa tim i nemogućnost uvođenja zakonske obaveze plaćanja savetodavnih usluga od strane poljoprivrenih proizvođača, zbog male platežne moći poljoprivrednih proizvođača i krize u kojoj se nalazimo i nepostojanja odgovarajućeg realnog modaliteta za ovu namenu.

Nedovoljan broj ljudi za moguće poslove, koje bi službe mogle obavljati za Pokrajinski Serkretarijat za poljoprivredu, vodoprivredu i šumarstvo, kao i za Ministarstvo poljoprivrede, šumarstva i vodoprivrede RS ali i neke druge druge korisnike.

Strategija razvoja službi zasnovana je na STAR projektu Svetske banke koja nije dovoljno jasna i ne odgovara u svim segmentima realnom stanju (opredeljena su značajna sredstava za razvoj Poljoprivredne stručne službe na nivou cele RS, ali se ne zna, da li i koliko od toga dobijaju službe u APV)

Kako prevazići probleme?

- završiti transformaciju službi u D. O. O. ili AD jednočlana društva sa većinskim državnim kapitalom (preneti naležnosti da bi se jasno znalo ko je odgovoran i upravlja određenom imovinom Pokrajina ili Republika),
- segmente Savetodavne službe-organizacione jedinice razvijati u skladu sa vrstom proizvodnje i problemima, koji se javljaju u praksi, na terenu (području),
- sistemskim pristupom i uspostavljanjem određene strukture unutar službe (uz korišćenje sopstvenih potencijala povećeva se nivo odgovornosti svakog pojedinca) te su moguće uštede, a istovremeno se izbegavaju preklapanja
- uvođenje određenih segmenata koje bi službe vodile kao naplativ servis (vođenje knjigovodstva, priprema dokumentacije za dobijanje kredita, izrada idejnih rešenja za projekte, vođenje i nadgledanje određenih specifičnih vrsta proizvodnje i dr.)

Iskoristiti maksimalno raspoloživi kadar u okviru određenih sektora službe

- po potrebi angažovati pojedince ili privatne službe za realizaciju određenih programa, ako se za to ukaže potreba
- inovirati opremu i znanje, kako bi bili uvek za korak ispred ostalih
- informisati neprekidno širu javnost o rezulattima rada savetodavne službe i dodatnim mogućnostima ovakvog servisa
- proširivati i jačati sistem informacija i stvoriti što veću bazu podataka, koja će biti dostupna po potrebi svum korisnicima
- uspostaviti tešnju saradnju sa lokalnom samoupravom i regionima iz okruženja (zasnovanu na partnerskim odnosima u projektima ili određenim akcijama koje bi se mogle realizovati u perspektivi
- omogućiti službama da se osim ogledne proizvodnje uspostave i određeni specifični oblici proizvodnje ,kao dodatni izvor prihoda, a koji bi imali demonstativnu ulogu za proizvođače.
- omogućiti pojedinim službama da se specijalizuju (Licenciraju-akredituju) za određene oblasti i vrše treninge i obuku proizvođača i drugih zaintresovanih lica, kako bi se obezbedio kontinuiran izvor prihoda kao podrška budžetskog finansiranja savetodavnog rada

ZAKLJUČAK

Poljoprivredna savetodavna služba AP Vojvodine nalazi se u transformaciji. Nacrtom novog zakona država je priznala postojanje privatnih savetodavnih službi i njihovo ravnopravno tretiranje na tržištu. Ako želimo da poljoprivreda ima prosperitet moramo naći mehanizme kako to da omogućimo. Postojanje savetodavne službe koja je finansirana od strane države je jedna od realnih mogućnosti.

LITERATURA

1. Nacrt zakona o obavljanju savetodavnih i stručnih poslova u oblasti poljoprivrede, 2009.
2. Pravilnik o organizaciji i radu Poljoprivredne savetodavne službe AP Vojvodine.
3. Materijali Pokrajinskog sekretarijata za poljoprivredu, vodoprivredu i šumarstvo od 2006 do 2009.
4. Mitrović D, Škrbić N, Ogrizović B. 1999. Osvrt na ulogu i značaj poljoprivredne stručne službe iz ugla mehanizatora, *Savremena poljoprivredna tehnika*, 25(1-2), p. 23-31.
5. Tumbas P, Krmpotić T. 1998. Poljoprivredno savetodavstvo-strategije i modeli organizovanja, *JUMTO časopis za traktore, pogonske mašine i održavanje*, 3 (5), p. 51-56.

THE ROLE AND IMPORTANCE OF AGRICULTURAL ADVISORY SERVICE OF AP VOJVODINA

SUMMARY

This paper focuses on the place and role that the Agricultural advisory service of AP (Autonomous Province) Vojvodina has within the agricultural policy of the Republic of Serbia. By reviewing the organizational model, mode of operation, tasks of the service and its preparations to meet the challenge of advisory work on the Provincial level, this paper presents the work of this service. Special section is devoted to the training of advisors. It is expected that in the future more attention shall be devoted to the advisory service and user sector, i.e. the farmers, because this area shall be regulated by the Law on professional services in agriculture, which is to come into force in the Republic of Serbia.

Key words: *agriculture, advisory service, advisors*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 338.43:631.1](497.5)
Izvorni znanstveni rad
Original scientific paper

HRVATSKA POLJOPRIVREDA SA STANOVIŠTA RURALNIH ŽITELJA

IVO GRGIĆ[1], VLADIMIR LEVAK[2], ĐURĐICA ŽUTINIĆ[1], MAGDALENA ZRAKIĆ[3]

[1]Sveučilište u Zagrebu, Agronomski fakultet, Svetošimunska cesta 25, 10 000 Zagreb, Hrvatska
[2]Poljoprivredna zadruga JALŽABET, Suhodolska 21, 42 203 Jalžabet, Hrvatska
[3]Graničarska 2, 10310 Ivanić Grad, Hrvatska

SAŽETAK

Poljoprivreda kao još uvijek značajna gospodarska sastavnica ruralnog prostora Hrvatske temelji se na prosječno malim poljoprivrednim gospodarstvima, neodgovarajućoj tehničko-tehnološkoj opremljenosti te nepovoljnoj dobnoj i obrazovnoj strukturi poljoprivrednika. Dodatni problem predstavlja i nerazvijena tržna infrastruktura za proizvode seoskog prostora, nedostatak poslovnog organiziranja te neriješeno tržište poljoprivrednim zemljištem.

Cilj ovog rada je, na temelju anketnog istraživanja, utvrditi razinu zadovoljstva ispitanika životom u ruralnom području Hrvatske kao jednim od preduvjeta smanjenja demografskog pritiska na urbana središta. Zadovoljstvo i očekivanja ispitanika neizravno utječu na voljnost za dugoročnim ulaganjima kao što su ulaganja u strojeve i opremu te u poljoprivredne proizvodne objekte.

Istraživanje je provedeno metodom ankete na uzorku od 941 ispitanika u svim županijama Republike Hrvatske. Anketno istraživanje obuhvatilo je 941 kućanstvo/osobu od čega je u panonskoj regiji bilo 67,3%, u gorskoj 11,9% te u mediteranskoj regiji 20,8% kućanstava/ispitanika

Preko polovice ispitanika (55,2%) posjeduje zemljišni posjed. Najveći udio čine gospodarstva od 2 do 5 hektara (43,4%), zatim iznad 5 ha (33,4%) te najmanje ih je u kategoriji do 2 ha (23,3%).

U narednih pet godina blizu polovica ispitanika (46,2%) namjerava zadržati poljoprivrednu proizvodnju na istoj razini, jedna četvrtina (25,2%) ne zna što će se dogoditi, jedna desetina će je smanjiti te njih 17,2% namjerava je povećati.

Očekivane promjene često su u uzročno-posljedičnoj vezi sa zadovoljstvom životom na selu. Ispod trećine ispitanika (26,6%) smatra da se na selu danas živi dobro do jako dobro. Značajan dio ispitanika (43,6%) misli da se živi prosječno – niti dobro niti loše, a trećina da se živi loše do jako loše. Da će se na hrvatskom *selu za pet godina živjeti bolje nego danas misli ih trećina (33,9%), petina (22,3%) da će se živjeti lošije te najveći dio (43,8%) ne očekuje nikakve promjene.*

Ključne riječi: *Hrvatska, ruralno područje, poljoprivreda, budućnost*

UVOD

Hrvatska je šezdesetih i sedamdesetih godina prošlog stoljeća zabilježila najbrži ruralni egzodus u povijesti industrijskih zemalja (Gelo, J. 1987; Turčić, I. 2000). Novi veći egzodus ruralnog stanovništva događa se tijekom i nakon Domovinskog rata (Wertheimer-Baletić, Alica; Živić, D. 2003). Raste pritisak ruralnih migranta na urbana središta što za posljedicu ima mnogostruke negativne posljedice kako za ta središta, tako i za područja iz kojih pučanstvo dolazi.

Jačanje gospodarstva i podizanje životnog standarda u ruralnom prostoru je preduvjet zaustavljanja negativnih demografskih promjena (starenja pučanstva, negativnog prirodnog priraštaja pojedinih područja) i rješenja problema nezaposlenosti (Akrap, A. 2002). Promišljanje budućnosti ruralnog prostora nezamislivo je bez poljoprivrede i djelatnosti vezanih uz nju (Živić, D. 1998).

Poljoprivreda kao još uvijek značajan gospodarski segment ruralnog prostora Hrvatske temelji se na prosječno malim poljoprivrednim gospodarstvima[1] sa neadekvatnom tehničko-tehnološkom opremljenošću te na radnoj snazi nepovoljne dobne i obrazovne strukture (Čizmić, I. Živić, D. 2005; Hodžić, A. 2000). Dodatni problem predstavlja i nedovoljno razvijena tržna infrastruktura za proizvode seoskog prostora, nerazvijeni oblici poslovnog organiziranja te neriješeno pitanje tržišta poljoprivrednim zemljištem.

Osim gospodarskih problema na zadovoljstvo životom u ruralnom prostoru značajan utjecaj ima i razvijenost komunalne i društvene infrastrukture koja ruralni prostor približava ili udaljava od urbanog prostora kao stožera vrijednosti – imaginarne ili stvarne.

Cilj ovog rada je, na temelju anketnog istraživanja, utvrditi razinu zadovoljstva ispitanika životom u ruralnom području Hrvatske kao jednog od preduvjeta smanjenja demografskog pritiska na urbana središta.

Zadovoljstvo i očekivanja ispitanika neizravno utječu na voljnost za dugoročnim ulaganjima kao što su ulaganja u strojeve i opremu te u poljoprivredne proizvodne objekte kojim bi se potaknuo rast dohotka i životnog standarda poljoprivrednog te s time i ukupnog ruralnog stanovništva.

[1] Ovdje se radi o obiteljskim poljoprivrednim gospodarstvima, a nasuprot njima su po proizvodnim resursima veće proizvodne jedinice - pravne osobe. Obiteljsko poljoprivredno gospodarstvo jest ekonomska jedinica kućanstva koje se bavi poljoprivrednom proizvodnjom bez obzira na njenu namjenu, odnosno bez obzira na to jesu li proizvodi za tržište ili samo za vlastitu potrošnju. Pojam je preuzet iz Strategije razvitka hrvatske poljoprivrede, koja je donesena 1995., a usklađen je sa statističkim pojmom poljoprivrednih kućanstava EU-a. Pojam "obiteljsko poljoprivredno gospodarstvo" uveden je u statistički sustav poljoprivrednih statistika 1998., a dotad su se koristili pojmovi "individualno gospodarstvo" i "individualni proizvođač". (Statistički ljetopis 2008, str. 250)

METODE

Istraživanje je provedeno na cijelom ruralnom području Republike Hrvatske koje obuhvaća površinu od 47.940 km2. Na ovom se području, prema Popisu pučanstva, kućanstava i stanova, 2001. godine nalazilo 1.613.814 pučanina.

Istraživanje je provedeno metodom ankete na uzorku od 941 ispitanika iz svih županija Republike Hrvatske.

Uzorak je odabran tako da su u prvom koraku isključena sva naselja sa više od 100 pučanina po km^2. Zatim je u drugom koraku određena kvota po županijama, a broj anketa u svakoj županiji određen je prema udjelu ruralnog pučanstva županije u ukupnom ruralnom pučanstvu Hrvatske[2]. Treći korak sastojao se od slučajnog odabira po dvije jedinice lokalne samouprave unutar županije i slučajan izbor tri seoska naselja unutar tih jedinica. U svakom od tih naselja proveden je razmjeran broj anketa.

Jedinica anketiranja je kućanstvo, a unutar kućanstva jedan ispitanik u dobi između 25 i 45 godina.

Kao ni u drugim zemljama tranzicijskim zemljama, ni u Hrvatskoj definicija i određenje ruralnosti do nedavno nije bio jasno određen[3]. Sama definicija ruralnog prostora za naše istraživanje nije bila od presudne važnosti nego je samo poslužila kao instrument u određenju broja anketa po pojedinim nižim teritorijalnim jedinicama (županija) te smo, uz sva ograničenja koja iz toga proizlaze, primijenili EU kriterij[4] tj. 100 pučanina na km^2.

Regionalni aspekt uključen u ovo istraživanje bio je nužan zbog svekolike različitost Republike Hrvatske. Regije korištene u ovom istraživanju su poljoprivredne regije[5] i preuzete su iz «Strategije razvitka hrvatske poljoprivrede» pri čemu ovakva regionalizacija, uz sve manjkavosti, nije umanjila kvalitetu dobivenih rezultata.

Obrada je obavljena pomoću SPSS paketa (Statistical Package for Social Sciences).

[2] Manje korekcije koje su učinjene bile su nužne zbog poznavanja stanja ruralnog prostora pojedine županije (ekspertna procjena)

[3] Uglavnom se pod ruralnim smatralo sve što nije urbano, a to znači područja seoskog ili prirodnog krajobraza, uključujući sela, mala naselja i slično. Sukladno tome, u popisima pučanstva podjela na ruralno i urbano svodila se na primjenu statusa naselja stanovanja: pučanstvo iz naselja sa statusom grada smatrano je urbanim, a ostalo je bilo ruralno pučanstvo

[4] Danas se u većini zemalja kao jedan od ključnih kriterija za određivanje ruralnosti rabi gustoća naseljenosti područja. U državama EU gustoća naseljenosti se također uzima kao kriterij za određenje ruralnosti, premda se prag ruralnosti može razlikovati ovisno o državi. Najčešće rabljena definicija koju primjenjuju međunarodne organizacije za razdvajanje seoskih (ruralnih) i urbanih regija je ona razvijena u OECD-u: ruralne regije su one u kojima gustoća naseljenosti iznosi manje od 150 pučanina po km^2. Zbog široke primjene, ova je definicija usporediva na međunarodnoj razini, a zbog jednostavnosti je vrlo prihvatljiva.

[5] U ruralnom prostoru poljoprivreda je još uvijek glavna djelatnost te se logički nametnulo da ovakvu regionalizaciju u našem istraživanju i uporabimo.

REZULTATI I DISKUSIJA

Anketno istraživanje obuhvatilo je 941 kućanstvo/osobu od čega je u panonskoj regiji bilo 67,3%, u gorskoj 11,9% te u mediteranskoj regiji 20,8% kućanstava/ispitanika. Prosječna dob ispitanika je 33,3 godine i ne razlikuje se značajnije po regijama.

Spolna struktura ispitanika bila je ravnomjerna (49,4% muških i 50,6% žena).

Dvije trećine ispitanika je oženjeno/udano, jedna trećina neoženjena/udana, rastavljeno 2,7% te u nevjenčanoj zajednici živi 2% ispitanika.

Više od polovice (55,4%) ispitanika živi u vlastitoj kući/stanu, manji dio (42,8%) živi s roditeljima te samo 2,1% su podstanari.

Kućanstvo prosječno broji 4,2 člana (raspon od 1 do 11) i najveći broj anketiranih kućanstava ima 4 člana (33,9%).

Tablica 1 Neka obilježja anketiranih kućanstava –prosjek

Obilježje	Hrvatska	Panonska	Gorska	Mediteranska
Dob*	33,3	33,6	33,4	32,6
Članovi kućanstva**	4,2	4,1	4,0	4,5
Predškolsko dijete**	1,3	1,3	1,3	1,4
Đak**	1,7	1,7	1,7	1,5
Student**	1,2	1,1	1,0	1,2
Poljoprivrednik**	1,5	1,5	1,6	1,5
Domaćica**	1,1	1,1	1,1	1,1
Zaposlen izvan gospodarstva**	1,6	1,6	1,7	1,9
Nezaposlen**	1,2	1,2	1,4	1,2
Umirovljenik**	1,4	1,4	1,2	1,4

*) godina; **) broj

Izvor: Vlastito istraživanje

U 277 kućanstava živi 366 predškolske djece pri čemu je većina anketiranih kućanstava sa jednim djetetom (72,9%), sa dvoje djece je 24,2% te ostala kućanstva su sa troje do petoro djece. 748 đaka živi u 452 kućanstva i to 45,8% sa jednim te 44,0% kućanstava sa dva đaka.

Broj studenata je značajno manji od broja đaka i ukupno 12,3% anketiranih kućanstava ima studenta pri čemu je najveći udio kućanstava s jednim (87,1%).

Ukupno 267 anketiranih kućanstava su sa poljoprivrednikom/poljoprivrednicom pri čemu je od toga dvije trećine kućanstava sa jednim poljoprivrednikom. Manje od polovice kućanstava (41,7%) ima kućanicu.

U 678 kućanstva žive osobe koje su zaposlene izvan gospodarstva. Od toga polovica kućanstava ima jednu osobu zaposlenu izvan gospodarstva, dvije osobe ima 39,4% kućanstava, a tri i više 10,5% kućanstava.

U četvrtini ispitivanih kućanstava (233 kućanstva) ima najmanje po jedna nezaposlena osoba.

Nešto više od trećine anketiranih kućanstava (310 ili 32,9%) ima umirovljenika/umirovljenicu.

Najveći dio ispitanih osoba je stalno zaposlen izvan gospodarstva (52,9%), manji dio je nezaposlen (29,8%), poljoprivrednika je 15,7% te umirovljenik 1,7%.

Od stalno zaposlenih izvan gospodarstva najveći dio su radnici (68,1%), potom službenici (22,9%), poduzetnici (6,7%) te slobodna profesija (2,3%).

Tablica 2 Struktura anketiranih osoba s obzirom na zanimanje (%)

Zanimanje	Hrvatska	Panonska	Gorska	Mediteranska
Poljoprivrednik	15,7	17,5	11,0	12,6
Radnik	36,1	36,7	33,9	35,1
Službenik	12,1	10,2	14,7	16,8
Poduzetnik	3,5	3,1	5,5	3,7
Slobodna profesija	1,2	1,0	0,9	2,1
Nezaposlen	29,8	29,5	32,1	29,3
Umirovljenik	1,7	2,0	1,8	0,5
Ukupno	100,0	100,0	100,0	100,0

Izvor: Isti kao za Tab 1

Prema stupnju obrazovanja, najveći dio ispitanika ima završenu srednju trogodišnju (38,4%), nešto manje (36,6%) srednju četverogodišnju školu, 15% ispitanika ima osnovnu školu, 6,2% ima višu te 4,2% završen fakultet.

Obrazovna struktura anketiranih je bolja od prosjeka Hrvatske s izuzetkom udjela osoba sa završenim fakultetom. Prema popisu iz 2001. godine u Republici Hrvatskoj bez škole je bilo 2,9% osoba starijih od 15 godina, sa osnovnom 37,5%, srednjom trogodišnjom 27,2%, srednjom četverogodišnjom 19,8%, višom školom 4,1% te sa fakultetom 7,8%. Razlika od 0,4% su osobe pod znamenkom nepoznata škola.

Osnovne informacije o gospodarstvu i poljoprivrednoj proizvodnji

Preko polovice ispitanika (55,2%) posjeduje zemljišni posjed. Najveći udio čine gospodarstva od 2 do 5 hektara (43,4%), zatim iznad 5 ha (33,4%) te najmanje ih je u kategoriji do 2 ha (23,3%). Podaci se značajno ne razlikuju po regijama.

Tablica 3 Struktura gospodarstava prema veličini posjeda (%)

Veličina posjeda	Hrvatska	Panonska	Gorska	Mediteranska
Do 2 hektara	23,2	20,7	30,8	27,5
2 do 5 hektara	43,4	46,8	36,5	35,8
Više od 5 hektara	33,4	32,5	32,7	36,7
Ukupno	100,0	100,0	100,0	100,0

Izvor: Isti kao za Tab 1

Na pitanje da navedu tri vrijednosno najvažnija proizvoda, kao prvi proizvod se pojavljuje kukuruz u 35,3% slučajeva, mlijeko i mliječni proizvodi u 14,4% te grožđe i vino u 11,0%. Kao drugi proizvod stoka i meso su najčešći proizvod (kod 17,8% slučajeva), zatim pšenica (17,4%) te kukuruz (15,7%). Na trećem mjestu po važnosti pšenica je opet najzastupljenija (28,2%), zatim povrće (24,2%) te stoka i meso (20,9).

Prema izjavi ispitanika, 62,8% gospodarstava su mješovita, četvrtina (25,6%) su poljoprivredna te 11,6% su nepoljoprivredna.

Na pitanje «Što namjeravate sa poljoprivrednom proizvodnjom na Vašem gospodarstvu u narednih pet godina» blizu polovica (46,2%) ih je odgovorila da je namjeravaju zadržati na istoj razini, jedna četvrtina (25,2%) da ne zna, jedna desetina će smanjiti proizvodnju, a blizu petine (17,2%) namjerava povećati poljoprivrednu proizvodnju.

Tablica 4 Odluka o poljoprivrednoj proizvodnji u narednih pet godina (%)

Odluka	Hrvatska	Panonska	Gorska	Mediteranska
Povećati	17,2	15,9	14,0	22,5
Zadržati istom	46,2	41,3	67,4	53,2
Smanjiti	11,4	12,4	11,6	8,1
Ne znam	25,2	30,4	7,0	16,2
Ukupno	100,0	100,0	100,0	100,0

Izvor: Isti kao za Tab 1

Najviše ispitanika namjerava povećati poljoprivrednu proizvodnju u mediteranskoj regiji, njih 53,2%, a najmanje u gorskoj, svega 14%. Najviše neodlučnih je u panonskoj regiji, njih čak 30,4%. Isto tako, najviše ovih ispitanika namjerava smanjiti poljoprivrednu proizvodnju.

Kao najčešći razlog kod odluke o budućoj poljoprivrednoj proizvodnji ispitanici ističu financijske razloge (22,4%), njih 15,1% je zadovoljno postojećim stanjem, 14,6% ih ima drugi posao, a njih 12,2% imaju dodatan izvor prihoda. Problem isplativosti i nedostatka radne snage kao čimbenika odluke o svojoj proizvodnji navodi 12,9% odnosno 11% ispitanika. Ostali dio ispitanika ne vidi opće perspektivu, smatra se nesposobnim za EU te u niskim cijenama vidi razloge svojih razmišljanja.

Pozitivan odnos (da će povećati poljoprivrednu proizvodnju) nalazimo kod 27,3% ispitanika koji su izjavili da su zadovoljni stanjem i da im je to dodatan prihod, dočim svi ostali razlozi spadaju u negativne razloge odnosno ukazuju na razloge smanjenja buduće poljoprivredne proizvodnje.

U rangu vrijednosti odgovora u panonskoj regiji je na prvom mjestu financijski razlog, dočim su u gorskoj i mediteranskoj regiji zadovoljni sa postojećim stanjem. Ovakva struktura odgovora je jasnija jer u mediteranskoj regiji značajan dio ispitanika je izjavio da imaju drugi posao odnosno i drugi izvor prihoda.

Procjena kvalitete života osobno i kolektivno je pitanje percepcije i usporedbe. Ispod trećine ispitanika (26,6%) smatra da se na selu danas živi dobro do jako dobro. Značajan dio ispitanika (43,6%) misli da se živi prosječno – niti dobro niti loše, a trećina da se živi loše do jako loše.

Na pitanje «Kako će se živjeti na hrvatskom selu za pet godina trećina (33,9%) ih smatra da će biti bolje nego danas, petina (22,3%) lošije nego danas te najveći dio (43,8%) ne očekuje nikakve promjene.

Tablica 5 Kako će se na selu živjeti za pet godina? (%)

Ocjena	Hrvatska	Panonska	Gorska	Mediteranska
Jednako kao danas	49,5	44,3	31,1	49,0
Lošije nego danas	27,1	21,5	37,9	16,7
Bolje nego danas	23,4	34,3	31,1	34,4
Ukupno	100,0	100,0	100,0	100,0

Izvor: Isti kao za Tab 1

Gospodarska i društvena stagnacija sela za posljedicu ima pesimističan stav ispitanika pri čemu je on najviše izražen u gorskoj Hrvatskoj te najmanje u mediteranskoj. Ispitanici iz panonske Hrvatske kojima je poljoprivreda ne samo stvarni gospodarski stožer nego i tradicijsko mjerilo dobrog ili lošeg najpesimističniji su u pogledu budućnosti. Dok se za gorski dio Hrvatske nadomjestak poljoprivredi pronalazi u planinskom turizmu, a u mediteranskim selima konačne cijene nekretninama niti ne naziru selo u panonskoj Hrvatskoj, po mišljenju ispitanika, osuđeno je na stagnaciju i propadanje.

ZAKLJUČAK

Uz sve do sada nastale promjene ruralni prostor Hrvatske u značajnoj mjeri je pod utjecajem stanja poljoprivrednog sektora. Poljoprivreda nije samo važna sa ekonomskog aspekta (zapošljava dio stanovništva, osigurava dohodak, tržište je inputa itd.) nego je bitna i u očuvanju i čuvanju ruralnog krajobraza. Zbog toga je za kreatore ekonomske politike vrlo bitna spoznaja o očekivanjima stanovnika ruralnog područja.

Provedeno istraživanje je pokazalo visoku razinu pesimizma ispitanika što sigurno ima značajan utjecaj na njihovu trenutačnu i buduću ekonomsku aktivnost gdje posebno percipiramo dugoročna ulaganja u poljoprivredi (strojevi, oprema, gospodarski objekti itd.).

LITERATURA

1. Akrap, A. (2002): Regionalne i naseljske značajke vitalnih procesa u hrvatskom seoskom stanovništvu, u «Prostor iza: Kako modernizacija mijenja hrvatsko selo», Institut društvenih znanosti Ivo Pilar, Zagreb
2. Bašić, Ksenija (2005): Depopulacija u gradskoj regiji Zagreba, Stanovništvo Hrvatske-dosadašnji razvoj i perspektive / Živić, dražen, Pokos, Nenad i Mišetić, Anka (ur.). - (Zagreb) : Institut društvenih znanosti Ivo Pilar , 198-210.
3. Čizmić, I. Živić, D. (2005): Vanjske migracije stanovništva Hrvatske - kritički osvrt, u «Stanovništvo Hrvatske - dosadašnji razvoj i perspektive», Institut društvenih znanosti Ivo Pilar, Zagreb
4. Državni zavod za statistiku, redovite publikacije i priopćenja
5. Gelo, J. (1987): Demografske promjene u Hrvatskoj od 1780. do 1981. g., Globus, Zagreb
6. Grupa autora (1995): Strategija razvitka hrvatske poljoprivrede, Ministarstvo poljodjelstva i šumarstva Republike Hrvatske, Zagreb
7. Hodžić, A. (2000): Socijalna struktura i mobilnost seoskog stanovništva, Sociologija sela (0038-0326) g 38. 147/148 (2000), 1/2; 79-107
8. Ilišin, Vlasta (2006): Slobodno vrijeme i kultura mladih, u «Mladi između želja i mogućnosti. Položaj, problemi i potrebe mladih Zagrebačke županije», Institut za društvena istraživanja, Zagrebačka županija, Zagreb
9. Petak, A. (2002): Što znamo o mladim seljacima?, Sociologija sela (0038-0326) g. 40. (2002), 1/2 (155/156); 43-48.
10. Pokos, N. (2005): Glavne značajke obrazovne strukture stanovništva Hrvatske, u «Stanovništvo Hrvatske - dosadašnji razvoj i perspektive», Institut društvenih znanosti Ivo Pilar, Zagreb
11. Turčić, I. (2000): Dugoročne tendencije kretanja stanovništva županija u Republici Hrvatskoj 1961. do 1991., Ekonomski institut, Zagreb
12. Živić, D., Pokos, N., Mišetić, Anka (urednici) (2005): Stanovništvo Hrvatske - dosadašnji razvoj i perspektive, Institut društvenih znanosti Ivo Pilar, Zagreb
13. Živić, D. (1998): Neki pokazatelji i posljedice deagrarizacije i deruralizacije u istočnoj Slavoniji, Sociologija sela 36 (1998), 1-4; 103-125
14. Wertheimer-Baletić, Alica; Živić, D. (2003): Demografske promjene u ruralnim područjima Slavonije i Baranje od 1953. do 2001. godine, u «Razvojne perspektive ruralnoga svijeta Slavonije i Baranje», Institut društvenih znanosti Ivo Pilar, Zagreb

CROATIAN AGRICULTURE FROM THE VIEW OF THE RURAL POPULATION

IVO GRGIĆ[1], VLADIMIR LEVAK[2], ĐURĐICA ŽUTINIĆ[1], MAGDALENA ZRAKIĆ[3]

[1]University of Zagreb, Faculty of Agriculture, Svetošimunska cesta 25, 10 000 Zagreb, Croatia, e-mail: igrgic@agr.hr

[2]Agricultural association JALŽABET, Suhodolska 21, 42 203 Jalžabet, Croatia

[3]Graničarska 2, 10310 Ivanić Grad, Croatia

SUMMARY

Agriculture, as a significant economical component of Croatia's rural areas, is still based on relatively small agricultural estates, inadequate technological equipment and unfavourable educational structure of the farmers, as well as the inexperienced age groups involved in farming. Some additional problems can be found in the undeveloped market structure for the agricultural product, bad marketing organization and the unsolved problem of farmland marketing.

The aim of this article is to determine on the basis of a survey the level of people's satisfaction with the life in the country, that being one of the ways of lowering demographic pressure on urban areas.

The satisfaction and the expectations of the participants in the survey indirectly affect the possibility of long-term investments, for example machinery and equipment investments as well as agricultural manufacturing projects.

The survey was performed by method of sample which included 941 respondents in all districts of Croatia. The survey covered 941 housekeeping / respondents, out of which 67.3% were in the continental part, 11.9 % in the highland part, and 20.8 % in the Mediterranean part of Croatia.

Over half of respondents (55.2%) have a landed property. The largest share of the economy is 2 to 5 hectares (43.4 %) and over 5 hectares (33.4 %) and the fewest were in the category of up to 2 ha (23.3%).

In the next five years nearly half of the respondents (46.2%) intended to keep agricultural production at the same level, one quarter (25.2%) didn't know what would happen, one tenth would reduce it and 17.2 % is planning to increase it.

Expected changes are often mutually related to the satisfaction with life in the country. Under one third of respondents (26.6%) believe that nowadays people in the country live well and very well. A significant portion of respondents (43.6%) thinks that life is average, nor good nor bad, and a third thinks that life is poor and very poor. A third or 33.9% of them think that five years from now life in the country in Croatia will be better, one fifth (22.3%) thinks that life will be even worse and most of them (43.8%) don't expect any changes.

Key words: *Croatia, rural area, agriculture, future*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.164:658.155
Prethodno priopćenje
Preliminary communication

OPTIMIZATION OF PRODUCTION BRANCHES JOINT IN AGRICULTURAL IASI COUNTY, FROM ROMANIA IN ORDER TO INCREASE THEIR PROFITABILITY

CORNELIA TUREAC, GEORGETA DRAGOMIR, GRIGORE AURICA

Danubius University, Galați, Romania

SUMMARY

In order to achieve efficiently the optimum joint of the production branches at the level of an exploitation it is necessary to observe correlations imposed by the principles which are at the basis of the optimum use of the exploitation resources.

The model of the linear programming adequate to the optimum joint of the production branches at the level of the studied zone has called for a differentiation on two seasons of production: May-October and November-April, and depending on it levels of the surfaces and livestock raised on them have been established.

In what follows, we will present one such model developed in the case of the op-time combination of the vegetal and animal productions. Towards the progresses recorded by the method of economic calculation, the optimal variant of specialization and rational combination of the branches can be determined more accurately, for example, using mathematical programming methods. An example of calculation will clear us on the results that can be obtained in this way.

***Key words**: optimization, production, branches, profitability*

INTRODUCTION

The county Iasi has a socio – economic structure of the population specific to the localities specific with agricultural profile, but also with some non-agricultural activities in course of development.

The share of the active occupied population in agriculture exceeds 70%, and within the inactive population the group of pensioners holds 45.8%

From the analysis of the appreciation of the terrain, in the county Iasi, the terrain meets the highest note of quality of the terrain from the county, and to the natural meadows are recorded minimum values.

In the studied area, the harvested arable surface presented a slight increase, so that in the year 2008, compared with 2005, the growth was of 5.3%

In the county Iasi, the harvested surface with cereal grain for seed, had an upward trend, so in 2005 comparative with 2008, the increase share was 24.6%

The larges increases of the harvested surface with cereal grains for seed, on species were recorded to maize, at which the surface from 2008 doubled compared with 2005, while the barely and two row barely the harvested surfaces have known significant decreases.

The evolution of the average production per hectare has a direct impact on the total production for the main species of cereals for seed, which at the maize for grain, excepting 2007, has presented an accelerated growth trend with a significant increase, which was 2911 tones.

From the total production of grain cereal for seed, in average, over 70% is destined for selling, and the rest is retained for own consumption.

The distribution of seeds is directly from the producing units, without any intermediaries.

In the studied area, the producing units of cereal grains, adopted a strategy oriented toward market, so that sizing the surface is closely related with the rented contracts with the specialized companies.

From the analysis of the data is showed the general trend of increasing the costs to all the species of grains for seed.

The largest production increases were recorded for wheat grain and maize grain.

METHODS

The mathematical models have emphasized that in the process of the production branches joint within an agricultural exploitation a special role has the criterion according to which the economic phenomenon is modelled.

RESULTS AND DISCUSSION

After the cadastral situation of the specialized institution (OCPI), on January 1, 2008, the county Iasi was of 547558 hectares representing 2.3% of the total surface of the country.

The county Iasi is ranking on the country classification among the medium sized counties, ranking on 24, with a higher proportion of the private land sector.

In territorial profile the land fund is reflected in different services structures with characteristics from an area of agricultural productions to another.

In these countries, the large specialized cooperatives appear and coexist with the multi-functional ones. A part of the specialized cooperatives were associated with food companies.

To illustrate the way of calculation in determining the optimal combination between the embranchments of vegetal and animal production, using the mathematical programming, we will serve as an example in the agricultural area of the city Iasi (Iasi County) including an area of 1.500 – 2.500 ha. In this area can be harvested fodder plants and are growing the following animal species whose coding we present below. The areas occupied with: new alfalfa for hay (x_1), old alfalfa for hay (x^2), grassland temporary cultivated for hay (x_3), grassland temporary cultivated for green mass (x_4), annual fodder of autumn for green mass (x_5), annual forage of spring for the green mass (x_6), double maize crop for green mass (x_7), corn for silage in own estate (x_8), corn for silage in dual culture (x_9), fodder beet (x_{10}), maize for consumption (x_{11}), natural pastures for green mass (x_{12}), natural meadow (x_{13}), livestock; dairy cows (x_{14}), cattle for fattening (x_{15}), adult sheep(x_{16}), sheep for fattening (x_{17}); areas of cereal crops of which it should be used the secondary production of : corn cobs (x_{18}), wheat straw (x_{19}), barely straw (x_{20}), rye straw (x_{21}).

The linear programming model appropriate to the problem of optimal combination of the branches of production at the level of the analyzed area made necessary a differentiation on two seasons: May – October and November – April, depending of which are established the level of the surfaces and of the livestock that can be raised:

a) Mathematical model for optimal combination of branches in the period May – October.

The restrictions considered relate to:

Using of the entire surface:

$$x_4 + x_5 + x_6 + x_{12} = 1.618$$

Achieving at least the minimum level necessary of nutritive units:

$$4.480\,x_4 + 4.420\,x_5 + 4.250\,x_6 + 2.520\,x_7 + 2.250\,x_{12} - 2.190\,x_{14} - 1.736\,x_{15} - 328\,x_{16} - $$
$$- 197\,x_{175} + 1.148\,x_{19} \geq 0;$$

Achieving at least the minimum required level of dray matter:

$$7.680\,x_4 + 4.420\,x_5 + 5.250\,x_6 + 2.240\,x_7 + 3.000\,x_{12} + 2.592\,x_{14} - 1.736\,x_{15} - 328\,x_{16} - $$
$$- 480\,x_{17} + 3.485\,x_{19} \geq 0;$$

Achieving at least the minimum level necessary of digestible crude protein:

$$608\,x_4 + 416\,x_5 + 650\,x_6 + 224\,x_7 + 237{,}5\,x_{12} - 228\,x_{14} - 153\,x_{15} - 29{,}2\,x_{16} - - 27{,}8\,x_{17} + $$
$$12{,}3\,x_{19} \geq 0;$$

Achieving at least the minimum necessary level of phosphorus:

$$22{,}4\,x_4 + 7{,}8\,x_5 + 17{,}5\,x_6 + 4{,}2\,x_7 + 7{,}5\,x_{12} - 9{,}9\,x_{14} - 7{,}6\,x_{15} - 1{,}1\,x_{16} - 0{,}7\,x_{17} + 2{,}1\,x_{19}$$
$$\geq 0;$$

Using the entire area occupied by natural pasture:

$x_{12} = 973$;

Ensuring the surface occupied by double crops:

$-0,18\,x_4 - 0,18\,x_5 - 0,18\,x_6 + x_7 = 0$

Achieving the planned level of the cows for milk:

$x_{14} \geq 2.200$

Achieving the planned level of herd of cattle for fattening:

$x_{14} \geq 5.400$

Achieving the planned level of adult sheep flock:

$x_{16} \geq 3.000$

Achieving the planned level of the livestock of sheep for fattening:

$x_{17} \geq 2.350$;

Minimizing the costs of production throughout the area:

$f\,(x) = 6.016\,x_4 + 7.982\,x_5 + 4.060\,x_7 + 2\,413\,x_{12} + 5.350\,x_{14} + 5.061\,x_{15} + 155\,x_{16} + 394\,x_{17} + 984\,x_{19}$ – minimum

The solution obtained from solving this mathematical model showed the structure of the cultures and of livestock presented below:

X_6= 645 ha occupied with annual forage of spring for green mass;

X_7= 116 ha occupied with corn in double crops for green mass;

X_{12}= 973 ha occupied with natural pastures for green table;

X_{14}= 2.200 cows for milk;

X_{15}= 5.400 cattle for fattening;

X_{16}= 3000 adult sheep;

X_{17}= 2350 sheep for fattening;

X_{19}= 65.397 hectares of wheat from which is obtains the secondary production (straw) necessary for the equilibration of the fodder balance of the animal from the analyzed area. Given this production structure considered, can be stated that optimizing the process of merging the branches (plant and animal), the production costs reach a minimum level of 111.965,778 RON, much lower than in the variant in which the structure of production wasn't optimized. In addition to this, is achieving the planned level the full production zootechnical requirements.

b) Mathematical model for optimal combination of branches in the period from November to April.

The restrictions include:

Using the entire surface:

$x_1 + x_2 + x_3 + x_8 + x_{10} + x_{11} + x_{13} = 827;$

Achieving at least the minimum level necessary of nutritive units:

$3.744\, x_1 + 3.024\, x_2 + 3.328\, x_3 + 8.800\, x_8 + 3.520\, x_9 + 9.600\, x_{10} + 6.600\, x_{11} + 1.692\, x_{13} - 2.190\, x_{14} - 1.737\, x_{15} - 784\, x_{21} \geq 0;$

Achieving at least the minimum required level of dray matter:

$6.552\, x_1 + 5.292\, x_2 + 5.440\, x_3 + 10.000\, x_8 + 4.000\, x_9 + 10.400\, x_{10} + 4.730\, x_{11} + 3.096\, x_{13} - 2.592\, x_{14} - 2.117\, x_{15} - 438\, x_{16} + 3.444\, x_{18} + 3.485\, x_{19} + 4.250\, x_{20} + 2.380\, x_{21} \geq 0;$

Achieving at least the minimum level necessary of digestible crude protein:

$784{,}8\, x_1 + 604{,}8\, x_2 + 358{,}8\, x_3 + 440\, x_8 + 176\, x_9 + 800\, x_{10} + 363\, x_{11} + 201{,}6\, x_{13} - 228\, x_{14} - 153\, x_{15} - 29{,}2\, x_{16} + 73{,}8\, x_{18} + 12{,}3\, x_{19} + 40\, x_{20} + 8{,}4\, x_{21} \geq 0;$

Achieving at least the minimum necessary level of calcium:

$78\, x_1 + 63\, x_2 + 41\, x_3 + 48\, x_8 + 19{,}2\, x_9 + 24\, x_{10} + 1{,}1\, x_{11} + 19{,}4\, x_{13} - 14{,}1\, x_{14} - 12{,}5\, x_{15} - - 1{,}9\, x_{16} - 12{,}7\, x_{18} + 8{,}6\, x_{19} + 12\, x_{20} + 6{,}2\, x_{21} \geq 0;$

Achieving at least the minimum necessary level of phosphorus:

$12{,}5\, x_1 + 10{,}1\, x_2 + 16{,}6\, x_3 + 20\, x_8 + 8\, x_9 + 24\, x_{10} + 12{,}7\, x_{11} + 7{,}2\, x_{13} - 9{,}9\, x_{14} - 7{,}6\, x_{15} - - 1{,}1\, x_{16} + 4{,}5\, x_{18} + 2{,}1\, x_{19} + 6\, x_{20} + 1{,}1\, x_{21} \geq 0;$

Using entirely the occupied surface with natural meadow:

$x_{13} = 157;$

Ensuring the surface occupied by double crops:

$-0{,}81\, x_1 - 0{,}81\, x_2 - 0{,}81\, x_2 - 0{,}81\, x_3 - 0{,}81\, x_8 + x_9 - 0{,}81\, x_{10} - 0{,}81\, x_{11} - 0{,}81\, x_{13} = 0;$

Achieving the planned level of the cows for milk:

$x_{14} \geq 2.200$

Achieving the planned level of herd of cattle for fattening:

$x_{15} \geq 5.400$

Achieving the planned level of adult sheep flock:

$x_{16} \geq 3.000;$

Minimizing the costs of production on the ensemble of the unique agro-industrial council:

$$f(x) = 7.309\,x_1 + 7.535\,x_2 + 5.664\,x_3 + 10.480\,x_8 + 4.368\,x_9 + 24.240\,x_{10} + 6.001\,x_{11} + 3.049\,x_{13} + 5.350\,x_{14} + 5.062\,x_{15} + 154\,x_{16} + 738\,x_{18} + 984\,x_{19} + 1.050\,x_{20} + 896\,x_{21} -$$
minimum.

After solving this system of linear programming it was obtained the optimal solution of combination of the branches formed from: x_1= 503 ha with new alfalfa for hay, x_3= 167 ha with meadow harvested temporarily for hay; x_9 670 ha with corn for silage in double crop; x_{13}= 157 ha with natural meadow, x_{14} = 2200 cows for milk; x_{15}= cattle for fattening; x_{16}= 3.000 adult sheep, x_{18} = 11.238 ha corn after which it follows to harvest a production of stalk necessary to equilibrate the balance.

The corresponding production costs are 55.887.040 RON.

The mathematical model presented are highlighting the fact that in the process of combining the branches of production within an agricultural enterprise an important role is having the criteria by which is modeling the present economic phenomenon. In addition to the criterion of minimizing the total production, used in the presented modeling, are still can be used the ones referring to the maximization of the production of the exercise, of the total net production, of the profit, minimization of the energetic consumption. They can provide an appropriate structure of the agricultural production concordantly with the company profile, with the development programs of the agricultural considered unit.

To those described above, the optimal combination of the production branches, especially in terms of fodder production - as a branch of the vegetal production and the livestock, is also still a matter of sizing the livestock seen in the light of the existent fodder resources at microeconomic level.

Of the total production of cereal grains for seed, on average, over 70% is destined for selling, and the rest is retained for own consumption.

Usually, the grain cereals for seed, are destined on the domestic market from Moldavia, and sometime and in other geographic areas of the country from the south and west of the country, as well as and at export.

The seed distribution is made directly to the producing units, without any intermediaries.

The payment terms and delivery are established jointly between both parties, and the prices are negotiated by the biological category and the year of harvesting.

Selling-off the products are having character of season by the fact that the certified seeds are sold in two seasons: spring and autumn, in the moment of establishing the crop, in the spring is commercialized the corn seed, oats, barley and in the autumn the seed of wheat and barley.

This strategy envisages that by selling seeds, the units may substantially increase the revenues, especially in the situation in which are in compliance the quality norms contained in the standards and protocols concluded with the beneficiaries. Also,, the units are producing their internal seed requirement, given their economic state of these, compared with the variant of purchasing from other suppliers.

The ensemble of the corresponding of consumption costs of the production factors, on which the economic agents affect them for producing and selling of goods, bearing the name of cost of production. This concept reveals:

- The cost of production is the monetary from of the consumption of human resources and of materials within the economic activity.
- The production cost has in its structure all the expenses incurred by the manufacturer, both for the actual production of the good, as well as and of its selling.
- The production cost allows updating a common denominator of the consumption of different factors and in this way, are becoming possible the measuring and comparability in the market economy, the unitary cost is one of the basic synthetic indicators that reflects in the end the result of the influence of the total expenditure of the production and of the total production on the evolution of this.

The size of the cost per unit is different and namely: from a product to another, depending on the particularities of each individual, by the consumption of production factors, from one producer to another, etc.

From the analyze if the presented data shows the general trend of increasing og the costs to all the species of grain for seed.

The largest increases were recorder for wheat grain and maize grains.

One of the factors that may directly influence the economic and financial results is by the selling price of production.

The price is a major variable for training and influencing the demand of consumption, to determine the volume and of the value of selling the agricultural firm and/or agro-alimentary, of the size of its gross and net income.

The level of the price influences directly the consumption demand and determines the purchasing power of the consumers.

Price can influence the qualitative nature of the market, as well as and the quantitative dimensions of these.

During the transition to a market economy, in general the selling prices are having an upward trend, correlated with the rate of inflation and with other factors specific to this period.

During 2005 – 2008, the average selling prices for the main species of cereal grains for seed harvested in the County Iasi, followed the same trend, registering the biggest increases recording to the wheat grains for seed .

CONCLUSIONS

The county Iasi is a favorable area for the crops of seed due to the water regime, soil quality, rainfall, which are generally evenly distributed and also is the are where it is functioning the irrigation system, and in the favorable years have been obtained very high yields with a coherent strategy of protection of the plants and using the seed from varieties and valuable illogical categories.

In every year are established demonstrative plots with a high number of varieties and hybrids to establish the implementation in the area of the most valuable varieties and hybrids with high production more reliable and stable.

The mathematical models presented above point out the fact that in the process of production branches joint within an agricultural exploitation a special part is played by the criterion according to which the economic phenomenon is modelled.

Besides the criterion of minimizing the total expenses of the production, used in the presented modelling, we may also use those referring to the maximizing the exercise production, of the net production, of the profit, minimizing of the energy consumption etc. They may ensure an adequate structure of the agricultural production in concordance with the exploitation profile, with the development plans of the agricultural unit under study.

As compared to those presented above, the optimum joint of the production branches, especially when fodder production is concerned – as a branch of vegetal production, and zootechnical production, represents also a problem of livestock dimensioning, seen form the angle of the existent fodder resources at microeconomic level.

REFERENCES

1. Magazin P. şi colab. (1988). Optimisation of agricultural production structures on regions and economic efficiency Program study. CNST, Bucharest
2. Otiman P. (1987). Optimisation of agricultural production, Facla Editors, Timisoara.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.372(497.4)
Prethodno priopćenje
Preliminary communication

STANJE TRAKTORSKE TEHNIKE V SLOVENIJI

TOMAŽ POJE

Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko, Hacquetova 17,
SI – 1000 Ljubljana, Slovenija, E-mail: tomaz.poje@kis.si

IZVLEČEK

V Sloveniji je po popisu kmetijstva iz leta 2000 nekaj več kot 108000 traktorjev. Konec leta 2008 je bilo registriranih 84316 traktorjev. Pri nakupu novih traktorjev jev zadnjih letih značilen trend naraščanja kategorij med 60 in 80 kW in nad 80 kW moči. Kategoriji med 20 in 40 ter med 40 in 60 kW moči pa imata tendenco padanja. Izvedena je bila tudi analiza ponudbe standardnih traktorjev v Sloveniji. Največ različnih modelov je v kategoriji moči motorja od 60 do 80 kW, sledita mu kategoriji od 40 do 60 in od 80 do 100 kW. Glede na moč motorja smo ugotavljali specifično maso traktorja, ki ima tja do 100 kW kar velik razpon glede na model traktorja. Ugotovili smo specifično ceno glede na kW moči po proizvajalcih.

Ključne besede*: število traktorjev, moč traktorjev, novo registrirani traktorji, ponudba traktorjev*

UVOD

V Sloveniji imamo po Popisu kmetijstva iz leta 2000 nekaj več kot 108000 traktorjev. Nekateri ocenjujejo, da ji je celo tja do 130 tisoč. Od tega je bilo konec lanskega leta registriranih 80193 traktorjev. Poje in sodelavci (2006) ugotavljajo, da je moč novih traktorjev v Sloveniji od leta 1952 do leta 2002 narasla iz 19,6 na 53,5 kW. Povprečna starost traktorjev je takrat bila v Sloveniji 18,8 let. Ti traktorji pa v povprečju napravijo na leto 280 delovnih ur ali manj kot eno uro na dan. Iz proizvodno tehničnega vidika je torej potrebna modernizacija slovenskega traktorskega parka. Ob samem odločanju ali svetovanju za traktor pa je potrebno poznati tehnične karakteristike traktorja. Namen prispevka je analiza registriranih traktorjev in analiza ponudbe standardnih traktorjev z vidika izbranih tehničnih in cenovnih karakteristik.

V Evropskih državah in tudi drugod je opravljeno kar nekaj raziskav glede tehničnega stanja traktorjev, ki je tudi eden izmed pokazateljev stanja v kmetijstvu. V Avstriji (Schrottmaier in Handler, 2001) ugotavljata porast zmogljivejših traktorjev zaradi večje velikosti kmetijskih gospodarstev. Na Madžarskem je bilo na primer leta 2005 vseh traktorjev 120475, od tega jih je 80 % v lasti privatnih gospodarstev (Hajdu J, Mago L. 2008). Mago (2007) ugotavlja, da je madžarsko kmetijstvo pred resnimi izzivi, ki jih lahko reši tudi z ustreznejšo (efektivnejšo) mehanizacijo, problematične pa so zlasti manjše kmetije. Grgić (2009) pa za Hrvaško ugotavlja, da je zlasti na družinskih kmetijah mehanizacija zelo stara in velikokrat nefunkcionalna.

METODIKA

Kot vir podatkov za analizo smo uporabili podatkovno bazo Ministrstva za notranje zadeve RS o registriranih vozilih (traktorjih) in podatkovno bazo o traktorjih iz Kataloga traktorjev 2009, ki ga je izdal ČZD Kmečki glas. V prispevku analiziramo vse in na novo registriane traktorjev v izbranih letih ter ponudbo 439 standardnih traktorjev. Iz obravnavanja smo izločili druge posebne skupine traktorjev. V analizo zajeti podatki so obdelani z ustreznimi statističnimi analizami (opisna statistika).

REZULTATI IN DISKUSIJA

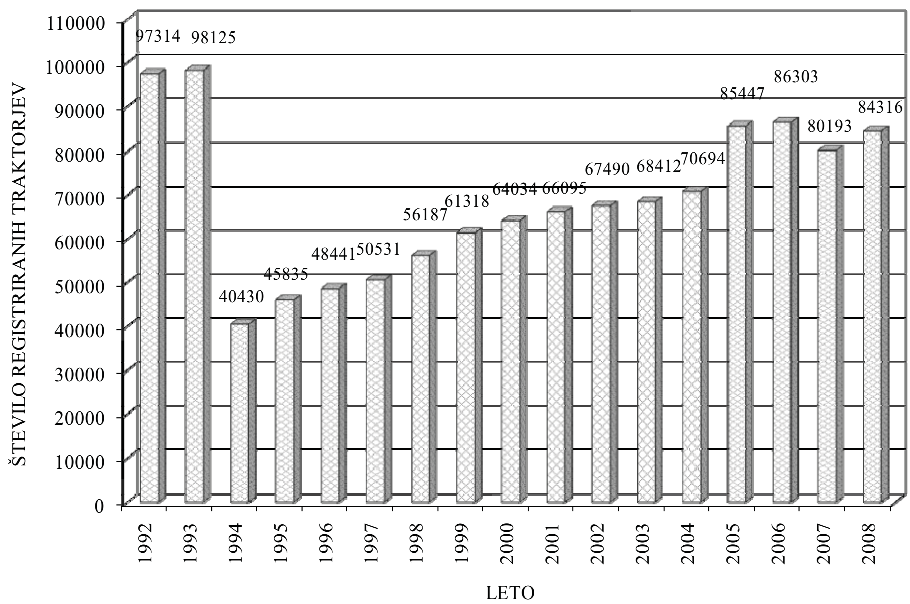
Registrirani traktorji v Sloveniji

Ministrstvo za notranje zadeva ima podatkovno bazo o vseh registriranih vozilih v Sloveniji. V okviru te baze so zajeti vse registrirani traktorji v Sloveniji. To je dejansko tudi največja podatkovna baza o traktorji v Sloveniji. Po podatkih iz Popisa kmetijstva, ki ga je leta 2000 napravil Statistični urad RS je bilo takrat v Sloveniji nekaj več kot 108000 traktorjev. Nekateri slovenski strokovnjaki trdijo, da je v Sloveniji traktorjev celo več, nekje do 120 ali celo do 130 tisoč traktorjev.

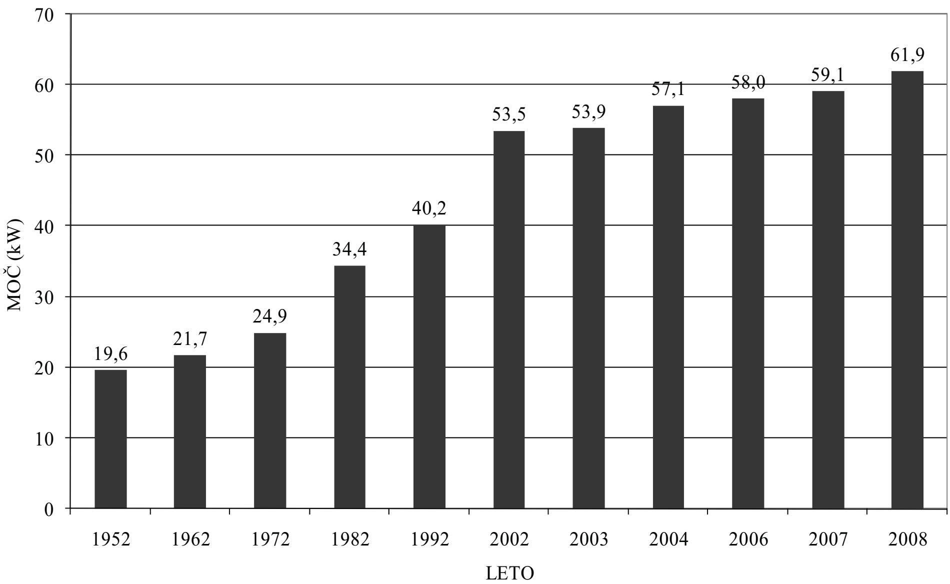
V grafu 1 je prikazano število vseh registriranih traktorjev v Sloveniji za zadnje obdobje. V letu 1993 je bilo registriranih 98125 traktorjev, naslednje leto pa se je število registriranih traktorjev zmanjšalo na 40430 traktorjev zaradi prehoda na nove slovenske registrske tablice in takrat marsikdo ni več registriral traktorja. Po tem letu je število registriranih traktorjev počasi naraščalo, velik porast registriranih traktorjev pa je bil v letu 2005 ko je bilo v Sloveniji možno registrirati star traktor tudi brez podatkov o lastništvu. Konec leta 2008 je bilo registrirani 84316 traktorjev.

Iz podatkov Ministrstva za notranje zadev RS smo izračunali tudi povprečno moč registriranih traktorjev za posamezna leta. Iz grafa 2 je razvidno, kako se je povečevala moč po desetletjih in v nekaj zadnjih letih.

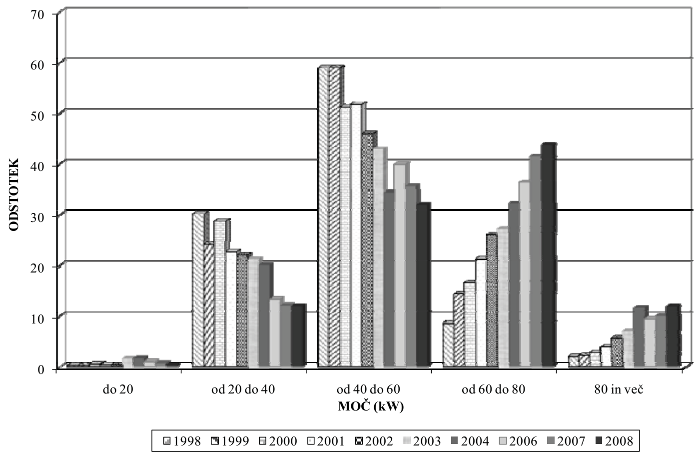
Graf 3 prikazuje prvič registrirane traktorje (nove traktorje) v Sloveniji za zadnja leta. Razporejeni so po kategorijah moči, ne glede na proizvajalca ali državo porekla. Iz grafa je razvidno, da v zadnjih letih raste kategorija traktorjev z močjo motorja med 60 in 80 kW ter kategorija nad 80 kW. Kategoriji novih traktorjev z močjo med 30 in 40 kW ter med 40 in 60 kW upadata. Kljub trendu upadanja pa imajo v absolutnem številu še vedno veliko število traktorjev. Odstotek novih traktorjev v Sloveniji z močjo motorja pod 20 kW je majhen in relativno konstanten.



Graf 1: Registrirani traktorji u Sloveniji po letih

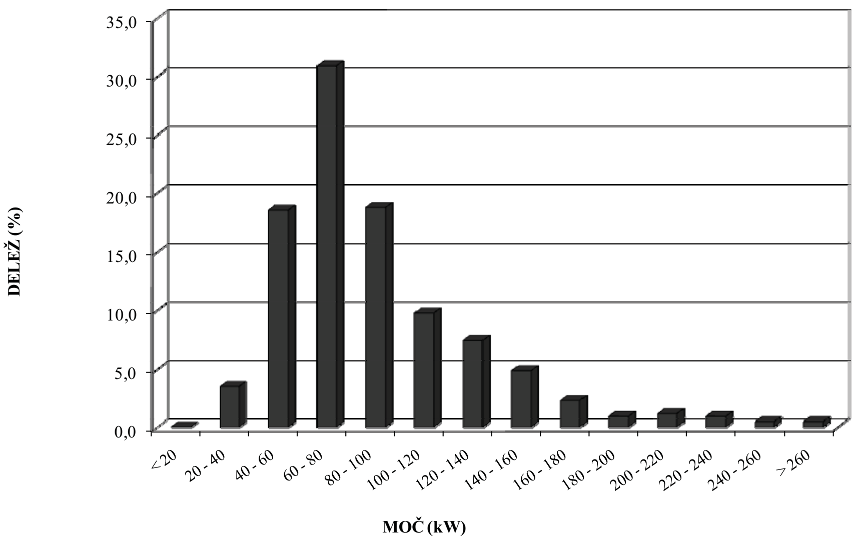


Graf 2: Porast moči traktorskih motorjev v Sloveniji v obdobju od 1952 do 2008



Graf 3: Novi traktorji registrirani v Sloveniji za zadnja leta po različnih kategorijah moči

Ponudba traktorjev

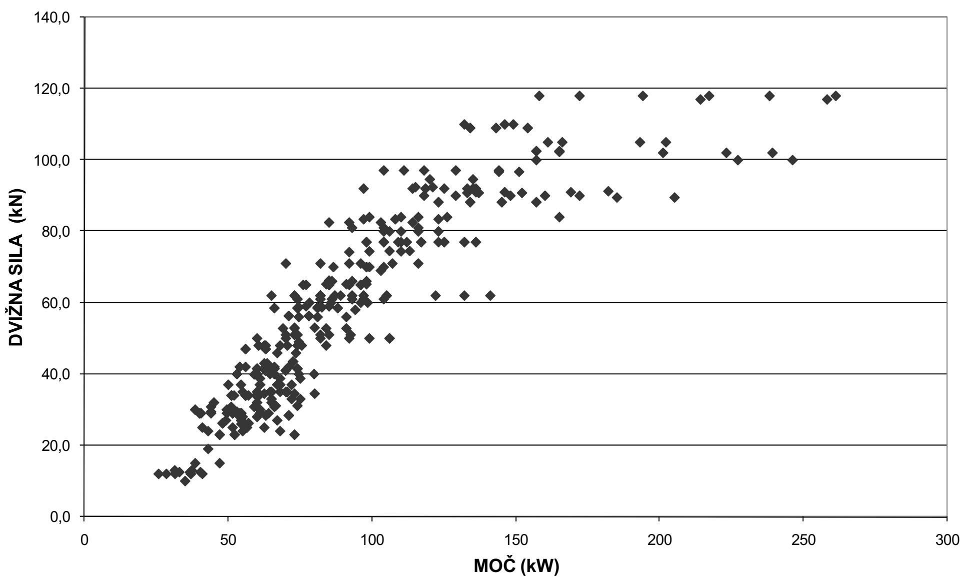


Graf 4: Delež standardnih traktorjev (modelov), ki jih lahko kupec izbira v Slovenije v letu 2009 glede na kategorijo moči

Na osnovi analize Kataloga traktorjev 2009, ki ga je izdal ČZP Kmečki glas, smo standardne traktorje razvrstili v kategorije po moči traktorskega motorja. Po velikem deležu (oziroma številu) različnih modelov izstopajo 3 kategorije, kjer je moč med 40 in 100 kW. V kategoriji moči od 40 do 60 kW je 80 modelov, v kategoriji med 80 in 100 kW je 81 modelov. Največ modelov - kar 133 pa je v ponudbi v kategoriji od 80 do 100 kW moči traktorja. V tem območju moči je izredno velika izbira, kupci pa po analizi prodanih oziroma registriranih traktorjev kupijo največ traktorjev ravno v kategoriji moči med 40 in 80 kW.

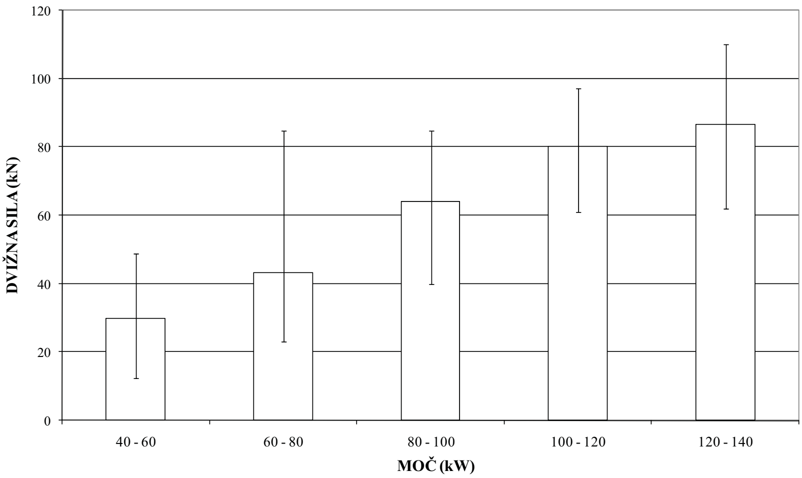
Če število modelov pogledamo po proizvajalcih oziroma blagovnih znamkah potem po velikem številu modelov (več kot 25) izstopa Mc Cormick, Landini, Case IH in New Holland. Tri ali manj modelov pa imajo med standardnimi traktorji Pasquali, De Pietri, Farmtrac, Impodan in Limb. V letu 2009 v Sloveniji ni bilo več Belarus-a in YTO Group. IMT pa je konec leta 2009 pridobil novega zastopnika in zato še ni vključen v to analizo.

Zaradi vedno večje moči novih traktorjev so tudi priključki vedno večji in s tem težji, zato mora traktorsko hidravlično dvigalo zagotoviti dovolj veliko dvižno silo za normalno delo. Na grafu 5 je prikazana dvižna sila zadnjega hidravličnega dvigala standardnih traktorjev glede na moč motorja. Razvidno je, da imajo modeli ob isti moči lahko zelo različno dvižno silo.



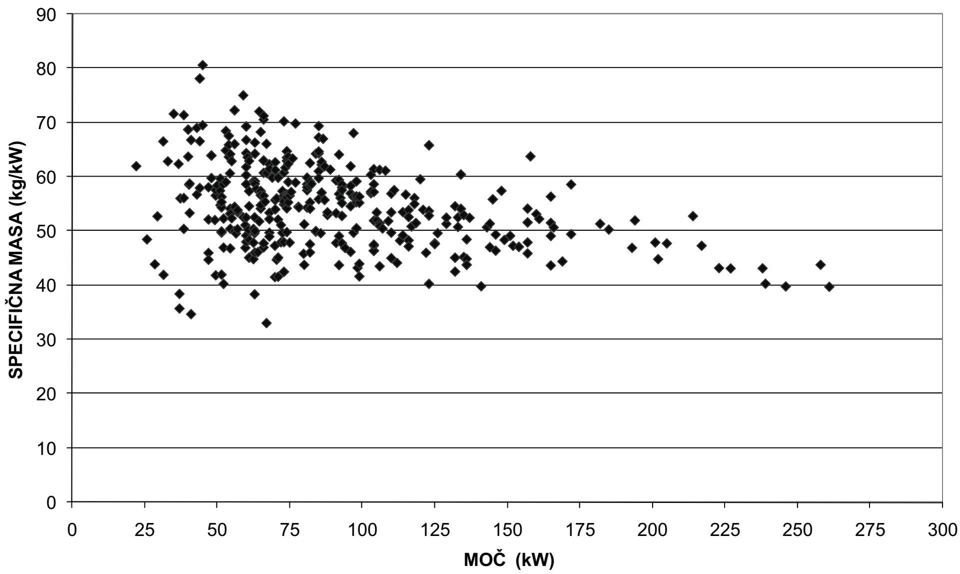
Graf 5: Dvižna sila zadnjega traktorskega hidravličnega dvigala v kN glede na moč motorja.

Na grafu 6 je prikazana bolj podrobna analiza podatkov za dvižno silo za traktorje med 40 in 140 kW moči. V skupini traktorjev med 40 in 60 kW je povprečna dvižna sila 29,6 kN, za traktorje med 60 in 80 kW 41,7 kN , za traktorje med 80 in 100 kW 63,5 kN, za traktorje med 100 in 120 kW 78 kN in za traktorje med 120 in 140 kW 87 kN. Na grafu 6 vidimo pet stolpcev s povprečno dvižno silo v teh kategorijah moči. Višina črne črte (ročaja) nad stolpcem pomeni maksimalno dvižno silo v tej kategoriji. Spodnji del črne črte (ročaja) v stolpcu pa označuje minimalno dvižno silo v določeni kategoriji moči.



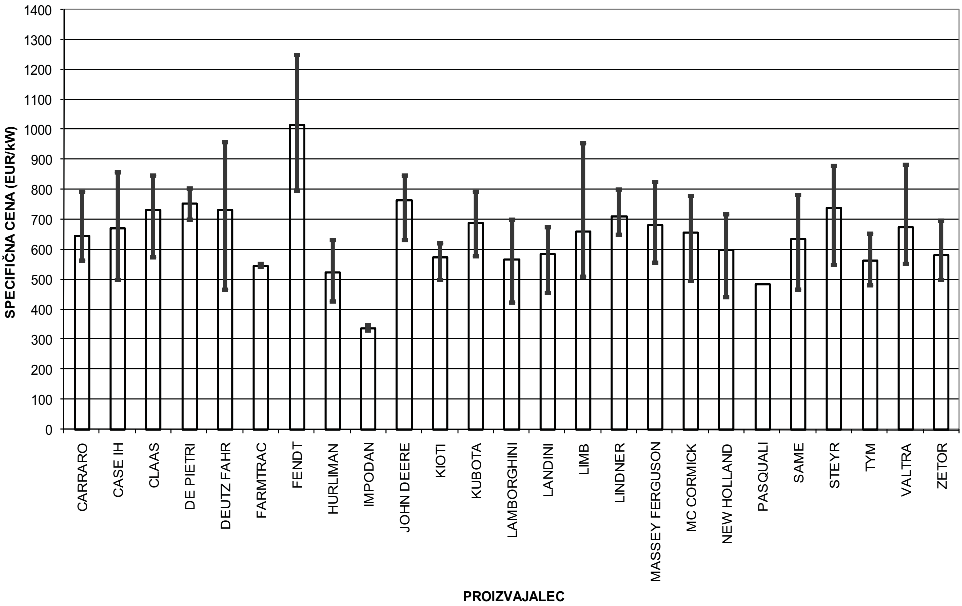
Graf 6: Povprečna dvižna sila označena s stolpci ter maksimalna in minimalna dvižna sila označena z ročaji glede na kategorijo moči motorja

Če govorimo, da masa traktorjev narašča z večjo močjo traktorja pa je slika drugačna če maso preračunamo na kW moči traktorskega motorja. Iz grafa 7 je viden trend padanja specifične mase traktorja izražene v kg/kW glede na porast moči traktorskega motorja.



Graf 7: Specifična masa traktorja izražena v kg/kW instalirane moči traktorja glede na moč motorja

Eden izmed glavnih podatkov pri izbiri traktorja pa je tudi njegova cena. Če prikažemo specifično ceno po proizvajalcih oziroma blagovnih znamkah potem navzgor izstopa Fendt, kjer je povprečna specifična cena 1045 EUR/kW moči. Relativni nizke cene ima vzhodni Belarus s 412 EUR/kW in kitajski YTO Group s 387 EUR/kW moči. Na grafu 8 so prikazani proizvajalci (blagovne znamke) standardnih traktorjev in njihove povprečne specifične cene na kW moči motorja. Z ročaji so podane tudi minimalne in maksimalne cene.



Graf 8: Povprečna specifična cena na kW moči in minimalne ter maksimalne cene glede na proizvajalce standardnih traktorjev

ZAKLJUČEK

Slovenija je sicer vodilna v svetu po številu traktorjev na milijon prebivalcev. Vendar če pogledamo celotni traktorski park potem lahko za njega rečemo, da je star in tehnično zastarel. Problematična pa je lahko tudi ekonomska izraba traktorjev, saj izsledki kažejo, da je slovensko povprečje manj kot ena delovna ura na dan. Pri modernizaciji kmetij in izkoriščanju državnih subvencij pa traktor ostaja ena glavnih investicij na kmetiji. Analiza registriranih traktorjev kaže, da se kmetje odločajo za vedno močnejše traktorje, tako je bila v letu 2008 povprečna moč kupljenih traktorjev 61,9 kW. Pri analizi ponudbe traktorjev pa ugotavljamo, da pri odločitvi za določen model traktorja poleg njegovih tehničnih lastnosti (predvsem moči) veliko vpliva tudi njegova cena.

LITERATURA

1. GRGIĆ I., LEVAK V., MATIJA R. (2009). Regionalni aspekti opremljenosti obiteljskih poljoprivrednih gospodarstva poljoprivrednim strojevima. In proceedings of the 37. International Symposium on Agricultural Engineering, Opatija, Croatia, 10.-13. February 2009. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, pp 337 - 345
2. HAJDU J., MAGO L. (2008). Mechanization of the Hungarian agriculture in present days. In proceedings of the 35. International Symposium on Agricultural Engineering, Opatija, Croatia, 11.-15. February 2008. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, pp 567 - 575
3. MAGO L. (2007). Survey of the present mechanization of small and medium size plant production farms. In proceedings of the 35. International Symposium on Agricultural Engineering, Opatija, Croatia, 19.-23. February 2007. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, pp 497 - 506
4. POJE T., JEJČIČ V., CUNDER T. (2006). Tehnično stanje traktorjev na slovenskih kmetijah. Acta agriculturae Slovenica. 87/2 pp 343 - 354
5. POJE T. (2008). Analysis of the offer for sale on the Slovene tractor market. V zborniku posveta Novi izzivi v poljedelstvu 2008, Rogaška Slatina, 4. in 5. december 2008. Ljubljana: Slovensko agronomsko društvo, pp 401-406
6. SCHROTTMAIER J., HANDLER F. (2001). Rahmenbedingungen und Situation der Landtechnik in Österreich. 1. Tagung Landtechnik in den Ackerbaugebieten in Ungarn, Slowakei und Österreich, 26. - 27. April 2001 Eisenstadt, Österreich: pp 13 – 27

STATE OF TRACTOR POOL IN SLOVENIA

ABSTRACT

The Agricultural Census of Slovenia from 2000 contains a few more than 108000 tractors. At the end of 2008 the number of registered tractors was 84316. At the purchase of new tractors in the recent years a characteristic increasing trend in the categories between 60 and 80 kW and above 80 kW engine power was observed. The two categories between 20 and 40 and between 40 and 60 kW engine power have witnessed the falling tendency. An analysis of offer for sale of standard tractors in Slovenia was carried out. The majority of different models are to be found in the category from 60 to 80 kW engine power followed by the two categories from 40 to 60 and from 80 to 100 kW. As far as the engine power is concerned we studied the specific mass of tractor with the wide range up to 100 kW regarding the tractor model. Specific price with regard to kW of power was determined according to manufacturers.

***Key words**: number of tractors, power of tractor, new registered tractors, offer of tractors, Slovenia*

38.
SIMPOZIJ
AKTUALNI
ZADACI
MEHANIZACIJE
POLJOPRIVREDE

UDC
631.
Pre rad
Re paper

THE INFLUENCE OF DIFFERENT TRACTION SYSTEMS ON TRACTORS PERFORMANCE IN SOIL TILLAGE

ZORAN MILEUSNIC, MILAN DJEVIC, RAJKO MIODRAGOVIC, MARIJA BOZIC

Faculty of Agriculture, Belgrade

ABSTRACT

This paper presents results of testing two different traction systems and analysis of their influence on tractor's efficiency in soil tillage. Results of the field testing concerning energy requirements and technical-economical characteristics in two different tillage systems it can be concluded that tractor with rubber belts was significantly efficient in comparison to tractor with dual tires. The tractor with rubber belts achieved 27.05 % higher rate of work and 11.67% higher energy efficiency. The fuel consumption of the tractor with the rubber belts traction system was 15.17% lower compared to the tractor with tractor with dual tires.

Key words: *tractor traction system, tillage, energy efficiency.*

INTRODUCTION

It is very well known that the selection of tractor traction system is very significantly related with the production conditions and agro-technical requirements. The common production practice of achieving “maximum yields”, besides all of various factors, imposes very intensive soil exploitation, proper tillage system applied and the maximal energy efficiency.

In this paper testing results of the tractors with two traction systems in tillage are presented. In order to provide maximum yields an up-to-date technology level is required, so, according to Hillel, D. (1982), Koolen, A.J., Kuipers, H. (1983), and Ronai, Đ. (1986):

- primary tillage by plough should be done to minimize compaction by either "plough pan" or tractor wheels,
- secondary tillage could be done with the various implements,

- final soil compaction is unavoidable as a consequence of plough pan as well as "wheel pan".

The choice of tractor type and its category depends on agro-technical requirements, possible combination with various implements, scope and deadline of tillage operations and particular soil conditions Mileusnić, Z. *et. al*., (2009), Obradović, D. (1990). To provide proper tillage quality, various operations demand adequate velocity. There is difference between motion velocity in the working regime of η_t and technology velocity equal to optimum work quality. The technology velocity should run within the exploitation range of velocity at $\eta_{t\ max}$. In the opposite case the tractor is inadequate and must be replaced. Deviation from this rule is acceptable in case of relatively small working scope when it is more rational to use the existing tractor with lower η_t and lower rate of work than to buy a new one Chancellor, W., Zhang, N. (1989), Nikolić R *et. al* (2007), Novaković, D. (1992) and (1993), and [10].

The aim of this paper is to compare different traction systems and define its influence on tractors performance in soil tillage.

MATERIAL AND METHOD

Testing material were two tractors with different traction system, used in tillage as follows :

- two types of traction systems (Tab. 1)
- two types of surfaces with the applied tillage model (Tab. 2): stubble and ploughed.

Table 1 Technical characteristics of the tested tractors

Technical characteristics	C	T
1. Tractor concept	Track laying	Articulated wheel
2. Engine power (kW)	201	198
3. Specific engine fuel consumption (g/kWh)	261	228
4. Gear No.	10+2	16+2
- min/max (km/h)	4.2/29.3	2.6/32.2
5. Drive	Rubber belts	Dual pneumatics
- front	-	18.4/15-38
- rear	-	18.4/15-38
- width/length (mm)	622/2718	-
6. Mass (kg)	15500	11700
7. Energy supply (kW/t)	12.97	16.92

Table 2 Tillage operations, implements, working velocity and specific soil resistance

Operation	Implement	Velocity (km/h)	Specific resistance
1. Stubble shallow ploughing - 12 cm	Plough	10	10 (N/cm^2)
2. Ploughing – 40 cm	Plough	5	10 (N/cm^2)
3. Tillage with disc harrow	Disc harrow ϕ 810 mm	9	11 (kN/m)
4. Disc harrowing	Disc harrow ϕ 610 mm	9	5 (kN/m)
5. Seed-bed preparation	seed-bed cultivator	10	4.5 (kN/m)

Comparison of traction systems according to fuel and energy consumption was based on the parameters calculated with equation 1 to 7 as follows:

a) Working width of the implements:

- ploughs:

$$b = \frac{F_v}{k_{or} \cdot a} \tag{1}$$

- disc harrows and seed-bed cultivators:

$$b = \frac{F_v}{k_s} \tag{2}$$

b) Rate of work:

$$W = 0.1 \cdot b \cdot v \tag{3}$$

c) Working hours per hectare:

$$1/W \tag{4}$$

d) Fuel consumption per hectare:

$$Q_{ha} = \frac{Q}{W} \tag{5}$$

e) Technological energy consumption:

$$E_{ha} = \frac{F_v \cdot v}{W} \tag{6}$$

f) Energy generated from one liter of tractor fuel consumed:

$$Eq = \frac{Pv}{Q} \tag{7}$$

List of symbols

T - four wheel tractor

C - tractor with rubber belts

η_t - tractor efficiency coefficient

b (cm) - plough working width

a (cm) - plough working depth

F_V (N) - drawbar force

W (ha/h) - Rate of work

P_V (W) - drawbar power)

v (km/h) - velocity

Q_{ha} (1/ha) - fuel consumption per hectare

Q_h (1/h) - fuel consumption per hour

E_{ha} (kWh/ha) - technological energy consumption

E_Q (kWh/l) - energy generated from 1 l of fuel

δ (%) - slip

q (g/kWh) - specific tractor fuel consumption

φ (-) - adhesion coefficient

k (N/cm^2) - specific ploughing resistance

l/W (h/ha) - working hours per hectare

RESULTS AND DISCUSSION

Characteristics of the rubber belts in stubble are shown in Table 3. and in plough-field in Table 4.

Table 3 Performance of tractor with rubber belts at stubble ploughing

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q_h (l/h)	q (g/kWh)	φ (-)	η_t (-)
133.32	129.72	3.70	12.51	63.36	394	0.812	0.663
152.42	96.06	5.71	5.03	63.25	344	0.631	0.758
155.43	83.64	6.69	3.75	63.37	338	0.550	0.773
153.20	70.26	7.85	2.91	63.38	342	0.462	0.762
150.89	61.36	8.85	2.50	63.34	348	0.404	0.751
147.45	51.44	10.32	2.01	63.31	356	0.338	0.733
142.49	42.43	12.09	1.50	63.25	368	0.279	0.709

Tractor with rubber belts in stubble provided maximum tractor efficiency coefficient of 0.773 at: Pv=155.43 kW, Fv=83.64 kN, v=6.69 km/h, δ=3.75%, Q=63.37 l/h, q=338 g/kWh and φ=0.550

Table 4 Performance of tractor with rubber belts at harrowing ploughed soil

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
82.81	87.68	3.40	18.84	63.23	633	0.590	0.412
104.22	69.77	5.37	8.78	63.23	503	0.459	0.518
108.54	60.80	6.43	6.00	63.24	483	0.400	0.540
106.93	51.07	7.54	4.52	63.20	490	0.336	0.532
105.52	44.69	8.50	3.08	63.26	497	0.294	0.525
102.91	37.39	9.91	2.44	63.18	509	0.246	0.512
99.49	30.86	11.61	1.82	63.24	527	0.203	0.495

Tractor with rubber belts in plough-field provided maximum tractor efficiency coefficient of 0.540 at: Pv=108.54 kW, Fv=60.80 kN, v=6.43 km/h, δ=6.00%, Q=63.24 l/h, q=483 g/kWh and φ=0.400

Performance characteristics of wheeled tractor in stubble are shown in Table 5 and in plough-field in Table 6

Table 5 Performance of wheeled tractor at stubble ploughing

Parameters at P_{vmax}							
P_V (kW)	F_V (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
67.53	80.50	3.02	24.36	54.50	669	0.700	0.341
97.02	71.42	4.89	18.66	54.42	465	0.621	0.490
119.99	61.52	7.02	14.03	54.42	376	0.533	0.606
131.67	51.75	9.16	10.58	54.48	343	0.450	0.665
130.09	42.50	11.02	7.94	54.45	347	0.370	0.657
124.15	32.48	13.76	5.02	54.51	364	0.282	0.627
119.21	26.62	16.12	3.84	54.50	379	0.231	0.602

The wheeled tractor in stubble provided maximum tractor efficiency coefficient of 0.665 at: Pv=131.67 kW, Fv=51.75 kN, v=9.16 km/h, δ=10.58%, Q=54.48 l/h, q=343 g/kWh and φ=0.450.

Table 6 Performance of wheeled tractor at harrowing ploughed soil

Parameters at P_{vmax}							
P_v (kW)	F_v (kN)	v (km/h)	δ (%)	Q (l/h)	q (g/kWh)	φ (-)	η_t (-)
40.99	55.89	2.64	33.00	54.44	1101	0.486	0.207
65.38	48.42	4.86	25.66	54.49	691	0.421	0.330
78.00	42.32	6.63	20.44	54.48	579	0.368	0.394
81.58	37.03	7.93	17.25	54.42	553	0.322	0.412
79.84	31.05	9.25	14.00	54.41	565	0.270	0.403
75.92	25.42	10.75	10.88	54.49	595	0.221	0.383
71.84	21.28	12.15	9.02	54.42	628	0.185	0.363

Wheeled tractor in plough-field provided maximum tractor efficiency coefficient 0.412 at: Pv=81.58 kW, Fv=37.03 kN, v=7.93 km/h, δ=17.25%, Q=54.42 l/h, q=553 g/kWh and φ=0.322.

Technical characteristics (Table 1.) show that tractor with rubber belts provides higher power by 1.51% as well as higher specific engine fuel consumption by 14.51%. Its mass is 32.48% higher and energy supply 23.35% lower compared to the wheeled one.

Comparison of drawbar characteristics at stubble ploughing and ploughed soil disc-harrowing at $\eta_{t\ max}$ shows the following:

- tractor with rubber belts achieved 61.6% higher drawbar force at stubble ploughing and 64.2% in disc-harrowing,
- velocity reduction due to surface type (stubble-plough-field) was lower with rubber belts tractor (3.9%) than with wheeled one (13.4%),
- 64.5% lower slip at stubble and 65.2% in ploughed-field was recorded with rubber belts tractor than with wheeled one,
- surface type caused η_t decrease by 30% with rubber belts tractor and by 38% with the wheeled one,
- tractor with rubber belts achieved 14.51% higher engine specific fuel consumption (q_m), 1.5% lower tractor specific fuel consumption (q_t) at stubble and 12.6% in plough-field,
- total fuel consumption of tractor with rubber belts (Q) is 16% higher,
- rubber belts tractor generated 1.2% more energy per one liter of fuel (E_Q) at stubble and 14% at ploughed-field.

Table 7 Rate of work, fuel and energy consumption of different tractor concepts in tillage

Tractor	F_v (kN)	b (cm)	W (ha/h)	1/W (h/ha)	Q_{ha} (l/ha)	E_{ha} (kWh/ha)	E_Q (kWh/l)
			Stubble shallow ploughing				
C	53	442	4.42	0.226	14.34	33.33	2.32
T	47	392	3.92	0.255	13.90	33.33	2.39
C/T (%)	112.75	112.75	112.75	88.63	103.16	100.00	97.07
			Ploughing				
C	105	263	1.32	0.758	48.01	111.11	2.30
T	71	178	0.89	1.124	61.21	111.11	1.81
C/T (%)	147.89	147.89	148.31	67.44	78.43	100.00	127.07
			Plough-field disc harrowing				
C	42	382	3.44	0.291	18.42	30.55	1.66
T	32	291	2.62	0.382	20.79	30.55	1.47
C/T (%)	131.25	131.25	131.30	76.18	88.60	100.00	112.93
			Disc harrowing				
C	42	840	7.56	0.132	8.38	13.89	1.66
T	32	640	5.76	0.174	9.46	13.89	1.47
C/T (%)	131.25	131.25	131.25	75.86	88.58	100.00	112.93
			Seed-bed preparation				
C	37	822	8.22	0.122	7.71	12.50	1.63
T	28	622	6.22	0.161	8.76	12.50	1.43
C/T (%)	132.14	132.15	137.15	75.78	88.01	100.00	113.99
			Total				
C	-	-	-	1.529	96.86	201.38	9.57
T	-	-	-	2.096	114.12	201.38	8.57
C/T (%)	-	-	-	72.95	84.88	100.00	111.67

Different tractor concept comparison regarding work rate and fuel/energy consumption in soil tillage (Table 7.) in particular working conditions (Table 2.) shows the following:

- consumption of technical energy per surface unit (E_{ha}) is the same for both tractors for all operations due to the same working conditions,
- in the stubble shallow ploughing the tractor with rubber belts provided 12.75% higher rate of work (W), 11.37% lower time consumption per hectare (l/W), 3.16% higher fuel consumption per hectare (Q_{ha}) and 2.93% lower energy exploitation per liter of fuel (E_Q) in comparison to the wheeled tractor,

- in ploughing at the depth of 40 cm the caterpillar tractor provided 48.31% higher rate of work (W), 32.56% lower time consumption per hectare (l/W), 21.57% lower fuel consumption per hectare (Q_{ha}) and 27.07% higher fuel energy exploitation (E_Q) in comparison to the wheeled one,
- in plough-field disc harrowing with heavy disc harrow 810 mm diameter, the rubber belts tractor provided 31.30% higher rate of work (W), 23.82% lower time consumption (l/W) , 11.40% lower fuel consumption per hectare (Q_{ha}) and 12.93% better fuel energy exploitation (EQ) in comparison to the wheeled one,
- in disc harrowing with the disc diameter of 610 mm the rubber belts tractor provided 31.25% higher rate of work (W), 24.14% lower time consumption per hectare (l/W), 11.42% lower fuel consumption per hectare (Q_{ha}) and 12.93% better fuel energy exploitation (E_Q) compared to the wheeled one,
- in seed-bed preparation the rubber belts tractor provided 37.15% higher rate of work (W), 24.22% lower time consumption per hectare (l/W), 11.99% lower fuel consumption per hectare (Q_{ha}) and 13.99% better energy exploitation per fuel liter (E_Q) in comparison to the wheeled one,
- for particular tillage technology the rubber belts tractor provided 27.05% lower time consumption per hectare (l/W), 15.17% lower fuel consumption per hectare (Q_{ha}) and generating 11.67% higher fuel energy (E_Q) than the wheeled one.

CONCLUSIONS

The following conclusions can be drawn from the testing of potential traction characteristics of the same power tractor with rubber belts and wheeled tractor types in tillage:

- rubber belts tractor achieved higher rate of work in all tillage operations, ranging from 112.75% - 148.31% in comparison to the wheeled tractor, thus providing 27.05% faster tillage per hectare,
- total fuel consumption per hectare of the rubber belts tractor in tillage was 15.12% lower in comparison to the wheeled one,
- rubber belts tractor generated 11.67% higher fuel energy per one liter of fuel consumed in tillage by than the wheeled one.
- The results obtained show higher tillage efficiency of the rubber belts tractor type.

REFERENCES

1. Chancellor, W., Zhang, N. (1989): *Automatic Wheel Slip Control for tractors*, Transactions of the ASAE, Vol. 32, No. 1, pp. 17-22, St. Joseph, Michigan, USA
2. Hillel, D. (1982): Introduction to soil physics, Academic press, New York.

3. Koolen, A.J., Kuipers, H. (1983): Agicultural Soil Mechanics, Springler Verlag, Berlin Heilderberg, Germany

4. Mileusnić, Z., Petrović, D., Đević, M. (2009): *Comparison Of Tillage Systems According to Fuel Consumption*, Energy, (doi:10.1016/j. energy.2009.09.12)

5. Nikolić R., Savin L., Furman T., Tomić M., Simikić M., Gligorić R., (2007), *Teorija vuče i koeficijent efikasnosti gumene gusenice*, Poljoprivredna tehnika Godina XXII, No 2, str. 15 – 23, Beograd.

6. Novaković, D. (1992): *Mogućnost uštede energije korišćenjem traktora guseničara*, Zbornik radova, Dan poljoprivredne tehnike, Beograd-Zemun

7. Novaković, D. (1993): *Primena traktora guseničara u primarnoj poljoprivrednoj proizvodnji,* doktorska disertacija. Beograd: Poljoprivredni fakultet Zemun.

8. Obradović, D. (1990) *Optimalni parametri traktorsko-mašinskih agregata za poljoprivredna gazdinstva,* Institut za mehanizaciju poljoprivrede Zemun-Beograd.

9. Ronai, Đ. (1986): *Sabijanje zemljišta kao posledica kretanja točka,* Monografija, Novi Sad.

10. http://www.oecd.org

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.3.027.5
Stručni rad
Expert paper

EVALUATION OF THE SUPER ELLIPSE MODEL FOR THE TYRE-GROUND CONTACT PATCH

RADU ROSCA, IOAN TENU, PETRU CARLESCU, DAN CAZACU, VIRGIL VLAHIDIS

University of Agricultural Sciences Iasi, Romania

SUMMARY

In this paper a study of the tyre-ground interaction is developed, using a previously developed model for wheel traction prediction. The model was modified, taking into account a "super ellipse" shape of the tyre-ground contact area.

In order to validate the theoretical results, field tests were developed, using the U-650 tractor, equipped with the P2V plow. Variation of plow width and depth allowed different traction forces and drive wheel slips to be obtained. During the experiments, drive wheel slip and net traction force were measured directly, for wheel slip up to 30%.

The goodness-of-fit of the model with the experimental data was evaluated, taking into account two cases:

- elliptical shape of the tyre-ground contact patch;

- super elliptical shape of the contact surface.

The conclusion was that the use of the super ellipse equation in order to describe the shape of the contact surface led to a better fit between theoretical and experimental data for almost all the criteria taken into account: lower mean absolute deviation, mean scaled absolute deviation and root mean squared deviation then the ones obtained in the case of the elliptical contact patch. In the meantime, in the case of super ellipse 44.4% of the points predicted by the model lie within the 95% confidence interval of each corresponding experimental data point, compared to only 33.3% when the elliptical shape is considered.

Key words*: tire traction, wheel slip, traction model, shear area*

INTRODUCTION

Accurate prediction of traction performance of a tractor wheel depends largely on the model of the tyre-terrain interaction.

Hambleton and Drescher (2008) classified wheel-soil interaction models into empirical, analytical and numerical models.

Empirical methods are mainly based on soil properties (cone index, plate sinkage, shear strength) using similitude and dimensional analysis. The empirical models were developed using traction data recorded from operating vehicles and, for some of them, cone index, measured with a standard cone penetrometer, was the only soil property taken into account. These methods were originally developed by the U.S. Army Waterways Experiment Station (WES).

Analytical models were formulated using elasticity and plasticity approaches. Elasticity models are based on the classical mechanical contact theory in order to predict deformations and stresses (using, for example, the Boussinesq's approach), while plasticity based models take into account material (soil) failure theories.

While analytical models presume a certain geometry of the contact patch between tyre and ground - section of a circle for the Bekker approach, parabola etc. – the real geometry of the contact area results from mutual deformation of tyre and ground, which can be better described by the finite element method or FEM (Schmid, 1994). The first attempt to use FEM was made by Perumbral et al. (1971), assuming a circular (axisymmetric) contact area.

Although FEM methods give better predictions regarding tyre-ground interaction, the precision of the model is conditioned by the accurate knowledge of many soil characteristics; calibration of the model, with the help of experimental tests, is also required. The mathematical calculations demand the most resources in measuring the soil parameters.

Many traction models assume that the tyre - soil contact patch is symmetrical; Grecenko (1995) suggested that it has an elliptical shape and its area could be obtained by multiplying the product of the length and width of the contact area by a coefficient with values between 0.8 and 0.9. Hallonborg (1996) used a super ellipse model for the tyre-ground contact area; the value of the positive exponent in the equation defined the shape of the contact patch.

McKyes (1985) developed a simple formula in order to compute the area of the contact patch, using the diameter and width of the tyre.

Schjønning P. Lamande M et al. (2008) also took into account the super ellipse to describe the symmetrical shape of the contact patch, with values of the exponent comprised between 2.45 and 4.51, depending upon tyre inflation pressure and model.

Saarilahti (2002) made a comparison of the footprint area given by different models and concluded that, for the same tyre, the contact patch area given by different models had values comprised between 0.05 m^2 and 0.25 m^2.

Schmulevitch and Osetinsky (2003) developed a model for wheel soil interaction, assuming that tyre-ground contact surface can be represented in a parabolic form in the longitudinal direction, but, excepting the Pearson correlation coefficient, no other goodness-of-fit parameter was taken into account in order to evaluate the developed model.

Keller (2005) also considered the contact patch as a super ellipse and made measurements of the vertical stress below tyres using compression cells. He developed an equation relating the shape exponent of the super ellipse to some tyre characteristics and remarked a good agreement with the model taken into account (Diserens, 2002).

The aim of this paper is to evaluate the tyre-ground contact patch, in terms of goodness-of-fit with the experimental results, taking into account both the ellipse and the super ellipse equations.

METHODS

The traction model is the one described in a previous paper (Rosca et al., 2008) and is based on the schematics shown in Figure 1.

The tyre-ground contact patch is assumed to be symmetrical and the following cases were taken into account:

- the shape of the contact patch is described by the equation of an ellipse:

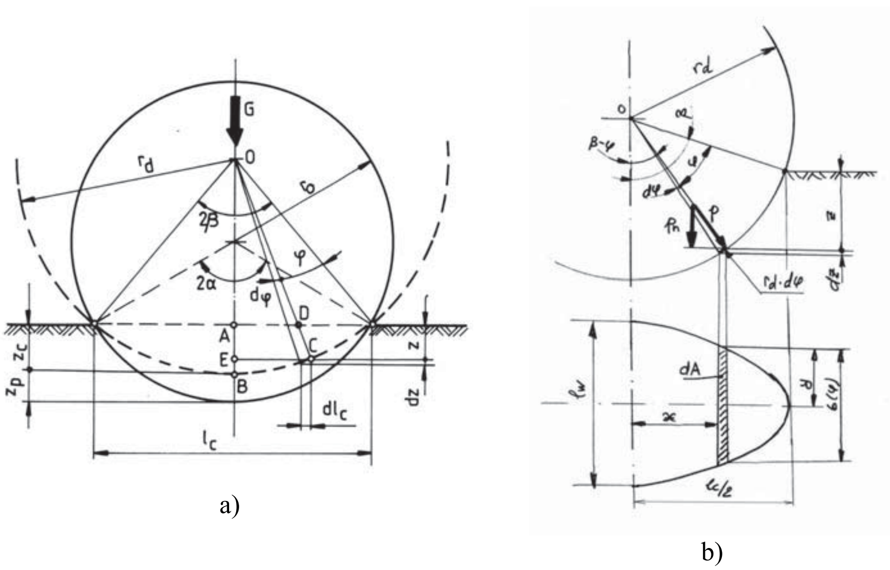


Fig. 1 Schematics of the model.

$$\left(\frac{x}{a}\right) + \left(\frac{y}{b}\right) = 1$$

- the equation of the contact patch is a super ellipse:

$$\left(\frac{x}{a}\right)^n + \left(\frac{y}{b}\right)^n = 1$$

where a and b are the semi major and semi minor axis respectively.

The value of the positive exponent n in the equation, defining the shape of the contact patch, was calculated with the relationship given by Keller (2005), for the same type of tyre as the one used in our experiments:

$$n = 2.1 \cdot (b \cdot d)^2 + 2,$$

where b is the tyre width and d is the outer diameter.

The traction force and traction equation, as given by the ASAE S296 standard, were considered in order to compare the theoretical and the experimental results.

In order to evaluate the goodness-of-fit between model and experimental data the following criteria were considered (Schunn&Wallach, 2005):

- percentage of points within 95% confidence interval of data (Pw95CI) – represents the percentage of model predictions that lie within the 95% confidence interval of each corresponding experimental data point;
- mean absolute deviation (MAD) – represents the mean of the absolute value of the deviation between each model prediction and its corresponding data point: $MAD = \frac{\sum_{i=1}^{n} |m_i - d_i|}{n}$,
  where m_i is the model mean for point i, d_i is the data mean for each point i and n is the number of points being compared;
- root mean squared deviation (RMSD):
  $$RMSD = \sqrt{\frac{\sum_{i=1}^{n} (m_i - d_i)^2}{n}},$$
- mean scaled absolute deviation (MSAD):
  $$MSAD = \sum_{i=1}^{n} \frac{|m_i - d_i| \cdot \sqrt{m_i}}{n \cdot s_i},$$
  where m_i is the number of values contributing to each experimental data mean d_i (in our case m_i = 9) and s_i is the standard deviation for each data mean. A MSAD value of 1.5 means that, on average, the model is 1.5 standard errors off from the experimental data.
- Pearson correlation coefficient r and r^2.

For this work the U-650 tractor was modeled. The main characteristics of the tractor and drive tire are shown in Table 1.

During the experiments, drive wheel slip and net traction force were measured directly. 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 on the test field are shown in Table 2.

In order to validate the relationship for the exponent in the super ellipse equation, in a previous set of experiments the tyre contact area was recorded using a specially developed test rig. The major and minor axes of the contact patch were then measured and the corresponding values of the exponent were calculated.

Table 1 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

RESULTS AND DISCUSSION

Using the previously mentioned technique, the average value of exponent in the super ellipse equation was found to be 2.709±0.25. The result given by the relationship presented by Keller was 2.706, so it was concluded that this equation accurately predicts the value of the super ellipse exponent.

The results of the goodness-of-fit analysis, in terms of traction force, are presented in Table 3 and Figures 2 and 3 (in which the error bars for the experimental data are also displayed).

Table 2 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, γ [^{0}]		32
Soil type		Sandy loam soil
Average bulk density [kg/m^3]		1280±102.4
Average humidity [%]		9.5±0.9
Average cone penetrometer index, CI [kPa]		970

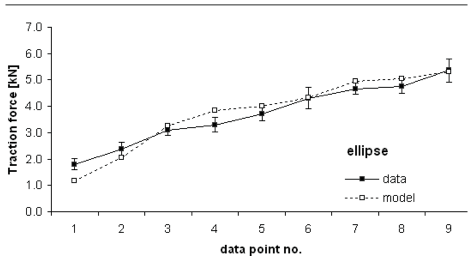


Fig. 2 Traction force for the ellipse type contact patch

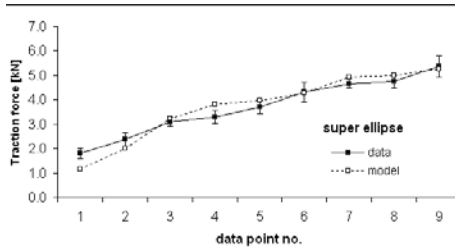


Fig. 3 Traction force for the super ellipse type contact patch

The results presented in table 3 show a better goodness-of-fit of the super ellipse type contact patch for almost all the criteria taken into account: lower mean absolute deviation, mean scaled absolute deviation and root mean squared deviation then the ones obtained in the case of the elliptical contact patch. In the meantime, in the case of super ellipse 44.4% of the points predicted by the model lie within the 95% confidence interval of each corresponding experimental data point, compared to only 33.3% when the elliptical shape is considered.

Table 3 Comparison of the goodness-of-fit criteria (traction force)

Item	Ellipse	Super ellipse
MAD	0.287	0.2797
MSAD	2.745	2.623
Pw95CI	33.3	44.4
RMSD	0.3462	0.3386
r^2	0.953	0.953

Figures 4 and 5 display the tyre-ground contact pressure for the both the ellipse and super ellipse; lower values were obtained when the super ellipse equation was taken into account in order to describe the shape of the contact surface. As a result, lower values of the average vertical pressure were predicted by the super ellipse model, as shown in Table 4.

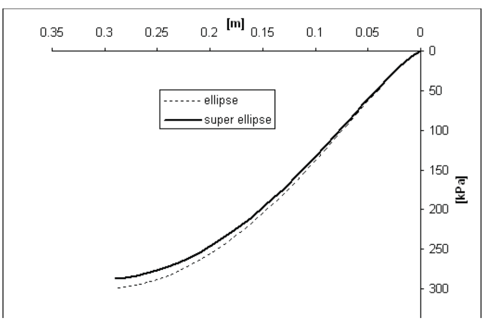


Fig. 4 Lugs pressure

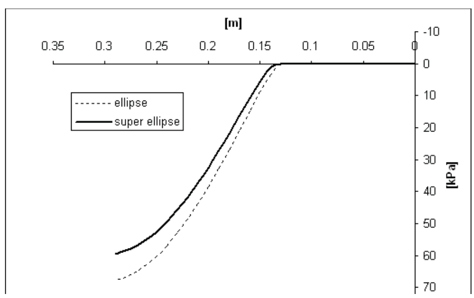


Fig. 5 Undertread pressure

Table 4 Average contact pressures

Item	Ellipse	Super ellipse
Lugs-ground average contact pressure	179.6 kPa	173.8 kPa
Undertread-ground contact pressure	84.0 kPa	76.3 kPa

CONCLUSIONS

- A previously developed traction model and experimental data were used in order to calculate the traction force.
- A comparative analysis was developed in order to compare the two models for the tyre-ground contact patch taken into account (ellipse and super ellipse).
- The positive exponent of the super ellipse equation given by the relationship developed by Keller was found to be consistent with the experimental results.
- The super ellipse shape of the tyre-ground contact surface was found to provide a better goodness-of –fit with the experimental results.
- The super ellipse model predicted lower vertical pressures, for both the lugs surface and the undertread surface.

REFERENCES

1. Diserens E. (2002). Determination of tyre contact area in the field using a mathematical model (in german). FAT – Berichte nr. 582, Swiss Federal Research Station for Agriculture Economics and Engineering. Tanikok, Switzerland (cited by T. Keller).
2. Grecenko A. (1995). Tyre foot print area on hard ground computed from catalog value. Journal of Terramechanics, 32: 325-333.
3. Hallonborg U. (1996). Super ellipse as a tyre-ground contact area. Journal of Terramechanics, 33: 125-132.
4. Hambleton J., Drescher A. (2008). Development of improved test rolling methods for roadway embankment construction. Research 2008-08, University of Minnesota, Minnesota Department of Transportation Research Services Section (available at http://www.lrrb.org/PDF/200808.pdf).
5. Keller T. (2005). A model for prediction of the contact area and the distribution of vertical stress below agricultural tyres from readily available tyre parameters. Biosystems Engineering, 92 (1): 85-96.
6. McKyes E. (1985). Soil cutting and tillage, vol. 7. Developments in agricultural science, Elsevier, Amsterdam, p. 217.
7. Perumbral J. V., Liljdehal J. B., Perloff W. H. (1971). A numerical method for predicting the stress distribution and soil deformation under a tractor wheel. Journal of Terramechanics, 8 (1): 9-22.

8. Roşca R., Tenu I., Cârlescu P., Rakosi E., Manolache Gh. (2008). Tyre traction models-comparative analysis and validation. 36th International Symposium Actual Tasks on Agricultural Engineering, Opatija Croatia, 11-15 feb. 2008, pp. 93-104.

9. Saarilahti M. (2002). Soil interaction model. Quality of life and management of living resources contract QLK5-1999-00991 (available at http://ethesis.helsinki.fi/julkaisut/maa/mvaro/publications/31/soilinte.html).

10. Schjønning P., Lamande M. et al. (2008). Modelling effects of tyre inflation pressure on the stress distribution near the soil interface. Biosystems Engineering, 99: 11-133.

11. Schmid I. C. (1994). Interaction of vehicle and terrain – results from 10 years research at IKK. 6th European ISTVS Conference, Wien.

12. Schmulevich I., Osetinsky A. (2003). Traction performance of a pushed/pulled drive wheel. Journal of Terramechanics, 40: 33-50.

13. 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, pp. 115-154.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.372
Prethodno priopćenje
Preliminary communication

THE INFLUENCE OF DIFFERENT STEERING SYSTEM ON WHEEL SLIP AT SIMULATION OF MOWING ON A STEEP SLOPE

D. STAJNKO, M. LAKOTA, B. MURŠEC, P. VINDIŠ, J. RAKUN

Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede, Katedra za Biosistemsko inženirstvo, Vrbanska 30, 2000 Maribor, Slovenija
University of Maribor, Faculty of Agriculture and Life Sciences, Vrbanska 30, 2000 Maribor, Slovenija, e-mail *denis.stajnko@uni-mb.si*

ABSTRACT

Modern and advanced mountain tractor allows four different modes of steering wheels (front wheels, back wheels, four wheels and crab steering). The purpose of a field experiment was to examine the impact of different ways of steering to control the slip in the work transverse on the slope (39.08%). We studied three different methods of control, in which we found that the smallest slip was measured, when steering with so called crab – steering was used. The slip was 5.96 % at average speed of 1.08 m/s. When steering with all four wheels the slip at average speed of 1.03 m/s was 7.27 %, and the biggest slip was measured when steering with only front wheels was applied. In this case the slip was 8.07 % at the average speed of 1.01 m/s. The most important conclusion indicated that it is very useful to have all wheels steering when working on step slope, because it is grass friendly, offers bigger agility of tractor and improve the safety of the operator.

Key words: *mountain tractor, slip, work on steep slope, steering*

INTRODUCTION

Stability problems arise with all types of machinery which travel on sloping land. Overturning accidents cost time and money as well as causing injury and sometimes death (Hunter, 1993).

The majority of agricultural tractor overturning accidents on slopes are of two types. The first, known as a stability loss accident, is when the tractor overturns directly, and the second, known as a control loss accident, is when the tractor runs away out of control before overturning (Hunter & Owen, 1983).

Mountain tractor is especially designed tractor to work on sloping ground where there is no longer possible to secure the use of a standard tractor. It is distinguished by a very low clearance and very low height of centre of gravity. Wheel distance is large, which means additional stability in the work on the steep slope. Tractors drive on all four wheels with the same size. The development of those tractors began after the Second World War, however the first commercial vehicle was the AEBI's Terratrac TT77 from 1976 (http://www.aebi.com/).

In vehicle dynamics, slip is the relative motion between a tire and the road surface on which the wheel is moving on. This slip can be generated either by the tire's rotational speed being greater or less than the free-rolling speed (usually described as percent slip), or by the tire's plane of rotation being at an angle to its direction of motion, referred to as slip angle (Macmillan, 2002).

Marenče & Košir (2007) measured in a field experiment with a mechanic and hydrostatic version of the AGT 835 T tractor a slip during empty travelling uphill and downhill. In empty travelling uphill, the slip in mechanic transmission reaches up to 10%, while about 2 % lower slip was measured in the hydrostatic tractor. In travelling downhill, the force of gravity predominates, thus negative slip (-6%) was measured. Owing to sliding caused by gravity, the distance travelled by a tractor wheel was shorter than the distance actually travelled by the tractor along the trail.

Since there are no precise investigations about the slip during the transverse travelling on the steep slopes with mountain tractors, our research was focused on the affect of different steering methods on the slip during the work on a meadow. Three various control methods and their impact on the slip during the work on the slope is presented in the following chapters.

METHODS

In the field experiment front wheel steering, four wheels steering and crab-steering were testing during travelling transverse on the slope. For each mode eight measurements were made i.e. four measurements at a forecasted speed of 0.69 m/s and four measurements at a speed of 1.39 m/s. During the two of four measurements the travelling direction was from the left to the right, and vice versa.

A mountain tractor REFORM METRAC 2003 with a 22.4 kW engine and a mass of 950 kg was applied in the experiment. The maximum allowed total weight of the tractor-coupled connections on the front and back was 1450 kg; wheelbase 1580 mm, width of the mid-to mid tires 1590 mm and width of the outer edge of the left tire to the outer edge of the right tire 1910 mm. During the measurements, the mower REFORM with a working width of 194 cm was coupled on the front three-point connecting.

The measuring site is located on a pasture "Above the road." with the average altitude: 343,945m and average slope 21,345 m of (39,079 %).

Figure 1 Design of the experimental field (left) and the test tractor (right)

The polygon (Figure 1) has been divided into four zones, each of which had a width of 4 m and a length of 40 m. Polygon has been pre-cleaned cut and mown grass. We fixed the sticks into the ground at each end and the middle path dug by hammer, or otherwise we just lay them on the site measured at intervals of five meters. At the end of each band there was a place for maneuvering, in which the slip measurements did not perform. The yellow arrows indicate the travelling direction to the right, and the red arrows indicate the travelling direction to the left.

Path and slip measurements

Before calculating the slip we had to measure the real length of travelling with so called fifth wheel and compare it with length travelled by each tractor wheel. Inductive cycling counters (Figure 2) were installed to measure the driven distance of each wheel separately, whereby the original 1 magnetic rim was replaced with 8 rims. On that way, we improve the original accuracy of measurements from 1.00 m on 0.25 m.

Figure 2 Cycling counter fixed on the dashboard (left), installation of sensor and magnet on the wheel (right)

RESULTS

Slip at crab-steering

As seen from Table 1, at a speed of 0.68 m /s the largest slip was measured on the front right wheel (6.26%), followed by the left front wheel (5.94%). Contrary, the smallest slip was measured on right rear wheel, namely 3.75%. With the increasing travelling speed, the average slip increased from 5.00 % to 8.12 %, due to the increase in slip on all wheels, At a speed of 1.46 m/s the maximum slip (10.94%), was on the front left wheel and the smallest on the front right wheel of (5.31%.)

Table 1 The slip of each wheel at crab-steering travelling mode

Steering	Speed [m/s]	Slip Front left [%]	Slip Front Right [%]	Slip Rear Left [%]	Slip Rear Right [%]	Slip Average [%]	Slip [m]
Crab-steering 1	0.68	5.94	6.26	4.06	3.75	5.00	2.00
Crab-steering 2	1.47	10.94	10.63	5.31	5.63	8.12	3.25

Four wheel steering

It is known that during a four wheels steering the minimum turning radius is required and therefore the tractor is most versatile. However, as seen from Table 2, the slip is higher than in the crab-steering for 1.64 % at a speed of 0.64 m/s and for 0.94 % at a speed of 1.42 m/s respectively.

The highest slip at a speed of 0.68 m/s was measured on the front wheels like in the crab-steering mode; on the front left wheel (8.75%) and on the left front wheel (8.13%). Contrary, the smallest slip was measured on left rear wheel, namely 4.69%. With the increase in the travelling speed to 1.42 m/s, the average slip increased from 6.64 % to 9.06 %, due to the increase in slip on all wheels. So the maximum slip (12.81%) was on the both front wheels and the smallest on the left rear (5.00 %).

Table 2 The slip of each wheel at four wheel steering mode

Steering	Speed [m/s]	Slip Front left [%]	Slip Front Right [%]	Slip Rear Left [%]	Slip Rear Right [%]	Slip Average [%]	Slip [m]
Front wheel steering 1	0.64	8.75	8.13	4.69	5.00	6.64	2.66
Front wheel steering 2	1.42	12.81	12.81	5.00	5.63	9.06	3.63

Front wheel steering

Front wheel steering is commonly applied on all agricultural tractors; however it is not convenient for travelling on the steep slopes. In our experiment with steering of the front wheels the rear wheels were aligned and fixed.

All the bad characteristics of such steering can be seen in Table 3, because the slip increased on all four wheels in comparison to four wheel steering. On the average the total slip was higher for additional 1.80% at a speed of 0.63 m/s and for 1.07 % at a speed of 1.38 m/s, respectively. Again the highest slip at a speed of 0.68 m/s was measured on the front axe; left wheel (15.94%) and right wheel (14.38%). Opposite to the four wheel travelling, the slip on the both rear wheels decreased on 4.06 % (left) and 6.25 % (right).

Table 3 The slip at front wheel travelling mode

Steering	Speed [m/s]	Slip Front left [%]	Slip Front Right [%]	Slip Rear Left [%]	Slip Rear Right [%]	Slip Average [%]	Slip [m]
Front wheel steering 1	0.63	11.56	11.25	5.31	5.63	8.44	3.38
Front wheel steering 2	1.38	15.94	14.38	4.06	6.25	10.15	4.06

SUGGESTIONS FOR MOUNTAIN FARMERS

In our field experiment with the mountain tractor REFORM METRAC 2003 three different steering modes was research on the meadow with an average transverse slope of 39.08 %. The smallest slip of all modes 5.00 % was measured during the crab-steering at the speed of 0.68 m/s. On average it was 1.64 % less than during the steering of the front wheels and 3.44 % less than during the front steering mode.

Although the crab steering indicated the smallest slip, our control tractor was not equipped with the automatic system for travelling in this specific mode. Therefore the operator consumed too much time for switching the rear wheels on, because the tractor had to stop each time. Another option represents tractors, in which sensors monitor wheel position. In this case, tractor driver only presses a button on computer command to switch between different modes of controlling the wheel position without stopping. These solutions are really user-friendly; however Slovenian farmers can not afford it, because the prices are enormous high.

From those reason the control of all four wheels use to be optimal solution for operating in the slope during mowing, hay processing and collecting. However, in this driving mode the average slip at a speed of 0.64 m/s was 6.64 %, which is higher than in crab steering and less than during steering of only the front wheels. The control of all four wheels is the most applied travelling on the Slovenian steep meadows, as there is no switching between different modes of control. For example, when the front wheels are turn left, we turn the rear wheels to the right. This results in extremely small turning circle, high productivity at work and low physical and mental load of a tractor driver. Again, that control requires additional cost of mountain tractors in comparison with a common agricultural tractor.

Steering front wheel had at a speed of 0.63 m/s an average slip of 8.44 %. This means that the wheels travelled at a 40 m experimental field 3.38 m distance longer, because of the slip. This does not sound a lot, however a slip is sufficient enough for the destruction of green cover, especially, if we know that the grass has to be turned, gathered and got down to the valley. This control mode was especially suitable for working with back connected to the three-point connecting in the past. However, the connectors at the front three-point system is not suitable for travelling transverse on the slope, because the whole rigid weight of the mower increases the slip-up of the front wheels.

ACKNOWLEDGMENT

The authors are gratefully acknowledged to the family Golob, the owners of the farm for friendly hospitably and patience during all the experiment period on their meadow. The authors also acknowledge the vital contributions made by Andrej Golob, B.S. student at the Faculty of Agriculture and Life Sciences in Maribor.

REFERENCES

1. Hunter, A.G.M., 1993. A review of research into machine stability on slopes, Safety Science, Volume 16, Issues 3-4, July 1993, p. 325-339.
2. Hunter, A.G.M., Owen, G.M., 1983. Tractor overturning accidents on slopes Journal of Occupational Accidents, Volume 5, Issue 3, November 1983, p. 195-210.
3. Macmillan, R.H. 2002. The Mechanics of Tractor – Implement Performance. A textbook for students and engineers, Int. Development Technologies Centre, Univ. of Melbourne. p. 165.
4. Marenče, J., Košir, J., 2007. Wheelslip in skidding with the AGT 835 T adapted farm tractor. Zbornik gozdarstva in lesarstva 82, p. 25–31
5. http://www.aebi.com/en/group-aebi/group-aebi/history/aebi-co-ag/ (11. marec 2009)

SAŽETAK

Utjecaj različitih načina upravljanja planinskog traktora na klizanje kotača prilikom vožnje na strmim terenima

Moderan i napredan planinski traktor omogućava četiri različita načina upravljanja (prednji kotači, stražnji kotači, sva četiri kotača i rakova vožnja). Svrha poljskog eksperimenta bila je ispitati utjecaj različitih načina upravljanja na kontrolu klizanja kotača prilikom vožnje na poprečnom nagibu (i= 39.08%). U tri različita načina upravljanja, najmanji klizanje (δ= 5,96%) izmjereno je upravljanjem rakovom vožnjom, a pri prosječnoj brzini v=1,08 m/s. Kada se upravljalo sa sva četiri kotača klizanje je kod prosječne brzine v= 1,03 m/s iznosilo δ= 7,27%, a najveće klizanje (δ= 8,07%) izmjeren je kod upravljanja na samo prednje kotače i prosječne brzine v= 1,01 m/s. Najvažniji zaključak je da je vrlo korisno imati upravljanje na sva četiri kotača prilikom rada na nagibu, jer se ne uništava travni pokrov, nudi veća okretnost traktora i poboljšava sigurnost traktorista.

Ključne riječi: *planinski traktor, klizanje, rad na nagibu, upravljanje traktorom*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.153.46:631.372
Prethodno priopćenje
Preliminary communication

DETERMINATION OF THE MINIMUM SURFACE OF AN AGRICULTURAL FARM FROM WHICH A CERTAIN POWER RANGE OF TRACTORS BECOME PROFITABLE

MOISE V., BIRIŞ S. ST., GRECU B., UNGUREANU N., DAVID L., PARASCHIV G.

"Politehnica" University of Bucharest, Romania

SUMMARY

To establish a machinery system and the optimal mechanization technologies for different types of agricultural farm and for various specific conditions it is necessary to use scientific methods of optimization. The success of a business, including agriculture, is determined by the amount of profit, which depends on the quality and quantity of the realized product. To determine the minimum surfaces from which a certain power range of tractors becomes profitable, the income limit must be equal to the costs required to perform works in that area. In this paper is determined the optimal surfaces matrix for 20-65 HP tractors, used in family farms. For the determination of the minimum surfaces, realized incomes and necessary costs for the considered works must be taken into account. The optimal usage time of the tractors, the matrixes of aggregates yields, as well as the matrix of equipment costs are also determined. Various methods of numerical optimization are used. After running numerical calculus and optimization programs, has been observed that, in case of family farms, the minimum surfaces from which a certain power range of tractors becomes profitable decreases if the work is performed by the farmer, with personal equipments. It has also been observed that the minimum surface required for the profit to be equal to zero at the limit, decreases with higher quality of the equipments.

Key words: *agricultural farm, optimization, minimum surfaces, tractors, working time.*

INTRODUCTION

Optimization methods have become indispensable in making a correct decision on the solution to be adopted in making a product. If by the appearance of an elevated mathematical device, decisions could be arbitrary or empirical, with the emergence of optimization methods decision became objective and scientifically proved. Thus, optimization methods offer the selection process of the optimal solution from the multitude of admissible solutions, a solution that meets the requirements and leads to the best result [3, 4, 7, 9, 15, 16].

In this paper, starting from a study on the costs made to perform one or more agricultural works, on a particular agricultural surface, is determined the surface from which the tractors in a certain power range become profitable. Thus, all costs involved in performing the work, as well as the annual income obtained, are taken into account.

METHODS AND MATERIALS

Determination of the minimum surface from which the tractors in a certain power range become profitable can be done in two situations, namely: if the agricultural operator is the farmer or if the agricultural operator is employed.

Determination of annual profit

Scope function that determines the annual efficiency of an entity considered is:

$$Z(X_1, X_2, \ldots, X_N) = V(X_1, X_2, \ldots, X_N) - C(X_1, X_2, \ldots, X_N) \tag{1}$$

where: Z is the annual profit obtained [€ / year]; V - annual incomes obtained [€ / year]; C - annual costs [€ / year]; Z, V and C are functions of several variables $X_i, i = \overline{1, n}$.

The variables of this problem can be:

$X_1 = x$ is the level of aggregate quality, $x \in [0,1]$. This variable is dimensionless. It is considered that the quality level of the machines that form the aggregate is the same as the tractors, as producers adjust the parameters of the aggregate machine to those of the tractors;

$X_2 = y$ - quantity, namely the number of farm land hectares [ha];

$X_3 = u$ - tractor power [kW (HP)];

$X_4 = w$ - working capacity of the aggregates [ha/h];

$X_5 = C_a$ - initial cost of the entity considered (aggregate, tractor, machine etc.) [€]; $X_6 = T_o$ - optimal time to use the entity considered [years]; $X_7 = \varphi$ - maintenance and repair cost coefficient (dimensionless) of the entity considered, which is defined as the ratio between the maintenance and repair cost of the entity considered for a period of 10 years and its original cost C_a.

$X_8 = N$ - number of farm plots;

$X_9 = D_i$ - distance between plots, [km];

$X_{10} = F_i$ - type of culture;

$X_{11} = Q_i$ - yield per hectare [t/ha];

Annual profit obtained can be determined using the relation:

$$Z = z \cdot y \quad [€ / \text{year}] \tag{2}$$

where z is the specific annual profit per corresponding measurement unit U.M., in [€/ year] U.M., where U.M. can be: pc., t, ha, etc. and y is the number of U.M.

Annual expenses will be:

$$C = C_1 + C_2 + \ldots + C_m = \sum_{k=1}^{m} C_k \tag{3}$$

where C_k, $k = \overline{1, m}$ are the expressions of different types of annual expenses. Annual expenses can be determined by calculating each C_k, $k = \overline{1, m}$ expression as a function of variables and parameters which determine it, namely:

a) Annual expenses with the payments of the entity considered will be [7]:

$$C_1 = \frac{\delta(1+\delta)^T C_a}{(1+\delta)^T - 1} \quad [€ /\text{year}] \tag{4}$$

where: $C_a(u, x)$ - initial cost ot the aggregate, which is a function of quality x and the power u; T - use time of the aggregate, which is a function of x; δ - average annual interest rate.

Function $C_a(u, x)$ is considered as a general function of two variables:

$$C_a(X_1, X_2) = A_0 + A_1x_1 + A_2x_2 + A_3x_1x_2 + A_4x_1^2 + A_5x_2^2 \tag{5}$$

where: coefficients A_0, A_1, A_2, A_3, A_4, A_5 are determined taking into account six known points on the surface $C_a(u, x)$.

b) Average annual costs of maintenance and repair

The total cost of maintenance and repair C_{aTR}, for a period of T years, varies with time. This cost can be determined as follows:

$$C_{aIR} = \int_0^T Y_{IR}(T)dT \tag{6}$$

where $Y_{IR}(T)$ it is the function showing the variation with time of the annual costs of maintenance and repairs and can be approximated by a parabolic function, i.e. those costs grow even more pronounced as the tractor is used for a longer period T. Therefore:

$$Y_{IR}(T) = A \cdot T^2 \tag{7}$$

where A is a coefficient that can be determined from the condition that at T = 10 years, $(C_{aTR}) = \varphi C_a$. In this case, from the relation (6) it results:

$$\varphi C_a = \int_0^{10} A \cdot T^2 \mathrm{d}T = \left.\frac{A \cdot T^3}{3}\right|_0^{10} = \frac{1000A}{3} \tag{8}$$

so that:

$$A = \frac{3\varphi \cdot C_a}{1000} \tag{9}$$

Taking into account relation (9), relation (6) becomes:

$$(C_{IR})_T = \int_0^T \frac{3\varphi \cdot C_a}{1000} T^2 \mathrm{d}T = \frac{\varphi \cdot C_a}{1000} T^3 \tag{10}$$

Between φ, the coefficient defined as the ratio between the maintenance and repair cost of the aggregate for a period of 10 years and *x*, the quality of the entity considered, can be established a corellation if, for the entity having the maximum relative quality $x = 1$, it is known $\varphi = \varphi_{\min}$, and for an entity of the same category, having a smaller quality $x = x_k$, it is known $\varphi = \varphi_k$. Function φ = φ (*x*) decreases with quality *x*, and as a result, it can be aproximated by a polynomial, exponential or geometrical function. If it is considered that the function variation is polynomial of 2nd degree, then:

$$\varphi = B_1 x^2 + B_2 x + B_3 \tag{11}$$

The coefficients can be determined from the conditions:

$$\begin{cases} x = 1 \Rightarrow \varphi = \varphi_{\min}, \dfrac{d\varphi}{dx} = 0 \\ x = x_k \Rightarrow \varphi = \varphi_k \end{cases}$$

c) The expenses on fuels and lubricants:

To determine the fuel and lubricants costs, the following relation is used:

$$C_3 = \frac{k_a}{1000\rho} c_s \cdot C_c \frac{u}{w} \alpha \cdot y \text{ [€ /year]} \tag{12}$$

where: c_s is the engine specific fuel consumption [g/kW hours]; C_c - fuel costs [€ /dm^3]; ρ - fuel density [kg/dm^3]; k_a - amplifier coefficient that requires to take into consideration the cost of lubricants consumption (1,1 - 1,2); *u* - engine power [kW]; $w = w(u, x)$ - aggregate productivity [ha/h], which is a function of the aggregate power *u* and the quality level *x*; *y* - farm surface; α - coefficient of surface use per year $[\frac{1}{year}], \alpha \in [0,2]$, where 2 is the corresponding value of two cultures all over the surface.

Function $w(u, x)$ is represented by a parabolic surface, whose coefficients can be determined if we know the corresponding aggregates yields of 6 points on the surface, namely:

$$w(u_i, x_i) = a_0 + a_1 x_i + a_2 u_i + a_3 x_i u_i + a_4 x_i^2 + a_5 u_i^2, \ i = \overline{1,6} \tag{13}$$

d) Annual travel expenses to work plots are determined using the following the relation:

$$C_4 = 2d_i \frac{\alpha y C_d}{w(u,x)N} \text{ [€ /year} \tag{14}$$

where: d_i [km] are the distances to the working points *i*, $i = \overline{1, m}$, *m* being the total number of plots; *N* - number of worked hours per day [h/day]; C_d -aggregate travel cost per km distance [€/km].

Assuming that the movement to work is made daily, from the farm to the plot, then the distance traveled per day up-and-down will be 2 km/day.

e) Expenses on salaries are calculated if the farm uses employee personal, with the expression:

$$C_5 = \frac{S\alpha y}{w(u,x)} \text{ [€ /year]} \tag{15}$$

where: *S* is the salary per hour [€/h].

Scope function of annual profit brought by the considered aggregate, taking into account the above relations will be:

$$Z = V(X_i) - \frac{\delta(1+\delta)^T C_a(u,x)}{(1+\delta)^T - 1} - \frac{\varphi(x) C_a(u,x) T^2}{1000} - \frac{\alpha k_a c_s C_c u \cdot y}{1000\rho \cdot w(u,x)} - \frac{2\alpha d_i y C_d}{w(u,x) N} - \frac{\alpha S y}{w(u,x)} \tag{16}$$

in which the terms of the above expression have the shown meanings.

Since expression (16) uses the optimal usage time of the aggregate, it is determined using relations (4) and (10), i.e.:

$$f(t) = \frac{\delta(1+\delta)^T C_a}{(1+\delta)^T - 1} + \frac{\varphi C_a T^2}{10^3} \tag{17}$$

and the solving is made using the Fibonacci method or golden section method.

Determination of the tillage productivity for an aggregate of certain power.

To determine the productivity of agricultural aggregates required to fulfill a specific work (plowing, harrowing, sowing, harvesting, etc.) on a given surface, it is necessary to set the time required for the properly work, given the aggregate characteristics, soil physical- mechanical properties, etc.

Productivity is given by relation $w = S / T$ [ha/h], so the time required to perform the work will be determined as follows:

$$T_{arat} = T_{cd} + T_{tr} + T_l + T_i \tag{18}$$

where: T_{cd} - coupling and decoupling time of the aggregate to the tractor [h]; T_{tr} - transport time from the farm to the plot and from the plot to the farm [h]; T_l - effective working time [h]; T_i - time required to achieve the turns at the ends of plots [h].

The expressions for each time category are:

- Coupling-decoupling time:

$$T_{cd} = T_{cp} + T_{dc} \tag{20}$$

where: T_{cp} is the aggregate coupling time, and T_{dc} is the decoupling time;

- Transport time:

$$T_{tr} = \frac{2D}{V_{tr}} \tag{20}$$

where: D - the distance between the farm and the plot [km], and V_{tr} - the transport speed [km/h];

- Effective working time:

$$T_l = N_{parcursuri} \frac{L}{V_{lucru}} = \frac{l}{n \cdot b} \cdot \frac{L}{V_{lucru}} = \frac{10S}{B \cdot V_{lucru}} \tag{21}$$

where: l - plot width [m]; L – plot lenght [m]; S - plot surface [m]; n – number of plough bodies; b – plough-body width [m]; $B = n \cdot b$ - working width [m].

- Return time:

$$T_i = N_{parcursuri} \frac{l}{2} \cdot \frac{1}{V_i} = \frac{10^5 S^2}{2L^2 B V_i} \tag{22}$$

where V_i is the return speed [km/h].

After replacing the relations (19), (20), (21) and (22) in relation (18), it results:

$$T_{arat} = \frac{2D}{V_{tr}} + \frac{10S}{B \cdot V_l} + \frac{10^5 S^2}{2L^2 B \cdot V_i} + T_{cp} + T_{dc} \tag{23}$$

Since the plot can be tilled by a single worker, working a single shift per day, or two workers, which means that they deliver their equipment in the field, appropriate relations will be established for each case to determine the time required for processing a parcel.

In the first case (one worker per day), relations will be established relations for time distribution of a shift for coupling and decoupling the aggregate, for transport to and from the plot, for effective work and turns at the ends of plots. Assuming that the surface size is greater than the surface that can be achieved in one shift, the following situations may emerge:

a) On the first day the aggregate is coupled, transported to the plot, where the work is executed, followed by the return to the centre, without decoupling the aggregate. S_1 is the surface processed on the first day. The relation of time occupancy for one shift, T_z, in this case, is:

$$T_z = \frac{2D}{V_{tr}} + \frac{10S_1}{B \cdot V_l} + \frac{10^5 S_1^2}{2L^2 B \cdot V_i} + T_{cp} \tag{24}$$

T_1 is the time required to process the surface S_1.

b) In the following days, the worker starts working with the aggregate coupled from the first day, and will process the area. The relation of time occupancy for these shifts is:

$$T_z = \frac{2D}{V_{tr}} + \frac{10S_2}{B \cdot V_l} + \frac{10^5 S_2^2}{2L^2 B \cdot V_i} \quad (25)$$

T_2 is the time required to process the surface S_2.

We agree to call these shifts as *full shifts*.

b) Following steps a) and b), we assume that it still remains surface S_3 to be processed, smaller than S_1. The worker moves to the plot, processes surface S_3, returns to the centre and decouples the aggregate. In this case, the time occupancy T_3 is:

$$T_3 = \frac{2D}{V_{tr}} + \frac{10S_3}{B \cdot V_l} + \frac{10^5 S_3^2}{2L^2 B \cdot V_i} + T_{dc} \quad (26)$$

If the tillage operation continues on another plot, then T_3 will be:

$$T_3 = \frac{2D}{V_{tr}} + \frac{10S_3}{B \cdot V_l} + \frac{10^5 S_3^2}{2L^2 B \cdot V_i} \quad (27)$$

Considering relations (24), (25) and (26) or (27), the time required to process the considered plot is:

$$T_{arat} = T_1 + mT_2 + T_3 \quad (28)$$

where: *m* is the number of full shifts.

Determination of S_1 and S_2 surfaces, depending on the kinematical and geometrical parameters of the aggregate

Relation (24) is used to determine the surface S_1:

$$\alpha_1 S_1^2 + \beta_1 S_1 + \gamma_1 = 0 \quad (29)$$

where: $\alpha_1 = \frac{10^5}{2L^2 B \cdot V_i}$; $\beta_1 = \frac{10}{B \cdot V_l}$; $\gamma_1 = \frac{2D}{V_{tr}} + T_{cd} - T_z$.

Of the two solutions of equation (29) we keep the one with the plus sign before the root, i.e.:

$$S_1 = \frac{-\beta_1 + \sqrt{\beta_1^2 - 4\alpha_1\gamma_1}}{2\alpha_1} \quad (30)$$

Similary, surface S_2 is:

$$S_2 = \frac{-\beta_2 + \sqrt{\beta_2^2 - 4\alpha_2\gamma_2}}{2\alpha_2} \quad (31)$$

where: $\alpha_2 = \alpha_1$; $\beta_2 = \beta_1$; $\gamma_2 = \frac{2D}{V_{tr}} - T_z$.

Surface S_3 is given by the relation:

$$S_3 = S_{parcela} - S_1 - mS_2 \tag{32}$$

Aggregate productivity is given by the following relation:

$$w = \frac{S}{T_{arat}} \text{ [ha/h]} \tag{33}$$

The average time for a hectare is:

$$T_m = \frac{T_{arat}}{S} \text{ [h/ha]} \tag{34}$$

Note:Productivity w was determined for quality $x = 1$. To determine the productivity of an aggregate having same power, but with quality x, the following relation can be used:

$$w_x = w \cdot x \tag{35}$$

In case of tillage determination, the working width of the aggregate was used. To determine the working width, provided by the power condition of the tractor, it was considered the plows tensile strength [13], given by:

$$R_{pl} = f \cdot G_{pl} + k \cdot a \cdot b \cdot n_t + \varepsilon \cdot a \cdot b \cdot n_t \cdot V_l \tag{36}$$

where: f – rolling resistance coefficient of the plough (0.15 – 0.5); G_{pl} – plough weight [N]; a – working depth of plough [m]; b – working width of a plough-body [m]; n_t – number of plough-bodies ($B = b \cdot n_t$); k – coefficient of soil tillage resistance [N/m^2]; ε – coefficient of resistance at the lateral movement of soil: (1500 – 2000) $N \cdot s^2 / m^4$; V_l – plough speed [m/s].

NUMERICAL EXAMPLE

To determine the minimum surface from which the tractors from a certain range of engine power become profitable, tillage operation was considered. Knowing the power range and the operation (operations) that are executed, gives us the possibility to determine the matrix of aggregate costs and the productivities matrices.

Surfaces from which the tractors from a certain power range become profitable are determined from the condition that the income is equal to the expenses, i.e. the value of scope function (37) to be equal to zero:

$$\begin{aligned} f(u,x,y) = Tarif \cdot y - \left[\frac{\delta(1+\delta)^{T_o(x)} C_a}{(1+\delta)^{T_o(x)} - 1} + \frac{\varphi(x) C_a (T_o(x))^2}{10^3} \right] - \\ - \frac{\alpha k_a c_s(x) C_c u \cdot y \cdot x}{1000 \rho w(u,x)} - \frac{2\alpha D_i y C_d}{w(u,x) N_{oz}} - \frac{\alpha \cdot y \cdot Sal}{w(u,x)} \end{aligned} \tag{37}$$

To exemplify, the following factors were considered: power range (20-65 HP); tillage operation; the income calculated at constant rate (50 €/ha); hourly payment of the worker (1

€/h); aggregates power range (20-65 HP); distance to the plot ($D = 5$ km); transport speed ($v_t = 10$ km/h); working speed ($v_l = 7.2$ km/h); returning speed ($v_i = 7.2$ km/h); coefficient of tillage resistance (k = 50000 N/m^2); coefficient of resistance at the lateral movement of soil ($\varepsilon = 2000$ Ns^2/m^4); adhesion coefficient ($\varphi = 0.65$); rolling coefficient ($f = 0.05$); tractor weights for 20, 45 and 65 HP ($G_{TR\_20} = 13000$ N, $G_{TR\_45} = 25000$ N, $G_{TR\_65} = 36000$ N); plough weights for 20, 45 and 65 HP tractor ($G_{PLUG\_20} = 2500$ N, $G_{PLUG\_45} = 4500$ N, $G_{PLUG\_65} = 6000$ N); coefficients of tractors loads distribution on the drive wheels ($\lambda_{20} = 1$, $\lambda_{45} = 0.67$; $\lambda_{65} = 0.67$); aggregate costs (see Table 1, matrix of aggregate costs in 20-65 HP range); number of worked hours per day ($N_{oz} = 10$); interest rate ($\delta = 5$ %); cost of a litter of fuel ($C_c = 0.5$ €/liter).

Table 1

Matrix of aggregate costs, in 20-65 HP range								
	x[1] 0.3	x[2] 0.4	x[3] 0.5	x[4] 0.6	x[5] 0.7	x[6] 0.8	x[7] 0.9	x[8] 1.0
u[1]=20.0	3000	3755	4592	5510	6510	7592	8755	10000
u[2]=26.4	3213	4193	5254	6397	7621	8928	10315	11785
u[3]=32.9	3546	4750	6036	7403	8852	10383	11995	13689
u[4]=39.3	3998	5427	6937	8529	10202	11957	13794	15712
u[5]=45.7	4569	6222	7957	9773	11671	13651	15712	17855
u[6]=52.1	5260	7138	9097	11138	13260	15464	17750	20117
u[7]=58.6	6070	8172	10356	12621	14968	17397	19907	22499
u[8]=65.0	7000	9327	11735	14224	16796	19449	22184	25000

- aggregate productivities (see Table 2, matrix of aggregate productivities in 20-65 HP range;

Table 2

Matrix of aggregate productivities during tillage, in 20-65 HP range								
	x[1] 0.3	x[2] 0.4	x[3] 0.5	x[4] 0.6	x[5] 0.7	x[6] 0.8	x[7] 0.9	x[8] 1.0
u[1]=20.0	0.057	0.076	0.95	0.114	0.133	0.152	0.171	0.190
u[2]=26.4	0.076	0.101	0.125	0.149	0.174	0.198	0.222	0.246
u[3]=32.9	0.095	0.124	0.154	0.183	0.213	0.243	0.272	0.302
u[4]=39.3	0.112	0.147	0.182	0.216	0.251	0.286	0.321	0.356
u[5]=45.7	0.128	0.168	0.208	0.248	0.288	0.328	0.369	0.409
u[6]=52.1	0.142	0.188	0.233	0.279	0.324	0.369	0.415	0.460
u[7]=58.6	0.156	0.206	0.257	0.308	0.359	0.409	0.460	0.511
u[8]=65.0	0.168	0.224	0.280	0.336	0.392	0.448	0.504	0.560

It was considered a usage coefficient of the tractor for tillage operation $k_{pl} = 0.25$.

Using scope function (16), it results the surfaces matrix from which tractors in the considered power become profitable. Calculus results are presented in Table 3.

Table 3

Surfaces matrix from which tractors in 20-65 HP range become profitable (salary=1 €/h)								
	x[1]	x[2]	x[3]	x[4]	x[5]	x[6]	x[7]	x[8]
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
u[1]=20.0	20.5	14.3	13.1	12.9	13.3	13.8	14.5	15.3
u[2]=26.4	13.7	12.7	13.0	13.6	14.4	15.3	16.3	17.3
u[3]=32.9	12.6	13.0	13.9	14.9	16.1	17.3	18.5	19.7
u[4]=39.3	13.0	14.1	15.4	16.7	18.1	19.5	20.9	22.3
u[5]=45.7	14.2	15.7	17.2	18.9	20.5	22.1	23.6	25.2
u[6]=52.1	16.0	17.7	19.5	21.3	23.1	24.8	26.6	28.2
u[7]=58.6	18.3	20.1	22.1	24.1	26.0	27.9	29.7	31.5
u[8]=65.0	21.2	23.0	25.0	27.1	29.2	31.2	33.1	35.0

Table 4 presents the surfaces matrix from which the tractor becomes profitable, if the tillage operation is performed by the farmer, i.e. the salary enters the profit.

Table 4

Surfaces matrix from which tractors in 20-65 HP range become profitable (no salary)								
	x[1]	x[2]	x[3]	x[4]	x[5]	x[6]	x[7]	x[8]
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
u[1]=20.0	7.1	7.7	8.4	9.3	10.1	11.0	12.0	12.9
u[2]=26.4	7.3	8.4	9.5	10.7	11.8	13.0	14.1	15.3
u[3]=32.9	7.9	9.4	10.9	12.3	13.7	15.1	16.4	17.8
u[4]=39.3	8.9	10.8	12.6	14.2	15.9	17.4	19.0	20.5
u[5]=45.7	10.3	12.5	14.5	16.4	18.2	20.0	21.7	23.4
u[6]=52.1	12.0	14.4	16.7	18.8	20.8	22.8	24.6	26.4
u[7]=58.6	14.0	16.7	19.2	21.5	23.7	25.8	27.8	29.7
u[8]=65.0	16.5	19.4	22.0	24.4	26.8	29.0	31.1	33.1

Table 5 presents the optimal surfaces matrix from which the aggregate becomes profitable for tillage, harrowing and sowing, and the income increases with the yield per hectare. It were considered: $Q_m = 3$ t/ha; $Q_{\max} = 5$ t/ha; $k_m = 0.42$; $k_{pl} = 0.25$ (coefficient of tractor use during tillage); $k_{gr} = 0.15$ (coefficient of tractor use during germinative bed preparation); $k_{sem} = 0.2$ (coefficient of tractor use during sowing).

Table 5

Surfaces matrix from which tractors in 20-65 HP range become profitable durin tillage, harrowing and sowing (salary=1 €/h)								
	x[1]	x[2]	x[3]	x[4]	x[5]	x[6]	x[7]	x[8]
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
u[1]=20.0	14.4	9.1	7.5	6.8	6.4	6.2	6.1	6.0
u[2]=26.4	13.5	9.7	8.4	7.8	7.4	7.2	7.1	7.1
u[3]=32.9	14.0	10.8	9.6	8.9	8.6	8.4	8.3	8.2
u[4]=39.3	15.4	12.2	10.9	10.3	9.9	9.7	9.5	9.4
u[5]=45.7	17.3	13.9	12.5	11.8	11.4	11.1	10.9	10.7
u[6]=52.1	19.7	15.9	14.4	13.5	12.9	12.6	12.3	12.1
u[7]=58.6	22.5	18.2	16.3	15.3	14.6	14.1	13.8	13.6
u[8]=65.0	25.8	20.8	18.5	17.3	16.4	15.8	15.4	15.1

If tillage, harrowing and sowing works are performed by the farmer, surfaces given in Table 6 are obtained.

Table 6

Surfaces matrix from which tractors in 20-65 HP range become profitable during tillage, harrowing and sowing (no salary)								
	x[1]	x[2]	x[3]	x[4]	x[5]	x[6]	x[7]	x[8]
	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
u[1]=20.0	7.9	6.8	6.3	6.0	5.8	5.8	5.7	5.8
u[2]=26.4	8.6	7.7	7.3	7.0	6.9	6.8	6.8	6.8
u[3]=32.9	9.6	8.9	8.5	8.2	8.1	8.0	8.0	8.0
u[4]=39.3	11.1	10.3	9.8	9.6	9.4	9.3	9.2	9.2
u[5]=45.7	12.9	12.0	11.4	11.1	10.8	10.7	10.6	10.5
u[6]=52.1	15.1	13.9	13.2	12.7	12.4	12.1	12.0	11.9
u[7]=58.6	17.6	16.0	15.1	14.5	14.0	13.7	13.5	13.3
u[8]=65.0	20.6	18.5	17.2	16.4	15.8	15.4	15.1	14.8

Similary are determined the surfaces from which tractors become profitable for other power ranges.

CONCLUSIONS

The present paper shows that the minimum surface from which the tractors become profitable decreases if the work is performed by the farmer.

For a tractor in a certain power range, the surfaces for which the profit is zero decrease with the incresement of quality.

REFERENCES

1. Alliere, G., Boyer, R., 1995, La grand transformation de l'agriculture, Economica, Paris.
2. Anderson, R.D., Sweeney, J.D., Williams, A.T., An introduction to management science. Quantitative approaches to decision making. Aouth-Western College Publishing.
3. Cârlan, M., 1994, Probleme de optimum în ingineria sistemelor tehnice, Editura Academiei Române, Bucureşti.
4. Dumitru, V., Programare neliniară, Editura Academiei R.S.R., Bucureşti, 1975.
5. Guigdu, J.L., 1972, Théorie economique et tranformation de R'espace Agricol. Gauthier – Villars Editeur, Paris.
6. Hunt, R.D., 1986, Engeneering Models for Agricultural Production. The AVI Publishing Co., Inc., Westport, Connecticut.
7. Lasdon, S.L., 1975, Teoria optimizării sistemelor mari, Editura Tehnică, Bucureşti.
8. Legay, I.M., 1988, Methodes et models dans l'etude des sistemes complexes. Pour une agriculture divesifieé, Ed. L'Harmattan, Paris.
9. Malița, M., Zidăroiu, C., 1971, Matematica organizării, Editura Tehnică, Bucureşti.
10. Moise, V., Maican, E., Moise, Şt.I., 2007, Metode numerice, Editura Bren, Bucureşti.
11. Nitescu, Gh., Năstăsoiu, S., Popescu, S., 1968, Tractoare. Editura Didactică şi Pedagogică, Bucureşti.
12. Popescu, T., ş.a., 1982, Tractoare şi maşini horticole. Editura Didactică şi Pedagogică, Bucureşti.
13. Scripnic, V., Babiciu, P., 1979, Maşini agricole. Editura Ceres, Bucureşti.
14. Steiner, H.M., 1992, Engineering Economic Principles, McGraw-Hill, Inc., New York.
15. Șandru, A., Popescu, S., Cristea, I., Niculăiasa, V., 1983, Exploatarea utilajelor agricole, Editura Didactică şi Pedagogică, Bucureşti.
16. Smigelschi, O., Woiaroschy, A., 1979, Optimizarea proceselor în industria chimică, Editura Tehnică, Bucureşti.
17. 1964, Îndrumar matematic şi tehnic. Editura Tehnică, Bucureşti.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.43
Prethodno priopćenje
Preliminary communication

RESEARCHES ON INTRODUCTION OF SOIL BULK DENSITY IN MATHEMATICAL MODELING OF SOIL COMPACTION

VERGIL MARIAN MURARU, PETRU CARDEI, ION PIRNA, CORNELIA MURARU-IONEL, RALUCA SFÎRU

National Institute of Research Development for Machines and Installation designed to Agriculture and Food Industry -INMA 6
Ion Ionescu de la Brad Blv, sector 1, 013813 Bucharest, Romania

SUMMARY

The soil compaction is seeing like a mechanical pollution produce by the farm machinery traffic on the farm land. The authors expose the main results obtained during the investigation of the soil compaction problem. The authors have applied two different ways for solving the soil compaction problem. The first way consist in using the analytical solving (calculus of variation for an equations system) for soil compaction phenomena and obtain solution which gives the possibility to estimate the influence of some process parameter about the compaction degree. The second one consists in structural solving, which uses the finite elements modeling for soil and different loads.

Key words: *soil, compaction, modeling, mechanical pollution*

INTRODUCTION

The soil compaction, named also soil mechanical pollution, is a very complex problem because the soil modeling with a continuum media body must reflect the changes in the soil structure produced by the traffic, and on the other hand, because the stress state in the soil is considered only a measure for the compaction. The soil compaction is defined as the soil bulk density increasing. Then, the soil compaction phenomenon must reflect the increasing of the density, but the structural software program, generally cannot reflect this aspect. There are few models which can give the measure of the soil bulk density and these models are complicated, many times using nonlinear formulae. Really the compaction phenomenon is profound non linear because of the soil non linear structure. A mathematical model which reflects the soil bulk density is given in the chapter 1.

The structural solution results evaluate the soil compaction in term of the state stress in the soil, and the state stress in the soil is accepted only as a measure of the soil compaction.

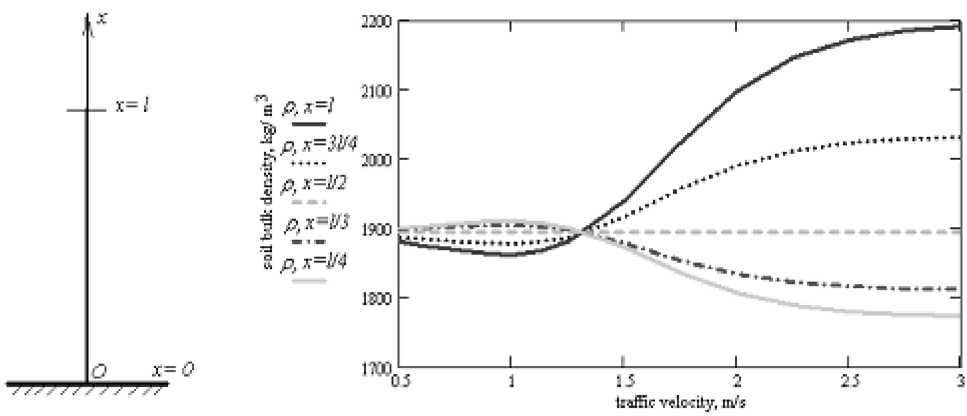
The compaction structural solution must take account about the non-linear soil structure, but not only this aspect, in plus, generally, the initial soil bulk density distribution is not constant. A good structural solution must reflect the residual changes in the soil bulk density distribution. After our knowledge, this solution did not exist until now.

Some structural solutions appear in the chapter two.

METHODS

A model of the soil compaction with soil bulk density modification

This model is 1-dimensional model and using the model of the unsteady quality materials, defined in (Cardei. P., 2000). The parameters significations are the next: u is the displacement, x is the coordinate on the vertical direction (figure 1, a)), t is the time, ε is the soil strain, ρ_0 is the initial soil density (the density of the initial soil configuration, as in D. I. Zolotarevskaya. (2007), for example), ρ is the soil density in the current configuration, f is the inertial load deliver by the soil mass (inertial force density), S is the Piolla – Kirchoff stress of first species in the soil, l is the length of the soil column (or the soil depth), M is the wheel mass specific load, m is the mass of the soil column situated under the contact zone between the wheel and the soil, R is the wheel dynamic radius, V is the vehicle velocity, L and b are the length and the width of the contact zone between the wheel and the soil. Φ is a function which gives the mechanical behavior of the soil material.



a b

Fig. 1 Scheme of the model: a) the geometry and b) soil bulk density dependence on the traffic velocity

The equations of this model are the next (Cauchy equation, geometrical equation, mass continuity equation, and material equation):

$$\frac{\partial S}{\partial x}+\rho f=\rho_0\frac{\partial^2 u}{\partial t^2},\quad \varepsilon=\frac{\partial u}{\partial x},\quad \rho_0=\left(1+\varepsilon\right)\rho,\quad S=\Phi(h,\varepsilon) \tag{1}$$

In (Cardei. P., 2000) is given an elementary approximate solution for the model (1). These solutions can be used for obtain the solution for the soil compaction. This solution provides the curve of variation of the soil bulk density in report with some parameters:

$$\rho(t,x)=\psi(\rho_0(x),M,m,R,V,L,l,t,x)\,. \tag{2}$$

Some graphical representations of the soil bulk density in report with the traffic velocity, for example, are shown in figure 1, b. These curves show the measure of the soil compaction is affected by the traffic velocity at different depths in the soil. The small traffic velocity affects more the surface soil and the big traffic velocity affects more the depth soil.

The information obtained about the traffic velocity on the soil compaction is possible only using models which can consider the impact between the vehicle wheel and the soil. Interesting relationships between the mass density of soil and applied stress are found in S. Assouline. (2002). In Kenneth W. McDonald. (2008) are given curves of dependence between the volume density of the soil and the number of passes on the floor. Another analytical solution that provides similar results is given in Keller. T., Defossez. P., Weisskopf. P., Arvidsson. J., Guy Richard, SoilFlex (2007).

A solution that highlights the influence of traffic parameters has the following structure:

$$\rho(t,x)=\frac{\rho_0}{1+\left(R-\sqrt{R^2-\left(\frac{L}{2}\right)^2}\right)\cdot\frac{M}{m}\cdot\frac{1}{2\pi}\cdot\left(\cos\frac{2\pi Vt}{L}-1\right)\cdot\left(\frac{1}{l}+\left(2x-l\right)\frac{5}{2l^2}\frac{1-12\left(\frac{cL}{2\pi Vl}\right)^2}{1-20\left(\frac{cL}{2\pi Vl}\right)^2+360\left(\frac{cL}{2\pi Vl}\right)^4}\right)} \tag{3}$$

where c is given by:

$$c=\sqrt{\frac{E_0}{\rho_0}}\,. \tag{4}$$

For R=1m, l=0.5 m, L=0.25 m, M=1000 kg, m=46.875 kg, V=1.38 m/s, E_0=50000 N/m^2, ρ_0=1500 kg/m^3, the variation of the bulk soil density is shown in the figure 2 using the formula (3). For this solution we suppose that, the initial soil bulk density is constant on the soil depth. Another numerical solution without this hypothesis is shown in the figure 3.

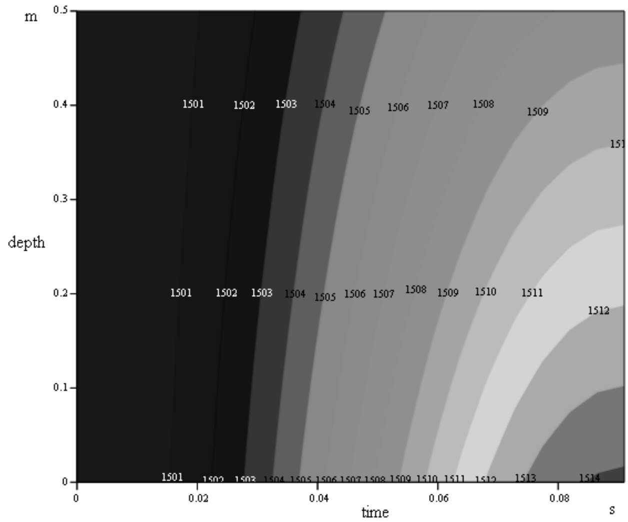


Fig. 2 Bulk density variation in time and space during the vehicle passage

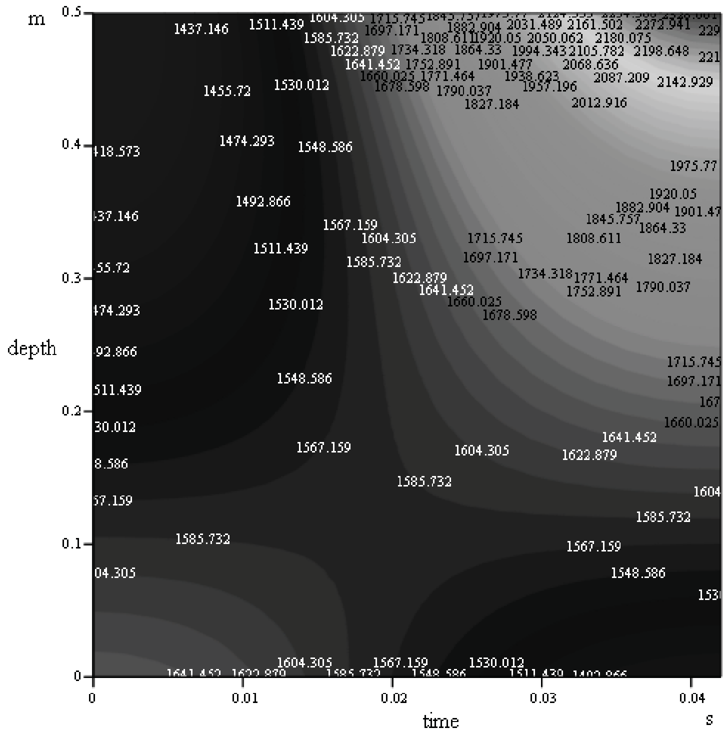


Fig. 3 Bulk density variation in time and space during the vehicle passage

RESULTS

In the last years a lot of soil compaction simulations have been based on the mathematical models which use the method of finite elements, or other numerical methods for the continuum body (R. C. Chiroux, W. A. Foster, Jr., C. E. Johnson, S. A. Shoop, R. L. Raper, 2005) and (Winfred A. Foster, Jr., Clarence E. Johnson, Robert C. Chiroux, Tom R. Way 2005). From the start we avoid the linear – elastic models, and, more generally, the elastic models. The soil elasticity can be neglected in the process of the soil compaction assessment. An elementary structural model is necessary to be nonlinear and to consider the soil plasticity. For the next example, is considers an elastic-plastic material (bilinear material). The material curve is shown in the figure 4, b. The elements finite network is shown in the figure 4, a.

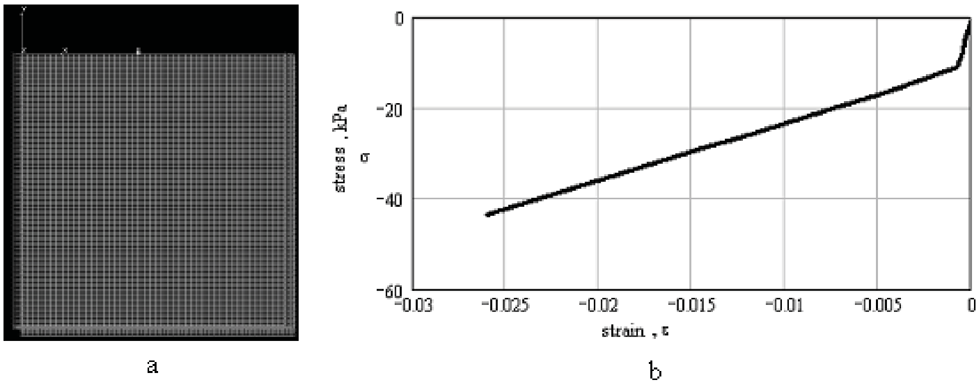


Fig. 4 The model based on the method of finite elements (a) and the material characteristic, (b)

For example, we consider, in the solutions with the result given in the figure 5, a soil modeled as an elastic-plastic bi-linear material. The main parameters of this model are: elastic modulus, E= 100000 N/m^2, Poisson ratio, ν= 0.4, soil bulk density, ρ= 1400 kg/m^3, the yield stress limit, σ_Y= 5000 N/m^2, and tangent modulus, E_T= 98100 N/m^2.

We consider many types of loads. For example in the figure 3, is considered a load given by a vehicle wheel. The wheel load is 1000 kg then the force which is applied on the soil is 9810 N. The force is applied in three successive nods of the network, each force heaving 3270 N value. In the figure 3, these forces are applied by the un-deformed shape. In these conditions, the vertical stress has values included between 236.98 and 11699 N/m^2. If we consider that the compaction zone is characterized by the vertical stress which over the yield limit of the material (zone of residual strain and stresses), then a delineation of these zone is shown in detail of the figure 5. In figure 6, the compacted zone is shown using the plastic vertical strain and the vertical total strain. Using these maps, the depth of the compacted zone is assessed to be 20 cm, and the width at the surface of the soil, 20 cm.

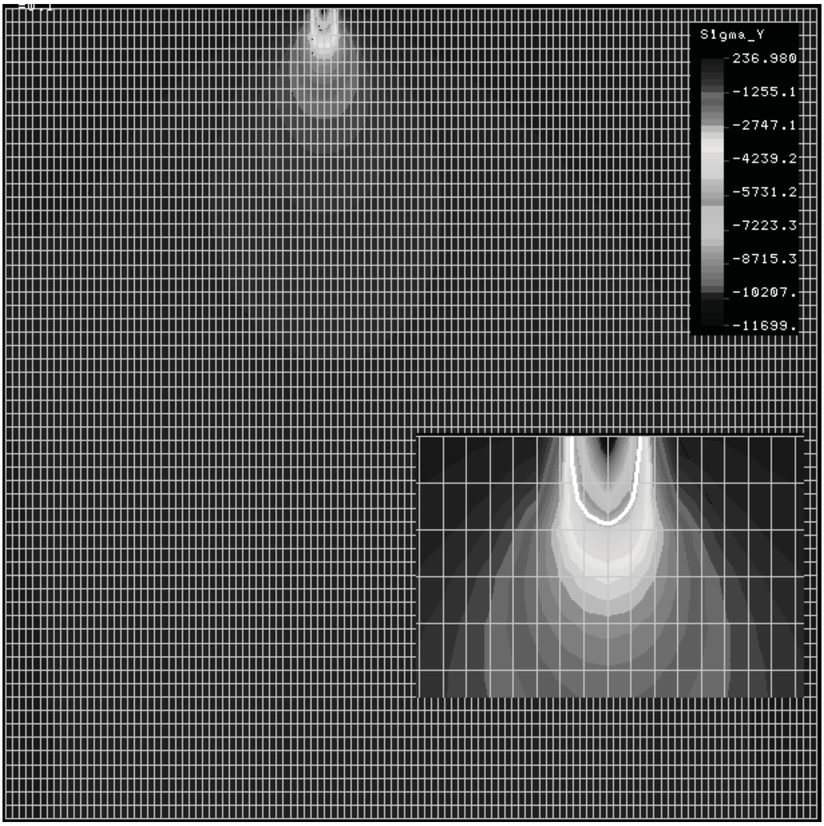


Fig. 5 Vertical stress in the plan MEF model for the soil which is load by a distribute force; The stress is given in Pa; In detail is shown the compaction zone

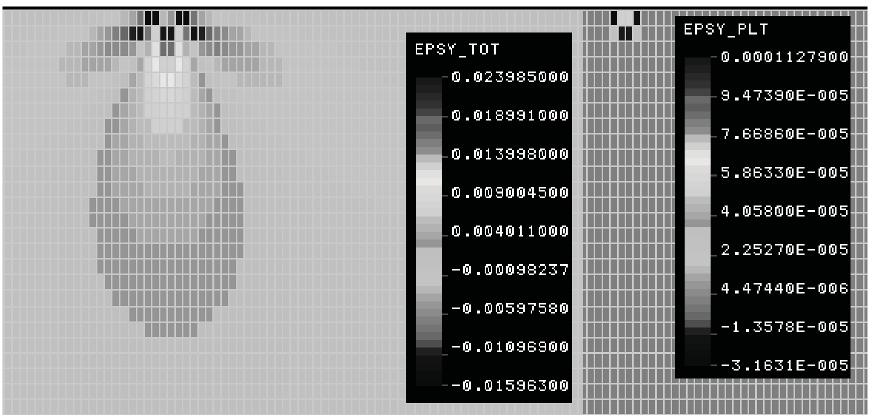


Fig. 6 The compacted and the un-compacted zones in the soil loaded by vehicle wheel, in the term of total vertical strain and plastic vertical strain

The map of the displacement in the soil is shown in the figure 7. The maximum value of the displacement field is 4.92 cm and its location is the soil which under the wheel. For other appreciations we precise that the distance between two succeeding nods in horizontal direction (Ox), is 5 cm, and on the vertical direction is 10 cm.

This elastic-plastic model is not influenced by the change of the soil bulk density value. Changing the soil bulk density, for example at the value 1000 kg/m3, the maximum value of the displacement, strain, and stress fields remain the same.

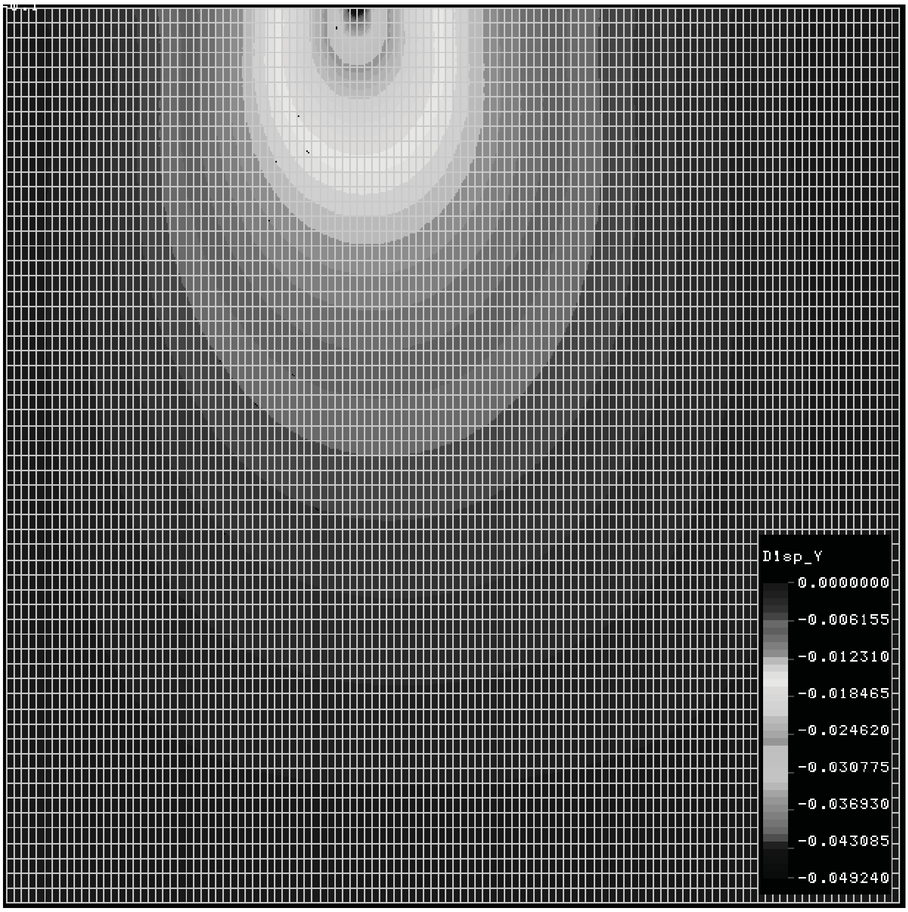


Fig. 7 The displacement state in the soil in m

However, there is some ways to approximate the compaction degree. If the report between the soil bulk density after and before the load action is considered equal with 1+ plastic strain, then, the maximum value of the compaction degree is 1.00011279.

For the assessment of the compaction degree we can do the hypothesis that the soil mass variation in the compacted zone is neglected. In this case an elementary calculus, using the maximum value of the soil displacement given for the maximum value of compaction degree, 1.14.

Now, for assessment of the effects of another load (another vehicle wheel), is necessary, at least, to modify the structural soil propriety in the compacted zone which is delineate in the figure 5. For this mathematical model the change of the soil bulk density cannot produce effects. Therefore, the way to find the effects of another load of the same soil is to consider a pre-stress state in the compacted zone, for example, but, we recommend to consider the residual deformation of the soil, for a good estimation of the new value of the residual displacement. These changes of the model are the minimum required to obtaining the same soil compaction phenomenon.

CONCLUSIONS

The soil compaction definition is based on the soil bulk density, which is considered the main characteristic of soil compaction. Generally, this characteristic is, not given by the classical structural solution, and many others solutions don't give the soil bulk density space-time variation.

- Manual solution for the compaction problem has the next advantages:
- it is possible to obtain the soil bulk density formulae which give the influence of each parameter considered about the compaction phenomenon (for example vehicle velocity influence);
- it is possible to consider many types of equations which describe the soil material behavior;
- the formulae obtained by this way can provide different optimal solution for the soil compacting problem, for example, we find the influence of the velocity traffic about the compacting phenomenon;
- using the explicit formulae that we have obtained it in this way it is possible to formulate some farm management principles, which lead to diminution of the compaction intensity;
- it is possible to precise a soil bulk density formula, which include the model parameters;
- it is possible to precise the depth of the compacting zone.

Manual solution for the compaction problem has the disadvantage, the solution is usually 1-dimensional because the 3-dimensional solutions are difficult to obtain.

The structural solving for the compaction problem has the next advantages:

- the solutions are 2 or 3 – dimensional and give the space-time variation of the stress, strain;
- by the way of structural analysis is possible to visualize the compacted zone of the soil in 3-dimensional space.

The structural solving for the compaction problem has the next disadvantages:

- generally, this way does not give the soil bulk density space-time variation;
- the structural analysis programs cannot consider whatever material equation for describe the soil behavior;
- to finding the influence of the parameters compacting problem about the compacting degree (with a exactly definition), we need many numerical solving and supplementary general studies.

Using results we can evaluate the time period which is necessary a deep tillage for the soil compaction amelioration.

REFERENCES

1. Assouline S. (2002). Modeling soil compaction under uniaxial compression. Soil Science Society of America Journal 66: 1784-1787
2. Cardei P. (2000). Materials with unsteady qualities. Journal of Applied Mechanics, vol 45(1), Printing House of Romanian Academy: 97-109
3. Chiroux R. C., Foster W. A., Johnson C. E. Jr., S. A. Shoop, Raper R. L. (2005). Three-dimensional finite element analysis of soil interaction with a rigid wheel. Applied Mathematics and Computation, vol 162: 707-722
4. Keller T., Defossez P., Weisskopf P., Arvidsson J., Guy R. (2007). A model for prediction of soil stresses and soil compaction due to agricultural field traffic including a synthesis of analytical approaches. Soil and Tillage Research, vol 93, Issue 2: 391 – 411
5. McDonald K. W. (2008). Soil response model verification: A multi-year study of foot traffic inpact. Environmental Impact Assessment Review, vol 28, Issues 4-5: 321-327
6. Zolotarevskaya D. I. (2007). Mathematical Modeling of the process of Soil Deformation and Soil Compaction. Eurasian Soil Science, vol 40, no. 1: 37 – 46
7. Winfred A. F., Johnson C. E. Jr., Chiroux R. C., Way T. R. (2005). Finite element simulation of cone penetration. Applied Mathematics and Computation, vol 162, Issue 2: 735 – 749

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.314.6
Izvorni znanstveni rad
Original scientific paper

THE FUNCTIONAL ANALYSIS OF THE MECHANISM OF THE SOIL LEVELING MACHINE

GIGEL PARASCHIV, BARBU GRECU, VICTOR MOISE, GEORGE ADIR, PAULA VOICU

University „Politehnica" of Bucharest, e-mail: paraschiv2005@yahoo.com; victor.moise@yahoo.com

ABSTRACT

The soil leveling machine is of half – carried type and it works, as unit, with the wheeled tractor (or caterpillar tractor). The leveling plane is established by the rear wheels of the tractor and by the wheels of the hind train of the machine. The positive and negative soil dislevelments are given against the leveling plane. In the paper there are established the displacements of the mechanism for the automatic working regime, in which the cutting blade is execution element.

***Key words**: mechanism, structural scheme, synthesis, soil, leveling machine*

INTRODUCTION

The soil leveling machine MNS 3.2 is of half- carried type and its works, as unit, with the wheeled (or caterpillar) tractor. During working, the machine and the tractor are rigid stabilized in the vertical-longitudinal plane, so that the leveling plane is established by the rear wheels of the tractor and by the wheels of the hind train of the machine. By respect to this plane, there are positive and negative dislevelments that are uniformized by the automatic leveling mechanism (fig.1).

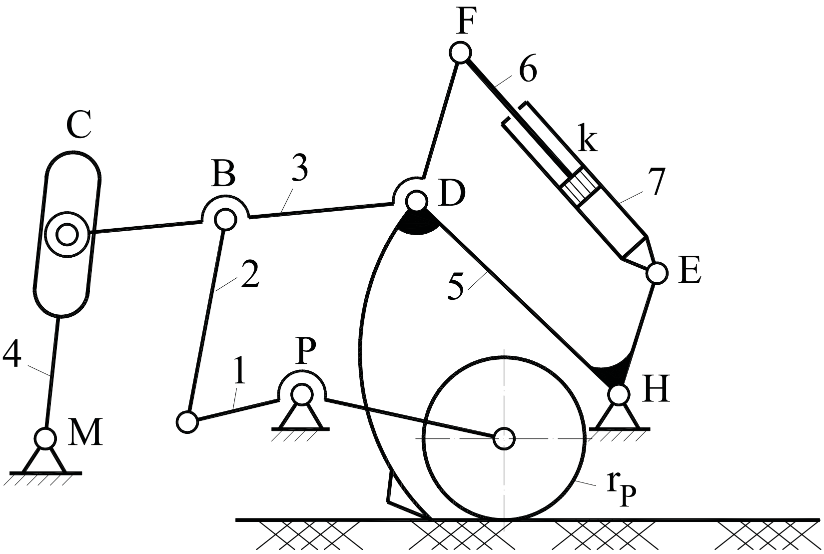


Fig. 1. Automatic leveling mechanism

THE STRUCTURAL PARAMETERS OF THE MECHANISM

The mechanism has two mobility degrees. One mobility degree is given by the motive translation couple K (6,7), which assures the adjustment of the position of the bucket blade by respect to the leveling plane – initial adjustment and the second mobility degree corresponds to the vertical movement of the tangible wheel and assures the input signal for the automatic working regime – automatic adjustment. Both sequences are independent.

The adjustment of the bucket blade by respect to the leveling plane is achieved in the stationary phase of the unit. The tangible wheel keeps the contact with the soil, so that its immobility involves, also, the immobility of the element 1. The insurance of function of the mechanism in the automatic regime (in the second sequence) involves positioning of the rototranslation couple C in the middle position of the movement and cancellation of the translation movement (its change into a rotation couple).

The configuration of the elements and couples identified for this sequence is highlighted in the structural draft (fig.2). The elements of the outlines I and II make a rigid construction, with zero mobility. Cancellation of the supraconstraints is possible only by sectioning the element 2, so that for each initial adjustment step it is imposed also an adjustment of the length of the element 2 (thru the screw-nut couple).

Working of the mechanism in the automatic regime stays in the taking over of the signal from the tangible wheel by the element 1 and then being sent to the execution element (blade of the leveling bucket), whose relative position by respect to the leveling plane has been established in the initial adjustment sequence.

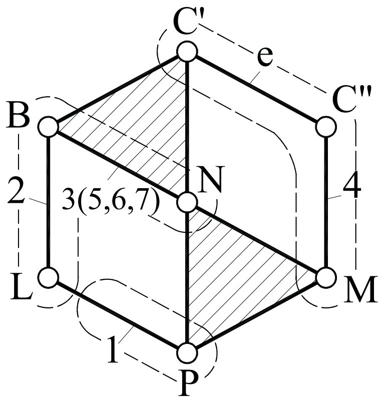


Fig. 2. Configuration of elements and couples

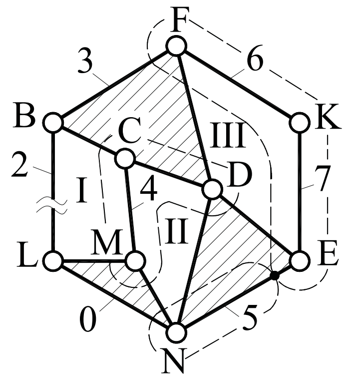


Fig. 3. Structural scheme

The mechano - hydraulical system (cylinder – crank) remains in blocked position, which ascertain cancellation of the rotation couple D (3, 5), the elements 3 and 5 being changed into one single element. To assure the desmodromy of the mechanism, it is reconsidered the rototranslation couple C (3,4).

The configuration of the elements and couples correspond to the structural scheme from fig.3.

THE GEOMETRICAL SYNTHESIS OF THE MECHANISM

The tangible wheel copies the ground having, by respect to the leveling plane [4], negative and positive displacements. At these displacements, the execution element go down and, respectively, up, achieving cutting of the dislevelments and, respectively, covering the negative dislevelments. Against the neutral position (tangible wheel is located in the leveling plane), for the command element it has to be assured equal positive and negative displacements.

The synthesis corresponds to the initial phase, of the adjustment of the bucket blade against the neutral plane. There are established both the relative displacements in the motive couples (of the crank against the cylinder) and the dimensions of the element 2.

The positional parameters are identified on the kinematic scheme (fig.4).

Positional parameters of the execution element

The bucket blade is vertically positioned thru the coordinate:

$$y_H = y_H^0 \pm K\,\Delta y \tag{1}$$

where: y_H^0 is the coordinate in the neutral position; K – a positive constant K = 0,1,2,3,...; Δy – dimension of the adjustment step.

From relation

$$y_H = y_N + 1_{NH} \sin\varphi_5 \tag{2}$$

it is established:

$$\varphi_5 = \arcsin\frac{y_H - y_N}{1_{NH}} \tag{3}$$

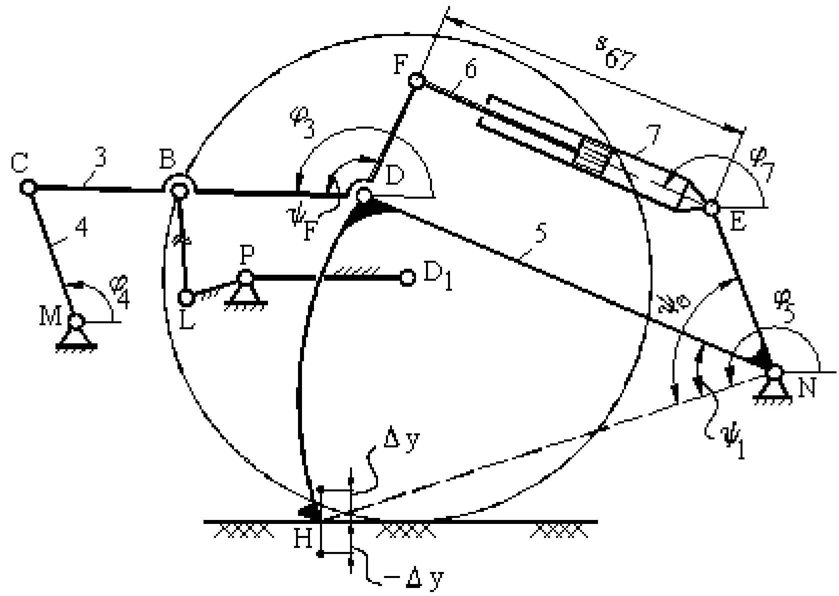


Fig. 4. The positional parameters on the kinematic scheme

Positional parameters at the elements of the dyad 3,4

There are established the coordinates of the potential couples:

$$X_M = C_1; \quad y_M = C_2$$

$$X_D = X_N + 1_{ND}\cos(\varphi_5 - \psi_D); \quad y_D = y_N + 1_{ND}\sin(\varphi_5 - \psi_D) \tag{4}$$

From the position equations of the dyad

$$X_M + 1_{MC}\cos\varphi_4 - X_D - 1_{DC}\cos\varphi_3 = 0$$
$$y_M + 1_{MC}\sin\varphi_4 - 1_{DC}\sin\varphi_3 = 0 \tag{5}$$

result the positional parameters φ_4 and φ_3:

$$\varphi_4 = \arccos\frac{AC \mp B\sqrt{A^2 + B^2 - C^2}}{A^2 + B^2}; \quad \varphi_3 = \arccos\frac{X_M - X_D + 1_{MC}\cos\varphi_4}{1_{DC}} \tag{6}$$

where:

$$A = 21_{MC}(X_M - X_D)\,; \quad B = 21_{MC}(y_{MC} - y_D)$$

$$C = 1^2_{DC} - 1^2_{MC} - (X_M - X_D)^2 - (y_M - y_D)^2$$

The position of B couple is given by the coordinates:

$$X_B = X_D + 1_{DB}\cos\varphi_3\,; \quad y_B = y_D + 1_{DB}\sin\varphi_3 \tag{7}$$

The length of the element 2 is established with the relation:

$$1_{LB} = \sqrt{(X_B - X_L)^2 + (y_B - y_L)^2} \tag{8}$$

Positional parameters at the elements of the dyad 6,7

There are established the coordinates of the potential couples:

$$X_F = X_D + 1_{DF}\cos(\varphi_3 - \psi_F)\,; \quad y_F = y_D + 1_{DF}\sin(\varphi_3 - \psi_F) \tag{9}$$

$$X_E = X_N + 1_{ND}\cos(\varphi_5 - \psi_D)\,; \quad y_E = y_N + 1_{ND}\sin(\varphi_5 - \psi_D)$$

From the positions equations of the dyad

$$X_E + s_{67}\cos\varphi_7 - X_F = 0$$

$$y_E + s_{67}\sin\varphi_7 - y_F = 0 \tag{10}$$

there are obtained the positional parameters S_{67} and φ_7.

$$s_{67} = \sqrt{(y_F - y_E)^2 + (X_F - y_E)^2}\,; \quad \varphi_7 = arctg\frac{y_F - y_E}{X_F - X_E} \tag{11}$$

By choosing $\Delta\, y = 50$ mm have been obtained, based on a computing program, the linear displacements S_{67} and the length of the element 2, which have the values given in table 1.

Table 1. Linear displacements and length of the element 2

k	y_{H5}	S_{67}	H_{LB}
0	0	667,3312	269,9922
1	50	687,7474	295,5487
2	100	706,3379	321,6319
3	150	723,3647	348,0090
4	200	739,1714	374,1020
1	-50	644,7073	245,1455
2	-100	619,4387	220,9712
3	-150	590,9642	197,2258
4	-200	559,5637	172,2357

THE ANALYSIS OF DISPLACEMENTS IN THE AUTOMATIC ADJUSTMENT

Establishment of the displacements of the execution element (blade of the leveling bucket), comprises, as input data, the positive and negative displacements of the tangible wheel. It is admitted as reference position, the position established in the initial adjustment sequence.

The calculus algorithm is compatible with the connections scheme of the modular groups [4]. The positional parameters are identified on the kinematic scheme in fig.5.

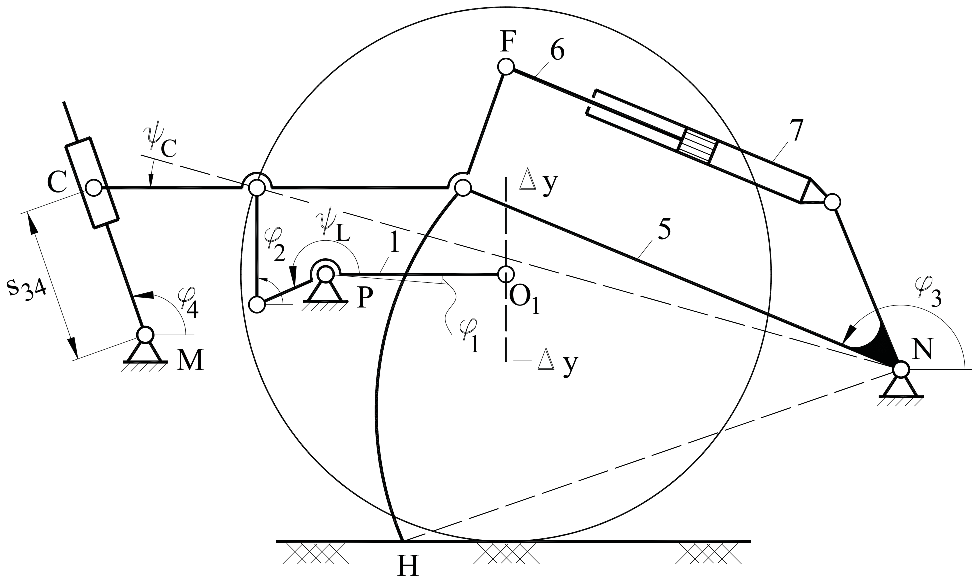


Fig. 5. The positional parameters in the automatic adjustment

Positional parameters of the leading element

The tangible wheel is vertically positioned by the coordinate:

$$y_O = y_O^0 + f \tag{12}$$

where: y_O^0 is the coordinate of the wheel centre in the neutral position; f = 0 function generated by the shape and dimensions of the positive or negative dislevelments.

From the relation

$$y_O = y_p + 1_{PO1} \sin \varphi_1 \tag{13}$$

It is established the displacement

$$\varphi_1 = \arcsin \frac{y_0 - y_p}{1_{PO1}} \tag{14}$$

Positional parameters at the elements of the dyad 2,3

There are established the coordinates of the potential couples:

$$X_N = \mathrm{C}_1; \quad y_N = \mathrm{C}_2$$

$$X_L = X_p + 1_{PL} \cos(\varphi_1 + \psi_L); \quad y_L = y_p + 1_{PL} \sin(\varphi_1 + \psi_L) \tag{15}$$

From the positions equations of dyad

$$X_L + 1_{LB} \cos\varphi_2 - X_N - 1_{NB} \cos\varphi_3 = 0$$
$$y_L = 1_{LB} \sin\varphi_2 y_N - 1_{NB} \sin\varphi_3 = 0 \tag{16}$$

result the positional parameters φ_2 and φ_3.

$$\varphi_2 = \arccos\frac{AC \pm B\sqrt{A^2 + B^2 - C^2}}{A + B}; \tag{17}$$

$$\varphi_3 = \arccos\frac{(X_L - X_N) + l_{LB} \cos\varphi_2}{l_{NB}} \tag{18}$$

where:

$$\mathrm{A} = 2; [\, l_{LB}(X_L - X_N)]; \quad \mathrm{B} = 2; [\, l_{LB}(y_L - y_N)\,]$$
$$C = l_{NB}^2 - l_{LB}^2 - (X_L - X_N)^2 - (y_L - y_N)^2$$

Positional parameters at the elements of dyad 4, e

There are established the coordinates of the potential couples:

$$X_M = C_1; \quad y_M = C_2$$

$$X_{C_3} = X_D + 1_{DC} \cos(\varphi_3 + \psi_C); \quad y_{C_3} = y_D + 1_{DC} \sin(\varphi_3 + \psi_C) \tag{19}$$

From the positions equations of the dyad 4, e

$$X_M + s_{34} \cos\varphi_4 - X_{C_3} = 0$$
$$y_M + s_{34} \sin\varphi_4 - y_{C_3} = 0 \tag{20}$$

result the parameters φ_4 and S_{34}.

$$\varphi_4 = arctg\frac{y_{C_3} - y_M}{X_{C_3} - X_M}; \quad s_{34} = \sqrt{(y_{C_3} - y_2)^2 + (X_{C_3} - X_M{}^2} \tag{21}$$

For the tangible wheel be able to support maximal displacements, positive and negative, equal in absolute magnitude, it is imposed that the relative displacement S_{34} be adjusted in the initial phase at a middle value

$$s_{34}^0 = \frac{s_{34}^{\max} + s_{34}^{\min}}{2} \tag{22}$$

By taking into consideration the dimensional parameters

$$s_{34} = s_{34}^{max} - s_{34}^{min} = 120\,mm \tag{23}$$

there have been established the displacements of the execution element and of the input element, these ones being highlighted for the case when the leveling blade is adjusted at $y = 50$ mm (fig.6).

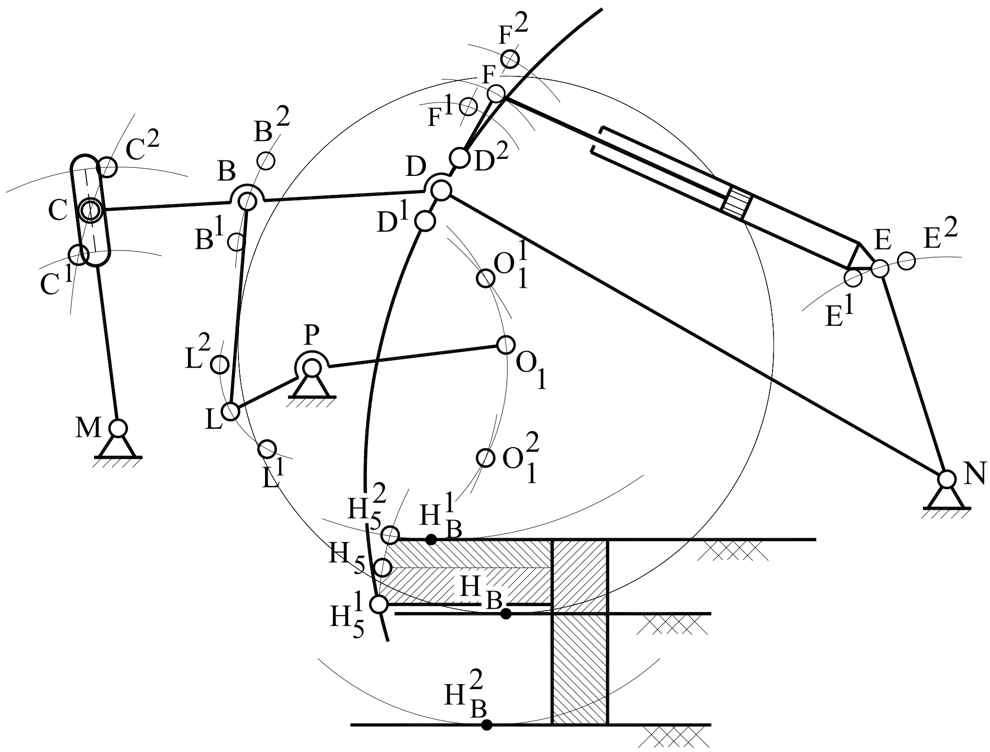


Fig. 6. Adjustment of the leveling blade

CONCLUSIONS

The leveling automatic mechanism involves an initial adjustment for which is established the length of the element 2 and an automatic adjustment in which there are established the displacements of the execution element by respect to the signal given by the tangible wheel. The adjustment length of the element 2 is of 202 mm. The positive displacement of the tangible wheel determines a descent of the bucket blade and the negative displacement determines a rising of the bucket blade.

REFERENCES

1. Antonescu, P., Mecanisme – calculul structural şi cinematic, Lit. Institutul Politehnic, Bucuresti,1979
2. Babiciu, P., Scripnic, V., Frăţilă Al., Sisteme hidraulice ale tractoarelor şi maşinilor agricole, Editura Ceres, Bucureşti, 1984;
3. Grecu, B., Caracteristici structurale ale mecanismelor din construcţia maşinilor agricole, Simpozionul naţional de roboţi industriali, Bucureşti, 1987;
4. Grecu, B., Proiectarea structural cinematică a mecanismelor manipulatoare cu mobilitatea M = 2, cu acţionare hidraulică, SYROM '89, pag. 257 – 267;
5. Grecu, B., Maican, C., Coltofeanu, N., Elemente structurale ale mecanismului de comandă de la maşina de nivelat MNS 3,2. Simpozionul naţional de R.I., Bucureşti, 1991;
6. Pelecudi, Chr., Precizia mecanismelor, Editura Academiei RSR, Bucureşti, 1975.
7. *** - Maşina de nivelat solul MNS 3.2, Notiţă tehnică.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 62-82:621.22
Izvorni znanstveni rad
Original scientific paper

RESEARCHES REGARDING THE REALISATION OF A HYDRAULIC SYSTEM WITH AUTOMATIC CONTROL OF THE AGRICULTURAL MACHINE POSITION TOWARDS THE SOIL

GIGEL PARASCHIV, MAGDALENA-LAURA TOMA, GABRIEL MUŞUROI, SORIN-ŞTEFAN BIRIŞ, GHEORGHE VOICU

„Politehnica" University of Bucharest-Romania, 313, Splaiul Independentei Street, Bucharest-Romania, Zip code 060042, e-mail: paraschiv2005@yahoo.com

SUMMARY

All the modern tractors are equipped with hydraulic systems to drive the hang up mechanism, having systems that automatically regulate the position of the agricultural machine in relation to the support surface of the tractor and/or systems that automatically regulate the position of the agricultural machine in relation to the tractor in accordance with the drag resistance of the machine.

Using this systems lead to an increase of the tractor adhesion weight causing an additional traction force and provide a constant working depth of the machine in case of homogenous levelled terrains.

These systems were implemented in modern tractors because the force and position control systems assure increased adhesion, low fuel consumption and higher productivity rate, choosing the proper control in accordance with the specific working conditions.

All over the world are still many heterogeneous uneven terrains and thus they are still ploughed using the classic system with guide wheel, loosing all the advantages mentioned earlier.

A new hydraulic system with automatic control of the agricultural machine position towards the soil that receives the information about working machine position from a detector or a detection wheel mounted on the machine frame is presented in this paper.

Key words: *soil, agricultural machine, automatic system with force and position control*

INTRODUCTION

The extended utilization of the hydraulic systems with automatic control of the agricultural machine position towards the soil represents a demand of the continuous development and improvement of the agricultural machines and installations, with a view to facilitate the controls and driving of the tractors, to simplify the design of the machine and, especially, to automatic control of the different parameters which define the best run of the machines.

For each concrete mode of operation corresponds an optimal operating condition that has to be assured and maintained during work.

Permanent modification of the agricultural machineries' working conditions involves the need to continuous observation of the work development and the quick adjustment of the parameters that define the optimal operating condition of the machine.

The hydraulic systems with automatic control solve these problems safely, quickly and efficiently.

All the agricultural tractor building firms have done massive researches in order to fit those with hydraulic systems with automatic control, including all theirs advantages and disadvantages.

The presentation of a hydraulic system with automatic control of the agricultural machine position towards the soil that do not have the disadvantages of the systems that control the force and position is done in this paper; the information regarding the agricultural machine is taken from an detector mounted on it's frame.

MATERIALS AND METHODS

For a system, the working depth measuring is done by a detector or a detection wheel mounted on the agricultural machine which aloud to maintain the machine in a fixed position towards the soil, independently of the tractor position, the necessary force to move the agricultural machine, the shape of the operating part and its propriety to dip into the soil.

The soil reaction on the detector or the detection wheel is limited to a value that aloud to follow the unevenness of the ground, the rest of the normal forces on the soil that act on the agricultural machine are transfer to the tractor (P. Babiciu, 1984).

Thus, the additional load of the driving wheels and, implicitly, reduction of the skidding, improvement of the tractor pulling proprieties and of the combiner economic performances are realised.

Signal transmission of the agricultural machine position towards the soil, between the detector or the detection wheel attached to the agricultural machine and the hydraulic system distributor mounted on the tractor, can be done mechanically, using an extension lead, or electrically, using circuit closers and cables, in which case the distributor is electromagnetically driven (G. Muşuroi, 2002).

The functional diagram of the hydraulic system with automatic control of the agricultural machine position towards the soil is presented in figure 1, in which 1 represents the hang up mechanism with 3 points grip; 2 – detector; 3 – the body of the plough working at “a” depth; 4 – flexible wire; D_T – tractor distributor; D_1 – automatic system distributor with double action – from the operating handle founded at the control board and at the detector; S_{r1}, S_{r2} – one-way valves composing the double blocking valve; C_h – hydraulic cylinder.

The distributor D_1 control from the detector is realized by the flexible wire, thus:

- if the detector descends, the distributor D_1 is switch to down position (C);
- if the detector rises, the distributor D_1 is switch to up position (R).

In order to put into service the hydraulic system with automatic control of the agricultural machine position towards the soil, the following operations are required:

- the detector position corresponding to the desired working depth is set;
- the distributor D_T is switch to up position (R);
- the plough is lowered using the operating handle of the distributor D_1;
- one test is performed and the working depth is measured;
- if the working depth is adequate, the operating handle detent of the distributor D_1 is brought near the distributor and it is fixed;
- if the desired working depth is not acquired, the detector position is modified and the test is done again.

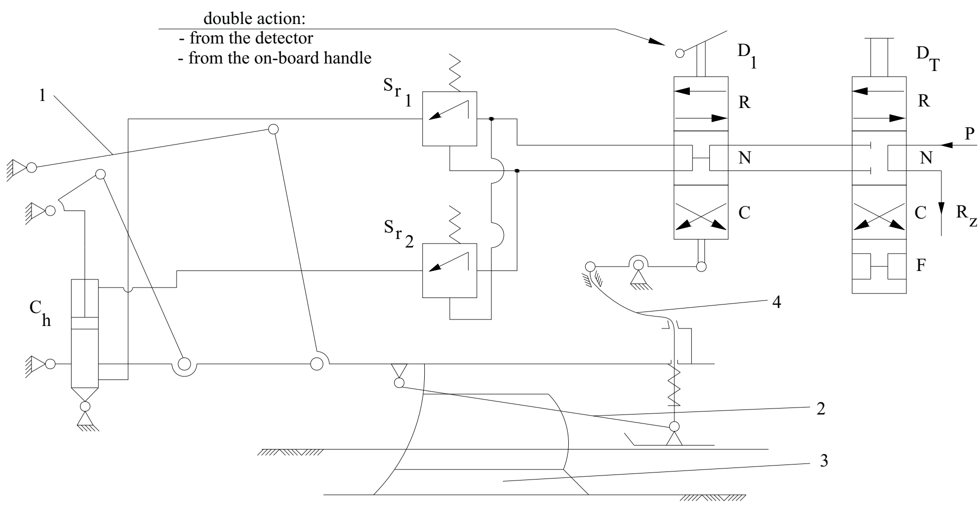


Fig. 1 Functional diagram of the hydraulic system with automatic control of the agricultural machine position towards the soil

At the end of the lot, in order to turn back, the automatic system distributor is operated to lift the plough. After turning back, for ploughing, the distributor D_1 operating handle is brought near the detent and the tractor distributor D_T is switch to up position. When the detector commands the distributor D_1 to switch to neutral position, the plough descends, penetrating the soil to the imposed working depth.

The conventional block of the hydraulic system with automatic control of the agricultural machine position towards the soil is presented in figure 2.

The connection between the pump and the tank through the passing valve S_T is realised when the distributor D_T slide valve is in neutral position (N).

When the hydraulic system with automatic control of the agricultural machine position towards the soil is driven (the distributor DT slide valve is switch to up position - R), the distributor D1 realises the following connections corresponding to its slide valve positions:

- neutral position (N) – the oil circulated by the pomp P runs through the distributors D_T and D_1, and reaches the tank. The two chambers of the hydraulic cylinder are blocked;
- up position (R) – the connection between pump and the chamber in front of the hydraulic cylinder is realised by D_T(b-d), D_1(h-k), S_{r2}. At the same time, the connection between the chamber behind the piston of the hydraulic cylinder and the tank is also realised by S_{r1}, D_1(j-i), D_T(c-g);
- down position (C) – the pump – hydraulic cylinder connection is realised by D_T(b-d), D_1(h-j), S_{r1} and the hydraulic cylinder – tank connection is realised by S_{r2}, D_1(k-i), D_T(c-g).

The distributor D_1 is mechanically driven from an operating handle founded at the tractor board or from the detector by the flexible wire.

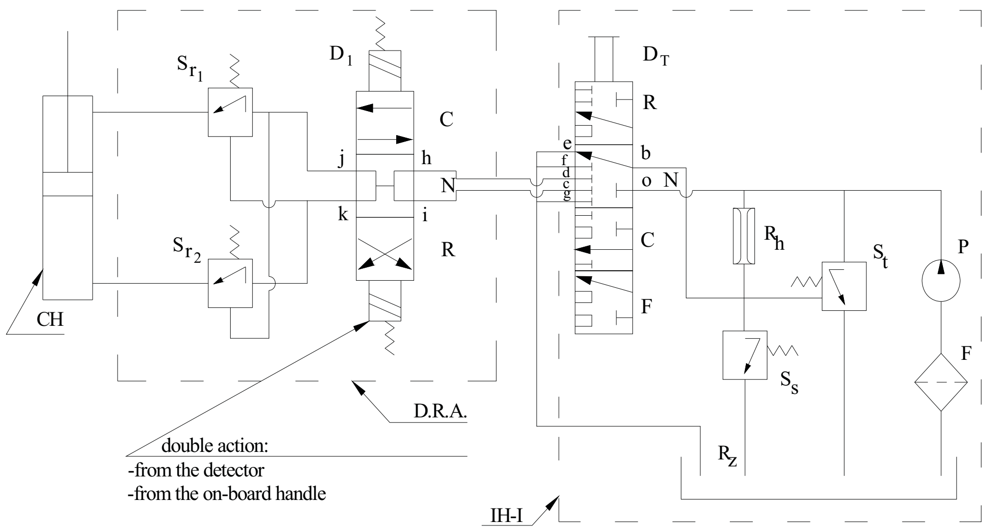


Fig. 2 Conventional block of the hydraulic system with automatic control of the agricultural machine position towards the soil; IH-1 – hydraulic installation of the tractor U650; P – pump; F – filter; St – passing valve; Ss – safety valve; Rh – hydraulic resistance; Rz – tank; DT – distributor; DRA – automatic control device; D1 – distributor with 3 positions, 4 paths; Sr1, Sr2 – retention valves; CH – hydraulic cylinder.

In order to determine the transfer function of the presented automatic system is necessary to find out: the detector transfer function, distributor – cylinder transfer function and the cylinder – technological installation transfer function.

The detector transfer function is determined starting from the detector mechanism and the forces acting on it (fig. 3), (G. Muşuroi, 2002).

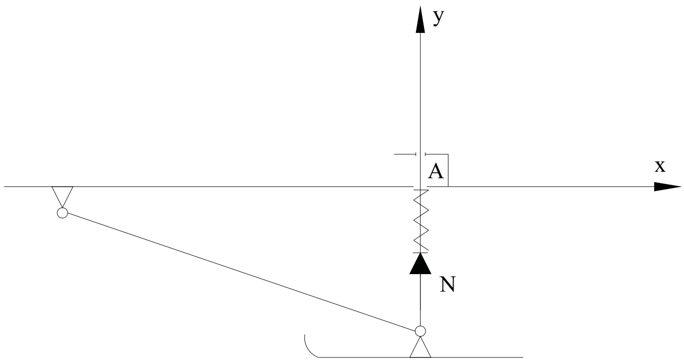


Fig. 3 Detector scheme

The differential equation of the law of motion is:

$$m_r \cdot \frac{d^2 Y}{dt^2} = N - k \cdot Y \tag{1}$$

where m_r is the detector mass reduced in point A (fig. 3); Y – point A displacement ; N – soil reaction on detector, translated in point A; k – spring constant.

For infinitesimal displacements, one can obtain:

$$m_r \cdot \frac{d^2 \Delta Y}{dt^2} = \Delta N - k \cdot \Delta Y \tag{2}$$

where N depends on the soil homogeneity and the unevenness of the ground, N = F(a), where a is working depth. As a result:

$$\Delta N = \left| \frac{\partial F}{\partial a} \right| \cdot \Delta a \tag{3}$$

where $\frac{\partial F}{\partial a} = k$.

Replacing, one can obtain:

$$\frac{m_r}{k} \cdot \frac{d^2 \frac{\Delta Y}{Y_o}}{dt^2} + \frac{\Delta Y}{Y_o} = \frac{a_o}{Y_o} \cdot \frac{\Delta a}{a_o} \tag{4}$$

In relation (4), $\varphi_Y = \dfrac{\Delta Y}{Y_o}$ represents deviation as a function of detector equilibrium position; $\varphi_Y = \dfrac{\Delta Y}{Y_o}$ represents the modification corresponding to the working depth and Y_o and a_o represent the values of Y and a for the detector equilibrium position.

Replacing $k = \dfrac{a_o}{Y_o}; T^2 = \dfrac{m_r}{k}$ and applying the complex factor $s = \dfrac{d}{dt}$, relation (4) become:

$$\left(T^2 \cdot s^2 - 1\right) \cdot \varphi_Y(s) = k \cdot \varphi_a(s) \tag{5}$$

As a result, the relation of the transfer function will be:

$$Y_1 = \frac{k}{T^2 \cdot s^2 + 1} \tag{6}$$

If in relation (6) one substitutes m_r = 10 kg, a_o = 30mm, Y_o = 5 mm, ΔN = 20 daN, Δf = 10 mm and $g \approx 10$ m/s^2, it results:

$$Y_1 = \frac{k}{T^2 \cdot s^2 + 1} = \frac{12 \cdot 10^3}{s^2 + 2 \cdot 10^3} \tag{7}$$

The deduction of the distributor – cylinder transfer function consists in three steps and it is based on the determination of the necessary shifts of the distributor slide valve to realize different parameters of the load movement (G. Paraschiv, 1999):

- shift of the slide valve in order to assure the load velocity;
- shift of the slide valve in order to assure the load acceleration;
- shift of the slide valve needed to compensate the fluid compressibility and the variation velocity of the load acceleration.

The distributor – cylinder transfer function have the following expression (A. Oprean, 1989):

$$Y_2 = \frac{C_1 \dfrac{1}{1 + \dfrac{C_1}{C_2}}}{s\left(\dfrac{1}{\omega_n^2 \cdot s^2 + \dfrac{2\delta}{\omega_n} \cdot s + 1}\right)} \tag{8}$$

where C_1 = 14 [s^{-1}] is velocity gradient; C_2 = 9200 [daN/cm] is force gradient; ω_n = 10 [rad/s] is angular resonant frequency and δ = 1.9 – damping coefficient.

To determine the cylinder – technological installation transfer function, one can begin from the design characteristics of the hang up mechanism with three points grip that realises a $s = 4 \cdot s_p$ stroke of the plough hang up arbour for a s_p piston stroke of the hydraulic cylinder.

$$Y_3 = \frac{x_e}{x_i} = \frac{s}{s_p} = i;\, i = 4 \tag{9}$$

The flow chart in figure 4 is taken into consideration for the determination of the automatic system transfer function which is a closed system with simple reaction.

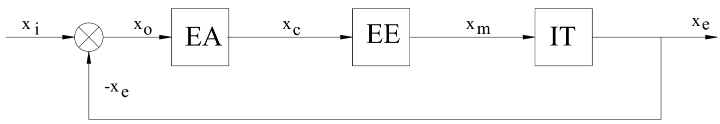


Fig. 4 Flow chart of the automatic system EA – amplifier (distributor); EE – output regulator (hydraulic cylinder); IT - technological installation (plough)

The automatic system transfer function is:

$$Y_o(s) = \frac{Y(s)}{1 + Y(s)} \tag{10}$$

where $Y(s) = Y_1 \cdot Y_2 \cdot Y_3$ and, if it is replaced, leads to:

$$Y_o(s) = \frac{336}{10^{-5} \cdot s^5 + 38 \cdot 10^{-4} \cdot s^4 + 11 \cdot 10^{-3} \cdot s^3 + 38 \cdot 10^{-2} \cdot s^2 + s + 336} \tag{11}$$

To calculate the stability of the automatic system is applied the Ruth - Hurvitz stability criterion to transfer function (11) which can be also written as:

$$Y_o(s) = \frac{672}{C_o \cdot s^5 + C_1 \cdot s^4 + C_2 \cdot s^3 + C_3 \cdot s^2 + C_4 \cdot s + C_5} \tag{12}$$

Applying this criterion, one can obtain: $C_o = 10^{-5} > 0$; $\Delta_2 = 38 \cdot 10^{-10} > 0$; $\Delta_3 = 3.8 \cdot 10^{-7} > 0$; $\Delta_4 = 12.76 \cdot 10^{-7} > 0$; $\Delta_5 = 101.4 \cdot 10^{-7} > 0$; $\Delta_6 = 101.4 \cdot 10^{-7} > 0$; thus, it results that the automatic hydraulic system verifies the stability conditions imposed by the Ruth – Hurvitz criterion.

The designed hydraulic system with automatic control of the agricultural machine position towards the soil is presented in figure 5.

One can intervene on the position control system in order to:

- modify the pre-compression of the spring 4 in order to assure different pressures of the detector on the soil;
- modify the connection point (joint) between rod 3 and lever 5 to adjust the working depth;
- block or free the joint 6 to prevent or allow the detector vibrations in horizontal plane.

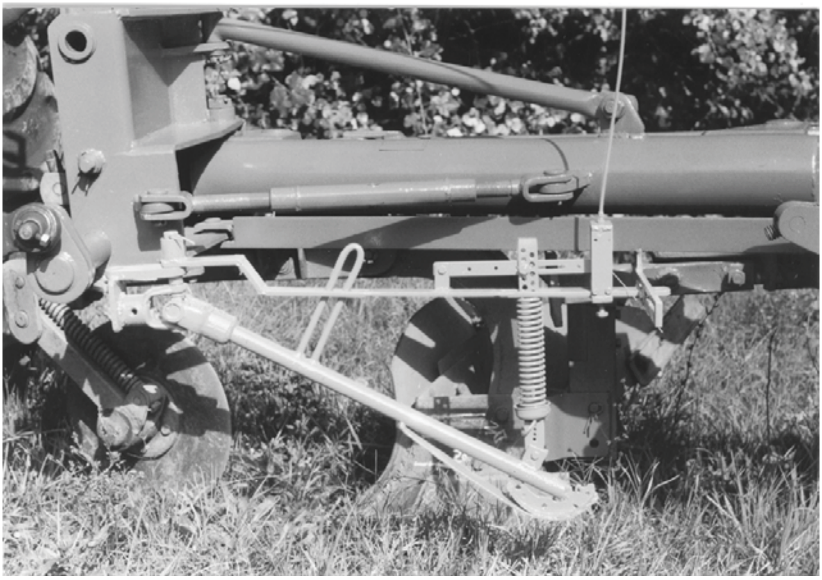


Fig. 5 Control device of the agricultural machinery position towards the soil; 1 – detector; 2 – fix skate; 3 – rod; 4 – spring; 5 – lever

Following the test of the automatic hydraulic system, it comes out the necessity to replace the fix skate with a mobile one in order to prevent the system to go into operation at smaller unevenness of the soil and to replace the flexible wire with one that works both on stretch and on compression (steel wire coated with flexible envelope) (G. Muşuroi, 2002).

RESULTS AND DISCUSSIONS

The following elements were observed during the experimental test: determination of the plough – tractor binding forces, the hourly fuel consumption and the skidding.

The obtained data during experimental researches for both the plough with automatic system and the plough with depth detent wheel are presented in table 1. The experimental tests for both aggregates were done on the same type of terrain and in same air and soil humidity conditions.

The skidding of the driving wheels as a function of traction force, for the both aggregates, is represented in figures 6 and 7.

The following functions for the skidding of the left driving wheel (δ_s) and of the right driving wheel (δd), δ = f(Ft), were obtained after processing the data:

- aggregate with automatic system:

$$\begin{aligned} \delta_s &= 10^{-5} \cdot F_t^2 - 0.0181 \cdot F_t + 15.441 \\ \delta_d &= 2 \cdot 10^{-5} \cdot F_t^2 - 0.0249 \cdot F_t + 12.319 \end{aligned} \tag{13}$$

- aggregate with working depth detent wheel:

$$\delta_s = 2 \cdot 10^{-5} \cdot F_t^2 - 0.0458 \cdot F_t + 31.84$$
$$\delta_d = 10^{-5} \cdot F_t^2 - 0.0192 \cdot F_t + 12.191 \qquad (14)$$

Table 1 Obtained data during experimental researches

No.	Average depth [m]	Aggregate velocity [m/s]	Hourly consumption [kg/h]	Wheels skidding [%]			Traction force [daN]
				Left wheel	Right wheel	Average	
Plough with automatic system							
1	0.1972	0.735	5.53	13.5	4.4	8.95	839.5
2	0.1963	0.725	5.70	9.9	5.6	7.75	1173.9
3	0.1631	1.042	4.45	6.0	1.7	3.85	712.7
4	0.1585	1.059	7.75	7.6	2.3	4.59	980.6
5	0.2315	0.862	9.59	22.7	24.8	23.75	1811.3
6	0.2377	0.954	9.92	20.4	13.2	16.80	1785.5
Plough with depth detent wheel							
1	0.24	0.709	11.71	33.5	23.8	28.65	1712.3
2	0.237	0.975	8.95	20.1	17.1	18.5	1555
3	0.2055	0.794	9.47	18.8	13.8	16.3	1465.5
4	0.205	0.926	9.44	17.75	16.05	16.9	1639.5
5	0.1668	0.943	6.85	10.25	6.95	8.6	1018.7
6	0.1681	0.877	9.94	18	18.4	17.20	1701.8

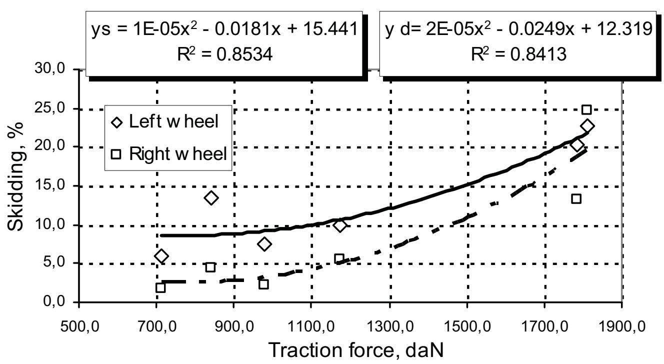


Fig. 6 Skidding of the driving wheels graphical representation as a function of traction force, for the aggregate with automatic hydraulic system

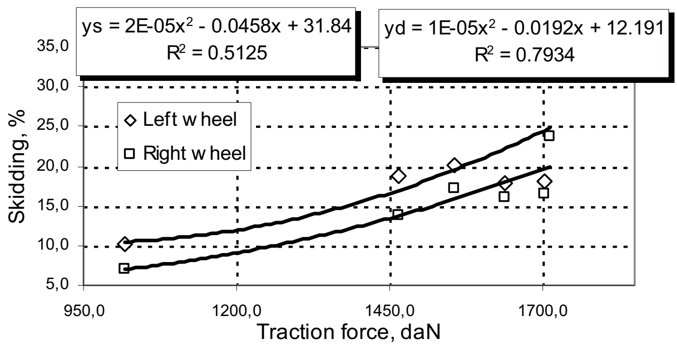


Fig. 7 Skidding of the driving wheels graphical representation as a function of traction force, for the aggregate with working depth detent wheel

Analysing these data it comes out that the skidding of the tractor driving wheels is smaller for the hydraulic system with automatic control of the agricultural machine position towards the soil.

The variation of the fuel consumption as a function of traction force, $C_h = f(F_t)$, represented in figure 8 for each one of the tested aggregates, was another element analyzed during experimental tests.

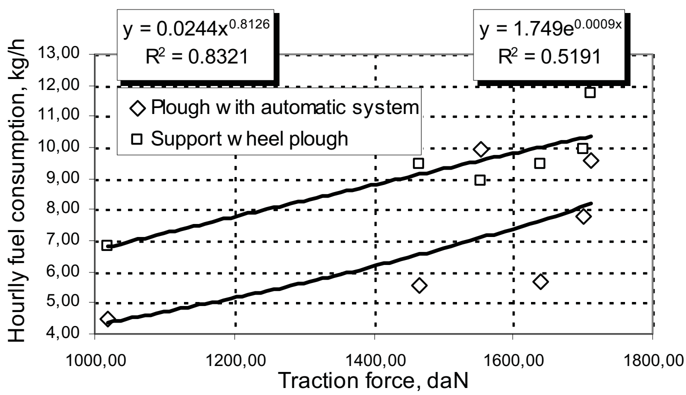


Fig. 8 Graphical representation of the fuel consumption as a function of traction force, for both cases

The variation laws $C_h = f(F_t)$ for both cases were obtained processing the experimental data:

- automat system:

$$C_{h_1} = 0.0345 \cdot F_t^{0.7513} \tag{15}$$

- detent wheel system:

$$C_{h_2} = 0.0244 \cdot F_t^{0.8126} \tag{16}$$

After analysing the experimental results, it comes out that the utilisation of the hydraulic system with automatic control of the agricultural machine position towards the soil reduces the fuel consumption with about 0.7 kg/l at a traction force of 1500 daN.

CONCLUSIONS

The hang up mechanisms which are not equipped with force and/or position control hydraulic systems, impose the existence of the supporting wheel to limit the machine working depth. These systems have the disadvantage that the whole machine weight and the vertical component of the resultant of the forces acting on the operating parts are absorbed by the supporting wheel and its do not transfer to the tractor.

The force and/or position control systems are used with excellent results on flattened and homogeneous terrains.

The system presented in this paper assures, in any working conditions (uneven and/or heterogeneous terrain), a constant depth furrow and, at the same time, it transfers to the tractor the plough weight and the vertical components of the forces acting on it, increasing the pressure on the driving wheels and, thus, by increase de adherence, the traction force and the aggregate productivity increase too, decreasing the skidding and energy consumptions.

As a result of the experimental tests, it comes out that using the presented automat system one can have the following advantages:

- pressure on driving wheels increases by 750 daN;
- skidding decreases by about 29%;
- fuel consumption decreases by about 0.7 kg/h.

The automat hydraulic system, presented in this paper, can be used on any agricultural machinery that needs to determine its position towards the soil.

REFERENCES

1. Dumitrache I. - Tehnica reglării automate, Ed. Didactică şi Pedagogică, Bucureşti, 1980;
2. Marin V., ş.a. - Sisteme hidraulice de acționare şi reglare automată, Ed.Tehnică, Bucureşti, 1981;
3. Muşuroi G – Cercetări privind realizarea unui sistem hidraulic cu reglare automată a poziției maşinii agricole față de sol, teză de doctorat, Facultatea de Ingineria Sistemelor Biotehnice, Universitatea Politehnica din Bucureşti, 2002
4. Muşuroi G., ş.a. - Sistem de reglare a poziției maşinii agricole față de sol, C.M., nr.1-2/2000;
5. Paraschiv G., ş.a.- Acționarea hidraulică a maşinilor agricole, Ed.Printech, Bucureşti, 2000;

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.4:631.45:634.11
Izvorni znanstveni rad
Original scientific paper

MONITORING OF SITE SPECIFIC Fe AND Zn VARIABILITY ON THE APPLE AREA USING THE GIS BASED SPATIAL PATTERN MAPS

TEKIN SUSAM[1], M. RÜŞTÜ KARAMAN[2], FATIH ER[3], İSMAIL İSERI[4]

[1]Gaziosmanpasa Univ., Dept. of Geodesy and Photogram., Tokat, Turkey, tsusam@gop.edu.tr
[2]Gaziosmanpasa Univ., Agri. Fac., Dept. of Soil Sci., Tokat, Turkey, rkaraman@gop.edu.tr
[3]Selcuk University, Dept. of Soil Sci., Vocational School, Konya, Turkey, fatier@selcuk.edu.tr
[4]Gaziosmanpasa University, Dept. of Computer Technology, Tokat, Turkey, iiseri@gop.edu.tr

SUMMARY

Geostatistical approaches is the key issues of the modeling implementation in recent years, and it allows to figure out the spatially distribution of soil parameters. These methods will help to agricultural managements in a more healthy and moderate way, especially in precision farmings. In this study, spatial variability of soil chemical properties such as iron (Fe) and zinc (Zn) were examined on the agricultural apple area. Site specific variations of Fe and Zn on this area were predicted by performing GIS based spatial pattern maps. For this aim, the soil samples were systematically taken from the study area at two depths (0-25 and 25-50 cm). The grid system was used for locating the sample position. As a result of descriptive statistics, the coefficient of variation was lower for Fe levels when compared with Zn levels in both top and subsoil layers. The coefficient of variations for Fe and Zn levels were 24.7%, 42.5% for topsoil and 20.6%, 29.6% for subsoil, respectively. There was also a significant correlation (R^2=0.30, $p<0.05$) between topsoil Zn and subsoil Zn. Geostatistical analysis techniques were used for predicting the spatial structure of soil Fe and Zn levels. The spatial distribution maps were constructed by using Simple Kriging Method (SKM) with spherical semivariogram model for topsoil Fe, SKM with guassian semivariogram model for topsoil Zn. Based on the selected kriging method and semivariogram models, soil Fe and Zn levels were spatially varied within the study area. The maximum range was reached at 29 m for Fe level at the topsoil layer. The ranges were varied between 27 m and 23 m for top and subsoil Zn *levels, respectively. The results have also revealed that soil chemical properties measured could be spatially varied within the small sampling points. For more accurate results, these geostatistical methods should be tested for varied conditions and spatial databases.*

Key words: *GIS, Iron, Zinc, spatial variability, semivariogram, kriging*

INTRODUCTION

Information on spatial distributions of chemical properties of agricultural soils such as iron (Fe) and zinc (Zn) are important for refining farm managements and precision farming. In many studies, importance of spatial analysis of soil fertility properties has been emphasized (Cahn et al., 1994; Han et al., 1994; Gupta et al., 1997). It has been demonstrated that large spatial variability existed at the submeter level for both mobile and immobile soil nutrients (Raun et al., 1998). The results of one study indicated that the fundamental field-element dimensions was likely to be 1.0 by 1.0 m or smaller (Solie et al., 1999). Geographic Information System (GIS) is the key issues of the modeling implementation in recent years to figure out the spatially distribution of soil parameters. These methods will help to the agricultural managements in a more healthy and moderate way especially in precision farmings. However, many researchers have avoided from using geostatistical methods for a long time due to the complexity and difficulty in measurements. Recently, these handicaps were greatly eliminated by commonly using of micro-computers and availability of package software of these methods. Geostatistical analyses have been used to estimate spatial variability of soil properties (Trangmar et al., 1985; Bonmati et al.,1991; Sutherland et al., 1991; Karaman et al., 2009), and soil microbiological process (Aiken et al., 1991; Rochette et al.,1991). Values for soil properties are predicted for the majority of locations in the region where the values are not actually measured (Burgess and Webster, 1980; Webster and Oliver, 2001). Geostatistics provide a tool for improving sampling design by utilizing the spatial dependence of soil properties within a sampling region and useful to illustrate spatial inter-relationship of collected data and it reduces error, biasness and increases accuracy of data for Kriging (Myers,1997). However, these computer based methods should be tested for many varied conditions and spatial databases. The objective of this study was to describe site specific Fe and Zn variability, and monitoring of spatial dependence of these nutrients on an apple area using the GIS based kriging maps.

MATERIALS AND METHODS

This study was conducted on the agricultural apple area located on a flat plain in Konya city (Turkey). The soil texture was clay loam, while the texture of surface layers ranged from clay loam to clay having. The soil is defined as Jawa series and it was classified as clayey. The grid sampling based on 20 m x 10 m was selected for this study because grid sampling reduces a large degree of uncertainty. Fourty five soil samplings were taken at depths (0-25 cm and 25-50 cm), the distance on the X direction was 20 m and on the Y direction it was 10 m. The soil samples were taken using a stainless steel soil auger, and three soil cores from each depth were taken and mixed together to obtain one sample at each point. The soil samples were air dried and ground to pass through a 2-mm sieve, and analyzed for Fe and Zn by flame AAS (Lindsay and Norvel, 1978). Some physical and chemical analyses were also made in the soil samples by routine methods. Organic matter contents were determined by the method of (Walkley, 1947). Determinations were also made for saturation percent (Richards, 1954), $CaCO_3$ (Allison and Moodie, 1958), pH (Jackson, 1958), electrical conductivity (E.C.) (Richards, 1954) and available phosphorus analysis (Olsen et al., 1954) for both topsoil and subsoil samples. In the experimental topsoils; saturation percent was 67.10 %. Average value of $CaCO_3$ was 34.9%, pH was 6.81, organic matter content was 1.90%, available soil phosphorus was 18.85 kg da^{-1} and EC was 407 µmhos cm^{-1}. In the subsoils; saturation percent was 66.00 %. Average value of $CaCO_3$ was 46.9%, pH was 7.25, organic matter content was 1.43%, available soil phosphorus was 12.81 kg da^{-1} and EC was 427 µmhos cm^{-1}.

Geostatistical analysis of the data was performed for determining the spatial structure of topsoil Fe ppm, Zn ppm and subsoil Fe ppm, Zn ppm levels. For this purpose, the ArcMap 9.3 GIS software by ESRI was used for the joining corresponding layers. Geostatistical Analyst, Spatial Analyst and 3D Analyst extendions were used for the geostatistical analysis of the data (Burrough and McDonnell, 2000). Geostatistical analyst extention has a number of models that can be fitted to estimate semivariogram by using non-linear square procedure. In this study, the spherical and guassian semivariogram model were selected according to root mean square error and coefficient of determination (R^2). The spherical function is one of the most frequently used models in geostatistics (Webster and Oliver, 2001). The spherical model is good choice when the nugget variance is important but not too large, and there is a clear range and sill (Burrough and McDonnell, 2000). If the variance is very smooth and the nugget variance is very small compared to the spatially dependent random variation, then the variogram can often best fitted with Gaussian model (Burrough and McDonnell, 2000). The spatial distribution maps were constructed by using Simple Kriging Method (SKM) with spherical semivariogram model for topsoil Fe, SKM with guassian semivariogram model for topsoil Zn, SKM with spherical semivariogram model for subsoil Fe %, SKM with spherical semivariogram model for subsoil Zn, to estimate the values at unsampled locations. Two classes were determined for Fe and Zn according to MAFF classification (MAFF, 1988). According to MAFF classifications, soil samples have classified based on concentration of available heavy metals. According to MAFF classification, Fe has been classified such as, <3, 3-12, 12-25, 25-50, >50, very low, low, sufficient, high, very high respectively and Zn has been classified <1, 1-3, 3-5, 5-8, >8, very low, low, sufficient, high and very high respectively.

RESULTS AND DISCUSSION

According to descriptive statistics shown in Table 1, the mean value of Fe was 2.098±0.519 ppm and 1.972±0.406 ppm for top and subsoil layers, respectively. Whereas, the mean value of Zn was 0.731±0.311 ppm and 0.787±0.233 ppm for top and subsoil layers, respectively. The coefficient of variation (CV %) for Fe levels was lower when compared with Zn both top and subsoil layers. The CV values of Fe and Zn were 24.7%, 42.5% for topsoil, and 20.6%, 29.6% for subsoil, respectively (Table 1). Similar studies carried out on the orchards have also revealed that minimum variation was found for Fe levels, and it was maximum for Zn levels (Kılıc et al., 2008).

Table 1 Descriptive statistics of top and subsoil parameters measured on the study area

Parameters	N	Min.	Max.	Mean	SD	C.V %	Kurtosis	Skewness
Topsoil Fe	45	1.36	3.74	2.098	0.519	24.7	1.167	4.222
Topsoil Zn	45	0.23	1.99	0.731	0.311	42.5	2.000	8.160
Subsoil Fe	45	1.27	3.52	1.972	0.406	20.6	1.250	6.110
Subsoil Zn	45	0.41	1.49	0.787	0.233	29.6	0.647	3.606

Results also showed that there was a significant correlation (R^2=0.30, $p<0.05$) between topsoil Zn and subsoil Zn. The semivariogram models and parameters of soil properties are shown in Table 2. The nugget effects (Co) for Fe and Zn were calculated zero for topsoil and subsoil layers. The range is the distance (*h*) at which semivaryans valuẹattains the maximum value (sill). Often the sill (Co + C) is approximately equal to the sample variance (Journel and Hujibregts, 1978). The values of the sill variance for topsoil Fe was 0.297 ppm and 0.139 ppm for subsoil Fe. The values of the sill variance was 0.109 ppm for topsoil Zn and 0.058 ppm for subsoil Zn (Table 2).

Table 2 Characteristics of selected semivariograms for Fe and Zn levels

Parameters	SD*. Model	Nugget C_0	Sill C_0+C	(C-C_0)/C %	Correlation R^2	Range m
Topsoil Fe	W-Spherical	0.000	0.297	100	0.68	29
Topsoil Zn	W-Guassian	0.000	0.109	100	0.81	27
Subsoil Fe	W-Spherical	0.000	0.139	100	0.40	22
Subsoil Zn	W-Spherical	0.000	0.058	100	0.70	23

*Spatial distribution (S-strong spatial dependence (<25%); M-modarate spatial dependence (26-75%); W-Weak spatial dependence (>75%);

The range can be interpreted as the diameter of the zone of influence. At a distance less than the range, measured properties of two samples become more alike with decreasing distance between them. Thus, the range provides estimate areas of similarity. In this study, the range were varied between 29 and 22 m for top and subsoil Fe, respectively, 27 m and 23 m for top and subsoil Zn, respectively. Zone of influence for topsoil Fe and topsoil Zn was greater than the subsoil layer. This is expected due to the effect of fertilizer addition during the apple-growing season. Kriging maps, three dimention visualitation and related semivariogram models, demonstrated the spatial pattern of the concentration of Fe (Fig. 1). As it is seen from Fig. 1, for the top layer map, very low Fe has covered the most of the field. Also, low concentration Fe has covered the left and right middle of the field. For the sublayer, very low Fe concentration has almost covered all of the area of the field. Only very little Fe concentration has been seen at the top left corner of the field. So, the topsoil might contain high organic matter which could hold nutrients more than the subsoil.

The spatial pattern maps for top and subsoil layers for Zn are shown in Fig. 2. For the top layer, very low Zn concentration was found, covering most of the area, also some areas with low Zn concentration in the top right of the field. For the sub layer, the Zn concentration is almost very low. Some low Zn concentration has been seen at the left side and at the top right side of the field. Soil nutrients such as Fe and Zn seem to have a much smaller range and may vary within a short distance. Therefore, more soil samples are required to characterize the spatial variance.

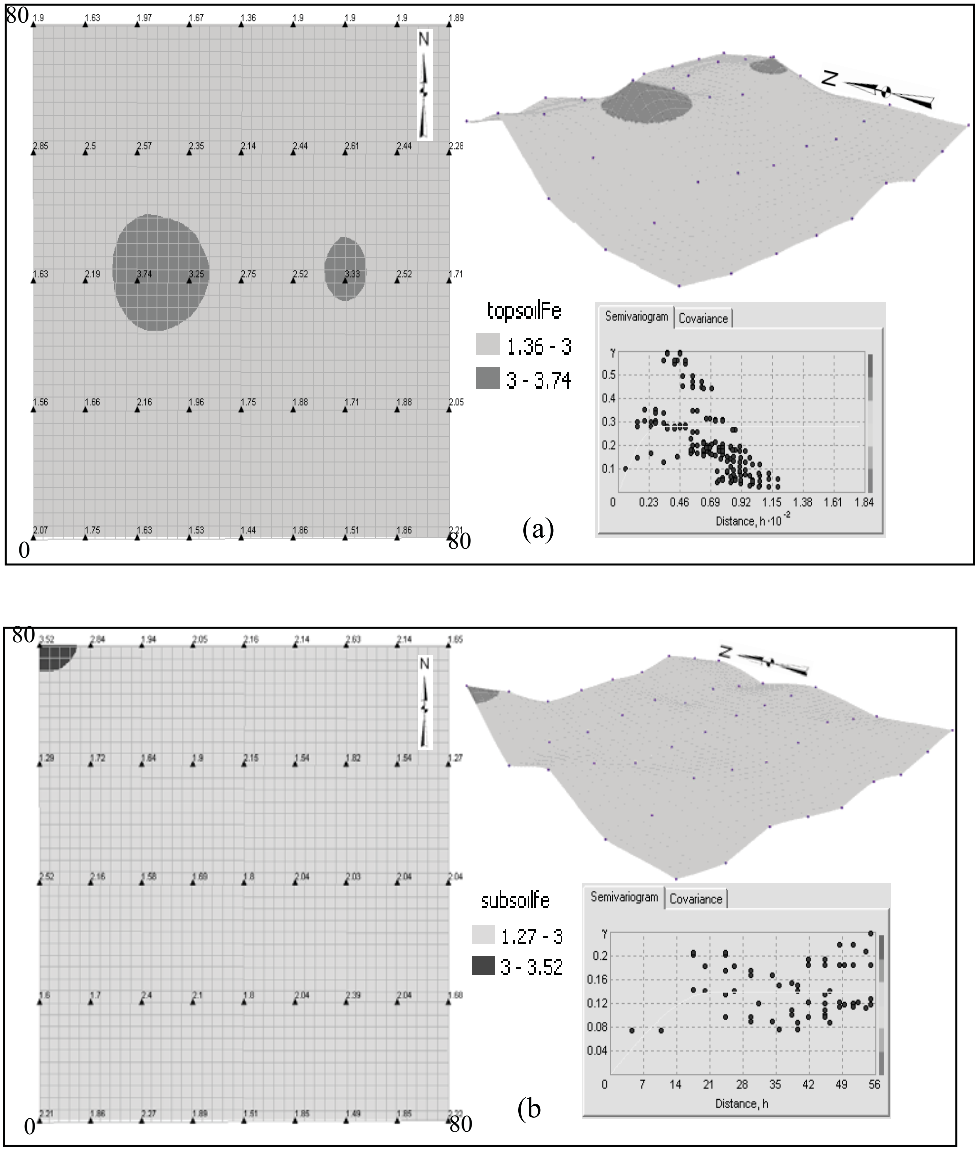
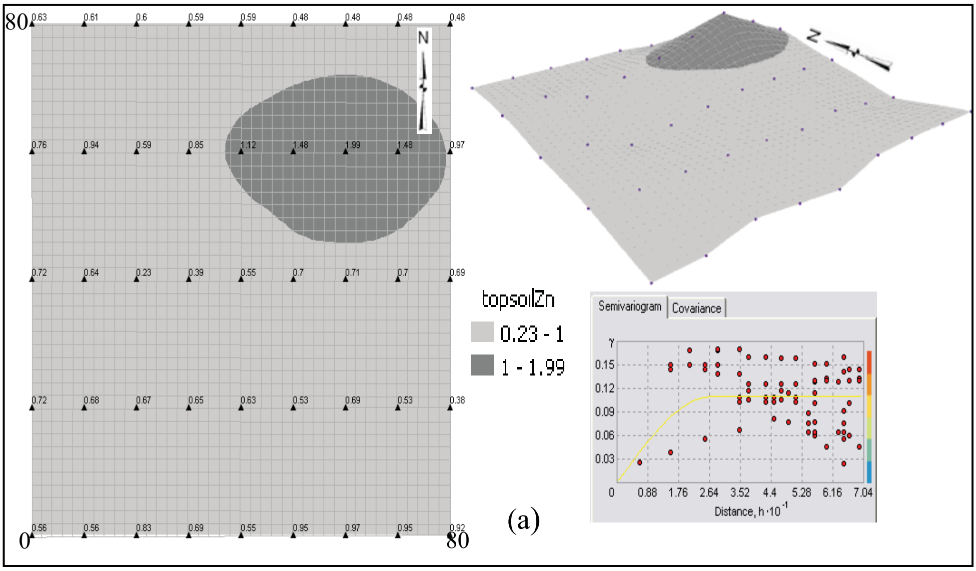


Fig. 1 Kriging maps showing distribution of Fe levels for top (a) and subsoil layers (b)



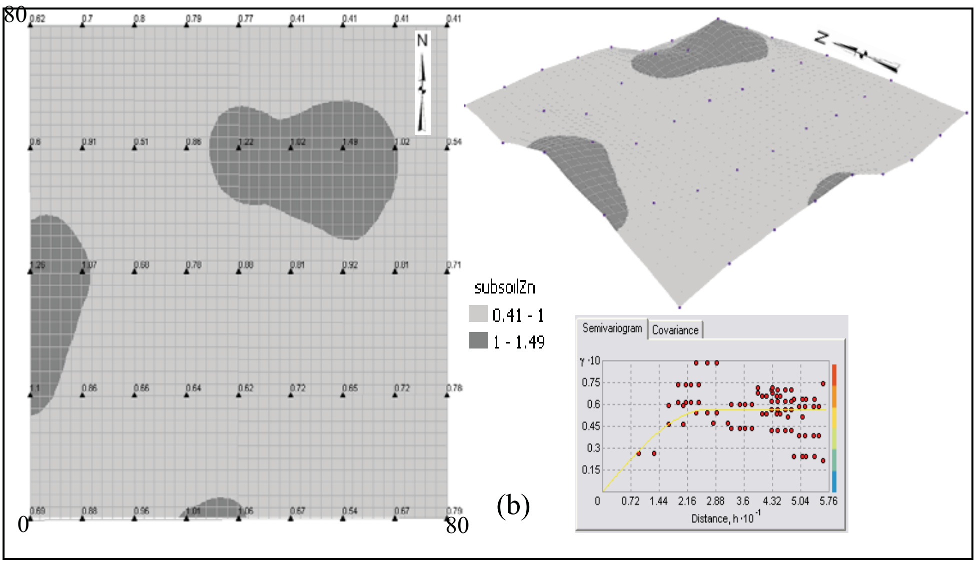


Fig. 2 Kriging maps showing distribution of Zn levels for top (a) and subsoil layers (b)

CONCLUSIONS

The variability of soil chemical properties such as iron (Fe) and zinc (Zn) were examined on an apple area. Predictions of site specific variations of Fe and Zn on this area were made by performing GIS based spatial pattern maps. As a result of descriptive statistics, the coefficient of variation for Fe levels was low when compared with Zn levels both top and subsoil layers. The spatial distribution maps were constructed by using Simple Kriging Method (SKM) with spherical semivariogram model for topsoil Fe, SKM with guassian semivariogram model for topsoil Zn. Kriging maps, three dimention visualitation and related semivariogram models demonstrated the spatial pattern of the concentrations of Fe and Zn in the experimental area. According to the selected kriging method and semivariogram models, soil Fe and Zn levels were spatially varied within the study area, the maximum range was reached at 29 m for topsoil Fe levels. Whereas, the ranges of the semivariogram were varied between 27 m and 23 m for top and subsoil Zn levels, respectively. Kriging maps calculated from the semivariogram was employed for spatial distribution map. The results showed that measured soil properties like Fe and Zn levels could be spatially vary within a short distance. Hence, more soil samples are required to characterize the spatial variance of these nutrients. The results have also revealed that kriging maps could improve the decision support for field management practices, such as fertilizer recommendation rates. The soil chemical properties commonly had spatial dependence and that understanding such structure may provide new insights into soil behavior for the land management. Evaluation of these methods will help to the agricultural managements in a more healthy and moderate way, especially in precision farmings. However, for more accurate results, these geostatistical methods should be tested for varied conditions and spatial databases.

REFERENCES

1. Aiken R.M., Jawson M.D., Grahammer K. and Polymenopoulos A.D. (1991). Positional, spatially correlated and random components of variability in carbon dioxide flux. J. Environ. Qual. 20:301-308.
2. Allison L.E. and Moodie C.D. (1965). Carbonate, In: Methods of Soil Analysis. Part 2., Agronomy J., Vol:9, pp. 1379-1400.
3. Bonmati M., Ceccanti B. and Nanniperi P. (1991). Spatial variability of phosphate, urease, protease, organic carbon and total nitrogen in soil. Soil Bio. Biochem. 23: 391-396.
4. Burgess T.M. and Webster R. (1980). Optimal interpolation and isarithmic mapping of soil properties. 1. The semivariogram and punctual kriging. J. Soil Sci. 31:315-331.
5. Burrough P.A. and McDonnell R.A. (2000). Principles of Geographical Information Systems, Oxford University Press, New York.
6. Cahn M.D., Hummel J.W. and Brouer B.H. (1994). Spatial analysis of soil fertility for site-specific crop management. Soil Sci. Soc. Amer. J., 58:1240-1248.
7. Gupta R.K., Motaghimi S., McClellan P.W., Alley M.M. and Brann D.E. (1997). Spatial variability and sampling strategies for NO3-N, P, and K determinations for site-specific farming. Trans. ASAE., 40:337-343.
8. Han S., Hummel J.W., Goering C.E. and Cahn M.D. (1994). Cell size selection for site-specific crop managemet. Trans. ASAE, 37:19-26.

9. Jackson M.L. (1958). Soil Chemical Analysis. Prentica-Hall Inc., Englewood Cliffs. New Jersey, USA.

10. Journel A.G. and Hujibregts C.H. (1978). Mining Geostatistics. AC-Academic Press, New York. Lascano, R.J. and Hatfield, J.L. 1992. Spatial variability of evaporation along two transects of Abare soil. Soil Sci. Soc. Am. J. 56:341-346.

11. Karaman M.R., Susam T., Yaprak S. and and Er F. (2009). Computer based geostatistical strategies in assessing of spatial variability of agricultural phosphorus on a sugarbeet field. IACSIT International Association of Computer Sci. and Information Technology, Proceedings of ICIME, Vol:13, pp. 201-205, Maleysia.

12. Kılıc C.C., Ongun A.R., Okur B. and Anac D. (2008). Geostatistical evaluation of the secondery plant nutrient status of satsuma mandarines in Gumuldur-Izmir. 4th National Plant Nutrition and Fertilizer Congress, Proceedings Book, pp.143-152, Konya, Turkey.

13. Lindsay W.I. and Norvel W.A. (1978). Development of DTPA. Soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Amer. Jour. Vol:42, No:3.

14. Maff. (1988). Fertilizer Recommendations. Reference Book 209, HMSO, London.

15. Myers J.C. (1997). GeoStatistical error management quantifying uncertainity for environmental sampling and mapping. Thomson Publishing Inc., U.S.A.

16. Olsen S.R., Cole C.V., Watanable F.S. and Dean L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Agricultural Handbook, U.S. Soil Dept. 939, Washington D.C.

17. Raun W.R., Solie J.B., Johnson G.V., Stone M.L., Whitney R.W., Lees H.L., Sembiring H., Phillips S.B. Microvariability in soil test, plant nutrient, and yield parameters in bermudagrass. Soil Sci. Soc. Am. J. 1998; 62:683-690.

18. Richards, L.A. (1954). Diagnosis and improvement of saline and alkaline soils USDA Agricultural Handbook, 60, Washington, D.C.

19. Solie J.B., Raun W.R. and Stone M.L. (1999). Submeter Spatial Variability of Selected Soil and Bermudagrass Production Variables, Soil Sci Soc Amer. J., 63: 1724–1733.

20. Trangmar B.B., Yost R.S. and Uehara G. (1985). Application of geostatistics to spatial studies of soil properties. Advances in Agronomy, Vol:38:45-93.

21. Walkley A. (1947). A critical examination of a rapid method for determining organic carbon in soils. Soil Sci. Vol:63, pp. 251-263.

22. Webster R. and Oliver M. (2001). Geostatistics for environmental Scientists. John Wiley & Sons, U.K.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 543.42:631.42
Izvorni znanstveni rad
Original scientific paper

SOIL PROPERTIES MAPPING USING SPECTROPHOTOMETRY

VERGIL MARIAN MURARU[1], PETRU CARDEI[1], CORNELIA MURARU-IONEL[1], ION PIRNĂ[1], ION TENU[2]

[1]National Institute of Research Development for Machines and Installation designed to Agriculture and Food Industry, 6 Ion Ionescu de la Brad Blv, sector 1, 013813 Bucharest, Romania
[2]University of Agricultural Sciences and Veterinary Medicine, 3 Aleea Mihail Sadoveanu, 700490 Iasi, Romania

SUMMARY

The mapping of the agricultural soil properties is a new developed method that used the latest generation technologies involving a mobile platform with sensors and spectrophotometers. Making maps of agricultural soil properties is carried out based on data collected in real time from ground, using the geo-spatial coordinates, provided by the Global Positioning System (GPS).

In order to rationally apply the fertilizer, the agricultural chemistry considers that one of its important tasks consists in determination of soil nutrients, soil analysis and especially determining their needs. Supply of available nutrients from the soil is not represented by a stable size it depends on numerous factors such as soil type, geological origin, soil texture and structure, biological, climate, etc.

Therefore, accurate determination of the chemical fertilizers requirements is done, taking into account all these factors. Efficiency of using chemical fertilizer depends not only on soil composition, but also on the particularities of culture nutrition.

Between the chemical composition of soil and chemical composition of plants there is a close relationship and this reflects one of the basic principles of biology, that of unity between body and environment in which it lives. Methods used until now have managed to accentuate in plants almost all of the chemical elements of Mendeleev's table.

Key words: *spectrophotometer, soil mapping, Global Positioning System (GPS), information system*

INTRODUCTION

The recent results of technical development of low cost GPS systems, geographic information systems, equipment and sensors which are needed to identify the state of the crops and soils have shown a growing awareness in agriculture and related sciences. The actual demand for modern crop management is dominated by the economic pressure and by the social request to increase the transparency of environmental impact of agricultural land.

Mapping represents action tracking on field and transposition through conventional signs and colors, on topographic maps of the spread and characteristics of various elements in nature (rocks, geological formations, water, soils, etc.).

Using active sensors for soil variability in order to define its variability, together with laboratory calibrations lead to improve accuracy of the maps of soil constituents.

The active mapping technology of soil can be classified as: electrical/electromagnetic, optical/radiometric, electro-chemical, mechanical, acoustic and pneumatic (Gebbers. R. and al.,2007).

To obtain high yields and good quality, a great importance have chemical fertilizers which complete the supply of soil nutrients, necessary substances for normal growth and development of plants. In order to rationally apply the fertilizer, the agricultural chemistry considers that one of its important tasks consists in determination of soil nutrients, soil analysis and especially determining their needs.

Supply of available nutrients from the soil is not represented by a stable size, it depends on numerous factors such as soil type, geological origin, soil texture and structure, biological, climate, etc. Efficiency of using chemical fertilizer depends not only on soil composition, but also on the particularities of culture nutrition..

Assessment of productive capacity, choosing the most appropriate way to use the land, and cultivation technology based on scientific bases and in relation to the degree of accessibility, contribute to the conservation and sustainable productivity, and thus to increase the resilience capacity of the most sensitive and fragile soils, so that improved technological systems have positive synergistic effect.

METHODS

Spectrophotometry is an optical method of analysis used in qualitative analysis and quantitative material known or unknown, pure or impure state, falling into the category of methods for mapping the agricultural soils of last generation. Using measurements one can determine the presence or absence of various elements or functional groups, and the quantity in which they are subject to material analysis.

Data derived through the spectroscopic measurement is presented as a graphical representation of energy absorbed or emitted, depending on the position of the electromagnetic spectrum. This chart is called the spectrum.

Spectrometers are being used in commercial agriculture today in milling, forage, meat processing and more (*** http://www.veristech.com). But using them to measure soil properties is relatively new. Spectrophotometers move these measurements out to the field, providing a platform for research into soil properties as they vary within a field. Payments for soil carbon may soon represent an additional source of farm income. Provided carbon can be measured accurately.

Someday, technology like this may be used to augment or replace traditional laboratory analyses for other soil constituents. All these possibilities require soil research made possible with tools like the Veris VIS - NIR spectrophotometer.

When light hits soil, molecules react: they vibrate. This vibration absorbs some of the light. How much light is either absorbed or reflected depends on what's in the soil. Soil with strong C-H, N-H, and O-H bonds absorb more light, which is why wet soil or soil with high organic matter looks darker, even to the naked eye. Spectral data, especially in the near - infrared, is even more powerful. The reflectance signature of a spectrum can be used to measure carbon, nitrogen and water content of soil and related to some soil chemical properties as well.

Precision measurement of the quantity of carbon may be an additional source of income for farmers.

During soil properties mapping can be used an information system which consists mainly of:

- Geostationary satellites;
- Global Positioning System - GPS or Differential Global Positioning System - DGPS (correct inaccuracies induced by the GPS system);
- Laptop for recording and processing data collected from the field and for maps of soil properties;
- Mobile Sensor Platform and NIR Spectrophotometer:
- Temperature sensor;
- Optical sensor;
- Coulters electrodes for electrical conductivity.
- Software for processing data collected from field;
- Geographical Information System - GIS (AutoCAD Civil 3D, ArcGIS, Google Earth);
- Software for modeling and simulation of nutrient requirements (virtual maps with nutrients).

Figure 1 shows the architecture of information system for soils properties mapping.

Veris Technologies, Inc., USA has developed a spectrophotometer for measurements in the soil. An on-the-go shank collects VIS-NIR measurements at a consistent depth—adjustable from 1.5 to 4 inches (38 to 102 mm) as it passes across a field.

The on-the-go shank collects VIS-NIR measurements (450…2200 nm) through a sapphire window pressed directly against the soil, at a rate of 20 spectra per second with an eight nm resolution. The shank is equipped with six coulter electrodes, which measure soil EC at 0…30 cm and 0…90 cm arrays.

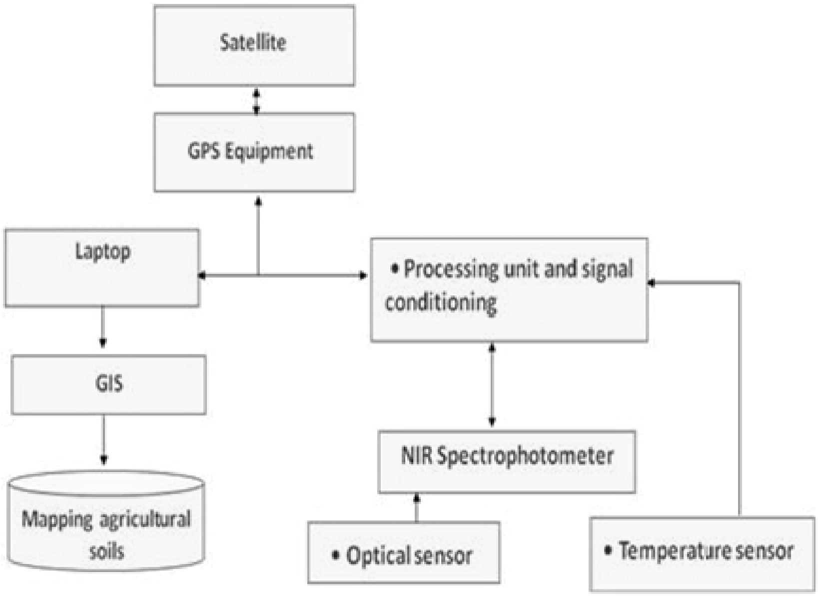


Fig. 1 Architecture of information system and measuring through satellite

At the heart of the VIS-NIR system is the optical shoe-the soil-engaging part of the shank (Fig. 2) (*** http://www.veristech.com).

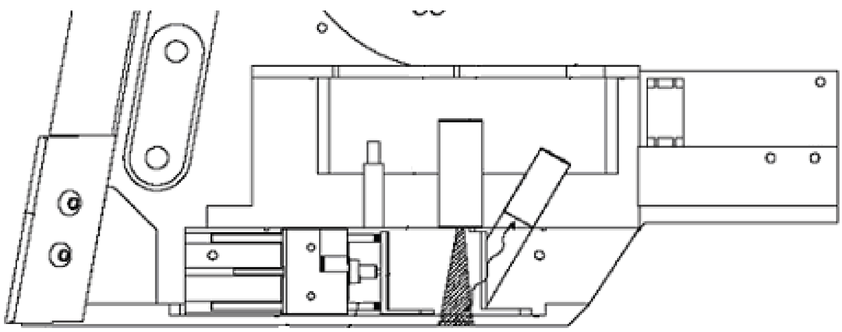


Fig. 2 Optical sensor

On the bottom of the shoe is a nitrite-hardened wear plate containing a sapphire window. Inside the intricately machined housing is a tungsten halogen bulb that illuminates the soil through the window, and an optic that directs reflected light into a fiber-optic cable for transmission to the spectrometer (Fig. 3).

In front there is a fluted coulter which slices through field residue and cuts a slit in the soil, followed by the shoe with optical sensor (Fig. 4).

Fig. 3 VIS-NIR shank during work

Fig. 4 Detail shank with optical sensor

Veris VIS-NIR spectrophotometer can be set as stationary mode in the laboratory for measurements of samples of absorbers (the samples). Method of determining the properties of soil components using NIRS spectrophotometric method is based on infrared spectroscopy (Fig. 5).

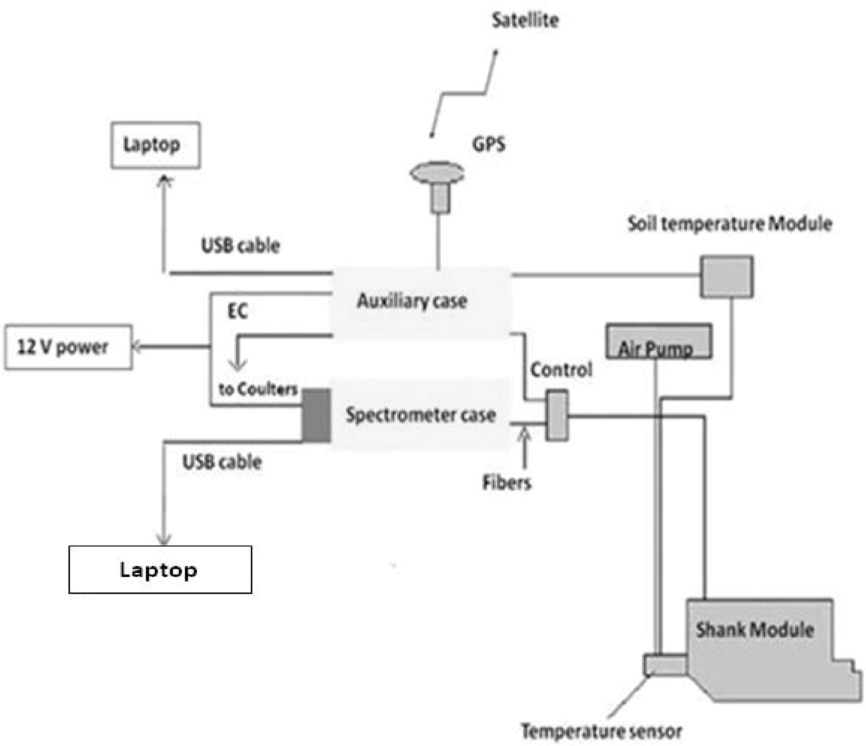


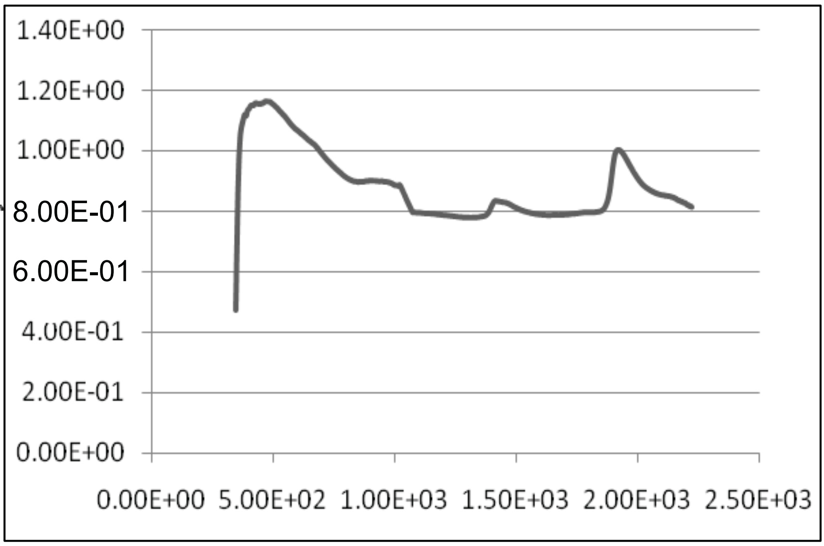
Fig. 5 System diagram

The Veris VIS-NIR spectrophotometer is controlled by a PC-based operating system, which ensures instrument control, data-recording, and data standardization functions (*** http://www.veristech.com).

The principal data registered:

- Soil reflectance measurements in a wide range;
- The auxiliary data recorded by the EC equipment :
- Electrical Conductivity Shallow (EC_SH);
- Electrical Conductivity Deep (EC_DP);
- Soil Temperature.

A typical spectrum for each measurement location appears in Fig. 6. This spectrum is interpreted using the calibration analysis and/or an atlas (archive) of tested soil, obtaining a likely concentration of some interest substances in the mapping parcel.



Wavelength, nm

Fig. 6 Typical spectrum for each measurement location.

The simulation location was chosen in the testing ground of INMA, as seen in Fig. 7. In Fig. 8 it is given a detailed picture of the parcel on which the theoretical tests had been performed.

There were simulated measurements in 2441 locations, having as results the absorbance spectra and as the final result the soil characteristics obtained by interpretation, which may be: the content of organic matter, organic carbon content, nitrogen content and other characteristics.

Working depth was approximately 3.8 cm. Therefore, the concentrations of substances listed above correspond to the shallow soil layer 0 - 3.8 cm.

Fig. 7 General view of simulating location

Fig. 8 Detailed view of simulating location

An example of map of the distribution in land of an interest component concentration (resulting from the interpretation of spectra in each measurement), is given in Fig. 9.

Overlaying of the map of distribution of the interest component mapped over aerial image plot appears in Fig. 10. This map can be used by the customer to correct any adverse situations (low content of the substance on the entire parcel or small areas of the case in which intervention is recommended at the local level (precision agriculture) (Lamp J. and al., 2001).

The 3D representation of concentration is given in Fig. 11, and an aerial view is given in Fig. 12.

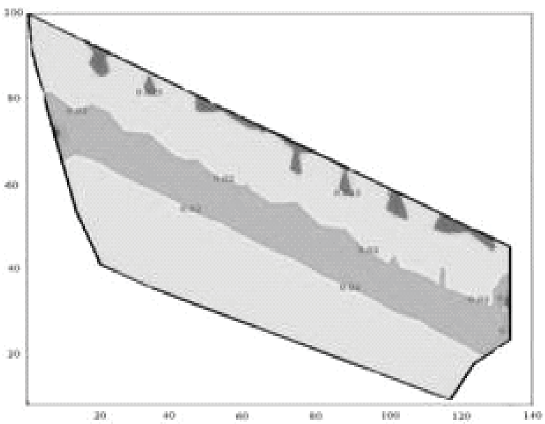


Fig. 9 Map of distribution of an interest component in the mapping domain [m, concentration]

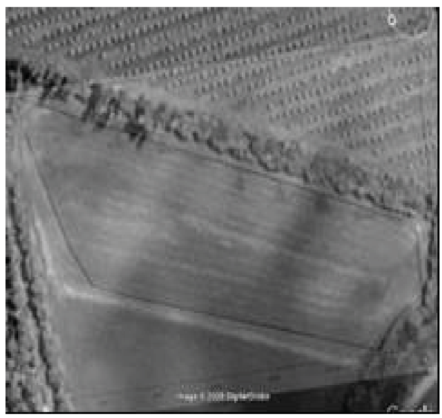


Fig. 10 Overlaying of the map of distribution of the interest component mapping over aerial image of the parcel

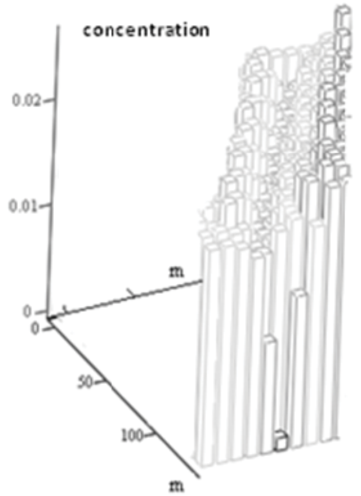


Fig. 11 Representation by bars of the concentration in the field mapped

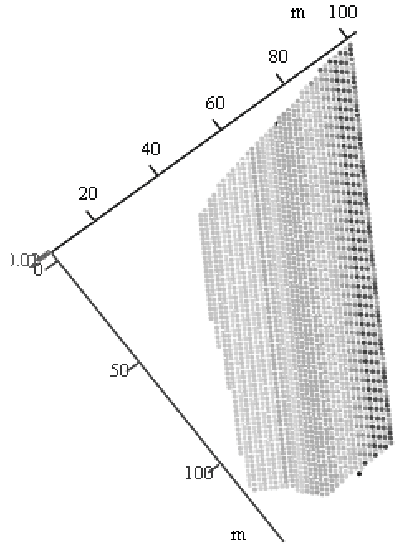


Fig. 12 Aerial view of representation from Fig. 11

RESULTS AND DISCUSSION

Agriculture was becoming an important supplier of greenhouse gases emissions while the farmers were anxious in point of view of payments for isolation the carbon and the nitrous oxide emissions from the excessive fertilizations with nitrogen, applied in agricultural crops (Lund E.D. and al., 2007).

The identification accuracy of the isolation carbon levels in soil is very important because leads to reduce atmospheric carbon by increasing the amount of carbon stored in soil. This would entail the collaboration with farmers for determining the quantity of carbon in their soils, using accurate measurements to checking the amount of carbon stored.

Measurements made to determine changes in soil carbon levels are difficult, because increasing the amount of (expected) probable carbon is small in comparison with the amount of carbon variability within many fields.

Using informational system we can obtain detailed maps of field and profile soil properties using calibration/validation soil sample (C.D. Christy, 2008).

Limits on greenhouse gas emissions could create a market for soil-sequestered carbon if we can accurately measure the level of carbon.

The carbon content widely varies in the same field. Using conventional method (by sampling) it is very expensive and very difficult (to obtain an accuracy similar to new system is necessary thousands samples).

Soil near infrared spectroscopy has big research potential to develop new methodologies and correlation between multiple soil properties.

A summary of the main stages of the mapping of soil properties using spectrophotometry, should include these steps:

- Marking territory (land, geometric properties, areas, elevations, etc..) for mapping, in order to characterize border and relief, eventually using GIS techniques in order to create GIS databases;
- Effective mapping of the working field chosen (the real border of it, resulting only from processing of the experimental data), after which the resulting data files will contains essentially the following data:
  - geographical coordinates of each measurement point (latitude, longitude and altitude);
  - intensity diagram - NIR wavelength for each soil sample;
- Processing of the raw experimental data;
  - transformation of geographical coordinates (geodetic) in rectangular coordinates and their relativization to a domain reference point (as in the example above, top left, top, point zero of the border);
  - graphical representation of intensity-wavelength dependencies for each sample measured during mapping process, its storage in computer memory.
- Calibration classical chemical analysis of the soil samples in the vicinity of the measurement locations (mapping), having provided the chemical composition of the soil, according to the standards in force;
- The interpretation of data recorded using the mapping results and the results of chemical analysis, endeavoring to obtain some relationships between chemical composition and NIR spectrum resulted during mapping process;
- Generalization of interpretation to the whole lot of data mapped, resulting a data structure of type: rectangular coordinates (abscissa, ordinate, elevation) with concentrations of interest elements;
- Creation of distribution maps of the soil interest components using the rectangular coordinates (usually, the abscissa and ordinate, for enough flat land) the third coordinate being the target component concentration (in case of tormented relief when the third coordinate is required elevation will have to represent the followed component concentration through variation of a color or multicolored maps, the conventional caption, which is somewhat more complicated);
- Archiving the results in terms of connection between the chemical composition of soil, determined by the conventional analysis and the resulted one as a result of interpretations of spectral diagrams;
- Eventually completion of results in the GIS file that describes the field mapped in order to an eventual archiving or tracking of its evolution in time;

Finally, the maps will be used by farm managers for remediation of the chemical composition of soil surface with deficient, either in whole or locally, as the map shows.

It also the results given through maps, will be integrated into the files of creditworthiness of agricultural land or will be used to predict the fertilizer need or optimal crop in the area.

CONCLUSIONS

Precision agriculture gives place to a new methodology (which is targeted by a new agricultural system) and may be one of the keys to sustainable agriculture.

Favorable development opportunities for precision agriculture are the followings:

- ability to understand the complexity of farming systems - a systemic and holistic approach, through precision measurements of soil composition;
- ability to monitoring the phenomena and systems - computer - controlled data acquisition;
- achievements in IT filed: hardware, software and databases allow this approach;
- improvements of interpretations and methods of calculation: statistical modeling, simulation;
- through soil mapping it is opening the way of decision support systems for agriculture, based on data collected from the field;
- modern measurements based on spectrophotometer make their appearance in agriculture;
- analysis of soil properties and the role of the nutrients elements for crop growth and agricultural development are key factors in developing a sustainable agriculture;
- analysis of fertilizers for agriculture and their regulate administration will be the basic element in the development of precision agriculture methods in the mapping and distribution of soil necessary nutrients (A. Luchiari, J. Shanahan, D. Francis, et al., 2000);
- the informational system for agricultural soils mapping opens the way to researches, as base of soil absorbance measurements can determinate other elements of interest in soil composition;
- through mapping, the system may contribute to reduce the emission of greenhouse gases.

REFERENCES

1. C.D. Christy (2008), Real-time measurement of soil attributes using on-the-gonear infrared reflectance spectroscopy, computers and electronics in agriculture 61 (2008), ELSEVIER, 10–19
2. Gebbers R. and al., (2007), Depth sounding with the EM38-detection of soil layering by inversion of apparent electrical conductivity measurements in Precision Agriculture ’07, Wageningen Academic Publishers, 95-102

3. Lamp J. and al., (2001), Precised and efficient soil surveys as basis for application maps in precision agriculture, Agro Montpellier Proc. 3 th European Conference on Precision Agriculture, vol.1, 49-54

4. Luchiari A. and al., (2000) Strategies for establishing management zones for site specific nutrient management [CD- ROM], Proc. 5-th International Conference on Precision Agriculture, P. C. Robert, Ed., Minneapolis, USA

5. Lund E.D. and al., (2007), Soil carbon and nitrogen mapping: How these relate to new markets and public policy

6. Lund E.L. and al., (1999) Practical applications of soil electrical conductivity mapping, Proc. 2 th International Conference on Precision Agriculture, J. V. Stafford, Ed., Odense, Denmark, 772-778

7. *** http://www.veristech.com

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.42:519.85
Pregledni rad
Review paper

MIXED TECHNIQUES SOFTWARE FOR ENVIRONMENT PROBLEM INVESTIGATION

PETRU CARDEI[1], VERGIL MARIAN MURARU[1], RALUCA SFIRU[1], VASILE HEREA[2], CORNELIA MURARU-IONEL[1]

[1]National Institute of Research Development for Machines and Installation designed to Agriculture and Food Industry –INMA
6 Ion Ionescu de la Brad Blv, sector 1, 013813 Bucharest, Romania
[2]ICDVV No 1, Valea Mantei Street, Valea Calugareasca, County Prahova, Romania

SUMMARY

This paper presents the results obtained by authors of research within the last 4 to 5 years. Research has been taken toward environmental issues. The authors try to impose a single viewpoint on environmental issues, uniting pure observation areas at the prediction of environmental phenomena in a modern vision, guaranteed by computing used. To achieve this aim, is developed a methodology whose central nucleus are methods based on a database containing information on software and software used in a modern approach to environmental issues. The methods contained in this methodology indicate binding processes of observation data from different sources (regular observation data, imaging data from air, etc.) with mathematical modeling of the environmental phenomena by methods of mathematical physics and solved by numerical methods. For retrieval and storage of data, we used a wide range of GIS software. To solve mathematical models, that model environmental phenomena, we used commercial software, free or developed by the authors. Both software are part of the software methodology. The methodology contains a rich archive of applications in various fields. Because the institutions where the authors belonging have the main activity in agriculture, most examples of environment-agriculture interaction phenomena. Pollution of soil mechanics (compacting), pesticide pollution, noise pollution of agricultural machinery, soil erosion, landslides, is only part of the border problems is the environment-agriculture. In essence, the two areas, agriculture and environment are intimately linked and influence each other.

Keywords: *GIS, numerical analysis, software, methodology*

INTRODUCTION

Currently, most times, investigation, reporting and the remediation of environmental problems, is made after schemes which don't use the latest possibilities of the science. Is using standardized observations for reporting and the actions are made after procedures, in general, arbitrary.

We have a unitary vision about the environment. Identifying, reporting and solving environmental problems must be done using a unitary theoretical and experimental scientific apparatus. This scientific apparatus is a methodology called EMGNA (Environmental Method based on GIS and Numerical Analysis software). EMGNA methodology has three components: a GIS database software and numerical analysis, a collection of methods to address environmental classical problems and a database containing practical applications of this device. We intend to widespread use of this methodology for solving environmental problems using GIS techniques and numerical analysis programs. Classical methods and GIS techniques are used for observation, referral and identification of environmental problems. These components will be sources of data for numerical analysis programs. Numerical analysis programs are used for mathematical modeling and simulation of environmental problems. Following the simulations are obtained forecasts and remedial optimal procedures. This way of dealing with environmental issues leads to procedures for rapid response to predictable environmental events relative to specific geographic areas.

For the moment, the main schedule of the environmental problems is done, but the specific of this domain gives to the methodology a dynamic character, because, in time, it is possibly to appear new category or subcategory, which required new solutions and new tools for obtain these solutions. In conclusion the methodology is a live and includes permanently new problems and domains. In this domain will appear permanently new problems and new solution for the new or for the old problems.

The environmental problem category assignation of the software are well described in the actual stage of the project if we are using the table 1.

METHODS

EMGNA short description

EMGNA methodology base structure is given in Table 1 and is based on classic themes of environment. For each topic there are one or more methods. These methods are experimental, theoretical or mixed (joint) theoretical and experimental.

List of GIS software used in working with EMGNA, appears in Table 2. All lists are opened, meaning you can add or remove components. Programs recommended for each category of environmental issues included in EMGNA methodology, appear in Tables 3 and 4. So far, not been included problems of radioactive pollution, wind erosion and flooding.

The database includes information on recommended programs: if are free or commercial, or belongs of the authors or users of the methodology. Producer's web page addresses of these programs are given.

For some programs are given applications: examples of software documentation or examples of the methodology authors.

Working with EMGNA expected to be made in open networks, where each user may proposes new and free applications and may request permission to use programs or applications belonging to community members who use EMGNA.

Table 1 EMGNA methodology structure

MIGAN Methodology	Methods
Soil mechanical pollution	method for estimation of soil compaction
Soil chemical Pollution	method to assess the impact of pesticides on the environment
Air Pollution	method for estimating chemical air pollution forecast
Water Pollution	method of assessment and remediation of water pollution by oil
	method of assessment and remediation of chemical pollution of aquifers
Soil Water Erosion	method for estimating the risk of erosion of slopes by water action
Hill slope stability	method to estimate the stability of slopes
Noise Pollution	empirical method for estimating the noise from one source to the environment
	theoretical and empirical method for estimating the noise source in an environment

Table 2 GIS software for use in EMGNA

ArcGIS	MapGuide Open Source
AutoCAD Civil 3D	MapWindow GIS
Chameleon	Open Layers
Geo Tools	PostGIS
GeoNetwork opensource	QUANTUM GIS
Google Earth	SAGA GIS
GRASS	SmartDraw
gvSIG	TerraView
ILWIS	uDIG
JUMP GIS	XARA
Map Maker	Xastir
	AutodeskMap3D

Table 3 Software for various environmental issues

Soil mechanical pollution	Soil chemical pollution	Air Pollution	Water Pollution
GeoStudio2007	Soil 3.00 (2005)	ALOHA	BIOPLUME III
COSMOS/M	VS2DHI 1.2	STANMOD	ADIOS
Soil Vision SOLID	STANMOD	AIRMOD	STANMOD
Geo5 FEM	WIN-PST 3	DISPER	StormNET
Geo5 Settlement	Soil Vision Chemflux	SIMTRAP	River CAD
	Soil Vision Flux	TRAQS	DESCAR
	Soil Physics Software Tools		AQTESOLV
	PESTAN 4.0		Aquifer Test Pro
	PIRI		Aquifer Win 32
	GeoStudio2007		AQUIPACK

Table 4 Software for various environmental issues

Soil Water Erosion	Hillslope stability	Lands Collaps	Noise Pollution
WEPP	STB	Geo5 FEM	SoundPlan
RUSLE2	STABLE Free	GEO5 (Ground loss)	Custic
USLE	GeoStudio2007		Predictor 5.1
ECMDS 4.31	Geo5 FEM		Lima5.0
	TSLOPE		CadnA
	CHASM		
	FLAC/SLOPE		
	LISA		
	DLISA		
	GeoStru		
	SLOPE		
	Soil Vision SVDYNAMIC		
	GSTABL7		
	MSTAB		
	Galena		
	Geo5 Slope Stability		
	Geo5 Rock Stability		
	SOLMEX (slope)		

Mixed techniques software in the environmental problem solutions

The mixed software techniques used in the solving of the environment phenomenon refers to the combined use of GIS software and numerical analysis programs. Most of the methods contained in EMGNA methodology and default applications, using a simple work schedule which is shown in the figure 1. Data that can provide GIS programs are geographical coordinates, distances, areas. Using GIS software, geographic data can be turned in profile field, for example. Together with the image processing, GIS programs can provide details of the ground cover, the evolution of field crops and on their distribution.

To solve the problems of pluvial erosion and stability of slopes (from landslides) can take relief from the archives of aerial photographs using a GIS program. This technique ignores sudden breaks in the soil, which does not notify the aerial photographs satisfactory. In Fig. 2, 3 and 4 we used Google Earth images from the archive, taken with the AutoCAD Civil 3D. To estimate the risk of pluvial erosion we used USLE model, WEPP, RUSLE2, or their own programs or calculus (see Cardei P., Cota ., Muraru V. (2008), Herea V., Cardei P., Sfiru R. (2008), Cardei P., Cota C., Muraru-Ionel C., Sfiru R. (2009), Cardei P., Herea V., Muraru V., Sfiru R. (2009)). To estimate the risk of landslide we have used programs STAB, stable, FLAC / Slope, structural analysis software (COSMOS), or their own simple programs, for the elementary models.

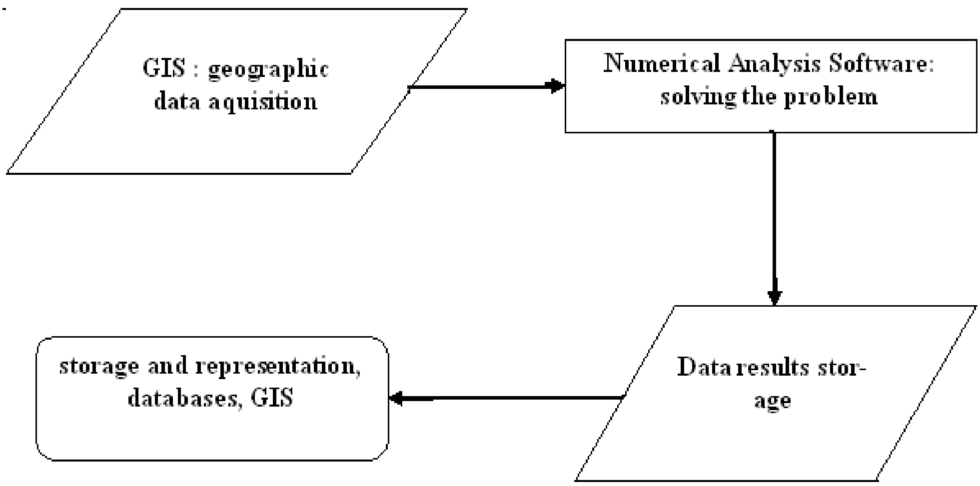


Fig. 1 The scheme of the mixed techniques application.

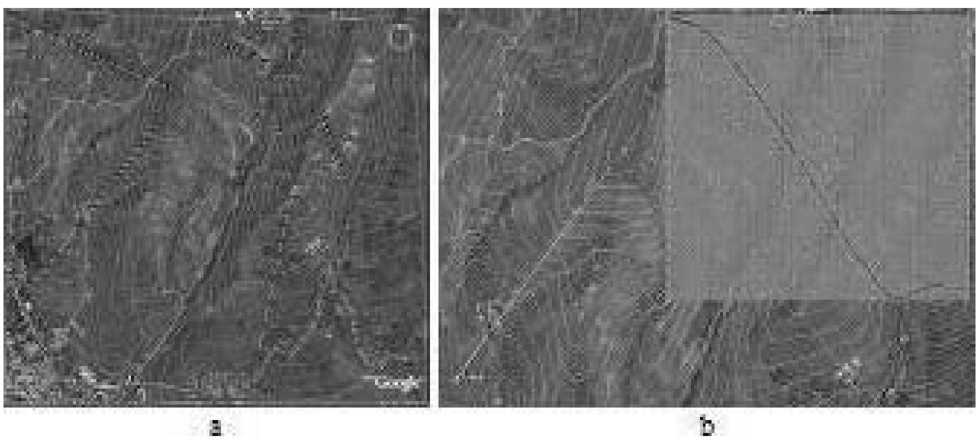


Fig. 2 Aerial picture from Google Earth to map the processing lines at the slopes and profiles.

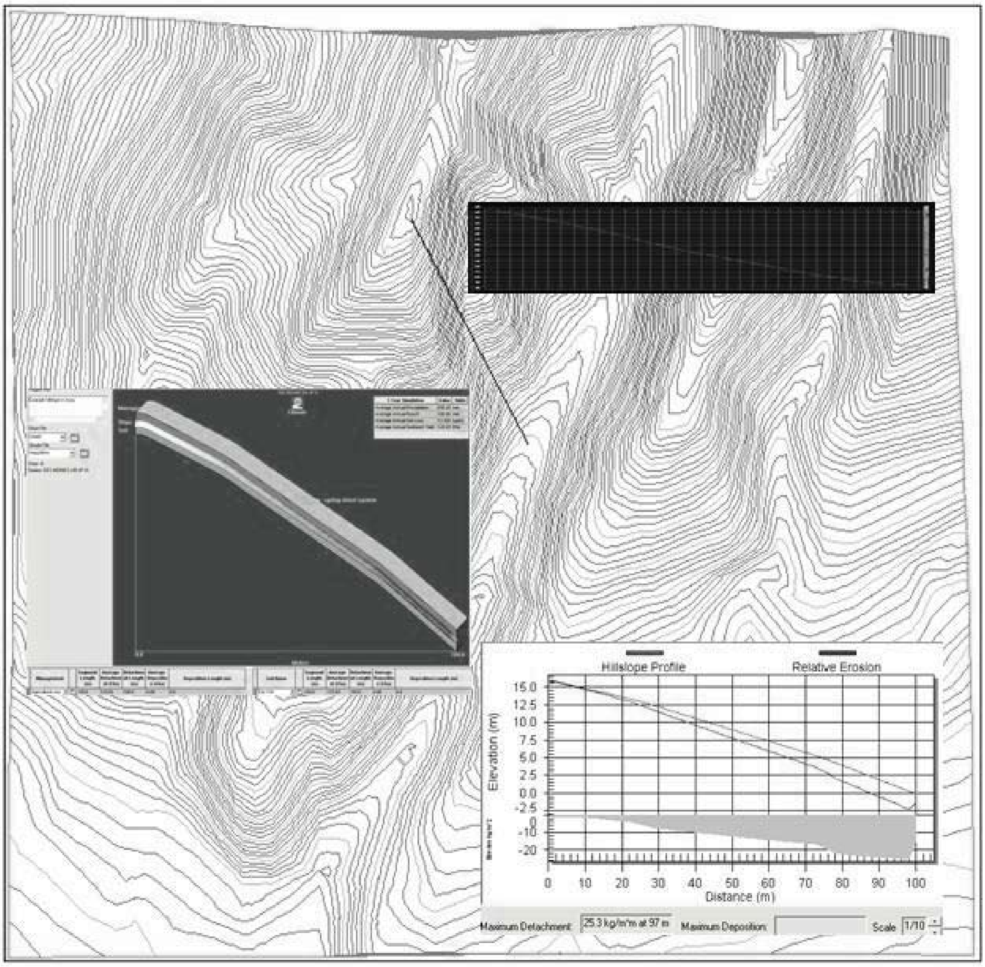


Fig. 3 Slope profile for calculating the risk of pluvial erosion.

In some applications, are interested in the land disposal of objects of high security areas. Geometric elements of the locations of these objectives can be extracted by the same technique described above. These elements are necessary, e.g. for predicting the movement of an organic pollutant in an aquifer. Prediction is used to develop an optimal procedure to limit the action and the elimination of substance (see fig. 5).

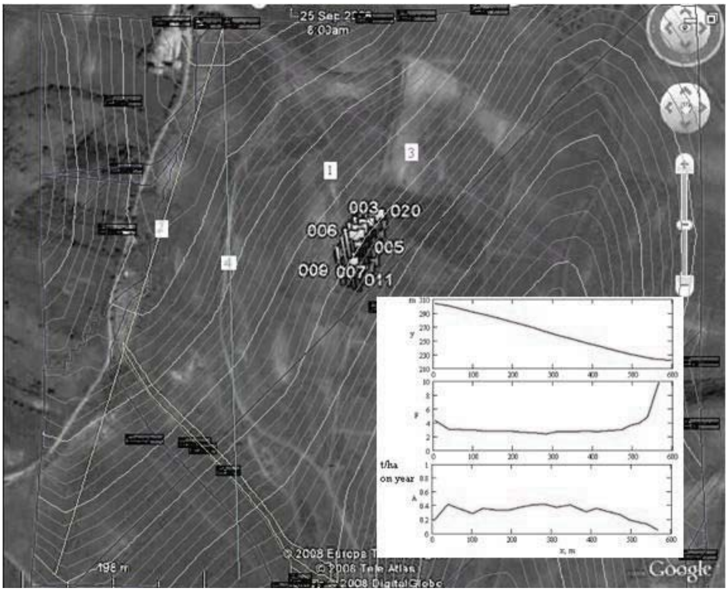


Fig. 4 Profile slope for calculating simultaneous storm erosion risk and stability.

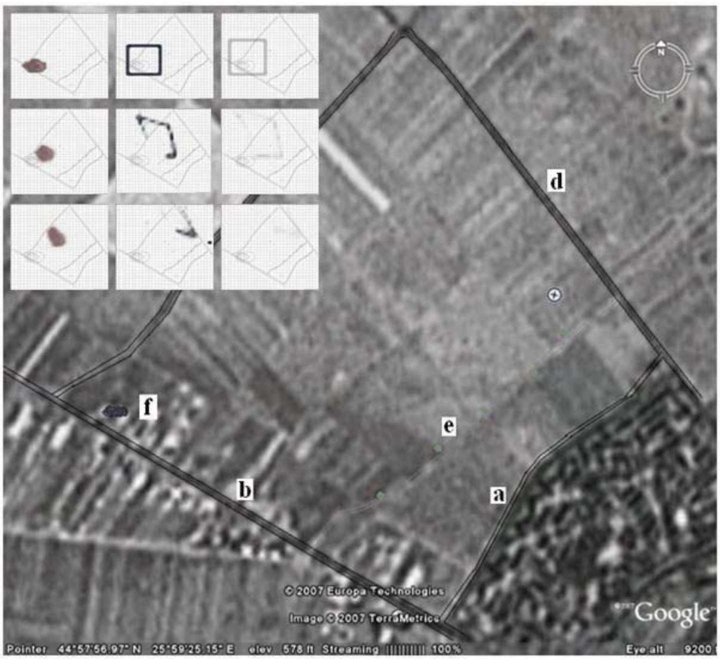


Fig. 5 Prediction movement of petroleum products and substances used to limit the action in an aquifer (Ploiesti City, Romania).

RESULTS AND DISCUSSION

The main applications developed so far (the methodology was launched in 2008) refer to some actual or potential environmental problems of geographical areas located in Romania.

Three-dimensional distribution maps of soil mechanical pollution (soil compaction) have been made in affected areas. These maps help farmers to identify compacted areas and take the optimal decision of raising deep works. Similar purposes, together with maps of pollution of soil mechanics have been determined and soil moisture maps. It was estimated the risk of pluvial erosion on slopes that was farmland. For the same slopes was estimated landslide risk. Soil pollution, groundwater and aquifers were tested using the EMGNA methodology recommended programs.

The methodology contains also noise pollution applications. Information to solve many environmental problems is handled by GIS software on aerial photographs (see fig. 6). The example treats a spread of pollutants in the sewage network in the outskirts of town. The aerial images have been used also for effective representation of the results of the numerical analysis (see fig. 7). In this example it predicts spread of sulfur dioxide coming from a factory located near a city.

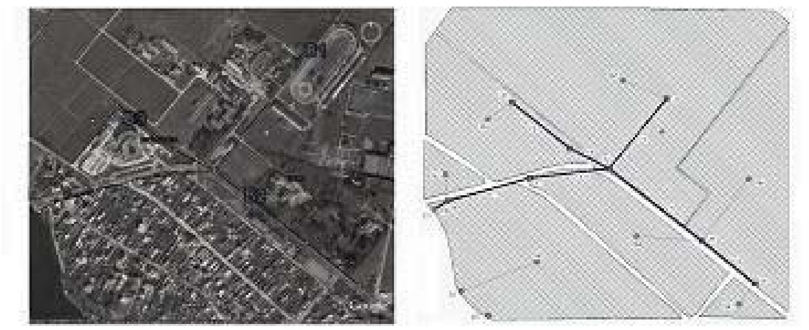


Fig. 6 The capture of the analysed site, using the program Google Earth – satellite image of Baneasa ward, Bucharest .

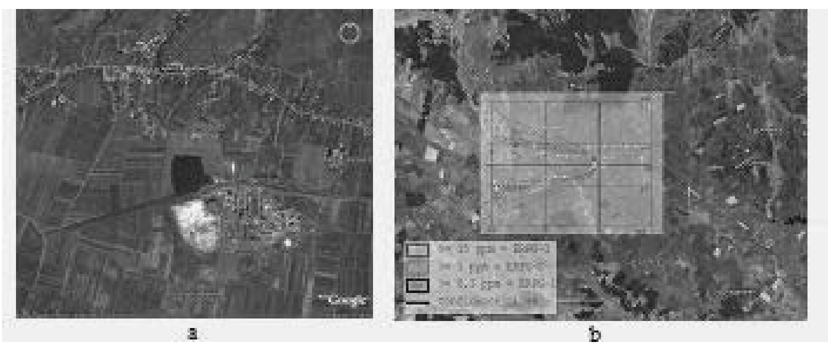


Fig. 7 The geographical location of the subject zone (a) and the superpositon of the analysis result on the site (b)

Application in Agriculture

Mapping soil properties for use in agriculture is an important direction for action in managing the farm. Moisture and soil compaction are just two important properties of soil. In the EMGNA methodology procedures, the moisture and compaction are determined experimentally by testing with special tools in the field (see Cardei P., Muraru V., Sfiru R. (2008)).

Moisture at different depths and in different places on the tested parcel, is determining together with the geographical coordinates (using a GPS device, for example). It is then map these values. The map is superposed on the aerial photography of the area and determines areas of excess or deficient distribution of moisture. The degree of compaction is estimated by soil penetration resistance. Compaction maps are made and used in the same way as the humidity. Different maps of these soil properties are shown in Fig. 8.

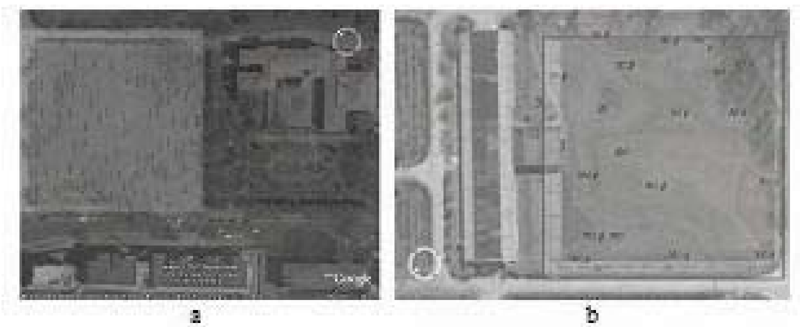


Fig. 8 The map of the soil moisture at the 20 cm depth superposed on the aerial photography of the zone - a. Map of the cone penetrometer resistance superposed on the aerial photography of the field - b

Fig. 9 Estimating the risk of pesticide contamination of surface waters: a) determining the minimum distance to surface water, b) estimation results

At the same methodology, a chapter was dedicated to noise pollution. It was estimated noise pollution caused by some noise agricultural sources (Cardei P. (2008)). Location of the source and identify of the polluted targets is made using GIS software: Google Earth, AutoCAD Civil 3D or other equivalent. Sound field produced by sources was simulated by commercial software: Lima V.1, Descar, CadnA, or simple programs based on elementary models (Cardei P. (2008)).

CONCLUSIONS

The methodology that we want offer to the specialists in environmental issues, but also in other areas such as agriculture in particular, was launched in autumn 2008.

The methodology tries to transform the environmental specialist or other area, a passive observer of environmental phenomena, in one actively. This means that the user will not be limited to obtaining data on environmental status, but will use in numerical analysis programs, to get forecasts and solutions to improve or fix. The methodology represents a useful instrument both environmental specialists and marketing agents with great potential for pollution, in order to prevent adverse environmental events. For the same reason the methodology is useful in establishing optimum response actions in case of adverse environmental events.

For example, in agriculture, management of pesticides can be aided by elements of the methodology, by establishing limited circumstances in which they can manage, according to the minimum distance to the most vulnerable targets. Soil Management (degree of compaction, moisture) is improved by using techniques methodology. Non-uniformities remediation in their distribution can be done optimally using the proposed techniques in methodology, combining the results presented with precision agriculture methods.

The methodology is a continuously changing. Will introduce new programs of numerical analysis or GIS, if they prove useful and remove obsolete ones. Also, if necessary, will introduce new methods and will continuously improve existing ones. So far, the methodology can be used free of charge, for testing and improvement.

REFERENCES

1. Cardei P. (2008). Theory and simulation of the acoustic noise propagation, 9th WSEAS International Conference on Acoustic & Music: Theory & Applications (AMTA ’08), Bucharest, Romania, June 24 – 26;

2. Cardei P., Cota C., Muraru-Ionel C., Sfiru R. (2009). Estimating the Efficiency of Anti – Erosion Agricultural Operation for the Corn Crop of the Slopes, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Volume 66 (2), p. 38-45;

3. Cardei P., Cota ., Muraru V. (2008). Consideration about the geometry of the slope spoil profilation with CPU tiller with OLAC working body, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Volume 65 (2), p. 1 -22;

4. Cardei P., Herea V., Muraru V., Sfiru R. (2009). Vector Representation for the Soil Erosion Model USLE, a Point of View, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Volume 66 (2), p.46-53;

5. Cardei P., Muraru V., Sfiru R. (2008). Investigation and mapping of the soil proprieties in aim to preservation the productivity, 8th International Scientific Conference SGEM, volume I, p. 715-722;

6. Herea V., Cardei P., Sfiru R. (2008). Experimental determination of the soil erosion measures, Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj – Napoca, Volume 65 (2), p. 88-93;

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.81:635.21
Izvorni znanstveni rad
Original scientific paper

NEW POSSIBILITIES FOR TECHNOLOGY OF POTATO FERTILIZATION

JAROSLAV CEPL, PAVEL KASAL, HELENA SOUCKOVA

Potato Research Institute Havlickuv Brod, Dobrovskeho 2366, 580 01 Havlickuv Brod, Czech Republic, cepl@vubhb.cz

SUMMARY

The study performed between 2004 and 2007 was focused on determination of effect of locally applied and broadcasted mineral N fertilizers on yield and quality parameters under conditions of conventional soil preparation and de-stoning. For the trial liquid N fertilizer DAM – 390 and solid ammonium sulphate were used at rates of 120 kg N ha^{-1} and 80 kg ha^{-1}. The results obtained in individual years clearly indicate very strong effect of weather progress on all studied parameters. A positive effect of local application of solid mineral N fertilizer was already expressed in study of crop nutritive state during vegetation. For tuber yield the best results were obtained using of local application of DAM 390 that was included into the trials between 2005 and 2007. Variants of local application of solid mineral fertilizer were also superior to variants of broadcast application in regard to tuber yield. Based on the results of field trials it could be noted, except for 2007, that for local application nitrogen rate in mineral fertilizer could be reduced compared to broadcast application with simultaneous maintaining of tuber yield.

Key words: *potato; N fertilization; yield*

INTRODUCTION

Technology of potato growing has been substantially changed across Europe and also in the Czech Republic during last fifteen years. Under conditions of the Czech Republic technology of growing in de-stoned ridges is almost implicitly applied. Other practices have to conform to the technology, e.g. weed management is markedly limited and only herbicides could be applied. In the conventional technology industrial fertilizers were applied using of applicators onto the whole field area in spring prior to potato planting. The application of industrial nitrogen fertilizers seems to be unsuitable, since granulated fertilizers are incorporated into the whole topsoil profile by further field operations and they are limited usable for potato plants. Therefore it was necessary to verify a possibility of fertilizer application at planting, when fertilizers would be directly deposited to a place.

Technology of de-stoning prior to potato planting affects soil physical characteristics. A positive effect of the technology was shown on soil compaction, clod presence, volume weight and porosity. However, the effect on moisture characteristics (max. capillary water capacity, actual soil moisture and relative soil moisture) is less favourable. We can say that the soil is loose for whole growing period; however, it shows a tendency toward increased drying-out. In general, the technology has a very positive influence on tuber yield and mechanical tuber damage (Čepl, Kasal, 1999).

Fér (1995) refers that medium and smaller stones and clods are placed onto the bottom of furrows during soil separation and form a drainage layer there. Excess water runoff in the surrounding of placed stones has a favourable effect on erosion reduction; however in drier years it could be negatively expressed in faster runoff of rainfall water and deterioration of soil moisture conditions (Diviš, 2000).

Considering better soil loosening in de-stoning technology and faster soil warming, mineralization and nitrification processes occur with higher intensity. Potato growing means a relatively high risk of nitrogen loss (Neeteson, 1995) and it was found that gaseous loss of nitrogen could be also important in potato growing (Ruser et al., 1998). High soil nitrogen content, especially nitrate nitrogen, increases risk of nitrate leaching into surface and sub-surface waters before and during growing period and after the harvest (Haberle et al. 2002). As causes of the risk the authors mention several factors: potato growing in light soil and soil with pervious subsoil, localities with higher rainfalls or irrigated early potatoes, delayed onset of vegetation, high doses of nitrogen fertilizers, high soil nitrogen content from autumn-applied manure, shallow to medium-deep potato root system, uneven water infiltration, high content of residual nitrogen after the harvest.

Local application of mineral fertilizers at planting, which could be used in de-stoning technology, contributes to reduction of nitrate nitrogen formation and risk of water pollution. The aim of this system is the most uniform supply of required nutrients for plants during growing period. A fertilizer is located in the zone of intensive rooting and therefore better use of supplied fertilizer could be expected. In consequence, higher yields and/or fertilizer savings could be determined (Pickny, Grocholl, 2003).

Maidl et al. (2002) describe an effect of application manner and time on nitrogen utilization by potatoes using of 15N isotope-labeled ammonium nitrate. A rate of 150 kg N ha^{-1} was broadcasted or applied into the ridges at planting or splitted. An application into the ridges at planting had a positive effect on tuber yielding ability, especially in case of single rate applied at planting. For local application of mineral nitrogen fertilizers there are recorded year differences in plant nitrogen use. Rainfall between planting period and growth beginning and conditions limiting the development in initial growth stages is connected to nitrogen loss. Therefore a positive effect of fertilizer application into furrows is most probable when growth conditions are unfavorable.

METHODS

Research hypothesis

Use of local nitrogen application in potatoes at planting enables to reduce fertilizer rate and simultaneously maintain the yield level. A liquid fertilizer will be more effective than a solid one.

Aim

Determination of an effect of solid and liquid mineral N fertilizer application at planting based on the results of a field trial established at Potato Research Institute H. Brod during 2004 and 2007.

Conditions of an exact field trial

Site: department PRI Havlíčkův Brod, s.r.o. – Valečov Research Station

Above sea level: 460 m

Agricultural production region: potato-growing (BVT)

Annual mean temperature: 6,99 °C

Mean temperature during growing period: 13.20 °C

Annual rainfall: 652 mm

Rainfall during growing period: 425 mm

Individual variants used in the trials are given in Tab. 1.

The trials were performed under conditions of standard cultural practices (organic fertilization and P, K, Mg fertilization was uniformly done on the whole trial area) with semi-late variety SAMANTANA.

Tab. 1: Scheme of field trial variants between 2004 and 2007

Conventional technology		De-stoning technology					
Broadcast application of solid mineral N fertilizer kg N ha^{-1}		Local application of liquid mineral N fertilizer kg N ha^{-1}		Broadcast application of solid mineral N fertilizer kg N ha^{-1}		Bocal application of solid mineral N fertilizer kg N ha^{-1}	
80	120	80	120	80	120	80	120
var. 1	var. 2	var. 3	var.4	var. 5	var. 6	var. 7	var. 8

Into the trials liquid mineral N fertilizer DAM 390 and solid ammonium sulphate were included.

DAM - 390 is a liquid nitrogen fertilizer containing 30 % N (1/4 ammonium N, 1/4 nitrate N, 1/2 amidic N). The fertilizer is urea ammonium nitrate solution. It contains 39 kg N in 100 l, density is 1300 kg/m^3 at 25 °C, salt-out temperature is -10 °C.

Ammonium sulphate is a water-soluble sulphur-containing nitrogen fertilizer. It contains ammoniac nitrogen (93 %) and nitrate nitrogen (7 %), sulphur is contained as sulphate. Total nitrogen content is 20 %. The fertilizer is delivered as coated, light beige granules.

The applicator of solid fertilizer (BPH-400) was mounted in the three-point tractor hitch with front hydraulic hitch, in aggregation with planter. The drive was performed with transfer of torque from the axle using chain drives. The volume of fertilizer rate was regulated by the moving of chain wheels and chain in the system.

The applicator of liquid fertilizers was directly mounted on the potato planter. A 300 l container was fixed in front three-point hitch. Pump drive was performed through back power take-off. Switching on and off of the applicator was hydraulically controlled together with planter operation. A nozzle was placed at the back of the front plough of the planter in order to apply fertilizer into soil prior to potato seed placement.

RESULTS

An effect of variants on crop status and development

In evaluation of crop nutritive state (Tab. 2) more favourable values were obtained in variants of local application of solid fertilizer (var. 7, 8) compared to broadcast application in de-stoning technology. During the trial differences of N-tester values were also investigated between variants of broadcast application of solid mineral fertilizer using of conventional soil preparation (var. 1, 2) and variants of de-stoning (var. 5, 6). Tendency to lower values was recorded for de-stoning technology. These differences were not statistically significant. Significant lower values were found in variants of local application of liquid fertilizer DAM 390 (var. 3, 4), especially in 2005 to variants 1 and 2 (conventional soil preparation using of broadcast application of solid mineral fertilizers). Significantly lower values were also found related to variants 7 and 8 of local application of solid mineral fertilizer at same nutrient rates.

An effect of variants on yielding and quality parameters

An effect of variants on tuber yield is summarized in Fig. 1. In individual years yielding level substantially differed, with the lowest one in 2004 and the highest one in 2005.

In 2004 no statistically significant differences were recorded between variants. Yield results obtained from variants of local application of mineral fertilizers at planting (var. 7. 8) are superior to variants of broadcast application of mineral fertilizers in conditions of de-stoning technology and also conventional technology with the same rate of nutrients.

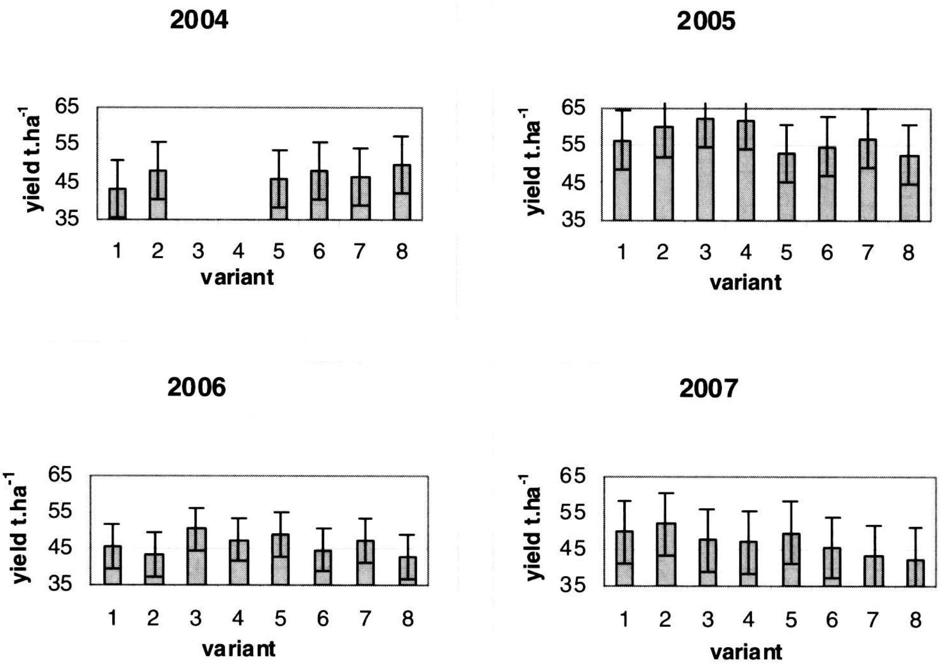
In subsequent years, the highest yields were obtained in variants of local application of liquid mineral fertilizer DAM 390 (var. 3, 4). In 2005 tuber yield of variant 3 (80 kg N.ha^{-1}) was significantly increased compared to var. 5 (broadcasted the same rate of N as solid mineral fertilizer) and var. 8 (locally applied 120 kg N.ha^{-1} as solid fertilizer). The similar situation was found for var. 4, i.e. variant of local application of 120 kg N.ha^{-1}. It corresponds to the results obtained by Pickny, Grocholl (2003) using local application of fertilizers.

Tab. 2: An effect of variants on crop nutritive state during vegetation evaluated by N-tester in individual trial years

	Flower bud stage			Flowering stage		
2004	N-tester value	F test	Significant differences	N-tester value	F test	Significant differences
1	576,7	10,33**		584,7	2,46*	
2	620,7			629,7		
3	-			-		
4	-		5% - 42,6	-		5% - 61,6
5	584,7		1% - 53,8	620,2		1% - 77,7
6	595,5			607,5		
7	630			612		
8	654,5			646,7		
2005						
1	609,7	7,17**		563,2	10,17**	
2	601,5			548,7		
3	578			484		
4	575,5		5% - 20,9	461		5% - 51,5
5	596,2		1% - 25,5	530,2		1% -63
6	587,5			515,7		
7	593,7			537		
8	600			495,7		
2006						
1	666,7	2,18*		657,7	3,15*	
2	567,2			660,5		
3	638,2			679,7		
4	626,5		5% - 105,2	654,5		5% - 60,3
5	641		1% -128,5	662		1% - 73,8
6	635,7			684,5		
7	652,7			682,5		
8	674,2			723		
2007						
1	647,3	4,04		612,8	2,74	
2	649,5			635,8		
3	648			639,8		
4	667		5% - 53,5	647,8		5% - 76,5
5	641		1% -65,4	656		1% - 93,5
6	675,5			665,8		
7	688,5			680,8		
8	703,8			685,8		

Comparison of the results from variants of conventional soil preparation and broadcast application of mineral fertilizer (var. 1, 2) with the same variants of mineral fertilization under conditions of de-stoning (var. 5, 6) indicates higher yield in variants 1, 2. Comparing these results, no statistically significant differences were found. It is also referred by Maidl et al. (2002), who attribute these differences to year effects.

In 2006 higher yield was obtained with reduced N rate (80 kg ha^{-1}) in both technologies of soil preparation and also in all variants of mineral N fertilizer application. This state was probably caused by weather progress during growing period 2006 – particularly above-mean temperatures and lack of rainfall, especially in July and September. The highest yield was recorded for the variants of local application of liquid mineral fertilizer. Var. 4 was statistically significantly superior regarding tuber yield to variants of local application of solid fertilizer (var. 8) and broadcast application under conditions of conventional soil preparation (var. 2) with the same N rates.



error vectors documents D_{min} *for* $\alpha = 0{,}01$*, Tukey*

Fig. 1 An effect of variants on tuber yield in individual trial years

In 2007 only small differences in yield between differentiated fertilizer rates could be found. Except for broadcast application of ammonium sulphate (var. 1, 2) reduced yields were found in variants of increased N rate; however, differences were statistically insignificant. This was probably caused by weather progress during growing period 2007, i.e. abnormal temperatures during almost whole growing period and especially rainfall distribution, when from June to August, as previously mentioned, potato crops were subjected to great water deficiency. It was a probable reason of the fact that the lowest yields were determined in variants of local application of ammonium sulphate. Yield of these variants was statistically significantly reduced, even on level of significance 0.01 than in the variant of broadcast application of the same fertilizer rate of 120 kg ha^{-1} under conditions of conventional soil preparation (var. 2).

Considering tuber yielding capacity in individual size fractions the most favorable results were obtained in variants of local application of liquid mineral fertilizers. Higher yielding capacities were determined in these variants for size fraction 35 – 55 mm (potato seed) and more than 35 mm (ware potatoes). In 2005 differences of these variants were statistically significant almost with all other studied variants in fraction of 35 – 55 mm.

Summary of results from verifying local application and use of mineral N fertilizers under conditions of field and laboratory trials

The results of field and laboratory plot trials obtained in individual experimental years clearly indicate very strong effect of weather progress on all studied parameters. A positive effect of local application of solid mineral N fertilizer was already expressed in study of crop nutritive state during vegetation. For tuber yield the best results were obtained using of local application of liquid mineral fertilizer DAM 390 that was included into the trials between 2005 and 2007. Variants of local application of solid mineral fertilizer were also superior to variants of broadcast application in regard to tuber yield. Based on the results of field trials we can say, except for 2007. that for local application nitrogen rate in mineral fertilizer could be reduced compared to broadcast application with simultaneous ensuring of tuber yield.

ACKNOWLEDGEMENTS

The results of the study were obtained within the research plan MSM6010980701, supported by the Ministry of Education, Youth and Sports of the Czech Republic.

REFERENCES

1. Čepl, J., Kasal, P. (1999). Technologie pěstování brambor v odkameněných hrůbcích ve ztahu k fyzikálním vlastnostem půdy a výnosu hlíz. Vědecké práce - Výzkumný ústav bramborářský Havlíčkův Brod 13: 7-15
2. Diviš, J. (2000). Příprava půdy před sázením brambor. Agromagazín 1: 17-18
3. Fér, J. (1995). Odkameňování půdy před sázením brambor. Zemědělec 3: 9
4. Haberle, J., Svoboda, P., Krejčová, J. (2002). Brambory – hnojení dusíkem, riziko vyplavení nitrátů a kořenový systém. Úroda 50: 24-25
5. Maidl, F.-X., Brunner, H., Sticksel, E. (2002). Potato uptake and recovery of nitrogen 15N-enrinched ammonium nitrate. Geoderma 105: 167-177.

6. Neeteson, J.J. (1995). Nitrogen management for intensively grown arable crops and field vegetables. In: Nitrogen Fertilization in the Enviroment (PE Bacon, ed). Marcel Dekker, New York, 295-325.

7. Pickny, J., Grocholl, J. (2003). 10 Jahre Unterfussdüngung. Kartoffelbau 54: 93-95.

8. Ruser, R., Flessa, H., Schilling, R., Steindl, H., Beese, F. (1998). Soil compaction and fertilization effects on nitrious oxide and methane fluxes in potato fields. Soil Sci. Soc. Am. J. 62: 1587-1595.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.347.45
Stručni rad
Expert paper

PROCJENA POKRIVENOSTI LISNE POVRŠINE U VOĆNJAKU JABUKE POMOĆU VODOOSJETLJIVIH PAPIRIĆA

Đ. BANAJ[1], V. TADIĆ[1], B. VUJČIĆ[2], J. LUKINAC[3]

[1]Poljoprivredni fakultet u Osijeku, Zavod za mehanizaciju, Trg sv. Trojstva 3, 31 000 Osijek, Hrvatska, vtadic@pfos.hr, dbanaj@pfos.hr
[2]Veleučilište u Slavonskom Brodu, 35 000 Slavonski brod, Hrvatska
[3]Prehrambeno tehnološki fakultet, Zavod za procesno inženjerstvo, 31 000 Osijek, Hrvatska

SAŽETAK

U radu su prikazani rezultati istraživanja raspršivača „Tifone Vento 1500“ i „Hardi Zaturn 1500“ pri radu u voćnjaku jabuke tijekom listopada 2008. Prilikom usporedbe korištena je čista vode uz primjenu metode vodo - osjetljivih papirića (VOP). Širina redova u nasadu iznosila je 3,5 m, uz prosječnu širina krošnje od 1,6 m, i visinu stabla od 3,6 m. Ispitivani raspršivači bili su opremljeni mlaznicama „Albuz ATR 80“(crvene boje), a sva ispitivanja obavljena su pri 540 min^{-1} priključnog vratila traktora. Prosječna temperatura zraka u vremenskom intervalu ispitivanja iznosila je 17,05 °C s prosječnom vrijednosti vlažnost zraka 56,50%. Prosječna brzina vjetra iznosila je 0,90 m/s u smjeru rada raspršivača.

Kod oba raspršivača korištena je hektarska dozu od 1000 l, uz korištenje radne brzine od 5 km/h. Raspršivač „Tifone“ na lijevoj strani stroja imao je prosječno ukupnu količinu zraka od 10048 m^3/h te ostvario prosječnu pokrivenost na VOP–a od 44,05 %. Kod raspršivača „Hardi“ utvrđena je prosječna količina na lijevoj strani od 24940 m^3/h te je polučio prosječnu pokrivenost na VOP–a od 45.85 %. Na desnoj strani stroja raspršivač „Tifone“ ostvario je ukupnu prosječnu količinu zraka od 8590 m^3/h i prosječnu pokrivenost na VOP–a od 41.33 %. Kod rasprskivača „Hardi“ utvrđena je ukupna prosječna količina zraka od 19650 m^3/h i ostvarena je prosječna pokrivenost od 42,47 % na postavljenim VOP–a. Prilikom istraživanja korištena je već priznata metodika pri čemu su VOP fotografirani, a slike su konvertirane sa softverom “Irfan View 4.0” te su kasnije obrađivane s “Adobe Photoshop”, “Global Lab Image/2” i “Graduate” softverom.

Ključne riječi: *rasprskivač, vodoosjetljivi papirić, pokrivenost lisne površine, brzina zračne struje, voćnjak, analiza slike*

UVOD

Na dobru pokrivenost rastvorom lisne površine u voćarstvu i vinogrdarstvu u vrijeme zaštite bilja nužno je ostvariti minimalno djelovanje većeg broja čimbenika koji se pojavljuju u vrijeme rada raspršivača. Svakako od značajnijih moramo ovdje spomenuti kao što su: vrijeme aplikacije, pravilan izbor pesticidne formulacije, i eksploatacijska pouzdanost raspršivača. Neujednačena raspodjela žaštitnog rastvora po lisnoj površini, kao i njegovi gubitci nastali odnošenjem pesticida ponekad mogu direktno djelovati na nedovoljnu zaštitu i kontrolu štetočina. Prema navodima autora Derksen i Bretha, [1] radi slabije pokrivenosti dolazi indirektno do povećanja troškova kao što su potrošnju goriva, radne snage te do povećanja troškova mehanizacije. Autor Raisigl i suradnici [6] navode da su ponekad gubitci pesticida u voćnjaku jabuke na tlu u rasponu od 14 do 39 % od ukupne aplikacijske doze. Gubitak rastvora odnošenjem prema istim autorima ponekad može biti u rasponu od 23 do 45 % od aplicirane rate rastvora

Dobra pokrivenost lisne površine rastvorom prema navodima autora Praat i suradnika [5], ponekad ne mora polučiti uvijek i dobar biološki efekt, ali navode da je dobra pokrivenost lisne površine signifikantno utječe na povećanje zaštite.

Perger i suradnici [4], izučavaju i pojavu listova koji imaju bolji položaj prema izlaznom dijelu mlaznica. Stoga, listovi s povoljnijim položajem imati će i veću pokrivenost površine rastvorom od onih s lošijim položajem Veliki problem navode autori Derksen i Gray, [2],također predstavlja gubitak pesticide kod raspršivača s velikim izlaznim brzinama vjetra, tj. s velikim ukupnim količinama zraka. Dobrobit većeg volumena zraka, prema istim autorima je mogućnost bolje pokrivenost lisne površine koja se nalazi u sredini krošnje. Primjena metodike s vodo - osjetljivih papirića (VOP) novijeg je datuma i vrlo je pouzdan. Prema navodima autora Hołownicki i suradnika [3] za potpuni uspjeh navedene metode relativna vlažnost zraka mora biti < 80 %. Jer u protivnom na višoj vlazi VOP postaju potpuno plavi.

ZADATAK I CILJ ISTRAŽIVANJA

Zadatak i cilj istraživanja bio je utvrditi pokrivenost lisne površine jabuke s različitim količinama zraka i s različitim raspršivačima.

MATERIJAL I METODE RADA

Istraživanja kvalitete rada raspršivača *„Tifone Vento 1500"* i *„Hardi Zaturn* 1500" provedena su u nasadu jabuke tijekom listopada 2008. godine. Korišteni raspršivači posjeduju aksijalne ventilatore s volumenom spremnika od 1500 litara. Dimenzije izlaznog otvora na lijevoj ili desnoj strani raspršivača *„Tifona"* (Slika 1.) iznosile su 100 x 10,5 cm a kod raspršivača tvrtke *Hardi* (Slika 2.) iznosila je 156 x 14 cm široke. Oba stroja opremljena su mlaznicama crvene boje (ISO 1625) raspoređene unutar izlaznog otvora.

Razmak redova stabala jabuka u voćnjaku iznosio je 3,5 m s prosječnom visinom stabala od 3,6 m, s prosječnom širinom krošnje od 1,6 m. Za ovu svrhu korištena je metodika vodoosjetljivih papirića (VOP) postavljenih na pet visinskih razina pa stablu. Prvi VOP postavljeni su do 120 cm visine biljke a ostali u naredne visinske razine po 60 cm do vrha stabla. VOP su postavljeni na lice i naličje lista na svakoj visini po 5 papirića. VOP imali su dimenzije 75 mm x 25 mm odnosno površinu od 18,75 cm^2. Sva istraživanja provedena su tri puta za svaki raspršivač. Nakon poljskih ispitivanja, VOP su pokupljeni, evidentirani i označeni te obrađeni pomoću analize slike. Glavni elementi za analizu slike korišteni u istraživanju bili su komora za slikanje sa 6 halogenih lampi (intenzitet osvjetljenja oko uzorka bio je 1360 ± 5 Lux), pozadina za slikanje s koje su uzorci slikani (*Canon EOS 1000D*) i softverski programi s pomoću kojih su slike obrađivane (*IrfanView, Adobe Photoshop®, Global Lab Image/2 and Graduate*). Papirići su fotografirani u JPG formatu te su s pomoću „*Irfan View* 4.0“ softvera konvertirane u BMP grafički format s 8 – bitnom paletom boja (2^8=256 boja). Ovakve grafike softver sprema u RGB tripletima za svaki piksel na uzorku bila ona crvena, zelena ili plava u rangu od 0 do 255. Korišteni softver za ovakva istraživanje izračunava prosječnu vrijednost crvene, zelene i plave boje u svakom pikselu na VOP – u dok se pozadina ne uzima u analizu.

Slika 1. Raspršivač (A) Tifone Vento 1500

Slika 2. Raspršivač (B) Hardi Zaturn 1500

REZULTATI ISTRAŽIVANJA

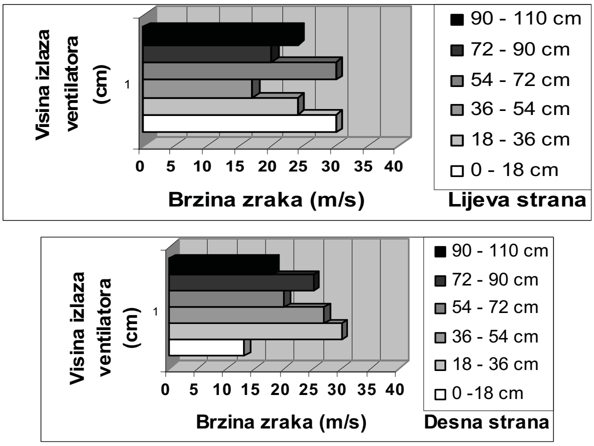
Vremenski uvjeti u vrijeme istraživanja raspršivača

U vremenskom intervalu poljskog testiranja vrijeme je bilo stabilno s temperaturom zraka od 16,4 do 17,7 °C s relativnom vlažnošću zraka od 61,2 do 51,9 %. Izmjerene brzine vjetra iznosile su od 0,8 do 1,6 m/s okomito u smjeru rada raspršivača. Sunčeva radijacija iznosila od 293 W/ mm^2 na početku testiranja te 323 W/ mm^2 na kraju istraživanja.

Brzine zraka na pojedinim dijelovima izlaza ventilatora

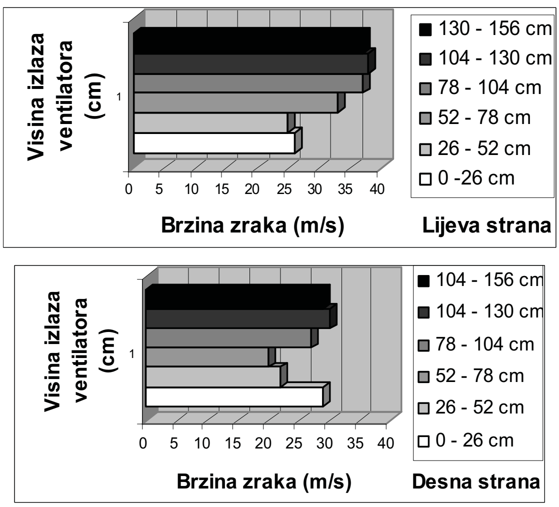
Ovisno o dužini izlaznog otvora ventilatora mjerena je i brzina zraka na 6 različitih razina kod obadva raspršivača. Brzina zraka mjerena je na udaljenostima od 15 – 20 cm, tj. neposredno pri izlazu ventilatora s vjetruljom tvrtke „Silva Windwatch“.

Rezultati istraživanja brzine zraka kod obadva raspršivača na lijevoj i desnoj strani, prikazani su grafikonima 1 i 2.



Grafikon 1. Raspodjela vrijednosti brzina zraka po razinama izlaznog otvora kod Tifone raspršivača

Iz grafikona 1. možemo uočiti da je prosječna brzina zraka na lijevoj strani kod navedenog raspršivača iznosila 24,16 m/s s prosječnom količinom zraka od 10048 m^3/h. Na desnoj strani izlaznog otvora prosječna brzina iznosila je 20.66 m/s s prosječnom ukupnom količinom zraka na istoj strani od 8590 m^3/h.



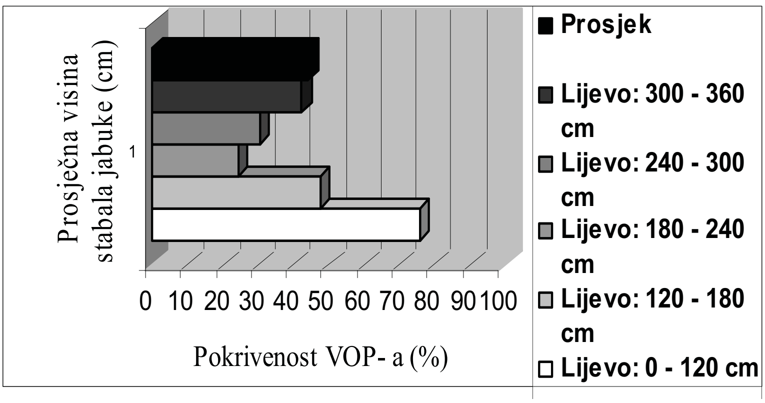
Grafikon 2. Raspodjela vrijednosti brzina zraka po razinama izlaznog otvora kod raspršivača Hardi

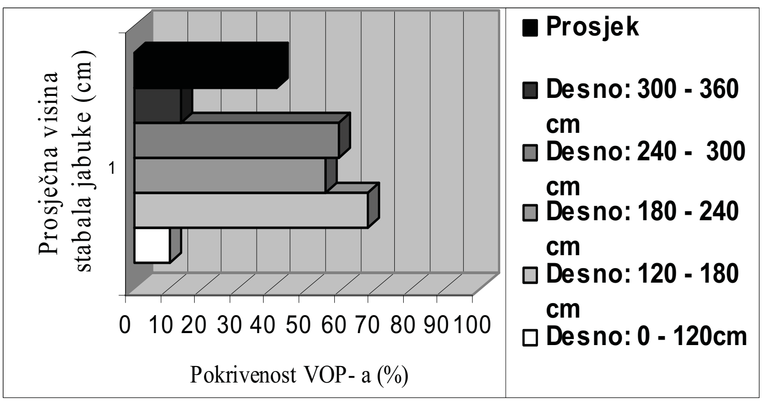
„Hardi Zaturn“ posjeduje nešto duži izlazni otvor ventilatora (156 cm) pa su brzine mjerenja obavljene na svakih 26 cm. Prva razina mjerena bila je od 0 do 26 cm, druga od 26 do 52 cm, itd.

Prosječna brzina zraka na lijevoj strani izlaznog otvora kod raspršivača Hardi iznosila je 33 m/s s prosječnom ukupnom količinom zraka od 24940 m^3/h. Na desnoj strani stroja imamo nešto manju prosječnu brzinu zraka za 21,2 % u odnosu na lijevu stranu. Prosječna brzina zraka iznosila je svega 26 m/s s prosječnom količinom zraka 23200 m^3/h.

Rezultati istraživanja pokrivenost VOP – a kapljicama vode

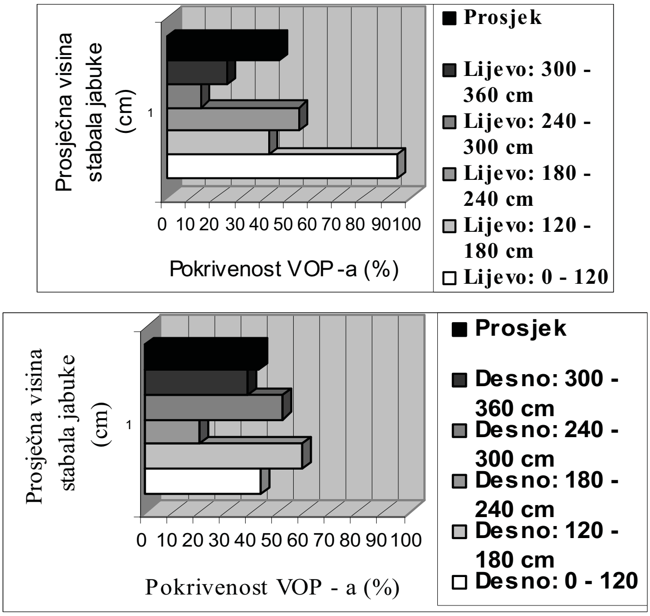
Dobiveni rezultati pokrivenosti VOP-a kapljicama vode kod raspršivača *„Tifone“* na obadvije strane prikazano je na grafikonima 3 i 4.





Grafikon 3. Pokrivenost VOP – a kapljicama vode kod Tifone rasprskivača

Iz grafikona 3. može se zaključiti da je navedeni raspršivač ostvario prosječnu pokrivenost na lijeve strane od 44,05 %, te na desnoj strani od 41,33 %



Grafikon 4. Pokrivenost VOP – a kapljicama vode kod Hardi atomizera

Tablica 1. Statističke vrijednosti rezultata utvrđivanja brzine zraka i pokrivenost VOP –a kapljicama vode istraživanih raspršivača

Razine mjerenja brzine zraka i pokrivenosti VOP–a	Brzina zraka na različitim razinama izlaza ventilatora (m/s)				Pokrivenost VOP –a na različitim visinama mjerenja (%)			
	Tip raspršivača				Tip raspršivača			
	Tifone Vento 1500		Hardi Zaturn 1500		Tifone Vento 1500		Hardi Zaturn 1500	
	Lijevo	Desno	Lijevo	Desno	Lijevo	Desno	Lijevo	Desno
1. razina	30	13	26	29	75,7	10,1	94,4	43,2
2. razina	24	30	25	22	47,5	67,9	41,9	58,8
3. razina	17	27	33	20	24,3	55,4	54,3	20,3
4. razina	30	20	37	27	30,1	59,3	14,0	52,0
5. razina	20	25	38	30	42,4	13,7	24,3	38,0
6. razina	24	18	37	29	-	-	-	-
$\overline{X}$	24,1	22,1	32,6	26,1	44,0	41,3	45,8	42,4
St. dev	6,3	6,3	5,8	4,1	20,0	27,2	31,3	14,7
KV	26,0	28,4	21,3	21,4	45,4	65,8	68,3	34,7

Kao što se može zaključiti raspršivač „*Hardi*“ ostvarioje je prosječnu pokrivenost na lijevoj od 45,85 i 42,47 % na desnoj strani rada.

Ostvareni koeficijent varijacije kod istraživanja brzine zraka ostvario je raspršivač „*Tifone“ od* 26 % na lijevoj i 28,4 % na desnoj strani. Kod raspršivača „*Hardi“* utvrđen je nešto manji koeficijent varijacije od svega 17,8 % na lijevoj i 15,9 % na desnoj strani.

Kod utvrđivanja pokrivenosti VOP –a kapljicama vode utvrđeno je da je kod raspršivača „Hardi“ koeficijent varijacije iznosio 42,4 do 68,3% ovisno o strani rada. Raspršivač *„Tifone“* ostvario je sličan koeficijent varijacije od 45,4 do 65,8 %. Zbirni rezulati statističkih vrijednosti prikazano je u tablici 1.

ZAKLJUČCI

Na temelju gore navedenog mogu se donijeti slijedeći zaključci:

- meteorološke prilike nisu utjecale na kvalitetu rada ispitivanih raspršivača a to se može tumačiti da je vrijeme bilo stabilno s temperaturom zraka od 16,4 do 17,7 °C s relativnom vlažnošću zraka od 61,2 do 51,9 %,
- brzine vjetra iznosile su od 0,8 do 1,6 m/s okomito u smjeru rada raspršivača
- prosječna brzina zraka na lijevoj strani kod «Tifone» raspršivača iznosila je 24,16 m/s s prosječnom količinom zraka od 10048 m^3/h,
- na desnoj strani izlaznog otvora prosječna brzina iznosila je 20.66 m/s s prosječnom ukupnom količinom zraka na istoj strani od 8590 m^3/h,
- prosječna brzina zraka na lijevoj strani izlaznog otvora kod raspršivača Hardi iznosila je 33 m/s s prosječnom ukupnom količinom zraka od 24940 m^3/h,
- na desnoj strani stroja imamo nešto manju prosječnu brzinu zraka za 21,2 % u odnosu na lijevu stranu te je prosječna brzina zraka iznosila svega 26 m/s s prosječnom količinom zraka 23200 m^3/h,
- prosječna pokrivenost VOP s kapljicama čiste vode raspršivača «Tifone» iznosila je 44,05 na lijevoj i 41,33 % na desnoj strani,
- raspršivač „*Hardi*“ ostvarioje je prosječnu pokrivenost na lijevoj od 45,85 i 42,47 % na desnoj strani stroja
- da je koeficijent varijacije brzine zraka kod raspršivača „*Tifone“ iznosio* 26 na lijevoj i 28,4 % na desnoj strani,
- koeficijent varijacije kod raspršivača „*Hardi“* iznosio je svega 17,8 % na lijevoj i 15,9 % na desnoj strani,
- kod utvrđivanja pokrivenosti VOP–a kapljicama vode utvrđeno je da je kod raspršivača „Hardi“ koeficijent varijacije iznosio 42,4 do 68,3% ovisno o strani rada, a kod raspršivača *„Tifone“iznosio je* 45,4 do 65,8 %,

LITERATURA

1. Derksen, R. C. and Breth, D. I. (1994) Orchard air-carrier sprayer application accuracy and spray coverage evaluations. App. Eng. Agri. 10(4). 463-470,
2. Derksen R.C., Gray R. L. (1995) Deposition and air speed patterns of air-carrier apple orchard sprayers. Transactions of the ASAE, 38(1), 5 – 11
3. Hołownicki R., Doruchowski G., Swiechowski W., Jaeken P. (2002) Method of eavluation of spray deposit and coverage on artifical targets, Electronic Journal of Polish Agriculture Universities, Vol. 5, Issue 1
4. Pergher G., Gubiani R., Tonetto G. (1997) Foliar Deposition and Pesticide losses from three air-assisted sprayers in a hedgerow vineyard. Crop protection 16(1): 25-33.
5. Praat J.P., Manktelow D., Suckling D.M., Maber J. (1996) Can application technology help to manage pesticide resistance? NZPPS paper, Canadian Application Technology
6. Raisigl, U., Felber, H., Siegfried, W. and Krebs, C. (1991) Comparison of different mistblowers and volume rates for orchard spraying. In: Air-assisted Spraying in Crop Protection (Ed. by A. Lavers, P. Herrington and E. S. E. Southcombe) pp 185-196. British Crop Protection Council, UK

METHOD OF EVALUATION LEAF AREA COVERAGE IN APPLE ORCHARD WITH WATER SENSITIVE PAPERS

In this research we showed results from testing of two mistblowers in an apple orchard at end of vegetation development in October 2008. We used a pure water and water sensitive papers (WSP). Width between apples rows were 3.5 m, average width of tree top were 1.6 m and average apple height were 3.6 m. Both of machines had the same “Albuz ATR 80” red nozzles and tractor’s PTO had rotational speed of 540 rpm. Average temperature during testing was 17.05 °C; average air humidity was 56.55 % and average wind speed was 0.9 m/s. Both of mistblowers used 1000 l/ha and work speed of 5 km/h. The „Tifone“ mistblower on left side of blower had 10048 m^3/h total amount of air and WSP coverage was 44.05 %, while the “Hardi” had 24940 m^3/h total amount of air and WSP coverage of 45.85 %. The “Tifone” mistblower on the right side of blower had 8590 m^3/h total amount of air and WSP coverage of 41.33 %, while the “Hardi” had 19650 m^3/h total amount of air and WSP coverage of 42.47 %. WSP were pictured with “Canon EOS 1000D”, and then pictures are converted with “Irfan View 4.0”, and on the last pictures are elaborated with “Adobe Photoshop”, “Global Lab Image/2” and “Graduate” softwares.

Key words: *mistblower, water sensitive paper coverage, airflow, apple orchard, air velocity, image analyze*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 004.89
Prethodno priopćenje
Preliminary communication

SELEKTIVNI NANOS FITOFARMACEVTSKIH SREDSTEV Z UPORABO PAMETNEGA ROBOTA

JURIJ RAKUN, PETER BERK, TOMAŽ PARIPOVIČ, PETER LEPEJ, MIRAN LAKOTA, DENIS STAJNKO

Univerza v Mariboru,Fakulteta za kmetijstvo in biosistemske vede, Vrbanska 30, 2000 Maribor, Slovenija, jurij.rakun@uni-mb.si
University of Maribor, Faculty of Agriculture and Life Sciences, Vrbanska 30, 2000 Maribor, Slovenija

POVZETEK

Poraba fitofarmacevtskih sredstev se iz leta v leto nezadržno veča, v zadnjem desetletju pa se je kar podvojila. Kljub dejstvu, da se vse bolj zavedamo tudi njihovih negativnih lastnostih in potencialno škodljivih učinkov za zdravje ljudi, brez njih ne moremo. Eden izmed načinov kako omejiti njihovo uporabo in omiliti negativne lastnosti je njihov premišljen in selektiven nanos samo na mesta, kjer je to nujno. V tem delu zato povzemamo robota, ki bo služil kot nadomestek za človeško delo, hkrati pa delo opravil hitreje, natančneje in z nižjimi stroški. Da pa bi dosegli zastavljen cilj, smo robota opremili z ultrazvočnimi senzorji za lažjo navigacijo, digitalno kamero visoke ločljivosti za nadzor okolice in vgrajenim računalnikom namenjenim procesiranju podatkov. Prototip avtomatiziranega stroja smo preizkusili v kontroliranih in nekontroliranih pogojih, kjer smo testirali natančnost upravljanja in iskanja referenčnih objektov. V primeru kontroliranih pogojev smo dosegli 100 %, v primeru nekontroliranih pa nekoliko nižjo, a še vedno vzpodbudno 93 % natančnost.

Ključne besede: *robot, računalniški vid, fitofarmacevtska sredstva, avtomatizacija*

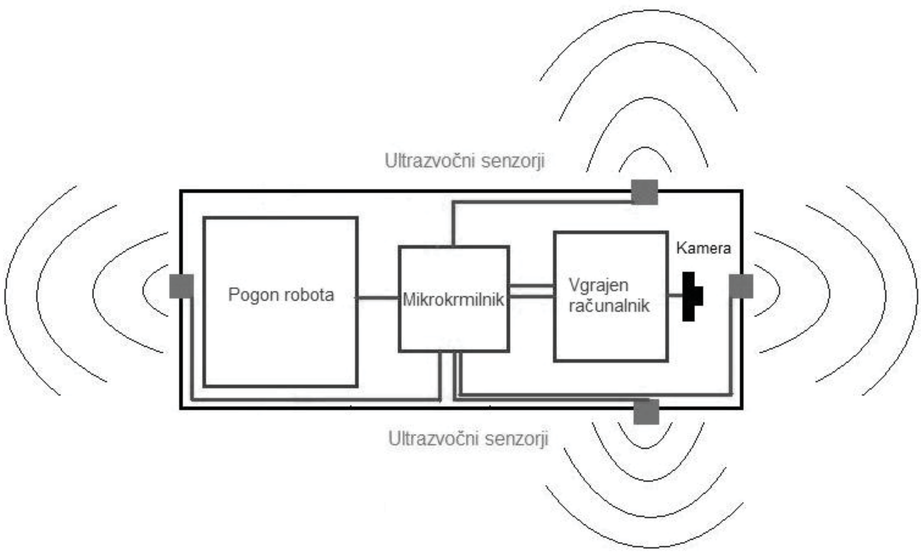
UVOD

Zanimiv in hkrati zastrašujoč je podatek o količini porabe fitofarmacevtskih sredstev, saj jih samo v EU na leto porabimo več kot 200.000 ton, njihova poraba pa se je v zadnjem desetletju kar podvojila [13]. Kljub razmeroma dobremu poznavanju njihovih neposrednih učinkov, ne vemo skoraj ničesar o vplivu »cocktail« efekta, do katerega pride pri uporabi več škropiv na isti obdelovalni površini. Nekateri avtorji [1,13] ocenjujejo, da se njihov učinek takrat poveča za približno 10- do 100-krat, njihove genotoksične in mutagene učinke pa primerjajo s tistimi, ki jih povzroča radioaktivno sevanje. Uporabo fitofarmacevtskih sredstev je zato treba zmanjšati in jih nanašati selektivno; po nekaterih ocenah bi jih tako porabili tudi do 80 odstotkov manj [5].

Zaskrbljeni zaradi opisanih razmer smo se odločili, da v naslednjem poglavju predstavimo posamezne dele [12] in delovanje našega poljedelskega stroja kot potencialno platformo za selektivno nanašanje fitofarmacevtskih sredstev. Ključno vlogo robota predstavljata predvsem dve komponenti. Prva je uporaba ultrazvočnih senzorjev, ki robotu omogoča, da se ta avtonomno premika po neznanem poligonu in se krmili glede na postavljene ovire. Druga ključna komponenta pa je digitalna kamera visoke ločljivosti, ki zajema videotok. Ta se procesira bodisi na vgrajenem ali oddaljenem računalniku in glede na njegovo vsebino proži ustrezne akcije (npr. odpiranje šob).

Ob pregledu področja smo naleteli na nekaj rešitev [2][3][4], ki so podobne naši in bi z nekaterimi spremembami lahko dosegli zastavljene cilje. V vseh primerih gre za robotizirane konstrukcije, kjer je pri nekaterih mogoče s pomočjo računalniškega vida dosegati zavidljivo dobre rezultate, vendar so za zdaj preizkušeni le v kontroliranih in idealnih pogojih, ki pa jih pri delu v naravi ni mogoče pričakovati [3]. Ključne slabosti sedanjih robotov za delo na polju so njihova velikost in teža [4], ki omejujeta mobilnost oziroma prenosljivost naprave, in stroški njihovega razvoja [4].

Idejna zasnova našega robota temelji na mobilnem štirikolesnem modelu avtomobila, avtomatiziranega s pomočjo servomotorjev. Robot je zasnovan kot samostojna konstrukcija, ki se premika po polju glede na nalogo in izvršuje dela. Njegove ključne dele prikazuje slika 1.



Slika 1: Ključni sestavni deli robota

Glavni sestavni del, ki omogoča samostojno in večnamensko uporabo robota, je digitalna kamera [6], ki predstavlja osnovo za računalniški vid. Poleg nje smo uporabili še servomotorje [17], vodene s pomočjo pulzno širinske modulacije, za lažji nadzor okolice pa smo dodali še ultrazvočne senzorje [16]. Digitalno kamero smo opremili s širokokotnim objektivom [11], vse to pa z oddaljenim računalnikom povezali s pomočjo vgrajenega računalnika [18], ki je nameščen na samem robotu.

Dojemanje okolice z uporabo samo splošno namenskih senzorjev je za realni svet precej skromno. Največ podatkov za izvajanje namenskih del tako ne dobimo iz senzorjev, temveč predvsem s slik, ki jih zajema digitalna kamera. Na žalost pa je interpretacija teh računsko in programsko zelo zahtevna. V primeru krmiljenja se zato omejimo predvsem na uporabo ultrazvočnih senzorjev, saj se za potrebe manevriranja izkažejo za dovolj zanesljive in hkrati preproste za uporabo. Delujejo z majhno porabo energije in imajo meritveno območje med tremi centimetri in tremi metri, kar zadostuje našim zahtevam za določanje razdalje.

Vsi zajete podatke prenesemo na oddaljen računalnik, kjer se izvaja obdelava. Prednost takšnega porazdeljenega sistema ponuja možnost stalnega nadzora in enostavno spreminjanje ali programiranje nalog mobilnega robota. Ko bomo dosegli zadovoljivo stopnjo zanesljivosti pa se bo sama obdelava izvajala na robotu, natančneje na vgrajenem računalniku. Oddaljeni računalnik bo služil samo za pisanje programov, spreminjanje aplikacij in nadzor delovanja, vse nastavitve in trenutno aktualen program pa se bo prenesel na vgrajen računalnik, kjer so bo tudi izvajal.

Predstavljeno delo smo povzeli v petih poglavjih. V drugem poglavju začnemo z opisom robota, njegovo delovanje pa pojasnimo v tretjem poglavju. Nadaljujemo s četrtim poglavjem, kjer potrdimo pravilnost delovanja z uporabo simulacije in izpostavimo nekaj ključnih meritev. Članek zaključujemo z ugotovitvami in nekaterimi smernicami nadaljnjega možnega razvoja.

SESTAVA IN OPIS DELOVANJA

Robota sestavljajo trije ključni deli. Pri del predstavlja mikrokrmilnik, ki skrbi za pravilno interpretacijo podatkov zbranih s pomočjo ultrazvočnih senzorjev in krmiljenje robota, oddaljen računalnik, ki zbrane podatke analizira in uporabi v fazi krmiljenja ter vgrajen računalnik, čigar naloga je posredovati podatke preko brezžične povezave med mikrokrmilnikom in oddaljenim računalnikom. Vgrajen računalnik se nahaja na samem robotu, zato služi tudi kot strežnik video vsebin, ki ga polni digitalna kamera, video tok pa obdeluje oddaljeni računalnik.

Naloga mikrokrmilniškega vezja je zajemati podatke o oddaljenosti zbranih s pomočjo štirih ultrazvočni senzorjev SRF04, kjer je eden namenjen zbiranju podatkov o oddaljenosti pred robotom, drugi za robotom, tretji in četrti pa za levo in desno stran robota. Ti delujejo tako, da oddajajo v prostor ultrazvočne (40 kHz) impulze, ki se nato širijo z zvočno hitrostjo, odbijejo od ovire in vrnejo do senzorja. Z merjenjem časa, ki je potreben, da se impulz vrne, je torej mogoče dokaj natančno določiti razdaljo do ovire. Merilno območje senzorjev sega od 3cm do 3 m in smo ga zaradi lažje obdelave kvantizirali na kvante. Smer vožnje tako popravimo le v primerih, ko zasledimo neujemanje kvantov iz vsake strani.

Kvantizirano je tud merilno območje senzorjev, ki sta nameščena spredaj in zadaj, njune podatke o oddaljenosti pa uporabimo za varno manevriranje po poligonu. Meritev razdalje iz posameznega senzorja v povprečju opravimo vsaj petkrat v sekundi, kar omogoča nemoteno in varno vožnjo med ovirami.

Poleg podatkov o senzorjih mikrokrmilniško vezje upravlja še s servomotorji, ki skrbijo za krmiljenje robota. Dva od njih sta namenjena krmiljenju sprednje in zadnje osi robota, eden za plin in zadnji za krmiljenje sklopke in zavore. Vse servomotorje krmilimo s pomočjo pulznoširinske modulacije. Krmilne ukaze mikrokrmilniško vezje prejema iz vgrajenega računalnika preko 8-bitne serijske (RS-232) povezave, ki deluje pri hitrosti 2400 zlogov v sekundi in preko katere pošilja tudi podatke o oddaljenosti.

Za vgrajeni računalnik, ki opravlja delo posredovanja podatkov, smo izbrali računalnik VIA EPIA PX10000, ki teče pri hitrosti 1 GHz, vanj pa smo vgradili 1 giga zlogov DDR2 pomnilnika. Kljub dejstvu, da gre za vgrajeno različico računalnika družine x86, porabi samo okoli 15 W moči in dosega izračun 1391 milijonov inštrukcij v sekundi (MIPS) oz. 1201 milijon inštrukcij s plavajočo vejico (MFLOPS). Dodatna računska moč bo dobrodošla predvsem v nadaljevanju razvoja, ko bomo pa vgrajene računalniku opravljali obdelavo ali vsaj predobdelavo slik. V računalnik smo vgradili še trdni disk zmogljivosti 80 giga zlogov, ki omogoča shranjevanje zajetega videotoka za poznejšo obdelavo, nanj pa naložili operacijski sistem Linux z jedrom 2.6.22. Na vgrajeno računalniško enoto smo prek USB 2.0 vodila priklopili kamero DBK31BU03, nanjo pa namestili širokokotni objektiv H0514-MP. Kamera omogoča različne načine kodiranja podatkov, kjer smo izbrali neobdelano (RAW) kodiranje, pri katerem kamera dosega največje hitrosti zajemanja podatkov (30 slik v sekundi pri ločljivosti 1024 x 768 slikovnih elementov). Ker vgrajena enota služi kot vmesnik med mikrokrmilniškim vezjem in oddaljenim računalnikom smo po standardu IEEE 802.11g vzpostavili še brezžični komunikacijski kanal.

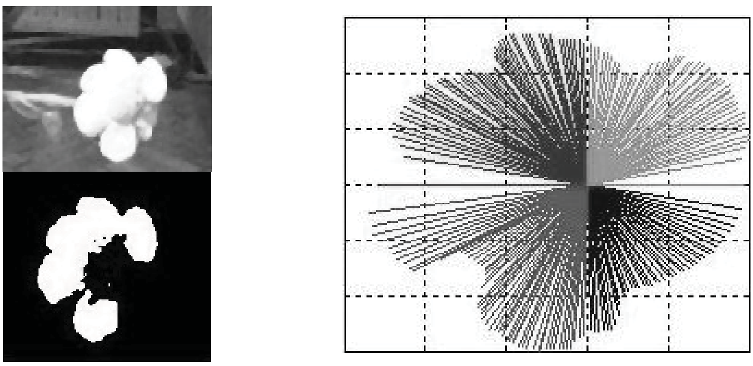
Na drugem koncu brezžičnega komunikacijskega kanala se nahaja oddaljen računalnik preko katerega spremljamo dogajanje na robotu. Nalogo oddaljenega računalnika smo prepustili osebnemu računalniku. Prvi del podatkov predstavlja video tok, drugi del podatkov pa informacija o oddaljenosti do ovir. Oddaljeni računalnik prejete podatke analizira in glede na njihovo vsebino sprejema odločitve kako krmiliti robot. Komunikacijski scenarij je zaradi varnosti zasnovan tako, da v primeru odpovedi enega izmed komunikacijskih členov (oddajnika, sprejemnika ali povezave) robot obstoji in nadaljuje svoje delo šele ob ponovni vzpostavitvi komunikacije.

ALGORITEM KRMILJENJA

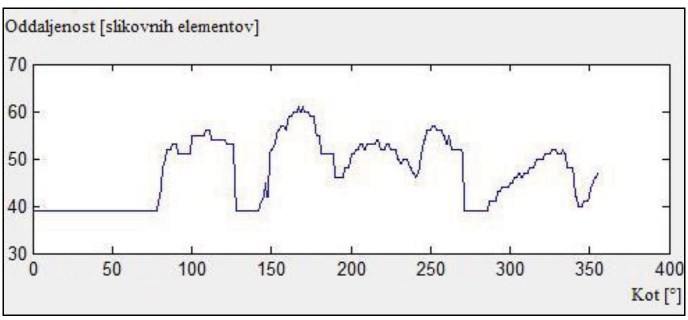
Algoritem krmiljenja servomotorjev je preprost, saj smo predvideli, da se bo robot uporabljal bodisi v sadovnjakih bodisi v vinogradu ali na poljih, kjer so med vrstami poljščin razmaki veliki vsaj 0,5 metra. Glede na oddaljenost od vsake vrste pridelka manevriranje izvedemo tako, da je razdalja na vsaki strani robota enaka. V primeru, da je robot preveč obrnjen proti eni vrsti, se bo razdalja do te vrste zmanjševala, medtem ko se bo razdalja do druge vrste povečevala. Večja bo razlika med razdaljama, večji kot zasuka bomo opravili z zadnjo in sprednjo osjo robota in popravili smer vožnje robota.

V algoritmu smo predvideli tudi situacijo, ko ena izmed vrst ni popolnoma posejana. V tem primeru se moramo zanašati na razdaljo samo ene vrste poljščin, manko poljščin v drugi vrsti pa moramo zaznati. To zaznamo tako, da pred vožnjo robota nastavimo parametre, kakšna je lahko največja oddaljenost od senzorja do ovire. V primeru, da je ta večja od predvidene, sklepamo, da zaznavamo poljščin iz sosednje vrste, zato to stran meritev zanemarimo. Tako upoštevamo samo nasprotno stran, ker si vodimo zgodovino oddaljenosti do ovir. V primeru, da se ta spreminja, ustrezno popravimo smer vožnje.

Poleg krmiljenja servomotorjev krmilimo tudi proženje šob. Te se prožijo le takrat, ko s kamero posnamemo iskani objekt (npr. plod), algoritem računalniškega vida pa ga pravilno prepozna. Objekte prepoznamo glede na njihovo barvo in obliko, kjer sledimo naslednjim korakom. Po prejemu slike to pretvorimo iz Bayer kodiranja v HSI barvni prostori, ki se izkaže kot najprimernejši za barvno analizo slik. Osredotočimo se na H komponento, ki predstavlja barvne odtenke in prejeto sliko binariziramo s pomočjo adaptivnih pragov, ki določita največjo in najmanjšo vrednost za izbrani barvni odtenek. Tako dobimo novo različico slike, ki razkriva samo potencialno prava območja. O njihovi pravilnosti nato sklepamo še glede na njihovo obliko, kar storimo s pomočjo podatkov o vrednosti oddaljenosti od težiščne točke, kot to za izbrani primer prikazujeta slika 2 in 3.



Slika 2: Posnetek iskanega objekta (zgoraj levo), njegova binarizirana različica (spodaj levo) in ocena razdalje med težiščno točko in skrajnimi robnimi slikovnimi elementi (desno).



Slika 3: Histogram oddaljenosti dobljen iz oddaljenosti na sliki 3 desno.

REZULTATI

Da bi ocenili ustreznost uporabljenih postopkov, smo izvedli več simulacijskih tekov, kjer smo testirali nadzor vodenja in uspešnost odkrivanja referenčnih objektov (rumenih žogic). Testiranje smo izvedli v kontroliranih pogojih in na prostem, v sadovnjaku. V obeh primerih smo robotu prepustili krmiljenje, dogajanje pa spremljali na oddaljenem računalniku, kjer smo izmerili število najdenih predmetov.

V primeru kontroliranih pogojev smo postopek izvedli v prostorih Fakultete za kmetijstvo in biosistemske vede, kjer smo pripravili pet različnih simulacijskih tekov z različno porazdelitvijo desetih rumenih žogic. Ugotovili smo, da je robot sposoben avtonomnega krmiljenja, v vseh primerih pa smo našli vse iskane predmete.

V drugem primeru smo postopek izvedli v nekontroliranih pogojih, kjer nas je zanimalo, kako se rešitev obnese v sadovnjaku. Ponovno smo izvedli pet simulacijskih tekov v sadovnjaku Srednje biotehniške šole Maribor. Tudi tokrat smo bili zadovoljni z rezultati krmiljenja, malenkost slabše pa se je izkazalo samo odkrivanje žogic, saj smo dosegli 93-odstotno natančnost. Po pregledu posnetkov smo ugotovili, da je razlog za nekoliko slabšo natančnost mogoče pripisati višji travi, ki je precej zakrila iskane objekte.

Ker na samo uspešnost ključno vpliva tudi časovni zamik komunikacije, smo se odločili izmeriti njen vpliv. Opravili smo pet meritev s po sto ponovitvami, kjer smo pošiljali pakete velikosti 270 K zlogov, kar ustreza velikosti posamezne prejete slike. Rezultati so povzeti v tabeli 1.

Tabela 1: Hitrost prejema podatkov

Povprečje [s]	Maksimum [s]	Minimum [s]
0,38	1,21	0,10
0,41	1,28	0,11
0,35	0,97	0,07
0,41	1,02	0,09
0,32	0,99	0,08

Glede na izmerjene hitrosti, podatek o hitrosti gibanja (1 m/s), s katero se robot navadno giba in velikost območja opazovanja (1,5 m) lahko sklenemo, da je hitrost prenosa tudi v najslabšem zamiku dovolj dobra, saj zaporedni posnetki zajamejo celotno območje, kjer se posnetki pokrijejo za vsaj 0,3 m.

Zaradi prekinitev, ki se dogajajo med izvajanjem programa na mikrokontrolerju pri prejemanju podatkov prek serijske povezave, lahko pride do napake pri meritvi dolžine povratnega pulza. Prekinitvena rutina pa je tako kratka, da napaka znaša le 56 mikrosekund. To predstavlja napako približno en centimeter. Ta je zanemarljiva, saj bi, da bi bila napaka opazna, bilo treba območje kvantizirati kar na 300, v trenutni realizaciji pa jih uporabljamo deset. Zanemarljivo majhne napake pri meritvah pa se lahko pojavijo tudi zaradi temperature, zračnega tlaka in celo zračne vlažnosti, saj se v tem primeru spremeni hitrost širjenja zvoka. Te imajo na delovanje še manjši vpliv kot zakasnitev zaradi prekinitvene rutine in jih lahko zanemarimo.

Kot zadnje pa nas je zanimalo še, kakšna je izmerjena časovna zahtevnost uporabljenih postopkov krmiljenja in iskanja predmetov na oddaljenem računalniku. Oba algoritma smo realizirali s pomočjo programskega paketa Matlab, časovno zahtevnost pa izmerili na računalniku s Core 2 duo procesorjem (2 GHz) in 2 giga zlogi DDR2 pomnilnika. Najprej smo simulirali prejem 1000 paketov s podatki o senzorjih, kjer se je izkazalo, da smo te v povprečju obdelali v 0,01 sekunde, kar je precej več, kot dejansko potrebujemo, saj v trenutni testni različici prejmemo samo okoli 20 paketov na sekundo.

Podobno analizo časovne zahtevnosti smo izvedli še s simulacijo iskanja referenčnih objektov na prejetih posnetkih. Prejem podatkov smo ponovno simulirali, saj se izkaže, da procesiranje slik ni ozko grlo v sistemu in lahko analiziramo veliko več slik, kot jih dejansko prejmemo. Po prejemu 100 različnih slik smo ugotovili, da je časovna zahtevnost uporabljenih postopkov v rangu 0,5 sekunde.

SKLEP

V delu smo predstavili poljedelski stroj, kot potencialno platformo namenjeno natančnejšemu in učinkovitejšemu kmetovanju. Trenutna izvedba omogoča iskanje preprostih predmetov glede na njihovo barvo in obliko, nanje pa opozarja z zvočnimi in svetlobnimi signali ter nanaša fitofarmacevtska sredstva. V fazi nadaljnjega razvoja pa je naš cilj dodelati algoritme tako, da bo stroj sposoben prepoznati kompleksnejše oblike, tudi ko bodo te deloma zakrite in nepopolne.

Faza testiranja je pokazala, da se v primeru procesiranja podatkov na oddaljenem računalniku kot ključni izkaže časovni zamik prenosa podatkov. Trenutna omejitev robota je zato hitrost gibanja, ki je omejena na en meter v sekundi; v tem primeru je komunikacija še vedno dovolj hitra, da s slikovnim vzorčenjem pokrijemo celotno interesno območje. To bomo v fazi nadaljnjega razvoja še izboljšali, za kar že imamo nekaj predlogov. Prvi govori o vsaj delni popolni ali vsaj obdelavi slik na že vgrajenem računalniku, ki smo jo izpostavili uvodoma. Oddaljeni računalnik bi tako opravljal samo ključne korake, morebiti samo vodenje in nadzor glede na podatke iz senzorjev. Brezžični prenos slik bi uporabili le v fazi razvoja algoritmov, tu pa bi z manjšimi spremembami v delovanju lahko namesto TCP povezave uporabili preprostejšo in hitrejšo UDP povezavo, ki bi propustnost še izboljšala.

Predstavljena raziskovalna platforma pomeni prvi korak na poti k izgradnji vsestranskega in natančnega avtomatiziranega kmetijskega stroja. Vsekakor pa je to korak v pravo smer, ko skušamo zagotoviti potencialno ekonomsko prednost in hkrati, kolikor je le mogoče, skrbeti za varstvo našega zdravja in okolja.

LITERATURA

1. A. Komat, Pesticidi, ubijalci življenja, Založba Tangram, Ljubljana, 1995.
2. Bulanon, D.M., T. Kataoka, Y. Ota, and T. Hiroma. A Machine Vision System for the Apple Harvesting Robot, Agricultural Engineering International: the CIGR Journal of Scientific Research and Development. Manuscript PM 01 006. Vol. III.
3. Guo Feng, Cao Qixin, Nagata Masateru, /Fruit Detachment and Classification Method for Strawberry Harvesting Robot/, International Journal of Advanced Robotic Systems, Vol. 5, No. 1, 2008.
4. Hortibot: http://www.hortibot.com/
5. J. F. Thompson, J. V. Stafford, P. C. H. Miller, Potential for automatic weed detection and selective herbicide application, Crop Protection, št. 10, str. 254-259, 1991.
6. Kamera DBK31BU03: http://www.theimagingsource.com/en/products/cameras/ usb_bayer/dbk 31bu03/overview/
7. L. Shapiro, G. Stockman, Computer Vision, Prentice-Hall, Inc. 2001.
8. M. Mrhar, Kmetijski stroji in naprave, Kmečki glas, Ljubljana, 3. izd., 1997.
9. Mikrokrmilnik: http://www.microchip.com/wwwproducts/Devices.aspx?dDoc Name=en 010242
10. Objektiv H0514-MP: http://www.theimagingsource.com/en/products/optics/lenses /#megapixel
11. Pesticidi: http://www.pesticidi.net
12. R. Bernik, Sestava in delovanje škropilnic: minimanlne zahteve, *Kmečki glas*, let. 49, št. 19, str. 13, 1992.
13. R. C. Gonzales, R. E. Woods, 2001. Digital Image Processing, 3rd edition, Upper Saddle River: Prentice Hall PTR.
14. R. C. Gonzales, R. E. Woods, S. L. Eddins, Digital image processing using Matlab, 1st edition, Upper Saddle River, 2004.
15. Senzor SRF04: http://www.acroname.com/robotics /parts/R93-SRF04.html
16. Servomotor Futaba S3003: http://www.gpdealera.c om/cgibin/wgainf100p.pgm ?I=FUTM0031
17. Vgrajen računalnik: http://www.via.com.tw/en/products/mainboards/motherboards
18. .jsp?motherboard_id=472

SELECTIVE PESTICIDE SPRAYING WITH THE HELP OF AN AUTONOMOUS ROBOT

ABSTRACT

As the use of pesticides increases over the years, people are becoming more and more aware of their negative effects and health risks they might pose. The use of pesticides could be reduced significantly by applying them with care, only on to the selected areas and in the right quantities. In this paper we represent a small automated self oriented robot, which would not only replace human labour, but also reduce the use of pesticides and the work quicker with higher precision and lower costs. To achieve this goal we equipped the robot with ultrasonic sensors, high resolution digital camera and an onboard computer. We tested the robot to detect simple objects, where several simulation runs proved 100 % success rate for controlled and 93 % for uncontrolled environments.

Key words: *robot, computer vision, pesticides, automation*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.21:663.28
Izvorni znanstveni rad
Original scientific paper

WINE-GROWING AND PRODUCING FARM BUILDINGS: META-DESIGN ANALYSIS FOR THE DEFINITION OF SPATIAL LAYOUTS

S. BENNI[1], D. TORREGGIANI[1], V. CORZANI[1], F. CUTTIN[1], P. TASSINARI[1], S. GALASSI[2]

[1]Dept. of Agricultural Economics and Engineering, University of Bologna
V.le G. Fanin, 48 -40127 Bologna (Italy). E-mail: stefano.benni@unibo.it
[2]Dept. of Food Science, University of Bologna (Italy)

SUMMARY

The study is part of a wider research aiming at defining building design criteria suitable for small and medium-sized wine-growing and producing farms. The goal of this paper is to work out and validate a specific meta-design process, suitable to lead to the definition of possible layout solutions optimized in terms of functional requirements. The production process has been resolved into two macro-phases and their main sections, whose operations and functions have been identified. The in-depth analyses performed on the spatial requirement of these operations and functions allowed the definition of the appropriate functional areas and spatial units suitable for building design. Finally, the analysis of their functional and spatial relations carried out through flow diagrams and a connection matrix allowed to outline examples of possible layout solutions.

Key words: *wine-making, functional area, spatial unit, building performance, spatial relations, building design*

INTRODUCTION

Italian wine sector has established itself as a world leader both for total production and export, covering the 18% market share of the world exports (Nomisma, 2008). Italian vine-growing farms are mainly small or medium sized and scattered over the national territory: 771 000 farms cultivate 840 000 ha of vineyards (Istat, 2000). No official data is available at national level about how many of these farms use their own grapes to produce wine. Nevertheless, several studies performed in various areas showed that they are very common and their products generally represent an important share of the wine market. Their ever increasing efforts have been focusing on quality productions and brand typical wines, which are proposed as concrete expressions of the local culture (Menghini, 2007; Tassinari et al., 2009).

The importance of defining specific building design criteria for these farms comes to the fore given the still topical and challenging need to combine functionality requirements related to the production process with technical and economic sustainability. Most of the scientific literature focuses on the design of buildings for industrial wineries (see Ayuga, 1999), mainly considering those aspects related to the innovation of their technological equipments and facilities (Nardin et al, 2006; Jacquet and Capdeville, 2007). On the contrary, quite poor attention is given to small and medium sized wine farms, which although are considered by some authors: Fichera et al. (2000) examined the theme of landscape and environmental sustainability of wineries, and Failla et al. (2008), with reference to the specific issue of workplace safety, worked out analysis criteria and design guidelines for wineries in eastern Sicily.

The present study is part of a wider research aiming at developing specific building design criteria for small and medium-sized wine farms that mainly process their own grapes. The general goal of this work of defining and validating a proper meta-design framework is organized into the specific objectives of defining: the phases and elementary operations of the production process; the most suitable functional areas and spatial units of wineries; possible layout solutions optimized with regard to the functional requirements identified.

METHODS

The wine farms of the considered typology in many cases manage directly the entire production chain, from the cultivation of grape-vines to the commercialization of wine. For this purpose, their built spaces are usually organized into areas on the basis of their functions: grapes receipt, processing, and storage, finished product aging, together with those for commercialization and wine tasting. Moreover, most of the farms do not have specific built spaces for bottling, since they mainly rely on specialized third-party firms, generally operating with mobile equipment.

The study of the characteristic of the productive and building systems was carried out according to a meta-design approach, proposed by various scholars who proved its effectiveness in the design of agro-industrial buildings (Fichera et al., 1995). This method is based on the identification of the areas which prove most suitable for the objectives and technical and organizational aspects of production. Two *macro-phases* of the process have been considered: transformation, consisting of the sequence of operations related to the wine-making process, and support and commercialisation, that is those actions dealing with quality management, health, hygiene and safety management, storage and commercialization. The macro-phases have then been resolved into *sections*, each one consisting in a homogeneous class of *operations* or *functions*. Each operation and function has been studied in terms of processed materials and suitable equipment. Workers and facilities movements have also been analysed. This detailed study led thus to the definition of the main spatial requirements that should be considered to design the layout of a wine farm building.

The used methodology, outlined in Figure 1, called for grouping those operations/functions spatially and temporally linked and compatible, in order to define the built areas where such operations/functions could be optimally carried out (*functional areas*, FA). Finally, the *spatial units* (SU) are obtained combining the various functional areas on the basis of their interactions through the various production stages and homogeneous requirements or intrinsic conditions of the transformation process. While various functional areas may be located in the same room of the building, each spatial unit represents a single and separate portion of the building, generally bounded by physical partitions. The spatial units where then grouped in the two transformation and support and commercialization *macro-areas*, depending on which macro phase the sections carried out in the spatial units belong to.

The materials and workers flow analysis and the definition of boundary conditions allowed to determine the basic correlations among the various spatial units and work out a synoptic connection matrix. These results proved useful for the definition of possible layout solutions.

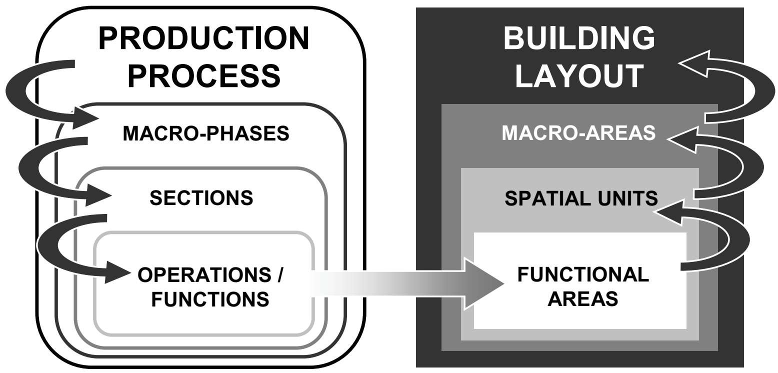


Figure 1 The flowchart outlines the main steps of the methodology, from the analysis of the productive process to the definition of spatial layouts for wine-growing and producing farm buildings

RESULTS AND DISCUSSION

High flexibility is characteristic for the production lines of the wineries considered in the study, since this makes easier to switch between different wine-making techniques and thus diversify the final products. It also allows to control the product quality, optimizing the use of the processing structure. Such flexibility is mainly achieved through movable equipment, high-adaptability plants, and the use of workers for different functions. The production process has been flowcharted according to its well known sections: grapes receipt, wine-making, storage, fining, aging, bottling and packaging, warehousing, tasting, selling, and services necessary to the process (Figure 2).

Grapes–receipt, wine-making and storage represent the core sections of the transformation macro-phase and the most complex systems of operations/functions within the whole production process. These operations and their material flows are illustrated in Figure 3.

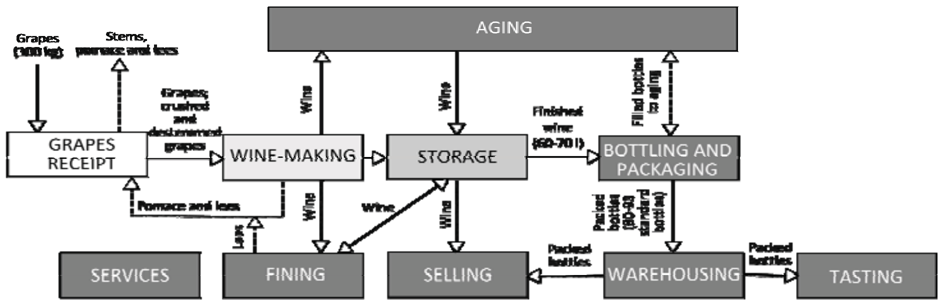


Figure 2 Flowchart of the main sections of the productive process; The services section is indirectly related to every other one

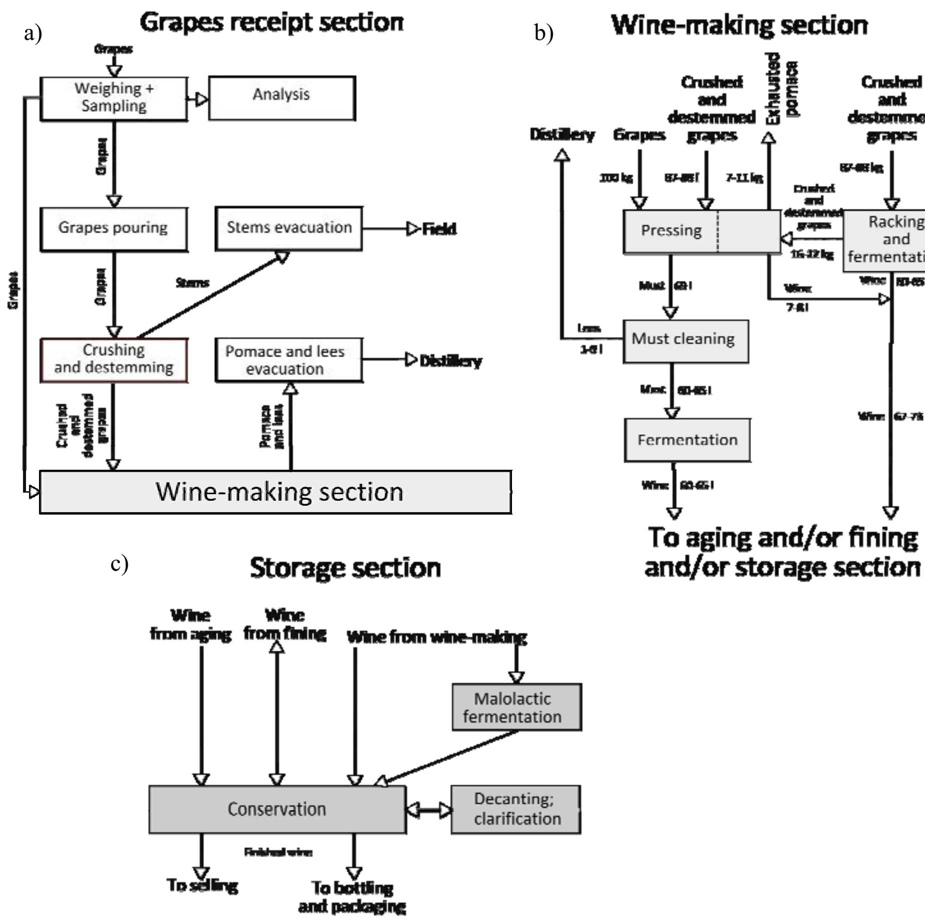


Figure 3 Flowchart of operations and material flows of the main sections of the transformation macro-phase: a) grapes receipt; b) wine-making (quantities are referred to a 100 kg grapes input); c) storage

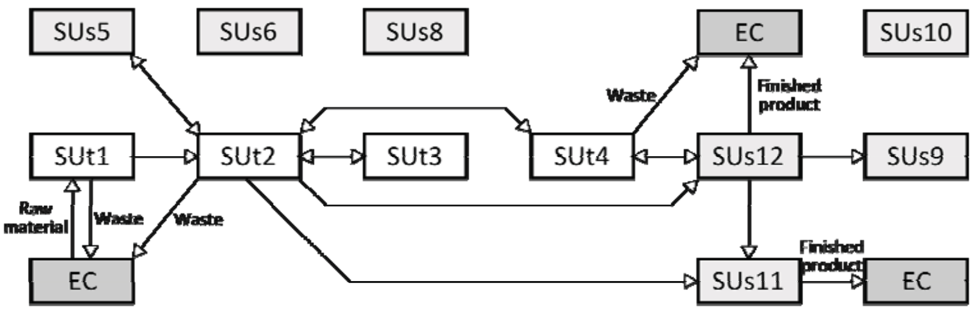
Table 1 Synoptic table of the production process and built spaces

PROCESS											BUILDING		
MACRO-PHASE	SECTION	OPERATION/ FUNCTION	MATERIAL	EQUIPMENT	MOVEMENT			STOP			FUNCTIONAL AREA	SPATIAL UNIT	MACRO-AREA
			M	E	M	E	O	M	E	O			
TRANSFROMATION	GRAPES RECEIPT	Weighing	Grapes	Weighbridge	X		X		X		FAt1	SUt1	TRANSFROMATION
		Sampling	Grapes	Sampling equipment	X				X	X			
		Analysis	Grapes	Refractometer	X				X	X			
		Pouring	Grapes	Hopper	X				X	X	FAt2		
		Crushing and destemming	Grapes	Crusher-destemmer	X				X	X			
		Evacuation	Stems; pomace and lees	Lorry	X				X	X	FAt3		
	WINE-MAKING	Pressing	Grapes; crushed and destemmed grapes; pomace	Press	X				X	X	FAt4	SUt2	
		Racking	Crushed and destemmed grapes	Fermentation tank			X	X	X				
		Fermentation	Crushed and destemmed grapes; must	Fermentation tank			X	X	X				
		Must cleaning	Must	Tank	X	X	X						
	STORAGE	Malolactic fermentation	Wine	Storage tank	X				X		FAt5		
		Conservation	Wine	Storage tank	X				X				
		Decanting Clarifications	Wine	Storage tank	X		X		X				
	FINING	Filtering	Wine	Filtering system	X	X	X						
	AGING	Aging	Wine	Barrel				X	X		FAt6	SUt3	
	BOTTLING AND PACKAGING	Bottling	Wine Bottles	Bottling machine	X				X	X	FAt7	SUt4	
		Packaging	Bottles Packages	Various	X				X	X			
SUPPORT AND COMMERCIALISATION	SERVICES	Depository	Various					X			FAs8	SUs5	SUPPORT AND COMMERCIALISATION
		Dressing									FAs9	SUs6	
		Showers									FAs10	SUs7	
		Workers' toilet									FAs11	SUs8	
	TASTING	Tasting	Finished product		X		X				FAs12	SUs9	
		Guests' toilet									FAs13	SUs10	
	RETAIL SELLING[1]	Selling	Finished product	Tap	X		X		X		FAs14	SUs11	
	WAREHOUSING [2]	Warehousing	Finished product		X		X				FAs15	SUs12	

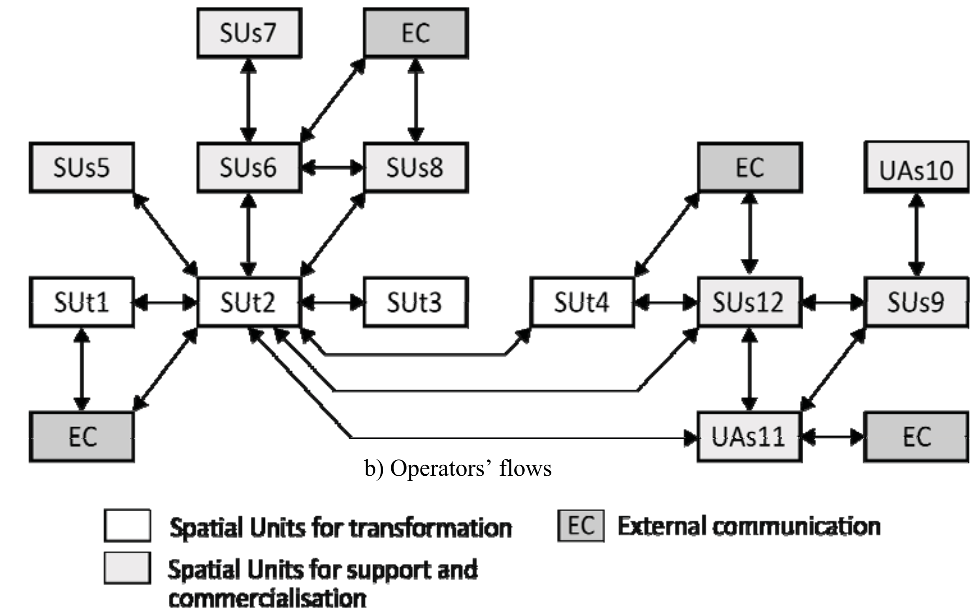
NOTES: [1] It could also take place in the tasting room ; [2] It often includes the aging of bottled product; O = operator

The macro-phases, sections and operations/functions of the production process and the functional areas suitable for them are shown in table 1. First we distinguished the areas functional to the transformation macro-phase (FAt*i*), from the ones functional to support and commercialisation one (FAs*i*). Afterward the functional areas have been aggregated into spatial units, which in their turn were defined as belonging to transformation macro-area (SUt*i*) or to the support and commercialisation one (SUs*i*). The defined spatial units are reported in Table 2.

We have analysed the relations among the various spatial units, in terms both of material (raw material, intermediate product, finished product, by-products) and operator flows. The results are outlined in Figure 4.



a) Materials flows



b) Operators' flows

Figure 4 The relations among the spatial units: materials (a) and operators (b) flows

Table 2 Spatial units identified as suitable for a wine-growing and producing farm building

SPATIAL UNITS				
Transformation macro area			*Support and commercialisation macro-area*	
SUt1 Grapes receipt area	**SUt3** Aging room		**SUs5** Depository	**SUs9** Tasting room
			SUs6 Dressing room	**SUs10** Guests' toilet
SUt2 Wine-making and conservation	**SUt4** Bottling and packaging area		**SUs7** Showers	**SUs11** Selling premises
			SUs8 Workers' toilet	**SUs12** Storeroom

Operators and materials flows in most cases overlap: routes mainly coincide when mobile equipments are used (pumps, flexible pipes, conveyor belts, etc.). In particular the spatial unit SUt2 (wine-making and conservation) is characterized by the highest concentration of inbound and outbound flows of operators and materials.

The matrix in Figure 5 shows the connections among the spatial units in terms of their physical links needed to allow materials and people movement. *Direct relation* indicates the need for a direct connection between the two spatial units, while *indirect relation* means their proximity is enough, since their link can be achieved through the outside spaces or inner corridors.

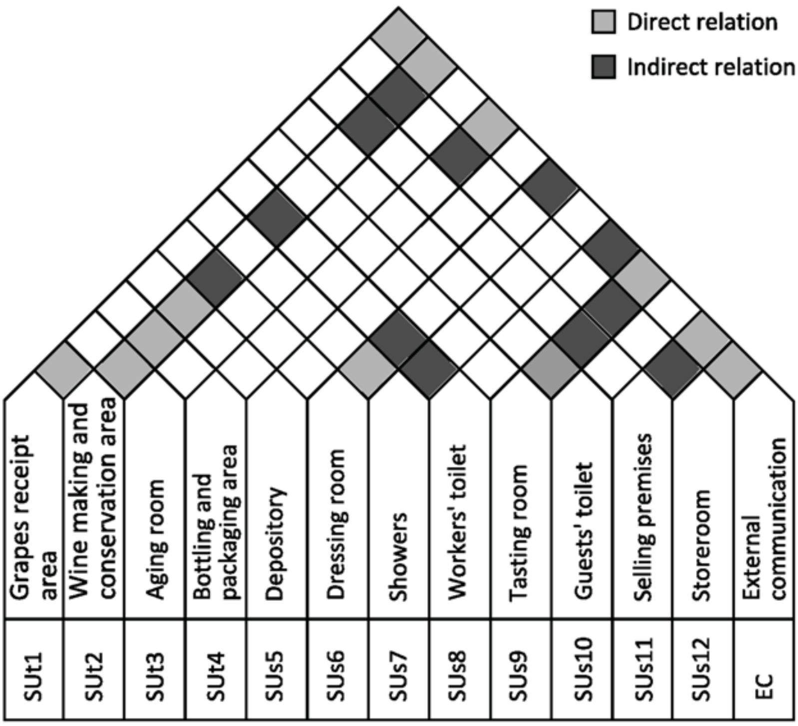


Figure 5 The matrix shows the connections among the various spatial units, thus supporting the definition of efficient building layouts.

The results of the analyses described above have been used to work out two alternative pilot building layouts. These have been defined assuming a theoretical new construction case study. All the above-mentioned spatial units necessary to the development of the whole production process have been considered in the layouts. We considered a flat construction site and a single-level building, with no basement. This kind of solution, commonly used in plain areas, is also useful in hilly regions, especially in case topography does not allow the creation of underground cellars. Nevertheless, specific needs and requirements, related to the farm structure, site conditions or other peculiar issues, can call for considering different layout solutions, thus modifying the proposed models. Also original architectural and engineering choices may play a key role in defining the final building layout. Moreover, further design phases follow the preliminary definition of the general layout resulted from the meta-design analysis: definition of the built spaces sizes, composition of the façades, choice of the most suitable structural, technological and material solutions, and definition of any other architectural, constructive, technical, formal and aesthetic detail.

The proposed layout are illustrated in the schemes of Figure 6, where the proportions among the size of the various spatial units are given purely as an indication. The two solutions mainly differ in their overall shape: axial in the first case (Figure 6.a), more compact and isodiametric in the second (Figure 6.b).

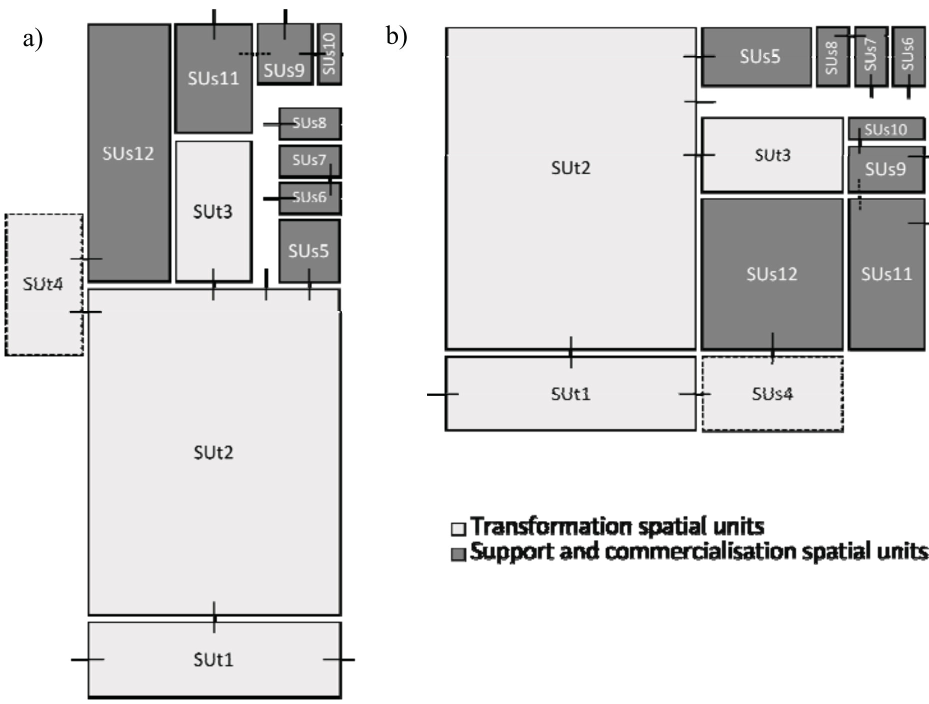


Figure 6 Two case-study layout solutions defined through the meta-design analysis:
a) Axial layout solution; b) Compact layout solution

The key design issues which led to the definition of the proposed layouts, together with the main design constraints and opportunities arisen from the analysis, are briefly outlined here.

The SUt1 spatial unit (grapes receipt) is conceived as a sheltered outer area located near the main building and connected with SUt2 (wine-making), in order to allow the lorries and trucks to easily manoeuvre, load and unload. Given the well-known need for optimizing the SUt3 (aging room) environment (see Fuller et al., 2004), we considered appropriate to locate it in the heart of the building, to enhance its natural heat insulation and thus improve the performance of any air conditioning system. On the contrary, two sides of SUt2 and at least one of the other spatial units consist in external walls, to allow natural lighting and ventilation. In case of production volume increase, this also facilitates building expansion. As for SUt4, we assumed that bottling and packaging operations were outsourced and carried out using movable semiautomatic bottling lines. These can be placed in SUt1, or in other outer paved areas near SUt2, from whose tanks wine is pumped into the bottling lines. Based on the flows analysis, the realization of corridors connecting SUt2 to SUs6 (dressing room), SUs7 (showers) and SUs8 (workers' toilet) and the outside proves effective. This also allows an entrance to SUt2 alternative to SUt1 and to directly enter the service spatial units from outside.

We also conceived a direct entrance to SUs9 (tasting room) and SUs11 (selling premises), to prevent visitors from going through SUt1 and SUs12 (storeroom) and differentiate visitors and workers external areas. This both improves visitors' safety and allows to enhance the farm image, focusing higher aesthetic quality design solutions to meet specific marketing requirements.

CONCLUSIONS

The study defined a specific approach aimed at designing building layouts suitable for small and medium-sized wine-growing and producing farms. The meta-design methodology allowed to translate production quality goals into functional and flexible building design criteria. The results proved useful references for preliminary building design.

The following design phases call for accurate production programming, since the definition of the spatial units sizes must rely on detailed data about grape-harvest and process time-scheduling.

The authors carried out this work within a broader research, which is now focusing on the analysis of the technical, architectonic and functional potentials and critical issues of wine-growing and producing farm buildings within an Italian study area of the Emilia-Romagna region. These in-depth analyses aim at investigating the main functional needs and the related building requirements, which represent basic information to define proper material and constructive solutions. These results prove suitable both for expansion or upgrading of existing buildings and new constructions, allowing to consider economical, environmental and landscape aspects.

In particular the architectural quality of farm buildings represents a key topic and a specific focus of the research, which is aimed at defining architectonic and landscape quality planning and design criteria. Besides proving useful to improve the farm image from a commercial point of view, they may be integrated into town planning regulations and building codes, thus contributing to preserve and enhance rural landscape and built environment.

REFERENCES

1. Ayuga F. (1999). Wine Processing. In: CIGR Handbook of Agricultural Engineering. Volume IV Agro-Porcessing Engineering (F.W. Bakker-Arkema ed), ASAE, St. Joseph, Michigan, 419-446
2. Failla A., Tomaselli G., Strano L. (2008). The definition of planning criteria for safe workplaces in wineries. In: Proc Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems. Ragusa, Italy, pp 1-8
3. Fichera C.R., Tomaselli G., Di Fazio S. (1995). La metaprogettazione edilizia per l'industria agraria. Note di metodo. In: P. Amirante, A. Failla, C. Bruno, F. Marzano (eds) Proc AIIA, Rivista di Ingegneria Agraria, Quaderno n. 18. Bari, pp 45-58
4. Fichera C. R., Di Fazio S., Bonomo G. (2000). Sustainable planning of winery in relation to land uses and the landscape in the wine-regions of Italy. In: Proc XIV Memorial CIGR World Congress 2000, pp 325-330
5. Fuller R.J., Luther M.B., Cheung C.K. (2004) Performance of a commercial wine store with insulated concrete walls. Building and Environment 39: 537-545
6. Istat, Italian statistic board (2000). 5° Censimento dell'agricoltura. Istat, Roma
7. Jacquet P., Capdeville C. (2007). Installazioni vinicole. Eno-one, Reggio Emilia
8. Menghini S. (2009). Il ruolo del settore vitivinicolo nei processi di sviluppo sostenibile. Franco Angeli, Milano
9. Nardin G., Gaudio A., Antonel G., Simeoni P. (2006). Impiantistica enologica: ciclo di vinificazione e progettazione degli impianti. Edagricole, Bologna
10. Nomisma. (2008). Wine marketing. Scenari, mercati internazionali e competitività del vino italiano. Agra, Roma
11. Tassinari P., Galassi S., Benni S., Torreggiani D. (2009). Il sistema costruito delle aziende vitivinicole: una metologia di analisi del comparto per la definizione dei requisiti metaprogettuali. In: Proc IX Convegno Nazionale AIIA. Ischia Porto, Italia, p 147

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.41:631.374
Izvorni znanstveni rad
Original scientific paper

A MULTI-RING MODEL TO SIMULATE PARTICLE-BASED SYSTEMS IN BIOMATERIALS TRANSPORT

J. KAFASHAN, P. VAN LIEDEKERKE, H. RAMON, B. TIJSKENS

Division of Mechatronics, Biostatistics and Sensors (MeBioS),
Katholieke Universiteit Leuven (K.U.L.),
Kasteelpark Arenberg 30, B-3001 Heverlee, Belgium
E-mail: Jalal.Kafashan@biw.kuleuven.be

ABSTRACT

Nowadays, simulation is a major concern of many researchers of different domains. The discrete element method (DEM) is a powerful tool to simulate complex physical systems, specially particle-based systems, and used by engineers and scientists more and more yearly. In these simulations, particles are represented as spheres, because of simplicity. Although several methods are proposed to model particles so far, particles generation is still one of the most significant issues to improve DEM in various applications.

Transport and handling of biomaterials involves particle-based systems that can be simulated by DEM along with different particle models. To date, for this type of application and very limited, only the use of single circles and spheres are reported. The main objective of this work is to present a technique to generate more realistic particle shapes compromising between simplicity of particles form and complexity of real particles in 3D. This paper generally focuses on a model to generate particles by multi-spheres using a new technique in order to use in of transport and the handling of biomaterials. Generated particles by the model showed that the technique is applicable for a range of fruits and products in 3D simulations. An increasing number of sphere-ring and spheres creates more realistic particles, but a time-consuming of simulation. Nevertheless, it can be therefore considered as an effective technique to complete gradually realistic particles in the simulation of biomaterials during handling, processing and transport.

Keywords: *DEM, Multi-Ring Model, Sphere, Fruit Transport Simulation, Particle-Based System.*

INTRODUCTION

In recent years, simulation has become a crucial step in the planning, managing, designing and reproducing of processes. The main reason is that it is economically low cost and the results can be technically provided more in detailed. In addition, simulation is a key in R&D activities and a modern complementary tool where designers, engineers and researchers can capture the critical and non-critical points in their works. As a known system, transportation is an essential sector in the chain of production where it sets between producers and consumers. Furthermore, quantity and quality losses in products typically take place in the phase between harvesting and marketing where the transportation comes in to play. Kader (2005) reported that the range of fruit loss quantity ranges from 20 to 50% and 5 to 25% in the developing and the developed countries respectively. Certainly, the nutritional and economical value of a such losses is never insignificant and ignorable.

As a simulation tool, discrete element method (DEM) deals with the behaviour of particulate media in most of dynamical systems. This have been appeared in the simulation from the time that computer technology enhanced its computational speed. Although it was originally pioneered in rock engineering, use of DEM is escalating in different engineering domains to simulate complex physical systems, especially for particle-based systems according to the number of published papers. Presented papers show that this is a new concern to take in to account biomaterials transportation in simulation (Kafashan et al., 2009) by DEM since neither many details are accessible nor a realistic particle shape in this area yet . In this application, Van Zeebroeck et al. (2006a,b) just used single-sphere particles in DEMeter++ (Tijskens et al., 2003). The particle shape may play a key role in the biomaterials transportation because it influences the motion and amount of contact in a collision. Products such as fruits, are also mostly irregular in shape. This makes difficulties in DEM initializing and computing procedures for simulation a system. However different methods have defined non-spherical particle shapes up to now (such as SC3 method (Kafashan et al., 2007), axi-symmetrical particles (Favier et al., 1999 ; Favier et al., 2001), cardioids (Tijskens et al., 2004) polyhedrals (Cundall, 1988b; Hocking, 1992), ellipsoids (Lin and Ng, 1997) and superquadric functions (Williams and Pentland, 1992; Hogue, 1998), generating particles is still one of the most considerable issues to develop DEM models in various applications and particularly in three-dimensional space (3D). And it is also a novel theme in the simulation of biomaterials transportation. Despite the fact that a simple particle shape model can be easily used in DEM simulations, in many scenarios more realistic particle shape model is preferred. This paper therefore focuses on a method generating more realistic particle shapes compromising between computation time and complexity of particle in 3D.

METHODS

DEM and particle shape

DEM is a method based on Newtonian and Lagrangian mechanics to simulate the dynamics of a large number of particles. A DEM simulation is generally limited to the simple particles due to the increase in expense of computation with increasing complexity of geometry. Mostly single-spheres in the simulation are used. Yet, the shape of particles can in a number of scenarios have a significant influence on the performance of a granular media, and so method of modelling non-spherical particles is needed. Certainly, particle shape plays a key role in DEM, which is the first crucial step in the models. Figure 1 describes the steps of a general DEM in a flowchart and it shows the location of particles shape in these processes.

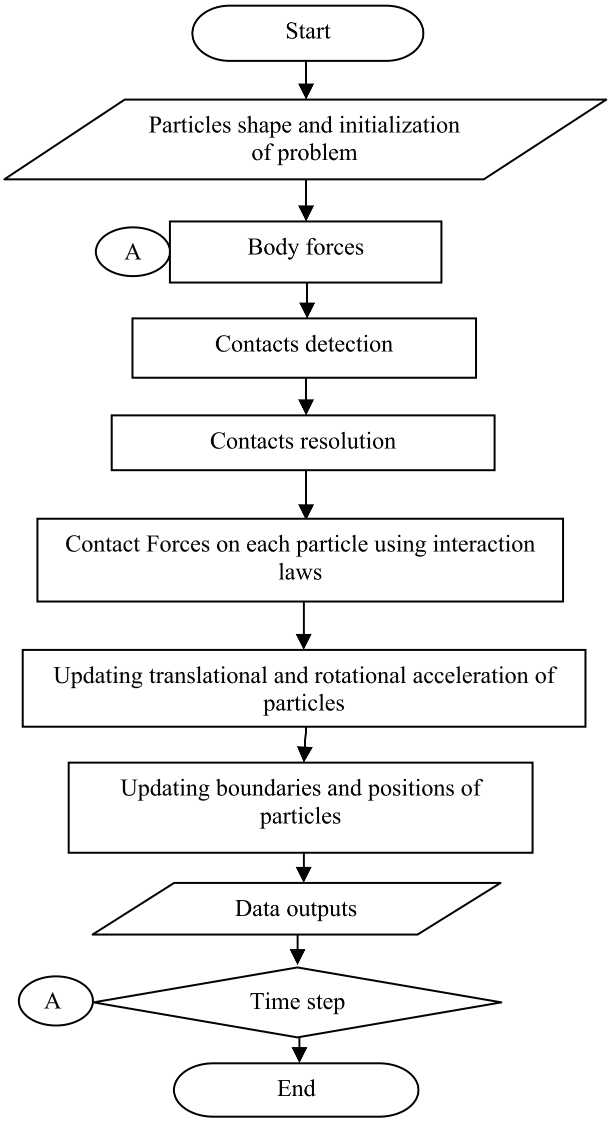


Figure 1 A general DEM procedure sequences

Forces and equations of motion in a multi-body system

Assume two spherical particles, i and j with ri and rj positions; mass of m_i and m_i , are in contact that are simply shown in two dimensional in figure 1.

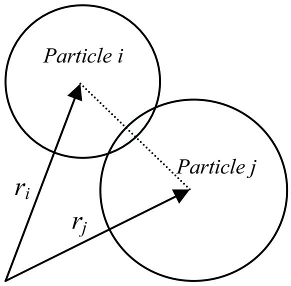


Figure 2 Scheme of two circular particles in virtual contact in 2D

According to dynamics equilibrium, the following force balance equation for particle i, can be written.

$$m_i \frac{d^2\vec{r_i}}{dt^2} = \sum\nolimits_{contact\,(s)} \vec{F_i} + m_i \vec{g}$$

$$\vec{v_i} = \frac{d\vec{r_i}}{dt}$$

$$\vec{a_i} = \frac{d^2\vec{r_i}}{dt^2}$$

Here, $\overrightarrow{r_i}$, $\overrightarrow{v_i}$ and $\overrightarrow{a_i}$ are respectively vectors of postion, velocity and acelaration for particle i at time of *t*.

$$I_i \frac{d^2\vec{\theta_i}}{dt^2} = \sum \vec{M_i} \qquad \vec{\omega_i} = \frac{d\vec{\theta_i}}{dt} \qquad \vec{u_i} = \frac{d^2\vec{\theta_i}}{dt^2}$$

Where $\overrightarrow{\theta_i}$, $\overrightarrow{\omega_i}$ and $\overrightarrow{u_i}$ are vectors of orientation, angular velocity and angular acelaration in that order.

2D description of particles shape

Now, we describe the method in 2D to form a shape of an object for example an apple. Apple has no a regular shape. The method, assumes the object boundary as a single-ring. In this way, the object can be modelled by at least 6 circles in 2D. The circles are positioned arbitrary locations, may vary in size, and may even overlap which is depends on the sphericity of the original particle shape (fruit). In each object, the number of these circles increases when sphericity decreases.

Figure 3 A particle (half of an apple fruit) and equalant created by 6 circles in 2D

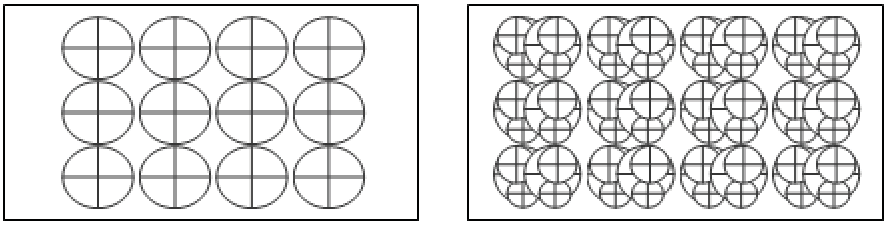


Figure 4 Scheme of a bulk of 12 particles in 2D: a) circular particles (left), b) equalant particles (right)

To create a more realistic particle shape, each circle must be placed such that it approaches the local curvatures of the particle shape. In addition, for having realistic particle, increasing number of circles is crucial as can be seen in figure 5.

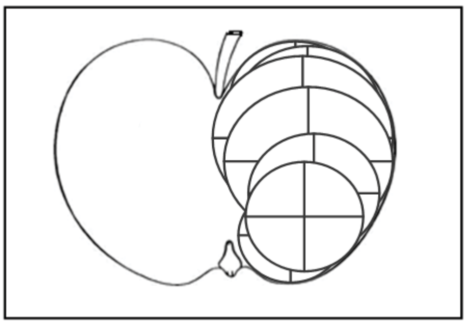


Figure 5 Circles placed on the boundary of a particle (14 circles for completed-fit)

Multi-Ring Model (3D description of particles shape)

The method is basically places a set of spheres as a ring to cover the surface. First an axis must be therefore defined either in a symmetrical or an asymmetrical object . Next, around this, the spheres will be placed to fit on the surface of particle. At least three rings of spheres are necessary to obtain an apple in three dimensional space. Certainly, it could be necessary to defined more than one axis for a very complex shape. Hence, in this scenario an skeleton must be defined in 3D and spheres place around each axis of the defined skeleton. Then, One or several axis can be defined as a skeleton to place spheres as rings around it. They may be paralleled, crossed each other or in different directions. The rings may vary in shape from a circle to any uninformed-shape, and may overlap. Additionally, the spheres may otherwise obtain arbitrary positions, may vary in size, and may even overlap. This method can be easily generalized for most of particles in use of DEM in other applications. For the case, DEM-MRPG++ program is written in C++ to generator particles information to be implemented in DEMeter++.

RESULTS AND DISCUSSION

Even if collision detection and calculations of particle overlapping are not as fast as for spherical particles, they can nonetheless be made effectively simple and fast for implementation in DEM applications. As explained earlier in 2D, since the motion and contact formulations are the same.

In figure 6, as a particle, an apple is reconstructed by the method by three rings with the different number of spheres per ring.

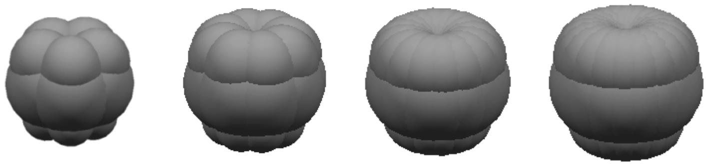


Figure 6 Examples of the method in 3D: 3 rings with different number of spheres per ring (5 , 8, 16 and 20 from left to right respectively)

The current technique has the advantage that particles of broadly differing shapes can be defined, despite the fact that the collision detection and calculation of overlapping are quite straightforward. The method is not only can cover axi-symetrical particles but also asymmetrical particles can be modelled in this restructuring. Oriented particles can be also prepared with different configurations by the program (figure 7). Three different configurations are available as: random, body centered cubic(BCC), simple cubic packing (figure 7&8). The method can be basically implemented not only for biomaterial particles such as flat peach, fig, pear, squash, potato, pumpkin, melon but also in other applications.

Results show that a rising in number of spheres in a particle forms a particle more realistic but a time-consuming simulation. Undoubtedly the number of segments should be compromised with an acceptable time step and an accuracy to carry out an efficient simulation. The number of circles or spheres in each particle should be increased by decreasing the roundness or sphericity.

Although the method is programmed in three-dimensional space, it is simply feasible in two-dimensional space. The method can be easily generalized for most of the particles in use of DEM in other applications. In addition, having a possibility of adding different properties for the same particle may be included (for example different properties from the top to the bottom of an object).

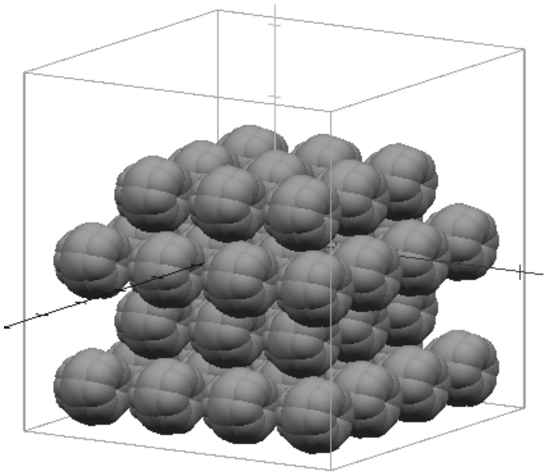


Figure 7 Oriented particles with *body centered cubic* (BCC) packing configuration

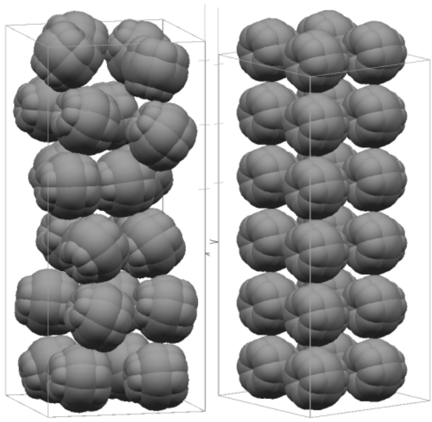


Figure 8 Different packing configurations: *random* (left), *simple cubic packing* (right)

CONCLUSIONS

A method for defining non-spherical particles in DEM has been addressed. Whilst no much difficulties exists in defining an irregular particle shape in two-dimensional space it is would be extremely complex in three-dimensional space. For that reason, an alternative technique to improve precision and simplicity of particle shape for DEM in 3D scheme is pioneered. The overall approach entitled "Multi-Ring Model" is described which allows definition of irregular particles in 3D. And a specific case for apple is illustrated. The method has the ability to generate complex particle shapes either symmetric or asymmetric in 3D. By the method, the generated particle shapes confirm that this is applicable for a range of products to simulate their dynamics in a transportation system. It can be considered as an effective method to complete realistic particles shapes in the simulation of biomaterials for transportation process and in other applications. As a gain of this approach, the generation of oriented particles, various layers, and numerous arrangements in DEM should be cited. This is therefore a novel approach of DEM using irregular shape of particles in transportation scenarios.

REFERENCES

1. Cundall PA. (1988). Formulation of a three-dimensional distinct element model –Part I. A scheme to detect and represent contacts in a system composed of many polyhedral blocks. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts; 25(3): 107–116.
2. Favier J.F., Abbaspour-Fard M.H., Kremmer M. (2001). Modeling nonspherical particles using multisphere discrete elements. Journal of Engineering Mechanics—ASCE 127, No.10: 971–977.
3. Favier J.F., Abbaspour-Fard M.H., Kremmer M., Raji A.O. (1999). Shape representation of axi-symmetrical, non-spherical particles in discrete element simulation using multi-element model particles. Engineering Computations, 16(4): 467-480.
4. Hocking G. (1992). The discrete element method for analysis of fragmentation of discontinua. Engineering Computations, 9(2): 145–156.
5. Hogue C. (1998). Shape representation and contact detection for discrete element simulations of arbitrary geometries, Engineering Computations, 15(2–3): 374-90.
6. Kader A.A. (2005). Increasing food availability by reducing postharvest losses of fresh produce. Acta Hort. 682; 2169-2175.
7. Kafashan J., Ramon H., Tijskens B. (2009). Mechanical Damages in Simulated Fruit Transport, CIOSTA2009, Italy, Vol.1, 187-191.
8. Kafashan J., Van Zeebroeck M., Ramon H., Tijskens B. (2007). A novel approach to a realistic Discrete Element Modelling (DEM) in 3D, Commun Agric Appl Biol Sci., 72(1): 205-208.
9. Lin X., Ng T.T. (1997). A three-dimensional discrete element model using arrays of ellipsoids, Geotechnique, 47(2): 319-329.
10. Tijskens E., De Baerdemaeker J., Ramon H. (2004). Strategies for contact resolution of level surface, Engineering Computation, 21(2/3/4):137-150.
11. Tijskens, E., Ramon H., De Baerdemaeker J. (2003). Discrete element modelling for process simulation in agriculture, Journal of Sound and Vibration, 266 : 493–514.
12. Van Zeebroeck M., Tijskens E., Dintwa E., Kafashan J., Loodts J., De Baerdemaeker J., Ramon H. (2006a). The discrete element method (DEM) to simulate fruit impact damage during transport and handling: Model building and validation of DEM to predict bruise damage of apples. Postharvest Biology and Technology 41(1): 85-91.
13. Van Zeebroeck M., Tijskens E., Dintwa E., Kafashan J., Loodts J., De Baerdemaeker J., Ramon H. (2006b). The discrete element method (DEM) to simulate fruit impact damage during transport and handling: Case study of vibration damage during apple bulk transport. Postharvest Biology and Technology. 41(1): 92-100.
14. Williams J.R., Pentland A. (1992). Superquadrics and model dynamics for discrete elements in interactive design, Engineering Computations; 9: 115–128.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

EQUIPMENT AND CERTIFICATION OF SEED PROCESSING CENTRE

MILENA JANČIĆ

Faculty of Agriculture 21000 Novi Sad, Trg Dositeja Obradovica 8

SUMMARY

In our times seed processing centre must have specific equipment and certificates in its property. The precise equipment organization is a guarantee for economic and effective work. Certificates are used to confirm the seed quality and safety standards. In this paper is shown the regular management way in seed processing to keep quality and health safety seed, proper equipment use, good business cooperation, profit and sustained environment.

***Key words**: seed processing centre, equipment organization, seed quality and safety certificates, minor waste, sustained environment.*

INTRODUCTION

Seed certification is necessary to ensure good quality, health and high yield. The State law insists that the seed in use has to be verified by certificates. It is wanted that every processing centre has information about seed origin, health, technology and quality. In the paper is shown the equipment organization which guarantees the whole operation technology done in time. This is the `key´ for good cooperation. The aim of this work is getting knowledge about certification and equipment technology, that gives the best results to have quality and health safety seed and food, good equipment organization and minor waste of seed and chemical packages.

MATERIAL AND METHOD

The processing centre is visited and the competent group of agronomists in management explained which equipment organization and certification is adequate for modern processing centre in compliance with State law and good business export and import cooperation. The literature, equipment organization and certificates were reviewed.

RESULTS AND DISCUSSION

Seed quality and health certification

In the seed processing centre, seed is from abroad and from domestic crops.

When the seed has to be imported or exported, the processing centre must have specific seed certificates. The seed must pass laboratory analyses which guarantee seed quality and safety.

Phytosanitary certificate has information about name and address of exporter, number and code of certificate, declared name and address of consignee, the type of conveyance, point of entry, number and description of packages, name and quantity of produce. This certificate has to confirm that the plants, plant products or other regulated articles described that they have been inspected and tested according to the appropriate official procedure and are considered to be free from the quarantine pests specified by the importing contracting party and are considered to conform with the current phytosanitary requirements of the importing contracting party, including those for regulated non – quarantine pests. This certificate contains additional declaration in which said that the plants, bulbs or seed are free from quarantine organisms, and crop was inspected during active growth by inspectors of the competent Inspection service, and the soil, fields and places of productions indicates the absence of quarantine organisms.

In this certificate there are information about disinfection treatment, if it was done. At the end of paper there is Stamp of Organization, signature of authorized officer, the place of issue, and date. This certificate gives the Plant Protection Organization (Plant Protection Organization of the Netherlands, 2009).

Orange international seed lot certificate is certificate for seed quality. This document gives the Institute of field and vegetables crops, Laboratory for seed testing, on the basis of the rules of International Seed Testing Association. This Association defines the uniformity in seed testing. Orange international seed lot certificate contains the information about: name of applicant, species, cultivar, category, weight of lot, name of testing laboratory, who got the samples, marks of lot, seal of lot. In the paper is the number of containers, date of sampling, date sample received, date test concluded, test number, and analysis results.

The results confirm information about: purity, germination, and moisture content, present of inert matter and other seeds in sample. In the paper it is mentioned the moisture method and germination method. At the end of paper there is the head of laboratory signature, place country, and date (Institute of field and vegetable crops, Laboratory for seed testing, 2009).

The ***OECD certificate*** is necessary for some seeds. The components of grass seeds mixture need that certificate. This certificate is getting on the basis of positive results of the seed crop recognition certificate.

The seed crop recognition certificate contains the data of seed producer, producing place, species, cultivar, the producing year, seed origin, size of seed producing area, yield and processed seed yield, the name of institution which has controlled the crop during all vegetation and seed health. This certificate gives the Ministry of Agriculture, forestry and water management (Ministry of Agriculture, forestry and water management, Serbia, 2009).

The OECD certificate gives Laboratory for seed testing on the basis of The seed crop recognition certificate. It has reference number, the name of species, cultivar, year of production, country of production, number of containers and declared weight of lot. At the end of paper is signature of laboratory worker for OECD, date and place (Institute of field and vegetable crops, Laboratory for seed testing, 2009).

The domestic seed crop must be certificated also. It needs the seed crop recognition certificate, mentioned above and after processing, the seed must have Orange international seed lot certificate. The seed get declaration on the basis of these two certificates.

After seed best-before date, the seed is used as live stock feed if the seed had not chemical treatment. If it had chemical treatment, the seed germination is again controlled. If the seed has good germination and germination energy, the seed is in sale again. When the chemically treated seed has not good quality and safety characteristics it becomes a waste. The waste has to be burned. In our country the waste removal is not adequate solved yet.

In modern processing centre the mechanization or equipment is “the heart” of processing technology.

The mechanization and necessary equipment, which is organized in effective totality, is consist of: granulate gravity separator KamasWestrup UB 1000, separator KamasWestrup UB 600, seed treater Rosengren R 2,5, laboratory Kamas Westrup LA – H, which is used for seed polished and to separate seed, laboratory trieur Kamas Westrup LA – T, gravity separator HEID GA 30, roll machine MCK II – 20 for separate mixing seed, magnetic machine Cimbria Heid K590A A04, roll machine Cimbria Heid SRM200, trieur machine SCHMIDT UN 401/5 (Jancic , 2004).

In this paper is shown the equipment project of modern and economic seed processing centre (Fig. 1, 2, 3, 4).

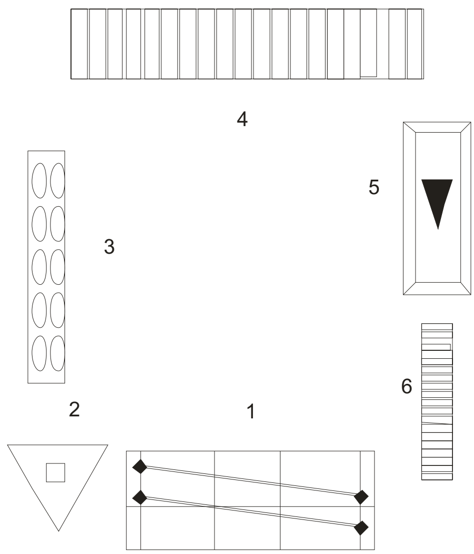


Fig. 1 Equipment disposition on top level; 1. separator, 2. aspirator, 3. roll machine, 4. sieves, 5. seed treater, 6. sieves (`Semenarnacoop´ d.o.o. Petrovaradin)

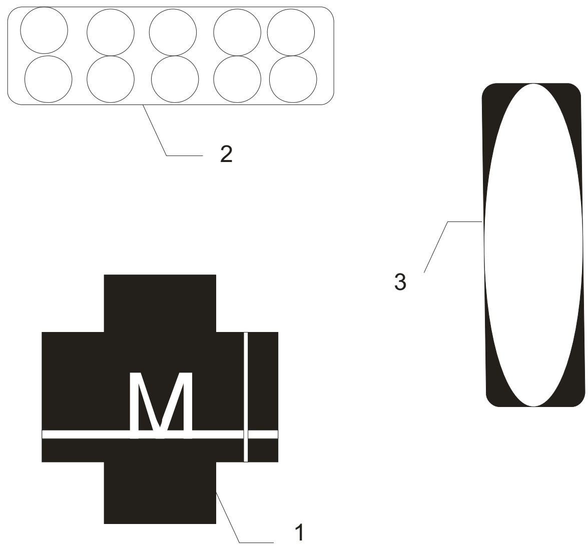


Fig. 2 Low level I; 1. magnetic machine, 2. roll machine, 3. trieur machine, (`Semenarnacoop´ d.o.o. Petrovaradin)

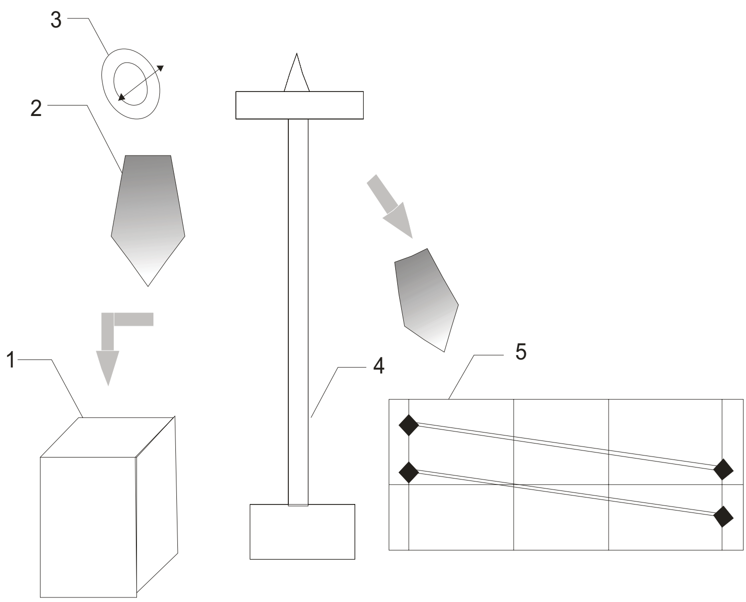


Fig. 3 Low level II (look from the side); 1. granulate gravity separator, 2. proportioner, 3. direction turner, 4. elevator, 5. separator (`Semenarnacoop´ d.o.o. Petrovaradin)

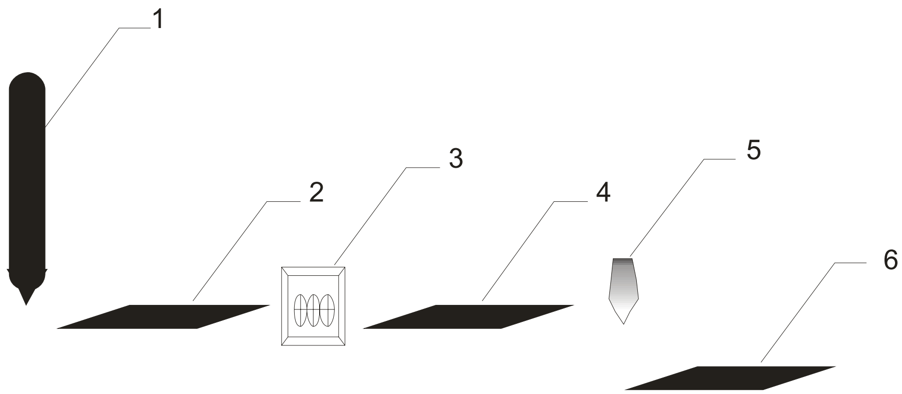


Fig. 4 Equipment for grass mixture seed and bird food; 1. receiving hopper, 2. screw conveyer, 3. mixing machine, 4. screw conveyer, 5. proportioner, 6. band conveyer (`Semenarnacoop´ d.o.o. Petrovaradin)

Safety in work area

Taking care of workers safety is completely ensured. In the work areas exists the complete Health safety equipment. It is done the evaluation of workers health safety risk for every work place as it is in compliance with State law. Also, in compliance with State law, every worker is trained for work place which is doing.

CONCLUSIONS

The adequate equipment organization guarantees economic, effective and good business cooperation.

Seed quality and health safety certificate confirms seed quality and that seed may be imported or exported in other countries.

The workers training enables good work organization and health safety at work place.

The competent group of agronomists in management confirms that whole mentioned organization is shown a great business results. In that case, the goods surplus, its sedimentation and best – before day expiration are minor.

The good plan of packing delivery and its quantity guarantees a well – stocked seed processing centre. The packing sedimentation is minor and packing for waste does not exist, what brings better conditions for environment.

ACKNOWLEDGEMENTS

To Professor Milan Martinov, Faculty of Technic Sciences, Novi Sad

To seed processing centre `Semenarnacoop´ d.o.o. Petrovaradin for cooperation

REFERENCE

1. Archival data of Institute of field and vegetable crops, Laboratory for seed testing, Novi Sad
2. Archival data of Plant Protection Organization of the Netherlands, s – Gravenpolder Holland
3. Archival data of seed processing centre `Semenarnacoop´ d.o.o. Petrovaradin
4. Jancic N. (2004). Osnivanje i razvoj D.O.O. `Semenarnacoop´, bachelor´s work, Faculty of Agriculture, Novi Sad.
5. Ministry of Agriculture, forestry and water management, Serbia
6. www.cimbriaheid.com
7. www.schmidt-seeger.com

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.81:633.11”324”
Izvorni znanstveni rad
Original scientific paper

EVALUATION OF EFFECT OF UNREGULATED FACTORS ON DEVELOPMENT AND YIELD OF WINTER WHEAT

GUNDEGA DINABURGA, DAINIS LAPIŅŠ, JĀNIS KOPMANIS

Latvia University of Agriculture, Institute of Soil and Plant Sciences,
Liela street 2, Jelgava, Latvia, LV–3001; phone: +371 63005632,
e-mail: Gundega.Dinaburga@llu.lv

SUMMARY

Formation of yield in crop cultivation is effected by influence of many factors; furthermore simple summation of individual factors is quite rare occasion. Interaction among factors is a dynamic value. The effect of interactions varies depending on the crop development stages as well as by graduation of factors. Rising of value of a single factor resulted in a rise of value of interactions effect.

There are almost no results presented in Latvia what deals with effect of unregulated factors on development and yield of winter wheat.

The aim of this study was to clarify effect of unregulated factors (relative height of observation points, content of organic matter and physical clay, thickness of humus horizon) to development and yield of winter wheat in production conditions.

Investigations were carried out in 2005–2007 in Kurpnieki field at Research and Study Farm Vecauce of Latvia University of Agriculture. 47 observation points (distributed as grid 50X50 m) were selected in the winter wheat Triticum aestivum L. sowing. In observation points were determined following data: relative height of observation points above the sea level, thickness of humus horizon, content of organic matter and physical clay, and data characterizing growth and development of winter wheat (number of leafs, total weight of plant, number of sprouts, the length of roots, coefficient of tillering, area of flag leaf, and grain yield).

Coefficients of linear correlation shows a significant positive effect of organic matter content (P<0.01) and thickness of humus horizon (P<0.05), but significant negative effect of differences in relative height of observation points on grain yield of winter wheat in 2006. In year 2007 what characterized with increased amount of precipitation effect of relative height of observation points on winter *wheat grain yield was insignificant. Whereas organic matter content and thickness of humus horizon remained as significant factors for formation of winter wheat yield.*

Key words: *cereals, factor analysis, precise crop cultivation, soil properties*

INTRODUCTION

Precision agriculture, being a popular movement in the USA, West Europe and some other countries, in Latvia is known a little. The main goals of precision agriculture in the crop production are: maximizing yields, minimizing inputs, maximizing financial advantages and minimizing impact on the environment. In other words - precision farming aims to match inputs and practices to localized conditions within a field – it involves attempting to do the right things in the right place at the right time, and in the right way (Vilde et al., 2006; Lapins et al., 2008a).

Precision crop cultivation is a form of modern field management using new technologies, machinery and equipment, including GPS (Global Positioning System). GPS allows detect, analyze and respectively respond to unevenness of cultivable area. It is closely associated with the new information technologies - GIS (Global Information System) and GPS – and includes development and use of structural planning of production processes and management of modelling of optimal solutions. Precision crop cultivation operational functionality requires computerized management of this process (Lapins et al., 2008b).

Formation of yield in crop cultivation is affected by influence of many factors. Simple summation of individual factors is quite rare occasion. Interaction among factors is a dynamic value. The effect of interactions varies depending on the crop development stages as well as by graduation of factors. Rising of value of a single factor resulted in a rise of value of interactions effect (Lapins et al., 2003).

In Latvia precision agriculture would be efficient to increase production, minimise expenditure and save environment because fields in Latvia reveal great heterogeneity of spatial soil properties and yield variability. Investigations in precision agriculture were initiated in 2004 at Latvia University of Agriculture. The results are already partly reflected in Latvia and foreign editions (Lapins et al., 2006; Vilde et al., 2008). There are almost no results presented in Latvia what deals with effect of unregulated factors on development and yield of winter wheat.

The aim of this study was to clarify effect of unregulated factors (relative height of observation points, content of organic matter and physical clay, thickness of humus horizon) to development and yield of winter wheat in production conditions.

METHODS

Investigations were carried out in 2005–2007 in Kurpnieki field at Research and Study Farm Vecauce of Latvia University of Agriculture. Winter wheat variety 'Tarso' was grown in 2006 and 2007. Forecrop of wheat was winter rape *Brassica napus* ssp. *oleifera*. The agrotechnology used in wheat cultivation was equal in the whole field and in both trial years. 47 points (distributed as grid 50*50 m) for sampling were selected in the winter wheat *Triticum aestivum* L. field. All points were attached to their geographic coordinates. The coordinates of observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional that allows to find the coordinates by accuracy of ±3 m, as well as to determine the field boundaries. Information from Garmin IQ 3600 was transferred into a computer and processed by the program AgroMAP Professional. Relative height above the sea level was determine with Trimble GeoXT, and adjusted with GPS Pathfinder Office software version 4.00. The thickness of humus horizon was determined by probing. Samples for organic matter content were taken from the depth of 0.20 m using a probe. Sampling was done after harvesting on August 14, 2006, in 3 replicates in each sampling point. Samples were analyzed in certified laboratory VSIA „Agroķīmisko pētījumu centrs", using local standard methods. Soil granulometric composition determined by field method and described as content of physical clay. Data characterizing growth and development of winter wheat (number of leafs, total weight of plant, number of sprouts, the length of roots, coefficient of tillering, and area of flag leaf) were determined from 10 plants in each sampling point at two times – in autumn at winter wheat growth stage BBCH 11-12 and in spring time at growth stage BBCH 25-29. The depth of drilling was determined in spring time as well. Flag leaf area was determined by using a specialized computer program WinFOLIA. The yield was harvested by combine CLASS LEXION 420.

Data analysis was performed using a mathematical descriptive statistics and correlation analysis.

Meteorological condition differs between trial years. Observed average air temperatures were above long term in both trial years, especially in the second part of the year 2006 (Figure 1).

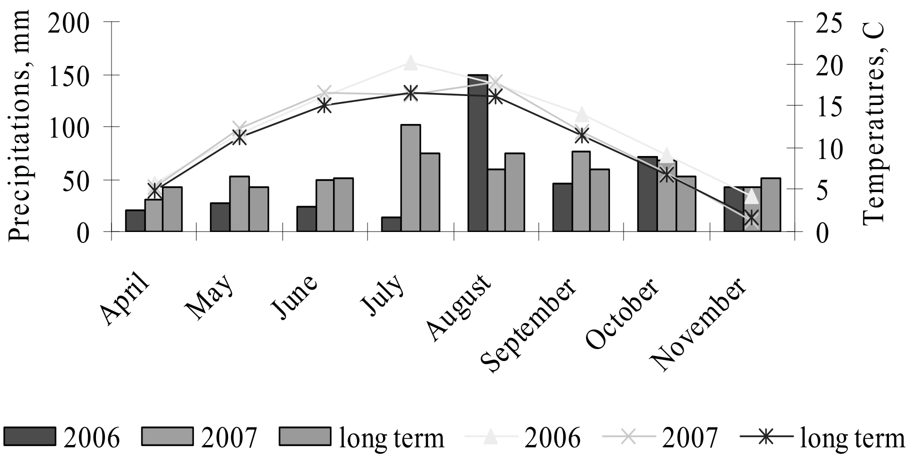


Fig. 1 Average day and night air temperatures and precipitations in years 2006 and 2007, °C (according to Vecauce HMS)

Average temperature of July 2006 was by 3.5 ºC higher than long-term observed. Alongside with insufficient amount of precipitations it causes rapid ripening and early harvesting of winter wheat compared with long-time observed harvesting time. The sum of precipitations was low in both trial years, but during the period April–August it was lower in year 2006 compared to 2007 despite of high amount of precipitation in August 2006 (Figure 1).

RESULTS AND DISCUSSION

Effect of relative height above sea level at different field points to growth and development of winter wheat were various between trial years. Level of significance was various as well (Figure 2). Growth and development of winter wheat in autumn period after drilling seemed to be more favourable in field spots with higher elevation – significantly higher number of leaves per plant in wheat yield-year 2006 ($r_{yx} = 0.3654$; $P = 0.0131$), and higher fresh weight of plant in 2007 ($r_{yx} = 0.2471$; $P = 0.0470$). Observed coherence resulted in a significant bigger mass of roots in spring 2006, but showed no significant effect to investigated indices in spring 2007. Area of flag leaf was significantly lower in both trial years in field sites with increased height above the sea level (Figure 2).

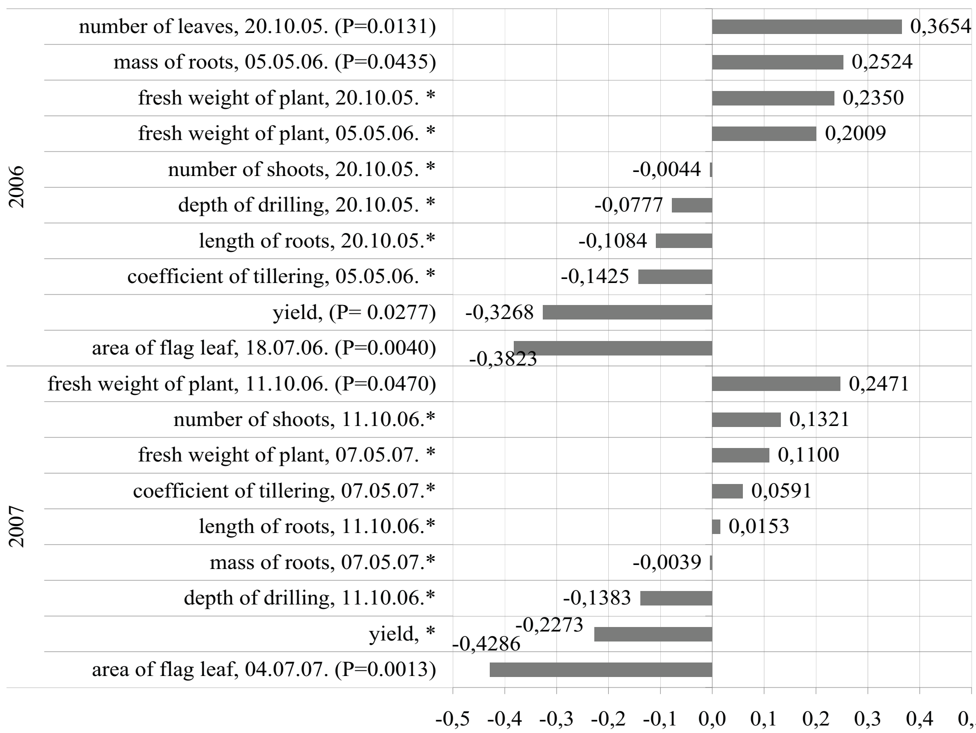


Fig. 2 Coefficients of linear correlation, r_{yx}, describing effect of relative height above sea level (x) and factorial indices (y), years 2006 and 2007; *P>0.05

Significantly bigger area of flag leaves of winter wheat was observed in both trial years in sampling points with organic matter content above 26.5 mg kg^{-1} (Figure 3). Numerically bigger area of flag leaf was observed in year 2007, furthermore it was significantly higher in areas with organic matter content below 26.5 mg kg^{-1}, compare to year 2006, what can be interpreted with more favourable growing conditions in spring-summer period of 2007 – more precipitation compare to year 2006.

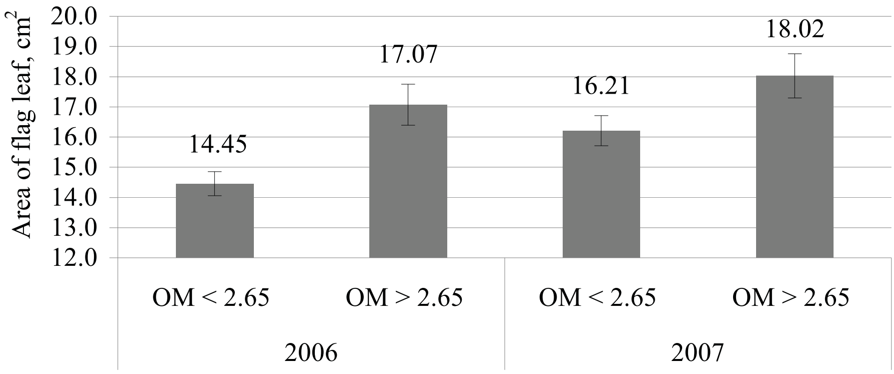


Fig. 3 Area of flag leaf (cm^2) by groups of organic matter (OM) content (mg kg^{-1})

Arranging of data of organic matter content in soil showed importance of this soil agrochemical property to grain yield of winter wheat. In both trial years grain yield was significantly higher in field area with higher content of organic matter (Figure 4), however differences between years are much bigger because of different growing conditions.

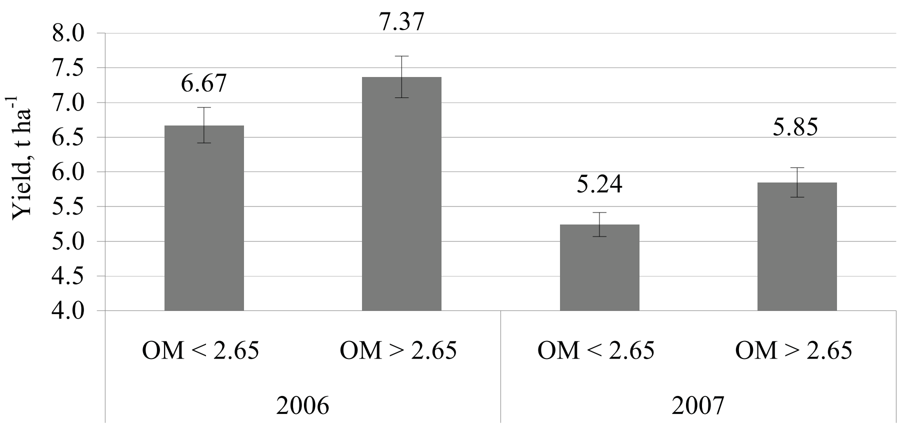


Fig. 4 Winter wheat grain yields in dependence on organic matter (OM) content (mg kg^{-1})

Thickness of humus horizon showed significant positive effect to number of winter wheat shoots $r_{yx} = 0.3757$ ($P = 0.0046$), total fresh weight of one plant $r_{yx} = 0.3665$ ($P = 0.0056$), grain yield $r_{yx} = 0.3217$ ($P = 0.0297$) and coefficient of tillering $r_{yx} = 0.2792$ ($P = 0.0286$) in year 2006 (Figure 5). Significant positive effect of thickness of humus horizon to winter wheat grain yield $r_{yx} = 0.2796$ ($P = 0.0284$) was observed in year 2007 too.

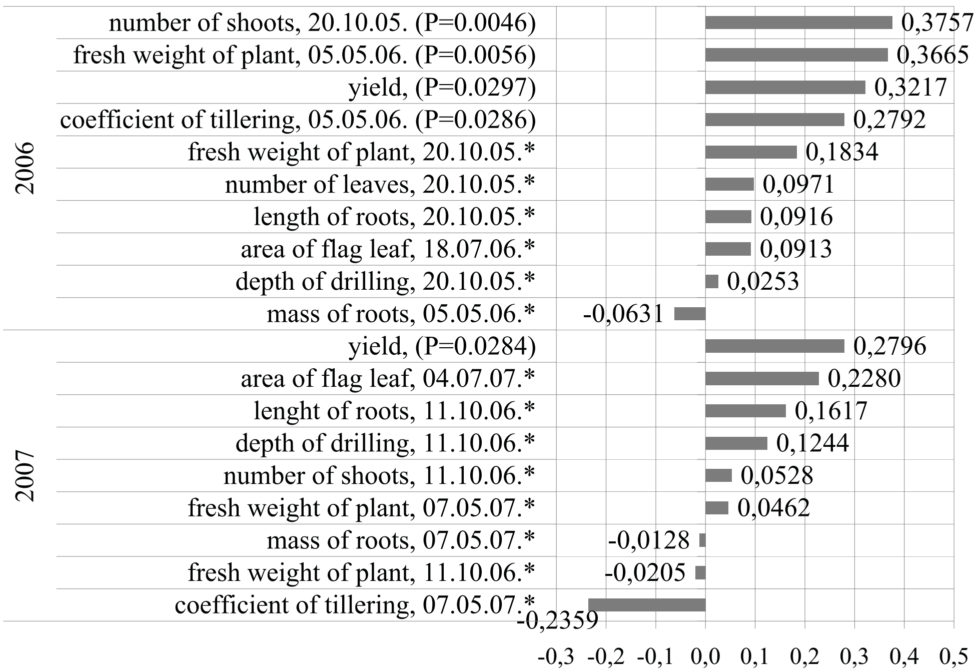


Fig 5 Coefficients of linear correlation, r_{yx}, describing effect between thickness of humus horizon (x) and factorial indices (y), years 2006 and 2007; $^*P>0.05$

Coherences among fresh weight of winter wheat plants and unregulated factors were different between trial years as well. Thickness of humus horizon effected fresh weight of wheat plant significantly ($P<0.01$) in year 2006, but coherence in year 2007 was insignificant (Figure 6). Negative, but insignificant effect to fresh weight of plant showed content of physical clay in both trial years.

The biggest positive significant ($P<0.01$) effect to area of winter wheat flag leaf showed organic matter content in both trial years. Effect of physical clay content to area of flag leaf was significant in both years too, but in lower degree of probability (Figure 7). On the contrary higher relative height above the sea level resulted in significantly smaller area of flag leaf. Also this coherence proved in both trial years.

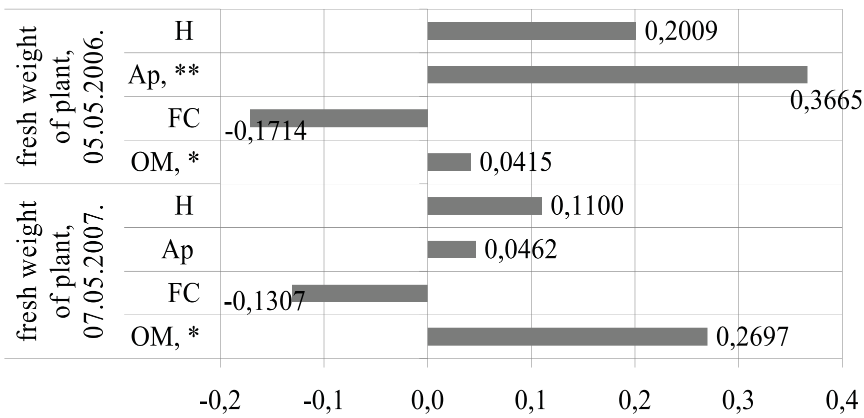


Fig. 6 Coefficients of linear correlation, r_{yx}, between fresh weight of winter wheat plant (y) and unregulated factors (x); *P<0.05, **P< 0.01; H – relative height above the sea level, m; Ap – thickness of humus horizon, m; FC – content of physical clay, %; OM - organic matter content (mg kg^{-1})

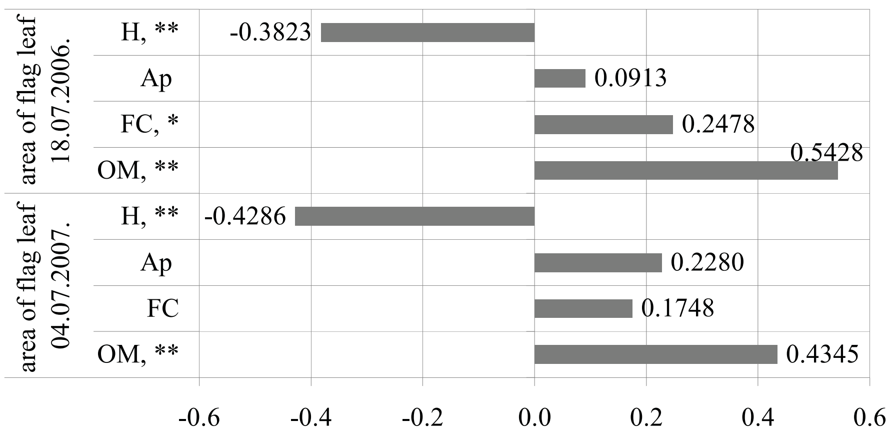


Fig. 7 Coefficients of linear correlation, r_{yx}, between area of winter wheat flag leaf (y) and unregulated factors (x); *P<0.05, **P< 0.01; H – relative height above the sea level, m; Ap – thickness of humus horizon, m; FC – content of physical clay, %; OM - organic matter content (mg kg^{-1})

Analyze of aforementioned coherences with exclusion of impact of relative height above the sea level shows higher importance of physical clay content on area of winter wheat flag leaf. Also exclusion of impact of organic matter content increased effect of physical clay content, especially in year 2006 (Figure 8).

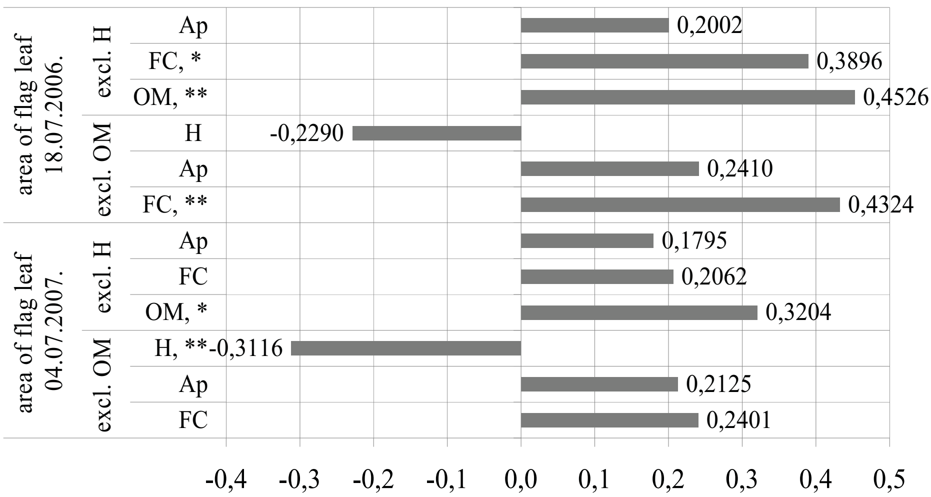


Fig. 8 Coefficients of linear correlation, r_{yx}, between area of winter wheat flag leaf (y) and unregulated factors (x), excluding importance of one of factors; *P<0.05, **P< 0.01; H – relative height above the sea level, m; Ap – thickness of humus horizon, m; FC – content of physical clay, %; OM - organic matter content (mg kg^{-1})

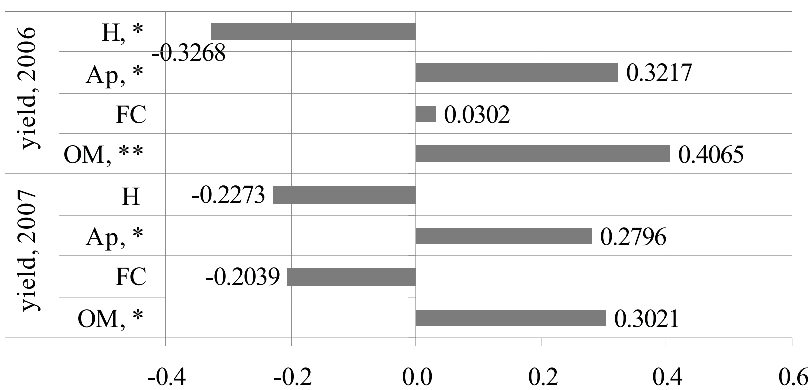


Fig. 9 Coefficients of linear correlation, r_{yx}, between winter wheat grain yield (t ha^{-1}) (y) and unregulated factors (x); *P<0.05, **P< 0.01; H – relative height above the sea level, m; Ap – thickness of humus horizon, m; FC – content of physical clay, %; OM - organic matter content (mg kg^{-1})

Coefficient of correlations shows high importance of organic matter content as well as thickness of humus horizon on grain yield of winter wheat – coherence was significant positive in both trial years (Figure 9). On the contrary, higher elevation of sampling sites shoved negative effect to grain yield. In year 2006 this coherence is significant (P<0.05), but in year 2007, what characterized with increase sum of precipitations, this effect was not significant (P>0.05).

Exclusion of differences in relative height above the sea level as a factor showed no differences in effect of organic matter content and thickness of humus horizon on grain yield of winter wheat compare to linear correlation without exclusion of factors. Exclusion of organic matter content leaved effect of relative height above the sea level negative, although it was not significant (P>0.05) (Figure 10).

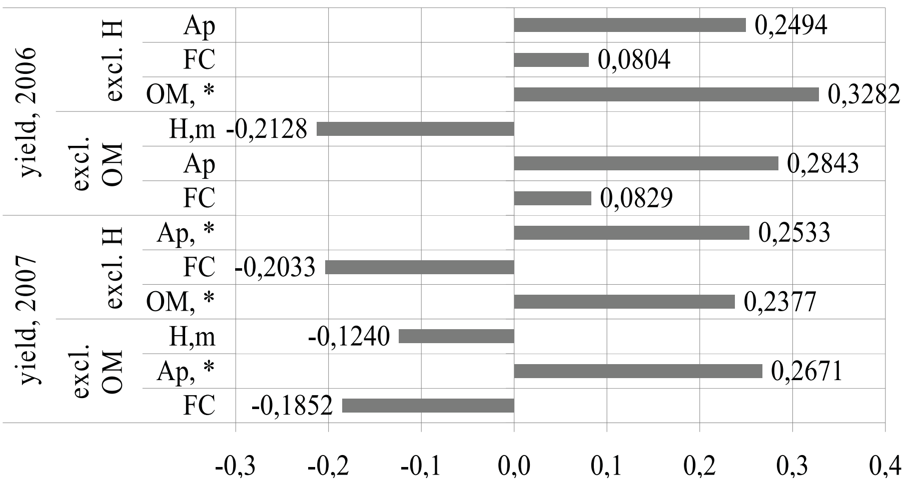


Fig. 10 Coefficients of linear correlation, r_{yx}, between winter wheat grain yield (t ha^{-1}) (y) and unregulated factors (x), excluding importance of one of factors; *P<0.05, **P< 0.01; H – relative height above the sea level, m; Ap – thickness of humus horizon, m; FC – content of physical clay, %; OM - organic matter content (mg kg^{-1})

CONCLUSIONS

1. Coefficients of linear correlation shows a significant (P<0.05) positive effect of organic matter content and thickness of humus horizon on grain yield of winter wheat.
2. Differences in relative height of observation points showed negative effect of winter wheat grain yield; in year 2007 what characterized with increased amount of precipitation this effect was insignificant. Whereas organic matter content and thickness of humus horizon remained as significant factors for formation of winter wheat yield.
3. The significant (P<0.01) positive effect to area of winter wheat flag leaf showed organic matter content in soil, as well as effect of physical clay content, but with lower (P<0.05) probability. On the contrary higher relative height above the sea level resulted in significantly smaller area of flag leaf
4. Thickness of humus horizon effected fresh weight of wheat plant significantly (P<0.01) in year 2006, but coherence in year 2007 was insignificant.

ACKNOWLEDGEMENTS

The study was supported by the grant of Latvian Council of Sciences Num. 05.1604.1.

REFERENCES

1. Lapiņš D., Bērziņš A., Gaile Z., Oboļeviča D., Grenovska K., Koroļova J., Sprincina A., Kopmanis J. (2003). Augsnes apstrādes un sējas tehnoloģiju ietekme uz ziemas kviešu graudu ražu un tās kvalitāti (The Soil Treatment and Sowing Technology Impact on Winter Wheat Grain Yield and Its Quality). Agronomijas Vēstis 5: 109-116 (In Latvian).
2. Lapins D., Rucins A., Vilde A., Cesnieks S., Berzins A., Aizsilnieks A., Kopmanis J., Plume A. (2006). Investigations in precision agriculture in Latvia: Soil tillage management. NJF seminar 378: 168-176.
3. Lapins D., Vilde A., Berzins A., Dinaburga G. (2008a). The Choice of the Differentiation Criteria of Soil Tillage Using the Geographic Information System (GIS). Agronomijas Vēstis 10: 51-57.
4. Lapins D., Vilde A., Berzins A., Dinaburga G., Plume A., Rucins A. (2008b). Investigations of Technologies for the Precision Agriculture and Estimation of Their Efficiency. Raudondvaris, Lithuania: 157-161.
5. Vilde A., Lapins D., Dinaburga G., Rucins A., Cesnieks S., Berzins A., Plume A., Repsons J. (2008). Investigation of Technologies for Precision Agriculture and Estimation of Their Efficiency. In: The 10th International Congress on Mechanization and Energy in Agriculture, Antalya, TŰRKİYE, pp 585-591.
6. Vilde A., Lapins D., Rucins A., Cesnieks S., Berzins A., Plume A., Repsons J., Dinaburga G., Aizsilnieks A., Upmacis D. (2006). Precision Agriculture as a Farming System Based on Wide and Versatile Information. In: Proceedings of the International Scientific Conference: Information Technologies for Rural Development, Jelgava, Latvia, pp 48-61.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.155.3:631.358:658.155
Izvorni znanstveni rad
Original scientific paper

THE EFFECTS OF THE RELATIONSHIP BETWEEN MACHINE AND PLANT ON THE LOSSES AND PROFITABILITY (BASED ON THE EXAMPLE OF DRY PEA HARVESTING)

KLÁRA BÉRES[1], ISTVÁN HUSTI[2]

[1] Department of Macroeconomics, Institute of Economics, Faculty of Economic and Social Sciences, Szent István University, 2103 Gödöllő Páter K.u.1. (Hungary), e-mail: hustine.beres.klara@gtk.szie.hu

[2] Department of Engineering Economics and Management, Institute of Systems Engineering and Management, Faculty of Engineering, Szent István University, 2103 Gödöllő Páter K.u.1. (Hungary), e-mail: husti.istvan@gek.szie.hu

SUMMARY

The profitability of plant production is influenced by many factors. Among these the harvesting losses have a significant role that decrease the potential yield and thus decrease the revenues. For this reason, it is important to deal with harvesting and its losses.

There are stresses and threats to „living” plants when they meet a “dead” material or construction through a mechanised technology. Among normal circumstances harvesting causes the biggest stress to plants because there is a direct contact between the living plant and the dead machine. In our paper the living material is illustrated by dry peas and the dead material by the harvesting machines. We examine the extent of the effects on losses and profitability caused by the machines. The stress-effect of machines manifests in the losses.

Dry pea production has decreased over the last few years in Hungary. The main reason for this is decreased profitability. With this in consideration, reducing the harvesting losses is the most efficient what the producers can do for higher yields in indirect way. We have well-developed production technologies for dry pea growing, but harvesting is the weakest point of these. In our paper we deal with the criteria of “modern and competitive harvesting” and how this effect losses and profitability. We hope that our statements and proposals can be useful not only for dry pea growing but for other plant production branches, too.

Key words: *harvesting losses, stress-effect of machines, profitability of dry pea production*

INTRODUCTION

The meeting of “living” and “dead” materials in the technology usually means danger and stress rather for the living materials. The stress-making effect of machines is expressed in the losses.

Out of the technological activities, the harvest causes the greatest stress for the plants under normal circumstances, because it is the only phase where there is direct contact between the “living” plants and the “dead” machines. In our study, dry peas before harvest are referred as the living materials, while the dead structures are illustrated by the harvesting machines.

Peas are legumes, and therefore improve soil fertility by fixing nitrogen (N) in the soil. Peas provide a good break crop against soil-borne cereal diseases, but grass weeds and wild oats may continue to build up in the pea crop if proper control measures are not practised.

It is well known that the profitability of the production of pea – similarly to other plants – heavily depends on the average yield that is directly influenced by the amount of harvesting losses. We can also say that sometimes, we are not able to reach profit because a certain portion of the costly produced final product (in our case the core product of dry pea seed) turns into losses possibly as a result of harvesting.

Several practical examples verify that if this loss is above a certain level then offset of the harvested crop is not even enough to cover the losses. This circumstance emphasise that harvesting as the last step of field technology deserves a special attention from producers.

MATERIALS AND METHODS

The mechanized technologies of dry pea production have already been created.

According to our experience, the weakest element of these technologies is the harvest. In our study we give an overview on the criteria of „professional harvest”. We examined the losses based on data of the Bóly joint-stock agricultural company and the possibilities for reducing the losses. The theoretical connections are shown by a breakeven analysis.

RESULTS AND DISCUSSION

In Hungary, dry pea production is not as popular as it used to be, because the profitability has declined. The profitability depends on the alternating selling prices and production costs. Under the present circumstances in Hungary, producers do the best if they increase the harvested yield indirectly, which can be done in practice by decreasing the harvest loss. Harvesting of the dried pea crop can be quite a problem, especially in a poor summer when the peas may be shed from the pods before being harvested. Conditions at the point of harvesting will have a marked effect on the eventual quality of the sample, e.g. human consumption or stock feed, and hence price.

Factors affecting pea’s yield

A number of factors influence the “final” dry peas yield (Fig. 1)

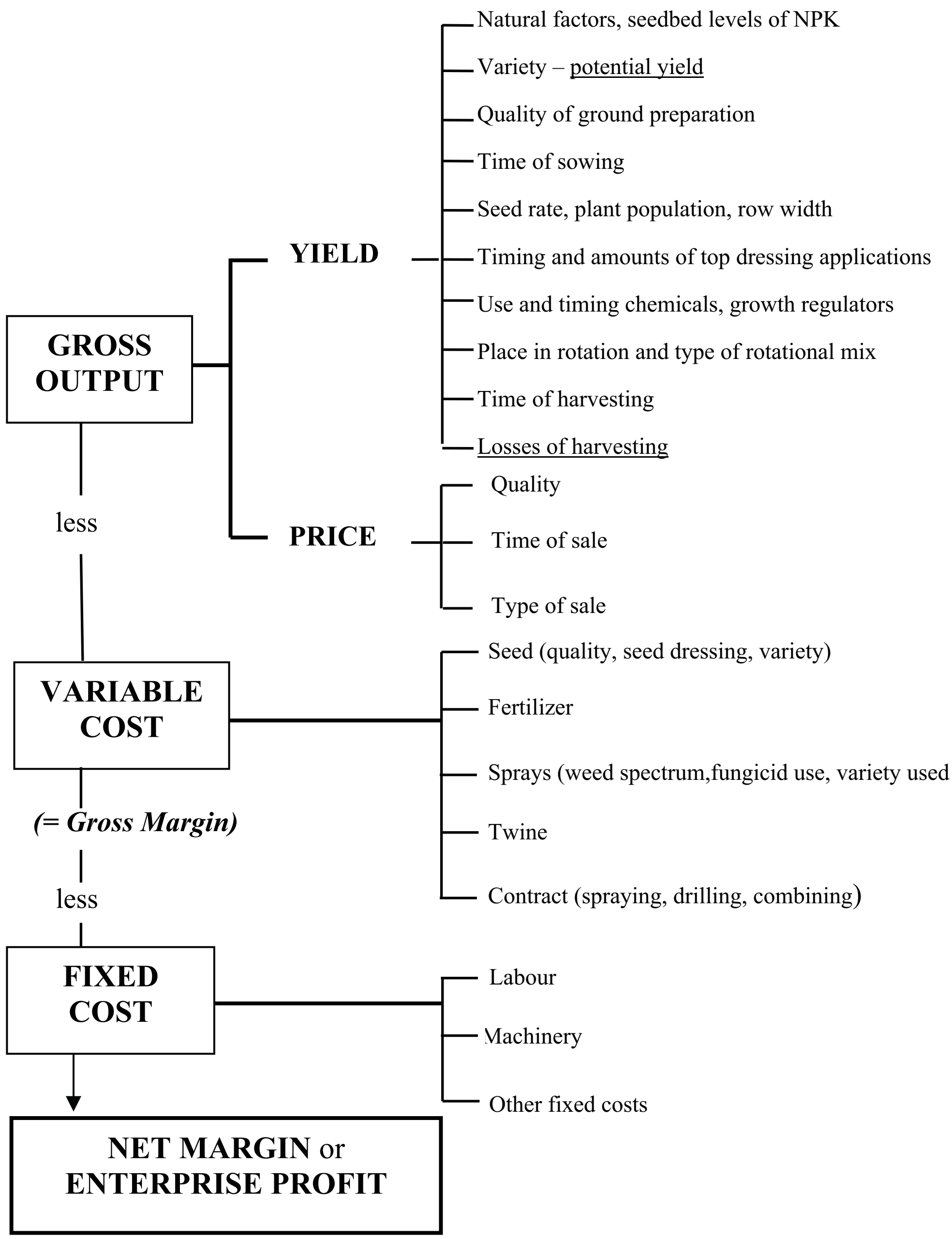


Figure 1 Factors affecting the profitability of the cereals enterprise
(based on Norman et al. 1985)

a) Natural factors: Peas, like all farm crops, are influenced by a number of natural factors, e.g. rainfall, soil type, aspect, etc. These factors cause variations in cereal yields from year to year to area in any one year, and the farmer has no control over them.

b) Variety: Variety of cereal grown influence yields obtained since each variety differs in its yield potential. The pea grower has to choose from wide range variety very carefully.

c) Quality of ground preparation: The condition of the seedbed at the time of planting is one of the most critical areas relating to eventual yield. Spring-sown crops, like peas, are sensitive for good-quality seedbeds. Three main methods are used (these are each capable of producing good yields and hence potential profit) – traditional plough and cultivate, minimal cultivation and direct drilling. The system chosen must suit the farm and the farmer. Economic aspects must be considered the important ones being timelines, fuel use and labour/machinery requirements per hectare of established cereals.

d) Time of sowing: Recognition that seeds establish more quickly and retain their vigour in seedbeds which are not so wet and cold have led to better potential yield. We have to remember that peas-sowing is one of the first activities in spring time on the arable land.

The most important management aspect is not how early or how late crop is sown, but in being organized in such a way so as to pick the optimum time. Labour and machinery planning plus skill in managing the soil are the key features of success.

e) Seed rate and row width: The basic principle to bear in mind when considering seed rates and row widths for cereals is that the overall objective should be an optimum plant population per unit area. Too high a seed rate will produce too many plants which will compete with each other for light, space and nutrients, while too low a seed rate will produce fewer plants, and although each plant may produce a larger number of ears of grain than usual the total yield per hectare will be lower due to fewer total ears per hectare. The plant population per unit area can be manipulated by the grower.

f) Fertilizer application: N fertilizer applied in the spring does lead to increased yields, but the extent depends on the time of the application of the fertilizer.

g) Use and timing of chemicals: Considerable variations can occur in cereal gross margin as a result of the selection and subsequence use of chemicals. Evaluating the many alternatives available to achieve the same end is a key business management area. On the farm evaluation will take a little more effort, but will enable the farmer to build in his own criteria with regard to the timing and cultural requirements of any combination of products.

Varietal selection with regard to disease resistance should never be overlooked. Exploiting the natural resistance of a variety to pests and diseases is invariable cost effective.

h) Place in rotation and type of rotational mix: Peas can fit almost anywhere in a sequence of crops and by skilful management prove successful. Making the best use of farm’s comparative advantages should influence the rotation and the mix of cereals and livestock where they are appropriate. Careful business management planning and good husbandry will enable a farm to do both of these things, e.g. evaluate a comparative advantage and get the rotational mix right.

i) Time of harvesting: One of the most important tasks in the management of pea harvesting is to choose the right time. Generally the optimal time is related to the percentage of moisture of the grains.

In case of too early harvest, the percentage of grains will be high thus we do not get a sterling crop and the grains need to be dried for lasting storage.

In case of too late harvest, the percentage of grains will be low thus the harvesting losses unambiguously increase.

j) Losses of harvesting: In case of peas the losses can occur in three main areas:

- in broken pods
- in the from of bled seeds and
- in the form of broken seeds.

These factors discussed above are the main ones influencing pea's yields. Since there is a close correlation between final profit margins and yields, the impact of these factors must be considered carefully. If these factors are within farmer's control then he should try to organize them in such a way as to achieve the greatest possible profit margins from dry peas.

Tasks of the complex development

Improving of stress-tolerance and reducing harvesting losses requires complex development, with the major elements as follows (Fig. 2):

Needs / Areas	Research	Development	Management	Practical
	Activities are needed			
Breeding	+			
Technology	+	+	+	
Machinery	+	+	+	
Practical				+
Others			+	

Figure 2 Simplified matrix-model of the main elements of the complex development to reduce harvesting losses (Husti, 1981)

Breeding and biotechnological tasks, on one hand, may aim at the plants, on the other hand, their produce (the seeds – in our case). Major requirements for the plants are the followings:

- length of stalk suitable for mechanical harvest (the modern harvesting machines are able to harvest plants with 30-35 cms stalk length);
- adequate fixity of stalk – to avoid or reduce the "collapse" during ripening;

- pods containing the produces need to be compact and located preferably in the upper third part of the plant;
- "high yield" should concentrate in the upper few (4-7) pods;
- homogenous ripening of pods (and the seeds inside) is important;
- certain varieties must be well thrashed, but they should not drop out;
- it may be also important to have "weak" fringes by the harvest time, i.e. to cause the least possible mechanical damage on the plants linked together as a carpet.

Former examinations related to the harvest losses have called the attention to another breeding problem. During examining the losses of pea harvest, we have experienced in almost every case that the rate of seeds in the pods which were broken exceeded the rate of loss in the number of seeds being dropped out. Therefore, the critical feature of plants from the loss-making point of view is rather the break of pods and not the drop out of seeds. It would be worth to clarify the economical features of strengthening the fringe through breeding.

As for the seeds, breeding tasks may aim at the improvement of content values on one side, and the improvement of the productiveness, on the other side. It is also important to have suitable range of varieties available for the farmers.

Indirect increase of yield is mostly influenced by the way of harvest. Our experiments have proven that the method of harvest has significant impact on the amount of losses during harvesting. The average loss of one-phase harvest is 8,99%, if the possibility rate is 95% (P=95 %), while that of the two-phase-harvest is 11,28%.

Having information on the significant difference (SZDP%), the confidence-margins of the difference are: 11,28-8,99±1,37 = 0,92 and 3,66%. It means that within such margins, we should decide on the one-phase harvest. (Husti, 1981)

Of course, if we want to decide whether we should choose the one-phase or the two-phase harvest, we need to take into account other factors too. It could help the decision-making if we study the features of both solutions, since both of them have advantages and disadvantages. (Magó-Jakovác, 2005)

The two methods may be even combined in practice. In such cases the two-phase method is applied in the first half of the harvest period, and later the application of the one-phase-method is recommended. (Magó, 2008)

The issue of desiccation has also been raised related to the development of technology, which causes special stress to the plants and increases the production costs. However, it also has some undoubted advantages.

In accordance with the stress-reduction, the cutting machine (and the attached elements) and the thrasher on the harvesting machines require special attention. Minor tasks may also be justified with the seed cleaning, -drying and -handling machines.

The final benefit of good and scientifically established thoughts and theories depends on the possibility of their practical application. That is why it is important to think about the conditions and obstacles of practical implementation while we are working on recommendations for reducing the stress. From the aspect of the final success, it is extremely important to have such a flat seedbed as a table, the precise sowing, the professional plant protection and the well organized harvest.

One of the basic issues of the well-organized harvest is the starting date of the different activities. While evaluating the results of our examinations, we have found coherences between the losses related to the harvesting technologies and the maturity status (moisture content) of the seeds.

After analyzing the functions which display the relations, we have got the values to the harvest minimum loss:

- One-phase-harvest: $\mathbf{n}_{\mathbf{k\ opt}}$ = 18,8 %,
- Two-phase-harvest: $\mathbf{n}_{\mathbf{r\ opt}}$ = 19,0 %, $\mathbf{n}_{\mathbf{k\ opt}}$ = 15,2 %. (Husti,1981)

These values are the results of theoretical calculations; their practical realization is more interesting within intervals.

In addition to the moisture content of the seeds, other factors also have impact on the creation of harvest losses.

These factors are for example:

- the ragged ground surface,
- the inadequate moving of the harvesting machines on the plot,
- the constructional and application parameters of harvesting machines and
- the local organizational failures.

Right way of organizing harvest starts with the creation of the combination of varieties. We must insist on choosing the most suitable varieties for the endowments of the field so that the ripening of the different varieties may allow the continuous and comfortable pace of harvest.

Using the breakeven chart

We have carried out experiments to see what kind of technical modifications could reduce the relatively high harvest loss, therefore improving the profitability. From the constructional changes recommended on the harvesting machine we have focused on the crop lifter, because this part meets the plant first during the process, thus it has determining role in the creation of losses. We have proven with our examinations that if we choose the right crop lifter, it may reduce the harvest losses itself, while other conditions remain the same. On Figure 3 we can see what economic effects the application of a crop lifter has. The application of a crop lifter causes ΔQ indirect increase in yields, due to the 12% decrease in the base-loss. Its “price” is the increase of total costs by ΔC.

Based on the massage of the Figure 3, we can see that the recommended technical modification is justified and therefore the profitability becomes higher. Further model calculations can also justify that our statement is right.

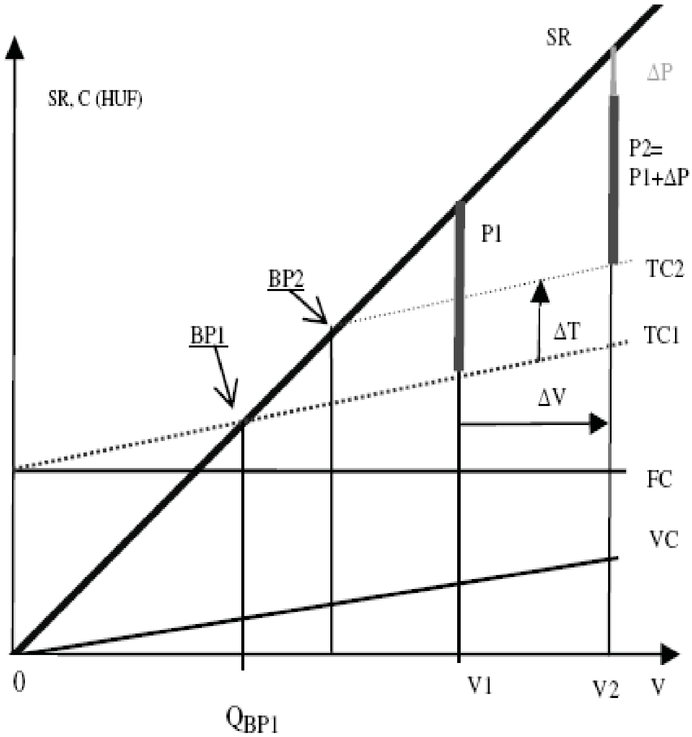


Figure 3 Economic effects of technical development on breakeven chart
(SR: Sales Revenue, C: Cost, BP: Breakeven Point, V: Volume, P: Profit, VC: Variable Cost, FC: Fixed Cost, TC: Total Cost, QBP1: Critical Volume)

CONCLUSIONS

There are some factors discussed on Figure 1 are the main ones influencing pea's yields. Since there is a close correlation between final profit margins and yields, the impact of these factors must be considered carefully. If these factors are within farmer's control then he should try to organize them in such a way as to achieve the greatest possible profit margins from dry peas.

Like in the case of many cereal crops, it is also true for the dry peas that the meeting of the "living" plant with the "dead" machines causes special stress. The consequence of stress may be harvest losses. These losses for dry peas may even exceed 15-20%, thus endangering the profit.

To increase the stress-tolerance may help indirectly the increase in yields, which would have advantageous impact on the profit too. In this study we introduce complex development tasks to improve the stress tolerance, which promote the decrease in losses with the harmonious combination of breeding, technological-development, mechanization and practical activities.

In order to display preliminary economic effects of the development decisions, the breakeven analysis has been applied, illustrating the economic advantages and disadvantages due to the application of crop lifters. This method is a suitable tool for preparing the decisions on developments. In our opinion, our thoughts aiming at the increase of stress tolerance may be useful not only in the case of dry peas, but in the case of other plants too.

REFERENCES

1. Husti, I.: (1981) Development of mechanized harvesting of dry pea. Dissertation for CSc degree. Budapest.
2. Magó L. - Jakovác F.: (2005) Economic Analysis of Mechanisation Technology of Field Vegetable Production, Hungarian Agricultural Engineering, Periodical of the Committee of Agricultural Engineering of the Hungarian Academy of Sciences, Vol. 18/2005. p. 55-58.
3. Magó L.: (2008) The Comparison of the Technical-economical Parameters of Machine Utilization under Different Level of Mechanization Subject to Farm Size, Agricultural Engineering Research – Bulletin of the Hungarian Institute of Agricultural Engineering, Gödöllő, 39 p.
4. Norman L. – Turner R.A.E. – Wilson K.R.S.: (1985) The Farm Business. Second edition. Longman. London and New York, p.: 241-253. ISBN 0-582-44255-9

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 628.8:631.234:635.64
Izvorni znanstveni rad
Original scientific paper

ENERGY EFFICIENCY OF THE OPEN FIELD AND GREENHOUSE TOMATO PRODUCTION

MILAN DJEVIC, ALEKSANDRA DIMITRIJEVIC

Faculty of Agriculture, Department for agricultural Engineering, Belgrade, Serbia

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. The greenhouses used were one tunnel structure, covered with double PE film, 5 x 20 m and one gutter-connected double PE covered structure 21m wide and 250m long. The results obtained lead to the conclusion that lower specific energy per production surface can be expected in conditions of the open field and that, regarding the greenhouses lower value for energy consumption can be expected in case of multi-span greenhouses.

Key words*: tomato, open field, greenhouse, energy efficiency.*

INTRODUCTION

Tomato is one of the most common vegetable used in human nutrition around the world. It is used for fresh consumption, conservated in some way or as a material for the food processing industry. It is also said that tomato is the most profitable vegetable variety and one of the most widely consumed vegetable crops in the world, with an estimated 99.4 million t of tomatoes being produced worldwide each year (Chapagain & Wiesman 2004). Serbia is a part of South-eastern Europe that has a good agricultural potential. In the 2007 (Statistical office of the republic of Serbia 2008) Serbia used 5 053 000 ha as agricultural land from which 3 299 000 ha considered as arable land. Vegetable production took 9.1% of the total arable land with production in the open field. One of the most common vegetable in this region is tomato and it is grown on, around 20 566 ha in the open field with average yield of 8.3 t/ha. Concerning the greenhouse production Serbia has 10 000 ha under plastic cover greenhouses and 80 ha under glass-houses. The most common vegetable grown in greenhouses is tomato (more than 50%) followed by lettuce, cucumber and pepper.

Since the tomato plays an important role in the human health, the quality of the nutritional components of this major crop fruit of particular concern to producers throughout the world. This topic raises many questions mostly based on ecology, economy and energy issues. Serbian agriculture is having similar problems like other developing countries (Sonmez & Sari, 2006, Trejo-Perea et al. 2009). The problems mostly arise regarding registration and monitoring of agricultural producers and their product quantity and quality. This leads to economical and ecological problems, mostly related to fertilizer and other chemicals application that farmers are facing with.

Tomato is grown in open field as well as in greenhouses. Concerning the greenhouse production, tomato in Serbia is still grown in non-heated greenhouses that enable two up to three week earlier harvesting compared to open field production. In the open field, according to Dasgan *et al.* (2004) tomato production is not considered a great problem because solar radiation and temperature are adequate for pollination and fertilization. If tomato is grown in heated greenhouses harvesting can start in April. The reasons why tomato is rarely grown in heated greenhouses are high energy inputs for the production and higher investments in heating systems and high-yielding varieties (Stevens *et al.*, 1994). However, there are researches that shows that using double PE inflated film can reduce energy for heating in early tomato production for 30 up to 40% (Athanasios *et al.*, 1997; Nelson, 2003) thus leaving this direct energy input under 10% share in the total energy consumption which is very important concerning the energy situation in the World today. Indirect energy use through chemicals, specially through fertilizers, also plays very important role in vegetable production (Chapagain & Wiesman, 2004). The share of fertilizers in total energy consumption for the open-field grown species can reach 30% (Ortiz-Canavate, 1999). As for the greenhouse production the numbers are similar (Hatirli *et al.*, 2006). There are reports that tomato production is very intensive in sense human labor engagement (Bechar *et al.*, 2007). Since there are a few results about the compare of open-field and greenhouse vegetable production that confirm that greenhouse production is more intensive in sense of yield and energy consumption compared to open-field production we thought that it would be interesting to see if production technology influences on yield of different vegetables and what is the influence of different greenhouse construction on vegetables yield and energy use. As stated by Trejo-Perea *et al.* (2009) sustainable crop production system requires keeping a high-quality harvest, while keeping energy and raw material consumption low. The agricultural sector is an important energy consumer. The increase in energy demand under greenhouse agricultural production has made its use, administration and estimation to be essential issues.

The aim of the research presented in this paper was to analyze effects of open-field and greenhouse production on tomato yield and the energy use patterns in order to see whether greenhouse tomato production can be beneficiary in sense of yield and energy efficiency compared to the open and to see if there are differences in energy consumption and energy consumption structure in the open field and in the two mostly used types of greenhouse structure.

MATERIALS AND METHODS

The same variety of tomato (*Lycopersicon esculentum* Tamaris) was grown in the open field and in tunnel and gutter-connected greenhouse. The tunnel structure (Fig. 1) was 8 m wide, 25 m long and covered with double PE UV IC film that was 180 µm thick. The gutter-connected plastic greenhouse (Fig. 2) was covered with double PE film. It was 21 m wide and 250 m long. The inner film was 50 µm thick and outside film was 180 µm thick. Both, open field and greenhouse tomato, were grown on the red mulch film 25 µm thick. Specific volume of the tunnel structure was 16.08 m^3/m and 104.81 m^3/m of the gutter connected structure. The experiment was carried out at private property near Jagodina (Serbia) on 44° 1' 59" latitude and 21° 16' 30" longitude. Tomato production was evaluated regarding the yield, energy consumption, energy efficiency and energy productivity.

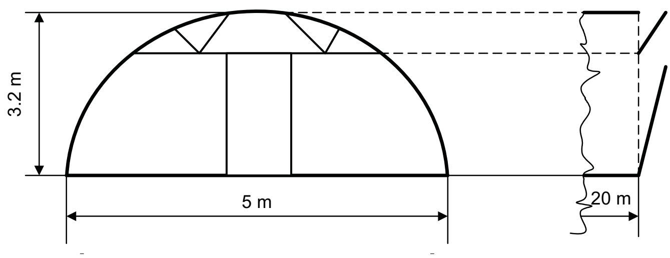


Fig. 1 Tunnel structure

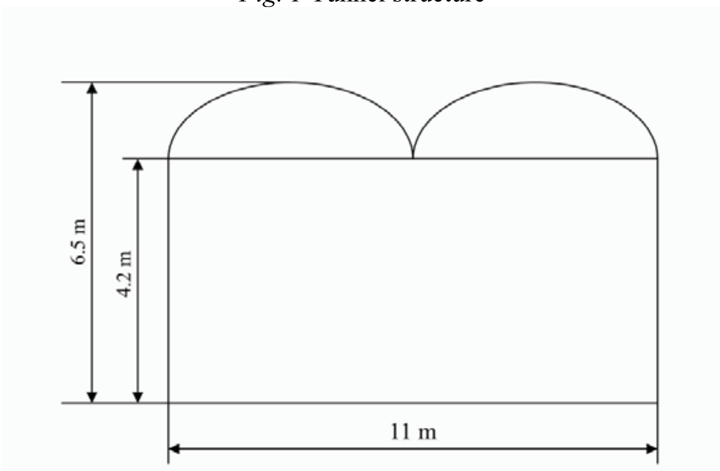


Fig. 2 Greenhouse construction

Tomato was planted in the greenhouses in April 2008 and harvested from July 2008. In the open field 204 tomato seedlings were planted. In the greenhouse number of plants was 14463 in the gutter-connected structure and 400 in the tunnel structure. Production technology was based on soil preparation with rotary hoe, fertilizer application prior to planting and, during the vegetation period, application of pesticides and fungicides and irrigation.

The method used for energy efficiency analysis (Storck, 1978; Enoch, 1978; Athanasios *et al.*, 1997; Djevic & Dimitrijevic, 2009; Hatirli *et al.*, 2006; Ozkan *et al.*, 2007) was based on the energy input analysis (definition of direct and indirect energy inputs), energy consumption for given plant production and energy efficiency. On the basis of the tomato production output and the energy input, energy input/kg of product, energy out/in ratio and energy productivity were estimated (Ortiz-Canavate & Hernanz, 1999). 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).

RESULTS AND DISCUSSION

Quantities of materials used during this production period in 2008. in the open field and greenhouse tomato production are shown in tables 1 and 2 as well as their energy values. Based on the total energy input and production area specific energy consumption was calculated.

Based on the obtained values it can be concluded that there are differences in the open field and greenhouse production technology in case of tomato. The first parameter that was calculated was the energy consumption per production area. The lowest value was calculated for the open field tomato production and the highest value was calculated for the tunnel structure. It can be calculated that the tunnel structure was 51.6% and the gutter-connected structure 33.2% more energy consuming in tomato production compared to the tomato production in the open field. If greenhouse structures are compared it can bee seen that tunnel structure had a 13.8% higher energy consumption. So, based on the results obtained, beside the open field, gutter-connected structures and structures with higher specific volume can be recommended for the tomato production.

Tab. 1 Energy consumption for open field 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
Fertilizer (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
Energy consumption (MJ)		954.87	100
Specific energy consumption (MJ/m^2)		15.91	

From the structure of the used energy (Tab. 1) it can be seen that share of indirect energy input in the open field production is higher compared to the other similar researches (Hatirli et al. 2006; Ozkan et al. 2007) and was 95.23%. In the tunnel energy consumption structure (Tab. 2) indirect energy inputs had their share of 94.05% while in the gutter-connected structure the share of indirect energy input was 81.45%. The reason for the higher share of direct energy input was straw usage for maintaining adequate soil structure. The main reason for lower share of direct energy inputs is that greenhouses were not heated and only fuel consumption for technical systems was considered as direct energy input.

Tab. 2 Energy consumption for the greenhouse tomato production

Energy input	Tunnel structure			Gutter-connected structure		
	Quantity	Total energy (MJ)	Share %	Quantity	Total energy (MJ)	Share %
Fuel (l)	3	143.4	5.95	70	3346	3.01
Straw (kg)				1050	17293.5	15.55
Technical systems (h)	0.17	2.22	0.09	5.2	67.91	0.06
Fertilizer (kg)						
Nitrogen	19.26	1515.76	62.84	625.23	49205.6	44.23
Phosphorus	8.75	152.25	6.31	327.75	5702.85	5.13
Potassium	22.75	311.67	12.92	817.4	11198.38	10.07
Pesticides (kg)	0.02	3.98	0.17	0.58	115.42	0.1
Fungicides (kg)	0.203	18.68	0.77	3.26	299.92	0.27
Water (l)	1032	9.29	0.39	1445400	13008.6	11.69
Human labor (h)	130	254.8	10.56	5616	11007.36	9.89
Energy consumption (MJ)		2412.05	100		111245.50	100
Specific energy consumption (MJ/m^2)		24.12			21.19	

In all three cases the most energy consuming operation was fertilizing. The share of fertilizers in the total energy consumption in the open field was 64.84%. In the tunnel this share was 82.07% and in the gutter-connected greenhouse it was 59.43%. The other indirect energy inputs showed different values on all three cases. In the open field, after fertilizer, the highest energy consumption was through human labor (21.11%) and water for irrigation (9.05%). In the total energy consumption in the tunnel tomato production, after fertilizer, most energy was consumed through human labor (10.56%). Other energy inputs were lower than 1%. In the gutter-connected greenhouse after fertilizer, most energy was consumed through water for irrigation (11.69%) and through human labor (9.89%).

Energy output was calculated based on the energy value for tomato and obtained yield (Tab. 3). The highest specific energy output was obtained in the gutter-connected greenho-use (19.02 MJ m^{-2}) and the lowest in the open field tomato production (13.6 MJ m^{-2}). If compare, tomato grown in the open field had 28.5% and in tunnel 15.88% lower specific energy ouput.

Tab. 3 Tomato yield and energy output in open field and greenhouse

	Yield (kg)	Energy output (MJ)	Specific energy output (MJ/m2)
Open field	1020	816	13.6
Tunnel structure	2000	1600	16
Gutter-connected structure	124848	99878.4	19.02

For the open field production measured tomato yield was 17 kg/m^2 while in the tunnel greenhouse this value was 20 kg/m^2. In the gutter-connected greenhouse tomato yield was 23.78 kg/m^2. The reason for this can be searched in more uniform micro-climatic and production conditions under the double inflated PE film (Athanasios et al. 1997) compared to the open field production. Forced ventilation systems had played important role in making the production conditions beneficiary for greenhouse tomato. Shibuya et al. (2006) stated that forced ventilation within the canopy is an effective technique to enhance the gas exchange of the plant canopy and the consequent plant growth. The 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 and solar radiation 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. Red mulch film had also showed as beneficiary regarding energy consumption for the plant protection as well as good isolator in combination with greenhouse cover during a few cold days (Moreno 2008).

Based on the measured energy inputs and the energy output, parameters for energy analysis were calculated (Tab. 4). It can be seen that the different values were obtained for the open field and the greenhouse tomato production regarding basic energy parameters.

Tab. 4 Parameters for the energy analysis

Energy parameter	Open field	Tunnel structure	Gutter-connected structure
Energy input / kg product (MJ/kg)	0.98	1.21	0.89
Energy ratio	0.81	0.66	0.9
Energy productivity (kg/MJ)	1.02	0.83	1.12

The highest energy input per kg of product was calculated for the tomato produced in tunnel greenhouse, 0.98 MJ/kg, and the lowest value for this parameter was calculated for the tomato produced in the gutter-connected greenhouse, 0.89 MJ/kg. These values are directly influenced by the yield and the energy consumption which were in both cases beneficiary in the greenhouse. If greenhouse structures are compared it can be stated that, for the tomato production in tunnel structure, 36% more energy is needed compared to gutter-connected greenhouse structure.

The results obtained for the out-in ratio could be compared with other similar researches. Hatirli et al. (2006) reported that in the greenhouse tomato production these values varied from 0.7 up to 2.3 depending on the size of the greenhouse holdings in Turkish region. The 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 tomato production in gutter-connected greenhouse had the better productivity compared to the tunnel structures and the open field production. If the values are compared (Tab. 4) it could be seen that tomato production in the tunnel structure has 26% and the open field tomato production has 9% lower energy productivity compared to tomato production in the gutter-connected greenhouse.

Based on the results obtained, the fact that open field vegetable production is less energy consuming production technology, can be confirmed. If tomato yield is compared in the production in the open field and in the greenhouses, it can be seen that greenhouses can have a protective role against the temperature gradients and solar radiation thus, creating the more uniform production conditions in the greenhouses. As stated by Nelson (2003) the efficiency of plant production in greenhouses depends significantly on the adjustment of optimal climate growth conditions to achieve high yield at low expense, good quality and low environmental load. It is also reported (Saeed *et al.,* 2007) that tomato is highly sensitive to high temperatures. High temperatures during the growing season have been reported to be detrimental to growth, reproductive development and yield. In tomato high temperature during reproductive development can cause significant increment in flower drop and significant decrease in fruit set and consequently fruit yield decreased to a great extent.

Results obtained for the yield lied to the conclusion that higher yield obtained in the greenhouses not necessarily lead to the better energy utilization and productivity. In the case of tomato production in tunnel tomato yield of 20 kg/m^2 was not sufficient for obtaining lower specific energy input. In the case of tomato production in the gutter-connected greenhouse, energy input and tomato yield were much better balanced. In this case, energy output was high enough to justify the energy consumption thus having a better energy productivity and energy utilization.

Further research will focus on the energy consumption and energy efficincy of different vegetable and fruit species in order to obtain enough experimental data for prepration of model for greenhouse plant production optimisation regarding energy concumption and energy efficiency.

CONCLUSION

Tomato is one of the most important vegetable in the human daily nutrition. It can be grown in the open field as well as in the various greenhouse structures. The aim of this paper was to analyze energy consumption patterns in tomato production in the open field and in the greenhouse tunnel and gutter-connected construction.

Based on the energy consumption and the energy output it can be seen that the tomato production in the open field is less energy demanding compared to the tomato production in the greenhouses. The structure of energy inputs shows that 80 up to 90% of the total energy consumption is based on indirect energy inputs, mostly fertilizers, human labor and water for irrigation. Results also show that energy consumption must be analyzed together with the energy output. Greenhouse structures had better ratio between yield and energy consumption compared to the open field production system. This has also led to the higher energy productivity in the greenhouse tomato production systems.

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.

LITERATURE

1. Athanasios, P. P., Hao, X., 1997. Effects of three greenhouse cover materials on tomato growth, productivity and energy use. *Sci. Hortic.,* 70: 165-178
2. Badger, P. C. 1999. *Solid Fuels*, CIGR Handbook, vol. 3: 248-288
3. Bechar, A., Yosef, S., Netanyahu, S., Edan, Y., 2007. Improvement of work methods in tomato greenhouses using simulation. *Transactions of the ASABE.,* 50(2): 331-338
4. Dasgan, H. Y., Ozdogan, A. O., Kaftanoglu, O., Abak, K., 2004. Effectiveness of bumblebee pollination in anti-frost heated tomato greenhouses in the Mediterranean Basin. *Turk J Agric For*., 28: 73-82
5. Djevic, M. and Dimitrijevic, A., 2009. Energy consumption for different greenhouse construction. *Energy*, 34, No. 9: 1325-1331
6. Enoch, H. Z., 1978. A theory for optimalization of primary production in protected cultivation, I, Influence of aerial environment upon primary plant production, *Acta Hort.*, 76: 31-44.
7. Hatirli, S. A., Ozkan, B., Fert, C., 2006. Energy inputs and crop yield relationship in greenhouse tomato production, *Ren. Energy,* 31: 427-438
8. Moreno, M. and Moreno, A., 2008. Effect if different biodegradable and polyethylene mulches on soil properties and production in a tomato crop. *Sci. Hortic.,* 116: 256-263
9. Nelson, P. 2003. *Greenhouse Operation and Management*, 6th edition, CRC Press
10. Ortiz-Cañavate, J. and Hernanz, J. L., 1999. *Energy analysis and saving in energy for biological systems,* CIGR Handbook, vol. 3: 13-37.
11. Ozkan, B., Fert, C., Karadeniz, F., 2007. Energy and cost analysis for greenhouse and open-field grape production, *Energy*, 32: 1500-1504.
12. Saeed, A., Hayat, K., Ali Khan, A., Iqbal, S., 2007. Heat Tolerance Studies in Tomato (*Lycopersicon esculentum* Mill.) *Int. J. Agri. Biol.,* Vol. 9, No. 4, 649-652
13. Shibuya, T., Tsuruyama, J., Kitaya, Y., Kiyota, M., 2006. Enhancement of photosynthesis and growth of tomato seedlings by forced ventilation within the canopy. *Sci. Hortic.*, 109: 218-222
14. Sonmez, N. K. and Sari, M., 2006. Use of remote sensing and Geographic Information System technologies for developing greenhouse databases. *Turk J Agric For*, 30:413-420

15. Statistical office of the republic of Serbia, 2008. http://webrzs.statserb.sr.gov.yu

16. Stevens, A. B., Stevens, S. A., Albrecht, M. L., Karen, I. B., 1994. *Starting a Greenhouse Bussinies*. Cooperative Extension Service, Kanzas State University Manhattan, Kansas.

17. Storck, H., 1978. Towards an Economic of Energy in Horticulture, *Acta Hort.* 76:15-30.

18. Trejo-Perea, M., G. Herrera-Ruiz, J. Rios-Moreno, R.C. Miranda and E. Rivas-Araiza, 2009. Greenhouse energy consumption prediction using neural networks models. *Int. J. Agric. Biol.,* 11: 1–6

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.17:635.132
Stručni rad
Expert paper

POLJOPRIVREDNA TEHNIKA U UZGOJU MRKVE

ZVONKO RADAN[1], ROBERT ZIMMER[2], RENATA MATIĆ[1],
DOMAGOJ ZIMMER[2]

[1]Belje d.d. PC Povrtlarstvo, renata.matic@belje.hr
[2]Poljoprivredni fakultet Osijek, zimmer@pfos.hr, domagojz@hotmail.com

SAŽETAK

Na proizvodnim površinama Belje d.d. RJ Topolik uspješno se uzgaja povrće. U 2008/09. proizvedena je konzumna mrkva. Osnovnu obradu obavili su okretni plugovi (s 4 i 7 plužnih tijela), a prorahljivanje tla prorahljivači (tzv. podrvači). Osnovna gnojidba obavljena je pneumatskim raspodjeljivačima. Gredičar je oformio gredice na razmaku 75 cm, a visina gredice iznosila je 22-25 cm. Sjetva mrkve obavljena 15 do 17. 03, sa četverorednom vučenom pneumatskom sijačicom zahvata 3 reda, s tim da se na svaku gredicu usijavalo sjeme mrkve u tri reda. Navodnjavanje je obavljeno s pokretnim kišnim krilom zahvata 750 m. Slijedila je zaštita usjeva, a zatim pokrivanje usjeva s folijom mase 17 g m $^{-2}$. *U prihrani je korišteno gnojivo KAN, a u zaštiti usjeva korištena je vučenu prskalica zahvata 24 m.*

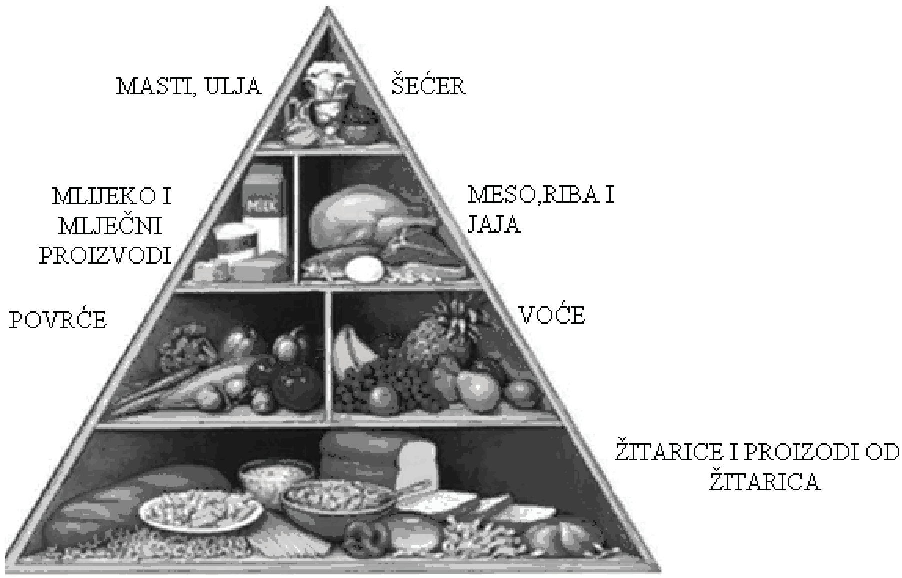
Nakon uklanjanja zaštitne folije počelo je vađenje mrkve jednorednim vučenim kombajnom francuske marke Simon. Mrkvu vade dva transportera, djelomično je čiste i odmah odlažu u omanje kontejnere koji se nalaze u troosovinskoj prikolici kapaciteta 20 sanduka. Kontejner prati kombajn i relativno čistu mrkvu odvozi na doradu.

Ključne riječi: *poljoprivredni strojevi i oruđa, mrkva*

UVOD

Povrća su voluminozne namirnice s visokim sadržajem vode, niske kalorične vrijednosti, te s dosta celuloznih vlakana koja pomažu normalnoj probavi. Prehrambena vrijednost povrća leži u njegovu bogatstvu hranjivim tvarima, a posebno vitaminima i mineralima koji izravno utječu na fizičku i mentalnu kondiciju čovjeka, a time i na njegovu radnu sposobnost. Iako je povrće uz voće najvažniji i najjeftiniji izvor vitamina u Hrvatskoj je prosječna godišnja potrošnja povrća po stanovniku manja od polovice najpovoljnije količine. A najpovoljnija količina povrća u dnevnom obroku je 400 do 500 grama, odnosno 150 do 180 kg/godišnje.

Američko udruženje za prehranu preporuča kako svakodnevni jelovnik uskladiti sa znanstveno utemeljenom i opće prihvaćenom Piramidom pravilne prehrane, koja je osmišljena 1992. god. Namirnice su podijeljene u šest glavnih skupina koje su raspoređene na četiri razine Piramide (Slika 1.). Niže razine Piramide imaju veću površinu, pa se hrana prikazana u njima treba uzimati u većim količinama. Obrnut je slučaj s višim razinama Piramide budući imaju manju površinu, pa se hrana prikazana u njima treba uzimati u manjim količinama. Žitarice i proizvodi od žitarica i (integralni kruh, peciva, riže i tjestenine) čine bazu Piramide i predstavljaju temelj prehrane, odnosno namirnice koje se mogu konzumirati najčešće tijekom dana.



Slika 1. Piramida hrane

Da bi ljudski organizam dobio sve potrebne energetske i nutritivne tvari potrebno je smišljno izbalansirati obroke i pravilno ih iskombinirati iz svih šest skupina: žitarice i proizvodi, riža, kruh, tjestenina; voće; povrće; mlijeko i mliječni proizvodi; meso, riba i jaja, masti, ulja i slatkiši.

U prvoj razini Piramide su proizvodi od žitarica i njihovi proizvodi, koje možemo često konzumirati u većim količinama bez bojazni da ćemo narušiti sklad svoje prehrane.

U drugoj razini su voće i povrće. Voće je bogat izvor ugljikohidrata, vode, vitamina, minerala, celuloze, vlakana i organskih kiselina, dok je povrće prava riznica vlakana, vitamina i minerala, posebno A i C, te željeza i magnezija, niskokalorično je i lako probavljivo. I voće i povrće nezamjenjive su komponente svakodnevne pravilne prehrane ljudskog organizma.

Na trećoj razini Piramide su mlijeko i njegovi proizvodi, te meso, riba i jaja. Mlijeko kao najsavršenija namirnica na svijetu jedan je od glavnih izvora kalcija, a važan je izvor i bjelančevina, vitamina A i fosfora. Meso nije samo važan izvor energije za ljudski organizam, već je prava riznica bjelančevina, vitamina, posebno A i B-grupe, minerala, fosfora, magnezija i kalija, te elemenata u tragovima (željeza, cinka i selena). U prehrani pri izboru mesa prednost treba dati nemasnim dijelovima, te mesu peradi, piletini i puretini. Ribe, a posebno one bogate omega 3 masnim kiselinama (sardina, skuša, losos i tuna) predstavljaju ne samo kvalitetnu hranu nego i namirnicu kojom se mogu spriječiti različita oboljenja. Jaja sadrže nezaobilazan izvor proteina, željeza, kalcija, fosfora, i vitamina A i D, te vitamina B-skupine.

Na vrhu Piramide su masti, ulja i šećer koje treba koliko je to moguće što manje koristit u svakodnevnoj prehrani. Naime, masti, ulja i slatkiši sadrže mnogo Jula (kalorija), te malo ili nimalo kvalitetnih hranjivih sastojaka. Pri izboru masnoća i ulja za pripremu hrane, treba izbjegavati masnoće životinjskog podrijetla i zamijeniti ih onima biljnog podrijetla. Ukoliko se treba koristiti ulje prednost je na strani maslinovog ulja, jer je najveći prirodni izvor mononezasićenih masnih kiselina, pa zato predstavlja jedno od najkvalitetnijih i najzdravijih ulja. Prema koncepciji Piramide treba izbjegavati namirnice s dodatkom šećera, bezalkoholna pića, bombone, čokolade, kolače, kekse, sirupe, marmelade, te rafinirani (stolni) šećer, a potrebu organizma za slatkim utažiti prirodnim voćnim sokovima, sušenim voćem i medom.

U najnovijoj mediteranskoj Piramidi prehrane naglasak je na obilatom korištenju voća i povrća, a dodatna su novost začinsko bilje i trave. Ta piramida potiče i konzumiranje ribe i plodova mora, a nezabilazno je korištenje crvenog vina (www.vitamini.hr)

MATERIJAL I METODE

Uzgoj mrkve (Daucus carota L.) obavljen je na proizvodnim površinama Belje d.d., PC Povrtlarstvo, lokacija Topolik. Tip tla je aluvijalno pjeskovito tlo. Nakon žetve pšenice tanjuračom (B= 4,5 m) je obavljena plitka (10 do 15 cm) obrada tla. Nakon toga je obavljeno ravnanje tla, a zatim podrivanje tla s podrivačem s 5 tijela u dubinu od 50 cm. Osnovna gnojidba obavljena je s pneumatskim Amazone raspodjeljivačem zahvata B = 24m, a doza je iznosila 610 kg ha $^{-1.}$, formulacije 7:20:30.

U jesen je obavljeno oranje okretnim plugovima s rešetkastom odgrnjačom od 8 i 4 plužnih tijela u dubinu 28 do 30 cm. U proljeće 2008.god. obavljena je dopunska obrada tla uporabom gredičara s kojim su u jednom prohodu na razmaku od 75 cm oblikovane 4 gredice. Debljina (visina) gredice pripremljene za sjetvu mrkve iznosila j 22 do 25 cm. Korišten je gredičara pod nazivom Baselier.

Sjetva mrkve četveroredním sijačicom Agricola italiana, model SNT-2/3-290 trajala je od 15 do 17. 03 2009. god. Sijao se je hibrid mrkve Napoli F1. Sjeme mrkve sijalo se u tri reda na svaku gredicu, pa je razmak redi na gredici iznosio 7,5 do 8 cm . Sijačica ima mogućnost sjetve mrkve u dva reda, s tim da je tada razmak redi na gredici iznosio 6 cm.

Nakon sjetve zasijana površina natopljena je vodom pri čemu je korištena kišno krilo tipa VALLEY ukupnog zahvata 750 m. Sistem za navodnjavanje ima i dva dodatna spremnika za vodu, kapaciteta svaki po 1000 litara i služi kao rezerva.

Prekrivanje nasada folijom tipa Agryl obavljeno je 18.03 s polja, a uklanjanje folije obavljeno je 27.04 2009. god. Masa folije je 17 g / m^2,

Zaštitne mjere: Od insekticida korišten je Dursban u količini od 10 kg/ha, a od fungicida Signum 0,7 kg/ha, Score 0,5 l/ha i Switch 0,7 kg/ha.Upotrebljena je prskalica HARDY COMANDER 3200 litara, zahvata 24 m. Od herbicida korišten je Afalon u dozi 0,5 l/ha, Orion 0,15 l/ha, Ston 1,5 l/ha, Sencor 0,03 kg/ha i Ofalon 0,2 l/ha.

U prihrani mrkve korišteno je gnojivo KAN u dozi od 200 kg ha i Kalijeva sol u dozi od 305 kg/ha. Upotrebljen je pneumatski raspodjeljivač Kongskilde tipa Wing Jet S4024. Kapacitet stroja je 4000 litara.

Tijekom uzgoja mrkve utvrđivao se sklop. Na duljini od 1m u više navrata utvrđivan je broj biljaka.

REZULTATI

U uzgoju mrkve u PC Povrtlarstvo na pokusu u Topoliku na proizvodnim površinama izmjerena je količina i raspored oborina, te srednje mjesečne temparature zraka kako prikazuju tablice 1. i 2.

Tablica 1. Oborine (mm) tijekom vegetacije mrkve i višegodišnji prosjek (Belje d.d.)

Naziv	ožujak	travanj	svibanj	lipanj	srpanj	kolovoz	Ukupno
2009.	22,1	15,7	45,4	73,9	31,0	61,9	250,1
1993-2009.	36,5	48,6	56,9	57,6	57,8	67,1	324,5

Na proizvodno polje u vegetaciji mrkve od ožujka do kolovoza palo je ukupno 250,1 mm oborina ili 74,4 mm manje u odnosu na višegodišnji prosjek. U mjesecu lipnju utvrđeno je više oborina u odnosu na višegodišnji prosjek.

Tablica 2. Srednja mjesečna temparatura zraka, Belje d.d. (°C)

Naziv	ožujak	travanj	svibanj	lipanj	srpanj	kolovoz	Ukupno
2009.	6,9	14,6	19	19,7	23,7	23,5	107,4
1993-2009.	5,7	10,5	15,6	18,4	19,6	19	88,88

Srednja mjesečna temparatura zraka u razdoblju uzgoja mrkve bila je 17,9 °C.

Krajem kolovoza ravnanje tla obavljeno je s ravnjačima kako bi se ublažile depresije a time i gubitak vlage u tlu. S podrivačima obavljeno je duboko rahljenje u dubinu od 70 do 80 cm. Osnovna obrada tlo obavljena je s peterobraznim okretnim (Regent) i osmerobraznim (Lemken) okretnim plugovima s rešetkastom daskom. Sjetva mrkve obavljena je pneumatskom sijačicom Agricola italiana, model SNT-2/3-290. U prvom roku sjetve mrkva je navodnjavana sistemom kišnoga krila VALLEY, i nakon toga pokrivena Agryl folijom.

Vađenje mrkve obavljeno je s jednorednim vučenim francuskim kombajnom Simon u kombinaciji s posebno izvedenim transporterom za prijenos mrkve širine 2,46 metara, dužine 12 metara i visine 1,16 metara. Princip rada kombajna temelji se na mehanizmu za vađenje, čišćenje i odlaganje u transportnu prikolicu. Berački mehanizam se može podjeliti na tri sekcije: torpeda, raonik i transportna traka.

U prvoj sekciji torpeda služe za podizanje lisne mase od tla. Za točno visinu zadužen je kopirni kotač. U drugoj sekciji raonik otkida zemlju dok jedan par remenja tj. traka obavlja prihvat i transport mrkve. Ispod traka se nalaze zvijezde ili četke koje svojom vrtnjom obavljaju funkciju čišćenja. Trake odnose mrkvu do uređaja koji sa svoja dva ekscentrična rotora sa letvicama (4-5 letvica) skida list od korijena. Traka iznosi lisnu masu izvan kombajna, a korijen pada na posljednju sekciju stroja koja transportira mrkvu u box palete.

Transport mrkve obavljen je u posebnim box paletama dimenzija 113 cm X 113 cm X 73 cm (ŠxDxV) s kojima je izbjegnuta svaka nepotrebna manipulacija istovara i utovara.

Tablica 3. Sorta, prosječni sklop, podešeni razmak zrna u redu, visina biljaka i prosječni urod

Hibrid	Prosječni sklop biljaka (u travnju) na 1 m	Podešen razmak zrna u redu (cm)	Prosječni urod mrkve (t ha^{-1})
Napoli F1	131	U vanjski redovima 2,28, a u srednjem redu 3,99	48,6

Tablica 4. Prosječna dužina (cm), promjer (mm) i prosječna masa korjena mrkve (g)

1. Prosječna dužina (cm)	Prosječni promjer (cm)	Prosječna masa mrkve (g)	Najlakša i najteža mrkva (g)
23,25	3,0	135	63 i 309

Mrkva se sije u principu u svibnju i lipnju, a vadi u kolovozu, rujnu ili listopadu, ovisno o sorti, pa se na nekim područjima mrkva može brati od od sibnja do prosinca.

Berba mrkve na velikim gospodarstvima obavlja se vučenim kombajnima, koji izvađenu mrkvu istodobno čiste i odmah je transportiraju u transportno sredstvo. Tako izvađena mrkva odlazi na dodatno čišćenje i poslije toga na doradu.

ZAKLJUČAK

Na proizvodnim površinama Belje d.d. RJ Topolik uspješno se uzgaja mrkva. Koristi se osnovna i dopunska obrada tla, moderna sijačica Agricola italiana sa mogućnosti u sjetvi korištenja potlaka, odnosno pretlaka i suvremeni francuski vučeni kombajn za vađenje mrkve. Navodnjavanje velikih površina mrkve riješeno je uporabom kišnih pomičnih krila VALLEY zahvata 750 metara. Nakon vađenja mrkve ista se odlaže u box palete, a oni otpremaju gotov proizvod na mjesto dorade. U doradi se mrkva čisti od nečistoća i otprema u tvornicu za preradu.

LITERATURA

1. Borošić Josip, Buturac Ivan, Ćustić Mirjana, Poljak, Milan Romić, Davor: Povrćarstvo, Zrinski d.d., Čakovec, 2002.
2. Bajkin Anđelko (1994): Mehanizacija u povrtlarstvu, Poljoprivredni fakultet N. Sad, Novi Sad
3. Coolinarika.com, www.colinarika.com/clanak (19.02 2009.)
4. A.G., Bri Dgewater (2006): Povrtnjak, Za hrvatsko izdanje Leo Commerce d,o.o., Rijeka (2008).
5. A.G., Bri Dgewater (2006): Povrtnjak, Za hrvatsko izdanje Leo Commerce d,o.o., Rijeka (2008).
6. Matotan Zdravko: Proizvodnja povrća, Hrvatsko obiteljsko gospodarstvo, nakladni zavod Globus, Zagreb, 1994.
7. Zimmer Robert, Košutić Silvio, Zimmer Domagoj (2009):Poljoprivredna tehnika u ratarstvu, Poljoprivredni fakultet Osijek,2009.

AGRICULTURAL MACHINERY FOR CARROTS PRODUCTION

SUMMARY

At fields of Topolik, agricultural enterprise Belje d.d. vegetables at large scale has been successfuly produced. In the season 2008/09 when carrots were grown, some observations were made to show specific machinery within technological scheme of carrots production. Primary tillage was performed by 4 and 7 furrow reversible ploughs and soil loosening by chisel ploughs. Ridgers made ridges 75 cm apart and 22-25 cm hight. Sowing was done on 15th till 17th of March. 2009. With 3-row pneumatic planter. The crop was covered by special plastic film 17 g m^{-2}. Plant protetction was done by 24 m wide trailed sprayer. Harvest was performed by trailed single row harvester that partially cleans carrots and delivers them to containers set at three axis trailer.

Key words: *carrots, open field vegetable production, farm machinery*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

INVESTIGATION OF MECHANISED MARIGOLD FLOWERS HARVESTING

BRANISLAV VESELINOV[1], DUSAN ADAMOVIC[2], MILAN MARTINOV[1], SAVO BOJIC[1], IBRAHIM MUJIC[3]

[1]Faculty of Technical Sciences, Novi Sad, Serbia
[2]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[3]University of Rijeka, Rijeka, Croatia

ABSTRACT

*It is performed testing of mechanical harvest of marigold (*Calendula officinalis L.*) using virtual rotated comb type chamomile harvester. The influences of penetration of harvester cylinder into canopy, cylinder RPM and machine speed on harvesting characteristics: harvested yield of different flowers' classes according to stem lengths (0-2 and >2 cm) and harvest losses in a form of not picked-up and downfallen flowers were tested. There were performed five harvest passes during vegetation period.*

During the first harvest pass, cylinder penetration was 52% of average plants' height, cylinder RPM 130 min^{-1} *and machine speed 1,2 km/h, results with maximal yield, 2.150 kg/ha of flowers with stems length up to 2 cm, and 2.050 kg/ha of all others. The losses were: not picked-up flowers 160 kg/ha, and downfallen flowers 250 kg/ha. Mass productivity of harvester was 336 kg/ha, and surface 0.08 ha/h. By following harvest passes the yield of flowers was reduced to final 400 kg/ha, whereby the yield flowers with stems under 2 cm achieved 263 kg/ha. The losses were approximately the same.*

Investigation showed that marigold can be successfully harvested with this type of harvester. The shortening of long stems and separation of harvested stalks and leaves should be investigated in the future.

Key words*: marigold (*Calendula officinalis L.*), harvest, mechanization*

INTRODUCTION

Marigold (*Calendula officinalis* L.) is annual herbaceous plant, grown primarily as ornamental, although is more and more used in food industry, as a source of natural color, and as the component of crèmes for wounds, burns and *ulcus cruris*. It is also used as aromatic tea additive.

Marigold is grown in crop rotation. Propagation is provided by direct sowing, at beginning of April, with a row distance 40-60 cm. The flowers should be, after harvest, dried as soon as possible, to prevent reduction of the quality. Yield is 500 to 800 kg of dried flowers per hectare, and, if the conditions are favorable, even more [1].

The major problem presents cost of picking, which is, at vegetation period, provided every three to five days. From the other point, mechanized harvesting causes damage of blossoms, with reduction of yield as a result. Nearby, after mechanized harvesting, separation of green parts is needed (stems and leaves) and reduction of stems length under 2 cm.

Mechanized harvesting of marigold is seldom reported. Hecht et al. [2], as well as Dachler and Pelzmann [6] and Mohr [8] reported about mechanized harvest of chamomile flowers, marigold, St. John's worth with the machine with narrow tooth distance (comb) type. Example of such type of working device is presented at the Fig. 1. This consists of steered bars with combs, rotated with about 20 min^{-1}.

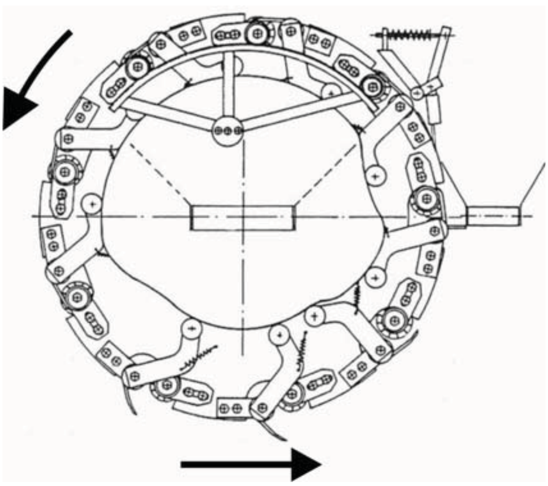


Fig. 1 Rotated comb chamomile harvester with narrow tooth distance–Hege 212

Zimmer and Müller [9], described working device for flowers harvesting with 2.5 m wide rotor, shorter tooth and bigger distance between them. The angular speed was about 300 min^{-1}. This type of harvesting device was built in on reconstructed combine harvester, Fig. 2. The tooth caught the flowers, stroke them and perpendicular bar situated beyond the rotor. The efficiency of the machine was about 0.3 ha/h.

The flowers of marigold have similarities with chamomile. Therefore was supposed that the chamomile harvesting device can be used same harvesting device. In the region of Western Balkan, for harvesting of chamomile flowers, almost exclusively, harvesting device with wide tooth distance, 40 to 60 mm, is used. This type of harvesting device is called also virtual rotated comb [3], [4]), Fig. 3.

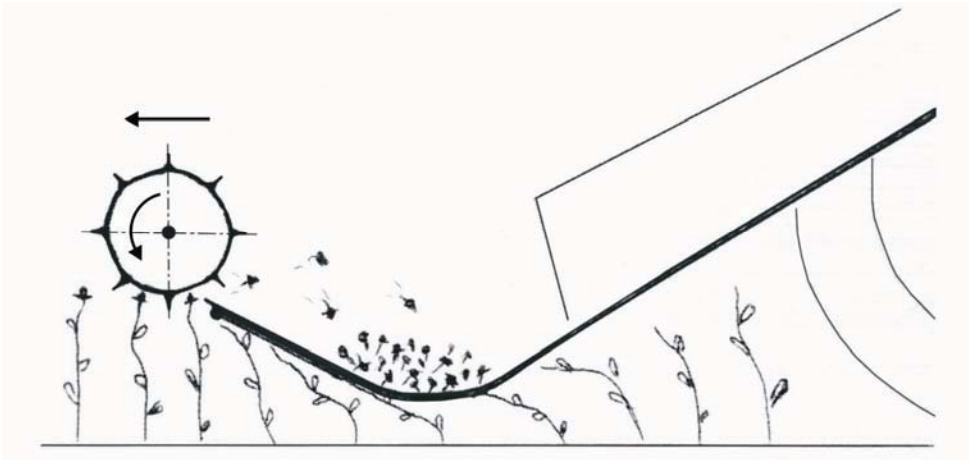


Fig. 2 Chamomile rotated comb harvester with wide tooth distance [9]

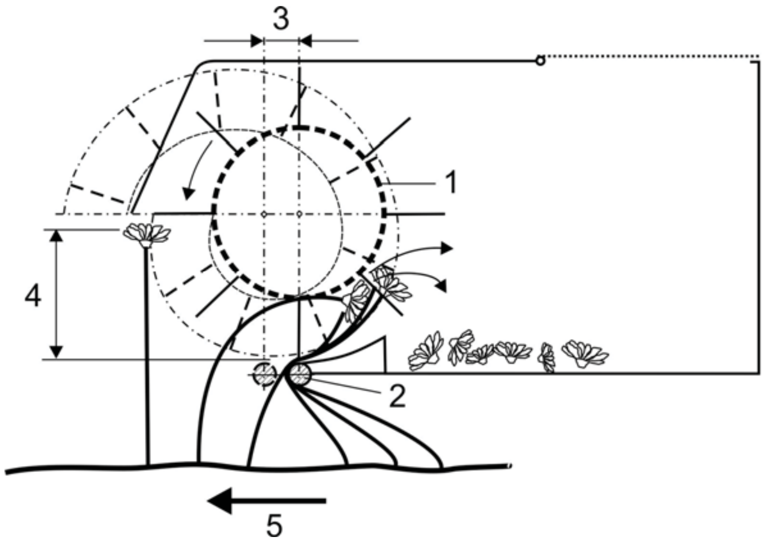


Fig. 3 Working principle of virtual rotated comb type flower harvester [3], [9]:
1– Harvesting cylinder, 2– Tube, 3– Path (Δs), 4– Cylinder penetration (h_c),
5– Speed of machine (v_m)

This harvesting device is considerably cheaper than that with narrow tooth distance. The laths with combs are situates spirally on central cylinder. The tooth (1), catches the flowers and pull them into working space. In the same time the tube (2) is moved with the velocity (v_m) for the distance (Δs), the plants are bent over, and strained by the tooth. The tooth of neighboring laths-combs are longitudinally shifted, forming spiral. That is why combing effect is generated causing tearing off of flowers are. Based on previous testing of such type of harvesting device [10], the set up of the hypothesis was that mechanized harvesting of marigold should be successful. The second hypothesis was that the losses of blossoms, and consequent yield reduction, can be compensated by lower costs of harvesting. Checking of these hypothesis needs few years of testing, whereby the previous, first year was oriented toward defining of significant harvesting parameters.

MATERIAL AND METHODS

The testing of mechanical harvesting was performed at the Institute for Field and Vegetable Crops, Research Station for Hop, Sorghum and Medicinal Plants in Backi Petrovac, Serbia, with the variety *Gelb Orange*. Marigold was sowed with 6 kg/ha at the beginning of April 2008, on 0.45 ha. Row distance was 45 cm, Fig. 4.

Fig. 4 Marigold field, 2008, before start of mechanical harvest

The testing was performed in June, July and August 2008, with mounted machine for chamomile harvesting, Fig. 5. The harvesting device, virtual comb type, was with 16 combs, tooth distance 50 mm, 720 mm diameter and 1,200 mm length.

It was measured penetration of harvesting cylinder plant canopy, flower horizon (h_c), revolutions per minute (RPM) of harvesting device, and machine speed (v_m). The penetration of harvesting cylinder was 19, 20, 24, 25 and 27 cm, for RPM 130 min^{-1} and working speed 1.3 km/h, and 33 and 31 cm, for RPM 150 min^{-1} and working speed 2.2 km/h.

Fig. 5 Tractor mounted harvester, virtual rotated comb type, used for mechanical harvest of marigold flowers

During testing period, from 26th of June till 21st of August, five harvests passes were performed, every ten to fifteen days. Before every harvest, twenty plants were taken to define their characteristics: distances between lowest and highest flowers – width of flower zone, flowers' diameters, share of flowers, stalks and leaves into total plant mass, and their moisture contents. It was also measured flower horizon, average value of five samples.

After every harvest, amount of harvested flowers and herbaceous part, leaves and stalks were measured. Harvested flowers were manually selected into two groups, with stem up to 2 cm, and these with stems longer than 2 cm, and mass of them measured.

It was, on harvested plots, manually collected flowers from the ground, downfallen, and not harvested ones. Their mass was measured, and presented as harvest losses. Collection of losses was provided on several, randomly selected, one square meter surfaces.

RESULTS AND DISCUSSION

Major characteristics of marigold crop, variety Gelb Orange, are presented in Table 1.

The highest mass of harvested flowers with stems shorter than 2 cm, 2,150 kg/ha, were obtained by first harvest pass. In the same time the yield of flowers with stems longer than 2 cm was 2,050 kg/ha, Fig. 6. The other working parameters were: RPM 130 min^{-1}, working speed 1.25 km/h, and penetration of working cylinder into plants 27 cm (52% of plants' height). Harvested mass of stalks and leaves was 4,500 kg/ha, approximately same as sum of both classes of flowers.

After this first harvest pass, remind on the field were 162 kg/ha of not harvested flowers, and 250 kg/ha of downfallen on the ground.

Harvest capacity was 176 and 164 kg/h for flowers with stems <2 cm and >2 cm respectively, or about 340 kg/h total. Surface productivity of harvester was about 0.08 ha/h.

Table 1 Major characteristics of marigold plants Gelb Orange

Characteristics	Number of harvest pass				
	1st	2nd	3rd	4th	5th
Average plant height, cm	62	55	52	51	42
Average flower horizon height, cm	52	49	50	45	39
Average width of flower zone, cm	17.5	12.6	15.2	10.3	8.0
Average diameter of flowers, mm	58	51	48	46	43
Share of flowers in total mass, %	18	15.6	12	17.7	14.5
Share of stalks in total mass, %	51	62	64	62	65
Share of leaves, %	31	23	24	20	21
Moisture content of flowers, %	87	83	83	81	78
Moisture content of stalks, %	88	83	82	81	78
Moisture content of leaves, %	89	82	83	81	77

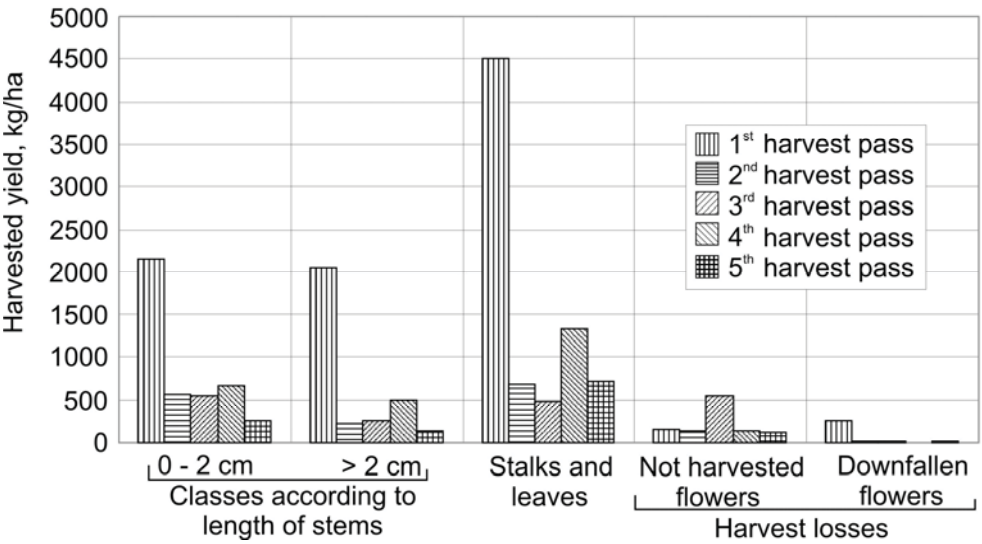


Fig. 6 Results of five harvest passes, penetration of harvester cylinder into canopy 27, 25, 24, 20 and 19 cm respectively

By second harvest pass, performed 16 days after first one, RPM was 130 min^{-1}, and working speed 1.22 km/h. The harvested yield of flowers <2 cm was 565 kg/ha, and these with stems <2 cm 219 kg/ha. Penetration in plant horizon was 24 cm, or 49% of plants' height. The yield of harvested stalks and leaves was 668 kg/ha, or about 50% of total mass. Losses of not harvested flowers were 130 kg/ha, and downfallen 20 kg/ha. Harvesting capacity was 45 and 18 kg/h for flowers with stems <2 cm and >2 cm, respectively. Surfaces productivity was 0.08 ha/h.

The third and fourth harvest passes were performed after ten, i.e. fifteen days after second one, with the RPM 130 min^{-1} and harvest speed 1.25 km/h. The penetration was 20 cm, i.e. 40% for third and 50% for fourth pass. The harvested yield of flowers with stems <2 cm was 550 kg/ha for third and 667 kg/ha for fourth pass, and flowers with stems >2 cm 253 and 503 kg/ha respectively. The losses in form of not harvested flowers were 546 kg/ha for third and 142 kg/ha for fourth pass. Amount of downfallen flowers were 24 and 0 kg/ha respectively. Harvesting capacities were for flowers with stems <2 cm 76, i.e. 53 kg/h, and for flowers with stems <2 cm 35 and 40 kg/h respectively for third and fourth harvest passes. Surface productivity were 0.14 and 0.08 ha/h respectively.

The fifth harvest pass was performed fifteen days after fourth with same RPM and harvest velocity as in previous. The penetration in plants horizon was 19 cm, i.e. 49%. Harvested yield of flowers with stems <2 cm was 263 kg/ha, and these with stems >2 cm 140 kg/ha. Losses in a form of not harvested flowers were 116 kg/ha, and downfallen 140 kg/ha. Harvest capacity was 21 and 11 kg/h for flowers with stems shorter and longer than 2 cm respectively. Surface productivity was 0.08 ha/h.

Additionally, for the first and second pass, harvest with RPM 150 min^{-1} and harvest speed 2.15 km/h was tested. Harvest cylinder penetrations were 31 cm, i.e. 51% of flower horizon for first pass, and 33 cm, i.e. 57% of flower horizon for second pass. The mass of harvested flowers with stems <2 cm was 1,820 and 490 kg/ha, and flowers with stems >2 cm 2,915 and 273 kg/ha respectively. The results are comparable with these obtained for RPM or harvesting cylinder 130 min^{-1}.

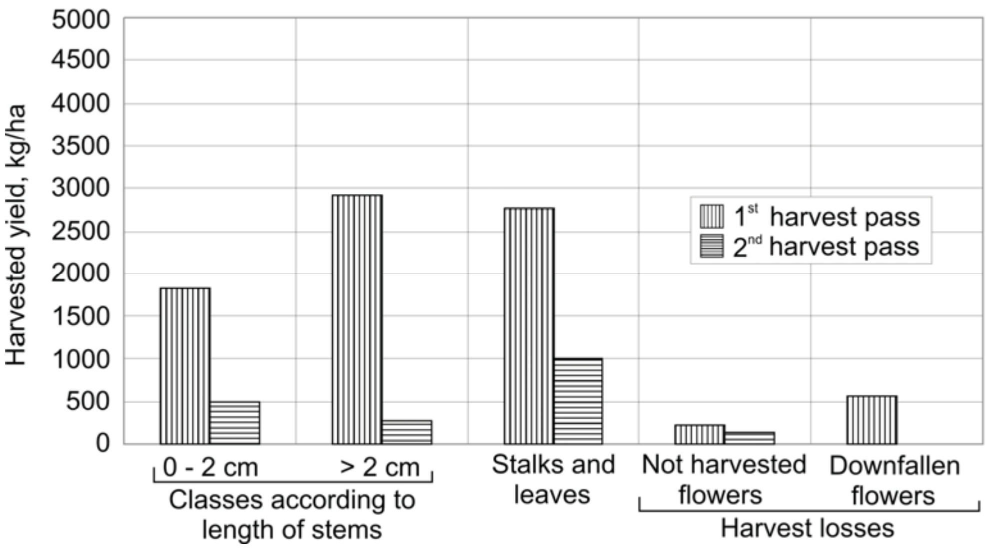


Fig. 7 Results of first and second harvest passes, penetration of harvester cylinder into canopy 31 and 33 cm, respectively, harvesting cylinder RPM 150 min^{-1}

In opposite, for the first harvest pass, the losses were higher than for the work with 130 min^{-1}, 222 kg/ha in the form of not harvested flowers, and 560 kg/ha of downfallen. For the second pass they were 140 and 0 kg/ha respectively, what is comparable with results achieved by 130 min^{-1}, Fig. 7.

Harvesting capacity was 480 and 760 kg/h for first pass and flowers with stems <2 cm and >2 cm respectively. For the second pass, it was considerably lower- 86 and 50 kg/h.

According to obtained results, it can be concluded that virtual comb type of chamomile harvester may be successfully used for mechanized harvest of marigold. The relation of harvested yield and losses in the form of not harvested flowers, as expected, is strongly influenced by harvesting cylinder penetration into plant canopy. Increase of penetration results with higher flower yield and reduction of losses, but also with the share of flowers with stems longer than 2 cm. This impact depends also on flowers band in canopy, distance between lowest and highest flowers. Flowers' band width is different along the field and changes during vegetation period. For the successful flowers' harvest the penetration of harvesting cylinder into canopy should be, for this harvester type, 1.7 times bigger than flowers band. That means lower losses in the form of not harvested flowers, but also higher share of flowers with stems longer than 2 cm, and higher amount of herbaceous mass (stalks and leaves). Optimal relation depends on success of further processing of harvested material, removal of undesirable parts and cutting of longer stems.

Obviously, the next step should be investigation of separation of harvested material in two steps: removal of herbaceous parts, stalks and leaves, and cutting of stems longer than 2 cm. First step should be performed before drying, to reduce costs, and second after. Cutting of flower stems is already successfully solved for chamomile [5]. This existing cutting device should be tested, but previously adopted for different flower size of marigold. The other need is to remove marigold fruits from flowers with stems shorter than 2 cm.

During the first tests, it was recorded that the row distance should be adapted to the width of working cylinder and tractor tires distance in order to achieve better effects of harvest. This should result with higher efficiency, lower damage of crop, and reduction of losses.

CONCLUSIONS

The best quality of harvesting and of harvested flowers can be, today, achieved by manual harvesting. Extension of the production on bigger acreage is possible only if the mechanized harvest and post-harvest processing would be achieved, whereby herbal parts and flowers with stems longer than 2 cm must be separated. Some of procedures of mechanized harvest, according to literature information, offer already now good harvesting quality, but the price of the machines is very high. Lower cost solution, like virtual comb harvesting device is, should be further improved regarding harvest quality.

Investigation of mechanized harvesting of marigold with virtual comb machine type showed that the best quality was achieved by first harvest pass, whereby the harvester cylinder penetration was 52% of plants height. By this test, the harvested mass of flowers with stems shorter than 2 cm was 2,150 kg/ha, and of these with stems longer than 2 cm approximately the same, 2,050 kg/ha.

As the result of damaged blossoms the harvested yield has been reduced for further harvest passes. For the fifth harvest pass, the yield of flowers with stems <2 cm was 263 kg/ha, or about 10% of this for first pass, and 140 kg/ha for flowers with stems >2 cm, or less than 10% of this for first harvest pass.

Losses in a form of not harvested flowers showed also reduction from first to fifth pass, with exception of third pass, where was the inadequate penetration into flower horizon (40%).

In the future, the investigations should be focused on impact of row distance and total flowers yield on the effect of mechanized harvest. The reduction of marigold flower yield, caused by mechanical damages of plants during harvest should be further tested in order to get relevant data for assessment of economy of mechanized harvesting.

Further objective is also investigation of possibilities of separation of undesirable plant parts from mechanized harvested material and reduction of flowers stems longer than 2 cm.

ACKNOWLEDGEMENT

This investigation was supported by the Ministry of Science and Technological Development of the Republic of Serbia

REFERENCES

1. Kišgeci. J. Adamović. D. 1994. Gajenje lekovitog bilja. Nolit. Beograd. p. 199.
2. Hecht. H. Mohr. Th. Lembrecht. S. 1992. Mechanisierung der Blütendrogenernte – Verglech zweier Pflücksysteme. Landtechnik 47. 6. 276–280.
3. Martinov. M. Tešić. M. Müller J. 1992. Erntemaschine für Kamille. Landtechnik. 47. 10. 505–507.
4. Martinov. M. Tešić. M. 1996. Mehanizovana žetva i prerada kamilice. Medicinal Plant Report 3. 3. 38–51.
5. Martinov. M. Oluški. L. 1998. Mašine i oprema za proizvodnju kamilice – Dvadeset godina posle. Medicinal Plant Report. 5. 5. 37–49.
6. Dachler. M. Pelzmann. H. 1999 Arznei- und Gewürzpflanzen. Anbau. Ernte. Aufbereitung). Agrarverlag, Wien.
7. Martinov. M. Adamović. D. 2002. Mehanizovana žetva buhača (*Pyrethrum cinerariaefolium* Trev.) – Rezultat prvih testova. Medicinal Plant Report. 9. 9. 23–27.
8. Mohr. Th. 2002. Examination and development of a harvest machine for the flowers of medicinal plants. Zeitschrift für Arznei– und Gewürzpflanzen 7 (Sonderausgabe). 196–202.
9. Zimmer. S. Müller. J. 2004. Erntetechnologie von Arznei– und Gewürzpflanzen. Fachagentur Nachwachsende Rohstoffe e.V. Gülzow.

10. Veselinov. B. Martinov. M. Adamović. D. Konstantinović. M. 2004. Mogućnosti mehanizovanog ubiranja cvasti nevena (Calendula officinalis L.). Medicinal Plant Report 11. 11. 29–34.

11. Veselinov. B. Adamović. D. Martinov. M. 2008. Istraživanje mehanizovanog ubiranja cvasti nevena (*Calendula officinalis* L.). 15. naučnostručni skup "Proizvodnja i plasman lekovitog. začinskog i aromatičnog bilja". Bački Petrovac. 10.10.2008. Book of Abstracts. 3–5.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

LOW-BUSH BLUEBERRY MACHINE CULTIVATION TECHNOLOGY IN PLANTATIONS ESTABLISHED ON MILLED PEAT FIELDS

L. KÄIS, J. OLT

Estonian University of Life Sciences, Institute of Technology, Department of Agricultural and Production Engineering; Fr. R. Kreutzwaldi 56, 51014 Tartu, Estonia; E – mail: lemmik.kais@emu.ee; jyri.olt@emu.ee

SUMMARY

*Designing a machine cultivating technology for lowbush blueberry (*Vaccinium angustifolium Ait.*) growing plantations set up on milled peat fields can significantly cut down the number of employees and reduce manual work time expenditure, increasing thus the income from berry growing. The promoted machine cultivating technology also enhances the berry grower's interest in introducing more exhausted milled peat fields into berry growing.*

The machine cultivating technology can be applied in constantly maintained and rejuvenated plantations and to allow normal functioning of maintenance and harvesting machines the soil surface in plantations should be land leveled at the beginning of cultivation and kept thus during the usage. The maintenance works must be done in time and regularly to control weed growth.

The surface of a new blueberry bed must be flat - plantation should be land leveled before planting and also after the young plants have been planted and new plantations should be formed bed-wise and for operating machines should be set up service-tracks.

For successful machine harvesting the olds branches should be cut down (pruned) regularly – first rejuvenation cutting is done in the 8...9th year, afterwards in every 3...4 years.

To preparing a plantation for machine cultivation technology must be done by a comprehensive plan and selected service-tracks as follows: the distance (useful) between drainage ditches is 19 m; the plant disposition 1.0 x 1.0 m, while a is plant step (distance) in a row and b is the distance between plant rows on bed; envisage 3...4 beds in the space between 2...3 service-tracks; the depth of a techotrack may be from 0.05...0.3 m; define work parameters of work machines (fertilizer, sprayer, harvester, bog locomotive).

The milled from service-tracks material (peat) can be used as landfill by leveling the bed surfaces and to avoid or compensate peat loss caused by plant cultivation and/or wind and water erosion, the milled peat from peat stacks or service-tracks can be used. The variants with virtual service-tracks are applicable in cases when the machine cultivating technology was not planned last, or in formerly set up plantations.

Key words: *bilberry machine cultivation technology, bilberry bed, service-track, rejuvenation, berry harvester*

INTRODUCTION

The main objective of this research is designing machine technology for cultivating berry plantations founded on exhausted peat fields which application makes possible to curtail time costs and keep down production expenses.

Reclaiming exhausted peat mining areas for lowbush blueberry (*Vaccinium angustifolium* Ait.) and cranberry bog cultivation has currently become topical in Estonia. A novel plant cultivation technology of machine cultivation of bilberries is an advanced mechanized technological process not applied in Estonia up to now.

The so-called exhausted milled peat fields have formed on abandoned by the industrial peat-producing areas. When exploiting the new peat fields the peaty soil was trenched with drainage system and technological water ditches (open drains) to dispatch of excessive moisture and to air peat stacks. The formerly used peat-producing technologies did not foresee land leveling the remaining peat layer, for possible cultivating bog berries' cultivars. From the essentials of machine cultivating technology the remaining milled peat layers that should form planned beds, have not been land leveled. These omissions have hindered applying of machine cultivation technologies or mechanized work operations, and the rational usage of intrinsically woven land and machinery problems have not found an integrated approach.

Plant cultivating technology based on machine cultivating technology intertwines into an integrated system human-plant-machine-soil, with the relevant connections and interactions of the system-constituent objects.

Water and wind erosion, and the plant is need own growth nutrients due to wear of the peat, which led to the plants root sods. Root sods are inevitable emergence of a natural process, which involves changes in relief and make it difficult for the machine-based operations.

Plant cultivating technology based on blueberry machine cultivating technology is a process during which damage to blueberry stems, foliage and berries may occur, for avoidance of which self-propelled and work machines should be carefully chosen. Due to gravity, wheels of operating machines penetrate into the soil destructing the field surface. To prevent extensive damage to the plants and soil by operating machinery it is necessary to optimize the width of blueberry beds, the number of service-tracks, self-propelled and work machines and their work routes. Calculating the resultant of optimization options, cost and quality considering light tillage machinery should be chosen.

The theoretical evaluation methodology, observations and empirical estimations of berry growers were made use of when elaborating the blueberry machine cultivating technology.

MATERIALS AND METHODS

Plant cultivating technology consists of general work operations – tillage, fertilizing and plant protection (pest and weed control) work, and special-purpose work operations, which include planting (also sowing/seeding), clearing, post harvest and pre-sowing processing, storing and preservation.

Machine cultivating technology is a mechanized production process, performed with simple, combined or complex aggregates, resulting in changes of soil and in the shape, size or number of plants and/or berries.

Simple aggregate – work machines with different purpose and efficiency in coupling with a single self-propelled vehicle, which performs a single work operation in a mechanized production cycle.

A plant cultivating farm – a farm cultivating a certain cultured plant and its land hold, strawberry farm, blueberry farm, lingonberry farm.

A plantation is a plot with cultivated plants e.g. strawberry plantation, blueberry plantation, lingonberry plantation.

Preparing the plantation for machine harvesting in the first case of variant with three service-tracks the bed width could be B_1 = 2.0 m and B_2 = 4.0 m; in this case the bushes are planted with 1.0x1.0 m span; the width of service-tracks B_t = 2.0 m. Top-dressing fertilization takes place on the bed B_1 = 2.0 m with one work routes and on the bed B_2 = 4.0 m with two work routes; for applying liquid fertilizer and for plant protection (overlapping motion) a sprayer with work range 6.0 m, traveling on service-track, is used. For harvesting a shuttle-wise traveling machine with B_m = 1.0 m grip scope can be selected, the working operation begins on the service-track side. During the harvesting process a transporter device (e.g. bog locomotive) – collecting berry boxes moves on service-tracks.

Preparing the plantation for machine harvesting in the second case of variant with two service-tracks the bed width could be B_1 = 3.6 m and B_2 = 7.2 m; in this case the bushes are planted with 0.9x0.9 m span; the width of service-tracks B_t = 1.8 m. Top-dressing fertilization takes place on the bed B_1 = 3.6 m with one work route and on the wider bed B_2 = 7.2 m with two work routes; for applying liquid fertilizer and for plant protection a sprayer with work range 9.0 m, traveling on service-track, is used. For harvesting a shuttle-wise traveling machine with B_m = 0.6 or 0.9 m grip scope can be selected, the working operation begins on the service-track side. During the harvesting process a transporter device (e.g. bog locomotive) – collecting berry boxes moves on service-tracks.

Preparing the plantation for machine harvesting in the case of third variant with two or three virtual service-tracks all characteristics of agrotechnical field work and the berry bed geometry are the same as in the two previous cases. Young plants are planted in rows about a = 0.9 ... 1.0 m apart, with row spacing b = 0.9 ... 1.0 m.

During the first 6 ... 7 years blueberry bushes are sprayed, fertilized, weeded and thinned mostly manually or with the help of an ATV, if possible. Berries are harvested with a combine harvester, or handpicked, the berry boxes collected by a bog locomotive - presuming that an ATV type motor vehicles wheels and ground clearance allow to travel on the spaces between blueberry rows and not to significantly damage the plants and berries.

Applying this blueberry plant cultivation technology a thinning cut (pruning) is performed in the 8 ... 9th year, when the bushes have well grown together and formed an even plant carpet. Early in the spring, in March-April, the blueberry stems are pruned (actually cut down to roots) above the ground, using a hand trimmer, a rotor mower or a breaker. Afterwards, the trimmed or mown stems are removed from the bed sites. Then, during the following 2 ... 3 years, virtual service-tracks, necessary for introduction of blueberry machine cultivation technology, are set up on the beds of a berry field. These virtual service-tracks serve as landmarks for orientating the machine users for set directions in the berry fields. The direction is traced on the berry beds with little flags, using a metering tape. From the marked-with-flags service-tracks the blueberry stems are mown according to the chosen technological variant 1 or 2.

The technology enables essentially lower and land level higher plant tufts. In Table 1 comparison of technological varieties data is given.

Table 1 Dates of comparison of technological varieties

Object characteristics	Variant I	Variant II	Variant III
Number of service-tracks	3	2	2 or 3
Interval of drains B m	20.0	20.0	20.0
Width of service-track B_t m	2.0	1.8	1.8 or 2.0
Width of blueberry bed B_1 m	2.0	3.6	2.0 or 3.6
Width of blueberry bed B_2 m	4.0	7.2	4.0 or 7.2
Width of protective zone B_0	0.5	0.5	0.5
Depth of service-track h_2 m	0...0.3	0...0.3	-
Length of blueberry bed L m	280	280	…

Blueberry harvesting should preferably be done by a self-propelled combine harvester, which technological operations must secure separation of berries from the stems unharmed and gathering them into transferable berry boxes or containers. The harvester should be easily operated and maintained.

Possible variants for harvesters: a self-propelled harvester or combine harvester, equipp-ed with a picking table; a mounted harvester, usually coupled or mounted on a tractor; a motor.block berry harvester.

For milled peat fields a motor-block harvester is the best choice (Fig. 1). In the case of this technical solution a bog transporter must also be added to the vehicle assembly.

The labour body of a blueberry harvester (Fig. 1) is a picking reel and the working element is a picking rake. The picking rake is analogous to the mechanical tool used by handpicking, its parallel teeth separate off berries from stems. Correct position of teeth (Olt, J., Käis, L., 2006) renders possible to separate berries from stems undamaged. The machine can be adjusted, but by handpicking picker's experience is required. Trash can be found in almost equal quantities by both picking methods. By machine harvesting the harvesters calculated annual work load is 240 h and seasonal productivity 19.2 ha.

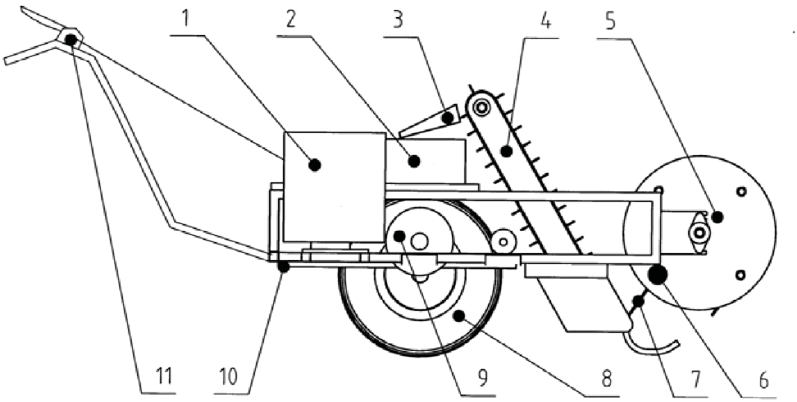


Fig. 1 Main assemblies and parts of a motor-block-type harvester: 1 – engine; 2 – berry box; 3 – chute; 4 – conveyor; 5 – picking real; 6 – picking rake; 7 – rake teeth; 8 – wheels; 9 – power transmission elements; 10 – frame; 11 – steering levers.

The main task of a bog transporter is to transfer the filled blueberry boxes from the combine harvester to the mobile collecting unit on the headland. The main characteristic feature of a bog transporter should be as smooth as possible getaway and therefore lesser damages to peat bog surface.

The harvester productivity W . Generally the acreage productivity of a harvester can be computed as the product of working-width B_m and working speed v_m of the machine:

$$W = B_m \cdot v_m \cdot \tau \cdot \beta \cdot \phi \tag{1}$$

where

τ - time-use factor;

B_m - aggregate width (working-width);

β - aggregate width efficiency-factor (the works without required the accuracy);

T - total operating time;

v_m - aggregate speed (working speed);

ϕ - special stipulation factor (shape and relief)

The time-use factor τ expressed as operating time T_t divided by the total operating time T:

$$\tau = \frac{T_t}{T} \tag{2}$$

where T_t - operating time;

The total operating time express by following formula:

$$T = T_t + T_{e.t} + T_r + T_{t.m} + T_{t.s} + T_{r.t} + T_{rep.t} + T_{w.o} + T_{w.o.w} \tag{3}$$

where

$T_{e.t}$ - empty trip temporal lastingness;

T_r - preparation, termination and routine maintenance temporal lastingness;

$T_{t.m}$ - technical maintenance temporal lastingness;

$T_{t.s}$ - technological services temporal lastingness;

$T_{r.t}$ - machine operator rest time temporal lastingness;

$T_{rep.t}$ - repair works temporal lastingness;

$T_{w.o}$ - work outage temporal lastingness;

$T_{w.o.w}$ - work outage by weather reason (temporal lastingness).

The time-use factor τ is composed of part-time amount:

$$\tau = \tau_m \left(\tau_e + \tau_{t.m} + \tau_{t.s} + \tau_{r.t} \right) \tag{4}$$

where

τ_m - time-use factor in moving;

τ_e - time-use factor in preparation, termination and routine maintenance;

$\tau_{t.m}$ - time-use factor in technical maintenance;

$\tau_{t.s}$ - time-use factor in technological services;

$\tau_{r.t}$ - time-use factor in machine operator rest time.

The operating time depends also on the choice of aggregate's kinematics, which significantly controls the performance.

The harvester throughput capacity q_{max} expressed by treated material quantity weight in time unit:

$$W_0 = \frac{q_{max} \cdot \tau}{Q_{gr} \cdot (1 + \delta_{tr})} \tag{5}$$

where

W_0 - productivity;

q_{max} - throughput capacity;

Q_{gr} - crop yield harvested culture;

δ_{tr} - trash, impurities mass quotient to crop mass.

The relationship between equations 1 and 2 can expressed the harvester throughput capacity q_{max}:

$$q_{max} = B_m \cdot v_m \cdot \beta \cdot \phi \cdot Q_{gr} (1 + \delta_{tr}) \tag{6}$$

If B_m = 0.9 m, Q_{gr} = 0.3 kg/m^2 and v_m = 0.3 m/s are chosen, then the theoretical productivity of a motor-block type blueberry harvester per time unit will be q_{max} = 0.08 kg/s. The productivity of machine harvester is 60 times larger than compare with handpicking but approximately 12% of berries remain unharvested by machine harvesting.

RESULTS AND DISCUSSION

Completion of blueberry cultivation machinery begins with accepting a technological chart which includes: choosing/deciding the blueberry bed profile; choosing/deciding the blueberry bed width; existence of service drives or service-tracks and their number; choosing the machinery depending on its productivity.

The technological variant with virtual service-tracks differs from those with two or three service-tracks in that: service-tracks lower than berry beds are not set up in spaces between beds; machinery operating on virtual service-tracks travels on intertwined with blueberry roots soil surface, which is considerably firmer than peat surface; virtual service-tracks are dust-free, their number and location can always be changed; better usage of berry habitat makes possible to exploit also previously founded blueberry plantations.

The choice of work machines is performed according to the following schema: deciding an appropriate operation area/grab scope (depends on field characteristics and configuration); selecting appropriate containers for materials (water tank, fertilizer bunker etc. – depending on operation area /grab scope of the machine and length of the swath); choosing an appropriate labour implement (sprayer, pump, picking reel etc. – depending on material norms per acre, kinematics and velocity of the operating machine; check-up equipment; steering gear; maintenance facilities; environmental safety.

As all peat milling fields in Estonia have been shaped with drainage ditches over every 20 m, a technological variant with two service-tracks and appropriate machinery should be chosen.

An average market price for one kilogram of bilberries in South-Estonia Tartu Market (Tartu Turg) in years 2007...2009 (July-August) remained in the interval which values are shown on the diagram (Fig. 2).

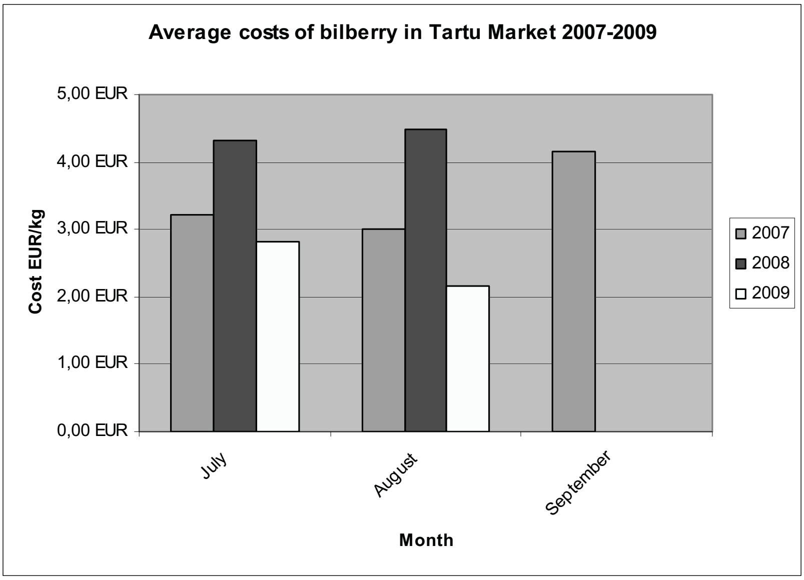


Fig. 2 Market average prices for one kilogram of bilberries

Unit costs of blueberry cultivation are mostly influenced by the harvesting process. A comparison statement of machine harvesting and handpicking is given in Table 2.

Table 2 Comparison of machine harvesting and handpicking

Characteristic	Machine harvesting (combine harvester +ATV)	Handpicking (1 worker)
Productivity kg/h	300	1…5(max)
Equipment costs EEK	270 000	100
Depreciable costs EEK/kg	0.375	0.05
Fuel costs EEK/kg	0.163	-
Labour costs EEK/kg	0.709	19.0
Management costs EEK/kg	0.020	0.40
Harvesting unit costs EEK/kg	1.267	19.45

Remark: 1 EUR=15.646 EEK

In Table 2 shows that unit costs by handpicking are 15 times larger than those by machine harvesting. The present data show that handpicking is a less profit-making and non-reasonable variant for industrial berry growing. Hand berry cultivation lacks essential ways and means to invest into maintenance of plantation, into fertilizers, pesticides etc. Handpicking is inefficient under the conditions established by industrial production. The only reasonable solution is introducing machine harvesters.

REFERENCES

1. Olt, J., Käis, L. 2006. Kinematics of the working unit of the blueberry harvester. Journal of Agricultural Science, pp. 101-105.

2. Haabpiht, J., Irman, E., Jakobson, A., Kaarmäe, A., Kallas, A., Karjane, I., Kask, H., Linnas, L., Miljand, K., Möller, H., Nirk, T., Older, H., Olm, A., Piirsoo, E., Saarlepp, A., Tagavälja, K., Tanvell, V., Tiigimäe, A., Tähnas, I., Valner, H. & Veevo, J. 1980. Põllunduse mehhaniseerimine. Koostanud Tiigimäe, A. Tallinn: Valgus.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 004.4:631.361.026
Izvorni znanstveni rad
Original scientific paper

THE COMPUTERIZED REVERSE KINEMATICS OF THE 3R MANIPULATOR IN THE STACKING PROCESS OF BALES

GEORGE ADIR, BARBU GRECU, LADISLAU DAVID, GHEORGHE VOICU

University „Politehnica" of Bucharest; e-mail: ghvoicu_2005@yahoo.com; bgrecu2000@yahoo.com

ABSTRACT

The manipulator mechanism with 3D working space is characterized by the configuration of 3 motor rotation joints. In this paper we consider $R \perp R \parallel R$ *configuration, on which the characteristic point with first rotation joint determines one plane, that represents the motion plane at the last two elements. With kinematic modulations, it can be established the command functions (position, velocity and acceleration in the motor joint) from the condition that the tracer point makes a motion according to a law, called motion law.*

Key words: *manipulator mechanism, synthesis, stacking process, bales*

INTRODUCTION AND LITERATURE REVIEW

The stacking process of bales is achieved by a manipulator that has to assure the positioning and orientation functions of bale, considered as rigid solid. The mechanical structure can be unitary for both functions or decomposed in 2 independent mechanisms, named positioning mechanism and, respectively, orientation mechanism [1,9].

The positioning mechanism, named also robot mechanism, is an open mechanism with rotation motive couples – R and translation – T, their number being compatible with the degree of freedom and working space.

There is a class of positioning mechanisms with 3D working space, achieved by serial attaching of two base modules, 1D (MB1) of type R or T and 2D (MB2) ($R\parallel R$), ($R\perp T$), ($T\perp R$), ($T\perp T$). In this way, it is obtained a 3D base module (MB3), which admits as kinematic model, one of the alternatives [11]: $R\perp(R\parallel R)$, $R\perp(R\perp T)$, $R\parallel(T\perp R)$, $R\parallel(T\perp T)$, $T\parallel(R\parallel R)$, $T\parallel(R\perp T)$, $T\perp(T\perp R)$, $T\perp(T\perp T)$.

In this paper, the 3D positioning mechanism with 3 motive rotation couples, has the configuration R ⊥ R ‖ R (fig.1). The parameters for positions, velocities and accelerations in the motive couples, are established so that the tracing-point M move on a given trajectory, according to a certain motion law.

THE SYNTHESIS OF THE MOTION LAW ON TRAJECTORY OF THE TRACING-POINT M

The motion of the tracing-point M of the positioning mechanism, is ascertained if we know: the trajectory (Γ), the motion law (LM) and the displacement time (t_m). The trajectory is considered to be a straight line segment ascertained by two points P_i şi P_{i+1}, given in the fixed system. The trajectory can be, also, on a polygonal outline, when it is imposed the passing thru more points. The motion on each side (straight or curve) of the polygon represents an "i" working sequence. In the tips of the polygon it is imposed, as a necessity, to stop the manipulator and thus, it has to be known the stopping time (t_s).

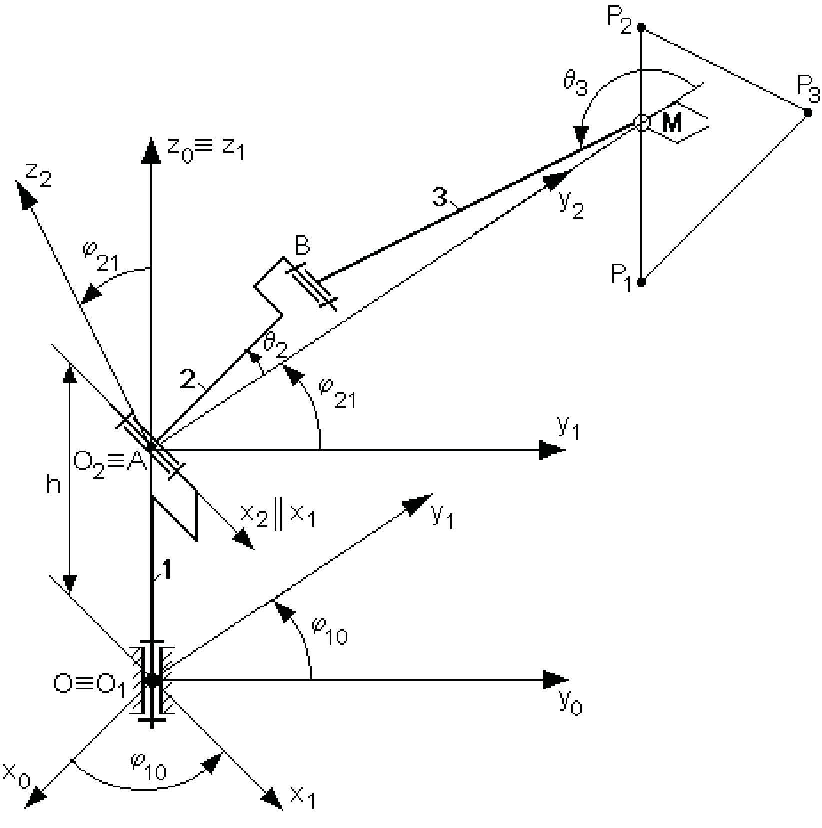


Fig. 1 3R Manipulator scheme

The directory vector of the movement on a straight line, is given as follows:

$$\overline{H} = H\overline{\delta} \tag{2.1}$$

where:

$$H = \sqrt{(x_{P_{i+1}} - x_{P_i})^2 + (y_{P_{i+1}} - y_{P_i})^2 + (z_{P_{i+1}} - z_{P_i})^2} \tag{2.2}$$

$$\overline{\delta} = \cos\alpha \cdot \overline{i} + \cos\beta \cdot \overline{j} + \cos\gamma \cdot \overline{k} \tag{2.3}$$

$$\cos\alpha = \frac{x_{P_{i+1}} - x_{P_i}}{H}; \cos\beta = \frac{y_{P_{i+1}} - y_{P_i}}{H}; \cos\gamma = \frac{z_{P_{i+1}} - z_{P_i}}{H} \tag{2.4}$$

To establish the position, velocity and acceleration, there have been achieved three subroutines in FORTRAN language.

a) Subroutine LEGI(X,Y,DY,D2Y,LM) gives us the motion law under adimensional aspect, thru the counter LM. The formal parameters represent:

$$X = x = \frac{t}{t_m}; Y = y = \frac{s}{H}; DY = \frac{dy}{dx}; D2Y = \frac{d^2y}{dx^2} \tag{2.5}$$

b) Subroutine TRASOR (H,XP,YP,ZP,TM,ALFA,BETA,GAMA,Y,DY,D2Y,PM, M, AM, N) establishes in the working sequence N, the position coordinates, velocities and accelerations of the point M, contained by the matrix:

$$[PM] = \begin{bmatrix} x_{0M} \\ y_{0M} \\ z_{0M} \end{bmatrix}; \quad [VM] = \begin{bmatrix} v_{0M}^x \\ v_{0M}^y \\ v_{0M}^z \end{bmatrix}; \quad [AM] = \begin{bmatrix} a_{0M}^x \\ a_{0M}^y \\ a_{0M}^z \end{bmatrix} \tag{2.6}$$

c) Subroutine STA(XP,YP,ZP,PM,VM,AM,J) indicates the parameters of point M in the final position of a sequence, countered by the counter J = N+1. The positions coordinates correspond to the coordinates of the fixed point XP(J); YP(J); ZP(J), and the velocities and accelerations are zero.

In case when the motion of the tracing-point has N working sequences [6], then it is necessary to index H(N), XP(N), YP(N), ZP(N), ALFA(N), BETA(N), GAMA(N).

THE SYNTHESIS OF THE COMMAND FUNCTIONS

The positioning mechanism taken into consideration in fig.1 is centric. For the reverse kinematic analysis, the mechanism is structured in two “modules”, namely:

- module RR with 2D working space;
- module R which assures a 3D working spece for the tracing-point.

We consider the fixed reference system $OX_0Y_0Z_0$ and the mobile systems $O_1X_1Y_1Z_1$; $O_2X_2Y_2Z_2$ attached to those two modules. The tracing-point is positioned in these three systems by the coordinates (x_{0M} y_{0M} z_{0M}); (x_{1M} y_{1M} z_{1M}); (x_{2M} y_{2M} z_{2M}). Between these ones, there are established the relations:

$$\begin{bmatrix} x_{1M} \\ y_{1M} \\ z_{1M} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ h \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\varphi_{21} & -\sin\varphi_{21} \\ 0 & \sin\varphi_{21} & \cos\varphi_{21} \end{bmatrix} \begin{bmatrix} x_{2M} \\ y_{2M} \\ z_{2M} \end{bmatrix} \tag{3.1}$$

$$\begin{bmatrix} x_{0M} \\ y_{0M} \\ z_{0M} \end{bmatrix} = \begin{bmatrix} \cos\varphi_{10} & -\sin\varphi_{10} & 0 \\ \sin\varphi_{10} & \cos\varphi_{10} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_{1M} \\ y_{1M} \\ z_{1M} \end{bmatrix} \tag{3.2}$$

Because of the centrical solution of the mechanism, it results:

$$\begin{aligned} & x_{1M} = 0; y_{1M} = \sqrt{x_{0M}^2 + y_{0M}^2}; z_{1M} = z_{0M} \\ & x_{2M} = 0; y_{2M} = \sqrt{y_{1M}^2 + (z_{1M} - h)^2}; z_{2M} = 0 \\ & \varphi_{21} = arctg\left(\frac{z_{1M} - h}{y_{1M}}\right) \end{aligned} \tag{3.3}$$

For the kinematic element 1 of the module R, the parameters of positions, velocities and accelerations, are established by using the relations:

$$\begin{aligned} & \varphi_{10} = arctg\left(\frac{-x_{0M}}{y_{0M}}\right) \\ & \omega_{10} = \frac{v_{0M}^x \cos\varphi_{10} + v_{0M}^y \sin\varphi_{10}}{x_{0M}\sin\varphi_{10} - y_{0M}\cos\varphi_{10}} \\ & \varepsilon_{10} = \frac{a_{0M}^x \cos\varphi_{10} + a_{0M}^y \sin\varphi_{10} - 2\omega_{10}(v_{0M}^x \sin\varphi_{10} - v_{0M}^y \cos\varphi_{10}) - \omega_{10}^2(x_{0M}\cos\varphi_{10} + y_{0M}\sin\varphi_{10})}{x_{0M}\sin\varphi_{10} - y_{0M}\cos\varphi_{10}} \end{aligned} \tag{3.4}$$

These parameters are established with the subroutine R: R(PM,VM,AM, FI10, OM10, EPS10).

The postions parameters of the elements 2 and 3 [4] are established in the reference system $O_2X_2Y_2Z_2$, with the relations:

$$\theta_2 = \arccos\left(\frac{l_2^2 + y_{2M}^2 - l_3^2}{2 \cdot l_2 \cdot y_{2M}}\right); \ \theta_3 = \arccos\left(\frac{l_2^2 - y_{2M}^2 - l_3^2}{2 \cdot l_3 \cdot y_{2M}}\right) \tag{3.5}$$

In the mobile plane $O_1Y_1Z_1$, the elements 2 and 3 are positioned by the angles :

$$\varphi_2 = \varphi_{21} + \theta_2 \ ; \ \varphi_3 = \varphi_{21} + \theta_3 \tag{3.6}$$

The elements 2 and 3 of the module RR, having motions in the plane Y_1Z_1, the kinematic modelling of the module RR for imposed motions to point M, is reduced to the kinematic model of the dyad RRR [3].

The two output parameters of the dyad, are comprised in the 1 column matrix:

X – positional parameters matrix;

Y – velocities matrix;

Z – accelerations matrix.

The X matrix containes the parameters φ_2 and φ_3, the Y matrix contains the parameters ω_2 and ω_3 and the Z matrix contains the parameters ε_2 and ε_3. The velocities and accelerations equations are established from the position equations by reiterated differentiation by respect to time and they are presented below.

Positions equations:

$$\begin{aligned} Y_2 + Y_3 &= y_{1M} - y_{1A} \\ Z_2 + Z_3 &= z_{1M} - z_{1A} \end{aligned} \tag{3.7}$$

Velocities equations:

$$\begin{aligned} -Z_2\omega_2 - Z_3\omega_3 &= v_{1M}^y - v_{1A}^y \\ Y_2\omega_2 + Y_3\omega_3 &= v_{1M}^z - v_{1A}^z \end{aligned} \tag{3.8}$$

Accelerations equations:

$$\begin{aligned} -Z_2\varepsilon_2 - Z_3\varepsilon_3 &= a_{1M}^y - a_{1A}^y + Y_2\omega_2^2 + Y_3\omega_3^2 \\ Y_2\varepsilon_2 + Y_3\varepsilon_3 &= a_{1M}^z - a_{1A}^z + Z_2\omega_2^2 + Z_3\omega_3^2 \end{aligned} \tag{3.9}$$

To establish the parameters, it has been used the subroutine RRR [5]: RRR(PB,VB, AB,PM,VM,AM,H1,H2,X,Y,Z,ER), where: *X(1)* = φ_2; *Y(1)* = ω_2; *Z(1)* = ε_2 and *X(2)* = φ_3; *Y(2)* = ω_3; *Z(2)* = ε_3.

Of course, for another structure of the 2D module: RT, TR or TT, the kinematic module is reduced to an adequate dyad: RTR, TRR and respectively, TTR [6,7].

NUMERICAL APPLICATION

To establish the functions for positions, velocities and accelerations in the motive couples, it is considered the motion of the tracing-point on a polygonal outline, defined in the reference fixed system, by the points: P1(0; 1.2; 0.84); P2(-1.2; 1.2; 0.84); P3(-1.2; 1.5; 0.84). The motion times, suitable to the sides P1P2; P2P3; P3P1 have the values: tm1 = tm2 = tm3 = 10 s. The stopping times in the points P1, P2, P3, have the values: ts1 = ts2 = ts3 = 5 s. The motion laws on the three working sequences are: sinus curve, cosinus curve and linear. The numerical values of the kinematic parameters in the motive couples A0, A and B (Table 1) are obtained by using a computing program and transposed in graphs in fig. 2, fig. 3 and fig. 4.

Table 1. The numerical values of the kinematic parameters in couples A_0, A and B

t [s]	Pos. Pct. M	φ_1 [grade]	ω_1 [s^{-1}]	ε_1 [s^{-2}]	φ_2 [grade]	ω_2 [s^{-1}]	ε_2 [s^{-2}]	φ_3 [grade]	ω_3 [s^{-1}]	ε_3 [s^{-2}]
0	P1	0.000	0.0000	0.0000	60.000	0.0000	0.0000	120.000	0.000	0.000
2		2.784	0.0689	0.0593	59.961	-0.0019	0.0281	120.039	0.001	-0.028
4		17.037	0.1654	0.0054	58.470	-0.0311	-0.0216	121.530	0.031	0.022
6		34.743	0.1221	-0.1043	52.520	-0.0650	-0.0180	127.480	0.065	0.018
8		43.572	0.0363	-0.0658	46.360	-0.0329	0.0246	133.640	0.032	-0.025
10	P2	45.000	0.0000	0.0000	45.000	0.0000	0.0000	135.000	0.000	0.000
15	P2	45.000	0.0000	-0.0062	45.000	0.0000	-0.0062	135.000	0.000	0.006
17		44.324	-0.0113	0.0064	44.308	-0.0118	-0.0053	135.692	0.011	0.005
19		42.629	-0.0171	0.0146	42.415	-0.0204	-0.0022	137.585	0.020	0.002
21		40.675	-0.0159	0.0157	39.902	-0.0221	0.0029	140.098	0.022	-0.003
23		39.199	-0.0092	0.0116	37.711	-0.0146	0.0076	142.289	0.014	-0.008
25	P3	38.659	0.0000	0.0048	36.833	0.0000	0.0088	143.167	0.000	-0.009
30	P3	38.659	-0.0390	0.0295	36.833	0.0684	-0.0035	143.167	-0.068	0.003
32		33.690	-0.0481	0.0282	43.854	0.0550	0.0012	136.146	-0.055	-0.001
34		27.552	-0.0594	0.0234	49.567	0.0449	0.0028	130.433	-0.044	-0.003
36		19.983	-0.0730	0.0141	54.180	0.0356	0.0010	125.820	-0.035	-0.001
38		10.784	-0.0875	0.0021	57.694	0.0256	-0.0042	122.306	-0.025	0.004
40	P1	0.000	-0.1000	-0.0050	60.000	0.0144	-0.0088	120.000	-0.014	0.009
45	P1	0.000	0.0000	0.0000	60.000	0.0000	0.0000	120.000	0.0000	0.000

In conclusion, the kinematic analysis of the manipulators with 3D working space, with their elements belonging to the base modules MB1 and MB2, it can be done computerized bu using STANDARD subroutines, established for ascertained statical subsystems of dyad type.

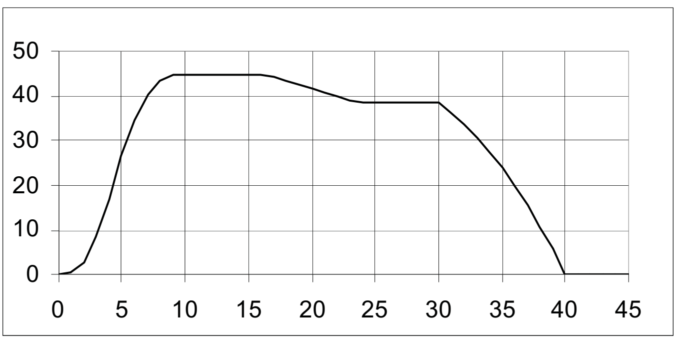


Fig. 2a Angular displacement $\varphi_1(t)$

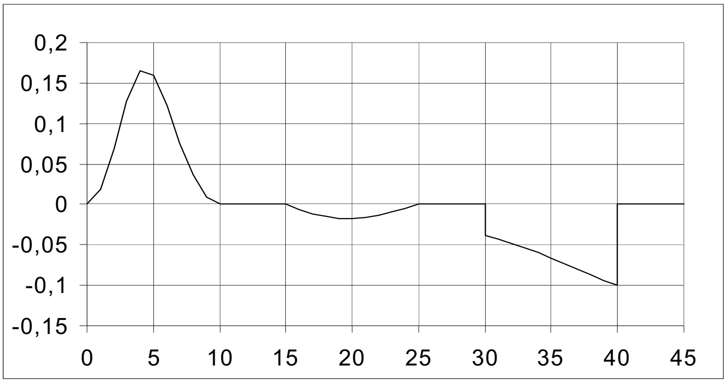


Fig. 2b Angular velocity $\omega_1(t)$

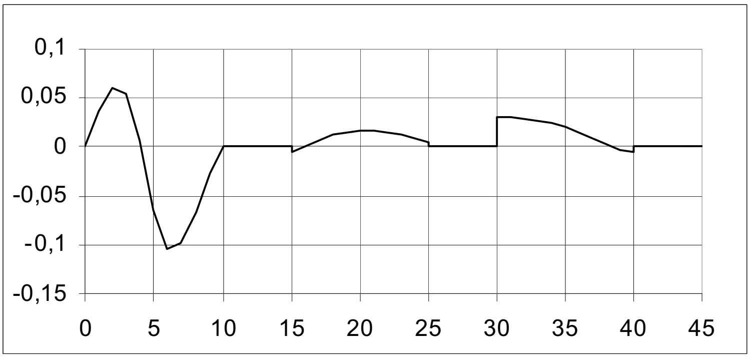


Fig. 2c Angular acceleration $\varepsilon_1(t)$

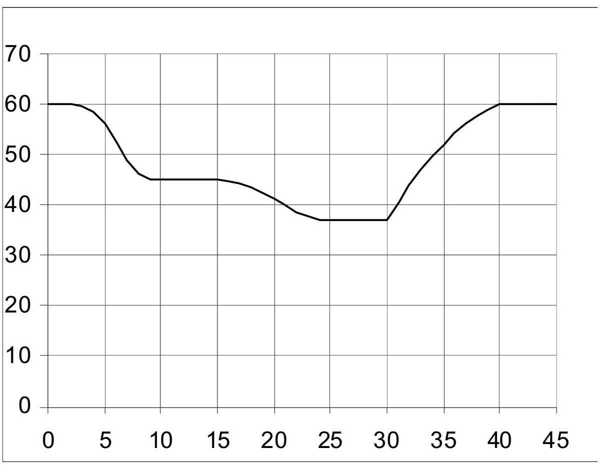


Fig. 3a Angular displacement $\varphi_2(t)$

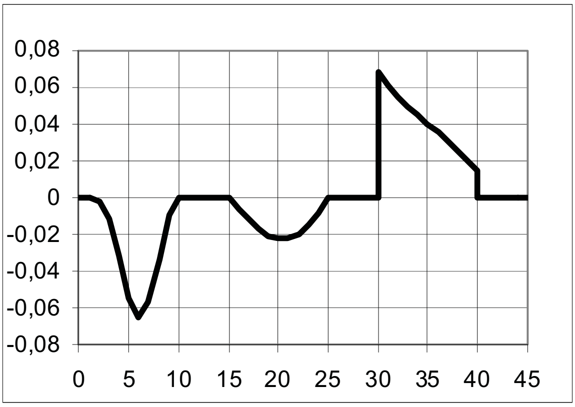


Fig. 3b Angular velocity $\omega_2(t)$

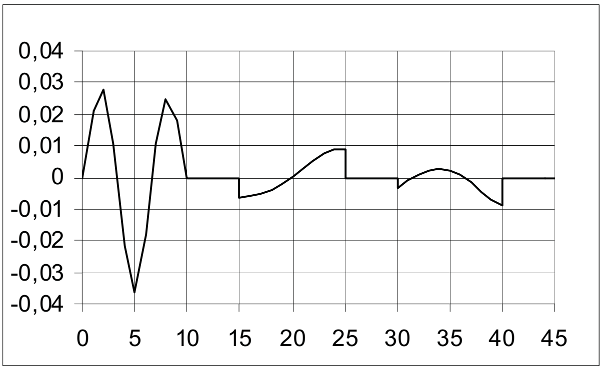


Fig. 3c Angular acceleration $\varepsilon_2(t)$

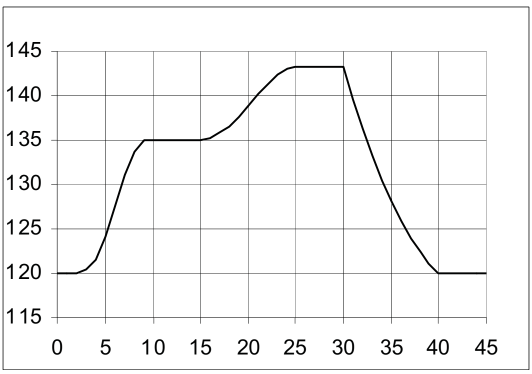


Fig. 4a Angular displacement $\varphi_3(t)$

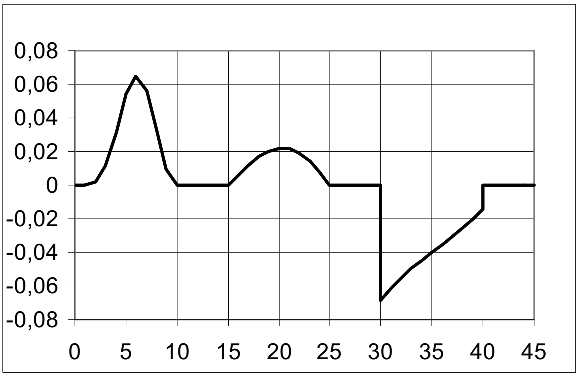


Fig. 4b Angular velocity $\omega_3(t)$

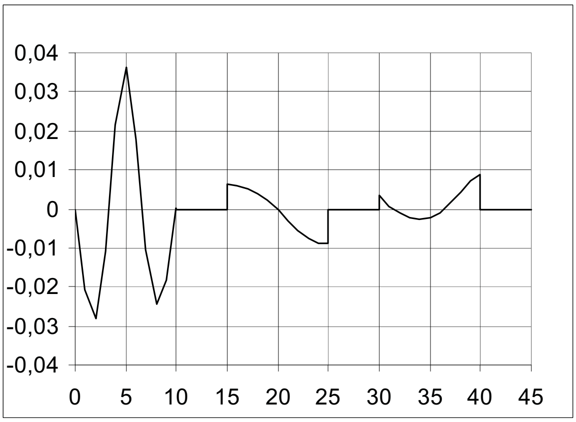


Fig. 4c Angular acceleration $\varepsilon_3(t)$

REFERENCES

1. Antonescu, P., Sinteza manipulatoarelor, Lit. Universitatea Politehnica, Bucureşti, 1993.
2. Dudiță, Fl., Diaconescu, D., Gogu Gr., Curs de Mecanisme, fascicula 4, Lit. Unversitatea Braşov, 1987.
3. Grecu B.,Proiectarea structural-cinematică a mecanismelor manipulatoare cu mobilitatea M=1, cu acționare hidraulică, IFTOM-SYROM'89, vol. 1.1, p.253 – 257, Bucureşti, 1989.
4. Grecu, B., Candrea, A., Asupra funcțiilor de poziții la grupele modulare simple, Simp.R.I., vol.2, p.247 – 252, 1985.
5. Grecu, B., Module de calcul geometro-cinematic ale grupelor modulare, PRASIC'86, Braşov, vol.1, p.65–73, 1986.

6. Grecu, B., Sinteza funcțiilor de comandă la mecanismele manipulatoare cu acționare hidraulică, IFTOM-SYROM'89, v0l. 1, p.279 – 291, Bucureşti, 1989.

7. Grecu, B., Adîr, G., The Kinematic and Kineto-Static Modelling of the planar bi-mobiles Manipulators, Ninth World Congress on the Theory of Machines and Mechanisms, Vol.3, pag.1821- 1825, Milano, 1995.

8. Grecu, B., Moise, V., Modelarea cinematică a mecanismului robot cu structura de bază RRT, Revista Construcția de maşini, Nr. 6, p. 30 – 33, 1998.

9. Ispas, V., Aplicațiile cinematicii în construcția manipulatoarelor şi a roboților industriali, Ed. Academiei, 1990.

10. Kovacs, Fr., Mesaroş-Anghel, V., Spațiul de lucru şi analiza cinematicã a mecanismelor generatoare de traiectorie ale roboților industriali, SYROM'81, vol. 2, p.193 – 205, București,1981.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

USE OF BIOETHANOL FUEL AS REGULAR FUEL

ARNE KÜÜT, JÜRI OLT

Estonian University of Life Sciences, Institute of Technology, 56, Fr Kreutzwaldi Street, Tartu - Estonia, Zip code 51014, e-mail: arne.kyyt@emu.ee, jyri.olt@emu.ee

SUMMARY

The article describes the features arising from using ethanol fuel as fuel for internal combustion engine. The work considers fuels with different ethanol content, obtained by mixing bioethanol with gasoline. The information underlying the study was received by performing laboratory tests. Laboratory tests have been used to indicate main parameters related to engine power and economy which are characteristic of tested fuel mixtures. A comparative analysis of gasoline and ethanol fuels has been prepared on the basis of test results. The analysis of fuels with different ethanol content explains the problems and disparities occurring during their use.

Key words: *bioethanol, regular fuel, gasoline, internal combustion engine, power, torque, specific fuel consumption.*

INTRODUCTION

Continuous price volatility of oil-based products, and supply problems on the world market have established serious need for alternative fuels. The most common alternative motor fuels are biofuels. The advantage of biofuels consists in the recycling opportunity which makes these fuels unlimited resource of raw material. One of the reasons to boost the introduction of production and use of alternative fuels is the requirement to reduce the content of dangerous substances emitted in the course of fuel consumption process (exhaust emission). Another argument for introduction of biofuels is EU Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport, which was adopted on 08.05.2003. Pursuant to this Directive, the proportion of biofuels in using motor vehicle fuels is expected to increase to 5.75% in 2010. Besides that European Commission has applied tax incentives (exemption from excise duty) to biofuels on 27.07.2005.

The most common biofuel used as fuel for internal combustion engine is ethanol, which has been used since 1908 and was first used as power source of Ford-T [1]. Ethanol or spirit is used either in plain form or blended with gasoline or diesel fuels in different ratio. Plain ethanol has been used in Brazil since the 1970ies. This, however, means using customized engines. Regular engines commonly use fuel mixtures, in which case the requirements (expenses) for readjustment and construction of the engine are lower than when using plain ethanol.

The improvement (customisation) of engines for ethanol fuel has become a priority area, considering that ethanol is widely used all around the world and especially in view of the developments in the second generation technologies for production of bioethanol (based on lignocelluloses).

MATERIAL

In order to refer to bioethanol as spark ignition motor fuel, it is easier and more purposeful to compare it with gasoline (table 1). Calorific value of ethanol is ca 30 % lower than the calorific value of gasoline, which means that the fuel consumption is increased by one third. On the other hand, greater detonation stability and higher octane number in comparison with gasoline allows achieving better results in terms of engine power and economy at higher engine pressure ratio.

From environmental management aspect, ethanol is more nature-friendly fuel than gasoline, both in terms of use and chemical composition. Higher oxygen content allows cleaner combustion process at relatively low temperature in comparison with gasoline. Complete combustion process results in the reduced content of CO and NOx in exhaust emissions. Ethanol is also sulphur-free fuel and thus does not cause pollution when released in the environment.

Table 1 The chemical and physical characteristics of bioethanol and gasoline [2]

Fuel characteristic	Gasoline	Bioethanol
Density, kg/l – 15 ^{o}C	0,75	0,80...0,82
Oxygen content, % by weight	-	34,8
Calorific value, MJ/l	31	21,4
Vaporising heat, $kJ \cdot kg^{-1}$	180	930
Octane number (RON)	97	120
Octane number (MON)	86	102
Boiling point, °C	30...190	78
Vapor pressure, kPa	75	16,5
Colour	Yellow	Colourless
Stoichiometric air / fuel ratio, kg	14,7	9

Vapour pressure represents an indicator of fuel volatility and it is very low in case of ethanol. This indicates slow vaporisation and smaller explosion hazard. At the same time low vaporising pressure and specific boiling point constitute the disadvantage of bioethanol, as problems may occur with starting the engine at lower temperatures (under 10 ºC) [2]. As demonstrated by Table 1, due to oxygen content in ethanol, the combustion temperature of ethanol is 35…40 % lower and vaporizing heat is more than five times higher than that of gasoline. When using the fuel with high ethanol content, problems may occur when starting the engine, because the temperature of working mixture may drop approximately 80 ºC. [3]

The quality requirements for using ethanol as motor fuel are not as strict as the requirements for potable spirit. For the purposes of motor fuel, bioethanol may be used both as plain ethanol and as an additive to gasoline. The most common gasoline and bioethanol mixtures are E10 and E85, but other common fuel mixtures include E15 and even E95, the latter is widely used in Brazil. They all have one principle in common: letter "E", followed by a number that indicates bioethanol content in the gasoline-bioethanol mixture in percentage by volume. For example, fuel E85 contains 85 % bioethanol and 15 % gasoline [4].

The use of ethanol is easier in engines with electronic injection. In this case the electrical injection system of a vehicle is supplemented with electronically programmed microprocessor-based additional device for ethanol fuel. The operation of the device is based on adjusting the composition of fuel mixture required for normal operation of the engine, by using information obtained from the exhaust emission λ-sensor. Based on the information received the device shall, at any time point, calculate the composition of fuel (ethanol-gasoline) used at the time and determines the amount of fuel required for preparing fuel mixture, which shall be transferred to the filling devices (injectors). The device is connected to the electrical system between engine control unit (ECU) and filling devices.

The aforesaid device enables to readjust the engines that have not been designed for using ethanol, but one obstacle still remains - the degrading (corroding) impact of ethanol on different materials that may cause damage to ignition and heating systems. Ethanol may damage plastic and rubber details and accelerates the corrosion of aluminium, brass, zinc, and lead.

Car manufacturers have started to show increased interest in using ethanol fuels because of a new type of vehicles added to the product range. These vehicles are equipped with supplementary devices and their design takes into account the selection of material for engine construction. These vehicles are labelled FFV (Flexible Fuel Vehicle) and different fuel mixtures that can be used for these vehicles range from regular gasoline to E85.

Today ethanol is still not very widely used as motor fuel, especially in case of used vehicles, although there are supplementary devices and materials available on the market for readjusting the vehicles. It is most likely that there are not enough experience and research-based tests and analyses available in this field. One objective of this study was to provide test-based explanations.

METHODS

Main parameters used to describe engine work upon using different fuel mixtures are characteristics related to engine power and economy as well as the composition of exhaust emission. Graphs (characteristics) prepared on the basis of test information were used in order to determine dynamic and economic characteristics of an engine upon different modes (load and speed modes). Using the speed characteristic allows to describe the relation between characteristics related to engine power and economy (net power P_e, hourly fuel consumption B_f, specific fuel consumption b_e, average net pressure p_e, torque *Mt*) depending on crankshaft rotational speed nm. In order to find the speed characteristic, the engine is braked on test stand at maximum power; the characteristic determined by partial choke position is called partial speed characteristic [5]. In order to find those characteristics practical tests were performed by using Audi A4 engine, working on gasoline, ethanol and their mixture in any ratio. Supplementary device for ethanol fuels was used when performing tests with plain ethanol fuel and mixtures. Tests were carried out in a laboratory on the test stand Dynas3 LI 250 by using automatic control device SCHENCK x-act, which enabled to obtain electronic data (crankshaft rotational speed n, min^{-1}; engine torque M, Nm; power P, kW and choke position %). The data on fuel used were calculated on the basis of the reading of electronic scales. The composition of exhaust emissions was measured by using Bosch BEA 350 device. The content of carbon dioxide (CO2), carbon monoxide (CO), unburned hydrocarbons (HC), nitric oxides (NOx) and oxygen(O2) in exhaust emissions was also measured. Besides that the aforesaid device also allowed measuring oil temperature, crank rotational speed and excess-air factor (λ).

According to manufacturer's data the maximum torque of Audi A4 is 173 N•m, at 3950 min^{-1}. At the aforesaid crankshaft rotational speed the choke position was 34 % when not loaded. Choke position 34% was thus selected as one of the test modes. In order to obtain partial speed characteristic, the following test was performed with every test fuel: constant choke position at 34 %; crankshaft rotational speed was changed by braking engine at fixed intervals n = 1350...3950 min^{-1}.

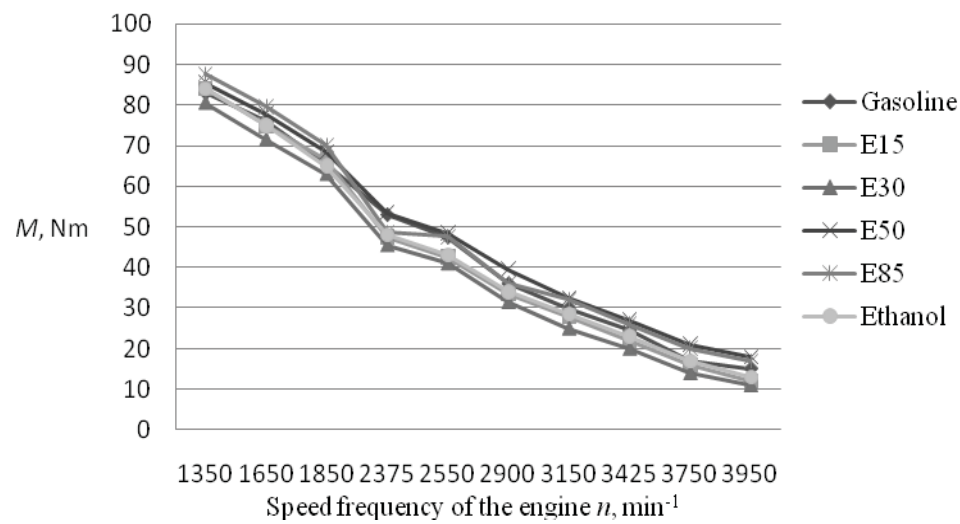


Figure 1. Engine speed characteristics (throttle is 34% open)

In the course of the tests the engine load was increased until the crankshaft rotational speed decreased to the limit where engine was still running steadily. The following parameters were measured at ten different crankshaft rotation speeds: torque M_t (Figure 1), fuel consumption m_f, test duration τ_f, air pressure p_{env}, air humidity φ_{env}, air temperature t_{env}, temperature of exhaust gases t_{egt}, position of injectors τ_i, ignition timing advance α_i, air consumption V_a, temperature of cooling liquid t_w. The information obtained was used for calculating the following parameters: net power P_e, hourly fuel consumption B_f, actual air consumption B_a, specific fuel consumption b_e, engine power efficiency η_e, effective pressure p_e. Exhaust emissions were measured at idling speed (800 min^{-1}) and at increased idling speed (2300 min^{-1}).

Tested fuels included gasoline 95, bioethanol E85, mixtures of gasoline and bioethanol (E15, E30 and E50) and spirit (96.3%). Gasoline 95 and bioethanol E85 were purchased from the filling station and relevant blended fuels E15, E30 and E50 were mixed in the testing laboratory.

RESULTS

Based on test results the average values of studied parameters are used to provide better characterisation of the fuels within the entire partial speed characteristic range (n = 1350... 3950 min^{-1}).

As for the comparison of torque for gasoline (Fig. 2) and for ethanol fuels, better results were received in case of fuels E50 (105.5%) and E85 (103.7%). The lowest result was achieved when using fuel E30 (90.1% compared to gasoline). In case of fuels E15 and ethanol the torque decreased by 4.6% and 3.8%, respectively.

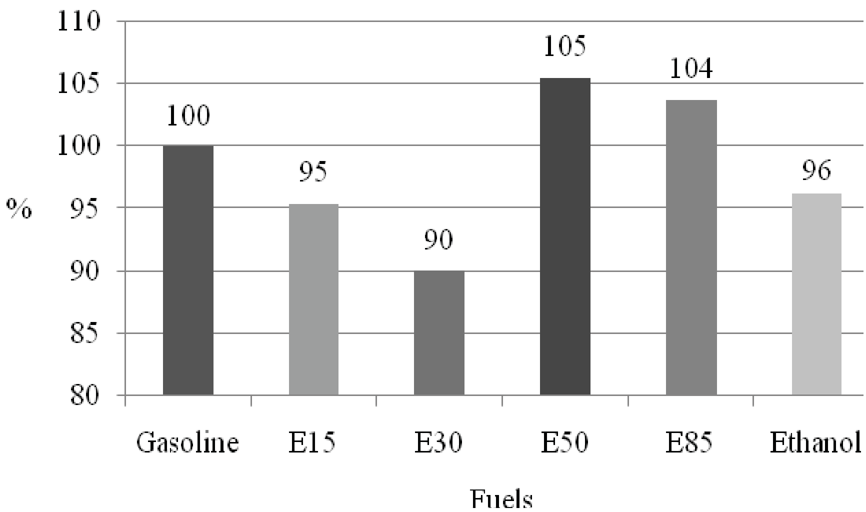


Figure 2 Bioethanol fuels compared to gasoline (torque M, Nm)

Based on the value of torque obtained from the test the engine power Pe (kW) was calculated for tested fuels:

$$P_e = \frac{M \cdot n}{9600}, \quad (1)$$

where:

M – engine torque Nm;

n – engine rotational speed min^{-1}.

The power was the highest in case of E85 at crankshaft rotational speed n = 1650 min^{-1}. At the same time, the best fuel in comparison of average maximum power of gasoline was E50, which improved by 6.9% (Figure 3). Fuel E30 yielded the lowest power (88%) within the entire measuring range. The power developed by using E30 was 12% lower than that of gasoline. Power developed when using ethanol was approximately the same as gasoline (4.8% lower).

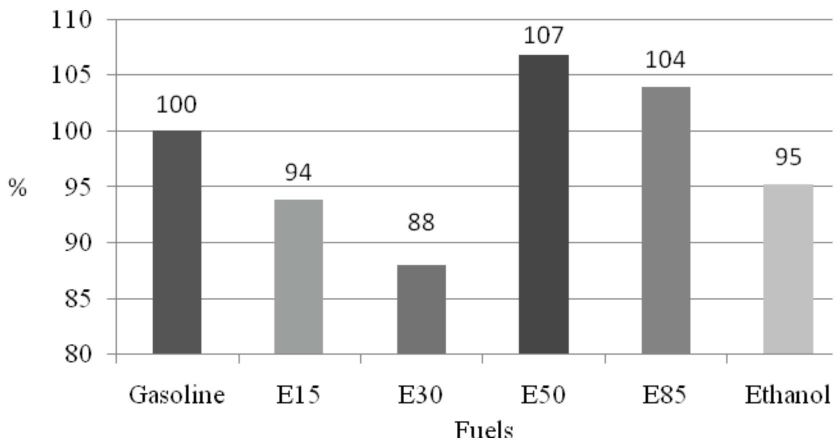


Figure 3 Bioethanol fuels compared to gasoline (power P_e, kW)

Resulting power and hourly fuel consumption (Figure 4) was used to find specific fuel consumption b_s (g/kWh):

$$b_s = \frac{1000 B_f}{P_e}, \quad (2)$$

where,

B_f – hourly fuel consumption kg/h;

P_e – engine power kW.

Specific fuel consumption is inversely proportional with fuel price, which has to be included in the cost analysis and calculation of cost price when using different fuels (fuel mixtures).

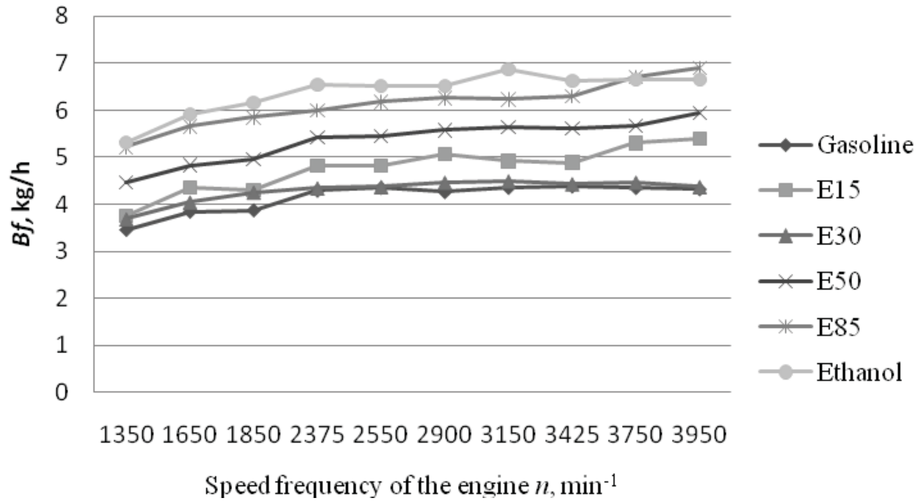


Figure 4 Fuel consumption B_f depending on the speed frequency of the engine n in case of different fuels

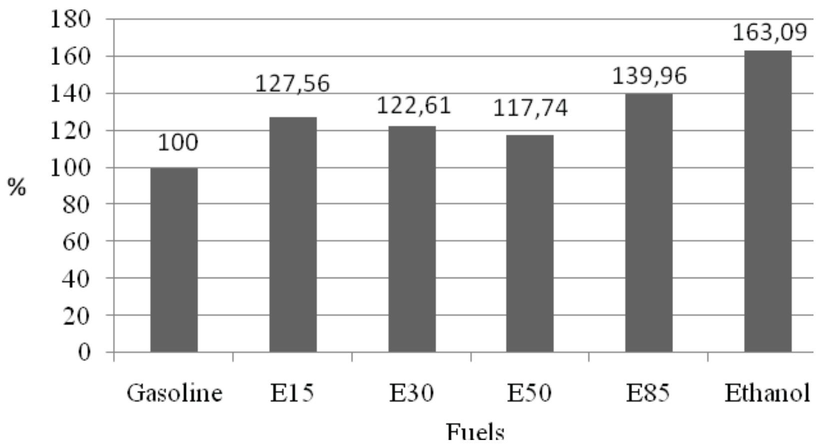


Figure 5 Specific fuel consumption compared to gasoline

Compared to gasoline, the average specific fuel consumption b_s, g/kWh increased during the test as follows (Figure 5):

bioethanol E15	27.6%;
bioethanol E30	22.6%;
bioethanol E50	17.7%;
bioethanol E85	39.9 %;
ethanol	63.1%.

Thus ethanol has the greatest and E50 has the smallest difference in specific fuel consumption, when compared to gasoline.

In terms of the content of dangerous substances in exhaust emissions, better result were obtained with fuel E85, which had the lowest content of carbon monoxide (CO) and hydrocarbons (HC). Fuels E15 and E30 with lower ethanol content were characterised by higher content of dangerous substances in exhaust emissions.

CONCLUSION

As a result of the research we may say that the use of ethanol fuels is justified due to improved engine power and reduced content of dangerous substances in exhaust emissions, but at the same time it also causes noticeable deterioration of parameters related to economy. However, it has to be noted that in comparison with gasoline, the results were remarkably worse in case of fuel with lower ethanol content. Based on these series of tests it is therefore recommended to use it in vehicles with gasoline engine equipped with supplementary bioethanol device, and use only fuels with higher ethanol content.

In order to confirm this statement, another series of tests will be performed under realistic conditions (street tests) by using aforesaid fuels and fuel mixtures.

REFERENCES

1. Ford Model T. 2009. (http://en.wikipedia.org/wiki/Ford_T) (15.01.2009).
2. Nordic Energy Works OÜ. Bioetanool E85. Kättesaadav: http://www.bioetanool.ee/e85 (06.01.2009).
3. Kruus R., Transport-biokütuste tootmise potentsiaal – sobivad tehnoloogilised lahendused, võimsused, asukohad. Tallinna Tehnikaülikool. http://demo.bestit.ee/bw_client_files//public/img/File/BE_AK_Uuringud/ Transportbiokytuste_tootmise_potentsiaal.pdf (22.02.2009).
4. Wikipedia. E85. http://en.wikipedia.org/wiki/E85 (12.03.2009).
5. Mikita V., Mootorite katsetamine. Veotehnika. http://veotehnika.pri.ee/katsetamine/index.html (14.01.2009).

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

UPORABNOST JATROPHINA (*Jatropha curcas* L.) RASTLINSKEGA OLJA ZA PROIZVODNJO BIODIZLA V SLOVENIJI

MIRAN LAKOTA, PETER BERK, DENIS STAJNKO, PETER VINDIŠ, BOGOMIR MURŠEC

Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede, Pivola 10, 2311 Hoče, Slovenija, Katedra za biosistemsko inženirstvo

POVZETEK

Globalni svet se je zavezal k zmanjševanju emisij, zato je uvajanje biogoriv, predvsem biodizla, ki ga dobivamo s procesom zaestrenja iz rastlinskih olj, zelo aktualno. Izmed številnih rastlin, primernih za proizvodnjo rastlinskega olja, je Jatropha curcas L. *dokaj neznana rastlina, ki ima številne prednosti, raste hitro in povsod po svetu, je nezahtevna, primerna je za zaščito pred erozijo, vsebnost olja v semenih rastline je zelo visoka, ima tudi velik donos na hektar, hkrati pa lahko nudi tudi možnost zaposlitve milijonom ljudi, ki živijo pod pragom revščine, zato je še posebej zanimiva predvsem za države v razvoju. Kljub vsem lastnostim in možnostim, ki jih nudi* Jatropha *in jih že poznamo, pa je ta še zmeraj relativno neraziskana. Zato smo v laboratoriju raziskovali njeno olje kot potencialni alternativni vir za proizvodnjo biodizla. Prišli smo do ugotovitve, da je jatrophino olje skupaj z degumiranim sojinim oljem sicer povsem primerno biogorivo, čeprav analize naših vzorcev niso dale pričakovanega rezultata, saj sta po raziskavi najbolj ustrezala le dva vzorca iz sintez, in sicer vzorec, kjer smo jatrophino olje mešali s sojinim degumiranim oljem v razmerju 1:1 ter vzorec jatrophina olja in sojinega degumiranega v razmerju 2:1 z 20% prebitkom katalizatorja natrijevega metilata. Vsebnosti metilnih estrov in ostalih merjenih parametrov v teh vzorcih biodizla so ustrezale standardu SIST EN 14214.*

Ključne besede: *biodizel, jatropha, emisije, zaestrenje*

UVOD

V ozračje se sproščajo uničujoči polutanti, ki ostanejo leta in leta v atmosferi. Pereč problem v svetu je transport, ki je največji porabnik nafte. Danes transport v Evropski uniji (dalje EU) prispeva 28% CO_2 emisij v evropskem prostoru, po ocenah strokovnjakov pa bo do leta 2010 prispeval 90% novih emisij. Edini način za zmanjšanje polucije je kontrola plinov, torej zmanjšanje CO_2 in ostalih toplogrednih plinov, [4]. Biodizelsko gorivo ima številne prednosti pred klasičnimi gorivi, od znižanja emisij CO in nezgorelih ogljikovodikov v ozračju, minimalne vsebnosti žvepla (pod 10 mg/kg), do 70% znižanja stopnje dimljenja izpušnih sistemov, ima zaprt krog CO_2, je netoksičen, v primeru izlitja ne predstavlja nevarnosti za okolje, [6]. V primerjavi z nekaterimi drugimi viri energije, biodizel ne zahteva posebnih vlaganj v opremo osebnih in gospodarskih vozil z dizelskim motorjem, saj ga lahko uporabljamo v že obstoječih dizelskih motorjih. V primeru nekompatibilnosti gumijastih tesnil je potrebna zamenjava tesnil iz materialov, ki so odporni na biodizel. Za proizvodnjo rastlinskega olja obstaja več kot 4000 rastlin, ena izmed teh je *Jatropha curcas*, ki je na našem prostoru dokaj nepoznana, [5]. Prav to je bil cilj natančnejšega raziskovanja te rastline, saj jo dosedanje študije predstavljajo kot rastlino z izjemnimi lastnostmi in njene predstavitve kot rastline bodočnosti v alternativnih energetskih virih, ki lahko vpliva na sistematično sliko globalnega sveta.

Raziskovalci pri Daimler Crysler Research že od leta 2003 raziskujejo uporabo Jatropha olja za avtomobilsko rabo in so zaključili, da olje Jatrophe kot gorivo še ni doseglo »optimalne kvalitete«, čeprav že izpolnjuje normative EU za kvaliteto biodizla, [10]. Tri Mercedesove avtomobile poganja Jatropha dizel in so prevozili že več kot 30.000 kilometrov. Projekt podpira Daimler Crysler in Nemško združenje za investicije in razvoj (Biopact), [8].

Po ZDA se soočajo z odločitvami ali rastlinska olja uporabiti za prehrano ali za proizvodnjo biodizla po katerem povpraševanje strmo narašča, [9]. Približno 80 % vsega proizvedenega biodizla v ameriki je iz sojinega olja. Zaradi občutnega povišanja njegove cene pa povpraševanje po njem vseeno pada, zato proizvajalci že opuščajo tradicionalne rastlinske vrste na primer sojo in koruzo ter se odločajo za komercialno ugodnejše rastline, kot je recimo Jatropha curcas (jatropha World series), [7].

Korporacija Goldman Sachs je nedavno navedla Jatropho curcas (slika 1), kot eno izmed najboljših kandidatk za prihodnjo proizvodnjo biodizla, [11]. Kljub svojemu bogastvu in rabi njenega olja, še nobena vrsta Jatrophe ni bila »udomačena«, zaradi tega je produktivnost Jatrophe curcas variabilna. Prav tako še niso znani dolgoročni vplivi na kvaliteto zemlje in okolja, kjer raste. Jatropho lahko posadimo na lokacijah, kjer ne bo tekmovala z viri, ki so pomembni za pridelavo hrane.

Slika 1: Plodovi Jatrophe curcas

METODE

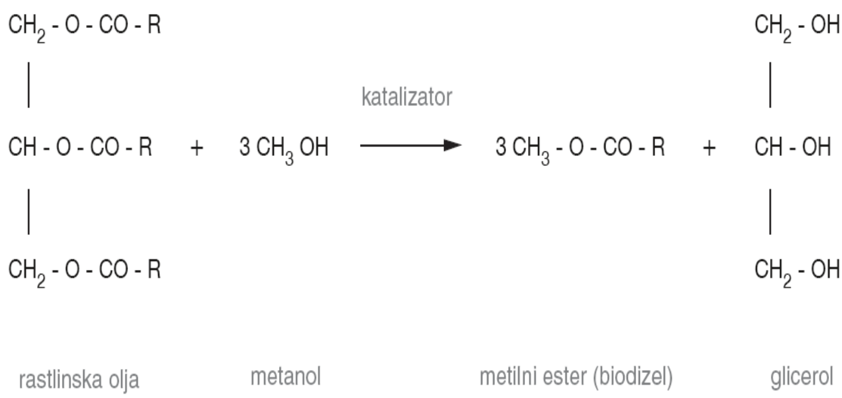
V tovarni Pinus v Račah ustrezno usposobljeni uslužbenci opravljajo kontrolo kvalitete v vseh segmentih proizvodnje: od vhoda surovin v tovarno, med formulacijo izdelkov, občasno med skladiščenjem in analitiko, [3]. Kontrola kvalitete je sestavni del sinteznih obratov (biodizel), kemijske in biološke čistilne naprave ter sežigalnice. Vhodna kontrola ugotavlja, ali surovine ustrezajo spremljajočim specifikacijam za zagotavljanje primerne kvalitete in s tem omogoča nemoten potek proizvodnje. Kontrola med proizvodnjo se deli na procesno kontrolo in končno kontrolo. Procesna kontrola zajema vse preizkusne postopke, ki zagotavljajo brezhibnost izdelka, njegovo ustreznost po identiteti, vsebnosti aktivne substance, teži in ustreznost vsem ostalim kriterijem. Končna kontrola ugotavlja, ali že dokončan artikel ustreza vsem postopkom, kriterijem, specifikacijam in predpisom. Za uspešno izvedbo vseh zgoraj omenjenih nalog imajo lasten analitski laboratorij (slika 2) z vso potrebno opremo.

Cilj je bil ugotoviti, ali je iz Jatropha olja mogoče pridobivati kakovosten biodizel ali pa ga je potrebno mešati s katerim drugim rastlinskim oljem. Na podlagi prejetih analiz mešanice dveh različnih rastlinskih olj (Jatropha olja in sojinega degumiranega olja) in na osnovi sintez biodizla, smo ocenili primernost olj za proizvodnjo biodizla, [1]. Biodizel je kemijsko metilni ester maščobnih kislin (FAME), ki nastane pri procesu transesterifikacije rastlinskega olja – v našem primeru je to Jatropha olje. Ker so pri rastlinskih oljih pomembni vsebnost prostih maščobnih kislin, vsebnost vode, fosforja, jodno število, sestava trigliceridov v posameznem olju, iz samega Jatropha olja nismo mogli sintetizirati kvalitetnega biodizla v skladu s standardom SIST EN 14214, saj je vsebovalo preveč prostih maščobnih kislin. Po tem standardu je potrebno preveriti 25 fizikalno-kemijskih lastnosti po ustaljenih metodah. Izpostavljene so najpomembnejše lastnosti, in sicer: vsebnost estrov, gostota, viskoznost, vsebnost vode, oksidativna stabilnost, kislinska vrednost, jodno število, linolenska kislina metilnih estrov, vsebnost metanola, vsebnost monogliceridov, digliceridov, trigliceridov, prostega glicerola, skupnega glicerola, filtrirnost in vsebnost vode.

Slika 2: Laboratorij podjetja Pinus TKI d.o.o. (foto Sanja Logar)

Viskoznost in filtrirnost sta odvisni od surovine (vrste olja). Vsebnost metanola in vode ter ostale lastnosti pa so povezane s tehnologijo proizvodnje biodizla.

Iz olj smo izvedli reakcijo transesterifikacije ob prisotnosti katalizatorja (slika 3).



Slika 3: Reakcija transesterifikacije ob prisotnosti katalizatorja

Pri sintezi biodizla je uporabljen metanol tehnične kvalitete (z vsebnostjo vode največ 0,1%) in katalizator natrijev metilat (30 utežnih % v metanolu) tehnične kvalitete. Upoštevali smo tudi, da lahko Jatropha olje zaradi visoke vsebnosti prostih maščobnih kislin uporabimo za proizvodnjo biodizla samo v kombinaciji s sojinim degumiranim in posušenim oljem. Degumacija pomeni, da rastlinska olja vsebujejo trigliceride maščobnih kislin, proste maščobne kisline in spojine, ki vsebujejo fosfor, znane kot fosfatidi ali fosfolipidi. Za sintezo kakovostnega biodizla lahko rastlinsko olje vsebuje največ 20 delcev na milijon (ppm) fosforja. S postopkom degumacije v surovem rastlinskem olju zmanjšamo vsebnost fosfolipidov (iz 500 do 3000 ppm na manj kot 20 ppm, računano na fosfor). Degumacijo surovega olja izvajamo v dveh stopnjah pri temperaturi 55-65 °C ob prisotnosti fosforjeve kisline, kalijevega hidroksida in demineralizirane vode.

Sušenje rastlinskega olja poteka pred reakcijo transesterifikacije. Degumirano olje je potrebno tudi posušiti tako, da vsebuje največ 500 ppm vode (vakuumska destilacija pri 70 °C in tlaku 0,2 bara). S tem postopkom preprečimo stranske reakcije, ki bi lahko potekale ob reakciji transesterifikacije rastlinskega olja, katerih produkti bi lahko vplivali na izkoristek reakcije in čistočo biodizla.

REZULTATI Z RAZPRAVO

Poskusno so sestavljene različne mešanice olj v drugačnih razmerjih, ki bi bile primerne za proizvodnjo biodizla v skladu s standardom SIST EN 14214. Pri tem je upoštevana omejitev jodnega števila biodizla (120 gJ2/100g), prostih maščobnih kislin v olju (do 1,5% FFA), kislinskega števila v biodizlu (0,5 mg KOH/g) in vsebnosti fosforja v rastlinskem olju (do 20 ppm). Po zadnjem ločevanju smo biodizel analizirali v službi kontrole kvalitete TKI Pinus d.d.

Preglednica 1: Rezultati sintez biodizla

	Sinteza 1 (n=3)	**Sinteza 2 (n=3)**	**Sinteza 3 (n=3)**	**Sinteza 4 (n=3)**	**Sinteza 5 (n=3)**	**Sinteza 6 (n=3)**	**Sinteza 7 (n=3)**	**SIST EN 14214 (n=3)**
Vsebnost metilnega estra (%)	91,9	96,6	97,6	96,9	96,3	96,8	96,4	96,5
Vsebnost metilnega estra linolenske kisline (%)	0,2	3,5	4,6	2,5	3,5	2,5	2,5	12,0
Kislinsko število, (mg KOH/g)	0,13	0,15	0,15	0,19	0,19	0,10	0,11	0,5
Gostota (g/ml), 15°C	0,8847	0,8840	0,8843	0,8834	0,8842	0,8830	0,8831	0,860 – 0,900
Vsebnost monogliceridov (%)	0,56	0,30	0,21	0,17	0,20	0,44	0,42	0,80
Vsebnost digliceridov (%)	1,44	0,08	0,07	0,08	0,30	0,15	0,12	0,20
Vsebnost trigliceridov (%)	-	0,07	<0,01	0,23	0,70	0,18	0,14	0,20
Jodno število ($gJ_2/100g$)	105,0	115,4	118,7	112,5	116,3	112,9	112,9	120,0

Rezultati sinteze 1

Rezultati, ki smo jih dobili pri sintezi 1, preglednica 3.1, kjer smo mešali čisto Jatropha olje z 20 % prebitkom katalizatorja kažejo, da je dobljena vrednost metilnega estra (91,9%) prenizka (predpisano 96,5%). Vsebnost digliceridov (1,44 %) pa presega predpisano vrednost, ki je za digliceride določena z največ 0,20%. Vsebnost trigliceridov pa je tako nizka, da se pojavi le v sledovih, zato je ni bilo možno izmeriti. Vzorec biodizla ne ustreza evropskemu standardu.

Rezultati sinteze 2

Mešali smo Jatropha in sojino degumirano olje v razmerju 1:1 z 20 % prebitkom natrijevega metilata. Vsebnost metilnega estra (96,6%) je kljub malenkostnemu odstopanju 0,01% v meji predpisanega standarda. Vsebnost metilnega estra linolenske kisline, kislinsko število, gostota, vsebnost monogliceridov, digliceridov, trigliceridov ter jodno število ustrezajo predpisom. Vzorec biodizla ustreza SIST EN 14214.

Rezultati sinteze 3

Mešanica je vsebovala 56,7 g Jatropha olja in 113,3 g sojinega degumiranega olja z 20% prebitkom katalizatorja. Standard določa vsebnost metilnega estra 96,5%, zato ta presega mejno vrednost za 1,1%. Vsebnost trigliceridov je samo v sledovih (<0,01%). Zaradi prisotnosti nečistoč je bil biodizel moten, zato ne ustreza standardu.

Rezultati sinteze 4

Rezultati, ki smo jih dobili pri mešanju olj v razmerju 2:1 z 20% prebitkom katalizatorja kažejo, da vsebnost metilnega estra presega vrednost 96,5%, in sicer za 0,4%, medtem ko vsebnost monogliceridov ne presega predpisane vrednosti 0,80%. Vzorec biodizla je bil moten tako kot pri sintezi 3 in ni primeren glede na predpisan standard.

Rezultati sinteze 5

Jatropha in sojino degumirano olje smo mešali v razmerju 1:1 z 8 % prebitkom katalizatorja, kar vpliva na rezultat, saj vsebnost metilnega estra (96,3%) ni dosegla standardne meje, digliceridi in trigliceridi pa so predpisano vrednost 0,20% presegli. Vzorec biodizla ni skladen s standardom.

Rezultati sinteze 6

Delež Jatropha olja je bil 113,3 g, sojinega degumiranega olja pa 56,7 g, torej je bilo razmerje mešanice 2:1. Prebitek katalizatorja je znašal 20% v korist Jatropha olja. Ugotovili smo, da vsi merjeni parametri kažejo na ustreznost biodizla po standardu.
Rezultati sinteze 7

Pri tej sintezi smo mešali olja v razmerju 2:1, prebitek katalizatroja pa smo povišali na 25%. Pričakovali smo, da bo vsebnost metilnega estra višja od dobljene (96,4%). Zaradi povečanega % katalizatorja pa včasih pride do hidrolize maščob, torej do razpada trigliceridov. Omenjeni vzorec biodizla ne ustreza standardu.

Iz rezultatov analiz biodizla , ki smo jih opravili, je razvidno, da analizni rezultati sintez 2 in 6 ustrezajo predpisanim standardom SIST EN 14214.

Olje Jatrophe ima jodno število med 90,8 in 112,5, kar je ugodno, saj višje jodno število zaradi toplotne nestabilnosti dvojnih vezi, ki so v maščobnih kislinah, ne bi ustrezalo. Zaradi visokega cetanskega števila lahko olje uporabimo kot aditiv za motorna olja. Odstotek se giblje 1–25% lahko tudi več, kar je odvisno od kakovosti bazičnega olja. V predstavitvenih testih oljnih mešanic dizla in Jatropha olja v enovaljnem motorju z direktnim vbrizgom goriva v razmerju:

- 97,4% dizla in 2,6% Jatropha olja,
- 80% dizla in 20% Jatropha olja ter
- 50% dizla in 50% Jatropha olja

so ugotovili, da ima slednje nižje izpuste CO_2 kot dizelsko gorivo. Emisije izpustov CO in ogljikovodikov so v drugem in tretjem primeru podobne. Omenjene mešanice izkazujejo, da se specifična poraba goriva z večanjem deleža Jatropha olja v uporabljenem gorivu veča, kar je neposredno povezano z nižjo temperaturo izgorevanja biodizla, maksimalna moč motorja je sicer manjša, zato pa mora biti prvotna moč motorja večja kot pri uporabi ostalih goriv. Testi kažejo, da se Jatropha olje lahko meša z mineralnim dizelskim gorivom v različnih razmerjih, lahko je 100 % nadomestek za dizelsko gorivo ali pa predstavlja aditiv le-temu.

SKLEPI

Glede na navajanje tuje strokovne literature, da je iz Jatropha olja možno proizvajati kakovosten biodizel, smo pri naših sintezah pričakovali, da bo čisto Jatropha olje primernejše oz. bo ustrezalo standardu SIST EN 14214, vendar pa analize našega vzorca biodizla niso dale pričakovanega rezultata. Po raziskavi sta najbolj ustrezala vzorca iz sinteze 2, kjer smo Jatropha olje in sojino degumirano olje mešali v razmerju 1:1 z 20% prebitkom katalizatorja in sinteza 6, kjer je bila mešanica olj v razmerju 2:1 ob istem % prebitka katalizatorja kot v sintezi 2. Vsebnosti metilnih estrov in ostalih parametrov so ustrezale vrednostim standarda SIST EN 14214.

Nesporno je, da se povpraševanje po biodizlu veča, še zlasti po biodizlu pridobljenem iz rastlinskih olj. V uvajanju novih tehnologij na področju alternativnih energetskih virov in njenih osnovnih surovin – rastlin, bi lahko imela Jatropha curcas pomembno vlogo. Ta rastlina lahko pridelovalcem na ruralnih območjih manj razvitih držav nudi ne samo pridelavo biodizelskega goriva in posledično tudi njegov izvoz, ter izboljšan status kmetijstva, pač pa lahko globalno poseže v samo kakovost njihovih življenj. S svojim oljem Jatropha daje možnost proizvajalcem biodizla za samooskrbo, kar pomeni, da bi domačo potrošnjo oskrbeli z domačo proizvodnjo. S tem se zmanjšuje odvisnost posamezne države od uvoza pogonskih goriv. Pomemben atribut te industrijske rastline je, da ne vpliva na sam proces pridelovanja poljščin, saj raste tudi v razmerah, kjer hrane ni mogoče pridelovati. Cena proizvodnje biodizla iz olja Jatrophe je lahko v prihodnosti, zaradi zgoraj opisanih dejavnikov, primerljiva ali celo nižja kot cene biodizla iz ostalih rastlinskih olj.

LITERATURA

1. Logar, Sanja (2009) Možnost uporabe Jatropha (Jatropha curcas L.) rastlinskega olja v proizvodnji biodizla, Diplomsko delo, Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede
2. Suwarni Tri Y. Jatropha oil (2005). *A promising clean alternative energy*. The Jakarta Post, 2005 (6. September 2009)
3. Berglez Tone (2009). *Elektronsko sporočilo, Služba kontrole kakovosti*. (7. september 2009)
4. http://www.kis.si/datoteke/File/kis/SLO/MEH/Alternativni-viri/1-radgona2007.pdf (3. september 2009)
5. http://www.ecoworld.com/fuels/europe-adopts-jatropha.html (30. avgust 2009)
6. http://www.mg.gov.si/fileadmin/mg.gov.si/pageuploads/Energetika/Predlogi_predpisov/EBRS_08_Sklep.pdf (3. september 2009)

7. http://www.futureenergyevents.com/jatropha/ (1. september 2009)

8. http://www.reuk.co.uk/D1-Oils-PLC-Biodiesel.htm (20. avgust 2009)

9. http://www.jatrophabiodiesel.org/aboutJatrophaPlant.php?_divid=menu1 (26. junij 2009)

10. http://news.mongabay.com/bioenergy/2007/06/interview-daimlerchrysler-farmers-see.html (20. avgust 2009)

11. http://en.wikipedia.org/wiki/Jatropha (21. avgust 2009)

12. http://www.uradni-list.si/1/content?id=57849, Pravilnik o vsebnosti biogoriv v gorivih za pogon motornih vozil, (22. avgust 2009)

USING OF JATROPHA (*Jatropha curcas L.*) VEGETABLE OIL IN BIODIESEL PRODUCTION

SUMMARY

The global world has decided to decrease the exhaust gases, so they initiated biofuel, which is produced from plant's oil. Among numerous plants suitable for the production of the plant's oil Jatropha curcas *is not widely known, but it has many advantages as follows: fast growth all over the world, it is very undemanding, it is used to prevent erosion. The substance of its oil is very high, it enables great yield on hectare, offers possibility of employment to millions of people who live at the edge of poverty. Therefore, is extremely interesting for developing countries. Because of insufficiency in researching of* Jatropha curcas *in country, we did laboratory work in Pinus factory to analyse its oil as potential alternative source in biodiesel production. We came to the conclusion that jatropha oil and soya oil are both perfectly suitable for bio-fuel even though analyses of our samples did not give the expected results. This research gave only two samples from syntheses, namely the sample in which jatropha oil was mixed with soya ungummy oil in proportion 1:1 and the sample of jatropha oil with soya ungummy oil in proportion 2:1 with 20% excess of catalyser sodium methylat. The contents of esters and other measured parameters in these samples of biodiesel corresponded to the standard SIST EN 14214 and 2003/30/ES.*

***Key words**: biodiesel, jatropha, emission, estrification*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 004.41:662.767.2
Stručni rad
Expert paper

SIMULACIJSKI MODEL PRIDELAVE IN PREDELAVE ENERGETSKIH RASTLIN V BIOPLIN

PETER VINDIŠ, BOGOMIR MURŠEC, DENIS STAJNKO, MIRAN LAKOTA

Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede,
Pivola 10, 2311 Hoče, Slovenija, peter.vindis@uni-mb.si

POVZETEK

V kmetijski proizvodnji in nadaljnji predelavi kmetijskih proizvodov je za nosilca odločanja nujna predhodna informacija o ekonomski in finančni upravičenosti proizvodnje in predelave specifičnega kmetijskega proizvoda. V ta namen smo zgradili simulacijski model s katerim simuliramo oziroma ugotavljamo ekonomičnost pridelave posameznih kmetijskih proizvodov in predelave le teh. Za potrebe našega dela je bil zgrajen kompleksen integriran tehnološko-ekonomski deterministični simulacijski model BIOPLIN. Simulacijski model sestoji iz treh glavnih modelov: modelne kalkulacije pridelave energetskih rastlin, simulacijski model predelave energetskih rastlin v bioplin in simulacijski model proizvodnje električne in toplotne energije iz bioplina. Za razvoj modela uporabimo programski paket MS Excel 2003, v kombinaciji s programskim jezikom VBA ("Visual Basic za aplikacije, VBA"). Razvito metodološko orodje je praktično uporabno za potrebe planiranja pridelave energetskih rastlin in za potrebe načrtovanja proizvodnje električne in toplotne energije v bioplinarnah.

Ključne besede: *simulacijski model, bioplin, energetske rastline*

UVOD

Simulacijski modeli temeljijo na sistemski analizi in jih prištevamo k metodam za podporo odločanja. Sistemski pristop nam predstavlja način iskanja najboljših ali vsaj dovolj dobrih rešitev problemov, ob upoštevanju celovitosti in omejitvi sistema. Tak sistem razumemo kot množico elementov, ki so v medsebojnih povezavah. Elementi množice imajo končno število zvez in odnosov z drugimi elementi in tvorijo strukturo sistema. Značilnost sistema kot celote je določena z raznolikostjo odnosov (Kljajić, 1994).

Povezovanje ljudi s procesi in tehnologijo daje veliko število dogodkov in rezultatov, ki jih težko razumemo oziroma ocenimo brez pomoči ustreznega računalniškega simulacijskega modela. Tako računalniška simulacija predstavlja neprecenljivo podporo pri procesu odločanja v kmetijstvu. Razvit računalniški simulacijski model nam izračuna tehnološke parametre kmetijske proizvodnje, ki so osnova za tehnološko karto s kalkulacijami skupnih stroškov. Glavni model lahko ima več podmodelov, pri čemer posamezen model zbere podatke in na osnovi matematičnih formul ob različnih vhodnih parametrih modela poda določene ekonomske parametre (lastna cena proizvodnje določenega proizvoda, koeficient ekonomičnosti). V tem primeru govorimo o računalniško podprtih determinističnih tehnološko-ekonomskih simulacijskih modelih (Tamubula in Sinden, 2000).

V kmetijskem managementu se večkrat poslužujemo metode simulacijskega modeliranja s katero simuliramo pričakovane stroške bodisi nove kmetijske proizvodnje ali stroške uvedbe nove tehnologije. Matematični model sistema (v tem primeru je sistem kmetijska proizvodnja oziroma kmetija) ponazarja tehnične odnose med inputi in outputi. Na osnovi razvitega modela računalnik izračuna tehnološke parametre kmetijske proizvodnje, ki so osnova za tehnološko karto s kalkulacijami skupnih stroškov. Osnovni rezultat takšnega modela je modelna kalkulacija skupnih stroškov (Rozman s sod., 2002).

Pri tovrstnih primerih so tehnološko-ekonomske simulacijske modele uporabljali različni avtorji (Rozman s sod., 2006, Pažek s sod., 2006, Pavlovič, 1997, Herrero s sod., 1999).

METODE

Kmetijski sistem je sistem, ki je odvisen od mnogih dejavnikov. S simulacijskim procesom tako simuliramo oziroma ugotavljamo ekonomičnost pridelave posameznih kmetijskih proizvodov in predelave le teh. V procesu simulacijskega modeliranja s pomočjo niza matematičnih formul in funkcijskih odvisnosti, opisujemo dejansko stanje oziroma dejanski proces, ki se odvija v nekem sistemu. Za potrebe natančnejših študij kmetijskega poslovnega sistema so nujno potrebni zanesljivi in verodostojni vhodni podatki, kar je še posebej pomembno pri razvoju in aplikaciji simulacijskih modelov. Zadosten obseg ustreznih vhodnih podatkov omogoča pripravo in izdelavo modelnih kalkulacij, ki so v nadaljnji fazi osnova za večkriterijsko odločitveno analizo.

Za potrebe našega dela je bil zgrajen kompleksen integriran tehnološko-ekonomski deterministični simulacijski model BIOPLIN, ki sestoji iz treh glavnih modelov:

1. Modelne kalkulacije pridelave posameznih energetskih rastlin.
2. Simulacijski model predelave energetskih rastlin v bioplin.
3. Simulacijski model proizvodnje električne in toplotne energije (SPTE) iz bioplina.

V kmetijski proizvodnji ali nadaljnji predelavi kmetijskih proizvodov je za nosilca odločanja, nujna predhodna informacija o ekonomski in finančni upravičenosti proizvodnje in predelave specifičnega kmetijskega proizvoda. S pomočjo razvitega sistema želimo:

- Oceniti pripadajoče stroške pridelave energetskih rastlin za predelavo v bioplin ob različnih vhodnih podatkih modela. V ta namen smo izdelali pripadajoče stroškovne študije za sisteme pridelave energetskih rastlin. Specificirali smo tehnološko-ekonomski simulacijski model, s katerim smo ocenili lastne cene enote posameznega energetskega proizvoda (EUR/enoto energije) pri različnih vhodnih tehnološko-ekonomskih parametrih.

- Z laboratorijskimi poskusi ovrednotiti pridelek energije (bioplina) iz posameznih energetskih rastlin. V ta namen smo zgradili laboratorijski fermentor za izvedbo anaerobne fermentacije iz posameznih energetskih rastlin.
- Ob predpostavljenih vhodnih podatkih modela, oceniti ekonomsko upravičenost proizvodnje posamezne energetske rastline in zbrati rezultate simulacijskega modela za vsak predviden scenarij.

Razvoj simulacijskega modela

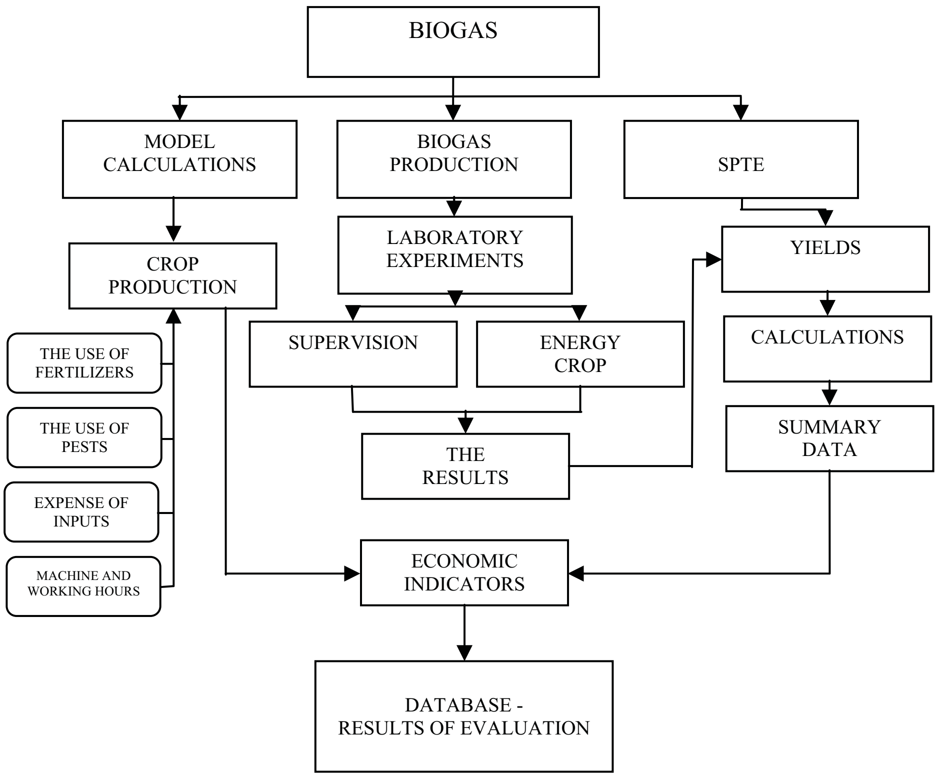


Figure 1: The structure of simulation system BIOGAS

Osnovna struktura (slika 1) simulacijskega modela BIOPLIN se razlikuje le v posameznih segmentih razvitega simulacijskega modela in je naslednja:

1. Modelne kalkulacije pridelave energetskih rastlin zajemajo rastlinsko proizvodnjo energetskih rastlin. Sestavljene so iz več podmodelov: gnojilni načrt, škropilni načrt, poraba inputov (repromaterial), poraba strojnih in delovnih ur, …

2. Predelava energetskih rastlin v bioplin, ki zajema laboratorijske poskusu anaerobne fermentacije s pomočjo zgrajenega laboratorijskega fermenterja (DIN 38414, 1985).
3. SPTE (soproizvodnja električne in toplotne energije) zajema predelavo bioplina s pomočjo kogeneracije v električno in toplotno energijo. V tem sklopu so zajeti pridelki bioplina in biometana ter predvideni pridelki električne in toplotne energije na 1 ha površine po posamezni energetski rastlini. Z uporabo stroškov obratovanja bioplinarne, stroškov substrata itd. so podani ekonomski indikatorji proizvodnje električne in toplotne energije.

Razvoj prototipa računalniške rešitve

Zaradi poenostavitve dela, izračunavanja in čim hitrejšega iskanja alternativnih rešitev je uporaba računalnika pri izdelavi in izračunavanju tehnološko - ekonomskih simulacijskih modelov neizogibna. Uporaba ustreznih programov omogoča hitro in preprosto izdelavo kalkulacij.

Za razvoj modela uporabimo programski paket MS Excel 2003, v kombinaciji s programskim jezikom VBA ("Visual Basic za aplikacije, VBA"). Na osnovi posameznih proizvodnih modelov, računalnik izračuna tehnološke parametre proizvodnje, ki so osnova za tehnološko karto, s kalkulacijami skupnih stroškov. Posamezen model tako zbere podatke in izračuna določene ekonomske parametre (lastna cena pridelave energetskih rastlin, lastna cena pridelave električne in toplotne energije, finančni rezultat, koeficient ekonomičnosti, itd.) ob različnih vhodnih parametrih (različni inputi, cene, različni pridelki, itd.). Slika 2 prikazuje osnovni meni glavnih razvitih modelov simulacijskega modela BIOPLIN.

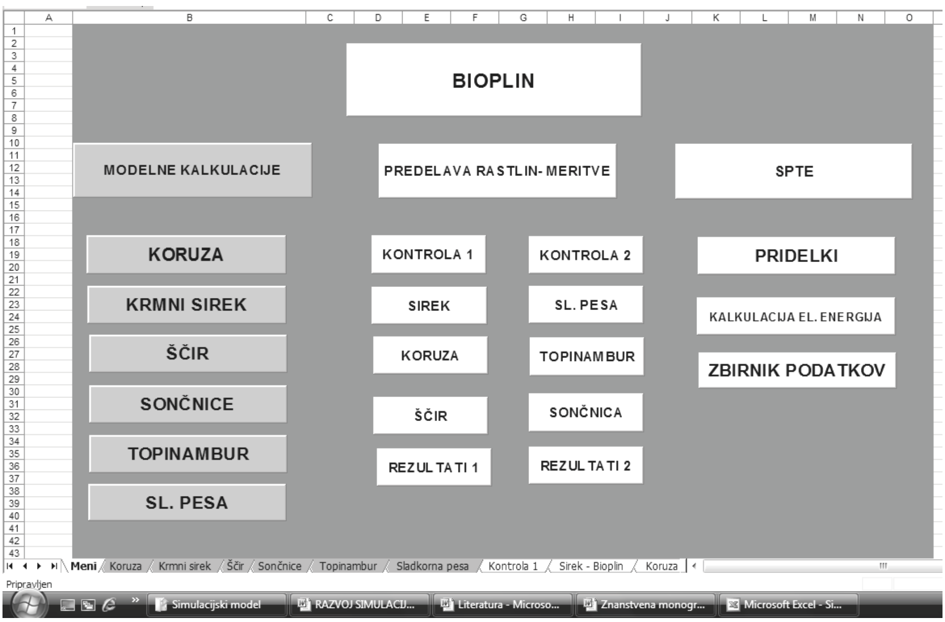


Figure 2: Main menu of the simulation model BIOGAS

Računalniško podprt simulacijski model generira bazo podatkov vseh proizvodenj in meritev v delovnem listu Zbirnik podatkov in zbere najpomembnejše ocenjene parametre za vse energetske rastline iz posameznih podmodelov. Zbrani podatki se nato s pomočjo niza programskih ukazov prenesejo v tabelo, kjer se izračunavajo posamezni ekonomski indikatorji upravičenost investiranja v predelavo energetskih rastlin. Podmodel predelave v bioplin temelji na podatkih pridobljenih iz laboratorijskih poskusov anaerobne fermentacije in je povezan z ostalimi modeli.

REZULTATI Z RAZPRAVO

Z uporabo tehnološko-ekonomskega simulacijskega modela BIOPLIN smo simulirali posamezne poslovne alternative – energetske rastline. S pomočjo razvitega simulacijskega sistema smo ocenili tehnološko - ekonomske parametre pridelave in predelave energetskih rastlin za predelavo v bioplin. Pri tem smo analizirali šest poslovnih alternativ – energetskih rastlin:

- Alternativa 1: Koruza (*Zea mays L.*) sorta PR 34N43 (FAO 580)
- Alternativa 2: Krmni sirek (*Sorghum L.*) sorta Autan
- Alternativa 3: Ščir (*Amaranthus sp. L.*) sorta Acruentus G6
- Alternativa 4: Sončnica (*Helianthus annuus L.*) sorta PR64A43
- Alternativa 5: Topinambur (*Helianthus tuberosus L.*)
- Alternativa 6: Sladkorna pesa (*Beta vulgaris sp. L*) sorta Remos

Pri izračunavanju ekonomskih in tehnoloških parametrov so bile upoštevane predpostavke in zahteve integrirane pridelave poljščin, kar se je odražalo predvsem pri škropilnem in gnojilnem načrtu v rastlinski proizvodnji. Prodajne cene proizvoda (silaža energetskih rastlin, električna in toplotna energija, digestat) so trenutno obstoječe prodajne cene, zbrane na različnih lokacijah (biolinarna, …). Cene inputov (repromaterial, strojno delo, …) pri pridelavi energetskih rastlin so bile zbrane na različnih lokacijah (trgovine, cenik strojnega krožka, …). Ostali vhodni parametri modela so bili določeni deterministično na osnovi ekspertnih mnenj.

V prvem delu simulacijskega modela (modelne kalkulacije) se zberejo posamezni ekonomski in tehnološki parametri pridelave energetskih rastlin ob določenih vhodnih podatkih modela (preglednica 1).

V drugem delu (predelava energetskih rastlin v bioplin) simulacijski model zbere podatke o količini proizvedenega bioplina oziroma biometana iz posameznih rastlin, kjer smo z mini digesterjem merili proizvodnjo bioplina v 35 dnevnem časovnem obdobju iz posameznih energetskih rastlin. Kvaliteto bioplina smo analizirali 11 krat z analizatorjem plinov GA 45. Izmerili smo odstotek CH_4, CO_2 in O_2 v bioplinu, ter podatke zapisovali v elektronsko tabelo. V preglednici 2 so podani rezultati meritev proizvodnje in sestava bioplina iz posameznih energetskih rastlin.

Table 1: Technological and economic parameters of the production of energy crops

Parameter	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Yield (kg/ha)	60 000	50 000	2 000	3 500	25 000	50 000
Side yield (kg/ha)	/	/	/	/	30 000	/
Income (€/ha)	1 800	1 500	1 800	875	6 500	2 000
Costs (€/ha)	1 561	1 461	1 565	1 151	1 983	1 883
Break even price (€/kg)	0,026	0,029	0,782	0,329	0,079	0,038
Financial result (€/ha)	239,0	38,6	235,4	- 275,9	4 517	117,1
Coefficient of economy	1,2	1,0	1,2	0,8	3,3	1,1

Table 2: The results of laboratory experiments

Energy crop	Biogas composition (%)		Biogas (Nl/kg oSS)	Biomethane (Nl/kg oSS)
Maize	CH_4	57,8	576	333
	CO_2	39,3		
	O_2	0,6		
Sorghum	CH_4	56,2	509	286
	CO_2	35,7		
	O_2	0,7		
Amaranth	CH_4	55,5	421	234
	CO_2	32,4		
	O_2	0,7		
Sunflower	CH_4	59,1	495	292
	CO_2	36,0		
	O_2	0,5		
Jerusalem Artichoke	CH_4	59,9	463	278
	CO_2	38,1		
	O_2	0,6		
Sugar beet	CH_4	53,1	649	345
	CO_2	38,5		
	O_2	0,5		

Pridobljeni podatki (količina proizvedenega bioplina) služijo kot vstopni podatki v tretji del simulacijskega modela – soproizvodnja električne in toplotne energije. Iz njih izračunamo hektarske donose bioplina in biometana, ter hektarske donose električne in toplotne energije po posamezni energetski rastlini. Nato se ovrednotijo skupni stroški predelave energetskih rastlin v bioplinarni in iz tega izračunajo ekonomski parametri (lastna cena pridelave električne energije in lastna cena pridelave toplotne energije).

Preglednica 3 prikazuje rezultate simulacijskega modela.

Table 3: The results of the simulation model

	Biogas (Nm^3/ha)	El. energy (kWh/ha)	Heat energy (kWh/ha)	BEP[a] farmer (€/kg)	BEP[a] el. energy (€/kWh)	BEP[a] h. energy (€/kWh)	C/N ratio
Maize	10332,5	20665	37197	0,026	0,18	0,10	1:24
Sorghum	7783,5	15567	28020	0,029	0,23	0,13	1:30
Amaranth	3641,4	7283	13109	0,782	0,51	0,28	1:14
Sunflower	5749,6	11499	20698	0,329	0,28	0,16	1:40
Jerusalem A.	5104,8	10210	18377	0,079	0,40	0,22	1:42
Sugar beet	5823,3	11647	20964	0,038	0,34	0,19	1:33

[a] break even price

SKLEPI

Cilj raziskave je bil razviti simulacijsko orodje, s katerim je omogočena pomoč pri načrtovanju poslovnih alternativ – energetskih rastlin za predelavo v bioplin. V ta namen smo razvili integriran deterministični simulacijski model BIOPLIN, ki v prvi fazi omogoča izdelavo modelnih kalkulacij pridelave energetskih rastlin, v naslednji fazi predelavo energetskih rastlin v bioplin, ki zajema laboratorijske poskusu anaerobne fermentacije s pomočjo zgrajenega laboratorijskega fermenterja. Zadnja faza simulacijskega modela predstavlja SPTE (soproizvodnja električne in toplotne energije), katera zajema predelavo bioplina s pomočjo kogeneracije v električno in toplotno energijo. V tem sklopu so zajeti predvideni pridelki električne in toplotne energije po posamezni energetski rastlini in pripadajoči ekonomski indikatorji proizvodnje električne in toplotne energije. Simulacijski model je zgrajen iz več podmodelov, ki so med seboj integrirano povezani. Rezultat računalniško podprtega simulacijskega modela je kalkulacija skupnih stroškov pridelave in predelave za posamezno energetsko rastlino in v končni proizvod. Model izračunava pomembnejše ekonomske in tehnološke parametre, ob predpostavljenih vhodnih parametrih modela.

Deterministični simulacijski model BIOPLIN z modelnimi kalkulacijami za posamezne energetske rastline, omogoča ob predpostavljenih vhodnih parametrih modela dokaj natančno izračunavanje tako posameznih ekonomskih, kakor tudi tehnoloških parametrov, za sleherno poslovno alternativo. Rezultati simulacije so dovolj kakovostna informacijska osnova za nadaljnji razvoj odločitvenih modelov. Parametri, pridobljeni s pomočjo simulacijskega modela, nadalje predstavljajo vhodne podatke za večkriterijsko odločitveno analizo.

LITERATURA

1. DIN 38 414, part 8. (1985). Determination of digestion behavior ‘‘sludge and sediments’’. Beuth Verlag, Berlin (in German).
2. Herrero M., Fawcett R.H., Dent J.B. (1999). Bioeconomic Evaluation of Dairy Farm Management Scenarios using Integrated Simulation and Multiple-criteria Models. Agricultural Systems 69: 169-188.
3. Kljajić M. (1994). Teorija sistemov. Moderna organizacija. Kranj: 238 str.
4. Pavlovič M. (1997). Systemanalyse internationaler Hopfenwirtschaft – Entwicklung des Simulationsmodells fur die technologisch – okonomische Analyse auf Hopfenanbaugebiten in Slowenien. Hamburg, Verlag Dr. Kovač: 184 str.
5. Pažek K., Rozman Č., Borec A., Turk J., Majkovič D., Bavec M., Bavec F. (2006). The multi criteria models for decision support on organic farms. Biological Agriculture and Horticulture 24/1.
6. Rozman Č., Jakob M., Turk J., Bavec F. (2002). Kmetijsko podjetniška analiza pridelave oljnih buč. Sodobno kmetijstvo 35/2: 91-96.
7. Rozman, Č., Pažek, K., Bavec, M., Bavec, F., Turk, J., Majkovič, D. 2006. The Multi-criteria Analysis of Spelt Food Processing Alternatives on Small Organic Farms. Journal of Sustainable Agriculture 28/2: 159-179.
8. Tamubula I., Sinden J.A. (2000). Sustainability and Economic Efficiency of Agroforestry Systems in Embu Distict, Kenya: An Application of Environmental Modelling. Environmental Modelling and Software 15/1: 13-21.

SIMULATION MODEL OF ENERGY CROPS GROWING AND THEIR UTILISATION AS SUBSTRATE FOR BIOGAS

SUMMARY

In agricultural production and further processing of agricultural products is for decision maker's prior information about the economic and financial viability of production and processing of a specific agricultural product. For this purpose the simulation model was developed to simulate the economy of production of selected crops and their utilization as substrate for biogas production. For the purposes the complex integrated technological-economic simulation model BIOGAS was developed. The simulation model consists of three main parts: model calculations of energy crops production, simulation model of utilisation of energy crops for biogas production and simulation model of electricity and heat production from biogas. As the base for the model was used software package MS Excel 2003, combined with the program language VBA ("Visual Basic for Applications, VBA"). A developed methodological tool is useful for the planning and production of energy crops and for the planning of electricity and heat production in biogas CHP units.

Key words: *simulation model, biogas, energy crops*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 633.15:662.767.2
Stručni rad
Expert paper

LABORATORIJSKO TESTIRANJE KORUZNIH HIBRIDOV ZA BIOPLIN

BOGOMIR MURŠEC, PETER VINDIŠ, MIRAN LAKOTA, DENIS STAJNKO

Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede, Pivola 10, 2311 Hoče, Slovenija

POVZETEK

Namen prispevka je bil ugotoviti, kateri zrelostni razred koruze in kateri hibrid določenega zrelostnega razreda, daje največjo proizvodnjo biometana in bioplina. Poskusi so potekali v našem laboratoriju, po tri serije poskusov s tremi ponovitvami, po metodi DIN 38 414, del 8. Proučevali smo tudi kemijsko sestavo plinov. Testirali smo koruzne hibride zrelostnega razreda FAO 300 – FAO 400, FAO 400 – FAO 500 in FAO 500 – FAO 600. Rezultati raziskave so pokazali, da se pri višjem zrelostnem razredu koruze (FAO 400, FAO 500) povečuje hektarski donos biometana in bioplina. Najvišji izplen biometana in bioplina med zrelostnimi razredi koruze so imeli hibridi zrelostnega razreda FAO 400 in FAO 500. Med hibridi koruze zrelostnega razreda FAO 300 – FAO 400, daje hibrid PR38F70 (FAO 330) največji donos biometana in bioplina. Med hibridi zrelostnega razreda FAO 400 – FAO 500, je dajal največjo proizvodnjo biometana in bioplina hibrid PIXXIA (FAO 420). Hibrid CODISTAR (FAO 500) pa je imel med hibridi zrelostnega razreda FAO 500 – FAO 600 največji donos biometana in bioplina. Proizvodnja biometana, ki ima bistveno vlogo pri proizvodnji bioplina, je pri hibridih koruze variirala od 50 – 60 % celotne količine nastalih plinov.

Ključne besede: *biometan, bioplin, energetske rastline, hibrid*

UVOD

Na splošno je mogoče bioplin uporabljati v enake namene kot zemeljski plin. Sestava bioplina se sicer močno spreminja v odvisnosti od uporabljenih surovin in načina nastanka, obenem je potrebno bioplin ustrezno obdelati, da je primeren za rabo v različnih plinskih porabnikih. Najpogostejši načini izrabe bioplina so proizvodnja toplote in pare, proizvodnja električne energije/soproizvodnja toplotne in električne energije, gorivo za motorna vozila, proizvodnja kemikalij, pridobivanje vodika iz bioplina ter nadaljnja poraba.

Po vstopu Slovenije v EU se je zanimanje za energetsko rabo bioplina hitro povečalo. Na eni strani ni več carinskih ovir glede nakupa ustrezne tehnologije in sanitarno-higienski predpisi ne dovoljujejo več dosedanjega ravnanja z vrsto organskih odpadkov, na drugi strani pa zakonsko zagotovljen odkup in ugodne odkupne tarife za električno energijo na osnovi bioplina. V Sloveniji zagotavljajo stabilen ekonomski okvir za investicije v to obetavno možnost pridobivanja energije preko predelave biološko razgradljivih in energetsko bogatih odpadkov. Država spodbuja energetsko izrabo bioplina z zagotovljenim odkupom in odkupno ceno električne energije. Pojem kvalificirane proizvodnje električne energije je uvedel energetski zakon z namenom povečanja obsega električne energije, ki se proizvaja na okolju prijazen način. Sem sodi proizvodnja električne energije iz obnovljivih virov energije ali odpadkov in soproizvodnja električne energije in toplote z nadpovprečno visokim izkoristkom (Weiland, 2003).

METODE

Poskus se je izvajal na posestvu Univerzitetnega kmetijskega centra Fakultete za kmetijstvo in biosistemske vede s sedežem v Pivoli, Hoče pri Mariboru. Predposevek poskusa je bila travno deteljna mešanica. Za poskus smo posejali 15 različnih hibridov koruze. Vsak hibrid koruze je bil posejan v štirih vrstah oziroma 3 m širine in 65 m dolžine, v izsušena tla, 23. 04. 2007, s sejalnico za presledno setev proizvajalca IMP Panonija na medvrstno razdaljo 70 cm in razdaljo v vrsti 15,3 cm. Za vsak hibrid koruze smo imeli 3 ponovitve parcelic. Vsak hibrid smo ročno poželi na treh naključno izbranih parcelicah velikosti 10 m^2 in stehtali pridelek celih rastlin. Nato smo stehtane rastline zmleli z enorednim traktorskim silažnim kombajnom Vihar 40 proizvajalca SIP. Silažno maso s posamezne parcelice smo potlačili v plastično posodo z volumnom 15 litrov, ki smo je nepredušno zaprli s pokrovom in ustrezno označili ter opravili meritev sproščanja in nastanek bioplina iz posameznega hibrida koruze. Preglednica 1 prikazuje načrt zasnove poskusa. Zastopanih je bilo 15 hibridov koruze, s tremi ponovitvami parcelic (Ošlaj, 2009).

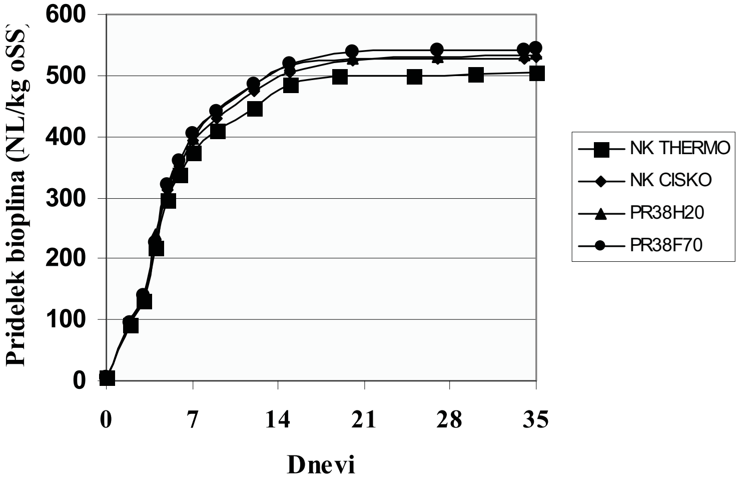
Preglednica 1: Načrt zasnove poskusa – porazdelitev poskusnih parcelic

V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
V14	V7	V11	V1	V13	V8	V10	V12	V15	V9	V3	V5	V2	V4	V6
V3	V12	V7	V15	V4	V1	V2	V10	V13	V5	V14	V6	V9	V8	V11

REZULTATI Z RAZPRAVO

Proizvodnja bioplina iz hibridov zrelostnega razreda FAO 300 – FAO 400

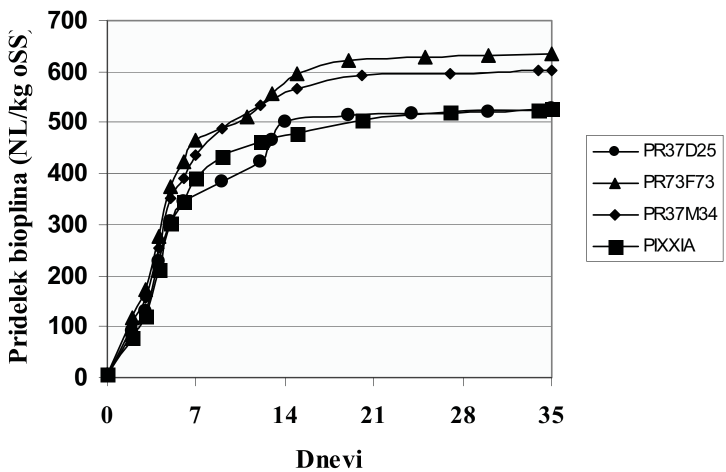
Grafikon 1 prikazuje testiranje hibridov koruze zrelostnega razreda FAO 300 – FAO 400, v katerem so bili vključeni hibridi PR38F70 (FAO 330), PR38H20 (FAO 340), NK THERMO (FAO 370) in NK CISKO (FAO 390).



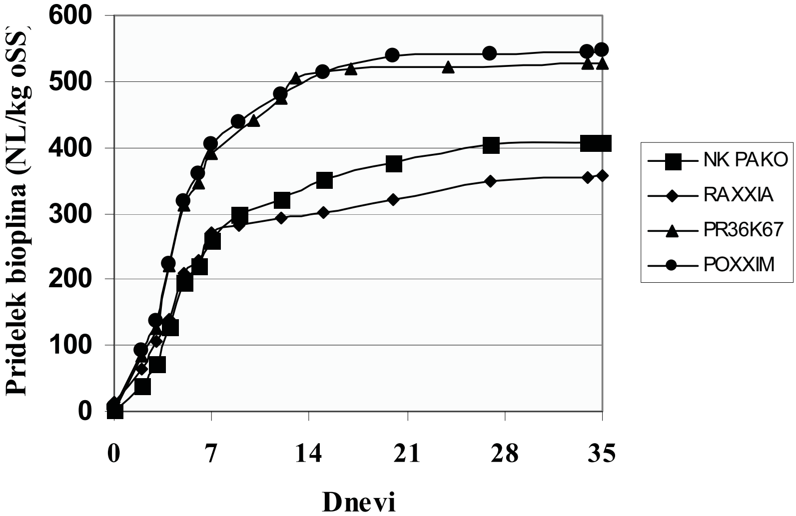
Grafikon 1: Proizvodnja bioplina (Nl/kg oSS) hibridov PR38F70 (FAO 330), PR38H20 (FAO 340), NK THERMO (FAO 370) in NK CISKO (FAO 390)

Proizvodnja bioplina iz hibridov zrelostnega razreda FAO 400 – FAO 500

Za testiranje hibridov za proizvodnjo bioplina, biometana zrelostnega razreda FAO 400 – FAO 500 (grafikon 2, 3) smo vključili hibride PR37D25 (FAO 400), PR37F73 (FAO 410), PR37M34 (FAO 410), PIXXIA (FAO 420), NK PAKO (FAO 440), RAXXIA (FAO 450), PR36K67 (FAO 450) in POXXIM (FAO 490).



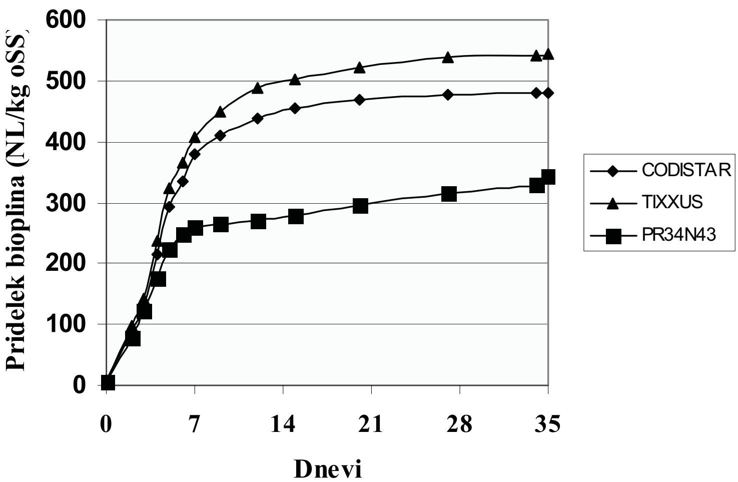
Grafikon 2: Proizvodnja bioplina (Nl/kg oSS) hibridov PR37D25 (FAO 400), PR37F73 (FAO 410), PR37M34 (FAO 410) in PIXXIA (FAO 420)



Grafikon 3: Proizvodnja bioplina (Nl/kg oSS) hibridov NK PAKO (FAO 440), RAXXIA (FAO 450), PR36K67 (FAO 450) in POXXIM (FAO 490)

Proizvodnja bioplina iz hibridov zrelostnega razreda FAO 500 – FAO 600

Grafikon 4 prikazuje rezultate testiranja hibridov koruze za proizvodnjo bioplina zrelostnega razreda FAO 500 – FAO 600, pri čemer smo za testiranje uporabili hibride CODISTAR (FAO 500), TIXXUS (FAO 500) in PR34N43 (FAO 580).



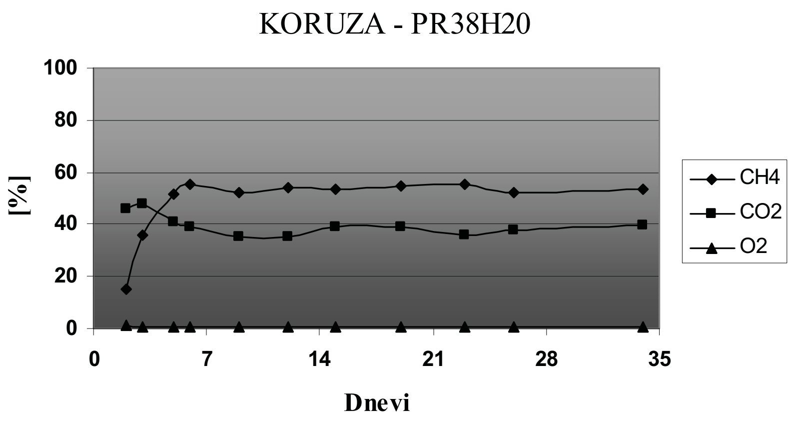
Grafikon 4: Proizvodnja bioplina (Nl/kg oSS) hibridov CODISTAR (FAO 500), TIXXUS (FAO 500) in PR34N43 (FAO 580)

Kemijska sestava plinov enega izmed hibridov zrelostnega razreda FAO 300 (PR38H20), FAO 400 (PR37D25) in FAO 500 (CODISTAR)

Analiziranje sestave plinov smo izvedli z merilnikom za pline (Geotechnical Instruments GA 45), kjer smo primerjali podatke proizvedenega plina med hibridi koruze.

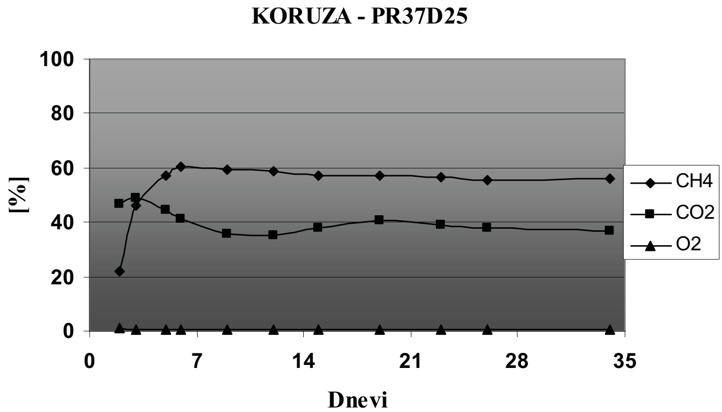
Slika 1: Merilnik za pline

Iz grafikona 5 je razvidno, da se je vrednost plina metana (CH_4) za hibrid koruze PR38H20 prvih sedem dni stopnjevala, potem pa je bila vrednost do 35 dneva več ali manj konstantna. Vrednost plina CO_2 je bila na začetku poskusa povečana, potem pa se je vrednost iz dneva v dan spreminjala oziroma zmanjševala vse do konca 35 dni. Vrednost plina kisika O_2 je bila skozi celo obdobje laboratorijskega poskusa bila manjša od 1 %, kar kaže na anaerobne pogoje v digestorju in s tem na potek anaerobnega vrenja. Kisik je indikator anaerobne fermentacije (Gunaseelan, 1997).



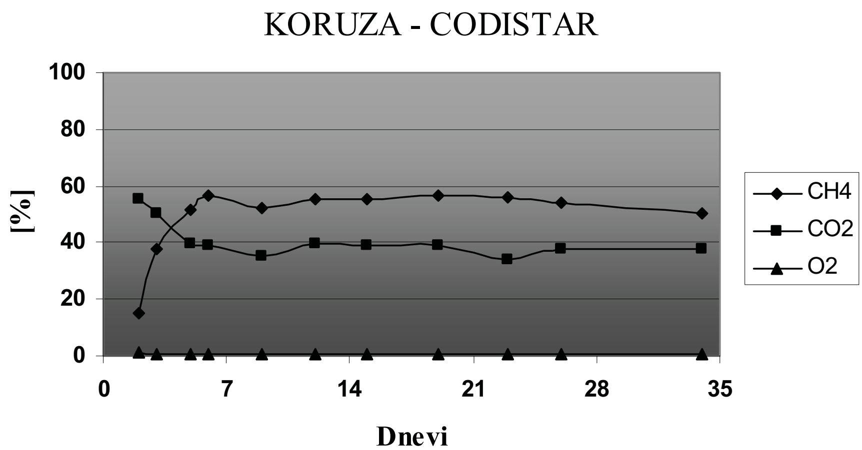
Grafikon 5: Kemijska sestava plinov hibrida PR38H20 (FAO 300)

Iz grafikona 6 je razvidno, da se je vrednost plina metana (CH_4) za hibrid PR37D25, prvih sedem dni prav tako stopnjevala, potem pa je bila vrednost do 35 dneva več ali manj konstantna. Vrednost plina CO_2 je bila na začetku laboratorijskega poskusa povečana, potem pa se je vrednost iz dneva v dan spreminjala z minimalnimi odstopanji in ostala na konstantni vrednosti. Vrednost plina kisika O_2 pa je bila celo obdobje laboratorijskega poskusa (35 dni) manjša od 1 %.



Grafikon 6: Kemijska sestava plinov hibrida PR37D25 (FAO 400)

Iz grafikona 7 je razvidno, da se je vrednost plina metana (CH_4) za hibrid CODISTAR prvih sedem dni stopnjevala, potem pa je bila vrednost vse do 28 dneva več ali manj konstantna, po 28 dnevu pa je vrednost plina začela upadati. Vrednost plina CO_2 za hibrid CODISTAR je bila na začetku laboratorijskega poskusa povečana, potem pa je vrednost začela upadati z minimalnimi odstopanji. Vrednost plina kisika O_2 za hibrid CODISTAR pa je bila celo obdobje laboratorijskega poskusa (35 dni) manjša od 1 %.



Grafikon 7: Kemijska sestava plinov hibrida CODISTAR (FAO 500)

SKLEPI

V letu 2007 je bil izveden poskus na lokaciji UKC Pohorski dvor. Ugotavljali smo, kateri zrelostni razred koruze, in kateri hibrid določenega zrelostnega razreda, daje največjo proizvodnjo bioplina, biometana. Preučevali smo tudi kemijsko sestavo plinov (DIN 38 414, 1985).

Na podlagi rezultatov lahko sklepamo naslednje:

1. Pri višjem zrelostnem razredu koruze (FAO 400, FAO 500) se povečuje hektarski donos bioplina, biometana. Najvišji izplen bioplina so imeli hibridi zrelostnega razreda FAO 400, in sicer 568 Nl/kg oSS, s kemijsko sestavo 55,2 % CH_4, 39,3 % CO_2 in 0,6 % O_2. Hibridi zrelostnega FAO 500 so imeli 530 Nl/kg oSS, s kemijsko sestavo 55,5 % CH_4, 38,1 % CO_2 in 0,5 % O_2. Proizvodnja biometana hibridov zrelostnega razreda FAO 400 je bila 315 Nl/kg oSS. Hibridi zrelostnega razreda FAO 500 pa so imeli 294 Nl/kg oSS proizvedenega biometana.
2. Med hibridi koruze zrelostnega razreda FAO 300 – FAO 400, daje hibrid PR38F70 (FAO 330) 544 Nl/kg oSS proizvedenega bioplina s kemijsko sestavo 58,2 % CH_4, 39,3 % CO_2 in 0,7 % O_2. Proizvodnja biometana hibrida PR38F70 pa je 312 Nl/kg oSS.
3. Med hibridi zrelostnega razreda FAO 400 – FAO 500, daje hibrid PIXXIA (FAO 420) 600 Nl/kg oSS proizvedenega bioplina s kemijsko sestavo 57,4 % CH_4, 34,8 % CO_2 in 0,4 % O_2. Proizvodnja biometana hibrida PIXXIA pa je 345 Nl/kg oSS.
4. Med hibridi zrelostnega razreda FAO 500 – FAO 600, pa daje hibrid CODISTAR (FAO 500) 559 Nl/kg oSS proizvedenega bioplina s kemijsko sestavo 55,1 % CH_4, 39,8 % CO_2 in 0,8 % O_2. Proizvodnja biometana hibrida CODISTAR pa je bila 330 Nl/kg oSS.
5. Proizvodnja metana, ki ima bistveno vlogo pri proizvodnji bioplina, je pri hibridih koruze variirala od 50 – 60 % celotne količine nastalih plinov.
6. Po rezultatih našega laboratorijskega poskusa priporočamo za proizvodnjo bioplina, hibrida PIXXIA (FAO 420) in CODISTAR (FAO 500), vendar bi še bilo potrebno opravit poljski poskus na kateri drugi lokaciji, na drugem tipu tal itd.

LITERATURA

1. DIN 38 414, part 8 (1985). Determination of digestion behavior ''sludge and sediments''. Beuth Verlag, Berlin (in German)
2. Gunaseelan V. N. (1997). Anaerobic digestion of biomass for methane production: a review. Biomass Bioenergy 13 (1–2): 83–114
3. Ošlaj M. (2009). Proizvodnja bioplina iz različnih hibridov koruze. Diplomsko delo. Univerza v Mariboru, Fakulteta za kmetijstvo in biosistemske vede. Maribor, 39 str.
4. Weiland P. (2003). Production and energetic use of biogas from energy crops and wastes in Germany. Appl. Biochem. Biotechnol. 109: 263–274

LABORATORY TESTING OF MAIZE HYBRIDS FOR BIOGAS

SUMMARY

The purpose of the paper is to establish which ripeness class and which hybrid of certain ripeness class produces most biomethane and biogas. The tests were carried out in our laboratory, namely three series of tests with three repetitions on each crop according to DIN 38 414, Part 8. Also the chemical composition of gases was studied. The maize hybrids of ripeness class FAO 300 – FAO 400, FAO 400 – FAO 500, and FAO 500 – FAO 600 were tested. The research results showed that the higher maize ripeness class (FAO 400, FAO 500) results in higher yield of biomethane and biogas per hectare. The hybrids of the ripeness class FAO 400 and FAO 500 had the greatest yield of biomethane and biogas out of the ripeness classes of the maize. Out of the maize hybrids of the ripeness class FAO 300 – FAO 400 the hybrid PR38F70 (FAO 330) yields most biomethane and biogas. Out of the hybrids of ripeness class FAO 400 – FAO 500 the hybrid PIXXIA (FAO 420) produced the greatest amount of biomethan and biogas. Further, out of the hybrids of the ripeness class FAO 500 – FAO 600 the hybrid CODISTAR (FAO 500) gave the highest yield of biomethane and biogas. Production of biomethane, having crucial role in the biogas production from maize hybrids, varied between 50 – 60 % of the total amount of gases produced.

Key words: *biomethane, biogas, energy crops, hybrid*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95.661.9
Izvorni znanstveni rad
Original scientific paper

BIOGAS PRODUCTION FROM GRAPE MARCS

RAJKO BERNIK, ALEŠ ZVER

University of Ljubljana, Biotehnical faculty, Jamnikarjeva 101,
SI-1000 Ljubljana Slovenia,

SUMMARY

Our polluted environment incessantly reminds us to limit the use of fossil fuels and to focus on renewable sources of energy which are not such a burden on the environment. Biogas is one of the possible solutions. It can be produced from organic material or organic waste material. Our work deals with producing biogas from grape marc.

The samples of grape marc were analysed for C:N ratio and the Weende analysis was carried out. With the results of the analyses we were able to calculate the quantity of the produced biogas/kg of dry matter. We can produce 331.3 m^3/ ha of biogas from grape marc. In Slovenia we have more than 16, 000 ha of vineyards in comparison to only 5300 ha of rape fields. We found that grape marc is suitable for the use in combined fermentation. C:N ratio of grape marc is unsuitable for the bacteria in the fermenter. The organic material of our experiment should be mixed with some other organic material to get the proper C:N ratio, from 25:1 to 30:1.

***Key words**: Energy production, biogas, grape marcs*

INTRODUCTION

Technology is developing and our demands for energy are increasing. Fossil fuels, which are currently the main source of energy, will soon run dry. It is high time that we start using renewable sources of energy. These include solar energy, wind energy, hydro energy, geometrical energy, and energy produced from biomass.

Biomass is the common term for organic waste material, especially of plant origin, which can be used for production of electrical and thermal energy. These include wood, as the prevalent source for energy production, fast-growing cultivated plants (sugar cane, rape), and organic waste (stock breeding waste, municipal waste, sewage water). Biomass can be used for burning, whereby thermal energy is produced. On the other hand we can use different technological processes to produce biogas or biodiesel.

By exploiting environmental friendly energy we can reduce pollution, enhance regional development and increase employment (Šolinc, 2005). The development of renewable sources of energy will raise the security of energy supply in the EU. Concurrently, the use and development of technologies for reducing greenhouse gasses will help shape the world leading role in the most dynamic industry (Šumenjak Sobol, 2007a).

REVIEW OF PUBLICATIONS

Vintage vines

Vine has been grown for 3000 years. Because of the attack of the vine louse at the end of the 19th century the European vine (*Vitis vinifera L.*) is now inoculated on American groundings, which are more resistant to the vine louse. In nature, vines climb on other plants and can grow up to 30 metres high. In the vineyards they are kept in the desired shape with the appropriate incision. With the incision the growth and the fertility is regulated and herby also the quality of grapes (Vršič in Lešnik, 2005).

The underground organs of the vine are the stem and roots. The super terrestrial parts of the vine are the stem, shanks, cordons and vine shoots. On the vine shots (one-year sprouts) are the leaves, lateral shoots, tendrils, buds and inflorescences from which later grapes spring up.

The fruit of the vine is grapes. It consists of the stalk and vine berries. There are considerable differences between the vine varieties in terms of the size and shape of the grapes and in terms of the size and shape of the vine berry. The vine berry, which is attaches to the stalk, consists of a thin skin, fruit pulp with juice and pips. The mass of the grapes depends on the variety and the growth conditions during the time when inflorescences are developing and the time when the grapes are developing. It varies from 60 to 2000g. The stalk represents 3 to 8% of the total grape mass; the vine berries represent 92 to 97%. The vine berry consists of approximately 10 % of thin skin, 86 to 92% of fruit pulp and 3 to 4% of pips.

After the fertilization is completed the vine berries start growing fast. The period of ripening starts when the growth is completed. The amount of sugar increases rapidly in the vine berries. The cells of the vine berries do not divide during the ripening; they are becoming bigger because the volume of the cells is rising. The grapes are technologically ripe when the acidity and sugar ratio is appropriate (Vršič in Lešnik, 2005).

Grape marc could be used as a growth medium for ornamental plants. The compost from grape marc can be used instead of peat. It could be mixed with peat and perlite. The concentration of the compost from grape marc depends on the plants` demands and can represent maximum 50% of the substrate mixture. The compost from grape marc is cheap and contains a considerable amount of potassium (Baran in sod., 2001). The amount of phosphorus and nitrogen is low and mainly found in a form which is not accessible by the plants (Patti in sod., 2004).

Biosurfactants can be extracted from grape marc. A surfactant is a surface-active substance, which used in small quantities changes the characteristics of the surface of liquids and solid matter. The surfactant reduces the surface tension between two incompatible liquids, e.g. water and oil. They function as detergents, emulsifiers or aerosols. There are microbial surfactants (Surfactine) and synthetic surfactants (SDS) (Portilla Rivera in sod., 2007).

Table 1: Weende analysis of the grape pips (Vidmar, 1978)

	Vidmar A. L.	Stahlin
Dry matter %	79-96	
Moisture %	5-20	8,6
Crude protein %	6-11	11,1-13,2
Crude fibre %	37-50	20,8-35,3
Crude fat %	9-17 (Malvazija 4)	13,6-18,5
Crude ash %	2-3	1,3-2,9
Nitrogen-free extract %	19-29	35,3-47

METHODS

According to the chemical analyses, which we carried out on the grape marc, we used formulas to determine the theoretical biogas potential of a plant.

Dry matter share calculation

$$\%DM = \frac{mass\_DM(g)}{mass\_fresh\_matter(g)} \times 100 \ [\%] \tag{1}$$

Calculation of the quantity of dry matter acquired on 1 hectare of land

$$mass\_DM / ha = \frac{\%DM \times harvest / ha}{100\%} \ [\text{g}] \tag{2}$$

Volume calculation of biogas, acquired from 1 kilogram of dry matter

$$V_{biogas} / kg\_DM = mass\_SS \times transform\_faktor \ [\text{m}^3] \tag{3}$$

Grape marss and pips

According to the method of growing, we determine the number of vines per hectare. On average there are 3000 vines planted on one hectare of land. The recommended grapevine bud charge is 3 kilograms per vine for the quality grade of wine. The harvest on each vine is regulated by winter incision. The quality of grapes declines if we leave more grapes on the vine as recommended for a certain variety. Beside the human factor also the weather conditions influence the harvest. Summer storms and draughts are especially dangerous and can halve the harvest or even destroy it.

An experiment was made in 2006. The average grape mass of the variety Ribolla vas 131g (Table 10) and of the variety Malvasia 123g (Table 11). The grape mass of the vine variety Ribolla was, according to available sources (Zirojević, 1974), bellow average, from

140 to 160g. The grape mass of the vine variety Malvasia was within limits stated in the source (Hrček in Korošec Koruza, 1996), from 120 to 200g. The difference between the grape masses, of the above mentioned vintage vine varieties, is the consequence of the different size of the grapes, which is a vine variety characteristic.

Table 2: Stalk, grape marc and pip share with vine variety Ribolla

Sample	Grape Mass (g) n	Stalk Mass (g) n	Pip Mass (g) n	Skin Mass (g) n
R1	1170	68,4	39,9	282,3
R2	1205	59,5	42,8	292,9
R3	1565	78,3	59,4	317,6
Average	1313	68,7	47,4	297,6
Percentage	100	5,2	3,6	22,7

n = 10 grapes

The share of the stalk was determined in the same way as the mass of the grapes. The sample contained 10 grapes (Table 10). The share of the stalk with vine variety Ribolla is on average 5.2%, the share of pip is 3.6%, and the share of thin skins is 22.7%. The rest of the grape mass is fruit pulp and juice.

Table 3: Stalk, grape marc and pip share with vine variety Malvasia

Sample	Grape Mass (g) n	Stalk Mass (g) n	Pip Mass (g) n	Skin Mass (g) n
M1	1180	56,8	40,2	184,9
M2	1325	83,3	54,4	215,0
M3	1180	60,4	41,2	198,2
Average	1228	66,8	45,3	199,4
Percentage	100	5,4	3,7	16,2

n = 10 grapes

The results of stalk, grape marc and pip share of vine variety Malvasia were similar. The grape contains 5.4% of stalk, 3.7% of pip, and 16.2% of thin skins. The percentage of stalk and pip of both vine varieties is almost equal. Notable difference has been noticed with thin skins. This is probably due to the thickness of the skins. The skin of the grapes of the vine variety Malvasia is thinner than with Ribolla. The mechanical structure of the grapes differs with vine varieties. The location of the vineyard also influences the mechanical structure of the grapes (Zirojević, 1974).

Organic matter is used for biogas production. It contains a significant quantity of fats, proteins, and carbohydrates. The results of the Weende analysis gave us the information about the contents of dry matter, moisture, crude protein, crude fibre, crude fat, crude ash, and nitrogen-free extract. For simplification reasons we calculated the average value for both vine varieties. The average value of dry matter in grape marc is 458.3g/kg of fresh mass. The average value of moisture is 541.7g/kg, crude protein 39.4g/kg, crude fibre 130.2g/kg, crude fat 78.9g/kg, crude ash 20g/kg, nitrogen-free extract 189g/kg.

Table 4: Weende analysis of pips and grape marc (Weendeska analiza grozdnih ..., 2006)

	Pips		Marc	
	g	g/kg DM	g	g/kg DM
Dry matter (g/kg)	940,45	1000	458,3	1000
Moisture (g/kg)	59,55		541,7	
Crude Protein (g/kg)	104,75	111,4	39,4	86
Crude fibre (g/kg)	356,25	378,9	130,2	284,2
Crude fats (g/kg	135,15	143,65	78,9	172,1
Crude ash (g/kg)	30,15	32,05	20,00	43,60
Nitrogen-free extract (g/kg)	314,2	334,05	189,70	414,00

The ratio of C:N in the analysis of grape marc is 37.9:1, and of pips 32.6:1. The ideal C:N ratio is from 25:1 to 30:1 (Stadler, 1999). The C:N ratio of pips is closer to the ideal proportion.

Table 5: Results of the C:N:S analysis of grape marc and pips

	C (%)	N (%)	S (%)	C:N
Marc	48,55	1,28	0,117	37,9
Pips	53,2	1,635	0,152	32,5

The conversion factor 0.4m³/kg DM was used for the calculation of the quantity of biogas produced from grape marc. The conversion factor was determined on the basis of the C:N ratio comparison. The C:N ratios of grape marc and pips were compared to the C:N ratio of those plants, for which the conversion factor into biogas is already determined. The C:N ratio of grape marc and pips was closest to the C:N ratio of hemp, (25.63-40.13): 1 (Herlah, 2008).

On one hectare of vineyard we acquire on average 828.3kg dry matter from grape marc and 322.3kg of dry matter from pips.

Table 6: Calculations of dry matter for vine varieties Ribolla and Malvasia

	DM g/kg Marc	DM g/kg Pips	DM kg/ha Marc	DM kg/ha Pips
Ribulla	0,458	0,943	934,0	306,4
Malvasija	0,458	0,943	722,5	338,2
Average	0,458	0,943	828,3	322,3

With the help of the formula (3,4) we calculated the theoretical quantity of produced biogas. If we used grape marc for biogas production, we would produce 331.3m³of biogas per hectare of vineyard. On the other hand, if we used grape pips for the production of biogas, we would produce only 128.9m³ of biogas per hectare of vineyard.

Table 7: Calculations of the theoretical quantity of biogas produced from grape marc and pips

	DM kg/ha	C %	N %	C:N	Biogas m^3/kg DM	Biogas m^3/ha
Marc	828,3	48,55	1,28	37,9	0,4	331,3
Pips	322,3	53,2	1,635	32,5	0,4	128,9

RESULTS AND DISCUSSION

Grape marc and pips

We determine the number of vines per hectare according to the method of growing. On average there are 3000 vines planted on one hectare of land. The recommended grapevine bud charge is 3 kilograms per vine for the quality grade of wine. The harvest on each vine is regulated by winter incision. The quality of grapes declines if we leave more grapes on the vine as recommended for a certain variety. Beside the human factor the weather conditions influence the harvest. Summer storms and draughts are especially dangerous and can halve the harvest or even destroy it.

An experiment was made in 2006. The average grape mass of vine variety Ribolla vas 131g (Table 10) and of variety Malvasia 123g (Table 11). The grape mass of the vine variety Ribolla was, according to available sources (Zirojević, 1974), bellow average, from 140 to 160g. The grape mass of the vine variety Malvasia was within limits stated in the source (Hrček in Korošec Koruza, 1996), from 120 to 200g. The difference between the grape masses, of the above mentioned vintage vine varieties, is the consequence of the different size of the grapes, which is a vine variety characteristic.

Table 8: Stalk, grape marc and pip share with vine variety Ribolla

Sample	Grape Mass n (g)	Stalk Mass n (g)	Pip Mass n (g)	Skin Mass n (g)
R1	1170	68,4	39,9	282,3
R2	1205	59,5	42,8	292,9
R3	1565	78,3	59,4	317,6
Average	1313	68,7	47,4	297,6
Percentage	100	5,2	3,6	22,7

n = grapes

Table 9: Stalk, grape marc and pip share with vine variety Malvasia

Sample	Grape Mass n (g)	Stalk Mass n (g)	Pip Mass n (g)	Skin Mass n (g)
M1	1180	56,8	40,2	184,9
M2	1325	83,3	54,4	215,0
M3	1180	60,4	41,2	198,2
Average	1228	66,8	45,3	199,4
Percentage	100	5,4	3,7	16,2

n = 10 grapes

The share of the stalk was determined in the same way as the mass of the grapes. The sample contained 10 grapes (Table 10). The share of the stalk with vine variety Ribolla is on average 5.2%, the share of pip is 3.6%, and the share of thin skins is 22.7%. The rest of the grape mass is fruit pulp and juice.

The results of stalk, grape marc and pip share of the vine variety Malvasia were similar. The grape contains 5.4% of stalk, 3.7% of pip, and 16.2% of thin skins. The percentage of stalk and pip of both vine varieties is almost equal. A significant difference has been noticed with thin skins. This is probably due to the thickness of the skin. The skin of the grapes of vine variety Malvasia is thinner than of Ribolla. The mechanical structure of the grapes differs with vine varieties. The location of the vineyard also influences the mechanical structure of the grapes (Zirojević, 1974).

Organic matter is used for biogas production. This contains a big quantity of fats, proteins, and carbohydrates. The results of the Weende analysis gave us the information about the contents of dry matter, moisture, crude protein, crude fibre, crude fat, crude ash, and nitrogen-free extract.We calculated the average value for both vine varieties for simplification reasons. The average value of dry matter in grape marc is 458.3g/kg of fresh mass. The average value of moisture is 541.7g/kg, crude protein 39.4g/kg, crude fibre 130.2g/kg, crude fat 78.9g/kg, crude ash 20g/kg, nitrogen-free extract 189g/kg.

Table 10: Weende analysis of pips and grape marc (Weendeska analiza grozdnih ..., 2006)

	Pips		Marc	
	g	g/kg DM	g	g/kg DM
Dry matter (g/kg)	940,45	1000	458,3	1000
Moisture (g/kg)	59,55		541,7	
Crude Protein (g/kg)	104,75	111,4	39,4	86
Crude fibre (g/kg)	356,25	378,9	130,2	284,2
Crude fats (g/kg	135,15	143,65	78,9	172,1
Crude ash (g/kg)	30,15	32,05	20,00	43,60
Nitrogen-free extract (g/kg)	314,2	334,05	189,70	414,00

The ratio of C:N in the analysis of grape marc is 37.9:1, and of pips 32.6:1. The ideal C:N ratio is from 25:1 to 30:1 (Stadler, 1999). The C:N ratio of pips is closer to the ideal proportion.

Table 11: Results of the C:N:S analysis of grape marc and pips

	C (%)	N (%)	S (%)	C:N
Marc	48,55	1,28	0,117	37,9
Pips	53,2	1,635	0,152	32,5

Conversion factor 0.4m³/kg DM was used for the calculation of the quantity of biogas produced from grape marc. The conversion factor was determined on the basis of the C:N ratio comparison. The C:N ratios of grape marc and pips were compared to the C:N ratio of those plants, for which the conversion factor into biogas is already determined. The C:N ratio of grape marc and pips was closest to the C:N ratio of hemp, (25.63-40.13): 1 (Zver, 2005).

On one hectare of vineyard we acquire on average 828.3kg dry matter from grape marc and 322.3kg of dry matter from pips.

Table 12: Calculations of dry matter for vine varieties Ribolla and Malvasia

	DM g/kg Marc	*DM g/kg Pips*	*DM kg/ha Marc*	*DM kg/ha Pips*
Ribulla	*0,458*	*0,943*	*934,0*	*306,4*
Malvasija	*0,458*	*0,943*	*722,5*	*338,2*
Average	*0,458*	*0,943*	*828,3*	*322,3*

With the help of the formula (3,4) we calculated the theoretical quantity of produced biogas. If we used grape marc for biogas production, we would produce 331.3m³of biogas per hectare of vineyard. On the other hand, if we used grape pips for the production of biogas, we would produce only 128.9m³ of biogas per hectare of vineyard.

Table 13: Theoretical quantity of biogas produced from grape marc and pips

	DM kg/ha	C %	N %	C:N	Biogas m^3/kg DM	Biogas m^3/ha
Marc	828,3	48,55	1,28	37,9	0,4	331,3
Pips	322,3	53,2	1,635	32,5	0,4	128,9

In theory, we could produce 331.3m³ of biogas from grape marc and 128.9m³ of biogas from grape pips per hectare. The separation of grape skins and pips denotes additional work. Thus it is reasonable to produce biogas from grape marc. To better illustrate the situation, we converted the quantity of biogas into electrical and thermal energy and calculated the indicative value of electrical energy. We produce 0.55MW of electrical energy and 1.42MW of thermal energy from 331.3m³ of biogas. With the help of electrical energy we can save 276 €/ha per year if we take into account the assured buying-in price for biogas from production devices OVE for biogas, produced from biodegradable waste, smaller than 1MW.

REFERENCES

1. Keter Organica. http://www.keterorganica.com/brosura/ (8.8.2009.)
2. Patti A. F., Issa J. G., Wilkinson K., 2004. What are we putting on the ground? Characterisation of Grape Marc Composts from the Goulburn and Yarra Valley Regions of Victoria. Yarra Valley Wine Growers Association Inc and Goulburn Valley Wine. Grape and Wine Research and Developemen Corporation
3. http://www.gwrdc.com.au/downloads/ResearchTopics/RT%2002-42%20and%20RT%2002-43.pdf (17.7.2009.)
4. Šolinc H. 2005. Obnovljivi viri energije v Sloveniji. V: Obnovljivi viri energije - razvojne možnosti, njihov vpliv na okolje in vloga lokalnih skupnosti. 2005. Ljubljana, Fon B. (ur). Ljubljana, Oddelek Državnega zbora Republike Slovenije za informiranje: 19 – 25
5. Šumenjak Sabol M. 2007b. Biomasa – vir energije za Slovenijo. V: Bioplin, tehnologija in okolje, Rakičan, Murska Sobota, 29. nov. 2007. Lakota M., Tušar R. (ur). Maribor, Fakulteta za kmetijstvo: 17 – 18
6. Vršič S., Lešnik M. 2005. Vinogradništvo. Ljubljana, ČZD Kmečki glas: 368 str.
7. Zver A. 2005. Obnovljivi viri energije, rastlina kot energija in rastlina kot hrana. Diplomsko delo. Ljubljana, Biotehniška fakulteta, Odd. za zootehniko: 60 str.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 662.767.2(497.4)
Stručni rad
Expert paper

ZAKONSKI OKVIRI ZA PROIZVODNJO BIOPLINA IN PRODAJO ELEKTRIKE V SLOVENIJI

TOMAŽ POJE

Kmetijski inštitut Slovenije, Oddelek za kmetijsko tehniko, Hacquetova 17, SI – 1000 Ljubljana, Slovenija, E-mail: tomaz.poje@kis.si

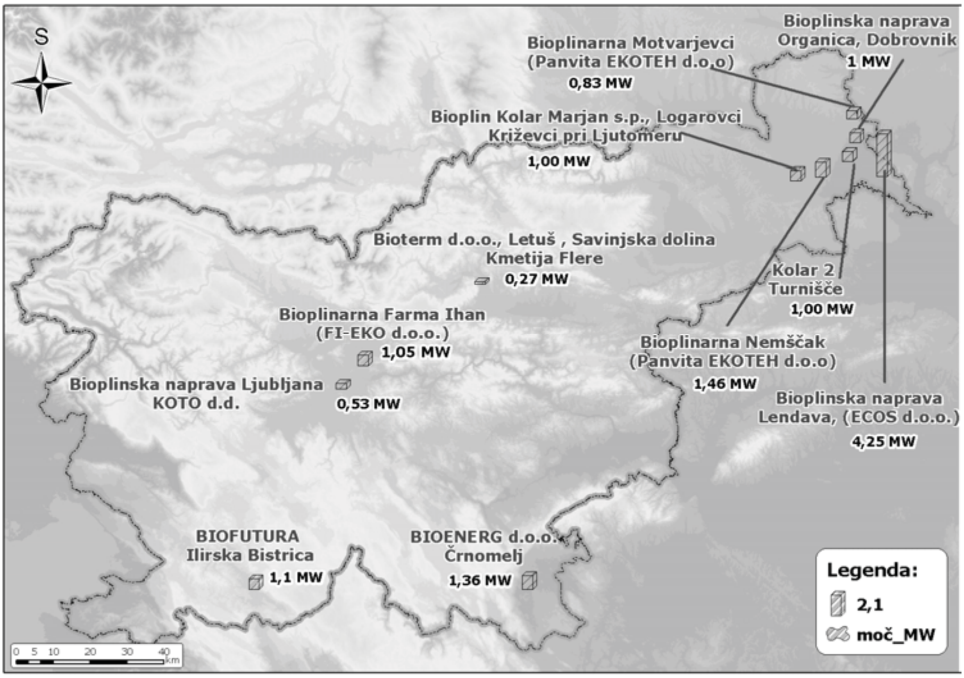
IZVLEČEK

V Slovenije že obstaja ali pa se gradi večje število kmetijskih bioplinskih naprav. Število narašča predvsem zaradi relativno ugodnega sistema za odkup električne energije. V letu 2009 je stopila v veljavo nova uredba za podpore električni energiji proizvedeni iz OVE. Biomasa, ki se lahko uporablja za proizvodnjo bioplina (elektrike) se deli na energetske rastline, biorazgradljive frakcije kmetijskih izdelkov, ostankov in odpadkov in na biološko razgradljive komunalni in industrijski odpadke. Bioplinske naprave se sedaj delijo v tri kategorije po nazivni električni moči kogeneratorskih motorjev. Podpora električni energije proizvedeni v bioplinskih napravah pa se deli na zagotovljeni odkup električne energije in na finančna pomoč za tekoče poslovanje. Bioplinske naprave morajo tudi pridobiti ustrezno okoljsko dovoljenje in odobritev Veterinarske uprave RS.

Ključne besede: *bioplin, zakonski okviri, okoljska dovoljenja, sistem za odkup električne energije, Slovenija*

UVOD

Gradnja kmetijskih bioplinskih naprav v Sloveniji se je povečala po letu 2002, ko je vlada Republike Slovenije določila ustreznejše odkupne cen in premije za kvalificirane proizvajalce električne energije, kamor spada tudi proizvodnja elektrike iz bioplina. Skupaj instalirana električna moč na kogeneracijskih napravah kmetijskih bioplinskih naprav je 13,8 MW. Toplota se povečini uporablja za ogrevanje same bioplinske naprave in bližnjih objektov, ni pa trenutno vzpostavljenega ogrevanja naselij ali česa drugega. Zadnja zgrajena bioplinska naprava v Dobrovniku oddaja toploto v bližnje rastlinjake, kjer pridelujejo orhideje. Bioplinske naprave so morale pridobiti status kvalificiranega proizvajalca električne energije. Vsak tak kvalificiran proizvajalec električne energije je dobival plačilo po enotni letni ceni 120,89 EUR za MWh proizvedene električne energije. Prav tako je bil upravičen do enotne letne premije, ki znaša 68,51 EUR na MWh proizvedene električne energije. Te odkupne cene so bile zadnje po starem sistemu odkupa, veljale so od 15.10. 2008 do 1.11.2009. V Sloveniji smo leta 2008 ustanovili tudi "Združenje proizvajalcev bioplina". Poleg kmetijskih bioplinskih naprav imamo v Sloveniji tudi proizvodnjo bioplina na 6 centralnih čistilnih napravah za čiščenje odpadnih voda, kjer je skupan instalirana električna moč 2,1 MW. Na treh odlagališčih komunalnih odpadkov pa se proizvaja bioplin, ki ga kličemo tudi deponijski plin. Skupna instalirana električna moč naprav za izkoriščanje deponijskega plina je 3,5 MW.



Slika 1: Karta (kmetijskih) bioplinskih naprav, december 2009

ZAKONSKI OKVIRI

Maja 2009 je vlada RS sprejela Uredbo o podporah električni energiji proizvedeni iz obnovljivih virov energije. Samo Uredbo je precej časa preverjala tudi Evropska komisija, tako da je sama uredba stopila v veljavo šele 1.11.2009. Od takrat lahko lastniki kmetijskih bioplinskih naprav že sklenejo pogodbe za odkup električne energije po novi uredbi.

Podpore v Sloveniji so državna pomoč in morajo biti skladne s Smernicami za državne pomoči za varstvo okolja. Načela državnih pomoči za OVE so: Podpore le elektrarnam, ki niso amortizirane in ne starejše od 15 let. Preprečevanje akumuliranja več vrst državnih pomoči. Pomoč je časovno omejena. Pomoč je sorazmerna dejanskim potrebam zaradi položaja na trgu.

Uredba o podporah električni energiji proizvedeni iz obnovljivih virov energije določa:

- vrste energetskih tehnologij proizvodnih naprav za proizvodnjo električne energije iz obnovljivih virov energije (v nadaljnjem besedilu: proizvodne naprave OVE), ki lahko prejemajo podpore,
- razvrstitev proizvodnih naprav OVE, ki lahko prejemajo podpore po tej uredbi, v velikostne razrede,
- podrobnejšo opredelitev podpor,
- način določanja referenčnih stroškov proizvodnje električne energije iz OVE,
- način določanja cen za zagotovljeni odkup električne energije, proizvedene v proizvodnih napravah OVE,
- način določanja višine podpor, ki se izvajajo kot finančna pomoč za tekoče poslovanje proizvodnih naprav OVE,
- pogoje za pridobitev podpore,
- način pridobitve podpore,
- način prejemanja podpor ter druga vprašanja, povezana s podporami električni energiji, proizvedeni iz OVE.

Uredba o podporah in bioplin

Določbe te uredbe se nanašajo na proizvodne naprave OVE z energetskimi tehnologijami, ki izkoriščajo energijo pridobljeno iz bioplina, ki izvira iz biomase in biološko razgradljivih odpadkov. Uredba o podporah električni energiji proizvedeni iz obnovljivih virov energije določa tudi pogoje delovanja za bioplinske naprave.

Tabela 1: Delitev proizvodnih naprav po nazivni moči

Velikostni razred proizvodne naprave		Nazivna moč naprave
1.	Mikro	< 50 kW
2.	Male	< 1000 kW
3.	Srednje	1 – 10 MW
4.	Velike	Od 10 do 125 MW

Glede na novo uredbo je sedaj zelo pomembna vrsta vhodnih substratov za bioplinsko napravo, kajti od le teh je odvisna tudi višina odkupne cene električne energije. Uredba definira naslednje vhodne substrate za bioplinske naprave:

- B 1 Energetske rastline: Energetske rastline so lesni ali nelesni pridelek gojen posebej v energetske namene.
- B 2 Biorazgradljive frakcije izdelkov, ostankov in odpadkov: Ta kategorija zajema biorazgradljive frakcije izdelkov, ostankov in odpadkov iz kmetijstva, vključno s snovmi rastlinskega in živalskega izvora.

- C 1, C 2 Biološko razgradljivi komunalni in industrijski odpadki: Biološko razgradljivi komunalni in industrijski odpadki so biološko razgradljiva frakcija industrijskih in komunalnih odpadkov, katerih energetsko uporabo dovoljujejo predpisi o ravnanju z odpadki.

Podpore električni energiji proizvedeni v bioplinskih napravah so:

- zagotovljeni odkup električne energije. Na podlagi te podpore center za podpore ne glede na ceno električne energije na trgu odkupi vso prevzeto neto proizvedeno električno energijo, za katero je proizvodna naprava OVE prejela potrdila o izvoru, po zagotovljenih cenah električne energije, določenih s to uredbo;
- finančna pomoč za tekoče poslovanje (obratovalna podpora). Ta podpora se dodeli neto proizvedeni električni energiji, za katero je prejeto potrdilo o izvoru in ki jo proizvajalci električne energije iz OVE prodajo sami na trgu ali jo porabijo kot lastni odjem.

Odkupna cena za proizvedeno (prodano) električno energijo pa se bo oblikovala glede na referenčne stroške.

Tabela 2: Referenčni stroški proizvodnih naprav na bioplin, proizveden iz biomase[1] (velja za biomaso z več kot 75 odstotnim prostorninskim deležem virov B1 in B2)

Velikostni razred proizvodne naprave	Nespremenljivi del referenčnih stroškov (EUR/MWh_{el})	Spremenljivi del referenčnih stroškov[2,3] (EUR/MWh_{el})	Skupaj (EUR/MWh_{el})
Mikro (do 50 kW)	118,72	41,33	160,05
Mala (do 1 MW)	111,75	44,00	155,76
Srednja (do 10 MW)	96,18	44,59	140,77

[1]Referenčni stroški v proizvodnih napravah na bioplin z uporabo enega ali več vrst substratov.
[2]Spremenljivi del referenčnih stroškov se letno ali tudi pogosteje usklajuje na podlagi napovedi o referenčnih tržnih cenah substrata koruzne silaže.
[3]Stanje spremenljivih stroškov za leto 2009.

Tabela 3: Referenčni stroški proizvodnih naprav na bioplin, proizveden iz biološko razgradljivih odpadkov (z več kot 25 odstotnim prostorninskim deležem virov C 1 in C 2)

<table>
<tr><th>Velikostni razred proizvodne naprave</th><th>Nespremenljivi del referenčnih stroškov (EUR/MWh_{el})</th><th>Spremenljivi del referenčnih sroškov[1] (EUR/MWh_{el})</th><th>Skupaj (EUR/MWh_{el})</th></tr>
<tr><td>Mikro (do 50 kW)</td><td rowspan="2">139,23</td><td>/</td><td rowspan="2">139,23</td></tr>
<tr><td>Mala (do 1 MW)</td><td>/</td></tr>
<tr><td>Srednja (do 10 MW)</td><td>129,15</td><td>/</td><td>129,15</td></tr>
</table>

[1]Spremenljivi del referenčnih stroškov, ki je odvisen od količine proizvedene električne energije, se za namene te uredbe zanemari.

Spremenljivi del referenčnih stroškov se letno ali tudi pogosteje usklajuje na podlagi napovedi Agencije za energijo o referenčnih cenah energije na trgu. Spremenljivi del referenčnih stroškov se na podlagi posebne metodologije uskladi s spremembami cen substrata koruzne silaže iz napovedi o referenčnih tržnih cenah energije.

Cene zagotovljenega odkupa so glede na uporabljeni vhodne substrate in velikostni razred bioplinske naprave enake referenčnim stroškom, in so sestavljene iz dveh delov:

1. nespremenljivi del cene zagotovljenega odkupa je enak nespremenljivemu delu referenčnih stroškov in se ne spreminja ves čas trajanja pogodbe o zagotovljenem odkupu;
2. spremenljivi del cene zagotovljenega odkupa je enak spremenljivemu delu referenčnih stroškov, če je ta določen, in se letno ali tudi pogosteje usklajuje po objavi referenčnih cen goriva.

Obratovalne podpore se določijo tako, da se od skupnih referenčnih stroškov za bioplinsko napravo in glede na njen velikostni razred, ki se letno ali pogosteje usklajujejo glede na referenčne stroške energentov, odšteje cena, ki jo lahko električna energija iz bioplinske naprave doseže na trgu z električno energijo

Tabela 4: Obratovalne podpore za električno energijo iz proizvodnih naprav za bioplin, proizveden iz kmetijske biomase

Velikostni razred proizvodne naprave	Obratovalna podpora (EUR/MWh_{el})
Mikro (do 50 kW)	102,85
Mala (do 1 MW)	96,61
Srednja (do 10 MW)	80,79

Tabela 5: Obratovalne podpore za električno energijo iz proizvodnih naprav za bioplin, proizveden iz biološko razgradljivih komunalnih in industrijskih odpadkov

Velikostni razred proizvodne naprave	Obratovalna podpora (EUR/MWh_{el})
Mikro (do 50 kW)	/
Mala (do 1 MW)	80,08
Srednja (do 10 MW)	69,35

Nova Uredba uvaja tudi bonuse – dodatke, ki jih dosedanja zakonodaja ni imela. Ti bonusi so:

1. Če se letno koristno izrabi toplota v obsegu več kot 15 % vhodne energije bioplina, je bioplinska naprava upravičena do izplačila dodatka v višini 10 % obratovalne podpore. Toplota iz bioplinarne, ki se porabi za pridobivanje bioplina, se ne šteje za koristno toploto.

2. Če gnoj in gnojevka letno pomenita prostorninsko več kot 30 % substrata za pridobivanje bioplina, je bioplinska naprava upravičena do izplačila dodatka v višini 10 % obratovalne podpore.
3. Če gnoj in gnojevka letno pomenita prostorninsko več kot 70 % substrata za pridobivanje bioplina, je bioplinska naprava z nazivno električno močjo do 200 kW upravičena do izplačila dodatka v višini 20 % obratovalne podpore.

Okoljevarstvena dovoljenja

Zakon o varstvu okolja poleg drugega nalaga povzročitelju onesnaževanja obveznost izvajanja ukrepov za preprečevanje in zmanjšanje onesnaževanja, tako da emisije v okolje ne presegajo predpisanih mejnih vrednosti. Naprava v kateri poteka dejavnost, ki lahko onesnažuje okolje z emisijami, mora imeti strokovno oceno ali okoljevarstveno dovoljenje ali IPPC dovoljenje. Pri tem je potrebno upoštevati Uredbo o emisiji snovi v zrak iz nepremičnih virov onesnaževanja, Uredbo o emisiji snovi v zrak iz nepremičnih plinskih turbin z vhodno toplotno močjo manj kot 50 MW in nepremičnih motorjev z notranjim zgorevanjem in Pravilnik o prvih meritvah in obratovalnem monitoringu emisije snovi v zrak iz nepremičnih virov onesnaževanja ter o pogojih za njegovo izvajanje.

Bioplinska naprava spada med naprave, ki lahko povzročajo onesnaževanje zraka. Viri onesnaženja zraka so lahko: skladišča vhodnih substratov, mešalna jama, digestorji, digestorji s plinohramom, končni zalogovnik, separacija, kogeneracijska enota – izpust, bakla. Uvrstitev bioplinske naprave v določeno skupino naprav glede vrste dovoljenja je odvisna od vrste vhodnega substrata in količine vhodnega substrata. Do sedaj so bile možne tri vrste dovoljenj: strokovna ocena, okoljevarstveno dovoljenje, IPPC dovoljenje.

Strokovna ocena vplivov emisije snovi v zrak je potrebna za bioplinske naprave, kjer je do 10 ton rastlinskega materiala na dan kot vhodnega materiala. Strokovno oceno izdela pooblaščeni izvajalec obratovalnega monitoringa, vsebina je predpisana, investitor jo potrebuje za pridobitev gradbenega dovoljenja. Okoljevarstveno dovoljenje je potrebno za bioplinske naprave, kjer je proizvodna zmogljivost več kot 10 ton rastlinskega materiala na dan. Pri okoljevarstvenem dovoljenju je potrebno preveriti ali je le to potrebno tudi za odpadke, vodo, hrup. Izda pa se le eno skupno dovoljenje. Prav tako je okoljevarstveno dovoljenje potrebno za bioplinske naprave, kjer je količina vhodnih rastlinskih substratov do 10 t ali več kot 10 t/dan in živalskih substratov do 10 t/dan. IPPC dovoljenje pa je potrebno za bioplinske naprave, kjer se uporabi več kot 10 ton gnoja/gnojevke na dan oziroma kjer se uporablja več kot 10 t živalskih stranskih produktov na dan.

Tudi za izpuste iz kogeneratorskih enot so določene mejne vrednosti, ki so prikazane v tabeli 6.

Tabela 6: Mejne vrednosti emisije snovi v zrak pri kogeneratorskih enotah

	Celotni prah (mg/m^3)	CO (mg/m^3)	NO_2 (mg/m^3)	CH_2O (mg/m^3)	H_2S (mg/m^3)	NH_3 (mg/m^3)	SO_2 (mg/m^3)
3 MW in več	20	650	500	60	3	15	350
manj kot 3 MW	20	1000	1000	60	3	15	350

Uredba o živalskih stranskih proizvodih

Bioplinska naprava, ki uporablja kot surovino živalske stranske proizvode mora v odvisnosti od vrste vhodnih substratov pridobiti odobritev (dovoljenje) Veterinarske uprave RS. Ta dejavnost VURS-a temelji na evropski in slovenski zakonodaji (Uredba Evropskega Parlamenta in Sveta št. 1774/2002, z vsemi dopolnili, izvedbenimi predpisi in ustreznimi slovenskimi zakoni.) Uredba (ES) 1774/2002 določa zdravstvena pravila za zbiranje, prevoz, skladiščenje, ravnanje z, predelavo in uporabo ali odstranitev, da ŽSP ne predstavljajo tveganja za zdravje ljudi in živali; dajanje na trg, uvoz in izvoz. Loči se tri kategorije snovi. Snovi kategorija 1 se ne smejo uporabljati za običajno proizvodnjo bioplina, razen s postopkom visokotlačne hidrolize v bioplin. Ta postopek je namenjen predelavi snovi, ki pridejo iz običajnih kafilerij z metodo 1 (220 °C, 20 min., 25 bar), nato pa sledi anaerobna predelava v bioplin. Nastali bioplin se hitro sežge v istem obratu pri 900°C. Celoten postopek poteka na istem mestu, v zaprtem sistemu. Take proizvodnje bioplina v Sloveniji še ni.

Snovi kategorija 2 so:

- gnoj in vsebina prebavnega trakta sesalcev,
- ostanki s čistilnih naprav za odpadne vode iz obratov za predelavo snovi kategorije 2 in 3 ter klavnic,
- itd.

Snovi kategorija 3 so:

- vsi deli zaklanih živali, primernih za prehrano ljudi (opravljen pregled pred in po zakolu),
- kri nesesalcev, koža in krzno, črevo in roževina, svinjske ščetine in perje zaklanih živali, pri katerih je bil opravljen pregled pred zakolom,
- lupine, stranski proizvodi valilnic, počena jajca živali, ki ne kažejo kliničnih znakov bolezni, ki se prenašajo na človeka ali živali;
- surovo mleko zdravih živali,
- živila, ki so namenjena za prehrano živali iz komercialnih razlogov ali napak, ki ne predstavljajo tveganja za zdravje ljudi ali živali,
- ribe, ujete na odprtem morju in drobovina rib, kot odpadek pri predelavi rib,
- kri, koža in krzno, črevo, roževina, perje, volna, dlaka in kožuh živali, ki na kažejo kliničnih znakov bolezni, ki so prenosljive na človeka ali živali, odpadki iz gostinskih dejavnosti, vključno z jedilnim oljem.

Glede na snovi kategorije 2 ali 3 so za uporabo v bioplinskih napravah v veljavi standardi predelave, kjer so zahteve glede velikosti delcev, minimalne temperature in minimalnega časa obdelave. Za snovi kategorije 2: po toplotni obdelavi v kafileriji (133°C/3 bari/20 min). Za snovi kategorije 3 (pasterizacijska enota) mora biti največja velikost delcev: 12 mm, minimalna temperatura v reaktorju pa 70°C, minimalni čas obdelave celotne snovi 60 min. Tako predobdelan substrat pa gre lahko v bioplinsko napravo v proces nastanka bioplina.

ZAKLJUČEK

Slovenija je tako kot druge članice Evropske skupnosti zavezana, da poveča delež obnovljivih virov energije. Med nje sodi tudi proizvodnja bioplina in posledično tudi »zelene elektrike« in toplote. Vlada RS je pospešila razvoj bioplinskih naprav že leta 2002 s sprejemom ustreznejših odkupnih cen za elektriko iz bioplinskih naprav. Nova uredba sprejeta leta 2009 je dokaj ugodna za lastnike bioplinskih naprav, saj bolje stimulira kmetijske bioplinske naprave, lastnikom pa daje tudi dolgoročno varovanje za njihove investicije. Po drugi strani pa lahko zlasti zakonodaja iz področja varstva okolja, ki je sicer nujno potrebna, zmanjšuje interes za bioplinske naprave.

LITERATURA

1. http://www.mg.gov.si/si/delovna_podrocja/energetika/sektor_za_razvoj_energetike/nova_podporna_shema_proizvodnji_elektricne_enrgije_iz_ove_in_spte/
2. http://www.mop.gov.si/si/zakonodaja_in_dokumenti/okolje/zakon_o_varstvu_okolja/
3. Kotesko I. (2009). Bioplinarne in emisije snovi v zrak. Predavanje na seminarju Bioplin (Od ideje do realizacije bioplinske naprave) v okviru projekta Biogas Regions, Ljubljana, 26. nov. 2009
4. POJE T., JEJČIČ V. (2009). The situation and perspective in the field of agricultural biogas plant in Slovenia. In proceedings of the 37. International Symposium on Agricultural Engineering, Opatija, Croatia, 10.-13. February 2009. Zagreb: Sveučilište u Zagrebu, Agronomski fakultet, Zavod za mehanizaciju poljoprivrede, pp 241-246
5. POJE T. (2009). Legal situation concerning the energy policy in the south-eastern Europe. Regulation of the purchase of electricity generated from renewable energy sources in Slovenia. Predavanje na konferenci Biomasse in Sűdosteuropa, Berlin, 29. okt. 2009.
6. POJE T. (2009). Utilizaton of biomass in the south-eastern Europe - current situation and perspectives. Situation and perspectives in the utilization of biodiesel, plant oil and biogas in Slovenia. Predavanje na konferenci Biomasse in Sűdosteuropa, Berlin, 29. okt. 2009.

LEGAL FRAMEWORK FOR BIOGAS PRODUCTION AND SELLING ELECTRICTIY IN SLOVENIA

ABSTRACT

In Slovenia already exist and are under construction a greater number of agricultural biogas plants. A growing number of biogas plants have developed mainly on account of a relatively favourable feed-in tariff system. In the year 2009 there are new support schemes for electricity generated from renewable energy sources (valid from 1.11.2009). Biomass that can be used for electricity production receiving support broken down by source in energy crops, biodegradable fraction of products, residues and waste; biodegradable municipal and industrial waste. Biogas plant shall be divided into three size category with regard to nominal electricity power. Support for electricity produced in biogas plants comprises guaranteed purchase of electricity and financial aid (operating support). There is also a novelty in the decree bonus – extra pays (supplement). Biogas plant must acquire proper environmental protection permit and approval of Veterinary Administration of the Republic of Slovenia.

***Key words**: biogas, legal framework, environmental protection permit, feed-in tariff, Slovenia*

UDK 620.95(497.4)
Prethodno priopćenje
Preliminary communication

MOŽNOSTI UPORABE KMETIJSKE BIOMASE ZA ENERGETSKE NAMENE V SLOVENIJI

VIKTOR JEJČIČ, TOMAŽ POJE

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

IZVLEČEK

Določen je potencial trdne kmetijske biomase za energetske uporabo iz poljedelskih kultur, ki se najbolj pogosto gojijo v Sloveniji. Za energetske namene je predvidena uporaba žetvenih ostankov različnih poljedelskih kultur. Iz podatkov za pridelke posameznih poljedelskih kultur je določena skupna bruto in neto energetska vrednost žetvenih ostankov v slovenskem kmetijstvu. Ugotovljeno je, da je potencial koruznice in pšenične slame, kot energenta v primerjavi z žetvenimi ostanki ostalih poljedelskih kultur v Sloveniji največji. Za pobiranje slame in koruzne mase s polj se v veliki meri lahko uporablja kmetijska mehanizacija, ki že danes obstaja v slovenskem kmetijstvu. Poleg energetskega potenciala žetvenih ostankov oljne ogrščice je določen tudi dodatni potencial rastlinskega olja za energetske namene in oljne pogače za krmo. Decentralizirana proizvodnja olja iz oljne ogrščice omogoča enostavno pridobivanje olja, ki je surovina za biodiesel in oljne pogače, ki je zanimiva kot visoko vredno beljakovinsko krmilo. Trenutno so enote za decentralizirano proizvodnjo olja v Sloveniji razširjena v majhnem obsegu.

Ključne besede: *kmetijska biomasa, žetveni ostanki poljedelskih kultur za energetsko uporabo, energetski potencial žetvenih ostankov, energetski potencial oljne ogrščice, decentralizirana proizvodnja olja*

UVOD

Uporaba biomase za energetske namene se uvršča med najstarejše tehnologije v uporabi človeštva. Z uvajanjem proizvodnje energije iz premoga, nafte, zemeljskega plina itn. je zgubila na pomenu. Stranski učinki proizvodnje energije iz fosilnih goriv (pospešeno onesnaževanje okolja in posledične klimatske spremembe) ter upadanje svetovnih zalog fosilnih goriv in pospešenega naraščanje cene tekočih in drugih goriv na svetovnem trgu je ponovno postavilo biomaso v ospredje (biomasa ponovno postaja eden od vodilnih energentov v razvitih državah). Pomembna komponenta za zmanjševanje energetske odvisnosti Slovenije od fosilnih energentov je proizvodnja energije iz obnovljivih virov energije, kot je npr. biomasa. Energija proizvedena doma ima manjše vplive na okolje, visok izkoristek (razmerje pridobljene energije v primerjavi z vloženo energijo; po nekaterih znanstvenikih je to razmerje pri biomasi boljše, kot pri fosilnih gorivih) ter omogoča ekonomski razvoj in energetsko varnost.

Obnovljivim virom energije ter uporabi biomase v energetske namene se v Sloveniji in EU posveča v zadnjih letih vse večja pozornost. Energetski zakon zagotavlja spodbujanje rabe obnovljivih virov energije, zagotavlja prednost učinkoviti rabi energije in obnovljivim virom energije pred oskrbo iz neobnovljivih virov energije ter omogoča več načinov spodbujanja proizvodnje energije na osnovi obnovljivih virov energije. Nacionalni strateški načrt razvoja podeželja 2007-2013 temelji na načelih trajnostnega gospodarjenja z obnovljivimi naravnimi viri. V sklopu strateškega cilja Slovenije za povečanje stopnje samooskrbe z energijo, lahko kmetijstvo odigra pomembno vlogo na področju alternativnih virov energije. Proizvodnja energije s pomočjo alternativnih virov energije ima minimalne vplive na okolje, zaprti krog CO_2 vpliva na lokalno izboljšanje kakovosti zraka, vpliva na upočasnjevanje klimatskih sprememb, povečuje zanesljivost oskrbe, pospešuje regionalni razvoj podeželja ter ohranja in ustvarja nova delovna mesta.

ENERGETSKI POTENCIAL POLJŠČIN

Za proizvodnjo energije se lahko uporablja različna kmetijska biomasa npr.: žetveni ostanki po žetvi žit, koruze, oljne ogrščice, sončnice, graha itn. Omenjeni žetveni ostanki se uvrščajo v rastlinske ostanke, ki se po lastnostih približno primerjajo z olesenelimi rastlinskimi ostanki. Uporabljajo se lahko ostanki jesenskega in spomladanskega obrezovanja v sadovnjakih in vinogradih (po kakovosti se biomasa trajnih nasadov približujejo gozdni biomasi). Posebno skupino predstavlja biomasa namensko gojenih drevesnih in grmovnih vrst, energetskih trav ter pokvarjena krma s travnikov in posušena trava iz manj kakovostnih travnikov. V skupino, ki je namenjena proizvodnji tekočih goriv pa se uvrščajo različne oljarice (oljna ogrščica, sončnica itn.). Iz biomase se lahko proizvajajo tudi pirolizna olja oziroma iz nje je s pomočjo Fischer – Tröpsch postopka možno proizvajati različna goriva, ki so še bolj kakovostna, kot današnja goriva mineralnega porekla.

Rastlina, ki se pretežno sestoji iz celuloze in je vlažna pri zgorevanju uporablja lastno energijo za izparevanje vode in s tem se ji kurilnost zmanjšuje. Za uporabo biomase, kot trdnega goriva je primerna uporaba predvsem suhe biomase ter biomase, ki se enostavno pobira (Katić 1985). To je lahko slama žit, koruznica, ki je pobrana nekaj časa po pobiranju koruze ali druge relativno suhe rastline (slama oljne ogrščice, sončnic, graha itn.). Energetska vrednost rastline kot goriva je odvisna od vlage. Rastlina, ki se pretežno sestoji iz celuloze, je vlažna in zato pri zgorevanju uporablja del lastne energije za izparevanje vode, kar ji zmanjšuje energetsko vrednost.

Ena od možnosti za energetsko ovrednotenje biomase oziroma biogoriv je uporaba koeficienta njihove energetske bilance, ki predstavlja razmerje med energijo, ki jo dobimo iz energetske rastline (končnega produkta) in energijo, ki jo porabimo za pridelovanje omenjene rastline. Biodiesel oziroma estrificirano ogrščično olje ima energijsko razmerje

1 : 5,5 z vključenimi žetvenimi ostanki (slama za energetske namene) in 1 : 3,2 brez vključenih žetvenih ostankov (slama). Za primerjavo etanol iz pšenice ima energijsko razmerje 1 : 3,6, etanol iz sladkorne pese pa ima energijsko razmerje 1 : 2,46 do 1 : 2,53 (El Basam 1998). Iz podatkov je vidna visoka pozitivna energetska bilanca estrificiranega ogrščičnega olja.

Najbolj značilne ovire, ki se pojavljajo pri uporabi kmetijske biomase za energetske namene so: financiranje naložb, varčevanje, zakonodaja, pomanjkanje adekvatnih integracij in logistika (Hajdu in Mago 2006).

Tabela 1. Površine (ha) zasejane z nekaterimi najpomembnejšimi poljščinami v obdobju od leta 2003 – 2008 v R. Sloveniji (baza SURS)

	Površina (ha)					
Poljščina	2003	2004	2005	2006	2007	2008
Pšenica in pira (C1120)	35585	32385	30059	32083	32040	35413
Koruza za zrnje (C1200)	44137	45996	42369	39839	40906	43698
Ječmen (C1160)	13789	15324	15451	17044	18532	19229
Oljna ogrščica (C1430)	2705	1945	2260	2809	5358	4442

Največji je potencial žetvenih ostankov koruze za zrnje in pšenice. Površine pod oljno ogrščico so manjše v primerjavi z ostalimi poljščinami, žetvenim ostankom oljne ogrščice je potrebno še prišteti rastlinsko olje dobljeno z ekstrakcijo semena ogrščice.

Potencialna energetska vrednost žetvenih ostankov je tista vrednost, ki bi jo dosegli, če bi v celoti izkoristili nadzemno biomaso poljščine razen pridelka zrnja (izjema je oljna ogrščice, kjer poleg žetvenih ostankov izkoristimo še zrnje za proizvodnjo olja). Osnova za izračun potencialne energetske vrednosti žetvenih ostankov sta podatka o obsegu pridelave izbranih poljščin v letih 2003 – 2005 v Sloveniji ter o njihovem žetvenem indeksu (pridelava se v letih 2006 do 2009 ni bistveno spreminjala). Z zajemom podatkov za obdobje treh let je zmanjšan vpliv rastnih razmer na količino pridelka v posameznih letih. Količina žetvenih ostankov posamezne poljščine je preračunana na absolutno suho snov, iz nje pa s pomočjo koeficienta energetska vrednost žetvenih ostankov. Zaradi velikega obsega pridelave in velike količine žetvenih ostankov sta za pridobivanje energije primerni zlasti koruznica in žitna slama, potencial nadzemne biomase pri koruzi pa je največji.

Dejanska energetska vrednost žetvenih ostankov je manjša od potencialne zaradi tehnološke narave. Kosa kombajna ob spravilu odreže nadzemno rastlino v določeni višini od tal. Ta je odvisna od vrste poljščine, razgibanosti terena in tehnološke izpopolnjenosti kombajna. Ocenjujemo, da je izguba energetske vrednosti žetvenih ostankov zaradi višine rezi do 10 %. Koruznica in slama strnih žit sta elastični in se med kombajniranjem skoraj ne drobita. Nasprotno je slama oljne ogrščice in večine zrnatih stročnic zelo krhke sestave, zato se jo velik del med potjo skozi kombajn zdrobi na tako majhne delce, da jih je s sedaj razširjenimi stroji težko pospraviti.

Tabela 2. Poprečni pridelek slame v tonah suhe snovi, zgorevalna toplota H_s in kurilnost H_i posameznih tipov slam ter skupna bruto in neto energetska vrednost rastlinskih ostankov v slovenskem kmetijstvu preračunana na leto

Poljščine	Pridelek slame (t)	Zgorevalna toplota* (GJ/t)	Kurilnost** (GJ/t)	Bruto energetska vrednost (GJ/leto)	Neto energetska vrednost (GJ/leto)
Pšenica in pira (C1120)	153.182	17,510	16,490	2.682.211	2.525.965
Rž (C1150)	4.103	17,588	16,496	72.168	67.687
Ječmen (C1160)	55.281	19,92	18,83	1.101.200	1.040.944
Oves (C1180)	6.176	17,588	16,496	108.621	101.877
Koruza za zrnje (C1200)	267.463	17,65	16,52	4.720.730	4.418.496
Tritikala (C1212)	10.201	17,588	16,496	179.411	168.272
Druga žita – Proso	828	17,588	16,496	14.569	13.664
Druga žita – Ajda	1.020	17,588	16,496	17.936	16.822
Druga žita (soržica, sirek, mešanica žit brez soržice, drugo)	406	15,4	14,32	6.256	5.817
Krmni grah (C1320)	2.723	17,588	16,496	47.899	44.925
Fižol in bob (C1330)	1.227	17,46	16,32	21.429	20.030
Oljna ogrščica (C1430)	8.133	17,588	16,496	143.049	134.167
Sončnice (C1450)	108	17,588	16,496	1.901	1.783
Soja (C1470)	252	17,588	16,496	4.426	4.151
Hmelj (C1560)	748	17,588	16,496	13.164	12.347
Skupaj				9.134.968	8.576.947

* Zgorevalna toplota H_s – (zgornja kurilnost) je vsa pri zgorevanju sproščena toplota
** Kurilnost H_i – (spodnja kurilnost) je tisti del zgorevalne toplote, ki ga dobivamo, če dimne pline ohlajamo samo do temperature nad rosiščem vodne pare. Kurilnost je manjša od zgorevalne toplote za uparjalno toploto vodne pare

Razumljivo je tudi, da vso koruznico, pšenično slamo ali druge žetvene ostanke ne moremo uporabiti v energetske namene, ker moramo vsako leto velike količine koruznice in slame zaorati (vzdrževanje biološkega ravnotežja ekosistema, del mase je potreben za ustvarjanje humusa v tleh) zaradi ohranjanja permanentne rodovitnosti tal ter preprečevanja erozije tal. Ne smemo pozabiti, da se koruznica tudi uporablja za prehrano živali. Koliko koruznice in žitne slame lahko vzamemo z njiv je odvisno od več faktorjev: pridelovalnega območja, topografije, tipa tal in količine letnih padavin. Na nekaterih tleh bi koruznico ali slamo morali v popolnosti zaorati, ker preprečuje vodno in vetrno erozijo (npr. obdelovalna tla na nagibu), na tleh, ki so bogata z organsko maso in se nahajajo v ravninskem delu pa bi po mnenju nekaterih strokovnjakih brez problema glede ohranjanja rodovitnosti tal lahko pobrali tudi 50 % žetvenih ostankov. Realno bi bilo za energetske namene porabiti 20 – 30 % od celotne mase koruznice ali slame oziroma ostalih žetvenih ostankov.

TEHNOLOGIJE ZA IZKORIŠČANJE TRDNE KMETIJSKE BIOMASE V ENERGETSKE NAMENE

Kmetijska biomasa je, kot energetski vir, problematična glede prostorninske gostote energije ter načina zbiranja, prevažanja, skladiščenja in uporabe. Danes obstajajo različne tehnologije s katerimi lahko obvladujemo omenjene probleme. Poleg baliranja za zmanjševanje prostornine biomase, obstaja še tehnika briketiranja in peletiranja žetvenih ostankov. Tehnologija briketiranja in peletiranja za zmanjševanje prostornine žetvenih ostankov se trenutno ne uporablja v Sloveniji. Zaradi enostavnejšega manipulativnega postopka s peletiranimi in briketiranimi žetvenimi ostanki (možna je uporaba že obstoječe tehnologije za sežiganje lesnih peletov) pa se ji odpira velike možnosti v prihodnosti.

Strojno pobiranje rastlinskih ostankov po žetvi

Za pobiranje slame in koruzne mase s polj se lahko uporablja v veliki meri kmetijska mehanizacija, ki že danes obstaja v slovenskem kmetijstvu. V poštev pridejo različne izvedbe samonakladalnih prikolic, stiskalnice za valjaste bale s pobiralno napravo (uporabljajo se za izdelavo valjastih suhih in mokrih – silažnih bal) in stiskalnice s pobiralno napravo za izdelavo kvadrastih suhih bal. Tehnika stiskanja rastlinskega materiala s stiskalnicami za valjaste bale je v Sloveniji dobro razvita. V zadnjih dveh desetletjih je število stiskalnic za valjaste bale praktično od vrednosti nekaj strojev naraslo na več tisoč primerkov, vseh tipov stiskalnic je 4161 (Statistični urad RS 2005), ocenjujemo da je njihovo število še naraščalo po letu 2005. Stiskalnice za valjaste bale so kmetje in izvajalci uslug s kmetijsko mehanizacijo pretežno nabavljali za stiskanje mokrih bal za travno silažo. Omenjeni stroji so primerni tudi za izdelavo suhih bal iz žetvenih rastlinskih ostankov, kjer so potrebni nekoliko manjši tlaki stiskanja, kot pri mokrih balah za krmo. Valjaste bale so ponavadi premera 1,2 m – 1,6 m in višine 1,2 m, masa pa se jim giblje do 450 kg za slamo (odvisno od tlaka stiskanja, vlažnosti vhodnega rastlinskega materiala, tipa rastlinskega materiala, pridelka), gostota pa jim znaša pod 120 kg/m^3. Zaradi dimenzij in mas valjastih bal z njimi je možna manipulacija samo s posebnimi stroji. Za dviganje in nakladanje, ter prevoz na krajše razdalje so v masovni uporabi traktorske vile (zaradi nizke cene ter proizvodnje lokalnega značaja), za prevoz na večje razdalje pa služijo klasične traktorske prikolice ali posebne prikolice za bale, ki so zaradi lažjega nakladanja v nizkopodni izvedbi. Za manipulacijo z velikim številom bal obstajajo samovozni teleskopski nakladalniki ter posebne izvedbe dvoriščnih traktorjev, omenjeni stroji imajo velike urne učinke. Teh strojev pri nas obstaja samo zanemarljivo število. S traktorskimi vilami in standardnimi traktorskimi prikolicami (51 602 prikolic, vir Statistični urad RS 2005) je opremljeno veliko kmetij, posebnih prikolic za bale pa je trenutno malo (ni uradnega podatka).

Stiskalnice za kvadraste bale manjših dimenzij so stroji, ki jih slovenski kmetje uporabljajo že desetletja. Namenjene so za stiskanje žetvenih ostankov in sena. Delijo se na nizko (gostota bale znaša do 120 kg/m^3) in visoko tlačne izvedbe (gostota bale do 250 kg/m^3). Dimenzija kvadrastih bal znaša: dolžina 80 – 100 cm, širina 30 – 50 cm in višina 30 – 40 cm, masa 15 – 30 kg pri senenih balah in 10 – 20 kg pri balah iz slame. V zadnjih dveh desetletjih pa so ta tip stiskalnic začele popolnoma izpodrivati stiskalnice za valjaste bale, ki imajo večji učinek (pri stiskalnicah za kvadraste bale manjših dimenzij je potrebno veliko časa za manipulacijo), izkoristek prostora pa je boljši, kot pri valjastih balah.

Stiskalnice za kvadraste bale velikih dimenzij so namenjene za izdelavo bal velikosti dolžine 70 – 280 cm, širine 80 – 120 cm in višine 50 – 130 cm, gostota bal pa jim znaša pod 150 kg/m^3. Masa bal se jim giblje do 900 kg za seno in do 700 kg za slamo. Pri nas jih je zanemarljivo število, uporabljajo se samo v nekaj kmetijskih podjetjih, ki razpolagajo z večjimi površinami obdelovalne zemlje. Za manipulacijo s temi balami so potrebni samovozni teleskopski nakladalniki. Kot je že omenjeno prej teh strojev pri nas praktično ni v uporabi. Prednost bal velikih dimenzij je da odlično izkoriščajo skladiščni prostor, to je izrednega pomena pri transportu na večje razdalje. Za zbiranje koruznice s stiskanjem v bale ter za njen transport do 20 km razdalje se porabi 6 – 8 % od energetskega potenciala zbrane koruznice (Katić 1997).

Žetvene rastlinske ostanke je mogoče pobirati tudi s samonakladalnimi prikolicami. Teh je pri nas veliko število, 40621 Statistični urad RS 2005). Problem pri takem pobiranju je da ima pobrana rastlinska masa veliko prostornino, kar pomeni da je potrebno rastlinsko maso skladiščiti na večjem prostoru (v primerjavi s skladiščenjem bal) oziroma je potrebno naknadno zmanjšati prostornino rastlinske mase s postopkom stiskanja v pelete ali brikete (ta tehnologija je v našem kmetijstvu v povojih).

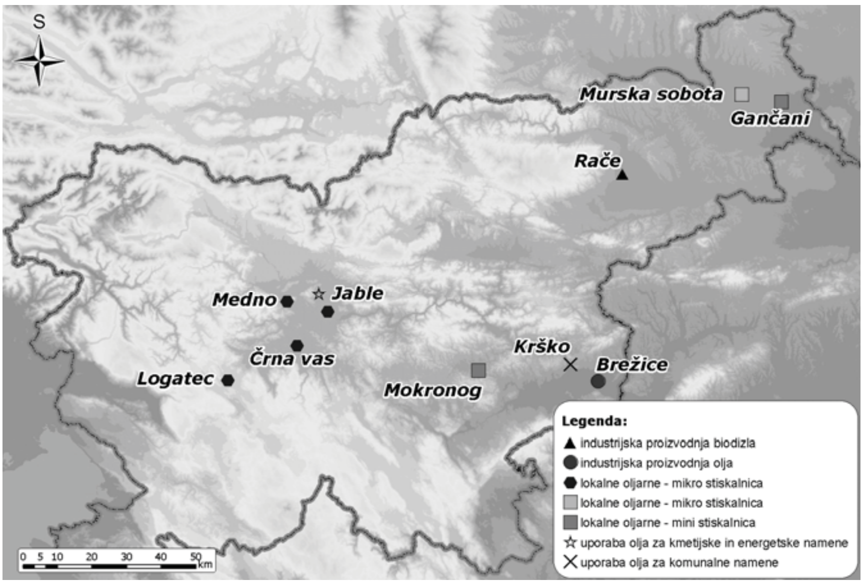
Slika 1. Za pobiranje slame in koruznice in stiskanje oziroma izdelavo suhih bal za zmanjševanje prostornine žetvenih ostankov za energetske namene se lahko uporabljajo obstoječe stiskalnice za valjaste bale, ki so razširjene v slovenskem kmetijskem prostoru

Rastlinsko olje iz oljne ogrščice za energetske namene

Pri žetvi oljne ogrščice poleg izkoriščanja žetvenih ostankov za energetske namene se uporabi tudi seme za proizvodnjo olja za energetske namene. Produkt stiskanja olja iz semena oljne ogrščice je tudi oljna pogača, ki služi za prerano domačih živali.

Za evropske in slovenske razmere (klimatski pogoji, kmetijska problematika, tehnologija proizvodnje, cena biogoriv itn.) je od tekočih biogoriv iz biomase trenutno najbolj zanimivo gorivo biodiesel narejen iz rastlinskih olj. Proizvodnja biodiesela iz oljnic je najbolj enostavna od vseh produkcijskih verig za biogoriva poleg tega so tudi stroški procesiranja najnižji v primerjavi z drugimi biogorivi. Sedaj je v svetovnem merilu 80 % biodiesela narejeno iz oljne ogrščice, 13 % iz sončnic, ostanek pa iz ostalih rastlinskih olj. Iz semena različnih rastlinskih vrst je mogoče proizvesti rastlinska olja, ki jih lahko neposredno uporabimo za pogon posebej za to predelanih dieselskih motorjev. Če pa izvršimo proces zaestrenja, dobimo biodieselsko gorivo, ki je po svojih karakteristikah podobno dieselskemu gorivu iz mineralnega olja (plinskemu olju) in je primerno za pogon dizelskih motorjev. Zelo pomembno je, da lahko biodiesel, proizveden s postopkom zaestrenja iz olja oljne ogrščice, sončnic, soje, itn., uporabimo za že obstoječe izvedbe dieselskih motorjev na vozilih in drugih strojih, ki so v uporabi v vseh segmentih človeške dejavnosti. To mu daje ogromno prednost pred nekaterimi drugimi viri energije, za katere je potrebno zasnovati popolnoma nove motorje.

Rezultati raziskav opravljeni v Nemčiji (UFOP 2009) kažejo konstantni razvoj na svetovnem nivoju na področju proizvodnje rastlinskega olja. Poudarek v prihodnosti bo na povečanih potrebah za človeško prehrano, vire surovin za biogoriva oziroma bioenergijo ter v uporabi za živalsko prehrano (stranski produkt stiskanja semena). Oljna ogrščica bo kot pomembna oljarica dobivala tudi vse večjo ekonomsko pomembnost v kmetijstvu EU. Njena pomembnost oziroma pomembnost produktov, ki nastanejo iz olje ogrščice bo v prehrambeni in energetski industriji ter drugje (npr. za proizvodnjo maziv za uporabo na vodovarstvenih območjih).



Slika 2. Proizvodnja rastlinskega olja in biodiesela, uporaba olja za kmetijske, komunalne in energetske namene v letu 2010 v R. Sloveniji (vir: Kmetijski inštitut Slovenije)

Rastlinsko olje za energetsko uporabo se da proizvajati z mehanskim procesom ekstrakcije - stiskanja ali pa z industrijsko ekstrakcijo s topili. Proces proizvodnje olja s stiskanjem ne potrebuje zahtevnih strojev v primerjavi z industrijskim procesom proizvodnje olja z ekstrakcijo s topili. Pomembna lastnost mehanskega procesa stiskanja je, da potrebuje nizke vložke energije in ne potrebuje uporabo kemikalij za ekstrakcijo (ekološko sporno).

Z vidika kolobarja bi bilo smiselno pridelovanje ogrščice s 4.442 ha (SURS 2008 SURS, podatki se nanašajo samo na pridelovalce, ki so deležni subvencij v kmetijstvu) povečati na 10.000 do 20.000 ha. Ocenjujemo, da bi lahko v okviru obsega pridelovanja ogrščice na 20.000 ha, letno pridobili približno 20.000 t olja (osnovna surovina za biodiesel) in približno 40.000 t pogač, kar predstavlja v primeru direktne porabe 1,4 % potreb po dizelskem gorivu (za leto 2008). Biodiesel pa se lahko tudi namešava v navadno dizelsko gorivo do 5 % in ga ni potrebno deklarirati kot mešanico goriv. Razpršena pridelava oljne ogrščice in posledično proizvodnja rastlinskega olja ima tudi številne ugodne stranske učinke kot so: izboljšanje kolobarja, manjše onesnaženje voda z nitrati zaradi zimske ozelenitve, manjša ranljivost kmetijstva zaradi poletnih suš, manjša nevarnost onesnaženja voda zaradi razlitij mineralnih goriv v naravnem okolju, zmanjšanje izpustov toplogrednih plinov, manjša onesnaženja z žveplovim dioksidom, nezgorelimi ogljikovodiki, ogljikovim monoksidom, z drobnimi prašnimi delci in s sajami.

Decentralizirana proizvodnja rastlinskega olja

Za slovenske razmere bo v prihodnosti zanimiva decentralizirana proizvodnja olja iz oljne ogrščice saj lahko pridobivamo kakovostno olje, ki je surovina za biodiesel in oljno pogačo, ki je zanimiva kot visokovredno beljakovinsko krmilo za prehrano domačih živali. Decentralizirana proizvodnja lahko poteka tudi na kmetijah, ki so razpršene po celotni državi, ker majhne proizvodne enote lahko ekonomsko in okolju prijazno obratujejo zaradi enostavne in cenene tehnične opreme in enostavnega delovnega procesa, ki je povezan z nizko porabo energije. Pri decentralizirani proizvodnji olja se uporablja mehansko stiskanje semena z mehanskimi kontinuiranimi stiskalnicami vijačnega tipa v eno ali dvofaznem procesu. Stiskanje s predgretjem omogoča odstranitev 95 % olja iz semena, brez predgretja pa je ta količina nekoliko nižja. Ekstrakcija s pomočjo topil je še bolj učinkovita saj omogoča odstraniti tudi do 99 % olja iz semena. Oljna pogača, ki ostane po ekstrakciji s topili pa je zaradi prisotnosti organskih topil manj primerna za živalsko krmo od oljne pogače, ki nastane pri mehanskem procesu stiskanja.

ZAKLJUČEK

Energetsko odvisnost Slovenije, ki se danes v celoti oskrbuje s tekočimi mineralnimi gorivi in zemeljskim plinom na svetovnem trgu, je potrebno zmanjšati. Zmanjšamo jo do določne mere tako, da izkoristimo lastne vire na področju pridelave in predelave kmetijske biomase.

Iz analize podatkov za najpomembnejše poljščine v Sloveniji je ugotovljeno, da je največji energetski potencial žetvenih ostankov pri koruznici in pšenični slami v primerjavi z žetvenimi ostanki ostalih poljščin v Sloveniji. V primeru oljne ogrščice poleg žetvenega ostanka slame nastane dodatni energent – rastlinsko olje, ki je surovina za proizvodnjo biodiesela. S tem se energetska bilanca oljne ogrščice občutno izboljša.

Zaradi potreb glede biološkega ravnotežja ekosistema, ki zahteva del biomase za ustvarjanje humusa bi realno bilo za energetske namene porabiti 20 – 30 % od celotne razpoložljive mase žetvenih ostankov.

LITERATURA

1. El Bassam, N.: Energy plant species, their use and impact on environment and development, James & James (Science Publishers), London 1998, str. 22 - 27
2. Hajdu, J./ Mago, L.: The possibilities of use of the biomass in Hungary, 34. Symposium »Actual Task on Agricultural Engineering«, Opatija, Croatia 2006, str. 111-120
3. Katić, Z.: Savjetovanje tehnologa sušenja i skladištenja, Zbornik radova, Fakultet poljoprivrednih znanosti Sveučilišta u Zagrebu, Zagreb 1985. str. 33 – 36
4. Katić, Z.: Sušenje i sušare u poljoprivredi, Udžbenik Sveučilišta u Zagrebu, Zagreb 1997, str. 14 – 19
5. MAN B&W Diesel AG: Bio fuels for Diesel Engines, 2004
6. Statistični urad Republike Slovenije. Statistične informacije, Kmetijstvo, Rastlinska pridelava Slovenije, Pridelava poljščin v letih 2003 - 2008
7. UFOP Bericht 2008/2009: Union zur Foerderung von Oel - und Proteinpflanzen e.V., Berlin 2009

POSSIBILITY OF USING AGRICULTURAL BIOMASS FOR ENERGETICAL PURPOSE IN SLOVENIA

SUMMARY

The potential of agricultural biomass for energy use from the most widely cultivated agricultural crops in Slovenia was estimated. For the energetic purposes the use of harvest residues of various agricultural crops was foreseen. The total gross and net energy value of crop residues in the Slovenian agriculture was estimated from data on yields of various agricultural crops. It was established that the largest energetic potential in Slovenia was that of harvest residues, corn stalks and wheat straw if compared to harvest residues of other agricultural crops. For the collection of wheat straw and corn stalks from fields, agricultural machines which already exist in the Slovenian agriculture can be used.

In addition to the energy potential of rapeseed harvest residues the potential of pure plant oil for energy use and cake for animal food was estimated. Decentralized production of pure plant oil from rapeseed enables simple oil production, i.e. the raw material for biodiesel and oil cake, which is an interesting and highly valuable protein material. Currently, the technology for pure plant oil production in Slovenia is spread on a small scale.

Key words: *agricultural biomass, harvest residues for energy use, energy potential of harvest residues of agricultural crops, energy potential of rapeseed, decentralized pure plant oil production*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:661.9
Stručni rad
Expert paper

SURVEY OF BIOMASS ENERGY POTENTIALS OF HUNGARIAN AGRICULTURE

LÁSZLÓ MAGÓ, JÓZSEF HAJDÚ, LÁSZLÓ FENYVESI

Hungarian Institute of Agricultural Engineering, Hungary, Gödöllő,
E-mail: laszlomago@fvmmi.hu

SUMMARY

The survey focuses on the biomass potential from the agriculture, the possibilities of the energetic use of the biomass, biogas, biodiesel and the bioethanol, in Hungary.

The biggest biomass producer in Hungary is the agriculture producing 58 million tons of organic material annually in which primary product is 53 % (30.5 million tons) and by-products 47 % (27,5 mill t). The biomass utilized for energetic purposes is barely 1.8 million tons, a merely 0.3 % of the total quantity.

The proportion of the renewable energies gained from the biomass hardly exceeds 1 % in the energy consumption of the agriculture.

The renewable energies gained from part of the biomass produced by the agriculture could cover 10 % of the national energy demand on the short term.

Key words: *biomass, biomass potential, renewable energy, bio-ethanol, bio-diesel*

INTRODUCTION

According to surveys there is a significant biomass potential in Hungary**.** The **total bulk of biomass in the country is up to 350-360 million tons** out of which **105-110 million tons** (about 30 %) **reproduce themselves** annually. The energy content of the biomass developing annually is up to 1185 PJ which is 5 % more than the total annual energy consumption of the country (1120 PJ). The fact that quantity of coal generated annually by plants is four times as much as the quantity of fossil coal exploited for energetic purposes in a year – as much as 30.4 million tons.

Tab 1: Potential and utilization possibilities of energetic biomass from the agriculture

No.	Biomass	Quantity 1000 t/year		Energy content PJ/year	
		Min.	Max.	Min.	Max.
I. Biomass for combustion					
1.	Straw	1.000	1.200	11,7	14,0
2.	Stalk	2.000	2.500	24,0	30,0
3.	Energy grass	500	600	6,0	7,0
4.	Vine- and orchard shoot	300	350	4,3	5,0
5.	Energy plants on arable land	1.800	2.500	27,3	38,0
II. Production of biofuels					
1.	Corn maize	1.200	2.000	14,4	24,0
2.	Wheat/rye	600	1.800	7,2	21,6
3.	Rape	220	460	3,3	7,0
4.	Sunflower	50	200	0,8	3,2
III. Biogas production					
1.	Liquid manure, organic waste	6.000	10.000	5,4	9,0
2.	Silomaize, sorghum	1.600	3.200	5,4	10,8
Total:				109,8	169,6
In % of the total Hungarian energy consumption of 1120 PJ				9,7 %	15,0 %

RESULTS OF THE SURVEY

Biomass for energy

In the primary biomass produced by the agriculture first of all the by-products arising in better amount can be reckoned with for energetic purposes. Under common or regular conditions 2,6-2,9 million tons of cereal straw is processed annually of which 1,6-1,7 million tons are utilized for animal breeding and for industrial purposes. The major part of the remaining 1,0-1,2 million tons of cereal straw could be used for energy production and annually 11,7-14 PJ energy could be produced of it. At present straw is practically not utilized for energetic purposes in Hungary due to the lack of appropriate stokes.

Maize stalk production in Hungary is **8-10 million tons** of which 2-2,5 million tons could be utilized for energetic purposes which could yield 20-24 PJ energy p.a. Among the by-products of crop growing sunflower stalk and rape straw also arise in big quantities which could be utilized for burning and could supply 5-6 PJ thermal energy annually should the appropriate technologies for harvesting and burning be available.

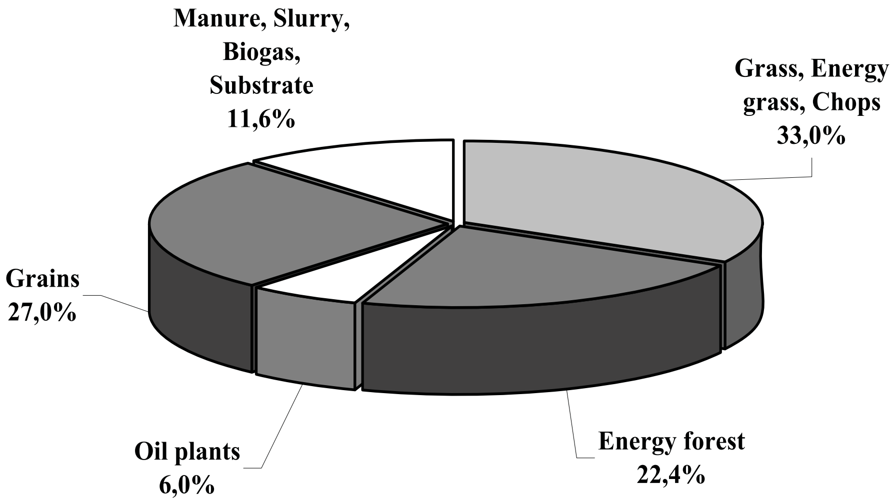


Fig. 1: Possibilities of agricultural energetic biomass potential and utilization in Hungary

The quantity of **vineyard and orchard pruning residues** (branch tendrils and fruit tree loppings) arising annually is 300-350 thousand tons which could supply 4,3-5 PJ energy. There have only been attempts for their burning till now. The harvesting in bales and burning in small stokes of branch tendrils is a viable solution on the vine growing farms. For the chopping, collecting and burning of pruning residues no technology has been developed so far.

Among the plants which can be produced on big areas for energetic purposes first of all the "Szarvasi energiafű" and the energetic tree plantations can come into consideration in Hungary.

The Szarvas **energy-grass** as a short rotation herbaceous grasses is able to provide a dry bulk of 10t/ha which can be baled for several years the energy content of which is 110-120 GJ/ha. The energy-grass can easily be pelletized. 6-7 tons of pellets can be produced of the grass yield of one hectare the burning features of which are more auspicious in lower capacity stokes than that of the chopped material in thermal power stations.

Should the final form of firing technology of energy-grass be developed cropping could be started in a short time maybe on 50-60 thousand hectares which would supply a 500-600 thousand ton bulk of biomass annually, of which 6-7 PJ energy can be produced.

Another prospective source of bio-energy is the energetic tree plantation classified in the agricultural plantation management cultivation sector by which dendromass can be produced relatively fast and in big quantity for energetic purposes.

According to experiences hitherto it is expedient to plant the **short rotation wooden crops** varieties (poplar, willow) with a number of plants 12000-15000/ha which will be ready for felling in 3-5 years. The re-shooting tree stock can be harvested in another 3-5 years by felling totally 5-7 times assuming a plantation lifespan of 15-25 years. On the basis of long term-experiments made with different tree varieties yields of 11-20 t/ha/year can be achieved, of which 185-330 GJ/ha energy can be produced.

Tab. 2: The real and feasible capacity for energetic utilization of solid biomass in Hungary

Biomass	Utilization	Actual capacity			Expected growth till 2020		
		Unit (pieces)	Capacity (MW)	Biomass demand (2000 t)	Unit (pieces)	Capacity (MW)	Biomass demand (1000 t)
1. Wood chips (forest or planted wood)	Electricity	5	140	1000	8	420	2800
	Central heating	5	24	25	25	120	150
	Central heating + electric energy production	2	12	32	20	120	180
2. Straw, Energy grass	Straw power plant, electric energy production and heat utilization	-	-	-	2-3	40-60	450
Sum total		12	176	1057	55-56	700-720	~ 3600

A rapid territorial expansion of the energetic plantations is expected in the near future which can achieve, or even exceed 100 thousand hectares of which 25-30 PJ energy can be gained.

For energy production under arable land conditions *triticale in the form of whole plant* cut into windrow and baled can also be taken into account the yield of which may reach 8-10 t/ha with 40 % grain bulk in it. Its energy content is 15-16 GJ/t so 120-160 GJ/ha energy can be produced. It has a favourable feature from the point of view of firing technology, that in baled form it burns more slowly and with a more even heat regress than wheat straw.

These biomasses originating from plants which can be produced on the field and utilized by direct burning are gaining a growing emphasis in our national energy policy in the coming years.

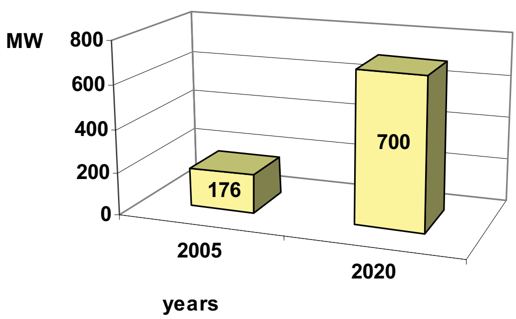


Fig. 2: Planned enlargement of energetic utilization of solid biomass

Biogas as a source of energy

The bulk of the biomass of agricultural origin – which can be gasified by biological means – is about 8-13 million tons Hungary of which 10-20 PJ energy can be produced. Taking the substrates into consideration the “wet” (by a dry matter content of 8-20 %) resp. the “semi-dry” (by a dry matter content of 20-50 %) technologies are applicable under the circumstances given in Hungary in view of the auspicious gasification and bigger livestock farms can serve as a basis for them. In this case organic matter of agricultural origin added to floating slurry manures of animals form a favourable substrate for anaerobic fermentation. Under ordinary conditions 300-400 litres of biogas with a methane-content of 60 % can be produced of 1 kg dry matter and this quantity can be increased by adding agricultural primary (e.g. mashed whole maize plant) or by-products (e.g. sugar beet chips) of higher energy content and with a heating effect.

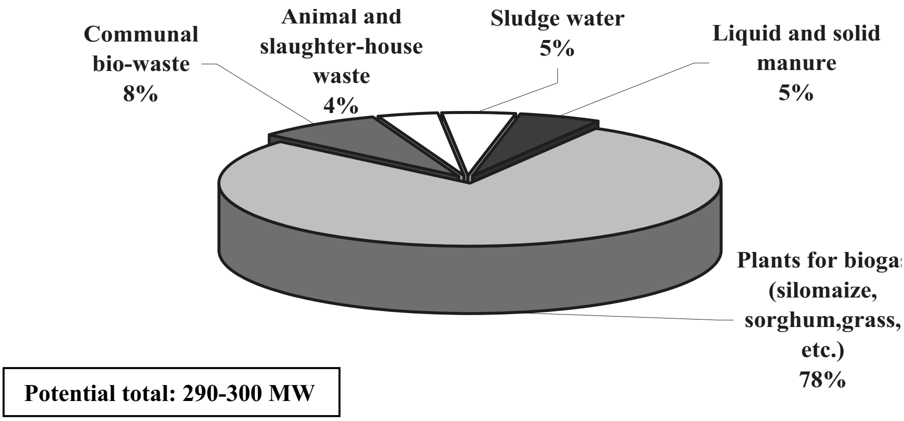


Fig. 3: Sharing of the biogas-potential

After cleaning and enrichment the raw biogas is – 1 m^3 of can which can substitute roughly 0.4 litre diesel oil – in so-called “Greengas” quality apt for propelling engines or for being dosed into the natural gas network.

Besides heating or chilling livestock farms biogas can be utilized first of all for the production of electric energy in Hungary. The waste heat of the electricity producing blocks can in turn be used for the fermenting appliances and for satisfying the own energy demand of the technology.

Tab. 3: Actual and expected capacities for biogas production in Hungary

Type of the plant	Actual capacity			Expected growth till 2020		
	Unit (pieces)	Capacity (MW)	Raw material demand (1000 t)	Unit (pieces)	Capacity (MW)	Basic unit (1000 t)
Agricultural	11	13	730	~ 45	~ 50	~ 2800

According to prevailing orders the electricity suppliers are obliged to take over the electricity produced by renewable energies in Hungary as well. In the next years new investments in biogas settlements are expected in Hungary.

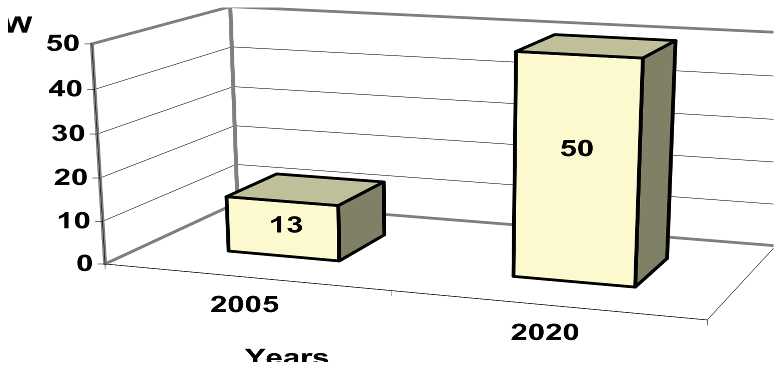


Fig. 4: Planned enlargement of biogas plants

Biomass as engine fuel or admixture

In Hungary – as well as in most of the EU member countries – government order allows that engine fuels of biological origin may be mixed in fuels produced of mineral oil derivatives distributed in the country. It can be expected, therefore, that the production resp. utilization as engine fuel additive of the two engine fuels of biological origin – the **bio-diesel (RME)** and the **bio-ethanol (ETBE or LCB)** - will gather space especially as the biggest national fuel producer and distributor the company "MOL Rt." has turned up on the market as a significant buyer. Naturally the expectations of the EU can be detected in the background of this according to which dealers of the member countries are expected to mix 5.25 % of fuel of biological origin into the fuel distributed till 2010.

Tab. 4: The volume of liquid bio fuels producing from industrial grains and oil seeds (unit of measure: th t)

Name	Wheat	Maize	Sunflower	Rape
Yield				
- min.	4.700	7.200	950	220
- max.	6.000	8.500	1.250	460
Utilization for liquid bio fuels				
- min.	600	1.200	50	220
- max	1.800	2.000	200	460
Volume of the producible fuels				
- bio ethanol: min.	215	420	-	-
max.	640	690	-	-
- bio diesel: min	-	-	23	77
max.	-	-	90	160

The ecological makings of Hungary are not really favourable for growing rapes. Autumn rape can be grown on 220 to 460 thousand hectares with acceptable yields. On this area 77-160 thousand tons of bio-diesel can be produced**.** This quantity partly covers the 120-130 thousand tons annual domestic demand for mixing to the diesel fuels.

Compared to the present diesel oil prices of the petrol stations the bio-diesel (RME) which is free of excise tax is still competitive. For the expansion of the production first of all investment needs to be encouraged.

The conditions of bio-ethanol production are more favourable in Hungary than that of bio-diesel. Part of the domestic **maize crop** can serve as raw material for bio-ethanol production. The annual maize crop is 7-8 million tons on the average, and in better years it may even exceed 8 million tons.

Due to the declining livestock the quantity of maize used for feeding is decreasing while the proportion of industrially processed resp. exported maize is increasing. Ideally the annual quantity of maize used for industrial procession can equal 1,2-2 million tons. Besides starch and iso-sugar production most of this quantity can be used for bio-ethanol production. So the volume of the inland production of maize-based ethanol can be up to 420-690 thousand litres annually which is six times as much as the ETBE demand of the Hungarian engine fuel producers and dealers expected till 2010.

Tab. 5: Actual and expected capacities for bio fuel production in Hungary

Bio-fuel	Plant capacity	Actual capacity			Expected growth till 2015-		
		Unit (pieces)	Capacity (1000 t)	Biomass demand (1000 t)	Unit (db)	Capacity (1000 t)	Biomass demand (1000 t)
1. Bio diesel / RME from rape	Small capacity	3	12	36	-	-	-
	Large capacity	-	-	-	2	150	450
Sum		3	12	36	2	150	450
2. Bio ethanol from grain	Small capacity	1	15	45	50	250	750
	Large capacity	1	68	200	6	720	2160
Sum		2	83	245	56	970	2910

Economical background

Among the obstacles of the transformation into energy and the utilization of biomasses of agricultural origin the financing of investments, matters of thrift, matters of regulation and the lack of appropriate integrations and logistics are the most significant.

The production and utilization of biomass for energetic purposes is effected by two major factors:

1. The price of traditional energy sources and the development of their costs
2. The production costs of bio-energy sources

The price and costs of the traditional energy sources are highly dependent from price changes in the international market and from the demand-offer relations but they are even more dependent from imposed taxes additional to production costs which are determined by the state. In the case of traditional engine fuels the taxes imposed are higher than the production and distribution costs. The costs of bio-energy production are in turn first of all effected by the costs of raw-material production, the preferences within agricultural production, the transformation costs of biomass and the state aid for bio-energy sources.

The costs of renewable liquid and gaseous fuels in general as well as that of traditional ones could be made competitive freed from taxes but it necessitates the abdication of the state. Besides the two main influencing factors the utilization of biomass for energetic purposes is also effected by the changes in the state of the natural environment and the social sensibility for unfavourable environmental effects.

The two renewable liquid energy sources - the bio-diesel and the bio-ethanol - which are also applicable as alternative engine fuel free of excise tax are competitive with the retail price of the traditional engine fuels – diesel oil and petrol. In case of implication the spillage of revenues is also decreasing in turn. The environmental advantages – which play a major part in the limitation of the glasshouse effect – can easily be realized by the application of renewable energy sources.

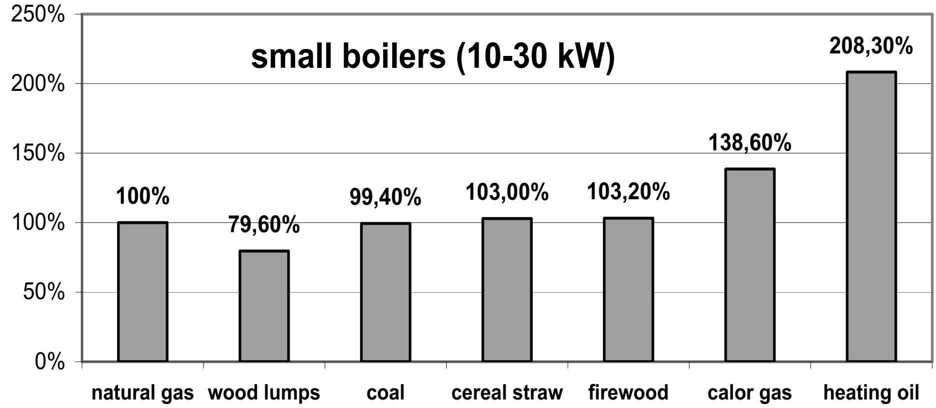


Fig. 5: The comparison of the expense of the heat production on natural gas base in case of different energy sources and 10-30 kW boilers

The costs of heat produced from the biomass are also highly dependent from the production costs of raw-materials, from the connected logistic costs, and from the construction and size of firing appliances, from the efficiency of firing and last but not least from the servicing and operational costs of the appliances.

The production costs of heat produced of renewable fuels are inversely proportional with the size of firing appliances. Among the renewable energy sources *young trees* can be used for heat energy production at the lowest cost. The price of heat energy produced by young trees can even compete with natural gas. The heat energy produced by burning straw-bales is in case of big size boiler – with a performance of 1-6 MW - *more economical than natural gas*.

Examining the inner cost structure of heat production it can be stated that by renewable energy sources the operational and maintenance costs of the firing appliances are far higher than those of firing appliances operating by traditional fuels. In the latter case the majority of the costs (85-95 %) arises from the price of fuels.

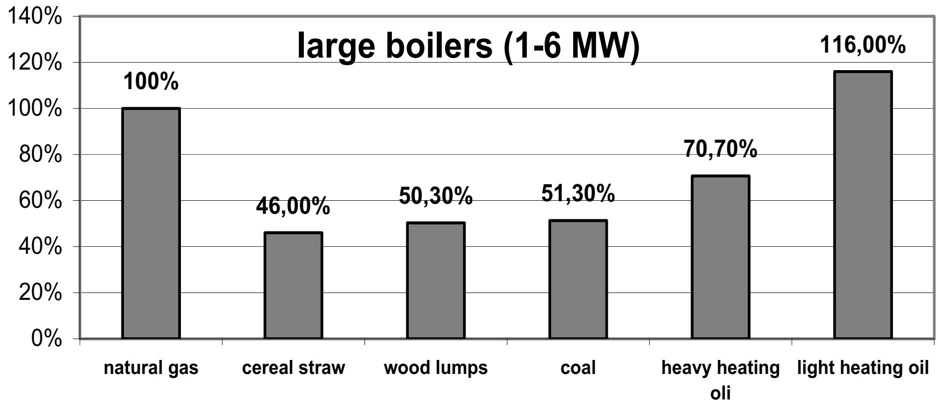


Fig. 6: The comparison of the expense of the heat production on natural gas base in case of different energy sources and 1-6 MW boilers

CONCLUSIONS

It can be stated that bio-ethanol and bio-diesel as fuels for internal combustion engines can be produced in Hungary at a competitive price by the utilization of biomass of agricultural origin as well as chopped wood on energy plantations and baled wheat straw apt for burning for the production of heat energy. The Hungarian agriculture could provide for 10 % of the domestic energy demand to be covered by these renewable energy sources.

ACKNOWLEDGEMENT

The authors would like to express theirs gratitude to the National Office for Research and Technology (NKTH) for the financial support (Sl 12/2008).

REFERENCES

1. Daróczi M.: (2007). Basic Tasks of the Agricultural Investment Process, Hungarian Agricultural Engineering. No. 20., p. 65-66.
2. Fenyvesi L.. Hajdú J.: (2005). Ökonomische Zusammenhänge der Nutzung von Biomasse, Biomasse – Energie aus der aus Landwirtschaft, Dreigrenze-Konferenz, Slowakei und Ungarn, Tagungsband, Nyitra, 3-4. May 2005, p.133-138.
3. Fenyvesi L., Pecznik P.: (2000). Potential Use of Renewable Energy Sources in Hungary, 1 st World Conference on Biomass for Energy and Industry, Sevilla, 2000. June 5-9. (1): 253-255.
4. Fenyvesi L., Pecznik P.: (2002). Energy Requirement of biomass compressing, Twelfth European Biomass Conference, Proceedings of the International Conference held in Amsterdam, The Netherlands 17-21 June 2002. (1): 498-500 p.
5. Fenyvesi L., Pecznik P.: (2004). Is Hungary the source of bioenergy for Europe?, Second World Biomass Conference, Proceedings of the World Conference held in Rome, Italy 10-14 May 2004. (1): 542-545.
6. Hajdú J., Fenyvesi L., Pecznik P.: (2005). Impaction of EU Joining for Renewable Energy Utilisation in Hungary, The 4th Research and Development Conference of Central and Eastern European Institutes of Agricultural Engineering. Moscow, 12-13. May. 2005. 25-32.
7. Hajdú J., Magó L.: (2006) The Possibilities of Use of the Biomass in Hungary, Proceedings of the 34th International Symposium "Actual Tasks on Agricultural Engineering", Opatija, Croatia, 21-24. February 2006. Proc. 111-120.
8. Hajdú J., Magó L.: (2006) Az energiatermelő mezőgazdaság", Mezőgazdasági Technika, mezőgazdasági műszaki fejlesztési és kereskedelmi folyóirat, 47 (8): 2-4.
9. Hajdú J., Magó L.: (2008) „Agricultural Biomass Potential in Hungary", Proceedings of 10th International Congress on Mechanization and Energy in Agriculture, Antalya, Turkey, 14-17 October 2008., p. 512-517.
10. Husti I.:, Kovács I.: (2009) „ Adaptation of Integrated Enterprise Management Systems for Farm Machinery Management", Abstracts of the International Conference "Synergy and Technical Development in the Agricultural Engineering", Gödöllő, Hungary, 31. August - 3. September 2009. p. 101.; Full Paper in CD Issue.
11. Jejčič V.: (2009) Development of Hot Bulb Engines for Tractors, Proceedings of the 37th International Symposium "Actual Tasks on Agricultural Engineering", Opatija, Croatia, 10-13. February 2009. Proc. 67-75.
12. Poje T., Jejčič V.: (2009) The Situation and Perspective in the Field of Agricultural Biogas Production Plants in Slovenia, Proceedings of the 37th International Symposium "Actual Tasks on Agricultural Engineering", Opatija, Croatia, 10-13. February 2009. Proc. 241-246.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 523.98:551.521.1](470)(497.2)
Prethodno priopćenje
Preliminary communication

MONTHLY PROFILE OF THE SOLAR IRRADIATION AT ROUSSE, BULGARIA

NICOLAY MIHAILOV

Angel Kunchev University of Rousse, 7017 Rousse, 8, Studentska str., Bulgaria
E-mail: mihailov@ru.acad.bg

SUMMARY

The results from the statistical analysis of the average daily measures of the global solar irradiation G(t) for every month for the period 2005-2008 are summed up. The parameters of the laws for distribution of G are estimated. The high potential of the diverse energy application of the solar irradiation is proved.

***Key words**: sunny irradiation, statistical analysis, monthly profile.*

INTRODUCTION

From a few years on in The University of Rousse “Angel Kunchev” are organized regular studies for the level and dynamics of the global solar irradiation G [21.The constructed database, received with experiments, is used for evaluation of the basic characteristics and parameters of the considered random process G(t). In this work the results from 2005 – 2008 are being summed up.

METHODS

The measures are realized with specialized system Kipp&Zonnen, created by the pyranometer CM11 and a professional software SOLRAD [1].The probabilistic analysis of the solar irradiation is conducted with the help of the programming product STATISTICA 8.0 [2].The results refer to a location with geographical coordinates 43° 49' 22" N, 26° 1' 19" E and average altitude 46 m. Noting the dynamics of the process time discretization $\Delta t = 1$ min (Fig. 1) was chosen.

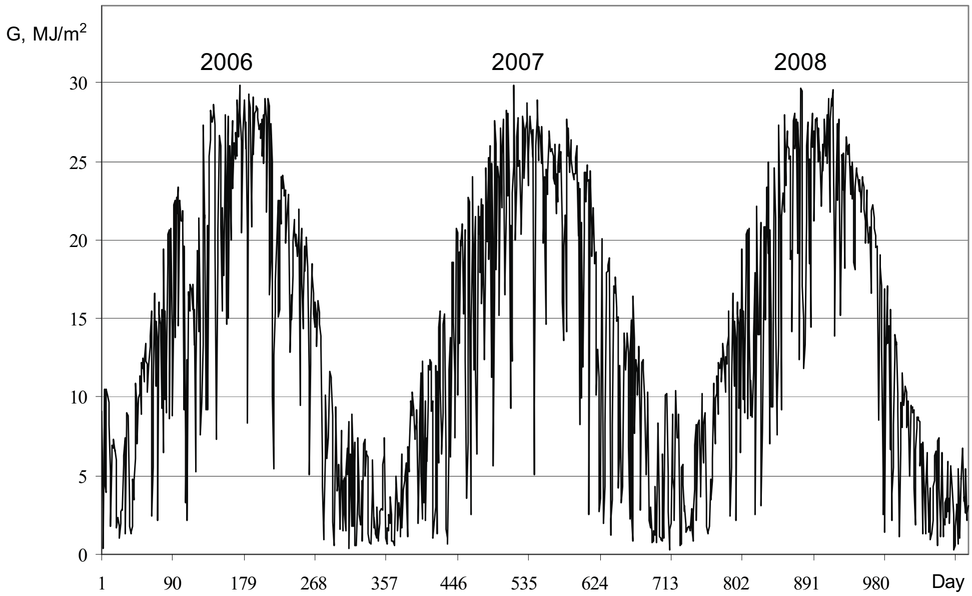


Fig. 1 Average values realized of the global solar irradiation

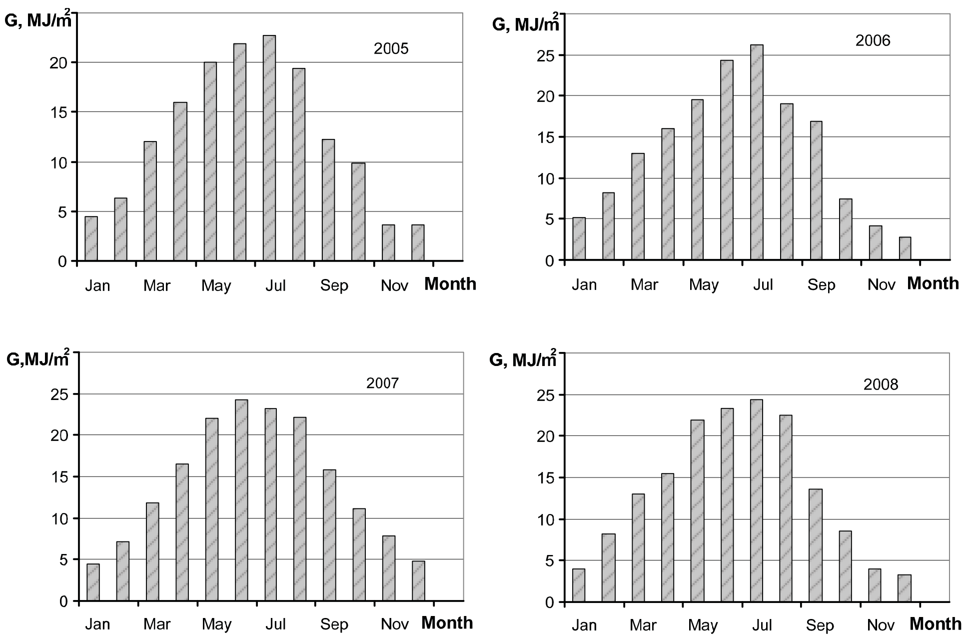


Fig. 2 Dynamics of the average values of the global solar irradiation for every month

RESULTS AND DISCUSSION

A number of agricultural household users, basic technological processes are being characterized with strong dependence of the electrical consumption from the climate and seasoning. For example, the air conditioning of the farms during the summer season, the irrigation and etc. That is why it is important when deciding about diverse engineer-economic tasks, connected to the application of PV systems, that the statistical information for the parameters of the monthly solar irradiation is available. (Fig. 2, Fig. 3).

And in this case the high average daily measures of the global solar irradiation for the period (March – September) and the relatively low rates of the respective standard deviations show the high potential for diverse energy applications. Most often the distribution of the random magnitude average global solar irradiation G_m is normal (Table 1, Fig. 4).

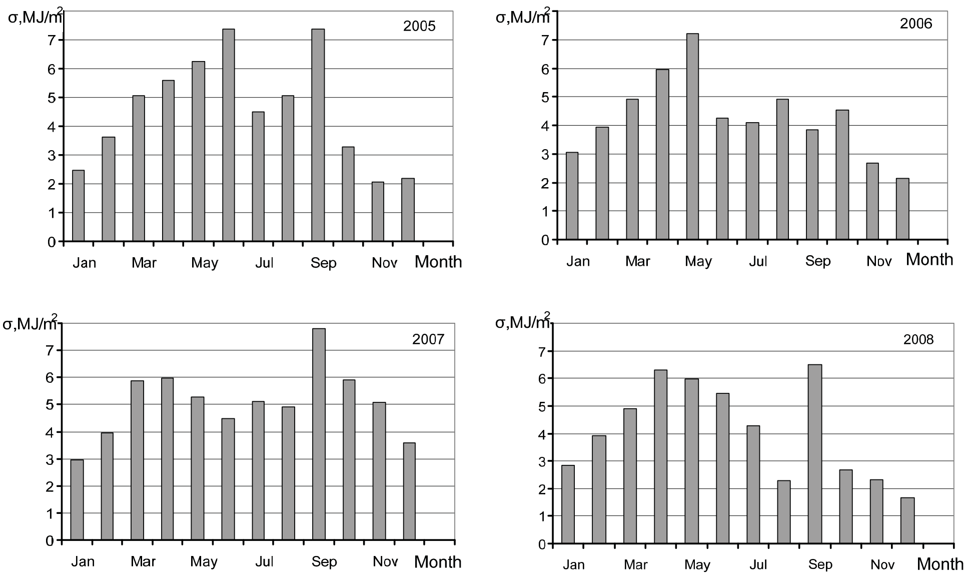


Fig. 3 Dynamics of the standard deviation σ_m for every month

The minimum value of G_m = 0,31 MJ/m^2 is during December (table 1). The maximum registered value is 29,82 MJ/m^2 and is observed in June. From March to September the average rate of global solar irradiation are high and are in the range of (11,83 – 24,21) MJ/m^2. During this period σ_g=(4,48 – 7,8) MJ/m^2, i.e. a significant part of the year is distinguished with high values of the disposable solar resource.

The inconsistency of the monthly solar irradiation is differentiated with a number of distinctive features. It is smallest during the summer season (June – August) and keeps practically one and the same values of K_v = (10.26 -19.82) % (Fig.5).

Table 1 Results from the statistical processing of the average global solar irradiation G_m (2007)

Month	Valid No	Mean	Confi.- 95%	Confi.95 %	Min.	Max.	Variance	Std. Dev	Coef. Var.	Std. Error	Skew- ness	Std. Err. Skewness	Kurtosis	Std. Err. Kurtosis	Nor: distr.
Jan	31	4.48	3.40	5.56	0.52	10.33	8.67	2.94	65.72	0.53	0.49	0.42	-0.80	0.82	Yes
Feb	28	7.22	5.68	8.75	1.06	12.36	15.64	3.95	54.80	0.75	-0.20	0.44	-1.46	0.86	Yes
Mar	31	11.83	9.68	13.99	0.69	20.70	34.41	5.87	49.57	1.05	-0.21	0.42	-0.81	0.82	Yes
Apr	30	16.52	14.29	18.74	2.50	24.00	35.54	5.96	36.09	1.09	-0.91	0.43	-0.01	0.83	Yes
May	31	22.05	20.12	23.98	5.66	28.20	27.71	5.26	23.88	0.95	-1.27	0.42	1.83	0.82	Yes
Jun	30	24.21	22.54	25.88	9.25	29.82	20.05	4.48	18.49	0.82	-1.93	0.43	4.45	0.83	Yes
Jul	31	23.33	21.46	25.21	5.08	28.87	26.12	5.11	21.90	0.92	-2.37	0.42	5.99	0.82	No
Aug	31	22.17	20.36	23.97	8.22	27.72	24.13	4.91	22.16	0.88	-1.58	0.42	1.87	0.82	Yes
Sep	30	15.80	12.88	18.71	2.01	24.77	60.85	7.80	49.39	1.42	-0.57	0.43	-1.11	0.83	Yes
Oct	31	11.14	8.97	13.31	1.23	18.81	35.01	5.92	53.12	1.06	-0.33	0.42	-1.45	0.82	Yes
Nov	30	7.77	5.87	9.67	0.78	16.45	25.86	5.09	65.46	0.93	-0.11	0.43	-1.54	0.83	Yes
Dec	31	4.76	3.44	6.07	0.31	10.38	12.87	3.59	75.43	0.64	0.37	0.42	-1.50	0.82	Yes

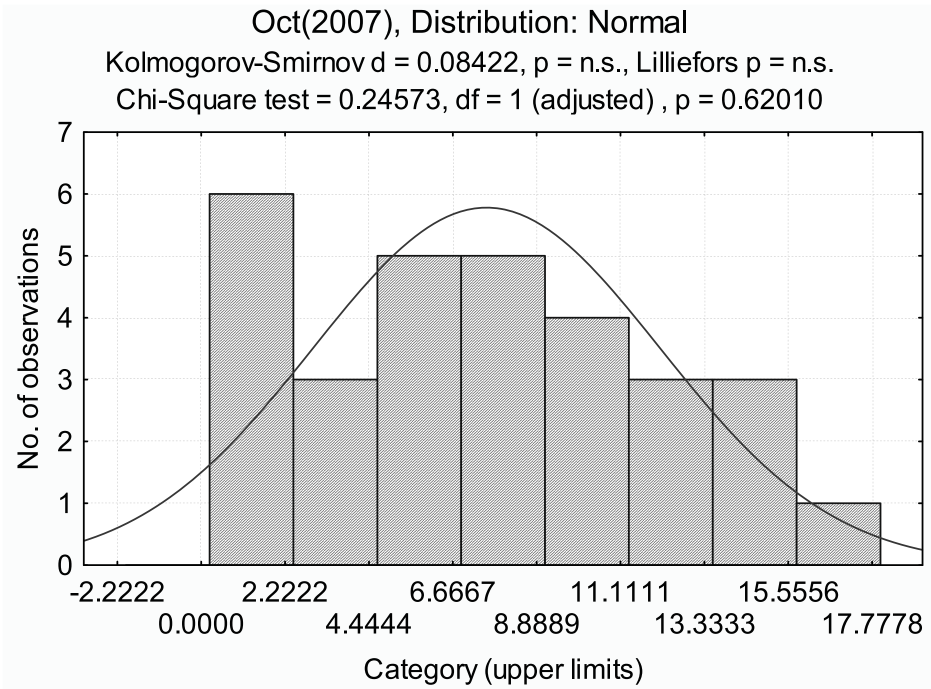


Fig. 4 Equalization of the empirical distribution of the average global solar irradiation with a normal law (for October 2007)

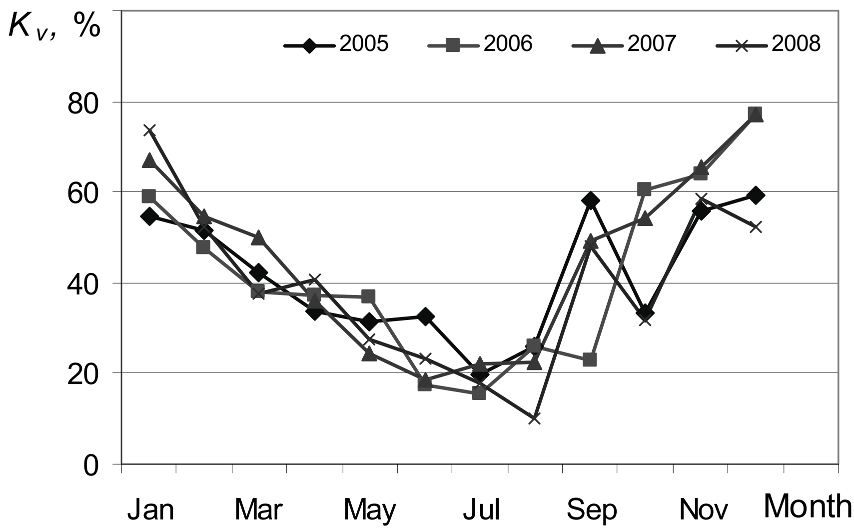


Fig. 5 Dynamics of the monthly coefficient of variation K_v

Because of the smaller scale of integrating the variable of the solar irradiation increases – the coefficient of variation changes in the range of (18,49 – 75,15)%.

CONCLUSIONS

1. The monthly dynamics of the global solar irradiation for the region of Rousse is studied. Its basic numerical characteristics are established.
2. With the help of the criteria of Kolmogorov – Smirnov and χ^2 it is established that most often the average solar irradiation every month is subject to of the normal law for distribution. The established parameters of the law allow for the calculation of the possibility for the acceptable value of *G* to appear.
3. The high average rates of G for the period (March – September) and the relatively small rates of the corresponding standard deviations show the high potential of diverse energy applications.
4. With the results obtained was constructed a database which can be used when projecting and exploiting micro energy projects in agriculture.

REFERENCES

1. Hill, T., P. Lewicki (2006):Statistics. Methods and applications. A Comprehensive Reference for Science, Industry and Data Mining. Stat Soft.
2. Mihailov, N., I. Stoyanov (2005): Evaluation of the Sunny Energy Potential for the Area of Rousse. The International Conference on Electrical Machines and Power Systems (ELMA 2005), 15-16 September, Sofia, Bulgaria, pp. 411-414.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 663.813
Izvorni znanstveni rad
Original scientific paper

EXPERIMENTAL STUDY ON RHEOLOGICAL PROPERTIES OF NATURAL VEGETABLE JUICES

GEORGE IPATE, TUDOR CASANDROIU, GHEORGHE VOICU, MADALINA TUDOSIE

Depart. of Biotechnical Systems, University “Politehnica” of Bucharest, Romania

SUMMARY

This paper describes the results of an experimental study on rheological behavior of the vegetable juices in order to have a suitable process design, operation and control. In the food industry, juices are the most important liquid derivatives of fruits and vegetables, and their flow characteristics have been an extensive topic of study in recent years. The aim of this work was to determine flow curves, the viscosity curve and other rheological properties of the vegetable juices as a function of temperature and concentration and to obtain simple equations to correlate experimental data. The vegetable juices used in this study were raw juices. The extraction process was performed using a unit powered by centrifugal force to yield the juice. Rheological properties were determined for red beet, carrot and cabbage juices, which was produced from beet fruit at 11.2 ± 0.5 °Brix, carrot at 10.2± 0.5 °Brix, respectively, cabbage at 6.5± 0.5 °Brix soluble solid content. Density measurements were carried out by a pycnometer method and are usually in range of 984 - 1.0334 g cm^{-3}. In order to obtain different concentrations, concentrated juice was diluted with distilled water. Rheological measurements were carried out using a Haake Viscotester model VT550, a Searle type rheometer. Based on the obtained result it was shown, that fresh vegetable juice has a non-Newtonian behavior. In the tested ranges, the samples, after a period storage will behave as pseudo plastic fluids and power-law model was satisfactorily fitted to the experimental data. Non-linear regression was performed to fit experimental data obtaining a good fit. Both temperature and concentration showed a strong influence on rheological properties of natural vegetable juices.

Key words: *vegetable juices; rheology; red beet; carrot; cabbage; temperature; viscosity; flow curves; properties*

INTRODUCTION

Vegetable juicing is critical to good health because it is an important source of raw food. Each of us needs raw foods every day, and juicing is an excellent way to make certain us to receive large quantities of such raw foods. Therefore, vegetable juice industry has become one of the world's biggest agribusinesses. In order to have a suitable process design, operation and control, knowledge of rheological behavior of the vegetable juice is of fundamental importance. During processing stages, the rheological properties of most of the liquid foods exhibit substantial changes because of their dependence upon temperature and concentration. That is the case of orange juice (Rao et al., 1984), fruits purées (Guerrero and Alzamorra, 1998), clarified fruit juices (Ibarz et al., 1994), soursop juice (Gratao et al., 2005).

Many fluids of interest in industrial practice are non-Newtonian on account of the presence of pectin substances and/or suspended solid. Different empirical equations are available for the description of their rheological behavior, such as the Bingham model (Dogan et al., 2002) and the Ostwald-de Waele model, also known as the Power-Law, which is one of the most extensively used to describe the rheological behavior of fruit juices (Rao et al., 1984), and provides a reasonable representation of many practical shear thinning fluids; besides the Power-Law is very convenient to use due to its simplicity and straightforward application in engineering process design.

In general, the viscosity of liquids decreases with increase in temperature, and a measure of the temperature influence on the rheological parameters is usually obtained from the Arrhenius-type equation (Saravacos, 1970), while the concentration effect is generally written in terms of power-type or exponential relations (Vitali and Rao, 1982).

The aim of this work was to determine flow curves, the viscosity curve and other rheological properties of the red beet, carrot and cabbage juices as a function of temperature and concentration and to obtain simple equations to correlate experimental data.

MATERIAL AND METHODS

Raw material

In this study a sample of raw vegetable juices (11.3 ºBrix-from red beet, 10.2 ºBrix from carrot and 6.5 ºBrix from cabbage) was obtained from vegetable pulp using centrifugal juice extractors to yield the juice. Samples with a lower soluble solid content at 10.7, 8.7, 6.5, 5.7, 4.4 ºBx for red beet, at 8.8, 5.5, 4.5 , 3.8, 2.8 ºBx for carrot, respectively, 5.6, 4.8, 3.5, 3.1, 2.3 ºBx for cabbage, were obtained from the original extract by dilution with distilled water. The soluble solid content at room temperature (25º C) was determined using the Digital Sucrose Refractometer HI 96801, a rugged portable laboratory refractometer. The density of juices at different concentrations (2.3 to 11.3 ºBrix) was obtained by pycnometer method.

Rheological measurements

Rheological measurements were carried out using a Haake Viscotester VT550 (Thermo Electron Corp., Germany) Searle type rheometer, equipped with a coaxial cylinder sensor system. The instrument can be operated at different speeds, which are changed stepwise with a program controller. All control and data evaluation tasks are performed by a powerful 16 bit processor. The speed of the rotating cylinder varied from 1 to 300 rpm. A thermostatic bath containing distillated water was used to control the working temperature within the range 24 °C to 60 °C. Shear stress values at the surface of the internal cylinder were obtained by multiplying torque readings by the rheometer constant, whereas shear rate values were evaluated according to Krieger and Elrod (1953).

The widely known empirical expression for the stress tensor, the Power-Law model and Bingham plastic mathematical models, was used for describing the flow behavior of vegetable juices. For the Power-Law model, the shear stress depends on the shear rates as given by Eq. (1), in which τ (Pa) is the shear stress, K (Pas^n) is the consistency index, n (dimensionless) is the flow behavior index and γ (s^{-1}) is the shear rate (Bird et al, 2002):

$$\tau = K \cdot \dot{\gamma}^n \tag{1}$$

For the Bingham plastic mathematical model the shear rates as given by [Eq. (2)] (Hegedusic et al., 1995):

$$\tau = \tau_0 + \eta \cdot \dot{\gamma} \tag{2}$$

where, τ_o is shear stress at zero shear rate (Nm^{-2}) and η is plastic viscosity (mPa s).

The viscosity values η is not a directly measurable quantity but is calculated from the quotient from shear stress τ and shear rate γ from Newton's equation (Kutschmann and Petri, 1997):

$$\eta = \tau / \dot{\gamma} \tag{3}$$

Statistical Analysis

The analysis of variance (Two-way ANOVA) was carried out to test the possibility of significance of solid soluble effect. The statistical tests were used to perform all possible pair comparisons between means of different treatments.

RESULTS AND DISCUSSION

The Power-Law is a very simple empirical model extensively used for engineering calculations due to its simplicity of having only two parameters (K and n). It has been used for describing many liquid foods, such as apple, peach and pear purees (Saravacos, 1970), guava puree (Vitali and Rao, 1982), potato fibres (Mason et al., 2006), blackberry juice (Cabral et al., 2007) and many others.

Rheograms of red beet juices were obtained in the range of shear rates from 5.423 s^{-1} to 1623 s^{-1}. In the tested ranges, the samples behaved as pseudo plastic fluids, and the Power-Law model was satisfactory fitted to the experimental data, with $0.72 \le R^2 \le 0.98$ and $216 \le$ RMS≤ 313 . The fitting of Eq. (1) to the experimental data permitted the evaluation of K and n, which are presented in table 1.

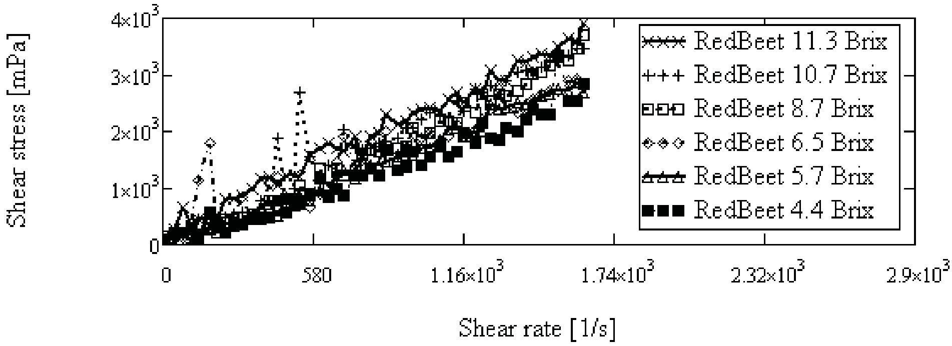


Figure 1 Flow curve for red beet juices at 28ºC

The Bingham model was also fitted to the experimental data and provided good statistical results ($R^2 \approx 0.95$ and RMS ≈ 219), since it is a two-parameter model, though the yield stress values were negative, which is meaningless from a physical standpoint.

The experimental shear stress and viscosity for red beet juices having solid soluble content in range to 4.4 ºBrix and 11.3 ºBrix are presented in figure 1 and figure 2, respectively; similar rheograms for the different temperatures were obtained for the samples.

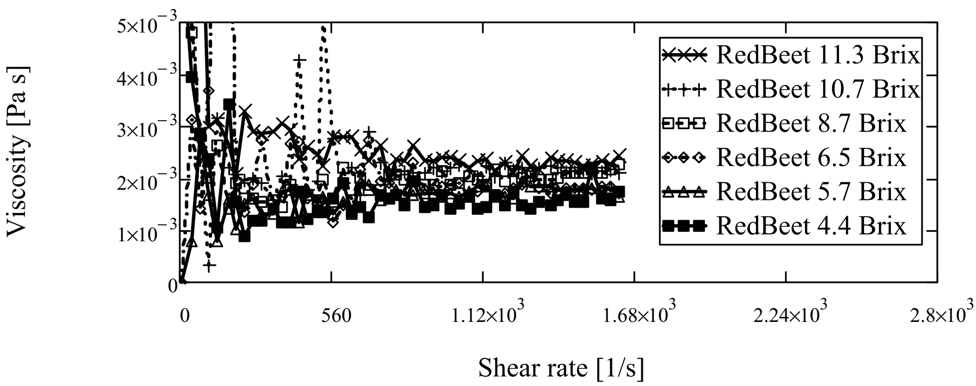


Figure 2. Viscosity curve for red beet juices at 28ºC

Figure 3 shows the flow curves in terms of shear stress – shear rate relationships for carrot juices (2.8, 3.8, 4.5, 5.5 and 8.8 ºBrix). For all samples, a shear-thinning or pseudo plastic behavior is found with presence of a Newtonian plateau at low shear rate values.

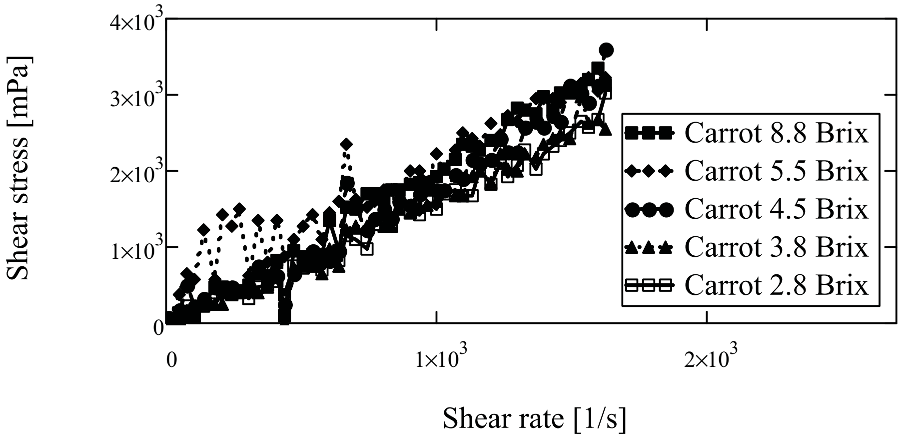


Figure 3 Flow curve for carrot juices at 28ºC

The Power-Law model was adequate to fitting the experimental data, with $0.70 \leq R^2 \leq 0.98$ and $180 \leq$ RMS≤ 286. Evaluation of K and n, are also presented in table 1, and is obtained by fitting of Eq. (1) with the experimental data. The Bingham model fitted to the experimental data provided good statistical results ($R^2 \approx 0.95$ and RMS $\approx$196). The flow curves shown on figure 3 indicated the Newtonian behaviour of carrot juice at shear rate 100 to 300 rpm. This same behaviour has also been reported for strawberry juice by Juszczak and Fortuna (2003). Over the range of shear rates investigated, viscosity values of the samples seem to be very close whereas those of the dilute suspension at 2.8 ºBrix are slightly lower. Viscosity curves are presented in fig. 4, and experimental values are found in range of 0.002022 (Pas) for juice at 8.8 ºBrix and 0.001607 (Pas) for juice at 2.8 ºBrix.

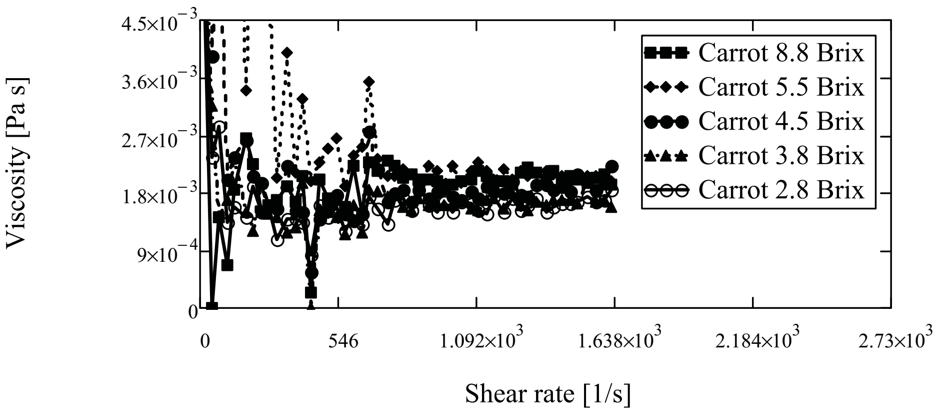


Figure 4 Viscosity curve for carrot juices at 28ºC

In the vegetable cabbage juice, the consistency index was high as a rule of fibre presence ($K=733.9$ Pas^n). The addition of distilled water had a unique reducing effect on the K-value, which was opposite to the effect seen in the other juices. The highest viscosity effects of the water addition was found in the vegetable juice that had viscosity slopes of 3.5-4 in response to fibre level content, while the other samples' viscosity slope responses ranged from 1-2.

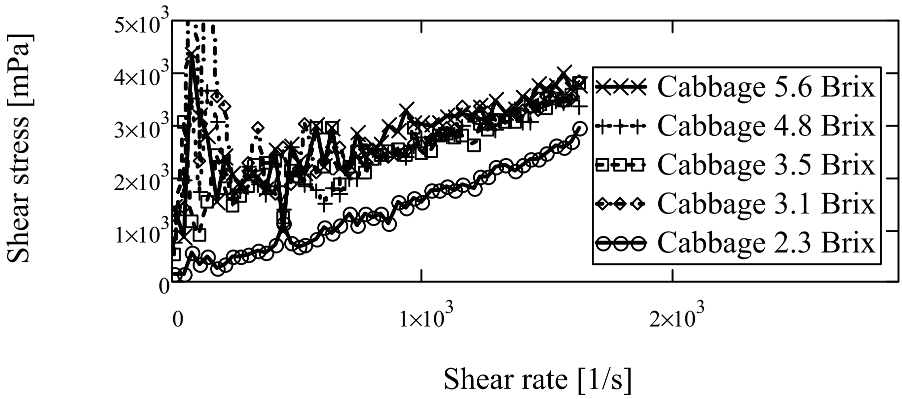


Figure 5 Flow curve for cabbage juices at 28ºC

Figure 5 shown the rheograms at concentration 5.6, 4.8, 3.5, 3.1 and 2.3 ^{o}Brix and at temperature 28 ^{o}C. Similar curves were obtained for samples at other temperature. The results shown that the values of shear stress decreases with decreases in soluble solid content.

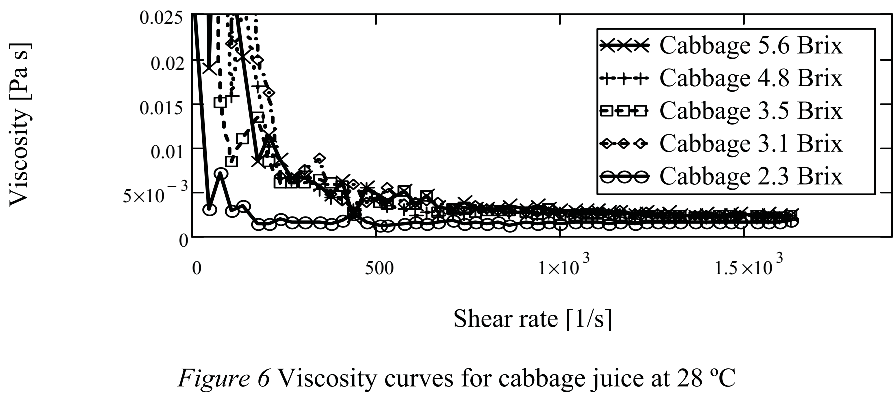


Figure 6 Viscosity curves for cabbage juice at 28 ºC

Figure 6 shown the viscosity curves of cabbage juice at temperature 28 ^{o}C. The results shown that the values of viscosity decreases with decreases in soluble solid content, from 0.002862 (Pas) at 5.6 ºBrix to 0.001624 (Pas) at 2.3 ºBrix.

Table 1 Regression coefficients (K and n) based on the tested model at 28 oC

Model		Power law				Bingham		
Red Beet		Parameters				Parameters		
°Brix	K [Pa s^n]	n	RMS	R^2	τ_0 [Pa]	η_p [Pa.s]	RMS	R^2
11.3	5.392	0.882	313.263	0.982	197.802	2.157	313.326	0.984
10.7	3.958	0.916	292.753	0.927	93.422	2.1	292.706	0.926
8.7	0.644	1.162	272.701	0.99	-117.216	2.141	272.481	0.984
6.5	4.493	0.873	216.414	0.875	196.931	1.649	218.72	0.88
5.7	0.79	1.111	2.36E-03	0.722	-93.843	1.824	6.831	0.987
4.4	0.689	1.119	214.076	0.952	-57.362	1.65	213.966	0.947
Carrot		Parameters				Parameters		
°Brix	K [Pa s^n]	n	RMS	R^2	τ_0 [Pa]	η_p [Pa.s]	RMS	R^2
10.2	0.066	1.424	180.727	0.959	-224.551	1.544	180.102	0.939
8.8	1.176	1.076	270.106	0.977	-98.17	2.106	270.111	0.977
7.2	18.642	0.692	286.67	0.902	474.519	1.695	287.034	0.914
5.5	0.723	1.134	214.528	0.963	-56.948	1.926	214.919	0.956
4.5	0.747	1.111	2.38E-03	0.694	-79.335	1.715	6.833	0.966
3.8	0.664	1.126	219.694	0.98	-81.73	1.697	217.391	0.977
Cabbage		Parameters				Parameters		
°Brix	K [Pa s^n]	n	RMS	R^2	τ_0 [Pa]	η_p [Pa.s]	RMS	R^2
6.2	166.462	0.38	296.115	0.521	1.03E+03	1.215	297.416	0.585
5.6	698.641	0.213	400.574	0.399	1.86E+03	1.144	402.32	0.519
4.8	733.967	0.19	359.582	0.325	1.70E+03	0.989	361.43	0.462
3.5	340.793	0.304	353.264	0.65	1.45E+03	1.263	350.843	0.702
3.1	255.698	0.358	2.38E-03	1.62E-04	2.72E+03	0.238	6.831	8.71E-03
2.4	1.468	1.015	221.331	0.973	58.071	1.583	219.142	0.972

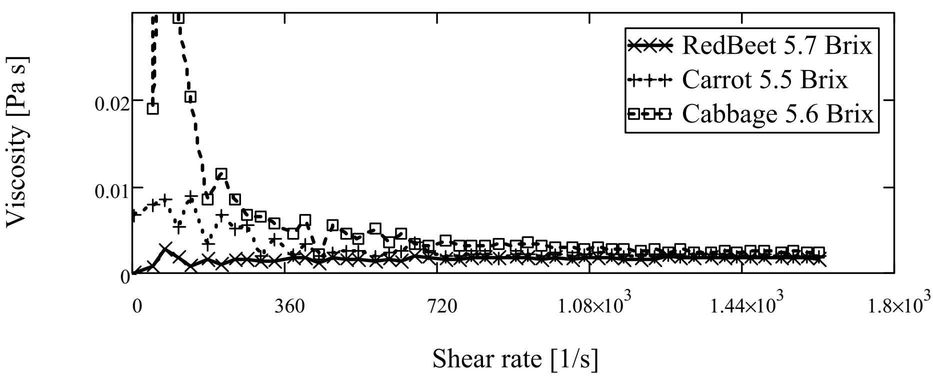


Figure 7 Viscosity curves of red beet, carrot and cabbage juices at 5.6 °Brix

Master-curves can be very useful in comparing data from different products such as crude extract juice made from different varieties of fruits. In the figure 7 are shown the viscosity curves of vegetable juices at same level of soluble content, 5.7 °Brix, and we can conclude that apparent viscosity for this groups increased with the fiber content of suspension, from 0.00174 (Pas) - red beet to 0.001851 (Pas) - carrot and 0.002862 (Pas) - cabbage.

An Arrhenius relationship [Eq. (4)] was used to describe the influence of temperature on apparent viscosity η (Pa s) at a shear rate of 100 s^{-1}:

$$\eta = A \cdot \exp^{\left(\frac{Ea}{RT}\right)} \tag{4}$$

where A is the pre-exponential or frequency factor associated with collision rates, E_a is the activation energy (kJ/mol), R is gas constant (8.314 kJ/molK) and T is temperature (K).

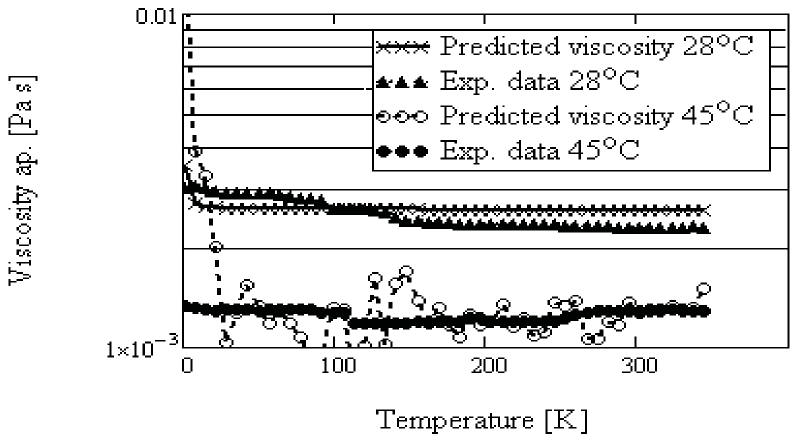


Figure 8 Influence of temperature on viscosity of red beet juices at 28 ºC, and 45 ºC

The activation energy (E_a) for viscous flow, based on the apparent viscosity at 100 s^{-1} shear rate (Steffe, 1996), was then calculated for red beet juice with 11.3 Brix. The E_a values corresponding to these Brix numbers were 2.5, 2.7, and 10.4 kJ/mol, respectively. The frequency factor A also increased with the concentration of dissolved solids from 0.00156 to 0.002104 (Pas) for 4.4 and 11.3 ºBrix juices, respectively. The E_a value for the 8.7 ºBrix juices differed from that of the 5.7ºBrix juices by 0.331 kJ/mol.

The influence of temperature on viscosity of red beet juice at two temperatures, 28 and 45 ºC, is illustrated in Fig. 8 for a shear rate of 100 s^{-1}. At 28ºC, the viscosity of red beet juices at 100 s^{-1} increased by about 0.00129 (Pa s) as temperature was increased from 28 to 45 ºC. For the carrot flow, the E_a values are in range of 2.7 and 12.4 kJ/mol, respectively. The frequency factor A calculated for the Brix numbers corresponding, also increased with the concentration of dissolved solids from 0.00158 to 0.00162 (Pas). For the cabbage flow, the Ea values are in range of 2.25and 2.74 kJ/mol, respectively. The frequency factor A, also increased with the concentration of dissolved solids from 0.00174 to 0.00427 (Pa s).

Table 2 Anova for viscosity data of vegetable juices

'Source'	'SS'	'df'	'MS'	'F'	'Prob>F'
'Columns'	6.68E-05	5	1.34E-05	3.9113	0.0019916
'Rows'	1.81E-04	9	2.02E-05	5.9026	1.91E-07
'Interaction'	0.0001663	45	3.70E-06	1.0825	0.34466
'Error'	0.0008195	240	3.41E-06	[ ]	[ ]
'Total'	0.001234	299	[ ]	[ ]	[ ]

An analysis of variance (Two-Way ANOVA) was be used to test the influence of solid soluble content in changes of viscosity of vegetable juices, and results are presented in table 2 for red beet. Computing the entries in the table, obtaining the *p*-value corresponding to the calculated F-ratio of the mean squared values. As might be expected, the *p*-value is small, and rejects the null hypothesis that all means are the same for the different groups. In our example above, that test is highly significant, and we would in fact conclude that the means for the groups are significantly different from each other, which correspond to assumption of strong influence of concentration to viscosity.

The *p*-value for the model effect is zero to three decimal places. This is a strong indication that the viscosity varies from one model to another. An *F* statistic as extreme as the observed *F* would occur by chance less than twice in 1000 times if the viscosity were truly equal from model to model. The *p*-value for the factory effect is 1.19E-07, which is also highly significant. This indicates that one factory is out-performing the other in viscosities of the solid content it produces. The observed *p*-value indicates that an *F* statistic as extreme as the observed *F* would occur by chance about once out of 7000 times if the viscosity were truly equal from factory to factory. There does not appear to be a strong interaction between factories and models. The *p*-value, 0.3446, means that the observed result is quite likely (34 out 100 times) given that there is no interaction. Results for carrot and cabbage juices are similarly.

Dendrogram consists in U-shaped lines connecting objects in a hierarchical tree from red beet juice shear stress is presented in figure 9. In this figure, the numbers along the horizontal axis represent the indices of the objects in the original data set. The height of each U represents the distance between the two objects being connected. The link representing the cluster that groups object 2, 30, 28 and 27 together with objects 14, 17, 18 and 19, (which are already clustered as objects 23, 22, 25, 24, and 21) has a height of 2320. The height represents the distance linkage computes between objects 2 and 18. The cophenetic correlation coefficient c = 0.71924, shows that using a different distance and linkage method creates a tree that represents the original distances slightly better.

The inconsistency coefficient compares the height of a link in a cluster hierarchy with the average height of links below it. Links that join distinct clusters have a high inconsistency coefficient 1.1546; links that join indistinct clusters have a low inconsistency coefficient 0.6984 (groups object 10, 13 and 15).

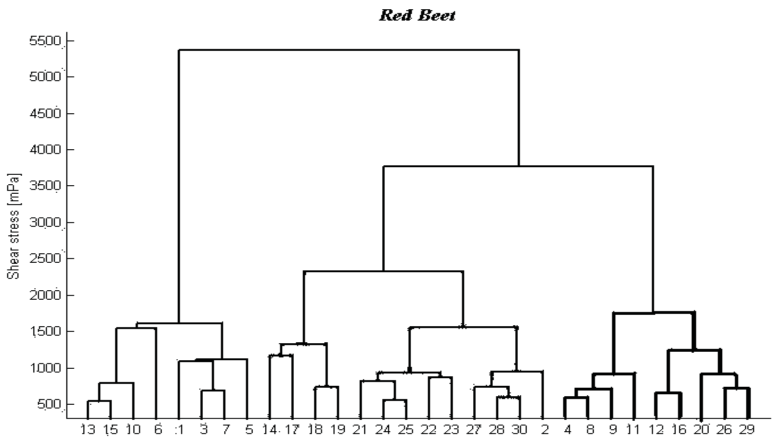


Figure 9 Dendrogram of shear stress groups for red beet

CONCLUSIONS

On the basis of the results obtained it was shown that concentrated vegetable juices exhibits Newtonian behavior. The effect of the content of soluble solids can be described by the power law or exponential functions but a better fit was obtained for the exponential function.The values of viscosity strongly depend on temperature and soluble solids content and were in the range from 0.001746 to 0.00242 (Pa s) for red beet juices, in the range from 0.001547 to 0.00192 (Pa s) for carrot juices, and in range from 0.00181 to 0.00233 (Pa s) for cabbage juices.

The effect of temperature on viscosity can be described by the Arrhenius equation while the values of flow activation energy ranged from 2.5 to 10.08 kJ mol^{-1} for red beet juices, from 2.7 to 12.4 kJ mol^{-1} for carrot juices, respectively, 2.5 kJ mol^{-1} for cabbage juices.

In order to express the combined effect of temperature and soluble solid content on viscosity in the further work will be determined two equations. The structure of the fibers and the extent to which they were previously processed seem to be the key parameters determining the rheological properties of these raw vegetable juices.

REFERENCES

1. Bird, R.B., Stewart, W.E., Lightfoot, E.N. (2002). Transport Phenomena. John Wiley & Sons, New York, USA.
2. Cabral, A.F., Orrego-Alzate, C.E., Gabas, A.L., Telis-Romero, J. (2007). Rheological and thermophysical properties of blackberry juice. Ciênc. Tecnol. Aliment., Campinas, 27(3): 589-596.
3. Dogan, N, Mccarthy, M. J., Powell, R. L. (2002). In-line measurement of Rheological parameters and modeling of apparent wall slip in diced tomato suspensions using ultrasonics. Journal of food science, vol.67, (6), pp.2235-2240.

4. Gratao, A.C.A., Silveira Jr., V., Telis-Romero, J. (2005). Rheology of soursop juice and friction factors in circular pipe flow. 4th Mercosur Congress on Process Systems Engineering, Costa Verde, Brasil.

5. Guerrero, S. N., Alzamora, S. M. (1998). Effect of pH, temperature and glucose addition on flow behavior of fruit purees: II. Peach, papaya and mango purées. J. Food Eng., 37: 77-101.

6. Hegedusic, V., Lovric, T., Parmac, A. (1995). Influence of phase transition (freezing and thawing) on thermophysical and rheological properties of apple puree – like products. Acta – Aliment, 22: 337-349.

7. Ibarz, A., Pagan, J., Miguelsanz, R. (1994). Rheology of clarified juices. III. Orange juices. J. Food Eng., 21, 485-494.

8. Juszczak, L., Fortuna, T. (2003). Viscosity of Concentrated Strawberry Juice. Effect of Temperature and Soluble Solids Content. Electronic Journal of Polish Agricultural Universities, Food Science and Technology, 6(2).

9. Krieger, I., Elrod, H. (1953) "Direct determination of the flow curves of non-Newtonian fluids. II Shearing rate in the concentric cylinder viscometer," J. Appl. Phys. 24, 134–136.

10. Kutschmann E. M., Petri H. M. (1997). Measuring uncertainties with the VT55 HAAKE Application report V97-140E.

11. Mason, S.L., Degutyte-Fomins, L., Meyer, A.S. (2006). Viscosity of Enzymatically-Extracted Potato Fibres in Fruit Juices. Annual transactions of the nordic rheology society, vol. 14. Stockholm, Sweden.

12. Rao, M. A., Cooley M. J., Vitali A. A. (1984). Flow properties of concentrated juices at low temperatures. Food Technol., 38, 3, 113-119.

13. Saravacos, G. D. (1970). Effect of temperature on viscosity of fruit juices and purees. J. Food Sci., 35,122-125.

14. Steffe, J.F. (1996). Rheological methods in food process engineering. Second edition. Freeman Press, East Lansing, MI 48823, USA.

15. Vitali, A.A., Rao, M.A. (1982). Flow behaviour of guava puree as a function of temperature and concentration. Journal of Texture Studies, 13: 275-289.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:665.753
Prethodno priopćenje
Preliminary communication

THE INFLUENCE OF EXTERNAL ENERGY CONDITIONING ON BIOFUELS PHYSICAL PROPERTIES

FLORIN MARIAŞIU, NICOLAE BURNETE

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

ABSTRACT

Even though currently there are pro and against in terms of wider use of biofuels, biofuels can and should become the basic fuel to power tractors and agricultural machines in terms of economic and environmental benefits obtained.

Based on numerous research effectuate the past 10-15 years is noted that the use of biofuels has beneficial effects in reducing pollutant emissions from internal combustion engines in the environment, but at the same time decreases engine power with values between 5-10% [2,4,11]. Taking into account that works in agriculture with the highest consumption of fuel and where it is necessary to use full engine power, are processing the soil, the further studies and experiments are necessary to optimize the use of biofuels.

This work presents the partial results obtained in a research project, results related to optimization of functional parameters of internal combustion engines fueled by biofuels by external energy conditioning. As sources of external energy conditioning used for biofuel conditioning was utilized ultrasonic waves. By conditioning biofuel it is possible to updates the physical properties (density, viscosity) with direct effect on the performance of power systems and fuel injection systems parameters of internal combustion engines

Key words: *external energy, conditioning, ultrasonic, speed of sound, biofuel*

INTRODUCTION

It is well know that the biodiesel is a biodegradable, sulfur-free, oxygenated and renewable alternative diesel fuel, consisting of the fatty acids (FA) from vegetable oil or (and) animal fats.

Biodiesel can be used in existing diesel engine without major technologically modification but the differences in physical properties between biodiesel and petroleum-based fuel may change the diesel engine's fuel injection timing process and combustion characteristics [1, 9].

These altered physical and chemical properties also may cause the exhaust emissions and performance to differ from the optimize settings chosen by the engine manufacturer [8, 11].

From this perspective the study presents experiments in order to optimize diesel engine performance and emission reduction by conditioning biodiesel by external energy intake in the form of microwave and ultrasound.

In conditions that biodiesel is irradiated by external energy, the biodiesel undergoes physical and chemical changes induced by the energy of the external source of irradiation. For example, the aromatic constituents become constituents of the fatty acids groups and the isoparaffins turn into normal paraffin [10], with immediate effect of cetane number and heating value increase. In same way the viscosity, surface tension and the Sauter Mean Diameter (SMD) of fuel spray decreasing.

Those physical and chemical processes reformed in good the biodiesel quality, promoting a better combustion and decreasing the soot emission [2, 10].

MATERIALS AND METHODS

The biodiesel physical parameters transformation is elevated trough the measurement of the sound speed. The sound speed measurement principle allow to obtain the value of isentropic bulk modulus (effect on combustion process), knowing also the value of density (of which variation have a direct effect on fuel injection process).

The sound speed measurement technique was adapted from the experiments made by Dzida, M., Prusakiewicz, P. (2008) [3] and Tat and Van Gerpen (2003) [6, 7, 8].

The sound speed measurements device used was Optel Opcard 1/100 type (figure 1) and the analyses of measured datas were made with the specific Optel developed software.

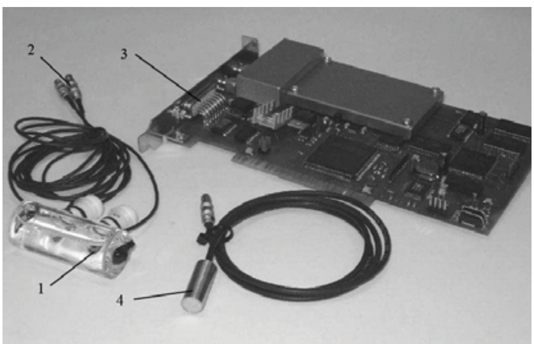


Figure 1 The speed sound measurement Optel system (1-tank with two opposite receivers, 2-connectors, 3-PCI board, 4-emiter)

The ultrasonic biodiesel conditioning system was created by adapting the Sonorex Bandelin apparatus. The power of ultrasonic device is 30/240 W, functions at AC 220V with ultrasonic frequency at 35 kHz.

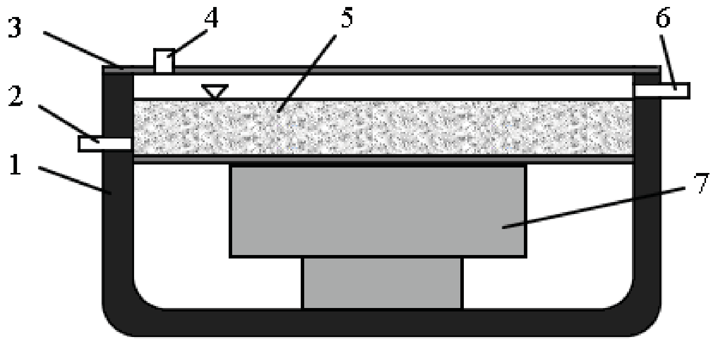


Figure 2 Schematic diagram of the ultrasonic conditioning fuel system (1-metallic case, 2-fuel outlet, 3-cover plate, 4-air hole, 5-biofuel, 6-fuel inlet, 7-ultrasonic transducer)

An IR thermometer Testo 810 type was used to measure the bulk surface temperature. The biodiesel used for this study was prepared from rapeseed oil and commercialized by KLAS Biodiesel Co. and the properties meet the requirements of EN 14214 standard. The petroleum-based diesel fuel was that is normally commercialized in OMV gas stations. The density of conditioned biofuels was Anton Paar DMA 48 apparatus. Measurements were conducted in laboratory and at atmospheric pressure.

The volume of biofuel conditioned by external energy intake was 500 ml and external irradiation on biofuel by energy intake was considered 15 minutes period.

The isentropic bulk modulus (in Pa) was calculated for each experimental level using Equation 1 [7].

$$\beta=\rho\cdot c^2, \tag{1}$$

were β is isentropic bulk modulus, ρ is density in kg/m^3 and c is the speed of sound in m/s.

RESULTS

Physical parameters considered to study following experiments were chosen as:

- Sound speed;
- Density;
- Isentropic bulk modulus (calculated using Eq. 1).

The results obtained from the experiment are shown in the figures 3 - 6.

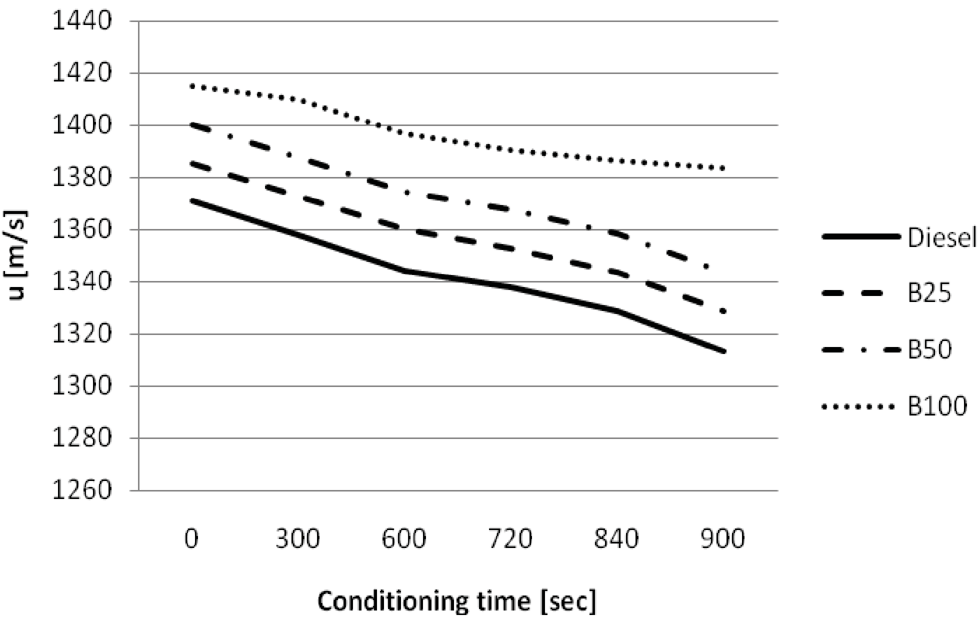


Figure 3 The speed of sound variation in case of ultrasonic conditioning

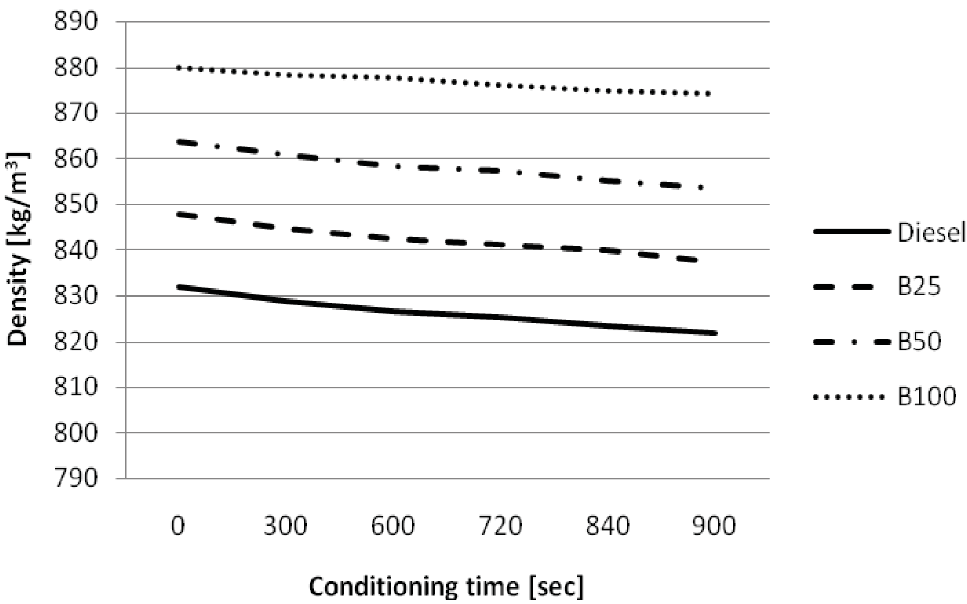


Figure.4 The biofuels density variation in case of ultrasonic conditioning

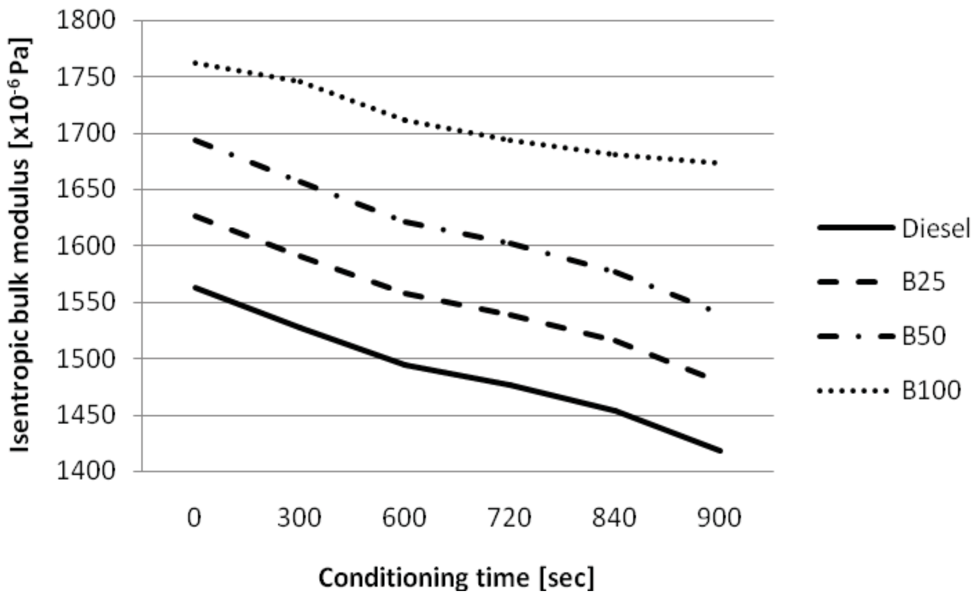


Figure 5 The isentropic bulk modulus variation in case of biofuel by ultrasonic conditioning

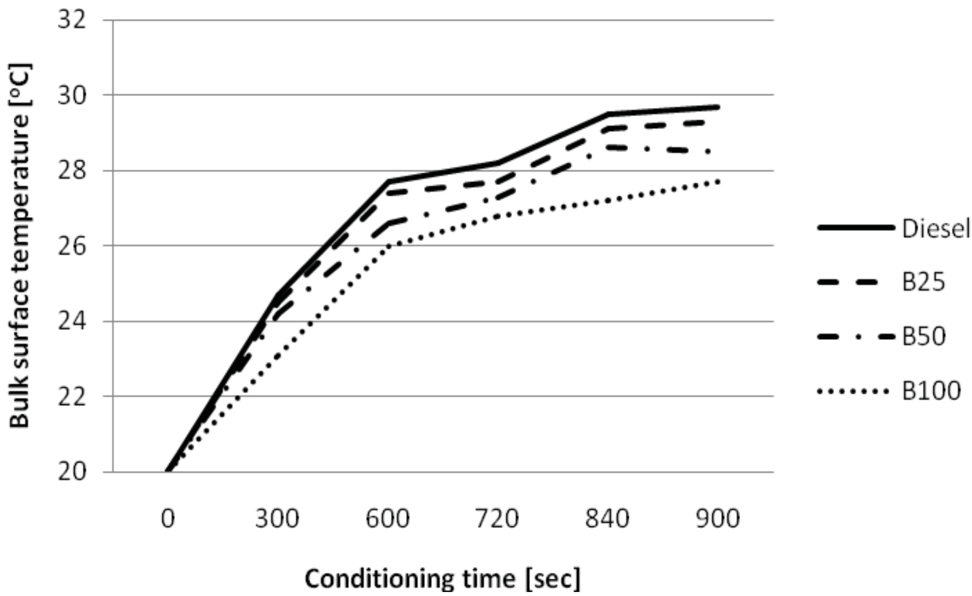


Figure 6 The ultrasonic thermal effect on conditioned biofuels

CONCLUSIONS

Following experiments on conditioning of vegetable oil based biofuels can be concluded that:

- Note that the effect of ultrasound on biofuels is highlighted by decreasing the density by both for biodiesel and for diesel oil.
- Decreased density of biodiesel conditioned by ultrasonic waves offers the first indicators of possibilities to improve the fuel injection parameters into the IC engine's combustion chamber (decrease of biofuel particle diameter SMD injected and reduced the degree of their coalescence).
- In the case of this experiment the volume of biofuels conditioned by ultrasonic waves was alleged at 500 ml (limitation induced by the proper use of ultrasonic device) but is needs further studies about the optimization of devices conditioning volume.
- Heat transfer process of ultrasound action is all the more the lower concentration of methyl ester increase in biodiesel composition. This phenomenon may be due to chemical reactions taking place at the molecular level due to the phenomenon of cavitation, which leads to the formation of new chemical compounds (peroxides) [5].
- Further research is needed on possible chemical transformations taking place in biofuels and their effects on modification of peroxide value (POV) and acid value (AV), parameters of importance in effect on the storage and use of biofuels. Also further studies are needed on the corrosive and wear that can affect engine components that are powered with biofuel conditioned by external energy intake.

ACKNOWLEDGEMENTS

This article was developed through the support and help given by Romanian National Council of Science and Research (CNCSIS) in the contract research No. 175/ PN-2008-II Ideas.

REFERENCES

1. Boehman, A. L., Moriss, D., Szybist, J. P. (2003). The impact of the bulk modulus of diesel fuel on fuel injection timing, Energy Fuels, Vol. 18, 1877-1882.
2. Demirbas, A. (2008). Relationships derived from physical properties of vegetable oil and biodiesel fuels, Fuel, vol. 87, 1743-1748.
3. Dzida, M., Prusakiewicz, P. (2008). The effect of temperature and pressure on the physicochemical properties of petroleum diesel oil and biodiesel fuel, Fuel, vol.87, 1941-1948.
4. Mariasiu, F., Burnete, N., Deac, T. (2009). Possibilities to determinate the biofuels physically parameters in functional conditions, in Proceedings of International Symposium "Trends in the European Agriculture Development", vol. 41(2), 451-456, ISSN 2066-1843, Timisoara, Romania.

5. Prosetya, H., Datta, A. (1991). Batch Microwave Heating of Liquids: An Experimental Study, Journal of Microwave Power and Electromagnetic Energy, vol.26, 215-226.
6. Tat, M. E., Van Gerpen, J. H. (2003). Speed Sound and Isentropic Bulk Modulus of Alkyl Monoesters at Elevated Temperatures and Pressures, JAOCS, vol. 80, nr. 12, 1249-1256.
7. Tat, M. E., Van Gerpen, J. H. (2003). Speed Sound and Isentropic Bulk Modulus of Mixtures of Biodiesel and Diesel Fuel, JAOCS, vol. 80, nr. 11, 1127-1130.
8. Tat, M. E., Van Gerpen, J. H. (2000). Measurement of Biodiesel Speed of Sound and Its Impact on Injection Timing, Final Report for National Renewable Energy Laboratory, subcontract no. ACG-8-18066-11.
9. Tate, R. E., Watts, K. C., Allen, C.A., Wilkie, K.I. (2006). The densities of three biodiesel fules at temperatures up to 300^{o}C, Fuel, vol. 85, 1004-1009.
10. Wong, C. L., Steere, D.E. (1982). The Effects of Diesel Fuel Properties and Engine Operating Conditions on Ignition Delay, SAE Paper no. 921231, USA.
11. Yamate, K., Ueta, A., Shimamoto, Y. (2001). Influence of physical and chemical properties of biodiesel fuels on injection, combustion and exhaust emission characteristics in a DI-CI Engine, in the proceedings of the fifth international symposium on diagnostic and modeling of combustion in internal combustion engines “COMODIA 2001”, July 1-4, Nagoya, 402-409.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.
Pre rad
Re paper

SPECTROPHOTOMETRIC DETERMINATION OF L-ASCORBIC ACID USING POTASSIUM THIOCYANATE AS A STABILIZER

MIRSAD SALKIĆ, AMRA SELIMOVIĆ, HUSEJIN KERAN

University of Tuzla, Faculty of Technology, Univerzitetska 8, 75000 Tuzla, Bosnia and Herzegovina

SUMMARY

A rapid, sensitive and accurate direct spectrophotometric method was developed for the determination of L-ascorbic acid in pharmaceutical preparations. Potassium thiocyanate (0.02 M) in phosphate buffer was used to stabilize ascorbic acid in aqueous solutions. The molar absorptivity of the proposed method was found to be 1.42×10^{4} dm^{3} mol^{-1} cm^{-1} *at 266 nm. Beer's law was obeyed in the concentration range of 0.25 – 12.0* $\mu g/cm^{3}$ *for L-ascorbic acid. The detection limit was 0.075* $\mu g/cm^{3}$ *and the relative standard deviation 0.73 % for a concentration of 8.00* $\mu g/cm^{3}$ *of L-ascorbic acid (n = 7).*

Many of the ingredients commonly found in vitamin C products do not interfere. The proposed method was successfully applied to assays of L-ascorbic acid in pharmaceutical preparations. The results obtained with the proposed method showed good agreement with those given by the titrimetric method using iodine.

Key words: *L-Ascorbic acid, Potassium thiocyanate, Stabilizer, Ultraviolet spectrophotometry*

INTRODUCTION

L-Ascorbic acid (vitamin C) is an important vitamin which participates in a great variety of biological events concerning electron transport reactions, hydroxylations, the oxidative catabolism of aromatic amino acids and so on. Vitamin C occurs in different concentrations in a variety of natural samples. It is added to several pharmaceutical products as an essential ingredient, a stabilizer for vitamin B complex and as an antioxidant. Many analytical methods have been reported in the literature for the determination of L-ascorbic acid. These include titrimetric (Verma, 1982), fluorimetric (Wu *et al.*, 2003), electrochemical (Li *et al.*, 2006), high-performance liquid chromatographic (Lykkesfeldt, 2000; Iwase, 2003), spectrophotometric (Fujita *et al.*, 2001; Janghel *et al.*, 2007; Arya *et al.*, 2001) and chemiluminescent (Kato *et al.*, 2005) methods. Spectrophotometric methods are commonly used for routine analyses.

The use of direct UV for the assay of ascorbic acid has not been easy due to its instability in aqueous solutions. The instability of L-ascorbic acid is due to its oxidation to dehydroascorbic acid which is a reversible reaction and subsequently to 2,3-diketo-L-gulonic acid. This later reaction is irreversible. These reactions can be inhibited by stabilizers.

The purpose of this work was to develop a direct and simple ultraviolet spectrophotometric method for the determination of L-ascorbic acid in vitamin C products with potassium thiocyanate as a stabilizer for ascorbic acid. The effects of a number of chemical substances commonly found in vitamin C preparations on the proposed method were assessed.

MATERIALS AND METHODS

Reagents

All reagents used were of analytical-reagent grade.

Buffer solution (pH = 5.4). A mixture of potassium dihydrogenphosphate (0.03 M) and disodium hydrogenphosphate (8.99×10^{-4} M) was prepared by dissolving 4.08 g of KH_2PO_4 (Fluka) and 0.16 g of $Na_2HPO_4 \cdot 2H_2O$ (Merck) in 1000 cm^3 of distilled water.

Potassium thiocyanate solution (0.02 M). Prepared by dissolving 2.10 g of KSCN (Fluka) in 1000 cm^3 of the buffer solution.

L-Ascorbic acid solution (1.13×10^{-3} M). A 0.05 g amount of L-ascorbic acid (Riedel-de Haën) was dissolved in 250 cm^3 of the potassium thiocyanate solution.

Iodine solution (0.017 M). About 4.5 g of reagent-grade iodine (Sigma) was transferred into a 100 cm^3 beaker containing 20 g of potassium iodide (Merck) dissolved in 25 cm^3 of water. The entire content was stirred and transferred into a glass-stopered amber liter bottle. The mixture was diluted to 1 dm^3 using distilled water.

Solutions of metal ions, anions, organic acids and sugars were prepared by dissolving calculated amounts of these substances in the (0.02 M) potassium thiocyanate solution.

Apparatus

All absorbances were determined on Cecil 2021 spectrophotometer, Cecil, using 1 cm path length. The pH measurements were made with a Quatro 220K pH meter, Mettler Toledo.

Procedure

Transfer a portion of the sample solution containing 60 – 300 μg of L-ascorbic acid to a 25 cm^3 standard flask. Dilute to the mark with the (0.02 M) potassium thiocyanate solution and measure the absorbance at 266 nm against the potassium thiocyanate solution as a blank.

Determination of L-ascorbic acid in tablets

Transfer an accurately weighed amount of powder obtained from several tablets into a 100 cm^3 volumetric flask, dissolve and make up to the mark with the (0.02 M) potassium thiocyanate solution. Filter and dilute a suitable aliquot of the filtrate to 50 cm^3 with the stabilizer solution. Take an aliquot of the final solution and determine the ascorbic acid content as described under Procedure.

Titrimetric method using iodine

Iodine solution (0.017 M) is standardized in the usual way with a primary standard of As_2O_3. Weigh an accurate amount of powdered vitamin C tablets and pour into a dry volumetric flask of the size chosen. When you are ready to titrate, dissolve powder by adding a volume of distilled water that is equal to about half the volume of the volumetric flask and shake. Fill to the mark. Pipet exactly 25 cm^3 of the vitamin C solution into a 250 cm^3 flask and add 5 cm^3 of starch indicator. Cover the opening of the flask with a piece of cardboard with a small hole for the buret tip. Titrate rapidly to reduce air oxidation of the ascorbic acid, but proceed dropwise near the end point, a deep blue starch-triiodide color.

RESULTS AND DISCUSSION

Optimization of conditions

Absorption properties of L-ascorbic acid are dependent upon the ionic species present and, therefore, dependent upon the pH of the aqueous media. Above pH 5.0, L-ascorbic acid exists predominantly as the monoanion and has maximal absorption at 265 nm. Undissociated, at more acid pH levels, maximal absorption occurs around 245 nm (Eitenmiller *et al.*, 1999). Since the position of maximum absorbance (λ_{max}) is pH-dependent, the potassium dihydrogenphosphate – disodium hydrogenphosphate buffer solution (pH = 5.4) was used throughout this work.

The degradation of L-ascorbic acid in aqueous solutions depends on a number of parameters. Oxygen partial pressure, pH, temperature, light and the presence of heavy metal ions are of great importance. Metal-catalyzed destruction proceeds at a higher rate than noncatalyzed spontaneous autoxidation. Traces of heavy metal ions, particularly Cu^{2+} and Fe^{3+}, result in high losses. L-Ascorbic acid can be stabilized with reducing reagents, amino acids, sugars and chelating agents (Francis, 2000; Miyake *et al.*, 1999). In the present work, potassium thiocyanate in the buffer solution was used to stabilize L-ascorbic acid in the aqueous media. The effect of potassium thiocyanate concentration on the stability of L-ascorbic acid was studied in the range of 0.001 to 0.025 M in the presence of 0.03 M KH_2PO_4 and $8.99x10^{-4}$ M Na_2HPO_4. When the concentration is within the range of 0.017 – 0.025 M, solutions of L-ascorbic acid remain stable for at least two hours at room temperature. Therefore, 0.02 M potassium thiocyanate concentration was selected for further investigation.

Analytical characteristics

By using the proposed method, linear calibration curve was obtained in the range 0.25 – 12.0 μg ascorbic acid/cm^3. The detection limit (three times the standard error of the intercept/slope), quantification limit (ten times the standard error of the intercept/slope), molar absorptivity (ε), as well as other analytical characteristics are summarized in Table 1. The precision of the proposed method, expressed as relative standard deviation, for the determination of 8.0 μg/cm^3 ascorbic acid, was 0.73% (n = 7). The molar absorptivity calculated from the slope of the calibration graph shows that the proposed method is highly sensitive. This procedure is more sensitive than other spectrophotometric methods, using 4-chloro-7-nitrobenzofurazane (Abdelmageed *et al.*, 1995) ($\varepsilon = 6.49 \times 10^3$ dm^3 mol^{-1} cm^{-1}), zinc chloride salt of diazotized 1-aminoanthraquinone (Backheet *et al.*, 1991) ($\varepsilon = 4.07 \times 10^3$ dm^3 mol^{-1} cm^{-1}), gold(III) ion (Pal *et al.*, 1988) ($\varepsilon = 2.30 \times 10^3$ dm^3 mol^{-1} cm^{-1}) and *peri*-naphthindan-2,3,4-trione (Hassan *et al.*, 1975) ($\varepsilon = 3.18 \times 10^3$ dm^3 mol^{-1} cm^{-1}).

Table 1 Analytical characteristics of the proposed method

Slope of the calibration line	14226.31
Intercept of the calibration line	-0.020
Standard error of the slope of the calibration line	46.2014
Standard error of the intercept point of the line	0.0020
Correlation coefficient (r)	0.99998
Limit of detection	0.075 μg/cm^3
Limit of quantification	0.25 μg/cm^3
Linear dynamic range	0.25 – 12.0 μg/cm^3
Molar absorptivity (ε)	1.42×10^4 dm^3 mol^{-1} cm^{-1}
Relative standard deviation	0.73%

Interference studies

To assess the selectivity of the proposed method, interferences caused by those foreign species that are commonly found with L-ascorbic acid in the samples analyzed were studied by adding different amounts of other species to a solution containing 8.00 μg/cm^3 of ascorbic acid. The criterion for the interference was an absorbance varying by 5 % from the expected value. The results are listed in Table 2.

None of the metal ions investigated interfered with the determination at the levels studied. The positive errors (all within 5%) caused by iron(II), molybdenum(VI) and lead(II) may be ascribed to the absorption of UV light by these substances. Lau et al. (1987) reported that the metal ions, such as Fe(II), Mg(II) and Mn(II), caused errors but did not interfere with a direct spectrophotometric method for the determination of ascorbic acid in pharmaceuticals with background correction based on the copper(II)-catalysed oxidation of ascorbic acid. The metal ions investigated did not interfere with other methods described in the literature for the determination of L-ascorbic acid (Arya *et al.*, 1997; Ferreira *et al.*, 1997). The results in Table 2 demonstrate that potassium thiocyanate at a concentration of 0.02 M is a suitable stabilizer for L-ascorbic acid in the developed method. Potassium thiocyanate prevents the ascorbic acid-metal ion complex formation and therefore inhibits effectively the oxidation of L-ascorbic acid.

Table 2 Effect of foreign substances on the determination of L-ascorbic acid

Foreign substance added	Mass ratio (foreign substance:ascorbic acid)	Error, %
Iron(II)	0.02	1.76
Calcium(II)	5	-
Magnesium(II)	2	-
Manganese(II)	1.3	-
Molybdenum(VI)	0.2	2.71
Copper(II)	0.02	-
Zinc(II)	2	-
Lead(II)	0.5	2.54
Nickel(II)	0.4	-
Cl^-	10	-
SO_4^{2-}	10	-
PO_4^{3-}	5	-
HCO_3^-	10	1.27
Citrate	20	-
Benzoate	2	> 5.00
Acetate	20	-
NO_2^-	2	-1.27
Citric acid	5	-4.12
Tartaric acid	2	-0.97
Sucrose	200	-
Glucose	200	-
Fructose	200	-

The anions tested except benzoate did not interfere with the determination of ascorbic acid using the proposed method. Benzoate interfered seriously because of the absorption of UV light. The negative error caused by nitrite may be ascribed to the oxidation of L-ascorbic acid with this oxidant in an acidic medium. Since absorption properties (λ_{max} and ε) of L-ascorbic acid depend on the pH of the aqueous media (Eitenmiller *et al.*, 1999), the positive error caused by hydrogencarbonate may be ascribed to an increase in the pH of the

L-ascorbic acid solution. Other workers also reported that anions, such as sulfate, nitrate, chloride and acetate ions, did not noticeably affect the accuracy of the determination of ascorbic acid, even when these ions were present in large excess amounts compared with that of ascorbic acid (Fujita *et al.*, 2001; Arya *et al.*, 1997). The experimental results revealed that a 200-fold excess of sucrose, glucose and fructose had no effect on the determination of L-ascorbic acid using the proposed method. Errors caused by citric and tartaric acids may be ascribed to a decrease in the pH of the ascorbic acid solution after the addition of organic acids.

Application of the proposed method to real samples

The proposed method was applied to the determination of the ascorbic acid contents in commercial pharmaceutical preparations (tablets). The results obtained are shown in Table 3. In every case, the sample was analyzed by both the proposed and the titrimetric method using iodine as titrant (Fritz *et al.*, 1987). The last one, used as a reference method, is a procedure based on the oxidation of L-ascorbic acid to dehydro-L-ascorbic acid by iodine.

The statistical study of precision and accuracy of the proposed method was made from F-criterion and the t-test, respectively. The t-test was applied to the results obtained by the proposed and the iodine method, and it showed that calculated t values were lower than the tabulated t value (t = 2.31, P = 0.05). This suggested that at 95 % confidence level differences between the results obtained by the two methods were statistically not significant. The F-test revealed that there is no difference between the precision of the two methods. In every case, the calculated value of F was lower than the critical value (F = 6.39, P = 0.05). Thus, the proposed method can be successfully applied to real samples.

Table 3 Determination of L-ascorbic acid in vitamin C preparations

Commercial name (Supplier)	L-Ascorbic acid (mg/tablet)			$F_{exp.}$	$t_{exp.}$
	Claimed value	Proposed method*	Iodine method*		
Vitamin C (Huxol)	100	99.22 ± 0.93	100.41 ± 1.36	2.15	1.99
Vitamin C (Krüger)	180	182.66 ± 1.76	183.28 ± 1.93	1.20	0.66
Plivit C (Pliva)	500	498.67 ± 3.70	498.33 ± 5.12	1.92	0.15
Vitamin (Galenika)	500	505.26 ± 6.82	498.94 ± 5.38	1.60	2.02

Theoretical value for F is 6.39 (P = 0.05) and for t is 2.31 (P = 0.05).
*The 95 % confidence limits of the mean (n = 5).

CONCLUSIONS

Potassium thiocyanate at a concentration of 0.02 M is a suitable stabilizer for L-ascorbic acid in a UV method of assay. The proposed method using the stabilizer is simple, sensitive, precise and accurate. Many common ingredients present in pharmaceutical preparations do not interfere. The results of applying the proposed method showed good agreement with those provided by the reference method. The results obtained by the proposed method also agreed well with the claimed values on the labels in all instances. Thus, the proposed method can be applied to the determination of vitamin C in commercial pharmaceutical preparations.

REFERENCES

1. Abdelmageed O. H., Khashaba P. Y., Askal H. F., Saleh G. A., Refaat I. H. (1995). Selective spectrophotometric determination of ascorbic acid in drugs and foods. Talanta 42:573-579

2. Arya S. P., Mahajan M., Jain P. (2001). Spectrophotometric determination of vitamin C with iron(II)-4-(2-pyridylazo) resorcinol complex. Anal. Chim. Acta 427:245-251

3. Arya S. P., Mahajan M. (1997). Nitroso-R salt as a sensitive spectrophotometric reagent for the determination of vitamin C. Analytical Letters 30(14):2541-2553

4. Backheet E. Y., Emara K. M., Askal H. F., Saleh G.A. (1991). Selective spectrophotometric method for the determination of ascorbic acid in pharmaceutical preparations and fresh fruit juices. Analyst 116:861-865

5. Eitenmiller R. R., Landen W. O. (1999). Vitamin Analysis for the Health and Food Sciences. CRC Press, USA

6. Ferreira S. L. C., Bandeira M. L. S. F., Lemos V. A., dos Santos H. C., Costa A. C. S., de Jesus D. S. (1997). Sensitive spectrophotometric determination of ascorbic acid in fruit juices and pharmaceutical formulations using 2-(5-bromo-2-pyridylazo)-5-diethylaminophenol (Br-PADAP). Fresenius J. Anal. Chem. 357:1174-1178

7. Francis F. J. (2000). Encyclopedia of Food Science and Technology. John Wiley & Sons, USA

8. Fritz J. S., Schenk G. H. (1987). Quantitative Analytical Chemistry. Prentice Hall, New Jersey, USA

9. Fujita Y., Mori I., Yamaguchi T., Hoshino M., Shigemura Y., Shimano M. (2001). Spectrophotometric determination of ascorbic acid with iron(III) and *p*-carboxyphenylfluorone in a cationic surfactant micellar medium. Anal. Sci. 17:853-857

10. Hassan S. S. M., Abd El Fattah M. M., Zaki M. T. M. (1975). Spectrophotometric determination of vitamin C in citrus fruits using *peri*-naphthindan-2,3,4-trione. Fresenius Z. Anal. Chem. 277:369-371

11. Iwase H. (2003). Routine high-performance liquid chromatographic determination of ascorbic acid in foods using L-methionine for the pre-analysis sample stabilization. Talanta 60:1011-1021

12. Janghel E. K., Gupta V. K., Rai M. K., Rai J. K. (2007). Micro determination of ascorbic acid using methyl viologen. Talanta 72:1013-1016

13. Kato T., Ohno O., Nagoshi T., Ichinose Y., Igarashi S. (2005). Determination of small amounts of L-ascorbic acid using the chemiluminescence of an iron-chlorophyllin complex. Anal. Sci. 21:579-581

14. Lau O. W., Luk S. F., Wong K. S. (1987). Determination of ascorbic acid in pharmaceuticals using direct ultraviolet spectrophotometry. Analyst 112:1023-1025

15. Li C. X., Zeng Y. L., Liu Y. J., Tang C.R. (2006). Simultaneous electrochemical determination of uric acid and ascorbic acid on a glassy carbon electrode modified with cobalt(II) tetrakisphenylporphyrin. Anal. Sci. 22:393-397

16. Lykkesfeldt J. (2000). Determination of ascorbic acid and dehydroascorbic acid in biological samples by high-performance liquid chromatography using subtraction methods: Reliable reduction with tris[2-carboxyethyl] phosphine hydrochloride. Anal. Biochem. 282:89-93

17. Miyake N., Kim M., Kurata T. (1999). Stabilization of L-ascorbic acid by superoxide dismutase and catalase. Biosci. Biotechnol. Biochem. 63:54-57

18. Pal T., Das P. K. (1988). A comparative study on spectrophotometric, conductometric and potentiometric determination of ascorbic acid. Anal. Lett. 21:2333-2343

19. Verma K. K. (1982). Determination of ascorbic acid with *o*-iodosobenzoate. Talanta 29:41-45

20. Wu X., Diao Y., Sun C., Yang J., Wang Y., Sun S. (2003). Fluorimetric determination of ascorbic acid with *o*-phenylenediamine. Talanta 59:95-99

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.21
Izvorni znanstveni rad
Original scientific paper

EXPERIMENTAL RESEARCHES ON THE PHYSICAL CHARACTERISTICS OF PRODUCTS OBTAINED FROM WHEAT MILLING

GHEORGHE VOICU, TUDOR CASANDROIU, CONSTANTIN TÂRCOLEA, ELENA-MĂDĂLINA TUDOSIE, PAULA VOICU

„Politehnica" University of Bucharest, Faculty of Biotechnical Systems Engineering e-mail: ghvoicu_2005@yahoo.com; cctu39@yahoo.com

ABSTRACT

Knowledge of physical and mechanical characteristics of seed and intermediate products grinding is very important both for the evaluation of grinding necessary energy with roller mills and as well as for the study of the sieving and sorting process for the products after grinding.

In this paper we are going to present the results of experimental researches made with the products obtained in primary grinding stage of wheat in a modern roller mill with capacity of 100 t / 24 h. References are made to as the statistical characteristics by size of seeds wheat for milling (grinding) and physical characteristics (natural slope angle, volume mass, density, degree of grinding etc.). Of great importance is the knowledge of particle-size distribution and in this paper it tested the validity of three types of cumulative distribution laws (Schuhman, Rosin-Rammler, logistics function with tow parameters) for to choice of low most suitable to describe real granulometric distribution. Research results are especially important the choice of the working regimen of the machines from the technological flow of the mill, regarding of appropriate parameters of the working regimen.

Key words: *wheat kernels, roller mill, milled wheat, size reduction, size distribution*

INTRODUCTION AND LITERATURE REVIEW

The seeds are organic materials in granular solid state with anisotropic and inhomogeneous properties both physically, as well as chemically [2,3,4,5,6].

The grinding process of the seed it happens due to some compound mechanical stresses to which they are subject (compression, shearing, crushing, cutting, friction, collisions) according to the constructive type of technical system used for grinding (roller mill, with hammers , with stones, with balls). Therefore, to the application of forces that exceed the mechanical strength of particles, there is a division of them into a number of smaller particles of various sizes and geometric shapes, [3,4,8,10,12].

The mass of particles obtained by crushing contains particles with size located in an enough large area. As for evaluating the weight of fractions formats of particles with dimensions in a fixed area (according to certain requirements - useful for separation machines with sieves, product quality, evaluation energy consumption, etc.), as well as to estimate of sizes values of mathematical models calculation of energy required for grinding operation. In all these cases is interest to know the most law appropriate of granulometric distribution for the grinding product, [1,2,3,4,12].

The researches made on grinding products obtained from hammer mills for the maize seeds, wheat, barley, sorghum showed that can be used, with good results, the normal-log type distribution, [4] and Schuhman type, [5].

In other papers, in case of some non-biological materials and various types of mills used for grinding are recommended the granulometric distribution laws of normal type (Gaussian) or, most often, Rosin-Rammler type, [1,7].

In the situation of the grinding seeds in the roller mills (particularly in the complex rollers mills of last generation), the first references to granulometric distributions laws of results grinding products are in the researches of the authors, [8].

Analyzing the real profiles curves of cumulative distribution of particles sizes of grinding wheat by the roller mills, corresponding experimental points, it was found that in most cases, they have sigmoid shape.

It is known that, in this situation, considering randomly varies of many factors that influence the process of grinding, the cumulative statistical distribution of size grist particles, can be described by logistic function with two parameters [9, 13, 14], which will be tested together with those proposed in the paper [8].

The other physical characteristics of grist useful in different activities are: average size, degree of grinding, surface area, volume mass, density, porosity, was defined in [6,11].

Through this we propose to: (1) identify the most appropriate granulometric distribution law of the frequent used to the biological grinding products (Schuhman, Rosin-Rammler, the logistics function with two parameters) for the grinding products in primary phase of technological flow of a roller mill of last generation, for wheat, such as entry and exit of the rolls, in the grinding process, (2) evaluation of the physical characteristics of grist for the flow mentioned.

THEORETICAL ASPECTS

In the milling industry, the wheat is the major industrialized cereal in which, by grinding is obtained flour as main product and bran, wheat germs and possibly semolina, as products of grist. For grinding, most used are the complex roller mills with different streams of grinding determined by a own technology type of seeds, destination of the products obtained and their quality.

The grinding of material particles, especially of cereals, in roller mills, it happens due to some complex stresses faced by that both the seeds, as well as the grinding intermediates product, such as: compression (crushing), shearing, friction, some of these stresses are more pronounced in the technological passages which through the material.

The main factors which influencing grinding process of cereals are physical and mechanical properties of seeds and products of grist, constructive and functional characteristics of grinding machines and technological schema adopted, most of these factors having a random character.

It is obtained, as a result of grinding, a particles mass with different smaller sizes and different geometrical shapes (grist).

Granulometric distribution of the grist material and leaving the grinding process can be assessed by the cumulative weight (%) of material passing through the sieve mesh of classifier T (x) or are refused by its sieves R (x), calculated on base of mass weight (%) of fractions from the sieves. The mathematical expression of granulometric distribution is based, in case of grinding biological materials, on laws based on mathematical statistical method of small particles [4,5,9,14].

According to previously mentioned three usual types of laws of cumulative granulometric distribution will be defined:

1. The Rosin-Rammler distribution type for material particles with larger sizes than the sieve meshes, is expressed by the equation:

$$R(x) = 100 \cdot e^{-b x^{n}} \tag{1}$$

where: R(x) is the mass percentage weight of fraction with larger particles than x (which remained on the sieve with meshes with size x); x – is the sieves meshes size by which the particles rest; b and n are the own coefficients of grinding material.

2. The Schuhman type distribution is defined by equation:

$$R(x) = 100 \cdot \left[1 - \left(\frac{x}{k}\right)^{a}\right] \tag{2}$$

where R(x) and x have the signification from to equation (1), k - the module product particles size (the size of sieve mesh through which, theoretical, pass all the sample particles (100%)), a - the distribution module.

The equation (6), as in previous case, is cumulative distribution law of percentage weight of fraction separated by sieves meshes of size x, depending on x.

We can observe that the relation (6) is the so-called law of cumulative distribution of percentage weight of fraction separated by sieves meshes of size x, depending on x.

3. The logistics type distribution with tow parameters is defined by equation:

$$R(x) = 100 \cdot \frac{e^{\alpha+\beta x}}{1+e^{\alpha+\beta x}} \tag{3}$$

where R(x) and x have the signification from equation (1), α and β are logistical constant.

In the grinding process should be known the physical characteristics of the materials both at entry, as well as exit within a processing machine, in our case, the roller mills. Of these characteristics is important the bulk density, ρ_v (kg/m^3), of the material to be processed, the density of that, ρ (kg/m^3), the equivalent sizes of material particle at entry and exit of the grinding machine, d_m (mm); angle of internal friction of particles appreciated by natural slope angle, ψ(°); angle of material friction with the surfaces working components, φ(°); material porosity, ε (%) and others.

Of particular importance is the size of seeds equivalent subjected to grinding in the first technological passage.

The parameters for assessment of the milling process are: degree of crushing, grinding finesse and specific energy consumption to grind.

The degree of crushing is defined by the index λ and it is the ratio of equivalent particle sizes before and after grinding, D respectively d, or the ratio of external surface of the particles resulting in the grinding process and initial surface of the particle subject of grinding, S_f, respectively S_i:

$$\lambda = \frac{D}{d} = \frac{S_f}{S_i} \tag{4}$$

The absolute value of increase external surface of the particles in the grinding process ΔS, is given by equation:

$$\Delta S = S_f - S_i = S_i(\lambda - 1) \tag{5}$$

The grinding finesse is assessed by the diameter d_m (average value) of grinding particle which is determined by the granulometric analysis of the mass of grinding material, calculated as the weighted average of the average fractions material size obtained by sieving through the classifier with sieves:

$$d_m = \frac{\sum_{i=0}^{n} p_i d_i}{100} \tag{6}$$

where: p_i – is mass weight of fraction remaining on the sieve i of the classifier, d_i – diameter (average value) of fractions particle on the sieve i, considered the arithmetic average of the sieves holes size that contain fraction i.

Knowing the diameter (average value) of newly formed particles, their external specific surface $S_{e.m}$ can be evaluated with the known equation:

$$S_{e.m} = \frac{6}{\rho \cdot d_m} \quad (\text{m}^2/\text{kg}) \tag{7}$$

where ρ is particles density, determined with the pycnometer.

METHODS, MATERIALS AND PROCEDURES

In this paper are presented the results of some experimental researches regarding the physical characteristics of grist products on the technological flow of wheat breakage phase to a mill with capacity of 100 t/ 24 h (S. C. Spicul Rosiori de Vede, Teleorman, Romania).

In this phase the technological diagram of mill contains five pairs of rolls, filled with one compartment of plane sieve, two semolina machines and three wheat bran finishers. The technological breakage phase is completed with one compartment of plane sieve without grinding machine, in which the material is sorted by fractions of different sizes as well as the other compartments of plane sieve.

The circulation of grist intermediate products in within technological diagram is shown in fig.1.

Material to experimental determinations was taken from the entry, respectively from exit of each pair of rolls (of five of the phase) and experimental determinations were made in the laboratory of the Department of Biotechnical Systems from Politehnica University of Bucharest.

So, were determined following physical characteristics: volume mass of material, density, natural slope angle, porosity, diameter (average value), surface area and degree of grinding. For determination of volume mass, for each of sample, was used a laboratory 200 cm^3 glass gradated from 10 to 10 ml and an electronic balance with precision of 10^{-1} g, after, in advance, the material was properly homogenized.

To determine of material densities of each sample was used a pycnometer with volume of 25 ml and the xylene with density of 825.4 kg/m^3 was used like reference liquid. The methodology is, also, explained in detail in paper [8,10] and for calculation of material densities was used known equation [6].

$$\rho_s = \frac{(m_c - m_a)\cdot \rho_l}{(m_b + m_c) - (m_a + m_d)} \tag{8}$$

where: m_a - mass of empty pycnometer; m_b - mass of pycnometer filled with reference liquid; m_c - mass of pycnometer with 3-5 grams of grist; m_d - mass of pycnometer filled with material to fill the working liquid (xylene).

To determine the natural slope angle was used the measurement method of cone element angle that is formed on the settlement of certain amounts of material on a flat horizontal.

Its porosity was evaluated for each sample of material knowing the values of volume mass and the material densities with this equation:

$$\varepsilon(\%) = \left(1 - \frac{\rho_v}{\rho}\right)\cdot 100 \ \ (\%) \tag{9}$$

For the granulometric analysis were used of 100 grams of material from each sample that passed through on a set of 5 overlapped sieves with meshes of different sizes mounted in the classifier and trained in a circular plain movement at an adjusted speed of 120 rpm for 3 minutes. The work methodology is presented in detail in the papers [8,10].

With the obtained data we established centralizing tables in which we placed the cumulative weights (%) of the particle fractions with a higher dimension than the dimension of any orifice from the machine used sieves, using the table calculus program MsExcel 7.0 version.

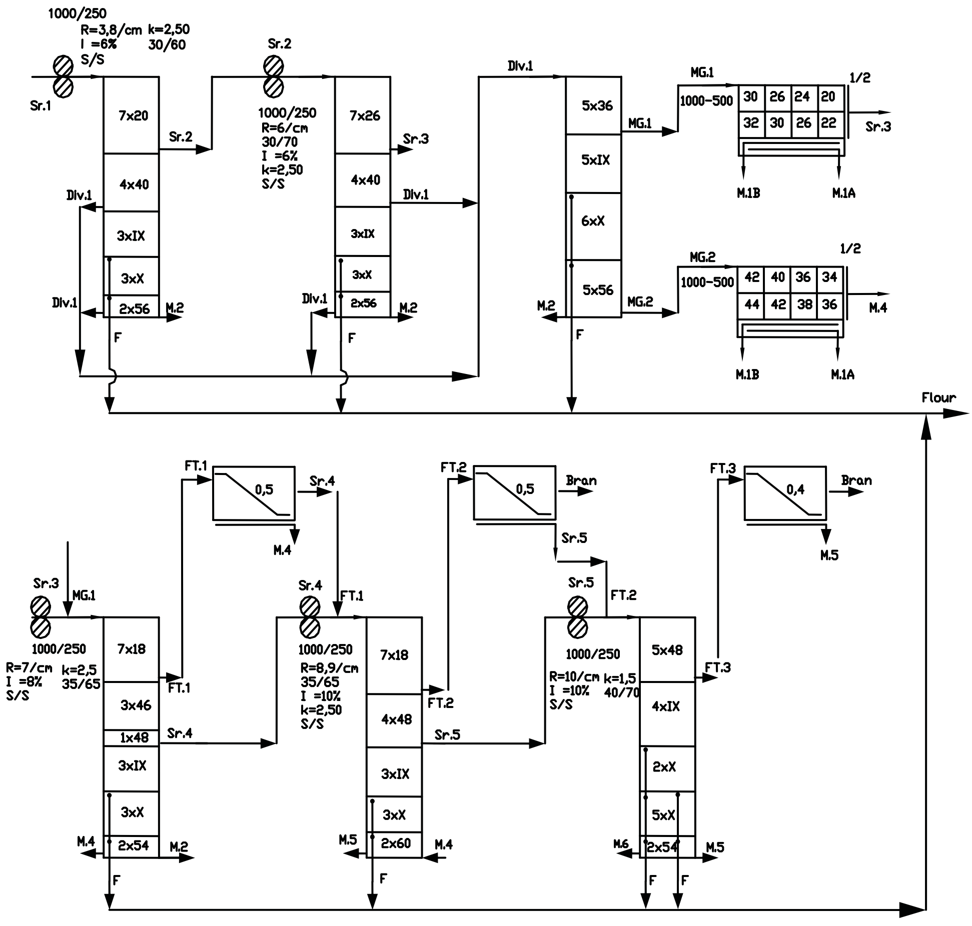


Fig. 1 The technological scheme of the wheat breakage phase for a mill with capacity of 100 t/ 24 h.

Its porosity was evaluated for each sample of material knowing the values of volume mass and the material densities with this equation (9).

For the granulometric analysis were used of 100 grams of material from each sample that passed through on a set of 5 overlapped sieves with meshes of different sizes mounted in the classifier and trained in a circular plain movement at an adjusted speed of 120 rpm for 3 minutes. The work methodology is presented in detail in the papers [8,10].

With the obtained data we established centralizing tables in which we placed the cumulative weights (%) of the particle fractions with a higher dimension than the dimension of any orifice from the machine used sieves, using the table calculus program MsExcel 7.0 version.

To determine the average equivalent size of seeds submissive to grinding according to the first breakage passage (Sr. 1 - I), measurements were conducted on the geometrical dimensions of a sample of 150 wheat seeds from the grinding lot, resulting the following medium values: for the length of the seeds, l = 6.492 mm; for the width b = 3.041 mm; for the thickness c = 2.699 mm. Based on these measurements and considering the seeds as ellipsoidal , was determined the equivalent size of the sphere volume equals the seeds volume according the relation, [6]:

$$D_e = \sqrt[3]{l \cdot b \cdot c} \tag{10}$$

with the mentioned data the result will be: D_e= 3.763 mm.

The total degree of the wheat breakage phase on the analyzed mill is approximately $\lambda = 7$ correspondent to a coarse grinding (crushing).

We determined with the use of relation (6) that the medium size of the material particle samples analyzed, also the grinding degree (eq.4), respectively the material specific surface (eq. 7), at the exit and entry of the each pair rolls and the surface increase through grinding at the indicated passage, (eq. 5).

RESULTS AND DISCUSSION

Following the finished determinations and evaluations, referring to the material physical characteristics, the table 1 results have been obtained.

Table 1 The physical characteristics of gritting products at wheat breakage passages, at S.C. Spicul Rosiori de Vede Mill, Romania

Physical characteristic	Sr.1-I	Sr.1-E	Sr.2-I	Sr.2-E	Sr.3-I	Sr.3-E	Sr.4-I	Sr.4-E	Sr.5-I	Sr.5-E
Bulk density, ρ_v (kg/m^3)	713.0	381.5	482.0	346.5	267.8	292.0	255.0	257.0	269.0	266.0
Density, ρ (kg/m^3)	1239	1250	1219	1200	1100	1063	1016	1130	1100	1191
Equivalent size, (mm)	3.76	2.13	2.23	1.22	1.51	0.90	1.06	0.84	0.65	0.63
Degree of grinding, λ	1.76		1.83		1.67		1.26		1.03	
Surface area, (m^2/kg)	1.29	2.25	2.21	4.10	3.61	6.27	5.57	6.32	8.39	8.00*
Increase the surface, ΔS (m^2/kg)	0.96		1.89		2.66		0.75		–0.39*	
Natural slope angle, ψ (gr.)	21.8	37.8	37.1	37.5	44.6	39.0	41.1	39.2	42.6	44.4
Porosity , ε (%)	42.5	69.5	60.5	71.1	75.7	72.5	74.9	77.3	75.5	77.7

The used sieves at granulometric analysis with sieve classifier and obtained results following the analysis are presented in table 2, for each of the five technological passages, at entry and exit from the roller mill.

Regarding the obtained results at established granulometric analysis with the sieve classifier have been tested through un-linear regression analysis with the help of Microcal Origin program, version 6.0, the three laws of cumulative distribution for the refusal of R(1) sieves (the Rosin-Rammler function, the Schuhman function with two parameters) for the products that enter, as well as the products that exit from the roll pairs, in the grinding process in the technological breakage phase.

The experimental points and cumulative distribution curves for sieves refusal (R(1)), for the three types of tested function (eq.1, eq.2, eq.3), are presented in fig.2.

Table 2 The ponder values (%) p_i of the fractions from the sieving machine classifier sieves and of the cumulative weights R_i (%) for the collected gritting products, at "I" entry and "E" exit from the mentioned roll pairs (Sr.1…Sr.5)

l_i (mm)	Sr.1 - E		l_i (mm)	Sr.2 - I		Sr.2 - E		l_i (mm)	Sr.3 - I		Sr.3 - E	
	p_i (%)	R_i (%)		p_i (%)	R_i (%)	p_i (%)	R_i (%)		p_i (%)	R_i (%)	p_i (%)	R_i (%)
0.00	24.20	0.00	0.00	2.00	0.00	34.70	0.00	0.00	13.40	0.00	43.10	0.00
1.00	8.40	24.20	0.71	6.00	2.00	11.50	34.70	0.71	22.50	13.40	20.60	43.10
1.40	15.10	32.60	1.00	19.20	8.00	22.20	46.20	1.00	22.80	35.90	23.00	63.70
2.00	20.10	47.70	1.40	13.90	27.20	11.50	68.40	1.40	12.00	58.70	5.10	86.70
2.80	27.00	67.80	2.00	29.50	41.10	14.90	79.90	2.00	20.10	70.70	7.20	91.80
4.00	5.20	94.80	2.80	29.40	70.60	5.20	94.80	2.80	9.20	90.80	1.00	99.00
d_{1E} = 2.13 mm			d_{2I} = 2.23 mm			d_{2E} = 1.22 mm		d_{3I} = 1.51 mm			d_{2E} = 0.90 mm	
			l_i (mm)	Sr.4 - I		Sr.4 - E		l_i (mm)	Sr.5 - I		Sr.5 - E	
				p_i (%)	R_i (%)	p_i (%)	R_i (%)		p_i (%)	R_i (%)	p_i (%)	R_i (%)
			0.00	26.00	0.00	42.60	0.00	0.00	5.20	0.00	5.80	0.00
			0.71	25.20	26.00	27.50	42.60	0.25	3.90	5.20	3.90	5.80
			1.00	28.30	51.20	20.70	70.10	0.32	21.10	9.10	22.60	9.70
			1.40	11.90	79.50	3.60	90.80	0.50	28.20	30.20	29.70	32.30
			2.00	7.80	91.40	5.00	94.40	0.71	35.30	58.40	32.70	62.00
			2.80	0.80	99.20	0.60	99.40	1.00	6.30	93.70	5.30	94.70
			d_{4I} = 1.06 mm			d_{4E} = 0.84 mm		d_{5I} = 0.65 mm			d_{5E} = 0.63 mm	

The coefficient values k, a, b, n, α and β, from the cumulative distribution relations Rosin–Rammler, Schuhman and the two parameters logistical function, as well as the R^2 correlation coefficient values (which verifies the distribution adequacy degree expressed through the (1), (2), (3) relations), correspondent for the nine analyzed probes (from the five roll pairs) are presented in table 3.

Table 3 The coefficient values a, k, b, n, α and β and of the R^2 correlation coefficients, for the three granulometric distribution laws tested, for the gritted products from the „I" entry to the „E" exit between the mentioned roll pairs (Sr.1...Sr.5)

Distribution type	Coeff.	Sr.1-E	Sr.2-I	Sr.2-E	Sr.3-I	Sr.3-E	Sr.4-I	Sr.4-E	Sr.5-I	Sr.5-E
Schuhman (1)	k	4.201	3.398	2.893	2.966	2.531	2.532	2.431	1.025	1.016
	a	0.996	1723	0.674	0.960	0.495	0.711	0.464	1.710	1.639
	R^2	0,999	0,981	0,985	0,956	0,958	0,933	0.940	0,991	0.987
Rosin-Rammler (2)	b	0.224	0.114	0.665	0.411	1.025	0.701	1.169	2.472	2.652
	n	1.659	2.302	1.382	1.747	1.682	2.220	2.093	2.852	2.817
	R^2	0,988	0,987	0,996	0,982	0,996	0,996	0,996	0,998	0,999
Logistics (3)	α	2.573	3.701	2.243	2.744	2.760	3.397	3.216	4.347	4.303
	β	-1.245	-1.666	-2.053	-1.981	-3.345	-3.380	-4.056	-6.739	-6.878
	R^2	0.984	0,974	0.972	0.963	0.988	0.995	0.994	0.997	0997

From the analysis and interpretation of the obtained data for the 9 probes, which come from the mill rolls with rifles (for the coarse gritting in the breaking passages) (fig.1), the following conclusion comes forward:

- For the vast analyzed material probes, from the mill's flux, the best law of cumulative distribution is the Rosin-Rammler (1) with a correlation coefficient $R^2 \geq 0,982$, time in which the Schuhman type distribution law with a correlation coefficient $R^2 \geq 0,933$ (usually $R^2 \geq 0,956$) can be used with satisfactory results, in these cases;
- For the two parameter distribution law, the R^2 correlation coefficient presents close values from the ones obtained through the Rosin-Rammler function, $R^2 \geq 0,963$, at half the probes being very close;
- The total grinding degree of the wheat breakage phase at the analyzed mill is approximately $\lambda = 7$, correspondent to a coarse gritting (crushing);
- It is appreciated that, in all cases, at seeds wheat grinding in the complex roller mills, we can consider that the best law of distribution is the Rosin-Rammler (1), ($R^2 \geq 0,982$), but the other methods, Schuhman and two parameter logistic, also can be used with satisfactory results.

These facts are illustrated in the given data, in table 3 as well as in the graphs from fig. 2.

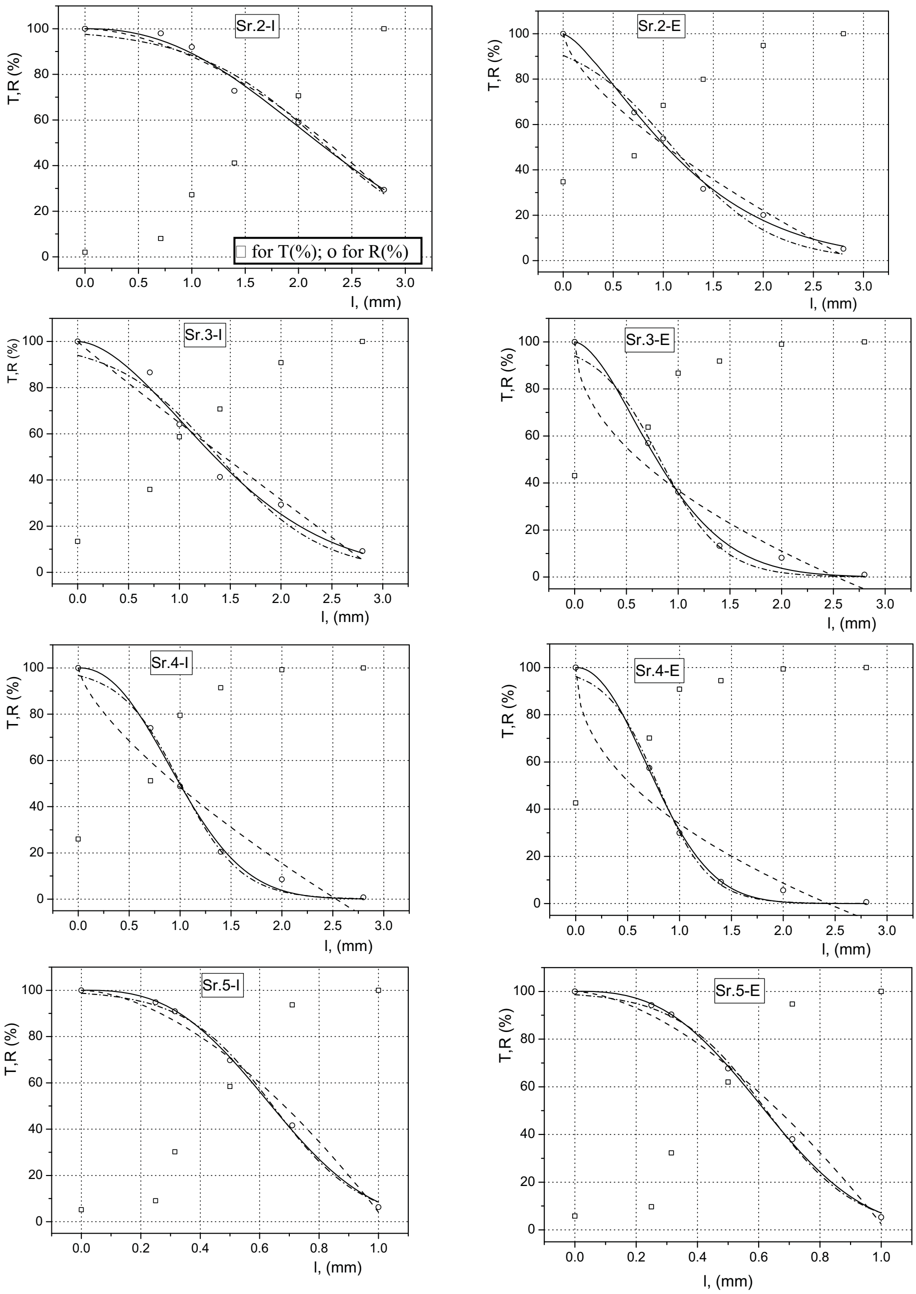


Fig. 2 The curves described by the cumulative distribution laws (1), (2), (3) towards the experimental points R(%) for the gritting product from the five roll pairs (Sr.2…Sr.5) (I-entrance; E-exit); ——— - Rosin-Rammler; - - - - - - Schuman; —·—·— - logistical function)

CONCLUSIONS

The researches referring to the corn and sorghum seed grinding in the hammer mills have shown that the gritted product dimensions distribution can be described with good results by the normal-log distribution law, and in the case of wheat and rice seed grinding in the same type of mills – the law of distribution type Schuhman, [4,5].

From our researches we can state that in the case of seed wheat grinding in complex mills with rolls, regardless of the grinding room from the technological flow of the mill, the granulometric distribution can be described in both cases, with the best results by the Rosin-Rammler law, ($R^2 \geq 0,97$), this law can be applied for gritted products, both at the entry and exit from the rolls, even if partial separation operations have been made on fractions in plane sieves blocks, [8].

Also, the fact that we can use with good results the distribution law, type Schuhman, at which the correlation coefficient values have been $R^2 \geq 0,931$, it is outlined, [8].

Through the results from this paper it is confirmed that in the case of seed grinding in complex roll mills, the law of distribution that describes the best is Rosin-Rammler ($R^2 \geq 0,982$).

Also, we outline the fact that both type Schuhman and two parameter logistical function types distribution laws can be applied with success, with the $R^2 \geq 0.956$, respectively $R^2 \geq 0.963$ values.

The mentioned findings suggest the fact that the type of granulometric distribution law which describes in the best way the granulometry of gritted biological materials depends on the material nature and the place and roll of the cylinder mill that does the chopping in the general technological flux.

The adequate mathematical model knowing of the description of the gritted granulometric distribution is useful in every engineering activity linked to the flux processes from the complex mills equipped with the latest rolls.

AKNOWLEDGEMENTS

This paper is a synthesis of experimental research effectuated in the first phase of the exploratory research IDEAS no. 753/2009, code ID_1726, financed by NURC.

Thank you, on this occasion, of leadership to S.C. Spicul SA Rosiori the Vede, Teleorman, Romania, which allowed us to collect samples from the technological flow of the mill.

REFERENCES

1. Crăescu I., Golcea N., Prepararea granulometrică a substanțelor utile, Editura tehnică, 1998;
2. Fang Q., Hanna M., Haque E., Spillman C., Neural network modeling of energy requirements for size reduction of wheat, Transactions of the ASAE 43(6), pp.947-952; 2000;
3. Guritno P., Haque E., Relationship between energy and size reduction of grains using a three-roller mill, Transactions of the ASAE 37(4), pp.1243-1248, 1994;
4. Headley V., Pfost H., A comminution equation relating energy to surface area by log probability method, Transactions of the ASAE 11(3), pp331-334 and 338, 1968;
5. Henderson S., Hansen R., Farm grain comminution: Hammer mill and burr mill performance analyzed, Transactions of the ASAE, 11(3), pp.339-402, 1968;
6. Mohsenin N.N., Physical properties of plant and animal materials, vol. I (Structure, physical characteristics and mechanical properties), Gordon and Breach Science publishers, N.Y., 1970;
7. Voicu Gh., Căsăndroiu T., Utilaje pentru morărit şi panificație, curs, vol. I - Procese şi utilaje pentru morărit, Litografia U.P.B., 1995;
8. Căsăndroiu T., Voicu Gh., Țuțuianu G.D., Cu privire la legile distribuției granulometrice al produselor mărunțite într-o moară cu valțuri, ISBTeh-2002, U.P.B., 194-199, 2002;
9. Voicu, Gh., Căsăndroiu T., Utilizarea funcției logistice pentru descrierea proceselor de separare pe sitele sistemelor de curățire de la combine, Lucrări științifice "Concepte, tehnologii şi echipamente tehnice moderne pentru agricultură şi industria alimentară" INMATEH- III, Bucureşti, p. 107-112, 2004;
10. Voicu Gh., Țuțuianu G.D., David Mihaela., Cercetări asupra indicilor caracteristici ai mărunțirii semințelor de cereale, Rev. Construcția de mașini, nr.4; 23-26, 2003;
11. Nelson S.O., Dimensional and density data for seeds of cereal grain and other crops, Trans. of the ASAE, 45(1), 165-170, 2002;
12. Fang Q., Haque E, Spillman C.K., Reddy P.V., Steele J.L., Energy requirements for size reduction of wheat using a roller mill, Trans. of the ASAE, 41(6), 1713-1720, 1998;
13. Garcia-Ramos, F.J., Barreiro, P., Ruiz-Altisent, M., Ortiz-Canavate, J., Gil-Sierra, J., Homer, I., A procedure for testing padding materials in fruit packing lines using multiple logistic regression, Trans ASAE, 45(3), 2002.
14. Voicu, Gh., Căsăndroiu, T., Toma Laura, A multiple logistic regresion statistical model to estimate grain losses on sieve cleaning system from combine, Proceedings "Actual tasks on agricultural engineering", Croația, p.481-491, 2006.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.22
Izvorni znanstveni rad
Original scientific paper

VARIATION OF THE CUTTING FORCE FUNCTION OF CUTTING ANGLE OF THE KNIVES FROM MINCING DEVICE OF THE BREAKING MACHINES FOR ROUGH FODDERS

C. BUDUI

University of Agricultural Sciences and Veterinary Medicine Iaşi, 3 Mihail Sadoveanu Alley, 700490 Iaşi, Romania

ABSTRACT

Cutting, breaking and mincing of rough fodders represent a complex technologic process being very different from metal cutting, due to the fact that effective division into sections is preceded by multiple stresses at compression, crushing, bending, stretching etc. The resistance at cutting depends on natural characteristics of fodder stems and also by technical and technologic factors (geometric characteristics of cutting organs, characteristics of flow material). The present paper aimed to track the influence of cutting angle (τ) on cutting force (F_t) of rough fodders. In this purpose was used a DTBC.1 device for measuring the cutting force created and realised by the author. The following cutting angles were tested: 0°, 5°, 10°, 15°, 20°, 25°. The shaping angle of the knife was $\beta = 15^0$, the distance between knife and counter-knife was $\delta = 0.3$ mm and fodder humidity (U) was 18 - 20%.

Keywords: *cutting force, fodder, cutting angle, mincing machines*

INTRODUCTION

By (τ) cutting angle is defined the angle formed by the cutting edge of the knife and counter knife, measured in a longitudinal plan – called also tilt angle. So the measurement of the cutting angle could be done through contact methods using a special device for angles measuring, respectively set square [2], [5].

Cutting force (F_t) of rough fodders is basic for all design concretion of cutting devices from the harvesting machines for different agricultural crops (cereals, fodder crops, technical crops, etc.), and also at chopping devices from harvest machines and other machines which minced stems of those crops [3], [4], [6], [7]. In literature are not enough dates for a better understanding of this cutting force, especially for rough fodders and this is the reason why the present paper offer some contributions in this field of activity.

MATERIALS AND METHODS

The paper have as target to track the influence of cutting angle (τ) on rough fodders cutting force (F_t). For this goal was used a device for measuring the cutting force called **DTBC.01** [1] design and realised by the author (figure 1). The main parts of the device are: frame (1), dynamograph (2), recording device (3), acting mechanism (4) and cutting knife (5).

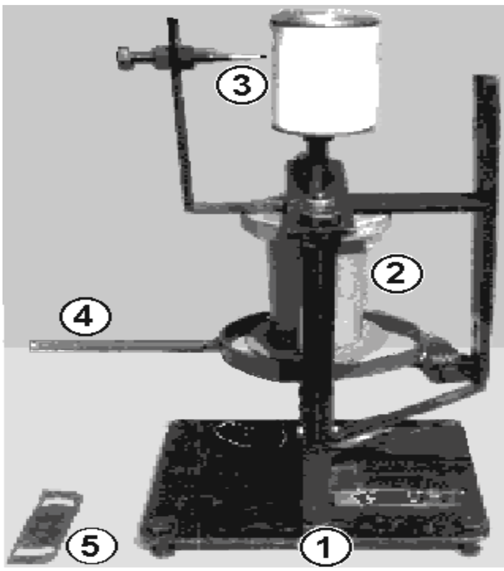


Figure 1 DT-BC.01 device (side view): 1 – frame; 2 – dynamograph; 3 – recording device; 4 – acting mechanism; 5 – cutting knife

The function of the device is based on the principle of elastic distortion of spring 12 (figure 2) under the action of resistance force to cutting, put up by the tested stems of the rough fodders [1]. This ones are placed stem by stem (for corn stalks) or under the form of bundles (for cereals or legumes stems) between knife (7) and counter knife (3), then the lever (21) is action through handle (22) which will go down the cylinder (11) in which is mounted the standard spring (12) and at the same time the recording device. In the moment in which knife reaches fodders' stem or the stems' bundle, due to the resistance opposed by them, spring (12) is compressed inside cylinder (11) which will continue to go down at the same time with the support (20) and pencil (17) which will draw a track on the recording paper of cylinder (15). The recorded value will be compare with the obtained diagram for a standard spring.

In figure 3 are presented the elasticity characteristics of the used springs. After a test the cylinder (15) is rotate and so could be done the next test and so on till the whole surface of cylinder is covered, after that the first layer of paper is moved away and the measurement continue for new samples of fodder.

DT-BC.01 device presents also some adjustment possibilities as follows [1]:

- distance between knife and counter knife, in vertical level, function of stem fodders diameter, function of the resistance opposed by fodders and also function of the length of used spring;
- cutting angle (tilt angle of the knife face to counter knife, in vertical level);
- distance between knife and counter knife, in horizontal level;
- horizontal position of the basic metallic plate (table);
- length of dynamograph cylinder, function of the length of used spring, etc.

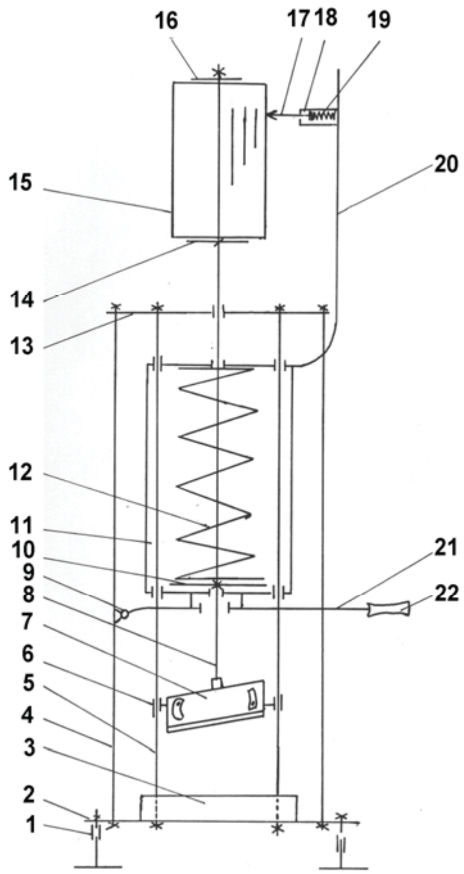


Figure 2 Main scheme of DT-BC.01 device

1 - adjustable supports;
2 - table (metallic plate);
3 - counter knife;
4 - hexagonal rod;
5 - rods with circular section;
6 - knife support;
7 - knife;
8 – rod with thread;
9 – oscillating support of the action lever;
10 - inferior thread shallow plate;
11 – metallic cylinder;
12 – helicoidally cylindrical spring;
13 – cross piece for stiffing the frame;
14,16 - M 12 screws;
15 – recording cylinder;
17 – recording head;
18 – support of recording head;
19 – spring of recording head;
20 – support of recording device;
21 – lever for device action;
22 - handle.

As regarding the distance variation, in vertical level, between knife and counter knife, this one could be adjusted by threading up or threading down the rod (8) in shallow plate (10), function of thickness of fodders' stem. We have in view that the inner spring (standard) not to be strained or free inside cylinder (11). Adjustment of the device for a certain length of the spring could be realised through adding or taking out of some distance pieces between spring (12) and superior flange of the cylinder (11). Distance between knife and counter knife in horizontal level (δ) is realised by weakening the fixed screw of the counter knife (3) and by its approaching or moving off face to knife (when this one is in the lower position). The screws go down through some orifices provided in table (2). The horizontal position of the table (metallic plate) (2) is assured with the help of some adjustable supports (1). Tilt angle (7) of knife face to counter knife (3) is adjusted by weakening the screws face to its support (6), placing one of wooden wedges specially designed for this purpose (figure 4), different angles (50; 100; 150; 200; 250; 300), and after that the screws are screwed and the wedge is removed to obtain the desire angle.

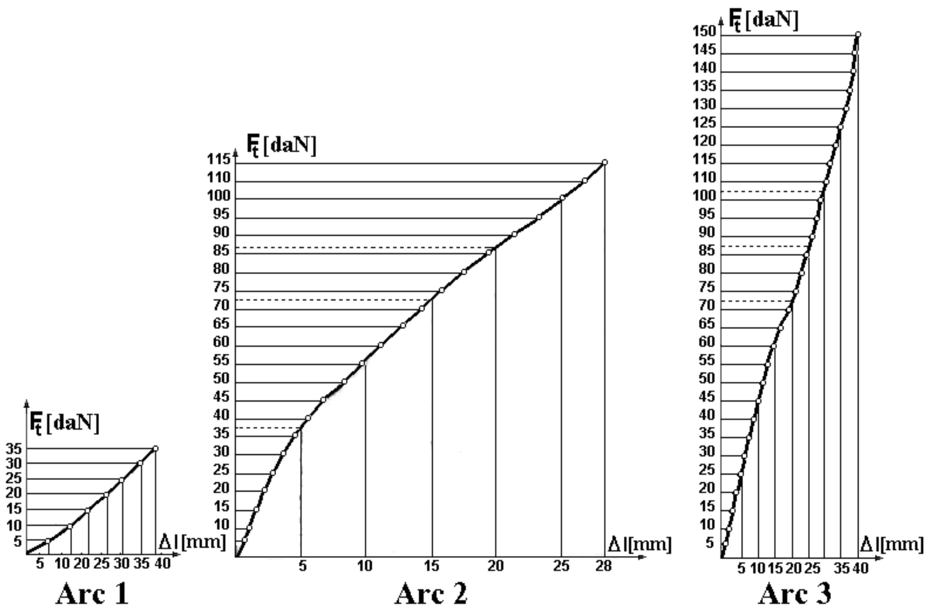


Figure 3 Elasticity characteristics of springs

DT-BC.01 device was tested in laboratory conditions for different types of rough fodders and the results will be presented below. Knife shaping angle (β) was 15°.

Were minced corn stalks obtained after harvesting corn grains hybrids ″Podu-Iloaiei 110″ and ″Pioneer 3978″, which are frequently cultivated at Farm 3 Rediu of Experimental Didactic Station of UŞAMV Iaşi. Was done a classification of corn stalks after stems' diameter as follows: ∅ = 0-10; 10-15; 15-20; 20-25; 25-30; 30-32; 32-34; 34-36 and 36-40 mm. The moisture of corn stalks was U = 18 - 20 %. The distance between knife and counter knife (δ) was adjusted at 0.3 mm.

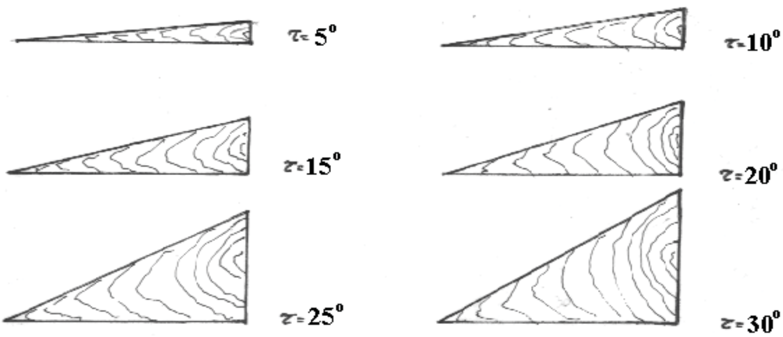


Figure 4 Wooden wedges for adjusting the cutting angle (τ^0)

RESULTS AND DISCUSSION

After experiments were determine the cutting force (F_t) function of cutting angle (τ).

The obtained dates are presented in table 1, and after that was drawn the curves of function $F_t = f(\tau)$ and are presented in figure 5.

From table 1 could be observed that the minimum cutting force (F_t = 3.5 daN) was realised for a maximum cutting angle of ($\tau = 25°$) and for the stalks' diameter of ∅ = 0-10 mm.

Table 1 Values of cutting force F_t (daN), function of cutting angle (τ) for: $\beta = 15°$, $\delta = 0.3$ mm; U = 18 - 20 %; ∅ = different values

Diameter	Cutting angle (τ) (degrees)					
(∅) (mm)	0	5	10	15	20	25
0-10	8.9	7.8	7.1	5.5	4.7	3.5
10-15	20.1	17.1	16.7	15.1	11.6	10.3
15-20	34.2	32.1	30.1	22.3	19.1	18.2
20-25	52.2	50.1	48.1	40.1	35.2	33.1
25-30	70.1	68.1	66.2	53.6	51.1	48.1
30-32	84.2	81.1	75.1	62.2	57.8	56.1
32-34	90.1	87.0	85.1	67.1	64.1	62.4
34-36	95.2	91.8	90.2	73.3	69.2	68.2
36-40	102.5	99.2	97.1	77.7	72.2	70.1

Maximum cutting force (F_t = 102.5 daN) was necessary for the minimum value of cutting angle ($\tau = 0°$) for stalks with ∅ = 36 - 40 mm diameter.

In figure 5 are presented the variation curves of cutting force function of cutting angle, for all nine classes of corn stalks diameters.

Studying those curves could be observed that at the same time with the increasing of cutting angle (τ), cutting force F_t decrease, but this decreasing is less significant in the case of small diameters (∅ = 0-10; 10-15; 15-20 mm) and much more visible in the case of big diameters (∅ = 30-32; 32-34; 34-36; 36-40 mm).

CONCLUSIONS

Cutting angle (τ) have a significant influence on cutting force of rough fodders. Its value must respect the condition of keeping the stalks between knife and counter knife, without permitting their movement upside down like in the relation: $\varphi_1 < \tau < \varphi_1 + \varphi_2$, where: φ_1 is friction angle between knife and fodders' stalks; φ_2 is friction angle between counter knife and fodders' stalk.

At the end of test we reach the conclusion that it is not proper to use angles smaller than $\tau = 15^0$, but the optimal value depends also by the shape and size of the studied fodder.

Over the value of cutting angle $\tau = 25°$ will appear a displacement of the stalks with great diameter, along the knife and counter knife, fact which leads to a jam of fodder layer in a certain area of supplying hole and the effect is that cutting force will increase.

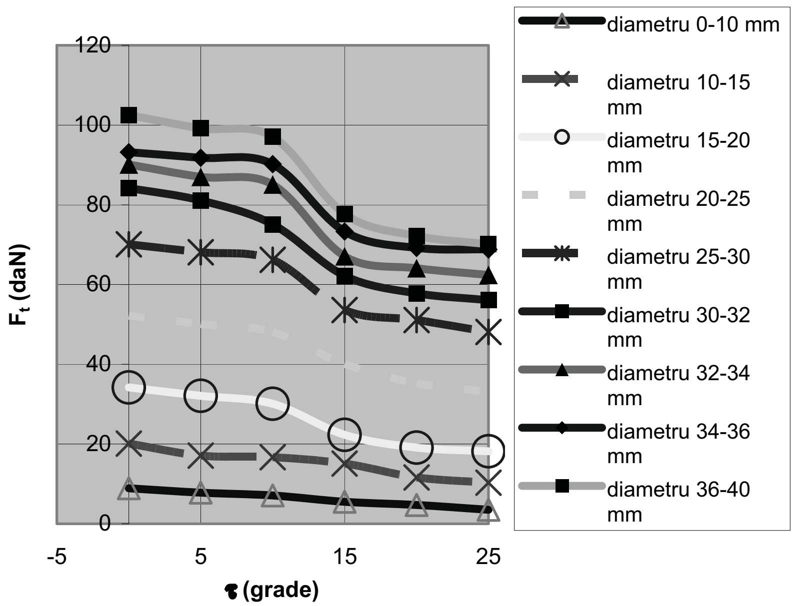


Figure 5 Variation of cutting force (F_t) function of knife cutting angle:
$\beta = 15°$, $\delta = 0.3$ mm, U = 18 - 20%

REFERENCES

1. Budui C.,: Studii privind modernizarea utilajelor de prelucrare a nutrețurilor pentru animale. Teză de doctorat, U.Ş.A.M.V. Iaşi, 2000.
2. Căprărescu P.,: Studiul proprietăților fizico-mecanice ale plantelor de porumb. Revista ”Studii şi Cercetări de Mecanică Agricolă”, vol. 4, nr. 2, 1970.
3. Ceskov A.I.,: O nekatorâh fiziko-mehaniceskih svoistv kukuruznâh rastenâi. Mehanizația i elektrifikațiea soțialisticeskovo seliskovo hoziaistve, nr. 4, 1962.
4. Csulak A.,: Contribuții la studiul geometric al cuțitelor şi contracuțitelor tăietoare de la combinele CSU şi CT-2R. Buletinul ştiințific, Institutul Politehnic Cluj, nr. 1, 1968.
5. *Article in book*
6. Cravcenko V.,: Îndrumătorul inginerului mecanic agricol. Ministerul Agriculturii şi Industriei Alimentare, 1976.
7. Neculăiasa V.,: Procese de lucru la maşini agricole de recoltat. Editura A 92, Iaşi, 1995.
8. Reznik N.E.,: Teoria rezania lezviem i asnavâ rasceta rejucih apparatov. Masinostroenie, Moscova, 1975.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 004.42:007.5:631.223.66
Prethodno priopćenje
Preliminary communication

REGULACIJA TEMPERATURE V VZREJALIŠČU PUJSKOV Z UPORABO MEHKE ODLOČITVENE LOGIKE

PETER BERK, JURIJ RAKUN, MIRAN LAKOTA, DEJAN ŠKORJANC, MARKO OCEPEK

University of Maribor, Faculty of Agriculture and Life Sciences
e – mail: peter.berk@uni-mb.si, jurij.rakun@uni-mb.si

POVZETEK

Uporaba regulatorjev mehke logike proti običajnim regulatorjem je dosegla najvišjo stopnjo v tehniki upravljanja in regulacij. Zato smo se v naši aplikaciji odločili za sintezo mehkega PI regulatorja temperature v vzrejališču pujskov in realizacijo strukture regulacijskega kroga. Sintezo mehkega regulatorja temperature smo realizirali s prenosnim računalnikom HP Compaque 6830s NA779ES, programskim orodjem Matlab/Simulink 2008b in vhodno-izhodno enoto Dragon Rider 500. S pomočjo programskega orodja smo simulirali delovanje mehkega PI regulatorja v regulacijskem krogu s procesom prvega in drugega reda, ter optimirali pravila in pripadnostne funkcije mehkega regulatorja. Prenosni računalnik smo razširili z vhodno-izhodno enoto za zajemanje podatkov. Pri statistični analizi rezultatov smo ugotovili, da je pogrešek mehkega PI regulatorja v regulacijskem krogu s procesom drugega reda enak nič. S pomočjo mehkega regulatorja temperature zmanjšamo porabo električne energije do 25 %.

Ključne besede: *regulator, mehka logika, sinteza, vhodno-izhodna enota*

UVOD

V regulacijski tehniki zelo pogosto srečujemo kompleksne dinamične sisteme, ki imajo nelinearno ali časovno spremenljivo obnašanje, [2]. Zato takim procesom težko določimo model, saj so tako dobljeni modeli lahko nenatančni in zaradi tega pogosto neuporabni. Vodenje takih procesov poteka večinoma na osnovi človekovih izkušenj in njegovih neposrednih posegov v proces. Mehki regulatorji so sposobni prevzeti take izkušnje in jih prevesti v zakone regulacij. To je omogočeno z razrešitvijo problemov vodenja brez oblikovanja natančnega modela, ki ga zahteva klasična regulacijska tehnika. To je tudi razlog, da je uporaba mehke logike v regulacijski tehniki postala glavno področje njene uveljavitve.

Japonska industrija je začela z agresivnim trženjem mehke (fuzzy) ideje v obliki prvih komercialnih realizacij. Na področju avtomatizacijske tehnike tako srečamo naslednja pomembnejša področja uporabe:

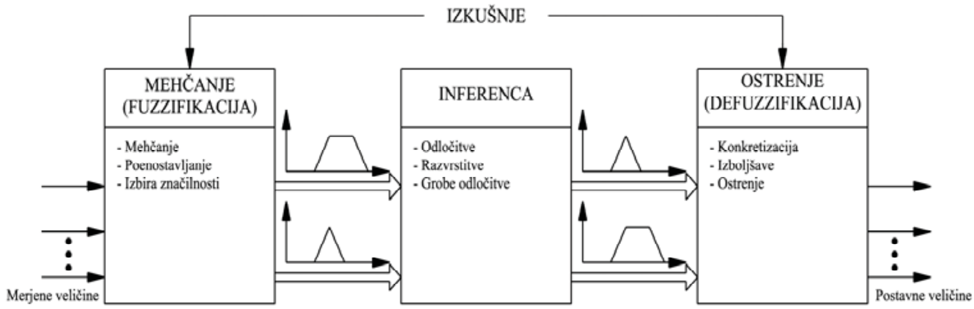
- Inteligentni mehki regulatorji (Fuzzy Logic Control; FLC), ki so zasnovani tako, da lahko z njimi reguliramo temperaturo pare v termoelektrarni (priključna instalirana moč; 300 MW), [5]. Temperaturna regulacija velja za najbolj zahtevno zanko kontrole v procesu proizvodnje pare. Zato so FLC vključili v proces, v katerem so nadzorovali temperaturno pregretost pare. Rezultati so pokazali, da daje FLC boljše rezultate kot konvencionalni PID regulator. Glavne prednosti so v zmanjšanju prekoračitve in strožja ureditev temperature pare. FLC regulatorji dosegajo zelo dobre rezultat za zapletene procese z nelinearno dinamično karakteristiko.
- Od 1987 leta obratuje v japonskem mestu Sendai podzemna železnica vodena po principu mehke logike. Ugotavljajo, da je tako vodenje bolj udobno in ekonomično, kot če ga opravlja izkušen vlakovodja.
- Upravljanje dvigal z mehko logiko je občutno zmanjšalo čakalne čase. Na tem področju skoraj vse japonske firme uporabljajo ta sistem. Sistemi za računalniško krmiljenje so množično opremljeni s komponentami mehke logike.
- Mehke komponente v klima sistemih zmanjšajo porabo energije do 25 %.
- Regulator temperature po mehkem principu daje občutno boljše obnašanje v primerjavi z običajnim zveznim PID regulatorjem, [3].

Uporaba mehke logike se je na Japonskem izredno razširila tudi na druga področja avtomatizacije (transportni sistemi, roboti, procesna industrija, avtomobilska industrija, ekologija, itd.). Število aplikacij na drugih področjih (zabavna elektronika, ekonomija, trgovina, turizem in gostinstvo, kmetijstvo itd.) izredno hitro narašča.

SINTEZA MEHKEGA PI REGULATORJA

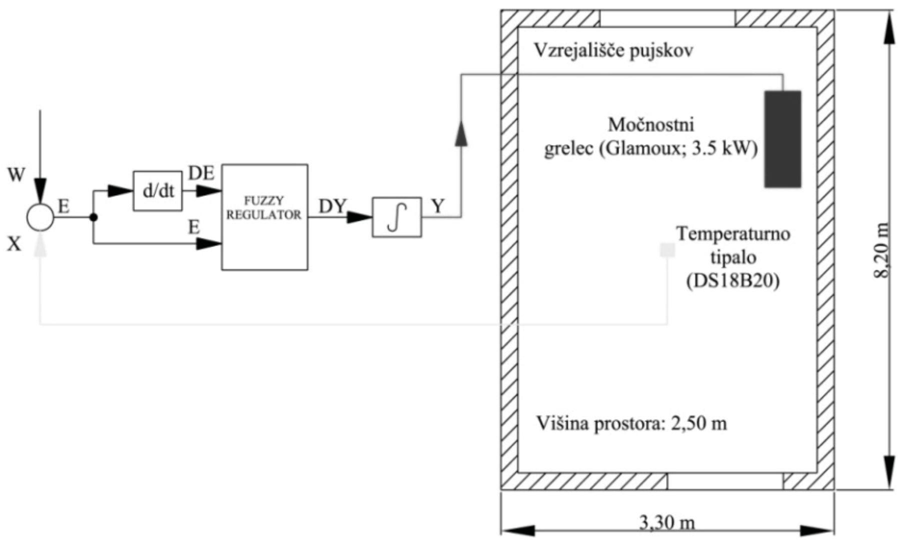
Sintezo mehkega PI regulatorja temperature v vzrejališču pujskov smo realizirali s programskim orodjem Matlab/Simulink, mehkim logičnim orodjem FIS (Fuzzy inference system) v podsistemu Matlab, prenosnim računalnikom HP Compaque 6830s NA779ES, ter vhodno-izhodno enoto Dragon Rider 500, ki služi za zajem podatkov iz temperaturnega senzorja (DS18B20). S pomočjo programskega orodja smo najprej simulirali delovanje mehkega in zveznega PID regulatorja v temperaturnem regulacijskem krogu s procesom prvega in drugega reda. Optimiranje pravil in pripadnostnih funkcij smo izvedli s pomočjo skupine grafičnih urejevalnikov (programski paket Matlab; FIS). V primeru nezadovoljivih rezultatov smo definirali dodatne jezikovne spremenljivke, spreminjali smo pripadnostne funkcije in temu primerno napisali nova pravila. Pri definiciji jezikovnih spremenljivk smo upoštevali gradient naraščanja temperature pri segrevanju in pri ohlajanju ter njegovo odvisnost od delovne točke. Pri snovanju mehkega regulatorja smo upoštevali tri delne postopke, slika 1, ki predstavljajo osnovo delovanja mehkega regulatorja, [1]. To so:

- Postopek mehčanja ali fuzzyfikacije, ki ga lahko naprej delimo na tri podpostopke,
- Postopek inference ali proces odločanja,
- Postopek ostrenja ali defuzzyfikacija.



Slika 1: Trije delni postopki snovanja mehkega regulatorja

Izvajanje sinteze mehkega regulatorja smo ponazorili na primeru realizacije strukture temperaturnega regulacijskega kroga v vzrejališču pujskov, ki ga prikazuje slika 2.



Slika 2: Struktura temperaturnega regulacijskega kroga v vzrejališču pujskov

Oceno odstopanj med zveznim PID in mehkim PI regulatorjem smo ugotavljali z učinkovito vizualno metodo (grafični uporabniški vmesniki; Matlab/Simulink), med katerima smo napravili primerjalno analizo.

Strojna oprema

Strojno opremo temperaturnega regulacijskega kroga sestavljajo naslednje komponente:

- prenosnik HP Compaq 6830s NA779ES,
- vhodno-izhodna enota Dragon Rider 500,
- temperaturno tipalo DS18B20,
- močnostni grelec (Glamoux radiator; priključna električna moč 3,5 kW).

Na prenosniku je dovolj prostora za aplikacije in orodne vrstice, uporabimo ga lahko na terenu, ker ima vgrajeno tehnologijo HP 3D DriveGuard, ki z merjenjem pospeška zazna nenadne premike in izvede zaščitne ukrepe ter nam pomaga varovati trdi disk pred udarci in padci, [8]. Prenosnik HP 6830s ima na voljo 3GB DDR2 800MHz pomnilnik, ki je razširljiv do 8GB. Trdi disk je velik 320GB-SMART SATA 5400 rpm.

Kot vhodno-izhodno enoto smo izbrali Dragon Rider 500 s katerim lahko programiramo široko paleto mikrokontrolerjev tipa Atmel, [6]. Preko USB in RS-232 vmesnika lahko komuniciramo s prenosnim računalnikom HP Compaq 6830s na katerem nalagamo podatke glede temperature v vzrejališču pujskov preko temperaturnega senzorja (DS18B20). Omogočeno je programiranje s pomočjo metod High Voltage, ISP in JTAG. Omejeni pa smo z 32 kilo zlogi programskega pomnilnika (umetna omejitev, ki jo ima Atmel).

DS18B20 digitalni senzor temperature zagotavlja 9 do 12 bitno merjenje temperature v $^{\circ}$C, [7]. DS18B20 senzor komunicira preko 1 – kanalnega vodila, kateri po definiciji zahteva samo eno podatkovno linijo (in maso) za komunikacijo s centralnim procesorjem. Temperaturno območje delovanja senzorja znaša od - 55°C do +125°C, njegova natančnost znaša ±0.5°C pri temperaturnem območju od - 10°C do +85°C.

Programsko orodje Matlab/Simulink 2008b

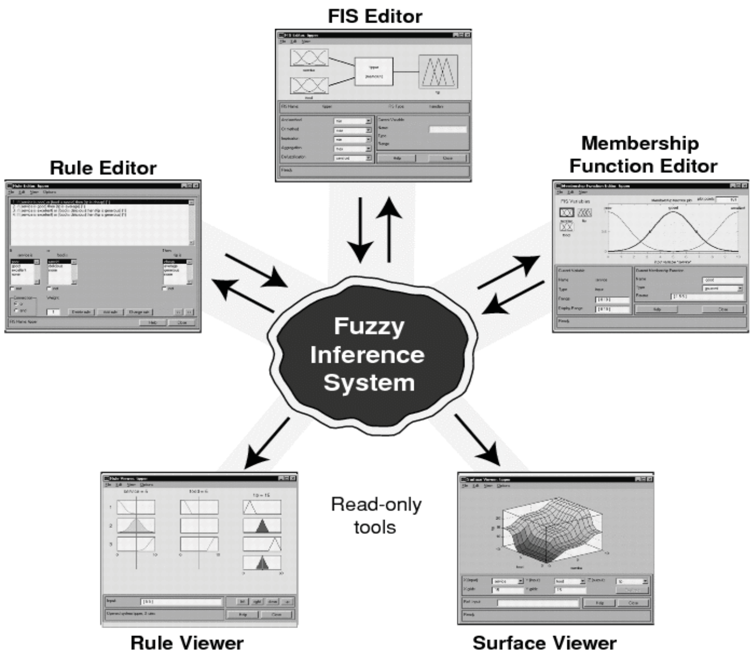
Matlab je programski paket namenjen numeričnemu računanju, kot so aritmetične operacije skalarjev, vektorjev, diferenčnih enačb, diferencialnih enačb in prikazovanju rezultatov, [9]. Za tako obširno rabo ima posebne knjižnice, s pomočjo katerih lahko pridemo do podrobnejših znanj s področja regulacij (zveznih, diskretnih, mehkih), načrtovanju filtrov itd. Vnos ukazov v Matlab-ov delovni prostor lahko poteka direktno s pomočjo ukazne vrstice v komandnem oknu ali pa lahko ukaze vpisujemo v posebno datoteko s končnico *.m. Zapis ukaza v komandno okno ali v datoteko omogoča njegovo večkratno izvajanje, brez ponovnega vpisovanja.

Simulink je programsko orodje in podsistem Matlab-a. Namenjen je za modeliranje in simulacijo matematičnih modelov, [10]. Omogoča nam tudi enostaven grafični prikaz rezultatov simulacije. Zaženemo ga lahko v Matlab okolju z ukazom simulink, ali s pomočjo ikone v Matlab-ovi orodni vrstici.

Mehko logično orodje FIS (Fuzzy inference system)

Mehki PI regulator smo načrtovali s pomočjo mehkega logičnega orodja (FIS; Fuzzy inference system), ki se izvaja v podsistemu Matlab, [4]. Obstaja pet osnovnih orodij v FIS-u (urejevalniki, prikazovalniki pravil in grafov) za gradnjo, urejanje in opazovanje mehkih logičnih sistemov, ki jih prikazuje slika 3. To so:

- urejevalnik za določitev mehkega inferenčnega sistema FIS (FIS Editor),
- urejevalnik pripadnostnih funkcij (Membership Function Editor),
- urejevalnik pravil (Rule Editor),
- prikazovalnik pravil (Rule Viewer),
- grafični prikazovalnik karakterističnega področja delovanja mehkega regulatorja (Surface Viewer).



Slika 3. Osnovna orodja v FIS-u

Vsa osnovna orodja so v FIS-u med seboj dinamično povezana. Vse spremembe (različna nastavitev pripadnostnih funkcij za vhodne in izhodne spremenljivke), ki smo jih nastavljali v mehkem logičnem sistemu FIS-a, imajo vpliv na posamezna funkcijska orodja. V FIS urejevalniku smo tako nastavljali različno število vhodnih in izhodnih spremenljivk (jezikovne spremenljivke; E, DE, dy). V urejevalniku pripadnostnih funkcij smo opredelili njihove oblike (trikotne, trapezne, pravokotne ...). Urejevalnik pravil smo uporabili za urejanje seznama pravil s pomočjo katerega smo določili odziv mehkega sistema. Prikazovalnik pravil (grafični prikazovalnik) predstavlja Matlab-ovo tehnično orodje, ki prikazuje mehke diagrame pripadnostnih funkcij v področju delovne točke. Prikazovalnik služi za diagnozo, ki prikazuje, katera so dejavna pravila, oziroma kako posamezne oblike pripadnostnih funkcij vplivajo na končni izračun izhodne vrednosti spremenljivke mehkega regulatorja. S pomočjo grafičnega prikazovalnika karakterističnega področja prikazujemo izhodno vrednost spremenljivke mehkega regulatorja, ki je odvisna od različnega nabora vhodnih vrednosti spremenljivk regulatorja.

Mehki PI regulator lahko obravnavamo kot regulator z nelinearno statično karakteristiko in množilniki, z vrednostmi faktorjev množenja K_P, K_D in K_I. PI regulator opišemo z naslednjo enačbo, [1]:

$$y(t) = K_P^* \cdot e(t) + K_I^* \cdot \int_0^T e(t)\,dt \tag{1}$$

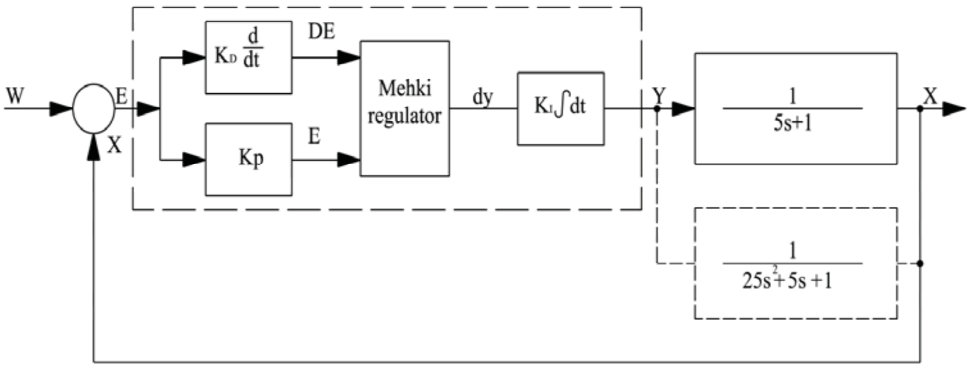
zgornjo enačbo z odvajanjem preoblikujemo v obliko:

$$\frac{dy(t)}{dt} = K_P^* \cdot \frac{dy(t)}{dt} + K_I^* \cdot e(t) \tag{2}$$

z definicijo novih spremenljivk zapišemo končno enačbo:

$$dy = K_D \cdot DE + K_P \cdot E \tag{3}$$

Zgoraj zapisano končno enačbo smo realizirali v mehki obliki, s pomočjo katere izdelamo blokovno shemo mehkega PI regulatorja v programskem orodju Simulink, slika 4.

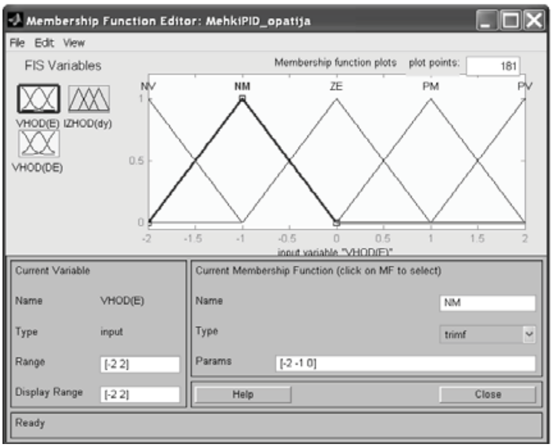


Slika 4. Blokovna shema mehkega PI regulatorja v regulacijskem krogu s procesom prvega in drugega reda

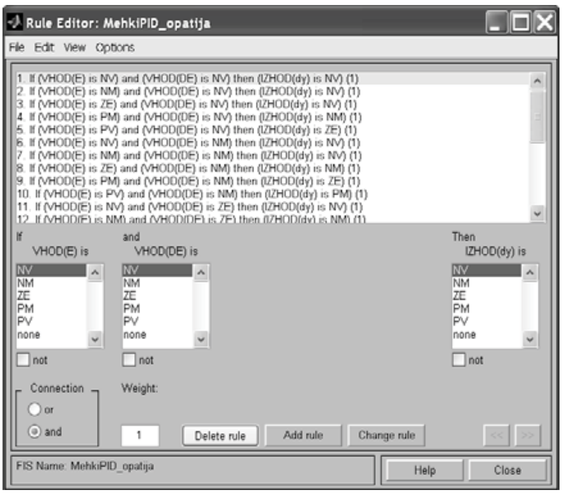
Vhod v mehki regulator je jezikovna spremenljivka E, ki jo izračunamo s pomočjo regulacijskega odstopanja (E=W–X) in odvod regulacijskega odstopanja (DE). Prenosni funkciji predstavljata temperaturni proces, zato smo normirali regulacijsko odstopanje v °C (0° do 26°C).

Izhod mehkega regulatorja (jezikovna spremenljivka Y**)** predstavlja moč grelnika v watih, ki zavzame pet jezikovnih vrednosti (NV, NM, ZE, PM, PV). Jezikovni spremenljivki (E, DE) smo opisali s petimi pripadnostnimi funkcijami trikotne oblike (mehko logično orodje FIS, slika 5.).

Na sliki 6. so prikazana pravila mehkega PI regulatorja, katera smo vpisali v FIS-ov urejevalnik pravil. Jezikovni opis sistema (mehki PI regulator) smo naredili s pravili oblike "ČE-TEDAJ" ("IF-THEN").



Slika 5. Pripadnostne funkcije regulacijskega odstopanja E in odvoda regulacijskega odstopanja DE

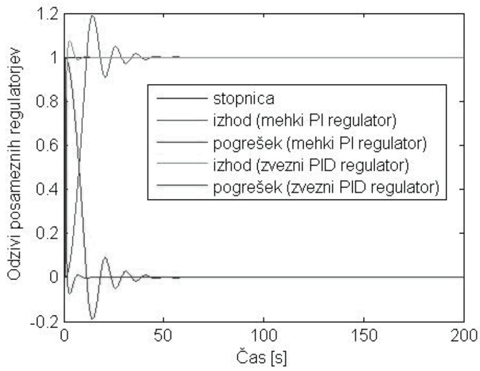


Slika 6. Pravila mehkega PI regulatorja

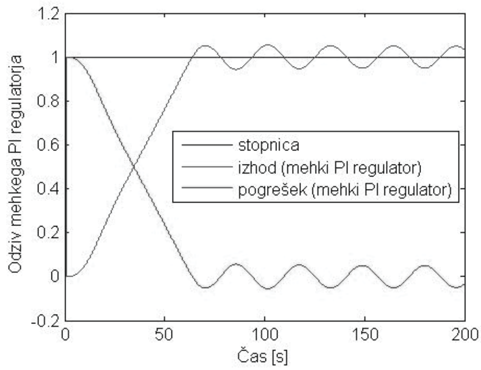
Predpostavili smo, da zavzemajo stopnje NV (negativno veliko), NM (negativno malo), ZE (nič), PM (pozitivno malo), PV (pozitivno veliko) vrednosti med 0 in 1. V mehkem PI regulatorju smo uporabili Mamdan-ijevo implikacijo, ki je za izračun najbolj enostavna. Po opravljenih treh postopkih (mehčanje, inferenca, ostrenje) smo zaključili z načrtovanjem mehkega PI regulatorja. Nato smo izvedli optimizacijo delovanja PI regulatorja, tako da smo ob tem nastavljali stabilnost, robustnost, kvaliteto regulacije in obnašanje pri spremembah vrednosti faktorjev množenja. Oceno odstopanj med zveznim PID in mehkim PI regulatorjem smo ugotavljali z učinkovito vizualno metodo.

REZULTATI

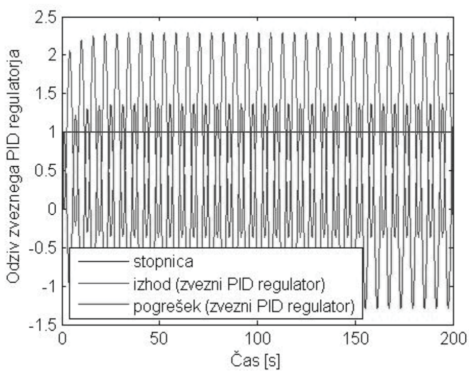
Na koncu smo naredili primerjalno analizo med zveznim PID in mehkim PI regulatorjem za temperaturni regulacijski krog s procesom prvega in drugega reda. Na sliki 7. je prikazan odziv na stopnico (normalizirana temperatura v vzrejališču pujskov: 26°C) klasičnega zveznega PID in mehkega PI regulatorja za temperaturni regulacijski krog s procesom prvega reda, kjer so znašale vrednosti faktorjev množenja; K_P=20, K_D=1, K_I=0.1. Na sliki 8. in 9. sta prikazana odziva na stopnico klasičnega PID in mehkega PI regulatorja za temperaturni regulacijski krog s procesom drugega reda, kjer so znašale vrednosti faktorjev množenja; K_P=20, K_D=1, K_I=0.01.



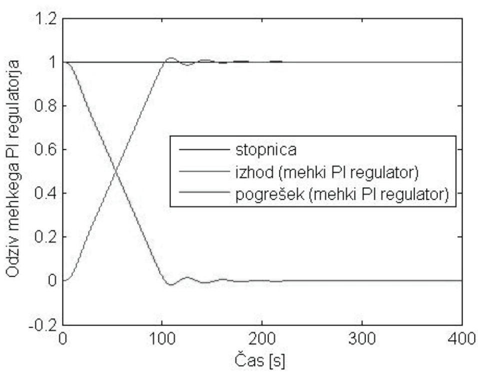
Slika 7. Odziv zveznega PID in mehkega PI regulatorja na stopnico, proces 1. reda



Slika 8. Odziv mehkega PI regulatorja na stopnico, proces 2. reda



Slika 9. Odziv zveznega PID regulatorja na stopnico, proces 2. reda



Slika 10. Odziv mehkega PI regulatorja na stopnico, proces 2. reda

Iz odzivov na stopnico zveznega PID in mehkega PI regulatorja za temperaturni proces prvega reda je razvidno, da je pogrešek zveznega PID regulatorja manjši od mehkega PI regulatorja. V primeru temperaturnega procesa drugega reda, ki ga prikazujejo slike 8., 9., 10., je razvidno, da je pogrešek mehkega PI regulatorja občutno manjši kot pa pri zveznem PID regulatorju.

Pogrešek dobi pri mehkem PI regulatorju v nekem ustaljenem stanju vrednost nič in sicer pri vrednosti faktorja K_I, ki znaša 0.006. Posledica manjšega pogreška pomeni manjšo porabo električne energije. Zato lahko potrdimo, da so mehki regulatorji primerni za temperaturne procese drugega in višjih redov, kar pa ne velja za običajne zvezne regulatorje.

ZAKLJUČEK

Iz rezultatov je razvidno, da je mehka logika uporabna v aplikacijah z nelinearno statično karakteristiko pri temperaturnih procesih drugega in višjih redov, kjer ponavadi klasične metode z zveznimi PID in PI regulatorji ne dajo zadovoljivih rezultatov. FLC omogoča uporabniku, da uporabi lastno znanje o problemu in ga prenese v primerno sistemsko okolje, ki je blizu človeškemu načinu razmišljanja. Ker je to bolj kompleksno opravilo, kot le vnašanje nekaj regulacijskih parametrov smo uporabili poseben uporabniški vmestnik (FIS) za načrtovanje FLC aplikacije. Mehki regulator se je v procesni aplikaciji regulacije temperature izkazal kot zelo dobra izbira, saj je postopek načrtovanja FLC dokaj preprost in primeren za inženirsko prakso.

LITERATURA

1. Dali Đonlagić s soavtorji (1995), Osnove snovanja mehkih (fuzzy) regulacij (2. izdaja), Maribor
2. B. Tovornik, D. Đonlagić, F. Jurković (1994), Basics of the design of fuzzy control systems, KoREMA, Zagreb
3. Borut Zupančič (1996), Zvezni regulacijski sistemi-I. del, Ljubljana
4. http://www.mathworks.com/products/fuzzylogic/description3.html
5. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2T-4DCWGCS-1&_user=940034&_rdoc=1&_fmt=&_orig=search&_sort=d&_docanchor=&view=c&_searchStrId=1080784157&_rerunOrigin=scholar.google&_acct=C000048764&_version=1&_urlVersion=0&_userid=940034&md5=d91d894ca825778bd0e3f45dbc5669eb
6. http://www.ecrostech.com/AtmelAvr/DragonRider/files/UsersGuide.pdf
7. http://datasheets.maxim-ic.com/en/ds/DS18B20.pdf
8. http://www.eworld.com.mt/downloads%5CPDF%5C6830s.pdf
9. http://courses.washington.edu/css457/matlab/learning_matlab.pdf
10. http://www.emse.fr/~pbreuil/auto/sl_using.pdf

TEMPERATURE REGULATION IN PIGLETS PRODUCTION WITH DECISION-MAKING THROUGH FUZZY LOGIC

ABSTRACT

The use of fuzzy logic regulators against the normal regulators has reached the highest level in engineering management and regulation. Therefore, we decided in our application for the synthesis of fuzzy PI temperature regulator in piglets production and realization structures regulating the circle. Fuzzy-temperature synthesis regulator was realized with HP Compaque 6830s NA779ES laptop, programming tool Matlab/Simulink 2008b and input-output unit Dragon Rider 500. With the help of programming tool, we simulated the operation of fuzzy PI regulator in regulating circle of the first and second order and optimized the rules and features fuzzy regulator. A laptop was expanded with the input-output unit for data aquisition. In the statistical analysis of the results, we found, that the fuzzy error PI regulator in regulating circle for the process of second-order was zero. With the help of fuzzy temperature regulator we reduced electricity consumption for 25 %.

Key words: *regulator, fuzzy logic, synthesis, input-output unit*

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 636.4.084
Izvorni znanstveni rad
Original scientific paper

WORKING TIME EXPENSES AND DEGREE OF DIFFICULTY OF FATLINGS TENDING

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

ABSTRACT

Few studies have been conducted on the working time expenses and the energetic workload of the pigtenders upon feeding and watering the pigs as well as removing the manure. These operations depend, at the same time, considerably on the size of the farm (the number of pigs). Before recommending or selecting rational technologies a research into the technological lines in use and the comparative assessment thereof have to be carried out.

In order to compare the most widespread technologies of keeping the fattening pigs a research on the working time expenses and the degree of human workload for tending work was carried out in pigsties of different size.

The daily working time expenses were determined by the chronometric research of the pigtender's work with the precision of a second. The working day was photographed by fixing, describing and entering in the chronological order the time spent by the employee on each work operation, break, etc. in the observation diary. The daily working time expenses were determined per ten youngs and fattening pigs.

Along with the chronometric research of the work a simultaneous measurement of the pigtender's pulse rate was carried out. The degree of difficulty of the pigtender's work was determined in accordance with the average and high pulse rate by using the qualification of the WHO and the data of the other authors. In order to measure the pulse rate the "Polar Sport Tester" kit, consisting of a transmitter and a receiver was used. The receiver saved the pulse rate at the intervals of 5 seconds. The measured pulse rates were saved from the tester into the computer and upon processing the data in the programmes "Polar" and MS Excel, the statistical rows and diagrams of the tenders' pulse rates and the minimum, maximum and average values of the pulse rate were received. The diagrams of the pulse rates were supplemented by an additional scale in order to determine the degree of workload of the pigtender's work when tending animals during different works.

The article presents the data about the human tending daily working time and the degree of the work difficulty, received in case of different animal keeping technologies of young and fattening pigs

Key words: *pigtender, keeping technology, feeding, watering, litter spreading, manure removal, working time expense, degree of difficulty of work, pulse tester*

INTRODUCTION

The selection of keeping technology shall determine the production efficiency in the farm. The technology selected should ensure the greatest efficiency. Before recommending or selecting rational technologies a research into the technological lines in use and the comparative assessment thereof have to be carried out. Usually the evaluation is performed on the basis of technical-economical indicators (such as reliability, ease of use, costs related to working time and exploitation, etc.). Today it is obvious that such evaluation of technologies cannot be perfect, as it does not take into account the impact of animal-keeping technologies on the level of physical effort for work. Therefore this study focused on the technologies used in pigsties not only in view of the determination of the amount of working time, but also in consideration of their impact on the human work load.

Work operations are classified on the basis of their method – manual or automated. Different methods of manure removal have been compared: drainage, removal with scraper or front loader of tractor (Berichte 1997, Reppo & Käämer 1998, Maatalouden…1988). The analysis of literature revealed that the amount of time spent on tending works is commonly presented by work technologies and size of the herd per ten pigs. Amounts of working time are presented in KTBL standard tables by pig-herds consisting of 50, 100, 200, 300, 500, 1000 pigs and in TMRM standards by pig-herds consisting of 60, 120, 250, 500 pigs (Maatalouden työnormit 1988; KTBL 1994, KTBL 2000). Finnish working time standards include data about smaller herds (Maatalouden työnormit 1988). This is due to smaller pig farms in Finland.

Amount of working time spent on specific works (placing pigs in pig-pen, major cleaning or disinfection, treatment, weighing etc.) is given in minutes per fattening pig and as total value for the fattening period. These works are performed less frequently, often only once during the weaning or fattening period.

MATERIALS AND METHODS

In order to study the working time expense and the degree of difficulty of the pig-tender's work, farms of different size (300…1,000 fatling) and feeding, manure removing, litter spreading and animal watering technologies were used, wherein fatlings (Table 1) were kept in groups of different size. The research involved seven farms with more or less the same forage portion, but with different feeding technologies (liquid or dry forage). All the seven farms used sawdust as litter in small amount; the manure was cleaned with a chain scraper conveyor (in case of groups of 1,000 fatlings with the scraper device) and removed from the animal keeping room by pumping into the tank machine.

The pig tenders were mostly women whose principal work duration consisted of the time necessary for loading the dry forage (concentrated feed, meal) into the forage deliverer (barrow), the transportation and delivery, cleaning the pens and tendering passages, loading the litter into the barrow and the delivery thereof, watering the pigs and working with some devices. The mechanical time of the devices was not included in the human working time expense. The daily working time expense was determined by the chronometric research of the pig tender's work with the precision of a second. The actual daily working time of the employee was calculated on the basis of the structural scheme (Maatalouden …, 1988; Reppo, *et. al*, 2000), in accordance wherewith the tending time consists of the permanent help time (10 minutes in a shift spent on dressing, washing, etc.) and the time spent on the performance of the production duty. The latter includes the principal work time and the preparation-conclusion time. The working day was photographed by fixing, describing and entering in the chronological order the time spent by the employee on each working operation, break, etc. in the observation diary. A more comprehensive overview can be obtained, however, if the working time special expenses are fixed per a pig, but the method more-widespread in the world determines the same in case of every ten pigs (KTBL 94/95; Maatalouden …, 1988). The daily working time expenses were determined per ten fatlings (Table 1).

Along with the chronometric research of the work a simultaneous measurement of the pig tender's pulse rate was carried out. The degree of difficulty of the pig tender's work was determined in accordance with the average and high pulse rate by using the qualification of the World Health Organization (WHO) (Tuure, 1991, Tuure 1995) and the data of the authors (Andersen *et. al*, 1978, Hettinger *et. al.*, 1983), according consideration to the fact that at the pulse rate of up to 100 beats per minute the degree of difficulty of the work of a human being is light (L) and at in between 100…124, 124…150 and at more than 150 beats the degree of difficulty of the work is moderate (M), heavy (H) and very heavy (VH), respectively.

In order to measure the pulse rate the "Polar Sport Tester" kit, consisting of the transmitter (sensor) and the receiver (tester) was used. The transmitter was fixed onto the body of the employee in the heart area and onto the hand of the receiver. The receiver saved the pulse rate at the intervals of 5 seconds. The measured pulse rates were saved from the tester into the computer and upon processing the data in the programs "Polar" and MS Excel, the statistical rows and diagrams of the tenders' pulse rates and the minimum, maximum and average values of the pulse rate were received. The diagrams of the pulse rates were supplemented by an additional scale in order to determine the degree of difficulty of the pig tender's work upon tending animals during different works (Figures 1 and 2)

RESULTS AND DISCUSSION

In general, the amount of working time is rather different in case of different pig-keeping technologies, due to tending activities used, type and number of pigs both in a group and in a pen, placement of pens in pigsty, feed rations and physical capacity of tenders.

Upon determination of the working time expense, it became evident (Table 1) that smaller working time expenses were incurred upon the mechanized delivery of forage with the automatic line “Pellon”, “Roxell” and with the battery wheelbarrow EK-2 into the feed trough for 0.24; 0.35 and 0.56 minutes respectively per 10 fatlings daily. The size of the herds was 500, 700, 730 and 1,000 animals respectively. Upon feeding with the automatic line, the human working time is practically zero as the device works in a timely programmed manner (Table 1).

Table 1 Working time daily expenses in minutes per 10 pigs

Technology	Material kg Pig/day	Pig sort and number						
		Fatlings (40...100 kg)						
		300	500	700	730	850	1000	1000
1. Feeding with dry forage (storage-transportation-delivery):								
- filling hopper-battery barrow-trough	3.5							0.56
- filling hopper/barrow/bucket/self-acting feeder „Groba“	3.5					0.70	0.64	
- filling hopper/mixer/barrow/bucket/ trough/self-acting feeder	3.5	2.57						
- filling hopper/ self-acting automatic feeder “Roxell“ (mechanical time)	2.8			0.35	0.35			
2. Feeding with liquid automatic feeder “Pellon“ (mechanical time)	2.1		0.24					
3. Cleaning pens and tending passages:								
- manual cleaning of pens (with a rake)	5	1.76	1.24	0.84	0.63	0.53	0.47	0.47
- cleaning forage passages		0.17	0.41	0.27	0.16	0.27	0.17	0.17
- removing manure with the conveyor (mechanical time)		0.68	0.59	0.51	0.43	0.22	0.14	0.14
4. Transporting and spreading litter (sawdust)	0.8	0.86	0.60		0.28	0.34	0.15	0.15
5. Watering:		*	*	*	*	*	*	*
TOTAL:		5.36	2.25	1.11	1.07	1.84	1.43	1.35
Incl. feeding		2.57	–	–	–	0.70	0.64	0.56

* - watering with nipple drinker

Upon manual feeding, the working time expenses were lower in case of 1,000 fatlings upon forage delivery with a bucket from the wheelbarrow into the feed trough and the forage machine “Groba”, 0.64 and 0.56 minutes respectively per 10 animals (Table 1). Upon feeding the fatlings, the wheelbarrow was filled from the filling hopper.

The greatest daily specific amount of working time was in the section with 300 fatlings – 2.57 minutes per fatling upon feeding with dry fodder (foodstuffs from filling hopper were forwarded to mixer and barrow and then loaded from barrow with bucket to trough or self-acting feeder (Table 1).

Manure removal in pigsties was performed by using technology where manure was manually scraped from pig-pen to manure passage and removed by using chain scraper conveyor (in case of herd of 1000 fattening pigs wing scrapers were used).

As for manual cleaning of pig-pens the amount of working time was the lowest (0.47 minutes per 10 pigs per day) in case of manure removal from 1000 fattening pigs (Table 1). It occurs that the amount of working time is equivalent in case of similar group sizes.

Mechanical time was the lowest in case of manure removal by conveyor (0.14 minutes per 10 fattening pigs per day) (Table 1) or by scraper device in case of the herd of 1000 fattening pigs, and the amount of working time was the highest (0.68 minutes per 10 pigs) in the section of 300 fattening pigs with chain scraper conveyor. It appeared that using drinking devices reduced the tending time significantly (Table 1).

The level of physical effort for tendering works was studied during working day and separately when feeding pigs (Table 2), removing manure and spreading litter (Table 3).

Table 2 Tender's Level of Physical Effort for Work During Feeding

Number of pigs and species	Way of keeping	Feeding technology[1]	Tender		Average pulse rate, Beats/min	Work intensity[3]
			sex[2]	age, years		
1000/1000 fattening	Low litter	Bar-aut/ batbar-tro	W	50	125 118	M M
313 fattening, young pig/75 sows	Low litter	Bar-tro	W	41	127	H
290 fattening	Low litter	Bar-aut	W	66	108	M
850 fattening/ 100 sows	Low litter	Bar-tro / Batbar-tro	M	35	147 138	H H
200 young pig / 600 fattening	Deep litter	Aut	W	57	-	-
1270 fattening	Deep litter	Aut	M	43	80	L
500 fattening	Liquid manure	Aut	W	27	-	-

[1] Bar-tro – manual feeding from barrow to trough;
Bar-aut – manual feeding from barrow to self-acting automatic fodder;
Bar-aut/Batbar-tro –tender use several technology, manual feeding from barrow to self-acting automatic fodder and from battery barrow to trough
Aut – self-acting automatic fodder
[2] M–Male; W–Women
[3] Work intensity: L – light; M – moderate; H – Heavy

Table 3 Tender's Level of Physical Effort for Work during Manure Removal and Litter Spreading

Number of pigs and species	Way of keeping	Manure disposal technology	Tender		Average pulse rate, Beats/min	Work intensity[2]
			Sex[1]	age, years		
1000/1000 fattening	Low litter	Scraper	W	50	132 132	H H
313 fattening, young pig/75 sows	Low litter	Chain conveyer	W	41	112	M
290 fattening	Low litter	Chain conveyer	W	66	96	L
850 fattening/ 100 sows	Low litter	Chain conveyer	M	35	133 130	H H
200 young pig / 600 fattening	Deep litter	With tractor	W	57	125	H
1270 fattening	Deep litter	With tractor	M	43	102	M
500 fattening	Without litter	Liquid manure	W	27	91	L

[1] M-Male; W-Women
[2] -Work intensity: L – Light; M – Moderate; H – Heavy

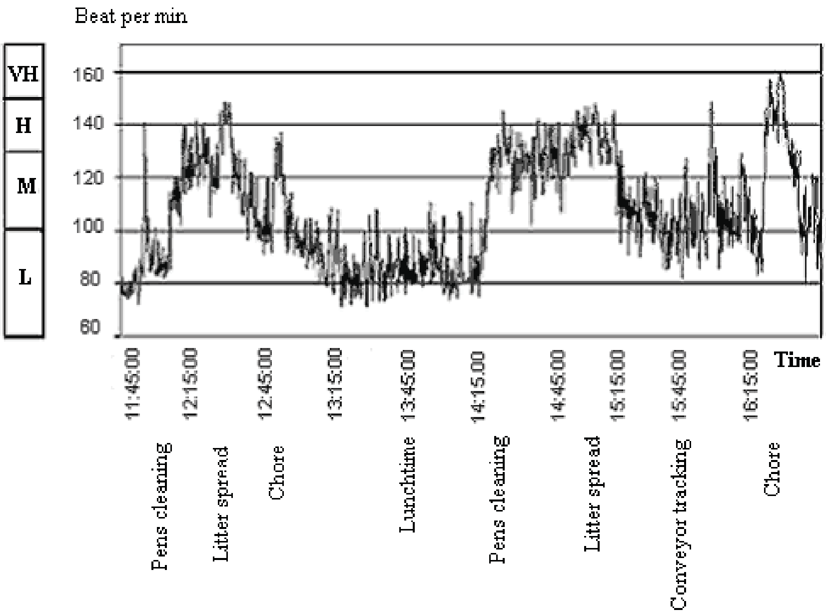


Figure 1 Tender's pulse rate and degree of work difficulty in the case of 500 fattening pigs and self-acting automatic feeder: L-Light, M-Moderate, H-Heavy, VH-Very Heavy.

The study (Figure 1) revealed that tender's level of physical effort for tending 500 pigs was higher in case of spreading litter and cleaning passages, the highest heart rate being 160 beats per minute. During the work shift the tender's level of physical effort for work was moderate (M), but during cleaning works it turned into very heavy (VH).

In low-litter pigsties where fodder was distributed manually, the tenders' level of physical effort for work ranged from moderate (M) to heavy (H) (Table 2), whereas it was considered moderate when feeding 850 fattening pigs and 100 sows by using feeding technology barrow-trough and barrow-automatic feeder.

Feeding of 600 fattening pigs and 200 young pigs in deep-litter pigsty was performed by automated feeding conveyor Roxell, where the tender only had to clean the feeding area and the average level of physical effort for work was heavy (Table 3)

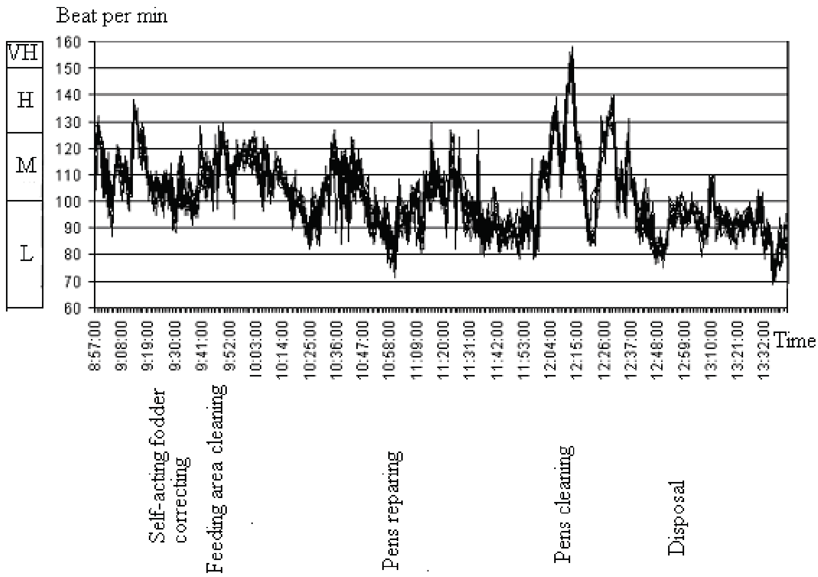


Figure 2 Tender's pulse rate and degree of work difficulty in the case of 1270 pigs on deep litter: L-Light, M-Moderate, H-Heavy, VH-Very Heavy.

In case of manure removal with conveyor system, the level of physical effort for tending works ranged from light to heavy. Main tending works included cleaning pens and spreading litter (Table 3). In deep-litter pigsty with 1270 fattening pigs the tender's average heart rate was 102 beats per minute, which makes it medium heavy effort for work, but it became very heavy when cleaning the pens (Figure 2), which caused maximum elevation of heart rate up to 158 beats per minute.

Selection of fodder distribution technologies should be based on the size of herd and biological type of animal. Manual feeding is unthinkable in pigsties with more than 500 pigs due to high volume of fodder to be delivered. In terms of specific amount of working time and the tender's level of physical effort for work it is more rational to use mechanised feeding.

Considering available equipment and financial possibilities, and based on the aforesaid, the following dry forage distribution technologies can be provided:

- fully mechanised technology is suitable for large farms (more than 700 pigs), where time-programmed automated feeders Roxell, Pellon, Big Dutchman or other similar equipment (feeding hopper-conveyor-automated feeder) or hopper-moving fodder distributor(barrow)-trough technology are used;
- technologies suitable for smaller pigsties consist of fodder hopper-barrow-automated feeder (Groba type).

Water is provided to pigs by using drinking devices that significantly reduce the amount of working time for tending animals.

The average level of physical effort for work of pig-tenders (Table 2) is generally medium heavy. It is light in case of feeding pigs by using automated feeder, where fodder is taken from hopper and extra works (such as manual loading of fodder in barrow) are unnecessary.

In case of feeding into trough the level of physical effort for work is higher, because fodder is distributed along trough as well. Distribution of fodder to farrowing sows was considered light because the size of herd was smaller.

Tender’s level of physical effort for work was light when feeding 1270 fatlings, because of trough clearing and smaller distances of fodder distribution.

In terms of the level of physical effort, straw spreading in deep-litter pigsty was considered to be medium heavy and heavy and cleaning the pig-pens in low-litter pigsties was considered heavy (Table 3)

CONCLUSIONS

In order to compare the most wide-spread technologies of keeping the fatlings a research on the working time expense and the degree of difficulty of human beings upon tending work was carried out in pigsties of different size and kinds of pigs.

Daily amount of working time was determined by pig tender’s chronological portrayal at the accuracy level of one second. The chronological portrayal of working day included determination of time spent on every operation, pause, etc., description thereof and registration in observation diary in chronological order. Daily specific amount of working time was determined per ten young pigs and fattening pigs. Along with the chronometric research of the work a simultaneous measurement of the pig tender’s pulse rate was carried out, whereby, in accordance, the degree of difficulty of work was determined.

In order to measure the pulse rate the “Polar Sport Tester” kit, consisting of the transmitter and the receiver was used. The measured pulse rates were saved from the tester into the computer and the data processed in the programmes “Polar” and MS Excel. The working time special expense of cleaning the pens (1.76 min per 10 pigs a day) existed in case of a herd of 300 fatlings. Smaller working time special expenses (practically the mechanical time) were in bigger farms and pigsties with mechanised removal of the manure where the wing scrapers were used.

The average level of physical effort for work of pig-tenders (Table 2) is generally medium heavy. It is light in case of feeding pigs by using automated feeder, where fodder is taken from hopper and extra works (such as manual loading of fodder in barrow) are unnecessary. In case of feeding into trough the level of physical effort for work is higher, because fodder is distributed along trough as well. Distribution of fodder to farrowing sows was considered light because the size of herd was smaller.

In terms of the level of physical effort, straw spreading in deep-litter pigsty was considered to be medium heavy and heavy and cleaning the pig-pens in low-litter pigsties was considered heavy (Table 3).

The results of multi-parametric study of pigsties allow supplementation of data that provide the basis for evaluation and selection of economically and ergonomically purposeful animal-keeping methods and technologies.

REFERENCES

1. Andersen Large, K., J. Rutenfranz, R. Masironi, V. Seliger. (1978). Habitual physical activity and health. World Health Organisation. WHO Regional publications. European Series 6:1, 188, Copenhage.

2. Berichte über Landwirtschaft. (1997). Mai. Münster-Hiltrup, Landwirtschaftsverlag Band 75(2):161-332.

3. Hettinger Th., W. Hollman. (2000). Sportmedizin. Grundlagen für arbeit, Training und präventivmedizin. 4., völlig neu bearbeitete und erweiterte Auflage. Stuttgard; New York, Germany, 710.

4. Hettinger Th., Müller B.H. und Gebhart H. (1983). Ermittlungs des Arbeitsenergieumsatzes bei dynamischmuskulären Arbeit. Schreifeteureiche der Bundesanstall für Arbeitsschutz. Forschungsanwendung. Fa 22: Dortmund. 80 S.

5. KTBL-Taschenbuch Landwirtschaft. (1994), KTBL – Schriffen – Vertrieb im Landwirtschaftsverlag GmbH, 19 Auflage 1994/95. Münster-Hiltrup.

6. KTBL-Taschenbuch Landwirtschaft. (2000). 20. Auflage 2000/2001. KTBL-Schriften-Vertrieb im Landwiertschaftserlag GmbH, Münster-Hiltrup.

7. Maatalouden työnormit. Työtehoseura. Työtehoseuran maatalous- ja rakennusosaston monisteita. Vantaa, Työtehoseura, 2/1988. –178 s.

8. Reppo, B. and J. Käämer. (1998). Arbeitszeitaufwand und energetische Belastbarkeit des Viehwärters bei der Entmistung der Vieha and nlage. Estnische Landwirtschaftliche Universität. Transactions. Agricultural Machinery, Building and Energy Engineering. 200, pp 103-107.

9. Reppo, B., Sada, O. (2000). Working Time Expenses of Pig Tending. Estonian Agricular University, Transactions. Agricultural Machinery, Building and Energy Engineering 206, pp163-169.

10. Tuure, V.-M. (1991). Maatilan töiden fyysinen kuormitavuuden määrattäminen. Työtehoseuran julkaisuja 332. Helsinki, 130.

11. Tuure, V.-M. (1995). Työympäristö kylmissä pihatoissa. Maatalousteknologian julkaisuja 18. Helsinki, 143.

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:633.17
Stručni rad
Expert paper

OPTIMIZATION OF RENEWABLE ENERGY SUPPLY

DUMITRU TUCU, DUMITRU MNERIE

POLITEHNICA University of Timisoara, Mechanical Engineering Faculty, Bd. Mihai Viteazul, No.1, 300222 Timisoara, Tel. 0040-744-264650, Fax 0040-256-403589, dumitru.tucu@mec.upt.ro, d_tucu@yahoo.com

SUMMARY

This paper presents some considerations about optimization of integrated systems for renewable energy by a systemic approach.

The objectives of present paper are: estimation on possibilities to identify optimum natural resources for renewable energy production including others than primary agricultural products; finding practical solution for manufacturing; estimating the potential problems for implementation in Romania, by using new approach of integrated engineering.

There are presented the advantage and disadvantage of the use of solutions, economic and social implications with an example of the use sorghum bicolor as renewable energy resource.

Special part is destined on the technologies processes and specific equipment.

Key words: *renewable energy, investments, environment, opportunities and threads, sorghum bicolor*

INTRODUCTION

The "White Book", a strategic paper about renewable energy resources, adopted by the European Commission, on November 11, 1997 in the European countries, established the target of minimum 12% renewable resources in Europe's primary energy consumption for the year 2010 (Kommission der Europaischen Gemeinschaften, 1997). Also, electrical energy will be in 2010 minimum 22.1% in total energy.

Usually, the energy needs could be: power for equipment and machines, houses needs (light, warm water, house heating, communication, offices etc.), transports (internal and external) etc.

The principal factors of consumption influence are:

- Civilization level

- Models of culture
- Number of family's members
- Clime
- Particularities of buildings
- Level of family's income etc.

Resources for energy consumption could be: hydropower, direct wind and solar energy, biomass – agricultural residues, forestry and SRC, other fats from animal fats (pork, tallow, restaurant grease, acidulated soap stock, non feed fats others), waste cooking oil, waste mineral oil and others.

According Kaltschmitt M., Hartmann H., (2001), the technical potential for using biomass means 8-10 % of primary energies in Germany and in Europe.

One possibility for Romania is to use solar energy, direct with solar collectors or by conversion in electricity by photovoltaic elements.

For Romania more than half of surface has year medium flux 1000 KWh/m^2 (3,96 GJ/m^2).

Another source could be the energy of wind, their capacity for Romania, for long time, is estimated at 3 GW installed power.

Other source is geothermal energy, but it can be used only in special places, in regions with possibilities for extract the hot water (55-105^0 C).

The most important direction, as it can see, is the biomass, their perspective being influenced by a lot of non-correlated factors, e.g.:

- the world market price of main crops (whet, barley, oilseeds etc.);
- the world market price for mineral energy resources (oil, gas and coal);
- the international food market regulation;
- continental, national and regional environmental restrictions for agricultural technologies (transgenic crops, fertilization, using of herbicides and pesticides etc.).

The biomass can offer 95% from total renewable energy for Romania, means 91.700 TJ/a, with the next structure:

- wood for fire, 40.032 TJ/a
- wood wastes, 10 627 TJ/a
- agricultural wastes, 35 000 TJ/a
- biogas, 6018 TJ/a.

These first considerations are made according to the sources.

The objectives of present paper are: estimation of possibilities to identify optimum natural resources for renewable energy production which can be used for farms consumption, others than primary agricultural products; finding practical solution for manufacturing and optimization; estimate the potential problems for implementation in Romania, by using principles of integrate engineering.

METHODS

In the field of renewable energy production, the first step means activities for promotion of renewable energies and connected production systems, after this it is necessary a process of optimization, considers not only technical criteria, but economical, social and strategic as well.

In many situations, the problem of optimization of renewable energy resources is limited at mathematical aspects of one or more technical aspects. A linguistically approaching of optimizing concept defines it as activity about that a process or action are made efficient, in conditions of determined restrictions. Unfortunately, in many situations, there is a technical vision of optimization concept, which accepts that exist only a mathematical relation between variables or it reduces the optimization activities at mathematical processing.

For these reasons, the present methodology supposes the use of one generalized systemically approach of the process that was developed in fabrication systems.

Based on this approach there was created a generalized input-output model, used at global optimization of systems, presented in figure 1 (Tucu, 1995, 2003).

Such a model considers the systemic relationship, by inter-dependence and reciprocal influence, between inputs in optimization process, outputs from optimization process and corrections, adjustments, can be made in global optimization process.

Generalized approach presented is supported, firstly, by including in **inputs** besides essential element – integrated systems for renewable energy resources – made from **ensemble equipment - technologies – devices and plants**, also, vectorial variables determined by complex state of investment (by approach at resources and material possibilities, know – how preparing and necessities for present and future), disposal of society (expressed by economical level development, technical and technological development and essential strategic objectives) and level of informational and communication technical (hard and soft of computers and connections between basis elements and external networks, analyzed as technical and technological possibilities).

In the same manner, **outputs** include the same groups of vectors, defined on the same structure, thanks to organization of optimization programs in "do" cycle, connect the inputs with outputs in the algorithm of optimization process.

The influences are reciprocally, optimization bringing not only benefit for integrated system, but also for other outputs which can contribute in the next steps of integrated system progress, always as inputs in global optimization process or by direct influences on integrated system after their optimization.

Of course, the essential elements of global optimization process of integrated systems for agro – food production are the **adjustment sizes**, that vectors which determine functional relationships, that can be determinate or not, used principally inside optimization process.

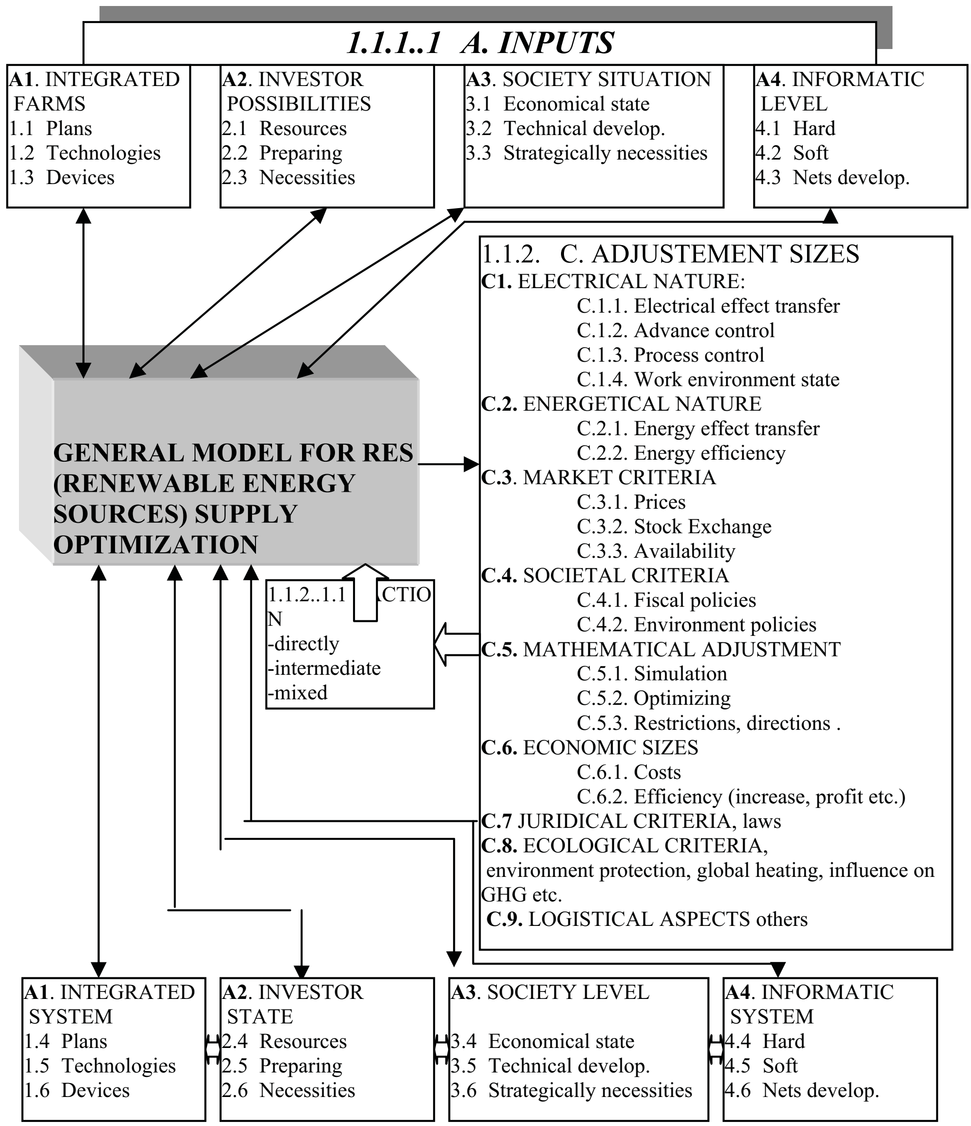


Fig. 1 General model for RES (Renewable Energy Sources) supply

This classification of adjustment sizes is based on “size nature” criteria, this way permit a rapid connection between specific optimization program sizes on that are operating and their essential characteristics.

The first considerations are made according to the sources, in different state of industrial implementation.

The second consideration is made by economic approach, considering the risk of investment.

Another basis conditions are the legal conditions that involved development and industrial implementation of research solution in Romania. It is necessary to consider both technical and economical aspects, in many steps.

Application in practice involves a lot of mathematic methods and starts with establishing of criteria hierarchy, quality costs and possibilities for application in enterprise manufacturing process.

Total costs are determined by the costs of implementing the measures themselves and those of administration, monitoring and enforcement.

All applications means a process of optimization, themselves target for optimization by the same presented method.

RESULTS

It is presented an example resulted for optimization process of the use of sorghum bicolor as culture plant, renewable energy source, animal feed and raw material for food industry (Habyarimana, 2004).

After input analysis it is important to consider adjustment sizes, especially ecological and social criteria. Upon this criteria, the most important is that photosynthetic cycles to be C3 (Calvin cycle) or C4 cycles (Hatch-Slack cycle), in which the molecule of the first stabile product presents three carbons (phosphor-glycerate) or four carbons (products such as oxalo-acetate, malate and aspartate) (Hall and Rao, 1990). The C4 cycle have the highest productivity among photosynthetic pathways, with higher photosynthetic saturation rate (absorbing more solar energy), absence of losses by photorespiration, higher efficiency in the utilization of water, higher saline tolerance and lower CO_2 compensation point, that makes C4 cycle plants more suitable for bioenergy production (Janssens et all, 2007).

Sorghum is included in C4 species with a transpiration rate between 150-300 kg of evaporated water per kg synthesized, average annual productivity between 60-100 tons/hectare with photosynthesis on external part of the leaf (Janssens et all, 2007).

After optimization of general decision, the most important part was to optimize the design of equipment for crush sorghum and obtaining light sweet juice.

After harvesting the stalks can be used for cattle food or fuel. It is best to practice crop rotation and only grow sorghum on the same land every 4 years.

The station for extraction of juice must insure continuous supply with green stalk that determine their placement in the middle of culture or near it, with free and rapid access.

For optimization the crushing process it is recommended that the stalks brought for broken be defoliated before the process.

According by proposed method, first step was to determine the optimum size of solution. The equipment will be used both in great farms and in small exploitation (for Romania these are specific conditions). Also, it must be flexible, for use in stationary position or/and mobile, transportable at each exploitation. Investors can be associations of small farmers. Equipment must be simple, easy to use and repair, but efficient, productive and adaptable to more productive structures

One important condition for work process optimization is correlation between capacity of crushing system and the capacity of supply system, which permits the continuous function of equipment between two successive transports from the cultivated area.

Based on all conditions it was realized an questionnaire for 12 specialists which answer at 15 question, answers was the basis for equipment designing.

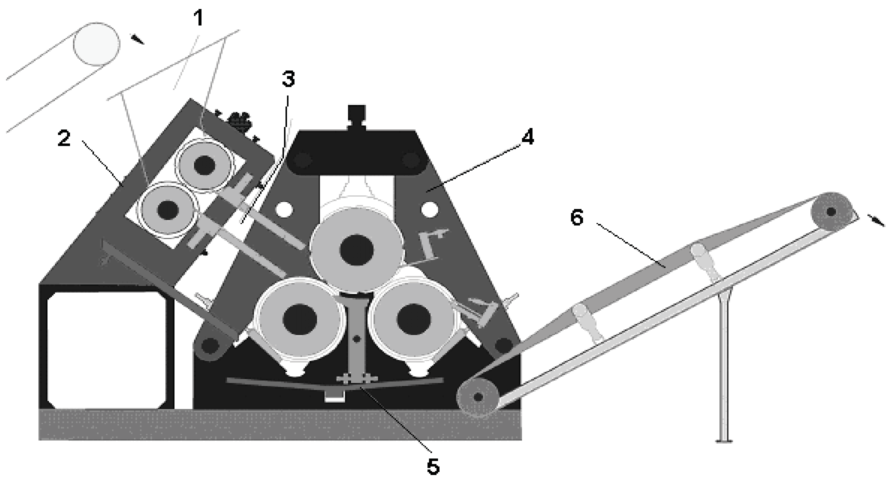


Fig. 2 Schema of crushing equipment for sorghum bicolor

The equipment, presented in figure 2 (Tucu D., 2007), was designed as system of three cylinders with horizontal position, assembled on the metallic support field (1- supply tank, 2-crusher with two cylinders, 3- supplying channel, 4- crushing system with three cylinders, 5- tank collector, 6- evacuation transporter).

CONCLUSIONS

Optimization process is complex and needs a systemic approach, based on nature of size and different mathematical methods. The use of sorghum bicolor as biomass resource involves many aspects, more favorable for Romania. Sorghum offers more energetic possibilities, both for bioethanol (sweet juice), biodiesel (oil from seeds) and biomass from the rest of plant, according to state of the art possibilities for conversion technologies, presented from European Commission, (1999). The use of bagasse resulted from sorghum stalks as biomass for lingocellulosic ethanol production could be also an alternative (Hamwlinck C.N., 2004), but it is necessary to respect the principle of non-competition with food (NILE Report, 2008).

According to Ionel I., Meyer Pitroff R. (1997) in the use of biomass appears the necessity of limiting the ambient pollution caused by thermal and electric power generation.

There are necessary optimization measures both for increase of harvest using level and for risks decrease. The enterprises from this field of activity present a high risk, that determine measures necessaries both for increase of harvest level and risks decrease (Seabra J.E. A., 2008).

Investments made in renewable energy installations serving all the needs of an entire community, in mixed integrated solutions (electricity in co-generation, ethanol, food and animal nutrition) are most important and involve many efforts from all responsible factors, but insure a good and sustainable alternative at present crisis of energy and resources (Smeets E. et al., 2005).

REFERENCES

1. Habyarimana E., Laureti D., De Ninno M., Lorenzoni C., (2004). Performances of biomass sorghum [Sorghum bicolor (L.) Moench] under different water regimes in Mediterranean region, Industrial Crops and Products, Volume 20, Issue 1, 23-28
2. Hamelink C.N., et al. (2005). Ethanol from lignocellulosic biomass: techno-economic performance in short, middle and long-term, Biomass and Bioenergy, vol. 28(4)
3. Ionel I., Meyer Pitroff R. (1997). The necessity of limiting the ambient pollution caused by thermal and electric power generation in Romania, Lucr. Ses.St. “Masini si echipamente termice”, Galati, vol.2, pp186-195
4. Janssens M.J.J. et al., (2007). The role of photosynthesis and bio-productivity on bioenergy yields, University of Bonn, Institute of Crop Science and Resource Conservation
5. Smeets E. et al., (2006). A bottom-up assessment and review of global bio-energy potentials to 2050, Progress in Energy and Combustion Science, doi:10.1016/j.pecs.2006.08.001
6. Hall D.O. & Rao (1999). K. Photosynthesis, 6th edition, Cambridge: Cambridge University Press, 1999
7. Kaltschmitt M., Hartmann H., (2001). Energie aus Biomasse, Grundlagen, Techniken und Verfahren, ISBN 3-540-64853-4, Springer-Verlag Berlin Heidelberg New York
8. Ţucu D., Mnerie D., (2003), Integrated systems for agri-food production, Ed. Orizonturi Universitare, Timişoara, ISBN 973-638-066-1, 127-130
9. Tucu D., Mnerie D., Oprean Letitia, Tita O., (2007), - Integrated Systems for Agri-Food Production-Durable Development, Ed. Orizonturi Universitare, Timisoara, ISBN 978-973-638-348-9, pp. 211-214
10. European Commission, Edith Cresson-member, (1999), - Biomass conversion technologies, Achievements and prospects for heat and power generation, Luxembourg, ISBN 92-828-5368-3.
11. Kommission der Europaischen Gemeinschaften (1997). Energie fur die Zukunft: Erneuerbare Energiequellen. Weisbuch fur eine Gemeinschaftsstrategie

12. NILE (New Improvements for Lignocellulosic Ethanol) (2008). Advances in Lignocellulosic Ethanol, Six Framework Programme RTD, Brochure, pp.3-5

13. Seabra J.E.A. et al., (2008). Analise de opcoes technologicas para uso integral da biomasa no setor de canade-acuare suas implicacoes, PhD Thersis, Universidade Estadual de Campinas, Faculdade de Engenharia Mecanica, Campinas, Brasil

14. Ţucu D., (1995) Contribuţii la optimizarea tehnologiei de fabricaţie a tuburilor flexibile, Teza de doctorat, UP Timişoara, 23-44

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.3:631.17
Prethodno priopćenje
Preliminary communication

GRIPPERS DESIGN INTEGRATED IN HANDLING SYSTEMS DESTINATED TO AGRICULTURE MECHANIZATION

DUMITRU TUCU, ANTONIO-GABRIEL GOLÎMBA, DUMITRU MNERIE

POLITEHNICA University of Timisoara, Mechanical Engineering Faculty, Bd. Mihai Viteazul, No.1, 300222 Timisoara, Tel. 0040-744-264650, Fax 0040-256-403589, dumitru.tucu@mec.upt.ro, d_tucu@yahoo.com, tommy_gyo@yahoo.com, dumitru.mnerie@mec.upt.ro

SUMMARY

This paper presents some considerations on grippers designing based on new approach according to specifically conditions of handling systems destined to agriculture mechanization.

The objectives of present paper are: estimation on possibilities to identify optimum ways and solutions, insuring of maximum fiability and maintenance; finding practical solution for manufacturing; estimating the potential problems for implementation in Romania, by using integrated engineering.

There are presented the advantage and disadvantage of the use of solutions, economic and social implications.

Special part is destined on the technologies processes and specific equipment.

The result of present paper is a new solution for gripper, simple, efficient and easy to manufacture and use.

Key words: *grippers, agriculture mechanization, designing, handling systems, optimization*

INTRODUCTION

Today in all developed countries large quantities of vegetables, especially tomatoes, cucumbers and pepper are produced in greenhouses. Regarding economic aspect, in conditions of the average size of the nursery increasing throughout the last decade to more than 1 ha and large production facilities of more than 5 ha (LEI/CBS, 2000), labor became the largest cost factor. More than 30% of the total production costs are spent on wages for the grower and his employees and this percentage is still showing a rising trend (Van Henten, 2006).

Obviously, the goal is to identify optimum ways and solutions, insuring of maximum reliability and maintenance, to find practical solutions for manufacturing, to estimate the potential problems for implementation in Romania, by using integrated engineering.

Another justifying of automation is the declining availability of skilled labor.

Manual labor in a greenhouse is demanding, the jobs are not prestigious and the earnings are low. Finally, the prevention of musculoskeletal disorders has motivated the replacement of human labor by automatons (Van Henten, 2006).

On the other hand the development of automation systems for agriculture and food industry supposes special conditions as: simplicity, friability, low cost both for investment and maintenance, low qualification level for workers, good attitude for vegetable total quality etc.

All these and others gave motivation for our experiment for the development of an autonomous handling systems picking robot at Fraunhofer IPA – Institute for Manufacturing Engineering and Automation in Germany.

Studying the application possibilities, various aspects of the development and field test of this agro-robotic system have been reported throughout the years (Van Henten et al., 2002a, 2002b, 2003a, 2003b; Van Willigenburg et al., 2004).

The development of such machines fits into a trend starting in the early 80s of the 20th century, aiming at the automation of tedious, repetitive or labor-intensive tasks in horticultural crop production.

The Electrotechnical Laboratory, Japan, was the first research institute that developed a flexible gripping robot hand. In 1979 T. Okada made the Okada Hand. It was a gripper with 3 fingers (main upper fingers and the opposable finger), 12 links, 11 joints and 11 controlled degrees of freedom. The gripper was bigger than a human hand. It could have gripped objects with the fingertips, but also with the phalanges. The structural design concept was an exoskeleton with a remote location of the actuator, which was an electrical revolute motor. The transmission was made by tendons, the routing being made by pulleys/sheaths. It had sensors for the motor position, motor effort and potentiometers for joint positions (Biagioti, 2007).

After the successful field test of the harvest machine in late 2001 (Van Henten et al., 2003b), the research effort was redirected in 2002 towards the development of a robot for removing the leaves from cucumber plants grown in a high-wire cultivation system.

This paper describes a functional model and field test of a gripper with a single motor (one motor) that operates three fingers which can be used for plants, fruits and vegetables harvesting in different cultivation systems.

METHODS

In many situations, the problem of optimization of automation systems for agriculture and food industry is reduced at mathematical aspects of once technical problems.

A linguistically approaching of optimizing concept defines it as an activity about that a process or action are made efficient, in conditions of determined restrictions (Tucu D. et al., 2003).

Unfortunately, in many situations, there is a technical vision of optimization concept, which accept that exist only a mathematical relation between variables or it reduce the optimization activities at mathematical processing.

Present solutions to the problem are very complex, but also complicated.

They have a lot of parts in composition what implicates a lot of possible problems: they have many actuators and sensors (a lot of difficult and complex programming), cables and connectors, things that make them not reliable. By trying to reproduce the human hand, the authors complicated their devices by adding many parts which allow them to make similar movements to a hand, but by doing this they have also raised the prices.

In conclusion, these solutions have many parts, are difficult to program, not reliable and expensive.

A good solution would be to have a gripper that isn't as simple, but also, not that complicated.

The gripper should be a device that:

- has a small amount of components (a small number of components results in small costs for production);
- has a strong structure but one that is also flexible;
- has the movement of the parts made by only a few motors, to have less programming problems and cables, which would make it more secure;
- has a reduced dimension (it should be small);
- has the fingers constructed in a way that would permit different gripping techniques without having to change or remove any component within the structure of the device (Becker R. et al., 2005, Becker R. , 2008).

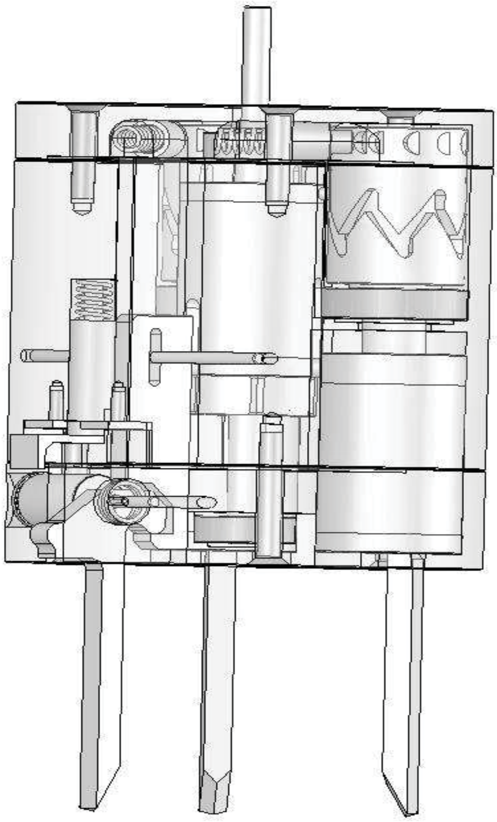
The working version (picture 1) respects the idea of the gripper and was realized in Fraunhofer IPA – Institute for Manufacturing Engineering and Automation, Stuttgart, Germany, by cooperation with Dipl.Ing.(FH) Ralf BECKER.

This version improves the older versions with many changes. By adding more components the gripper is able to work properly (ball bearings, axes, screws, some additional springs, parts that ensure a good contact between surfaces).

One of the most important changes is the motor. The working version is constructed for a rotating stepper motor, while the first concept used a linear motor. So in addition, this version has a trapezoidal screw and nut to which the motor is connected to, and the central part is mounted on the nut.

Once this version of motor was in calculus, there were added two more ball bearings for the screw to be fixed by them.

The concept had a blocking mechanism for the fingers' actuators made out of a metal part and a spring that permitted rotation only in one direction. The same mechanism would have been used if on the upper side of the fingers' actuator would have been mounted a needle bearing for rotation.



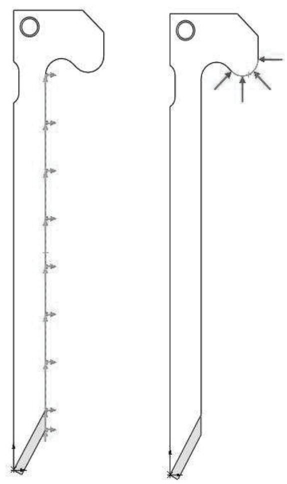
Picture 1 Working version for gripper

The problem is that the gripper would not work only in a vertical position and that means that it should need also axial support, which the needle bearings are not offering.

So the improvement is to replace the needle bearings with ball bearings, but who are of a larger diameter and so the blocking mechanism had to be changed also from lack of space.

All the versions of the blocking mechanism are the same idea as the push-push mechanic pens. The first version was depending on the friction coefficient and in some cases of collision the small sliding part from inside might as well fall from the trajectory and that is why it wasn't the best solution. In the next version, which was a totally different concept, the difficult parts were to mount the device and to operate the blocking part. This all problems were solved with the last version.

SYSTEM ANALYSIS



Picture 2 Forces distribution for chargement (left) and *powering (right)*

Application in practice involves a lot of mathematic methods and starts with establishing of criteria hierarchy, quality costs and possibilities for application in manufacturing process.

First step was to calculate and choose the principal elements of the gripper as:

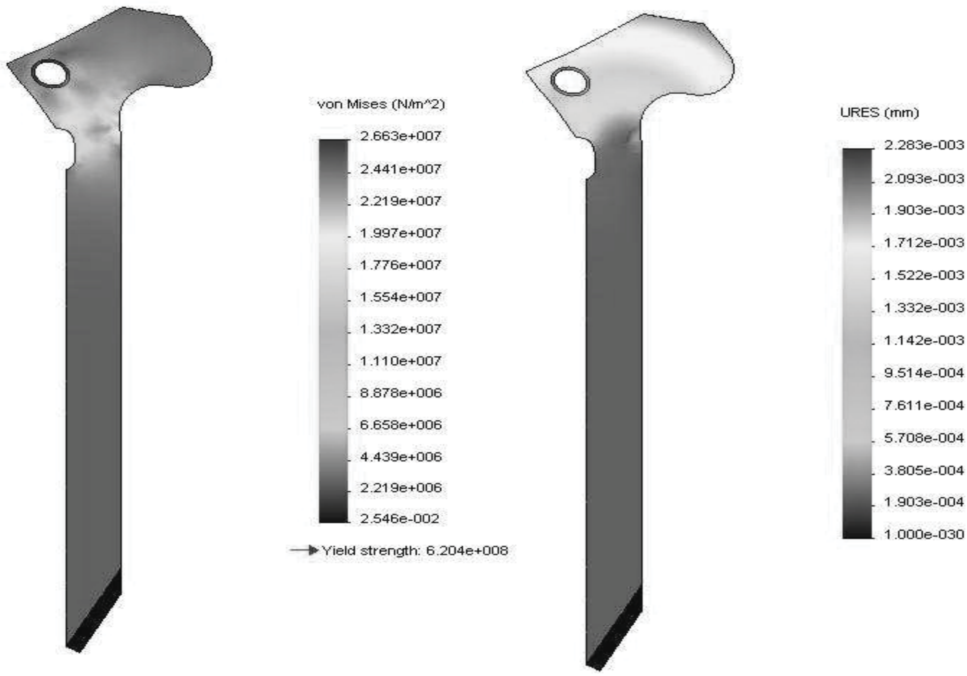
- Minimum angle for the path on the finger's actuator so that the device isn't blocking (determined value would be at least 20º).
- Choosing a potentially motor insuring a necessary torque for generating a 45,45 N force at one finger (results one motor ST4209M1206, a high torque stepper motor, from the Nanotec company, which has a 35,4 Ncm holding torque, low cost and is used for high precision applications).

Next step was to simulate the behavior of strengths using the finite element methods.

After supposing that the finger grips an object and the motor is still applying a 45N force after the finger can't move anymore, the stress distribution and it's values are like in the picture 3 (stress and deformation repartition for the gripping finger), according to the force repartition (picture 2, presentation of force distribution).

After the strength conditions were satisfied, next step was the optimum manufacturing solution.

The body needs to lose some material so that the building process would be less expensive.



Picture 3 Strength (left) and deformation (right) distributions

After reducing the body of the gripper and replacing the holes for the screws and fixing pins, the outer structure was prepare for manufacturing by rapid prototyping.

The present analyze suggest, according the specifically conditions from agriculture, some objectives for next grippers solutions as:

- using of a motor with its custom support and clutch mounted on top of the gripper;
- the length of every step of the path longer with 2 mm for more security, so that the pin would not brake in case of malfunction;
- the fingers' actuators are divided in two, the lower part being square for more resisting force at the portion were the finger is fixed;
- the actuator's rings don't have a pin to connect to the central part anymore, they have a disc, and now they rotate in the same time with the fingers;
- the fingers are bigger to resist at bigger forces and they also have been divided and got now two holes with a 4mm diameter for mounting different types of fingertips;
- the central part has the lower part, instead of two channels for the actuator rings' pins, two cuts that allow a smooth connection between the central part and the two actuators' rings.

FUTURE WORK AND CONCLUSIONS

The future works implicates:

- -some tests of the current working version in some agricultural harvesting machines;
- -reducing the number of components;
- -changing the electric rotational stepper motor with a pneumatic drive;
- -returning to the initial blocking mechanism of the fingers' actuators because if somehow the finger passes one step on the path, with the drawn cup roller clutch it can't go back, while with the initial mechanism it can go back until the last hole - implementing the changes and ideas from the advanced version (previous chapter).

The conclusion is that simple grippers are not a solution to the problem, but also the complex and complicated devices are not.

The proposed solution in this paper is better because it is simpler, easier to program, has a very flexible structure and can be reconfigured to do three different types of gripping.

However, even this solution can be improved and actualized to the mentioned above future work for systems used in agriculture and food industry.

There are necessary optimization measures both for increase of harvest using level and for risks decrease.

REFERENCES

1. Becker R. (2008), Industrial robot pick-up grip has three fingers two of which shift through both horizontal and vertical axes, Patent Number: DE102007006542-B3; Patent Assignee and Codes: FRAUNHOFER GES FOERDERUNG ANGEWANDTEN EV(FRAU-C); International Patent Classification: B25J-015/10
2. Becker R., Grzesiak A. (2005), Robot grip for manipulating articles has at least fixing flange, frame and actuator element made in one piece, Patent Number: DE102005046160-B3; Patent Assignee and Codes: FRAUNHOFER GES FOERDERUNG ANGEWANDTEN EV(FRAU-C); International Patent Classification: B25J-015/00
3. Biagiotti L., Lotti F., Melchiorri C., Vassura G., How Far Is the Human Hand? A Review on Anthropomorphic Robotic End-effectors, DEIS - DIEM, University of Bologna
4. Van Henten E J; Hemming J; Van Tuijl B A J; Kornet J G; Meuleman J; Bontsema J; Van Os E A (2002b). An autonomous robot for automated harvesting of vegetable fruit in greenhouses. Autonomous Robots, 13, 241–258
5. Van Henten E J; Hemming J; Van Tuijl B A J; Kornet J G; Bontsema J (2003a). Collision-free motion planning for a cucumber picking robot. Biosystems Engineering, 86, 135–144
6. Van Henten E J; Van Tuijl B A J; Hemming J; Kornet J G; Bontsema J; Van Os E A (2003b). Field test of an autonomous cucumber picking robot. Biosystems Engineering, 86, 305–313
7. Van Tuijl B A J; Van Henten E J; Hoogakker G -J; Van der Weerd M J; Hemming J; Kornet J G; Bontsema J (2004). An information based systematic design method for robotics in greenhouses. Acta Horticulturae, 691, 859–866

8. Van Willigenburg L G; Hol CWJ; Van Henten E J (2004). Online near minimum-time path planning and control of an industrial robot picking fruits. Computers and Electronics in Agriculture, 44, 223–237

9. Van Henten E.J., Van Tuijl B.A.J., Hoogakker G.-J., Van Der Weerd M.J.; Hemming J., Kornet J.G., Bontsema J. , An Autonomous Robot for De-leafing Cucumber Plants grown in a High-wire Cultivation System, Biosystems Engineering, (2006) 94 (3), 317–323

10. Van Henten E J; Van Tuijl B A J; Hemming J; Kornet J G; Bontsema J (2002a). CUPID—an autonomous cucumber picking device. Proceedings of the 8th Mechatronics Forum International Conference—Mechatronics 2002, 24–26th June 2002, Enschede, The Netherlands, pp 633–642

11. LEI; CBS (2000), Land en tuinbouwcijfers 2000, [Statistics of Dutch Agriculture and Horticulture.] Agricultural Economics Research Institute (LEI) and Statistics Netherlands

12. (CBS), ’s Gravenhage, The Netherlands

13. Țucu D., Mnerie D., (2003), Integrated systems for agri-food production, Ed. Orizonturi Universitare, Timişoara, ISBN 973-638-066-1, 127-130

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 330.32:620.95
Stručni rad
Expert paper

FUZZY METHODS IN RENEWABLE ENERGY OPTIMIZATION INVESTMENTS

DUMITRU TUCU, ANTONIO-GABRIEL GOLÎMBA, TITUS SLAVICI,

POLITEHNICA University of Timisoara, Mechanical Engineering Faculty, Bd. Mihai Viteazul, No.1, 300222 Timisoara, Tel. 0040-744-264650, Fax 0040-256-403589, dumitru.tucu@mec.upt.ro, d_tucu@yahoo.com, tommy_gyo@yahoo.com, tslavici@yahoo.com

SUMMARY

In the paper is analyzed a mathematic method, based on fuzzy methods, which can establishing the maximum profit potential and maximum efficiency of placement, by using estimated treasuries on next five years. The objectives of the paper are to analyze the effects and errors of the new method and establishing the practical restriction for next applications. Based on calculus from this method it is possible to obtain the values of functions for optimal profits, that depends on mathematical model used for each profit's function and size of investment. There are presented the advantages and disadvantages of application of the method by a case study.

Key words: *enterprise, integrated systems, fuzzy logic, investments, renewable energies, scenario, short time treasury*

INTRODUCTION

Efficiency problems of enterprises, both in economical and technical dimension impose reconsidering, with much careful, of the energy problem, both on investment cost and consumption cost.

Analyze and decision concerning investment involves many operation and information, demanding systemic approach, integrated and interdisciplinary.

Establishing of investments optimum is a very difficult process, determined, in the same time, by many variables as: type of energy, placement of source, availability, prices at date and strategic trends, local law, environment and other conditions, local and general political decision etc. (Tucu D. et al. 2008).

For example in Romania, where the power supply network and gas distribution network are not much developed, is important to develop systems, both for heating and warm water that use, principally, as energy source, the solid fuel (wood, coal, pallets etc).

This solution is also a possibility for develop renewable energy systems.

First of all it is necessary an introduction in which are presented the general aspects according with the paper thematic, the objectives followed and the way in which they are attended.

The objectives of present paper are: estimation on possibilities to identify resources for house heating and warm water equipment production, others than usually products; finding practical solution for manufacturing; the estimation of the potential problems for implementation in Romania, by using integrated engineering.

METHODS

Optimization starts with the process of criteria establishing, that must be organized according to integrated engineering principles.

It starts on general criteria as:

- production maximization;
- business maximization;
- economic equilibrium;
- decreasing of enterprise risk;
- maximization of customer satisfaction;
- maximization of employees satisfaction;
- maximization of quality;
- minimization of energy consumption;
- minimization of environmental effects, according to the third assessment, Kiev (2002);
- sustainable development etc.

According to general criteria, each product must satisfied specific conditions as: technical performance, cost/life cycle, physical demands (volume, weight, power etc.), environmental conditions (shocks, vibrations, radiations, pressure, humidity, temperature, noise etc), reliability, service, maintenance, testing, technical assistance, documentation, system development etc.

The manufacturing of equipment for heating and home warm water was re-designed according to the next steps:

- Market studies
- Specific prescription
- Manufacturing program

- Specification
- Manufacture deadlines
- Publicity and promotion
- Assurance of maintenance services
- Customers opinion

The best appreciation of enterprises value, at their assurance is analyzes of cash-flow (Tucu, 2006).

The generally classic mathematic model is:

$$CF_{(VA)} = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

where:

$CF_{(VA)}$ – monetary flux at actualized value ;

CF_t – monetary flux in year t (t = 1,n);

r – rate for actualization (medium capital cost).

In decision on investment in manufacturing activity the most important object is to obtained profit, according to different and difficult conditions, which are considered, at the same time, in many fields: technical, economic, political, social and strategic and all of these in turbulent conditions determined by transition period.

In the next presentation is made an analyze comparative for results in the practical example, obtained by two methods: classic and by using fuzzy logic method.

In classical analyze, method suppose elaboration of three scenarios, grouping many indicators in next categories: indicators for condition, indicators for effect and indicator for basis effect.

For making a correct estimation on prognosis period, based on the three scenarios (o-optimist, b-basis, p-pessimist) it is necessary to calculate:

- media on each year:

$$\overline{CF}t = \frac{CF_{pt} + CF_{bt} + CF_{ot}}{3}$$

- annual media:

$$\overline{CF}S = \frac{1}{n} \sum_{t=1}^{n} CF_{tS}$$

Actualized value will be calculated by relationship:

$$CF_{(VA)} = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

By application of these formulas results the estimated monetary flux which will be presented in table (Chiu-Yu, 1994).

In the case of fuzzy logic method, rata for actualization will be considered the pondered medium cost of capital.

Interval of confidence for actualization rate will be defined by (Kim K., 1990):

- Inferior limit: it(α) = ot+(bt-ot) α
- Superior limit st(α) = pt+(pt-bt) α,

where:

b_t - represents value of actualization rate in basis version,

o_t - represents value of actualization rate in optimist version,

p_t - represents value of actualization rate in pessimist version,

Results, for the case considered the rates for actualization and interval of confidences for actualization rate.

Basing on these results, next step will be establishing of coefficients of confidence interval for coefficients for actualization.

Using these values for confidences interval and actualization rates, it is possible to calculate intervals of confidence for cash-flow (Karson E., 1998):

- Inferior limit:

$$CF_{Inf} = \sum_{t=1}^{n} \frac{CF_t}{\prod_{t=1}^{n} \left[1 + s_t(\alpha)\right]^t}$$

- Superior limit:

$$CF_{Sup} = \sum_{t=1}^{n} \frac{CF_t}{\prod_{t=1}^{n} \left[1 + i_t(\alpha)\right]^t}$$

Results the values for actualized cash-flow by fuzzy logic.

For making comparison between classic methods and fuzzy logic methods it is necessary to calculate also actualized cash-flow by classical methods.

The variants of cash-flow accepted as sure will be that representing the intersection zones between the two categories of estimations (classic and fuzzy).

In the case of investment decision, could be applied, also, both the two method.

It results for analyzed situation the probably profit, in fuzzy interpretation.

All this data are utilities, so they will be defuzzyficated, which means re-conversion in concrete economical numbers.

RESULTS AND DISCUSSION

The method was used for decision regarding investments in manufacturing equipment for renewable energies at S.C. AMBASADOR PLUS S.R.L. Timisoara.

According to such method the estimated monetary flux is presented in table no.1.

Table 1 Monetary flux estimated on 2003-2007, [mil.lei, basis 2000]

Year	Flux	Scenario		
(t)	(Fn_t)	Basis	Pessimist	Optimist
2003	Fn_1	453	3837	2314
2004	Fn_2	2513	862	3072
2005	Fn_3	2152	804	4555
2006	Fn_4	2292	1251	6010
2007	Fn_5	3549	1652	7588

Rata for actualization of capital is presented in table 2.

Table 2 Rates of actualization estimated for period 2003-2007

No.	Scenario	Period of prognosis					Symbol
		2003	2004	2005	2006	2007	
1	Optimist	15%	15%	15%	15%	15%	o_t
2	Realist	20%	20%	20%	20%	20%	b_t
3	Pessimist	25%	25%	25%	25%	25%	p_t

The interval of confidences for actualization rate is presented in table 3.

Table 3 Interval of confidences for rate of actualization

	External limits of	Period of prognosis					Symbol
	Confidence	2003	2004	2005	2006	2007	
1	Inferior limit	17,5	17,5	17,5	17,5	17,5	$i_t(\alpha)$
2	Superior limit	22,5	22,5	22,5	22,5	22,5	$t_t(\alpha)$

The coefficients of confidence interval for coefficients for actualization are presented in table 4.

Table 4 The coefficients of confidence interval for actualization coefficients

Period	Scenario		
year	Basis	Pessimist	Optimist
2003	0,833	0,851	0,816
2004	0,694	0,724	0,666
2005	0,579	0,616	0,544
2006	0,482	0,525	0,444
2007	0,402	0,446	0,363

The values for actualized cash-flow by fuzzy logic are presented in table 5.

Table 5 Discounted cash-flow by fuzzy number

No.	Cash-flow	Values	Symbol
	for scenario	[mil.lei, 2000]	
1	Pessimist	5779	$CF_{(VA)}p= CF_{Inf}$
2	Basis	5899	$CF_{(VA)}b=CF_{Med}$
3	Optimist	11834	$CF_{(VA)}o= CF_{Sup}$

For making comparison between classic methods and fuzzy logic methods it is necessary to calculate also actualized cash-flow by classical methods, those are presented in table no. 6.

Table 6 Discounted cash-flow by classic methods

No.	Cash-flow	Values	Symbol
	for scenario	[mil.lei, 2000]	
1	Pessimist	4904	$CF_{(VA)}p= CF_{Inf}$
2	Basis	5899	$CF_{(VA)}b= CF_{Mediu}$
3	Optimist	14539	$CF_{(VA)}o= CF_{Sup}$

The variants of cash-flow accepted as sure will be that representing the intersection zones between the two categories of estimations (classic and fuzzy). Results are presented in table 7.

Table 7 Choice of optimum variants of cash-flow by intersection of multitude between classic and fuzzy methods

No.	Cash flow for scenario	Classic Values [mil.lei, 2000]	Fuzzy Values [mil.lei, 2000]	Optimum Values (intersection)
1	Pessimist	4904	5779	5779
2	Basis	5899	5899	5899
3	Optimist	14539	11834	11834

For concrete analyze in the case of S.C. AMBASADOR PLUS S.R.L., optimum values obtained by multitude intersection between classic and fuzzy, the values are the same for the multitude at level α=0,5, that means a financial political very good equilibrate and with medium chances for futures stability.

It results for this situation the probably profit, in fuzzy interpretation, at value 1.05 and it will be in interval of confidence defined by inferior limit 0.91 and superior limit 1.15.

CONCLUSIONS

All application presented depend on each conditions and stage of the enterprise.

It is recommended to use this system to complete the others classical solutions with results multitude.

On the other hand, economical aspects must be integrated with manufacturing applications; fuzzy logic gives for all decision posts methods very useful in situation of using a great volume of information with precision of processing.

These method aides also to have estimation correct about possibilities and tendencies of evolution of investments.

It is absolutely clear the most importance of financial equilibrium for each enterprise and their production in situation of Romanian integration in EU.

Using of fuzzy logic methods in financial equilibrium analysis give not a complete result in any situation. It depends on each conditions and stage of the enterprise.

It is recommended the usage, in the same time of classical and fuzzy logic methods and compare or see the intersection of results multitude.

REFERENCES

1. Chiu-Yu C., Park C. (1994). Fuzzy Cash Flow Analysis Using Present Word Criterion, The Engineering Economist, vol.39, no.2, 113-138;

2. Karson E., (1998). Measure of Liquidity Risk Supplementing Fuzzy Discounted Cash Flow Analysis, The Engineering Economist, vol. 43, no 4, 331-344

3. Kim K., Park K. (1990). Ranking Fuzzy Numbers with Index of Optimism, Fuzzy Sets and Systems, vol.35, 143-150

4. Țucu D., Rotărescu V. (2008). Introducere in economia intreprinderii, Ed. Orizonturi Universitare, Timişoara, ISBN 973-638-347-2, ch. 3, pp.51-84

38. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.76
Stručni rad
Expert paper

BIO-ETHANOL FROM CELLULOSE SWEEPINGS

DUMITRU MNERIE[1], DUMITRU ȚUCU[1], IONEL BALCU[2],
GABRIELA VICTORIA MNERIE[3], MARIUS MIRICĂ[2]

[1]POLITEHNICA Univ., Mech. Eng. Fac., Timisoara, Romania,
dumitru_mnerie@yahoo.com
[2]National Institute of R&D in Electrochemistry and Condensed Matter – INCEMC – Timisoara, Romania, florin_balcu@yahoo.com
[3]IOAN SLAVICI University, Timisoara, Romania, tslavici@yahoo.com

SUMMARY

Economically competitive breed based on cognition and the utilization of the funds regenerative is some from principal objective of European Union. The achievement bio-ethanol from cellulose sweepings it is known but is remaining an important and complex problem about the variety of raw materials and the difficulty to establish and to optimize the parameters for each technological step. The paper shows the structure of an integrated system used for prepare the cellulose sweepings used for obtain bio-ethanol with maximum efficiency and the possibility for capitalization of many kind of bio-mass. It used the combination of pre-treatment with celluloses chemical hydrolyze. It made a enzymatic-hydrolyze study of different raw materials and find a technology of disrupt in fermentable sugars used the enzymes performing (Novozyme, Genencor). These efforts are for to find ecologic fuels who can be obtain from ethanol (Ethyl–terbutil-ether).

Key words: *Bio-ethanol, cellulose-enzimatic, integrated system, ecologic-fuels*

INTRODUCTION

Cellulose is the most abundant organic material on the earth and is a major component of all plants. If fuel alcohol can be derived from cellulose, this will be a very flourishing industry. Each cellulose molecule consists of a few hundred to several thousand glucose units linked together. If cellulose can be degraded into glucose, the latter can be easily used for the production of fuel alcohol. Several fungi are known which possess the enzyme cellulase and, therefore, can degrade cellulose into glucose [6].

METHOD

Present research is based on the obtaining of some renewable energy sources for the replacement of the fossil fuels. Nowadys, ethanol is the most important biofuel on the market. The biggest ethanol quantity is obtained from matters that contain sugar (cane sugar) or starch (corn, wheat). Considering that these are used also for human or animal food, the limited matter savings and the price can affect the development and extension of the production of ethanol.

The conversion of cellulose into ethanol is based on the hydrolysis of the fractions of hemicellulose and cellulose (representing around 70% of the wood) for freeing sugars that can ferment. The biomass of cellulose is a complex material made of three major organic fractions which structure (reported to the dry substance) is the following: 35-50% cellulose, 20-35% hemicellulose and 12-20% lignin.

For that research was used some wastes from forestry, obtained with the equipment showed in figure 1.[4]

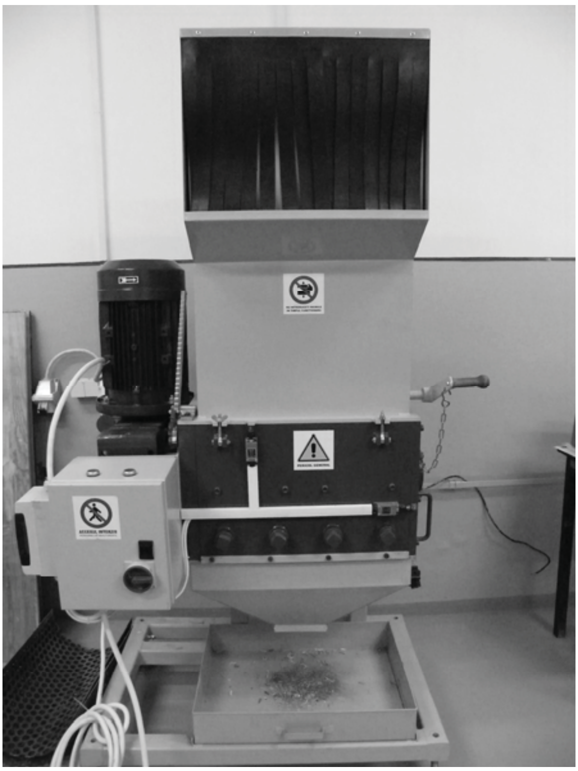


Figure 1 Equipment used for biomass milling.

After milling the samples looked well as images from figure 2.

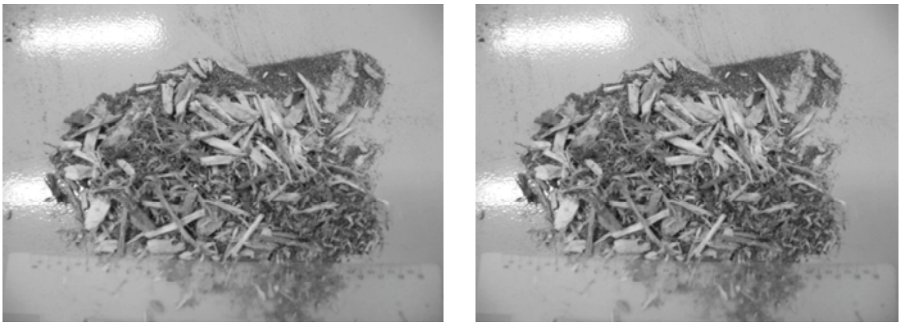


Figure 2 Biomass samples.

In table 1 the biochemical structure of the main wastes from forestry used in obtaining the ethanol is presented.

Table 1 The biochemical structure of the biomass

Components	%
Cellulose	50
Hemicellulose	25
Lignin	22
Resins, oils	3

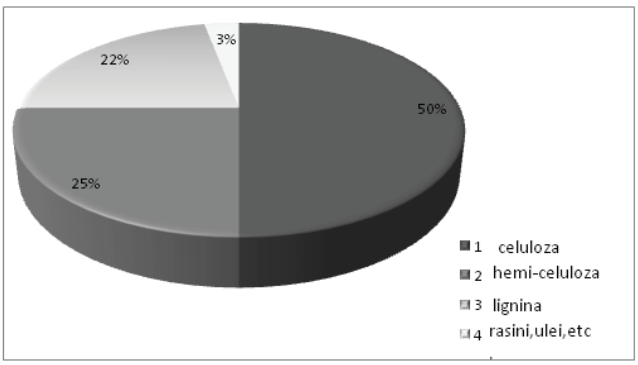


Figure 3 The biochemical structure of the biomass

In Table 2 we can find the presentation of the chemical composition for some lignin-cellulosic materials. The usage of the perennial lignin-cellulosic materials is extremely advantageous because they are cheap and have a diminished impact over the environment. Also, they can be obtained with very good efficiencies even on low quality areas. Table 2. The Structure of the lignin-cellulosic biomass (% dry mass)

Table 2

Matter	(poplar)
Cellulose	44,70
Glucal 6C	44,70
Hemicelluse	18,55
Xylose 5C	14,56
Arabinose 5C	0,82
Galactose 6C	0,97
Manan 6C	2,20
Lignin	26,44
Ash	1,71
Acid	1,48
Extractives	7,12
Caloric Value (GJ_{HHV}/ton land)	19,6

Advantages of the wastes' recycle of the wooden biomass:

- the turn into accound of the product obtain through its trade on both internal and external market;
- the usage of the quality and enivironmental standards at the european level;
- the guarantee of an efficient ecological protection of the population, as well as for the water, forest etc.
- the recycle of materials;
- the elimination of wooden wastes from the depositing areas;
- the efficient use of wooden wastes from wood's processing;
- the acceleration of ecological legislation's harmony from our country to the European one

In Table no 3 and Figure no 4 is presented the chemical composition of wood.

Table 3 Chemical composition of wood

Components	%
Carbon	51
Oxygen	42
Hydrogen	6
Nitrogen	0.4
Sulphur	0.6

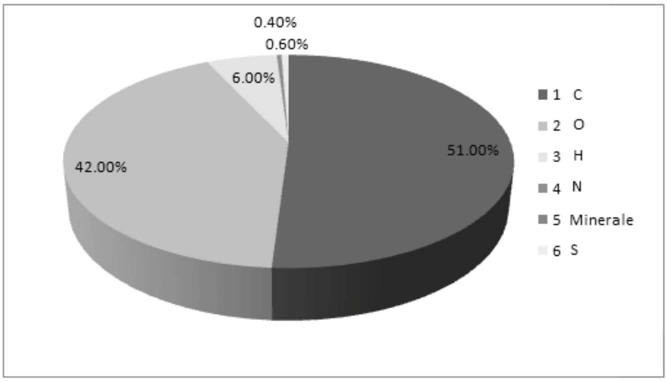


Figure 4 Chemical composition of wood

RESULTS AND DISCUSSION

The lignin-cellulosic mass, which will be treated before, will be exposed to a preliminary stage to vanish of the impurities (non-wood, metals, stones, earth, glass, plastic, etc.)

The humidity of the wooden mass

It is an important parameter in the pre-treatment stage. The higher the humidity is the lower the caloric power gets.

A sample of 10 g of biomass (% dry mass) has been dried in a drying stove at 115 $\pm$ 2^{o}C for two hours. This process has been repeteated until a constant mass had been obtained.

The humidity porcentage is calculated based on the sample's loss of mass. The dry sample had been weighted while it was hot, an important parameter that must be compensated for the cases in which a high precision is required.

Determining the humidity

A sample of 10 g of sawdust has been dried in a drying stove at 115 $\pm$ 2^{o}C for two hours. This process has been repeteated until a constant mass had been obtained. The humidity porcentage is calculated based on the sample's loss of mass.

In the following table we can find the values of the obtained mass, after the four drying stages in the drying stove:

Table 4.

Type sawdust	First drying stage 115^{0}C/2h	Second Drying stage 115^{0}C/2h	Third Drying stage 115^{0}C/2h	Fourth drying stage 115^{0}C/2h
poplar	125,3730	125,2893	125,2380	125,2380

Figure 5 The drying stove of the laboratory

The determination of the mass of the waste at the calcination has been obtained at 575 ^oC, for three hours, with a warming speed of 10^oC/minute. The melting-pots will be weighted at the end of the three hours, from which results the mass – marked as M_3 – after the three hour period.

Table 5

Type sawdust	The calculum of the damp mass	The calculum of the dry mass (drying stove)	The calculum of the mass after calcination
Sawdust of poplar	112,06	111,87	111,37

The total solid containt from the biomass represents the quantity of solids remained after the removal of all volatile components through the heating of the sample at 105^oC until the constant mass. On the other hand, the humidity content of the sample represents a size of the water quantity (and other volatile composites at 105^oC) present in such samples.

The calculum of the total solid content of the biomass is the following:

$$\%\ \text{total solids} = \frac{\text{the weight of dry sample with the vase} - \text{the weight of the vase}}{\text{the weight of the sample initially weighted}} \cdot 100$$

The humidity process of the biomass is calculated:

$$\%\ \text{humidity} = 1 - \frac{\text{the weight of dry sample with the vase} - \text{the weight of the vase}}{\text{the weight of the sample initially weighted}} \cdot 100$$

$$\%\ \text{total poplar} = \frac{125.2380 - 116.66}{10} \cdot 100 = 85.78$$

$$\%\ \text{poplar} = 1 - \frac{125.2380 - 116.66}{10} \cdot 100 = 14.22$$

From the point of view of the humidity and the total solid content, the characterization of each type of biomass used is presented in table 6.

Table 6

Type sawdust	% total solid	% humidity
Poplar	85.78	14.22

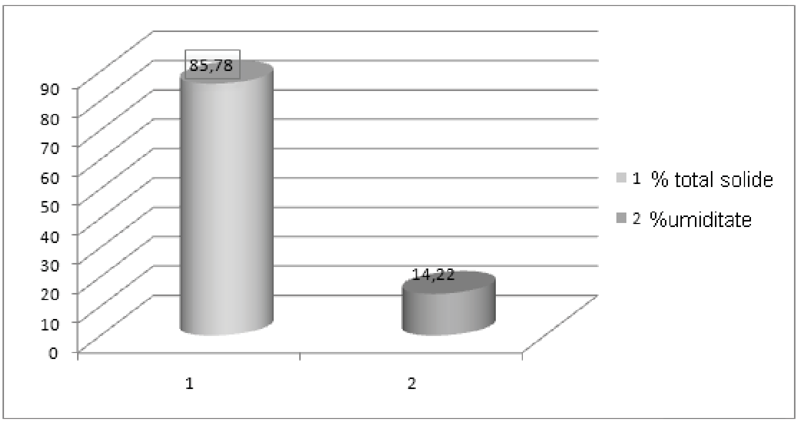


Figure 6 % total solid % humidity

Granulometry

Digital Electromagnetic Sieve Shaker FTL-0150 / FTL-0200 has been used in the particles' separation process. The sizes of the loops of the sieves start from 0,040 mm. The pedestal is made by a polyurethanic resin and a command pannel which allows the setting of the power, cycles and time of the process. The granulometer has a 3D move of the sieves in order to allow the optimum separation of the particles. It allows a simulatneous use of 8 sieves with a 50 mm height or 16 sieves with a 25 mm use height.

The fixing system has two saintless steel bars, two screw straining small fibres and a methacrylate transparent lid which transfers the pressure to the sieves for a better regulation.

The used method implies the weighting of a quantity of granular matter and its positioning on maximu size loop sieve.

The weighted quantity of the analytical balance was about 112,13 g of sawdust. The selected working parameters were: 7 sieves (granulation between 1,7 – 0,3 mm), working power 9, cycles 2, sieving time 16 minutes. Then the quantitites left on each sieve have been weighted.

Table 7

	The sieze of the sieves' loops (mm)	The hoarding quantity
1	1.7	91.3
2	1.25	3.9
3	1	5.08
4	0.71	1.17
5	0.5	3.27
6	0.4	0.55
7	0.3	1.23
8	tava	3.25

Losses-2.38 g

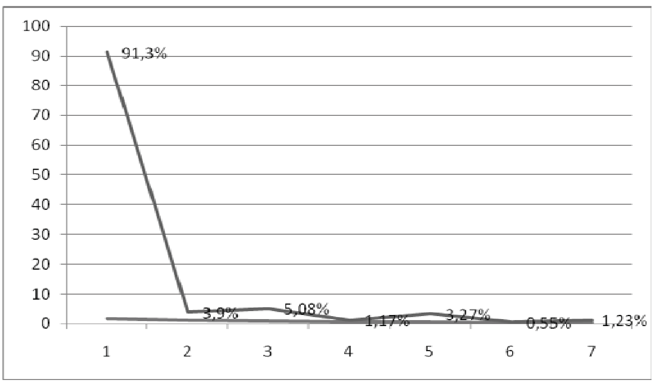


Figure 7 Cumulated quantity

CONCLUSIONS

Conversion technologies for producing ethanol from cellulosic biomass resources such as forest materials, agricultural residues and urban wastes are under development and have not yet been demonstrated commercially. In order to produce bioethanol from cellulosic biomass, a pretreatment process is used to reduce the sample size, break down the hemicelluloses to sugars, and open up the structure of the cellulose component. The cellulose portion is hydrolyzed by acids or enzymes into glucose sugar that is fermented to bioethanol. [1]

Last year it has achieved an estimated cellulase cost in the range of $0.10-$0.20 per gallon of ethanol in the NREL cost model • This represents an approximate 30-fold improvement in enzyme cost in that model. Biorefineries and ethanol from cellulose will happen sooner.[2]

REFERENCES

1. Demirbas, A., (2005), Bioethanol from Cellulosic Materials: A Renewable Motor Fuel from Biomass, Energy Sources, Volume 27, Number 4, Number 4/March 2005 , pp. 327-337(11)
2. Erickson, B., Ethanol from Cellulose and Biorefineries, Industrial and Environmental Section, Industrial and Environmental Section, www.BIO.org
3. Huang, H.J., Ramaswamy, S., Tschirner, U.W., Ramarao, B.V., (2007), Review of separation technologies in current and future biorefineries, Department of Bioproducts and Biosystems Engineering, Kaufert Lab, University of Minnesota, Saint Paul, MN 55108, USA, Department of Paper and Bioprocess Engineering, SUNY-CESF, Syracuse, NY 13210, USA
4. Țucu, D., Mnerie, D., Rotărescu, V., Anghel, Gabriela Victoria, (2007), The analyze of plastic material behavior in the process of milling for recycling – opportunities and threads, Scientific Bulletin of „POLITEHNICA" University of Timişoara, România, Seria Mecanică, Tomul 52 (66), Fascicola 4, 2007, ISSN 1224-6077, Editura Politehnica, pg. 100-103
5. Țucu, D., Rotărescu, V., Mnerie, D., 2007, Consideration about optimization systems for renewable energy ressource, Scientific Bulletin of „POLITEHNICA" University of Timişoara, România, Seria Mecanică, Tomul 52 (66), Fascicola 4, 2007, ISSN 1224-6077, Editura Politehnica, pg. 104-108
6. Villadsen, J., (2007), Innovative technology to meet the demands of the white biotechnology revolution of chemical production, Department of Chemical Engineering, DTU, 2800 Lyngby, Denmark.

In memoriam

Prof. dr. sc. Robert Zimmer (17.05.1942 – 05.01.2010.)

Robert Zimmer je rođen 17. svibnja 1942. godine u Osijeku. Osnovnu školu i gimnaziju završio je u Osijeku, a diplomirao na Poljoprivrednom fakultetu u Osijeku (tadašnja Visoka poljoprivredna škola) na ratarskom smjeru 1967. godine. Poslijediplomski studij „Poljoprivredno strojarstvo" završio je na Poljoprivrednom fakultetu u Zagrebu, a disertaciju iz područja biotehničkih znanosti, polje agronomije, obranio je 1986. godine na Fakultetu poljoprivrednih znanosti u Zagrebu. Tijekom 1968. godine bio je na specijalizaciji iz područja Zaštite poljoprivrednih proizvoda i prerađevina primjenom strojeva i uređaja u Institutu Degesch (Deutsche Gesellschaft für Schädlingsbekämpfung GmbH) u Njemačkoj. Od 1967. godine zaposlen je u Zavodu za zaštitu bilja i poljoprivrednih proizvoda na Visokoj poljoprivrednoj školi u Osijeku. Od 1969. godine do danas zaposlen je na Poljoprivrednom fakultetu. U zvanje asistenta izabran je 1969., a u zvanje znanstvenog asistenta 1976. U zvanje docenta izabran je 1987., a u zvanje izvanrednog profesora 1993. U zvanje redovnog profesora izabran je 1999., a 2001. drugi izbor za redovitog profesora.

U nastavno – obrazovni proces na Poljoprivrednom fakultetu u Osijeku uključuje se 1969. godine kao asistent na predmetu „Mehanizacija u ratarstvu", a 1987. godine postaje nositelj navedenog predmeta. Od travnja 1998, godine voditelj je

Katedre za mehanizaciju, a od 1981. 1983. upravitelj Zavoda za mehanizaciju. Bio je nositelj predmeta i koordinator modula: Mehanizacija u ratarstvu (Ratarstvo), Mehanizacija u biljnoj i stočarskoj proizvodnji (Opći smjer), Mehanizacija u poljoprivredi (smjer Agroekonomika), Tehnika proizvodnje i dorade sjemena (Poslijediplomski studij Sjemenarstvo), Strojevi u ratarstvu i vrtlarstvu (Smjer Mehanizacije), te Tehnički sustavi pri spremanju voluminoznog sijena (Poslijediplomski studij mehanizacije). U društvu inženjera i tehničara Osijek, bio je tajnik 2 godine, a od 1978. – 1981., predsjednik društva. Član je Hrvatskog društva za poljoprivrednu tehniku, a od 1997. - 1999. Godine i predsjednik (HDPT). Član je Europske udruge poljoprivrednih inženjera (EurAgEng) od 1997.

Objavio je veći broj znanstvenih i stručnih radova, sveučilišnih udžbenika, te sudjelovao na domaćim i međunarodnim kongresima. Također je bio voditelj nekoliko projekata financiranih od Ministarstva znanosti i tehnologije, Ministarstva obnove i razvitka, te Ministarstva poljoprivrede i šumarstva. Prof. dr. Robert Zimmer dao je najveći doprinos u radu na Poljoprivrednom fakultetu u Osijeku, u nastavnom procesu i obrazovanju mladih generacija agronoma, a tom kontinuiranom procesu bio je potpuno predan i maksimalno posvećen. Posao sveučilišnog profesora je savjesno radio, i za njega je živio. Nastojao je povezivati teoriju s praksom, popularizirati struku. Generacije studenata pamtit će ga kao strogog, ali prije svega pravednog i pravičnog profesora, uvijek spremnog razgovarati, pomagati i objasniti studentima. Bio je osoba koja je dostojno nosila status sveučilišnog profesora i ostati će nam u sjećanju kao miran i tih kolega, i nadasve skroman do zadnjeg dana.

Prof. dr. Vlado Guberac

Dekan Poljoprivrednog fakultet u Osijeku

Osijek 8.10.2010.

KOMERCIJALNE PORUKE

COMMERCIAL NOTES

INA MAZIVA

proizvodi za poljoprivrednu mehanizaciju

- INA SUPER 2009
- INA SUPER 2000
- INA SUPER MAX
- INA SUPER TURBO
- INA SUPER 5
- INA SUPER 3
- INA SUPER 2
- INA 2 taktol ST plus
- INA 2T scooter
- INA hipenol® GTL HD 80W-90
- INA hipenol® GTL HD 85W-140
- INA hipenol® GTL DB 90
- INA transmol® HD 80W-90

- INA transmol® DB 80W
- INA ATF super
- INA ATF TASA
- INA transhidrol ZF 20W-40
- INA transhidrol JD 50
- INA transhidrol 85
- INA agrina
- INA transmatik 10W
- INA transmatik 30
- INA UKA 4
- INA ANTIFRIZ AL super
- INA ANTIFRIZ AL 40
- INA ANTIFRIZ BS super

- INA hidraol® HDS 46
- INA biohidraol® HEES
- INA lancol® ST 200
- INA biolancol®
- INA lis® EP 2
- INA lipleks® S EP 2
- INA LIS® MOS EP 2
- INA LIS® EP 00
- INA LIS® CS EP 00
- INA viskoma® R 00
- INA GKS
- INA bioma EP 00
- INA bioma EP 2

SEKTOR PRODAJE I MARKETINGA
Tel: 01/2412-260 Fax: 01/2412-453

PRODAJNO PODRUČJE INA GRUPA I VELIKI KUPCI,
Tel: 01/2412-270, Tel: 01/2412-297, Fax: 01/2412-453

PRODAJNO PODRUČJE ZAGREB, Tel: 01/2412-447,
Tel: 01/2412-444, Fax: 01/2404-027

PRODAJNO PODRUČJE DALMACIJA,Tel: 021/202-206,
Tel: 021/202-210, Tel: 021/202-219, Fax: 021/202-306

PRODAJNO PODRUČJE ISTRA I PRIMORJE,
Tel: 051/201-369,Tel: 051/201-003, Fax: 051/201-246

PRODAJNO PODRUČJE SLAVONIJA OSIJEK,
Tel:031/512-944, Tel: 031/512-954 , Fax: 031/512-970,
SLAVONSKI BROD, Tel: 035/453-025, Fax: 035/452-681

www.maziva.hr

MAZIVA® ZAGREB d.o.o.
ČLAN INA GRUPE

ISO 9001
ISO 14001
OHSAS 18001