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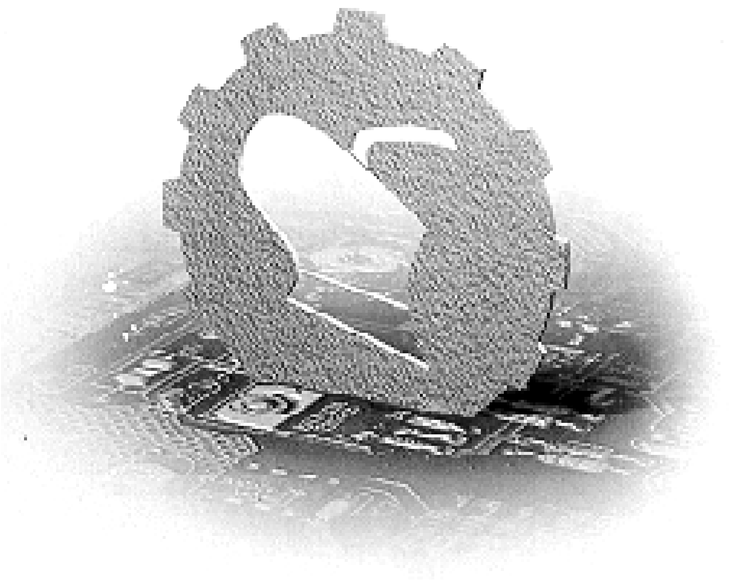

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COMPARISON OF MATHEMATICAL MODELS AND THIN-LAYER DRYING KINETICS OF OYSTER MUSHROOM (*PLEUROTUS SPP*) UNDER FLUIDIZED BED DRYER WITH THE ACCELERATED AIR TEMPERATURE AND VELOCITY

Goraksha Chimaji Wakchaure[1*], Lalitendu Das[2], Kaniyaiah Manikandan[3], Paramasivam Suresh Kumar[1], Kamlesh Kumar Meena[1], Manisha Rawat[1]

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Abstract: Effect of drying air temperature and velocity on thin-layer drying characteristics of oyster mushroom (*Pleurotus spp*.) was investigated using a fluidized bed dryer. Mushrooms were dried at three air temperatures 45, 55 and 65ºC coupled with the air velocity of 2, 3.5 and 5 $m \cdot s^{-1}$. Dehydration of mushrooms occurred in falling rate period and temperature has significant (P=0.04) effect on drying. From the regression model, best quality of dried oyster mushroom was obtained at 65°C temperature and 5 ms^{-1} air velocity and it was validated with sensory characteristics in terms of colour, crispy texture, flavour and comparatively less shrinkage. To determine the drying kinetics, experimental moisture ratio data were fitted to seven thin-layer drying models. Among the models studied, Page model was found to be the best fitted model to describe the drying behavior of oyster mushroom. At any given air velocity, with the increase in drying air temperature led to an increase in effective moisture diffusivity ranged from 7.78×10^{-10} to $2.11 \times 10^{-9} m^2 \cdot s^{-1}$. Drying at 5 $m \cdot s^{-1}$ air velocity required minimum activation energy of 22.15 $kJ \cdot mol^{-1}$ to remove water during the drying process by diffusion. Rehydration ratios (RR) values (1.95-2.75) increased with increase in drying air temperature and velocity. The results obtained could be for making appropriate design and operations of industrial drying system for further processing of mushrooms to value added products.

***Key words**: Oyster mushroom, drying kinetics, effective diffusivity, fluidized bed dryer, moisture ratio, sensory characters*

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INTRODUCTION

Mushrooms have been used throughout the world for many centuries as a good source of proteins, carbohydrates, lipids, and dietary fiber. Of the 2000 known species of mushrooms only 35 species are cultivated commercially. Cultivable mushrooms such as button mushroom (*Agaricus bisporus*), oyster mushroom (*Pleurotus spp.)*, milky mushroom (*Calocybe indica*), shitake mushroom (*Lentinus edodes*) and paddy straw mushroom (*Volvariella spp.*) are prized for their delicacy, nutritional and medicinal values [1]. Among these, oyster mushrooms grow on a wide variety of agricultural substrates in temperature ranging from 15 to 35ºC with 100% biological efficiency and are marketed in dried form worldwide. Due to their simplified and cheaper (1-1.5 times) cultivation practices compared to *Agaricus bisporus,* oyster mushrooms are believed to take over the mushrooms market of India in the near future. In addition to their pleasant flavour oyster mushrooms contain 20–30% protein, 57-65% non-starchy carbohydrates, minerals (Ca, Fe, Mg, P), vitamins, and low fat content (2–2.7%) making them an constituting excellent food supplement.

Moisture content of fresh mushrooms lies between 87-95% (w.b.) making it a perishable product leading to an extremely short shelf life. The quality of fresh mushrooms deteriorates if they are not marketed or processed immediately after harvesting [2]. Therefore, processing them to as table form requires special care when employing different preservation methods such as drying, canning, pickling and controlled environmental storage that improves shelf life [3]. Drying is an effective unit operation as it reduces bulk volume, facilitates better handling and storage by removing excess water necessary to inactivate microbial and enzymatic activities [4]. Dehydrated mushrooms are used in several food and medicinal formulations such as instant soups, pasta salad, snacks, stuffing, chocolates, biscuits, casseroles, meat and rice dishes, antioxidant capsules/tablets as food flavoring and anti-cancerous materials [5].

Oyster mushroom can be dried at (6-10% moisture content) by different methods such as sun, convective cabinet, fluidized bed and freeze drying depending upon harvest time, environmental condition and affordability [1]. Mushrooms are reported to be dried at temperatures ranging from 37.8–70°C with the finishing temperature up to 82.2°C alone or in combination with various blanching treatments [6].

Drying is cumulative effect of heat-mass transfer phenomenon that induces quality changes in dried food products. Hence, insight into the physical and thermal characteristics of food materials is essential to understand the drying mechanics [7]. Drying kinetics establish the relationship between drying parameters such as diffusion coefficients and moisture ratio to predict drying behavior. Thin layer drying, referred to as constant temperature drying, is a process where diffusion of water takes place from inside of the food material to the air–food interface and then to the air stream by convection. Therefore, thin-layer drying simulation is the most suitable approach to model drying of food materials. Mathematical models provides simple representations of complex drying process of geometrically different agricultural materials and have proven to be very useful for appropriate design, construction and operation of drying systems.

Several researchers have proposed thin layer drying simulations models for many agricultural products to generalize the drying curve and predict drying time of natural and forced convection drying systems. For example, apple [7], bamboo [8], banana peel [9], garlic [10], mango slices [11] and wheat [12] have been reported. Limited research on drying especially systematic studies on fluidized bed drying kinetics of oyster mushrooms is available in the literature [3]. Also proper investigation is prerequisite to enhance the efficiency of drying operation, design and construction of drying systems. Therefore, the objective of the this study was: (i) to investigate the effect of different drying air temperature and velocity on drying characteristics of oyster mushroom in a fluidized bed dryer (ii) to evaluate the suitable thin-layer model for describing the drying behavior (iii) to compute the effective moisture diffusivity, activation energy during drying of oyster mushroom and its quality evaluation through rehydration and sensory evaluation.

MATERIAL AND METHODS

Sampling and experimental setup

Freshly harvested oyster mushrooms of uniform maturity were obtained from the environmental controlled cropping unit of Directorate of Mushroom Research, Solan, India. Mushrooms were cleaned, sorted by size and their stipe's (stems) removed using sharp stainless steel knife. About 800 g of oyster mushroom sample of pileus (cap) diameter 75 – 80 mm and 7±1 mm thickness was selected for each drying experiment. The initial moisture content 92.32% (w.b.) of mushroom was measured using AOAC method [13] before starting the drying experiment. Drying kinetics of mushroom at three air temperatures 45, 55 and 65ºC and velocities 2.5, 3.5 and 5 $m \cdot s^{-1}$ was studied. The terminal velocity of above given size fresh mushroom was found to be 2 $m \cdot s^{-1}$; hence slightly higher air velocities were selected for thin-layer drying experiment. The laboratory scale cylindrical stainless steel fluidized bed dryer (Model: Retsch, TG 100, Germany) of 20 cm diameter and 314.28 cm^2 cross section area of plenum chamber was set at desired air temperature and velocity combination 1 h prior to start of experiment through proportional velocity and temperature controller. Pre-weighed mushroom sample was spread in thin layer of 8–10 cm thickness over perforated steel grit and dryer closed by wire mesh cloth cap. Loss in moisture content was measured continuously at every 30 min interval till constant weight was reached (using digital balance of 0.01 accuracy D'Arts-DG 25, India).The relative humidity of drying air was found between 23–41% and was not regulated. All experiments were performed in triplicates. The dried sample were collected from the grit, cooled at room temperature and subsequently packed in 500 g polypropylene bags to evaluate for rehydration and sensory qualities.

Drying kinetics and mathematical models for thin layer drying

To determine the most appropriate drying model, experimental data were fitted to different thin layer drying models (Tab. 1).

Moisture ratio *MR* of oyster mushroom samples during thin layer drying experiments in fluidized bed dryer were calculated using the following equation (1).

$$MR = \frac{M_t - M_e}{M_i - M_e} \tag{1}$$

where: M_i was initial moisture content, M_e equilibrium moisture content, and M_t was moisture content at time (t), all on dry basis (d.b.). During drying oyster mushroom samples were not exposed to uniform relative humidity and temperature throughout the process. Also values of M_e were relatively small as compared to M_i or M_t, and hence can be neglected.

Non-linear regression analysis was performed on drying data of *MR* versus drying time using SATISTICA 12 (StatSoft, Inc., USA) software package. Statistical parameters *viz.*, coefficient of determination (R^2)and goodness of fit determined by using chi-square (χ^2), mean bias error (*MBE*) and root mean square error (*RMSE*) values were used as selection criterion for best model fit [11, 14]. Model selection was based on higher R^2 value and lower χ^2, *MBE* and *RMSE* values. These parameters can be determined by using equations (2), (3) and (4).

Table.1. Mathematical models used for thin layer drying of oyster mushroom

Model	Mathematical equation	Reference
Newton/ Lewis	$MR = exp(-kt)$	[14]
Page	$MR= exp(-kt^n)$	[15]
Handerson and Pabis	$MR= aexp(-kt)$	[16]
Logarithmic	$MR=aexp(-kt)+c$	[1]
Two-term exponential	$MR=aexp(-kt) + (1-a) exp(-kat)$	[17]
Wang and Singh	$MR=1+at+bt^2$	[2]
Midilli *et al.*	$MR=aexp(-kt^n)+ bt$	[3]

Note: a, b, c, k, k_0, k_1, n are drying constants

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{exp} - MR_{pre})^2}{N - z} \tag{2}$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N} (MR_{exp} - MR_{pre}) \tag{3}$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}\left(MR_{exp} - MR_{pre}\right)^2\right]^{\frac{1}{2}} \tag{4}$$

Where, MR_{exp} is experimental moisture ratio, MR_{pre} is predicted moisture ratio, N is number of observations, z is number of drying constants.

Determination of effective moisture diffusivity and activation energy

Drying in general occurs in two periods, constant rate period followed by falling rate period. Effective moisture diffusivity at constant moisture content can be estimated using methods of slopes techniques. Hence Fick's second law of unsteady state diffusion was used assuming that oyster mushroom is of slab geometry, moisture migration occurred due to internal diffusion at constant temperature and negligible shrinkage. Simplified solution of Fick's second law for food material of slab geometry which describes thin layer drying process as shown in Eq. (5).

$$MR = \frac{8}{\pi^2}\exp\left(-\frac{\pi^2 D_{eff} t}{4L^2}\right) \tag{5}$$

Where, D_{eff} is the effective diffusivity (m^2s^{-1}), t is the drying time (s), and L is the half slab thickness (m).

The effective moisture diffusivity (D_{eff}) can be calculated from the slope of the normalized plot of ln(MR) versus time (t), using the following equation (6) [16]:

$$D_{eff} = \frac{-Slope\ 4L^2}{\pi^2} \tag{6}$$

As the D_{eff} value changes with moisture content of the drying material, sometimes it is not possible to get a linear relationship for the entire moisture content range i.e. a single D_{eff} value to represent the entire drying range. Hence, as explained by [2], the entire plot of ln(MR) versus drying time (t) was divided into two portions when needed so that it could be well represented by two linear relationships with higher R^2 value. Therefore, two D_{eff} values one for initial and another for later stages of drying were obtained.

Activation energy is termed as the minimum energy that must be supplied to break water-solid and/or water-water interactions, and to move the water molecules from one point to another in the solid. Activation energy of drying can be obtained from the linearized form of Arrehenius equation (7). Slope from the plot of ln(D_{eff}) versus 1/T yields E_a and from the intercept D_o is estimated [18]:

$$D_{eff} = D_0 \exp\left(-\frac{E_a}{RT}\right) \tag{7}$$

Where, D_0 is the pre-exponential factor of the Arrhenius equation ($m^2 \cdot s^{-1}$), E_a is the activation energy ($kJ \cdot mol^{-1}$), R is the universal gas constant (8.314 kJ mol⁻1·K^{-1}), and T is the absolute air temperature (K).

Rehydration characteristics and sensory analyses

Rehydration ratio (RR) of dried oyster mushroom samples of various treatments was calculated as the rehydrated mass to the dehydrated mass 30 days after dehydration. A sample of 5 g of the dried mushroom was kept in a 250 ml beaker containing 150 ml of boiling distilled water. The contents were boiled for 15 minutes for rehydration. After that excess water from the mushroom samples were removed and rehydration ratio (*RR*) was determined. Triplicate measures were done and average value was taken.

Quantitative descriptor analysis (*QDA*) method was used for sensory profiling of dehydrated oyster mushrooms. Organoleptic quality of dried mushrooms was inspected with the help of 10 semi-trained consumer panel of different age group. Descriptors used for sensory analysis were developed during initial sessions in which different samples were presented to the panelists. The panelists were asked to describe the samples with as many spontaneous descriptive terms (viz., colour, flavour, texture, overall acceptability, off flavour etc.) as they found suitable for application. The common descriptors chosen by at least one third of the panel were compiled along with some significant descriptors found in literature were used [8]. Quality attributes were scored using a 9-point Hedonic scale of 1-9 (1= dislike extremely, 9= like extremely), score of 5.5 and above considered as acceptable.

Statistical analyses

The data obtained in the present study was subjected to factorial CRD statistical analysis. The critical difference (C.D.) value at 5% level of probability was compared for making the comparison among different treatments. Drying kinetics and moisture ratio value were plotted against time in the MS Excel (Version, 2007). Sensory values were analyzed statistically and mean value for each descriptor for various treatments is plotted in spider chart using MS Excel. The statistical significance of the terms in the regression equation was examined by analysis of variance (ANOVA) with SATISTICA 12 (StatSoft, Inc., USA).

RESULTS AND DISCUSSION

Drying characteristics of the oyster mushroom

The typical drying curves describe drying characteristics of oyster mushroom at different air temperatures and velocities in fluidized bed dryer are shown in Fig.1 a and b. The initial moisture content of 92.32% (w.b.) of mushroom sample was decreased to final moisture content ranging from 6.1–9.6% (w.b.) with drying time ranging from 150–330 min depending on drying condition used. Drying time was reduced with increase of drying air temperature and velocity. For example oyster mushroom dried at higher air temperature of 65ºC and 5 ms^{-1}air velocity required lowest drying time of 150 min to obtained final moisture content of 6.1% (w.b.) for safe storage. It is evident that drying air temperature and velocity had important effect on moisture movement and reduction in drying time. These results showed inverse relationship between air temperature and drying time are corroborated with findings of drying in milky mushrooms [2] and raw mango slices [11].

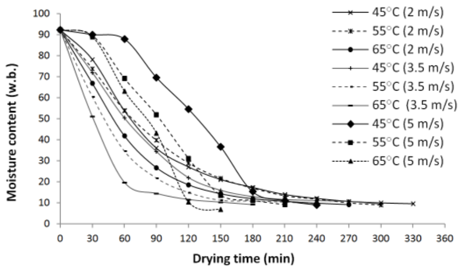

Figure 1(a). Variation in moisture content (w.b.) of oyster mushroom at different air-temperature and air-velocities in fluidized bed dryer

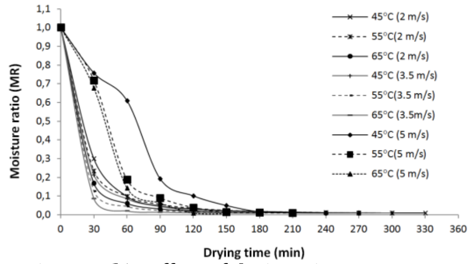

Figure 1(b). Effect of drying air-temperatures and air-velocities on moisture ratio of oyster mushroom

Drying of mushroom for 45, 55 and 65ºC at 2, 3.5 and 5 $m \cdot s^{-1}$ followed falling rate profile. Mushroom dried at 2 $m \cdot s^{-1}$ and 3.5 $m \cdot s^{-1}$ air-velocities, moisture content (w.b.) reduces in two stages i.e. initially at faster rate and then slowly with increase in drying time for different temperatures. However, moisture content (w.b.) of mushroom dried at 5 $m \cdot s^{-1}$ reduces slowly during initial stage, then decreases rapidly and again slowly decreases at the end of process with increase of drying time. Similar decreasing trends of moisture ratio with increase of drying time were observed for all drying treatments. The rate of moisture loss was higher at higher air temperatures and velocities resulted in substantial reduction total drying time with the increase in drying air temperature and velocity. Thus drying curves for all treatments indicated that entire drying process took place in the falling rate period. It is revealed that drying process was mainly controlled by physical diffusion mechanism governing moisture movement in the interior of mushrooms. These findings are consistent with previous studies by various researchers to explain thin layer drying behavior for different perishable fruits and vegetables [3, 9, 16].

$$MR = 0.014297 – 0.000445\ V\ (ms^{-1}) – 0.000034\ T(°C) – 0.000084 V\ T \tag{8}$$

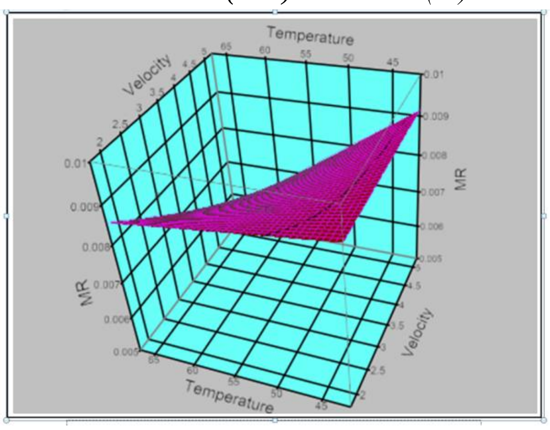

Figure 2. Surface plot showing the influence of drying air-temperature and air-velocity on moisture ratio of oyster mushroom

Drying at high temperature is not recommended due to detrimental effects on food constituents like proteins, vitamins, minerals, color, texture etc. A multiple lineal regression test was carried out using JMP 10.0 (Cary, NC, USA) on moisture ratios for the oyster mushroom resulted in equation (8). Fig. 2 illustrates the combined effect of drying air temperature and velocity evident that drying air temperature (*T*) has significant (p=0.04) effect on drying. The lowest moisture ratio of 0.006 was obtained at 65°C and 5 m·s^{-1} velocity with higher desirability of 0.67 and indicating the best quality of dried oyster mushroom.

Evaluation of the mathematical models

The moisture ratio data of oyster mushroom dried at different air temperatures (45, 55 and 65ºC) and velocities (2, 3.5 and 5 m·s^{-1}) were fitted into different thin layer drying models listed in Table 1 to evaluate their suitability to describes the drying process in fluidized bed dryer. The summarized results of drying model constants, coefficient of determination (R^2) and statistical parameters calculated from nonlinear regression analysis were presented in the Tab. 2. The higher values of R^2 and lower values of χ^2, *RMSE* and *MBE* were used as selection criteria for best model fit. From Table 2 it was found that R^2values are > 0.93 for Henderson, Newton, Page, and Two-Term exponential models indicating the best fit. It was also observed that Logarithmic model (R^2> 0.99) at 2 and 3.5 m·s^{-1} air-velocity and Wang and Singh model (R^2> 0.95) at 5 m·s^{-1} air-velocity are fitted best for mushroom dried at all drying temperatures. However, Page model gave highest values of R^2 (0.9846 to 0.9999) and lowest values of χ^2 (0.00001 to 0.00255), *RMSE* (0.0031 to 0.0445) and *MBE* (–0. 0005 to 0.0006) for all drying air temperatures and velocities. This model fitted well to the experimental and predicted values of moisture ratio. The linear relationship at 45º slope from the origin between predicted and experimental values of moisture ratio indicated that predicted model is a good fit for the actual drying data (Fig. 3). Hence Page model was suggested as the best model to explain thin layer drying behavior of oyster mushroom under fluidized bed condition. These results are similar with observations of air-drying of bamboo [8] and mango slices [11]. But inferences from this study are different from that of [3] for drying of oyster mushroom in convective hot dryer for which drying kinetics was explained by the Midilli *et al*. model [3].

Table.2. Model coefficients on drying of oyster mushrooms at different temperatures and velocities

Model	Temp. ºC	Velocity (ms^{-1})	Constants and coefficients				R^2	χ^2	RMSE	MBE
Newton/ Lewis			k							
	45	2.0	0.0391				0.9977	0.00019	0.0132	0.0100
	55	2.0	0.0448				0.9942	0.00050	0.0213	0.0137
	65	2.0	-0.057				0.9972	0.00027	0.0155	0.0110
	45	3.5	-0.0484				0.9961	0.00034	0.0177	0.0116
	55	3.5	-0.0666				0.9980	0.00022	0.0139	0.0102
	65	3.5	-0.0806				0.9992	0.0001	0.0094	0.0075
	45	5.0	-0.0142				0.9401	0.00868	0.0878	-0.0088
	55	5.0	-0.0212				0.9509	0.00721	0.0794	-0.0061
	65	5.0	-0.0233				0.9430	0.01005	0.0916	-0.0098
Page			k	n						
	45	2.0	0.0758	0.8192			0.9987	0.00012	0.0100	0.0059
	55	2.0	0.1867	0.6062			0.9997	0.00003	0.0048	0.0020
	65	2.0	0.2518	0.5789			0.9997	0.00003	0.0050	0.0023
	45	3.5	0.1864	0.6241			0.9997	0.00003	0.0049	0.0024
	55	3.5	0.4285	0.5154			0.9998	0.00004	0.0051	0.0017
	65	3.5	0.8369	0.3590			0.9999	0.00001	0.0031	0.0006
	45	5.0	0.0004	1.7829			0.9846	0.00255	0.0445	-0.0005
	55	5.0	0.0003	2.1059			0.9935	0.00112	0.0290	0.0143
	65	5.0	0.0002	2.2233			0.9964	0.00079	0.0229	0.0101

Handerson and Pabis			*a*	*k*						
	45	2.0	0.9979	0.0391			0.9977	0.00021	0.0132	0.0101
	55	2.0	0.9961	0.0447			0.9943	0.00055	0.0213	0.0140
	65	2.0	0.9988	0.0570			0.9972	0.00030	0.0155	0.0111
	45	3.5	0.9973	0.0483			0.9961	0.00038	0.0176	0.0118
	55	3.5	0.9994	0.0666			0.9980	0.00025	0.0139	0.0102
	65	3.5	0.9999	0.0806			0.9992	0.00013	0.0094	0.0075
	45	5.0	1.0707	0.0150			0.9456	0.00900	0.0837	-0.0179
	55	5.0	1.0533	0.0220			0.9505	0.00788	0.0769	-0.0129
	65	5.0	1.0478	0.0241			0.9459	0.01194	0.0892	-0.0183
Logarithmic			*a*	*k*	*c*					
	45	2.0	0.9847	0.0411	0.0148		0.9997	0.00003	0.0049	0.0000
	55	2.0	0.9775	0.0483	0.0206		0.9979	0.00022	0.0127	0.0000
	65	2.0	0.9838	0.0607	0.0157		0.9992	0.00009	0.0081	0.0000
	45	3.5	0.9817	0.0515	0.0169		0.9986	0.00015	0.0105	0.0000
	55	3.5	0.9853	0.0710	0.0145		0.9995	0.00007	0.0067	0.0000
	65	3.5	0.9886	0.0856	0.0114		0.9999	0.00001	0.0020	0.0000
	45	5.0	1.1692	0.0116	-0.1185		0.9597	0.00779	0.0721	0.0000
	55	5.0	0.8479	0.8000	0.1521		0.6120	0.07975	0.2233	0.0000
	65	5.0	1.1467	0.019	-0.1089		0.9576	0.01246	0.0789	0.0000
Two-Term exponential			*a*	*k*						
	45	2.0	0.4434	0.0648			0.9986	0.00013	0.0102	0.0072
	55	2.0	0.3522	0.0958			0.9969	0.00029	0.0155	0.0103
	65	2.0	0.3864	0.1127			0.9983	0.00018	0.0121	0.0089
	45	3.5	0.3605	0.1018			0.9980	0.00020	0.0127	0.0088
	55	3.5	0.4114	0.1246			0.9986	0.00017	0.0116	0.0086
	65	3.5	0.4512	0.1398			0.9994	0.00010	0.0084	0.0066
	45	5.0	0.0015	9.2180			0.9399	0.00996	0.088	-0.0096
	55	5.0	0.0018	12.0147			0.9507	0.00845	0.0796	-0.0065
	65	5.0	0.0018	12.7625			0.9428	0.01262	0.0917	-0.0102
Wang and Singh			*a*	*b*						
	45	2.0	-0.010836	0.000025			0.5215	0.04301	0.1893	-0.0488
	55	2.0	-0.011803	0.00003			0.5327	0.04490	0.1917	-0.0488
	65	2.0	-0.013307	0.000038			0.5256	0.05080	0.2016	-0.0499
	45	3.5	-0.011956	0.000031			0.5056	0.04776	0.1977	-0.0504
	55	3.5	-0.014961	0.000048			0.5667	0.05238	0.2019	-0.0481
	65	3.5	-0.019613	0.000083			0.7073	0.04796	0.1851	-0.0391
	45	5.0	-0.010152	0.000025			0.9732	0.00444	0.0588	0.0058
	55	5.0	-0.013633	0.000044			0.9559	0.00755	0.0753	-0.0015
	65	5.0	-0.01648	0.000066			0.9711	0.00637	0.0652	0.0061
Midilli et al.			*a*	*–k*	*n*	*b*				
	45	2.0	0.406686	0.000000	0.000000	-0.001673	0.4009	0.06732	0.2118	0.0000
	55	2.0	1.000062	-0.161048	0.64808	0.000031	0.9999	0.00001	0.0024	0.0002
	65	2.0	1.000000	-2.756115	1.113188	0.000095	0.9634	0.00523	0.0560	0.0202
	45	3.5	1.000000	-2.470894	0.770042	0.000095	0.9390	0.00758	0.0694	0.0252
	55	3.5	1.000000	-3.009014	1.424586	0.000097	0.9792	0.00352	0.0442	0.0159
	65	3.5	1.000000	-3.23332	1.66698	0.000110	0.9911	0.00244	0.0324	0.0112
	45	5.0	0.972627	-0.00024	1.920892	0.000046	0.9854	0.00339	0.0434	0.0001
	55	5.0	0.956234	0.004363	1.064802	-0.016259	0.9376	0.01604	0.0895	-0.0006
	65	5.0	0.820284	0.0000	0.0000	-0.006716	0.8052	0.08595	0.1693	0.0000

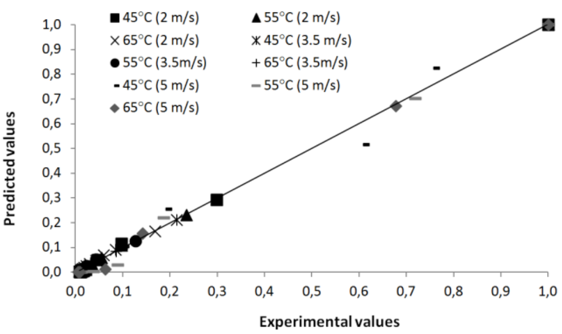

Figure 3. Comparison of experimental and predicted moisture ratio with page model

Computation of effective diffusivity and activation energy

The effective moisture diffusivity (D_{eff}) of oyster mushroom dried at different air temperatures and velocities were computed from the method of gradients of graphs [11]. The straight line relationship between ln (*MR*) versus drying time (*t*) were depicted to determine the values of effective moisture diffusivity by slope of the best fit using Eq. (7). The best-fit regression equations, coefficient of correlation (R^2) and corresponding D_{eff} values for different drying air temperatures and velocities during first and second falling rated drying period are given in Table 3. This table shows drying air temperatures and velocities greatly affected the effective moisture diffusivity of the oyster mushroom. At any given air velocity a rise in drying temperature led to an increase in effective moisture diffusivity. The D_{eff} values obtained at 2 and 3.5 m·s^{-1} air velocities ranged from 7.24×10^{-10}–2.11×10^{-9} and 7.78×10^{-10}–2.89×10^{-9} m2·s^{-1}, increased with air velocity for the first falling rate and almost same for second falling rate for mushroom dried at all air temperatures. At 5 m·s^{-1} air velocity, comparatively lower D_{eff} values of 2.44–4.02 ×10^{-9} m2·s^{-1} were found as drying process exhibited in single falling rate. This is attributed to the heat energy transferred at lower rate to oyster mushroom for higher air velocity as result of higher turbulent flow created under fluidized bed condition [10]. Also all these D_{eff} values are found within the range of 10^{-9}–10^{-10} m^2·s^{-1} as similar to previous report for most food, fruits and vegetable materials. Many studies performed on different perishable fruits and vegetables under similar drying air temperature and velocity conditions showed D_{eff} values to lie between 2.05–7.80×10^{-9} m^2·s^{-1} for kachkal banana peel [9], 2.62–4.39×10^{-10}m^2·s^{-1} for raw mango slices [11] and 6.59– 1.93×10^{-10} m^2·s^{-1} for spinach [16].

Table.3. Comparison of effective moisture diffusivity equation, R^2 and D_{eff} values for oyster mushroom at different temperatures and velocities

Temp. (°C)	Velocity (ms^{-1})	1st falling rate			2nd falling rate		
		Equations	R^2	Deff (× 10^{-9})	Equations	R^2	Deff (× 10^{-10})
45	2.0	$y = -0.0195x - 0.7307$	0.9020	2.11	$y = -0.0036x - 3.5932$	0.9482	3.89
55	2.0	$y = -0.0240x - 0.5031$	0.9361	2.59	$y = -0.0059x - 3.0521$	0.9768	6.38
65	2.0	$y = -0.0384x - 0.2963$	0.9549	4.15	$y = -0.0067x - 3.1150$	0.8986	7.24
45	3.5	$y = -0.0267x - 0.5062$	0.9468	2.89	$y = -0.0036x - 3.6883$	0.9231	3.89
55	3.5	$y = -0.0412x - 0.3830$	0.9365	4.45	$y = -0.0058x - 3.4626$	0.8089	6.27
65	3.5	$y = -0.0648x - 0.1674$	0.9782	7.00	$y = -0.0072x - 3.5540$	0.9434	7.78
45	5.0	$y = -0.0226x + 0.3510$	0.9747	2.44	-	-	-
55	5.0	$y = -0.0252x - 0.0288$	0.9655	2.72	-	-	-
65	5.0	$y = -0.0372x + 0.3154$	0.9724	4.02	-	-	-

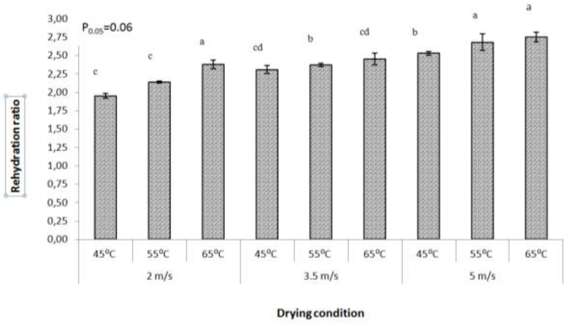

Figure 4. Effect of different air temperatures and velocity on rehydration ratio of oyster mushroom

Activation energy (E_a) of 30.17 and 39.17 kJ·mol^{-1} during initial stage were higher as compared to later stage, which were 27.91and 31.07 kJ·mol^{-1} for different drying temperature (45, 55 and 65º C) at 2 and 3.5 m·s^{-1} air velocities, respectively. Mushroom dried at different temperatures for 5 m·s^{-1} gave minimum value 22.15 kJ·mol^{-1} of activation energy to detach and move the water during the drying process. These activation energy values of oyster mushroom lie in the range of activation energy for mulberry (21.2 kJ·mol^{-1}) and grapes (40.14 kJ·mol^{-1}) [1, 14]. Similarly lesser activation energy requirement for drying at higher air velocities was observed for garlic sheets under semi-fluidized/fluidized bed condition [10] at different air-temperature.

Rehydration ratio

The rehydration characteristics of dried products are widely used as the quality index. It is evident from Fig. 4 that rehydration ratio was increased under high air temperature coupled with high air velocity and it was relatively poor with low temperature and slow air velocity. The rehydration ratio (RR) values ranged between 1.95-2.75. A highest value of *RR* (2.75) was obtained with 65ºC and 5.0 m·s^{-1} indicating the superior quality of mushroom. In practice, most changes caused by pre-drying and drying treatments are irreversible, and rehydration cannot be considered as simply as a process reversible to dehydration [8]. Higher rehydration displayed by high temperature might be due to the faster drying process that cause less cellular and structural changes in the final product while, the poor rehydration ratio poor in low temperature was due to longer time for drying, poor texture of the product caused by poor RH maintenance and fluctuation in air flow.

Sensory quality of dried mushroom

Acceptability of dehydrated products by the consumer is highly dependent on its sensory attributes. In addition, to visual appearance, colour, flavour and textural attributes are critical in determining their degree of acceptance. It was observed that 65°C with the air velocity of 5 m•s^{-1} recorded highest scores for almost all sensory quality parameters at the end of drying (Fig. 5). Mushroom colour changed from creamy whitish to yellow is preferred as the best quality and it was obtained when mushroom was dried at 65ºC and 5 m•s^{-1} during fluidized condition. However, the colour turned brown with higher temperatures and lower air velocity drying condition. Off flavor was due to over burning at higher temperature and lower velocity condition. The best colour of the dried product might be due to faster drying of mushroom under such an environment as described by [8] on different fruits.

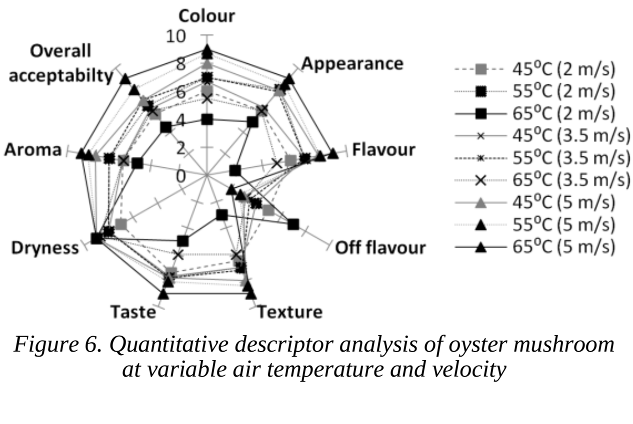

Figure 6. Quantitative descriptor analysis of oyster mushroom at variable air temperature and velocity

Texture of dried samples as revealed by scores of dryness was better with the same drying condition. Rapid and controlled loss of moisture, maintained the cell structure due to uniform heat transfer (65ºC) with the accelerated air velocity (5 $m \cdot s^{-1}$) which could be a probable factor for contributing high texture scores. Similarly, all other positively contributing sensory characteristics like flavor, aroma, after taste and over all acceptability of dried mushroom were also scored higher in high temperature with more air velocity. Off-flavor is mainly attributed to presence of phenolic compounds, degradation of quality components like sugar, acid and carotenes which might have got oxidized during drying [8].

CONCLUSIONS

From the study it was concluded that drying time reduced with the increase of drying air temperatures and velocities. The entire drying process of oyster mushroom occurred in the falling rate period. The mushroom dried at 65ºC and 5 $m \cdot s^{-1}$ was dried faster and gave the best quality in term of colour, texture, flavour and comparatively less shrinkage along with better rehydration ratio. Among the all models considered for this study; Page model explained drying process better than all other tested models. The effective moisture diffusivity ranged from $7.78 \cdot 10^{-10}$ to $2.11 \cdot 10^{-9}$ $m^2 \cdot s^{-1}$ with higher values at higher drying temperature for any given velocity. In addition, drying at 5 $m \cdot s^{-1}$ air velocity required minimum activation energy of 22.15 $kJ \cdot mol^{-1}$ to detach and move the water during the drying process by diffusion. The finding of this study will be helpful to optimize the drying process for oyster mushroom under fluidized bed heating system and would provide processing parameters for up scaling the oyster mushroom drying process and efficient utilization of dehydration systems.

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POREĐENJE MATEMATIČKIH MODELA I KINETIKE SUŠENJA BUKOVAČE (*PLEUROTUS SPP*) U TANKOM FLUIDIZOVANOM SLOJU SA UBRZANOM TEMPERATUROM I BRZINOM VAZDUHA

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Sažetak: Ispitivan je uticaj temperature i brzine vazduha na karakteristike sušenja tankog fluidizovanog sloja bukovače (*Pleurotus spp*.). Pečurke su sušene na tri temperature vazduha 45, 55 i 65ºC, kombinovane sa brzinama vazduha od 2, 3.5 i 5 ms^{-1}. Trajanje dehidracije pečurki se smanjivalo i temperatura je imala značajan (P=0.04) uticaj na sušenje. U regresionom modelu, najbolji kvalitet sušene bukovače postignut je pri temperaturi od 65°C i brzini vazduha od 5 ms^{-1}, a ocenjen je prema senzornim karakteristikama: boja, hrskava tekstura, ukus i komparativno manje kalo. Za određivanje kinetike sušenja, eksperimentalne vrednosti vlažnosti su poređene sa sedam modela sušenja tankog sloja. Među analiziranim modelima, Page model je najbolje opisivao tok sušenja bukovače. Pri svakoj brzini vazduha, povećanje temperature dovelo je do povećanja efektivne difuzivnosti vlage u interval od 7.78×10^{-10} do 2.11×10^{-9} m^2s^{-1}. Sušenje strujom vazduha brzine 5 ms^{-1} zahtevalo je minimalnu energiju aktivacije od 22.15 KJ mol^{-1} za odstranjivanje vode difuzijom tokom sušenja. Odnosi rehidracije (RR) (1.95-2.75) povećali su se sa povećanjem temperature i brzine vazduha. Dobijeni rezultati se mogu koristiti za pravljenje odgovarajućih konstrukcija i operacija industrijskih sistema sušenja gljiva radi dalje prerade i dobijanja prozvoda veće vrednosti.

Ključne reči: *bukovača, kinetika sušenja, efektivna difuznost, suušč fluidiziranog sloja, odnos vlažnosti, senzorne karakteristike*

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EFFECT OF FEED RATE, CONCAVE CLEARANCE AND PERIPHERAL SPEED ON THE PERFORMANCE EVALUATION OF PRE THRESHER FOR ONION UMBELS (*Allium cepa* var. *aggregatum* L.)

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Abstract: Freshly harvested, sun dried onion umbels consists of florets attached to the hard umbel heads. Conventional threshing method involves tractor treading, rubbing umbels using rubber slippers on hard surface and beating with sticks. This method resulted in seed damage and affected the germination and vigor index. High quality seeds can be produced through effective threshing and separation process. Threshing of onion umbels was carried out in a lab model thresher resulted in chocking of umbel heads in the threshing chamber and reduced the threshing efficiency of the thresher. Pre threshing is an important unit operation carried out before threshing of onion umbels. The main aim of the study was to develop a pre threshing unit to separate the florets from hard umbel heads. Hence, a pre thresher with peg tooth type threshing cylinder was designed and developed for separating the florets from onion umbels further florets are conveyed to the thresher for separation of seeds from the florets. The performance of the unit was evaluated in terms of florets threshing efficiency, floret separation efficiency, percentage floret loss and seed damage at different feed rate, concave clearance and peripheral speed. The peg tooth type pre thresher's performance was good at 100 $kg \cdot h^{-1}$ feed rate 6 mm concave clearance and 7 $m \cdot s^{-1}$ peripheral speed.

Key words*: pre thresher, umbels, seed damage, concave clearance, feed rate, peripheral speed, tractor treading, peg tooth, vigor index, floret loss*

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INTRODUCTION

Onion (*Allium cepa* var. *aggregatum* L.) is an important commercial horticultural crop grown all over the world. India ranks second in the world next to China followed by U.S.A, Turkey, Pakistan, Russia, Indonesia, Vietnam, Korea and Myanmar. India occupies 24.47% of area and 20.2% production [1] in the world. USA recorded the highest productivity of onion (54.6 $Mt\cdot ha^{-1}$), followed Netherlands (49.7 $Mt\cdot ha^{-1}$), and Egypt (33.7 $Mt\cdot ha^{-1}$). India the second major onion producing (16.81 mT) country in the world has a productivity of 16.0 $Mt\cdot ha^{-1}$ [1]. Lower productivity is due non availability of quality planting material. It is reported that in India, the area and production of onion are in increasing trend. It is expected to increase its production in coming years to meet the growing demand for onion of the state. Due to non availability of suitable machinery for post harvest operations, farmers are following the traditional methods. Traditionally, the farmers use tractor treading methods, rubbing the umbels using rubber slippers on hard concrete surface and beating with sticks. This results in more seed damage which affects the seed germination and vigor index. Moreover this method is labor intensive, tedious and costlier. Keeping this in mind a lab model thresher with rasp bar threshing cylinder was developed to thresh the onion umbels. During field experiments, it was found that the lab model thresher did not perform well and stopped the thresher due to choking of umbel heads. To overcome this problem, it was decided to fabricate a pre thresher to free or detach all florets from umbel heads, move all umbel heads outside the pre thresher after separation of florets from them and passing only florets below to a radial flow, rasp bar type thresher for easy threshing and separation of seeds from florets. This paper deals with the performance of the pre thresher under different feed rate, peripheral speed and concave clearance. The machine was evaluated in terms of floret threshing efficiency, floret separation efficiency, floret loss and seed damage.

MATERIAL AND METHODS

Pre thresher works based on the principal of impact force in detaching the florets from umbel head. Threshing chamber of pre thresher consisted of a threshing cylinder and a concave. The concave was made into two halves namely top and bottom portions. The top and bottom halves are made up of 18 gauge thick, mild steel sheet. Bottom half was provided with perforations of 10 mm diameter at a center to center distance of 20 mm. Threshing cylinder of pre thresher was made up of centre wooden drum of 300 mm diameter, 1300 mm length. This wooden cylinder was attached to, two shaft at onion umbels feed end and umbel head discharge end, respectively. The shafts were welded to two thick plates and screwed to both ends of the wooden roller, for firm fixing of the shaft in to it. Front end of the roller was made in the form of screw auger to feed the onion umbels positively in to the threshing chamber. Similarly at the discharge end four vanes baffles were fabricated and fixed such that these blades discharged the umbel heads from the threshing chamber of pre thresher. Two ball bearings were fixed for friction free rotation. One ‘B’ type two groove pulley was attached from the front end of the pre thresher threshing cylinder shaft to transmit power from prime mover to the threshing cylinder. Pegs were driven in four rows in a staggered manner over the remaining portion of the wooden drum such that during operation these pegs will not only perform beating action but also acts as a screw conveyor and convey the material from feeding end to discharge end.

A semi circular plate was cut and fixed on the discharge end of the wooden drum over the bottom concave portion of the threshing chamber to arrest the free movement of florets following a trajectory motion. This plate intercepts free flowing threshed materials and helped for agitation of the threshed materials near the discharge end for complete separation of detached florets from the umbel head. A discharge chute is fixed below the concave of the threshing chamber to release florets from pre thresher to thresher and the other after the thresher to discharge the threshed seeds and trashes through concave to the threshing unit. A clearance of 7.0 mm was maintained between the concave and the tip of pegs in pre thresher. This helped to make gentle impact action on the umbels and then rubbing the florets over the concave, which in turn helped to separate the florets from umbels from pre thresher. Normally, concave clearance influences threshing efficiency and seed damage. It is well known that increase in clearance would result in low threshing efficiency whereas, reduced clearance would cause more seed damage. Therefore, optimum concave clearance required was determined by varying clearance. By screwing the rod in to the wooden body of threshing cylinder in the pre thresher, clearance was varied and experiments were conducted.

In this study, performance of the developed pre thresher was carried by changing the feed rate, peripheral speed and concave clearance of the pre thresher and the readings were recorded and statistically analyzed using AGRESS and the results are discussed below.

RESULTS AND DISCUSSION

Performance of the pre thresher was carried out at different feed rate, peripheral speed and concave clearance and evaluated based on the floret threshing efficiency, floret separation efficiency, seed damage and floret loss. Each parameter was studied at three different levels and the results are represented in Tab.1.

Effects of feed rate, peripheral speed and concave clearance on florets threshing efficiency of pre thresher

Pre thresher for onion umbel was operated with feed rates of 100±5, 125±5 and 150±5 $kg \cdot h^{-1}$. During the experiments, peripheral speed and concave clearance were changed to 7, 8.5 and 10 $m \cdot s^{-1}$ and 6, 7 and 8 mm, respectively. Samples were collected, analyzed and the results are presented in the Fig.1. From figure, it is seen that for the same feed rate, increase in peripheral speed in general decreased the florets threshing efficiency. This may be due to less residential time of onion umbels within the pre thresher (threshing chamber) due to higher forward speed.

In case of 100±5 $kg \cdot h^{-1}$ umbel feed rate, pre thresher recorded the highest floret threshing efficiency of 99.93% at 7 $m \cdot s^{-1}$ peripheral speed with 6 mm concave clearance. Increase in peripheral speed from 7 to 8.5 $m \cdot s^{-1}$, decreased the floret threshing efficiency from 99.93 to 99.91% at 6 mm clearance and 99.28% at 8 mm clearance. Further increase in peripheral speed from 8.5 to 10 $m \cdot s^{-1}$, lowered floret threshing efficiency from 99.91 to 99.23% at 6 mm clearance. For the same feed rate of 100±5 kg·h^{-1}, 10 m·s^{-1} peripheral speed and increase in clearance from 6 to 8 mm lowered the floret threshing efficiency from 99.23 to 99.18%. From the figure it is clearly seen that changes in peripheral speed from 7 to 10 m·s^{-1} and clearance from 6 to 8 mm recorded only 0.75% decrease in floret threshing efficiency. This clearly indicates that the above mentioned changes in peripheral speed and concave clearance did not influence much on floret threshing efficiency.

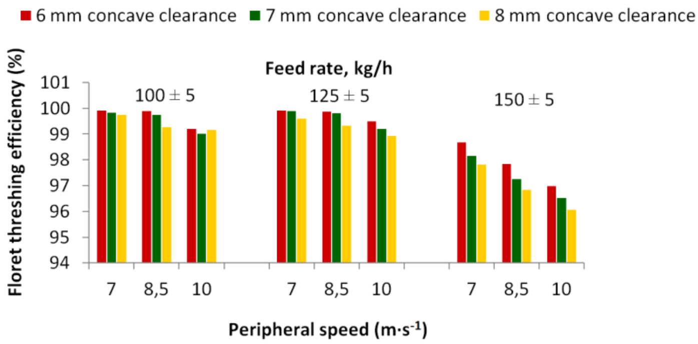

Figure 1. Effects of feed rate, peripheral speed and concave clearance on florets threshing efficiency of onion umbels in the pre thresher

Feed rate of 125±5 kg·h^{-1}, 7 m·s^{-1} peripheral speed and 6 mm clearance recorded 99.94% floret threshing efficiency. Increase in clearance from 6 to 7 and 7 to 8 mm, resulted in floret threshing efficiency of 99.91 and 99.62%, respectively. When the peripheral speed was increased from 7 to 8.5 m·s^{-1} lowered the floret threshing efficiency from 99.94 to 99.89% at 6 mm, 99.91 to 99.82% at 7 mm clearance and 99.62 to 99.34% at 8 mm clearance. As the peripheral speed was increased the floret threshing efficiency reduced. From this, it is seen that for this feed rate (125±5 kg·h^{-1}) change in peripheral speed from 7 to 10 m·s^{-1} and increase in concave clearance from 6 to 8 mm recorded 1.00% change in the floret threshing efficiency. As compared to 100±5 kg·h^{-1}feed rate, 125±5 kg·h^{-1}feed rate recorded a higher reduction in the floret threshing efficiency.

From the figure it is further seen that increase in feed rate from 125±5 to 150±5 kg·h^{-1} recorded lesser floret threshing efficiency for the above said conditions. It was noted that for 150±5 kg·h^{-1} feed rate and 7 m·s^{-1} peripheral speed, change in concave clearance from6 to 8 mm lowered floret threshing efficiency by 0.86%. From this, it is clear that at 150±5 kg·h^{-1} feed rate, change in peripheral speed from 7 to 10 m·s^{-1} and change in concave clearance from 6 to 8 mm lowered the floret threshing efficiency by 1.82%.

From this it is clear that, an increase in feed rate from 100±5 to 150±5 kg·h^{-1}, decreased the floret threshing efficiency from 0.75 to 1.82%, which indicates that increase in feed rate lowered the floret threshing efficiency.

Similar results were reported for threshing of chickpea seeds [2] and for cow pea thresher by [3]. [2]reported that increase in feed rate from 150 kg·h^{-1}to 200 kg·h^{-1} at 8.94 m·s^{-1} peripheral speed decreased the threshing efficiency from 99.99 to 98.67% in cow pea. [3] reported that increase in feed rate from 101.19 kg·h^{-1} to 110.86 kg·h^{-1} at 500 rpm beater speed, decreased the threshing efficiency from 98.26 to 96.29%. These findings are similar to the results recorded in the present study and supports the results of present study.

Effects of feed rate, peripheral speed and concave clearance on florets separation efficiency of pre thresher

The pre thresher for onion umbel was operated at 100±5, 125±5 and 150±5 kg·h^{-1} feed rates, 7, 8.5 and 10 m·s^{-1} peripheral speeds and 6, 7 and 8 mm concave clearances. Samples were collected, analyzed and floret separation efficiency was recorded and presented in Tab. 1 and shown in Fig. 2.

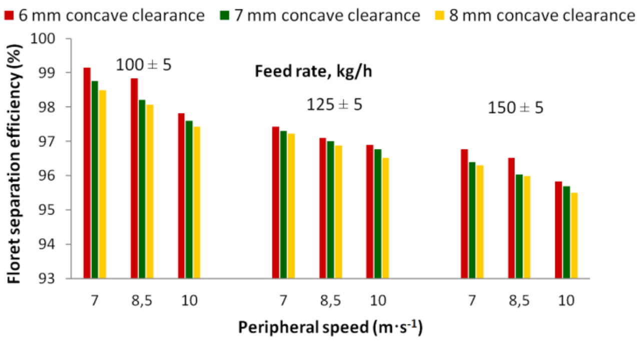

Figure 2. Effects of feed rate, peripheral speed and concave clearance on florets separation efficiency of onion umbels in the pre thresher

From figure, it is seen that among three clearances studied, 6 mm concave clearance recorded the highest floret separation efficiency of 99.17% for the feed rate of 100±5 kg·h^{-1} and 7 m·s^{-1} peripheral speed. For the same operating condition, 7 and 8 mm concave clearances, recorded a floret separation efficiency of 98.77 and 98.50%, respectively. Increase in peripheral speed from 7 to 8.5 m·s^{-1} recorded a maximum floret separation efficiency of 98.85% at 6 mm clearance and minimum floret separation efficiency of 98.09% and intermediate concave clearance of 7 mm recorded a floret separation efficiency of 98.23%. Further increase in peripheral speed from 8.5 to 10 m·s^{-1} recorded 97.84, 97.62 and 97.44% floret separation efficiency with 6, 7 and 8 mm concave clearances, respectively. From this, it is seen that at 100±5 kg·h^{-1} umbel feed rate, increase in peripheral speed from 7 to 10 m·s^{-1} and increase in concave clearance from 6 to 8 mm recorded a reduction in floret separation efficiency by 2.29%.

In case of 125±5 kg·h^{-1} feed rate at 7 m·s^{-1} peripheral speed with 6 mm concave clearance recorded a maximum floret separation efficiency of 97.45% and a minimum value of 96.53% for 10 m·s^{-1} peripheral speed with 8 mm concave clearance. For the same feed rate changes in peripheral speed (7 to 10 m·s^{-1}) and concave clearance (6 to 8 mm) recorded a reduction in the floret separation efficiency by 0.95%. At this feed rate and peripheral speed of 7 m·s^{-1}, increase in concave clearance from 7 and 8 mm recorded a floret separation efficiency of 97.32 and 97.24%, respectively. Increase in peripheral speed further 7 to 8.5 m·s^{-1}) recorded 97.12, 97.02 and 96.89% as floret separation efficiency with concave clearance of 6, 7 and 8 mm, respectively. At a peripheral speed of 10 m·s^{-1} and 6 mm concave clearance, the floret separation efficiency was 96.91%. Further increase in clearance to 7 and 8 mm, recorded 96.78 and 96.53% floret separation efficiency, respectively. From the figure, in general it is seen that irrespective of increase in peripheral speeds and concave clearances, increase in feed rate recorded decrease in floret separation efficiency. However, changes are much less (97.45 to 96.53%).

When the feed rate was increased to 150±5 kg·h^{-1}, the maximum and minimum floret separation efficiency recorded was 96.78 and 95.52% at 7 and 10 m·s^{-1} peripheral speeds and 6 and 8 mm concave clearances, respectively. For this feed rate, at 7 m·s^{-1} peripheral speed increase in concave clearance (6 to 7 mm) recorded a floret separation efficiency of 96.41% and further increase in clearance from 7 to 8 mm recorded 96.32% as floret separation efficiency. As the peripheral speed was increased to 8.5 and 10 m·s^{-1} with the concave clearance of 6, 7 and 8 mm the floret separation efficiency recorded a value of 96.54, 96.05 and 96.01 and 95.84, 95.70 and 95.52%, respectively. For this feed rate, increase in peripheral speed from 7 to 10 m·s^{-1} and 6 to 8 mm concave clearance recorded a change in floret separation efficiency by 1.32%.

Feed rates 125±5 and 150±5 kg·h^{-1} recorded a decrease in floret separation efficiency with increase in peripheral speed and concave clearances. This may be due to the reason that at higher peripheral speed, the residential time of umbels in the pre threshing chamber got reduced and hence chance for separation of florets got decreased. Similarly increase in concave clearance resulted in lesser mixing effect in the layer of materials present in between tip of pegs of pre thresher and concave surface and hence resulted in lower floret separation efficiency.

Effects of feed rate, peripheral speed and concave clearance on% floret loss of pre thresher

Floret loss in onion umbels fed in to the pre thresher occurred due to reduction in floret separation efficiency. To determine the% floret loss, studies were conducted at different feed rates (100±5, 125±5 and 150±5 kg·h^{-1}), various peripheral speeds (7, 8.5 and 10 m·s^{-1}) and concave clearances (6, 7 and 8 mm). Samples were collected, analyzed and the results are presented in Tab. 1 and shown in the Fig. 3.

From figure, it is evident that 100±5 kg·h^{-1} feed rate at 10 m·s^{-1} peripheral speed with a concave clearance of 8 mm resulted in maximum floret loss percentage of 2.56 and minimum value of 0.83% at 7 m·s^{-1} peripheral speed with a concave clearance of 6 mm. That is, in this case, there is an increase in floret loss by 156.00%. When the feed rate was increased to 125±5 kg·h^{-1}, the pre thresher performance recorded further increased results in floret loss. The maximum and minimum values of floret loss were 3.47 and 2.55%, respectively. This was recorded at a peripheral speed of 10 m·s^{-1} with a concave clearance of 8 mm and 7 m·s^{-1} peripheral speed with a concave clearance of 6 mm, respectively. In this case, the floret loss was increased by 36.08%. This value is lesser than the value recorded at 100±5 kg·h^{-1} feed rate. Further increase in feed rate to 150±5 kg·h^{-1} resulted in increased floret loss than the values observed in 100±5 and 125±5 kg·h^{-1} feed rates. The maximum floret loss was 4.48% and minimum was 3.22%, the increase in floret loss was increased by 39.13%.

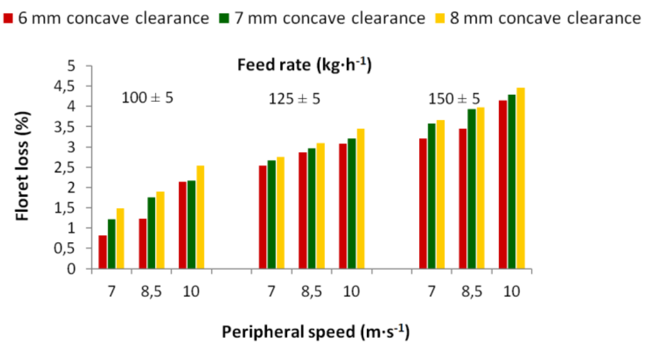

Figure 3. Effects of feed rate, peripheral speed and concave clearance on % floret loss of onion umbels in the pre thresher

From figure, it is clearly seen that maximum floret loss was 4.48% and minimum was 0.83%. Irrespective of feed rates, adopted increase in peripheral speed and concave clearance resulted in increased floret loss. This may be due to the following reasons. In case of onion umbel pre thresher, there is a screw auger in the feeding end which positively pushed the umbels in to the pre threshing chamber and at the discharge end there is a opening for the discharge of umbel head. When the peripheral speed was increased, the residential time inside the pre threshing chamber got reduced and this resulted in reduction in the floret separation efficiency, which in turn increased the floret loss along with umbel head at umbel head out let. As the concave clearance increases, the thickness of undisturbed layer of florets below the tip of pegs in the threshing cylinder got increased, which resulted in poor mixing and poor separation and higher loss of florets (along with umbel head at umbel head out let).

Effects of feed rate, peripheral speed and concave clearance on% seed damage in pre thresher

It was observed from the experiment that the impact force of the pegs not only detached the florets from umbel heads but also resulted in seed damage and discharged through umbel head outlet. Seed damage results collected during different operating conditions are also depicted in Fig. 4. From figure, it is seen that irrespective of feed rates and peripheral speeds adopted increase in concave clearances recorded reduction in seed damage. This may be due the fact that at higher clearance, the seeds moved along different directions during impact action caused by pegs and hence recorded lower seed damage. It is also seen that for the same feed rate, increase in peripheral speed recorded increase in seed damage. This may be due to higher impact force created by the pegs during higher peripheral speed, which caused higher seed damage. At constant clearance, as the feed rate increased the quantum of florets available for separation also got increased. If it exceeded the handling capacity of pre threshing chamber, accumulation of florets may take place, which may result in seed damage.

At 100±5 $kg{\cdot}h^{-1}$ umbel feed rate, 7 $m{\cdot}s^{-1}$ peripheral speed with 6 mm concave clearance, recorded a seed damage of 0.25%. For the same operating condition, increase in concave clearance to 7 and 8 mm recorded a seed damage of 0.24 and 0.20%, respectively. For the same feed rate, at 8.5 m·s^{-1} peripheral speed with 6 mm clearance, seed damage was 0.26%, 0.23% seed damage at 7 mm clearance and 0.21% seed damage at 8 mm clearance. In the case of 10 m·s^{-1} peripheral speed, 6, 7 and 8 mm concave clearances recorded a seed damage of 0.27, 0.25 and 0.23%, respectively. At this feed rate, a maximum seed damage of 0.27% was recorded at 10 m·s^{-1} with 6 mm concave clearance. The minimum seed damage of 0.20% was recorded at a peripheral speed of 7 m·s^{-1} with a concave clearance of 8 mm. That is, it recorded a reduction in the seed damage by 25.93%.

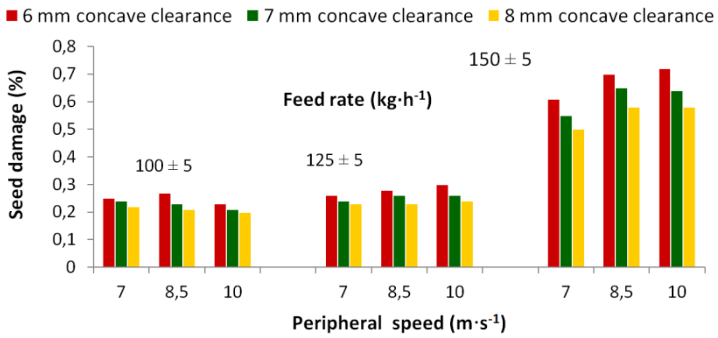

Figure 4. Effects of feed rate, peripheral speed and concave clearance on% seed damage of onion umbels in the pre thresher

For the feed rate of 125±5 kg·h^{-1} and 7, 8.5 and 10 m·s^{-1} peripheral speed recorded a seed damage of 0.26, 0.28 and 0.30% at 6 mm concave clearance and minimum seed damage of 0.23, 0.23 and 0.24% at 8 mm clearance and with 7 mm concave clearance recorded 0.24, 0.26 and 0.26% seed damage, respectively. In the case of 125±5 kg·h^{-1} umbel feed rate, a minimum seed damage of 0.23% and a maximum of 0.30% was recorded at 7 m·s^{-1} peripheral speed with 8 mm concave clearance and 10 m·s^{-1} peripheral speed with 6 mm concave clearance, respectively. That is, the above said operating conditions recorded a reduction in seed damage by 23.33%.

In the case of 150±5 kg·h^{-1} umbel feed rate, 7 m·s^{-1} peripheral speed recorded a minimum seed damage of 0.50% at 8 mm concave clearance and a maximum seed damage of 0.61% at 6 mm concave clearance and 0.55% at 7 mm concave clearance. When the peripheral speed was increased from 7 to 8.5 m·s^{-1}, higher seed damage was recorded at all clearances. It is seen from the figure that a minimum seed damage of 0.58% at 8 mm concave clearance, followed by 0.65% at 7 mm concave clearance and a maximum seed damage of 0.70% at 6 mm concave clearance was recorded at a peripheral speed of 8.5 m·s^{-1}. Similarly, in the case of 10 m·s^{-1} peripheral speed (threshing cylinder), 6 mm concave clearance recorded a minimum seed damage of 0.58%. The intermediate clearance of 7 mm recorded a seed damage of 0.64%.

From the study, it is seen that when the feed rate was increased from 100±5 to 150±5 kg·h^{-1}, peripheral speed from 7 to 10 m·s^{-1} and concave clearance from 6 to 8 mm recorded a minimum seed damage 0.2% (100±5 kg·h^{-1} feed rate, 7 m·s^{-1} peripheral speed with 8 mm concave clearance) and a maximum seed damage of 0.72% (150±5 kg·h^{-1}, 10 m·s^{-1} peripheral speed with 6 mm concave clearance). This clearly indicates that changes in the feed rate, peripheral speed and concave clearance did not affect the seed damage very much *(i.e)* the seed damage was less than 1% only in all cases.

Similar results were reported in soy seed thresher [3], and in chick pea thresher by [2]. [4] studied the machine-crop parameters of an axial flow thresher for threshing of soybean. They reported that increase in threshing drum speed from 600 to 700 rpm at 540 kg (plant)/h feed rate at 14.34% (wb) seed moisture content increased the seed damage from 0.72 to 0.96% and [2]reported that increase in peripheral speed from 8.94 to 10.62 $m \cdot s^{-1}$ at 200 kg (chick pea)/h increased the seed damage from 3.37 to 4.18%. This confirmed the findings reported in the present study.

CONCLUSIONS

It was observed from the pre thresher performance evaluation studies, it is seen that changes in the feed rate from 100±5 $kg \cdot h^{-1}$, 125±5 $kg \cdot h^{-1}$ and 150±5 $kg \cdot h^{-1}$, peripheral speed 7, 8 and 10 $m \cdot s^{-1}$ and concave clearance 6, 7 and 8 mm changed the floret threshing efficiency from 99.93 to 96.07%, floret separation efficiency from 99.17 to 95.52%, floret loss% from 0.83 to 4.48 and seed damage from 0.22 to 0.72%. For best performance the pre thresher has to be operated at feed rate of 100 $kg \cdot h^{-1}$, with a concave clearance of 6 mm and peripheral speed of 7 $m \cdot s^{-1}$. Under this operating condition pre thresher recorded floret threshing efficiency, floret separation efficiency, floret loss and seed damage of 99.93, 99.17, 0.83 and 0.25%, respectively.

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UTICAJ NORME PUNJENJA, ZAZORA PODBUBNJA I PERIFERIJSKE BRZINE NA PERFORMANSE PRED VRŠALICE CVASTI CRNOG LUKA (*Allium cepa* var. *aggregatum* L.)

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Sažetak: Sveže požnjevene cvasti crnog luka, osušene na suncu, sastoje se od cvetova usađenih u glave cvasti. Konvencionalna vršidba uključuje gaženje traktorom, trenje cvasti gumenim papučama po tvrdoj podlozi i udaranje štapovima. Ovaj postupak dovodi do oštećenja semena i smanjenja klijavosti i indeksa vigora. Visoko kvalitetno seme se može proizvesti efikasnom vršidbom i odvajanjem semena. Vršidba semena iz cvasti crnog luka izvođena je laboratorijskim modelom vršalice, što je dovelo do zagušenja glava cvasti u vršidbenoj komori i smanjilo efikasnost vršidbe. Pred vršidba je važna operacija koja je izvedena pre vršidbe cvasti crnog luka. Glavni cilj ovog istraživanja bio je da razvije pred vršidbeni uređaj za odvajanje cvetova od tvrdih glava cvasti. Zato je konstruisana i razvijena pred vršalica sa vršidbenim cilindrom sa klinastim zubima za odvajanje cvetova iz cvasti luka i dalje odvođenje cvetova do vršalice za odvajanje semena iz cvetova. Karakteristike uređaja su ocenjivane prema efikasnosti izvršaja cvetova, efikasnosti odvajanja cvetova, procenta gubitka cvetova i oštećenja semena pri različitim normama punjenja, zazorima podbubnja i periferijskim brzinama. Pred vršalica sa klinastim zubima imala je najbolje rezultate pri normi punjenja od 100 $kg \cdot h^{-1}$, zazoru podbubnja od 6 mm i periferijskoj brzini od 7 $m \cdot s^{-1}$.

Ključne reči*: pred vršalica, cvasti, oštećenje semena, zazor podbubnja, norma punjenja, periferijska brzina, gaženje traktorom, klinasti zub, indeks vigora, gubitak cveta*

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A TIMBER SORTING FOR DOUBLE-WHEEL SAW D9

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Abstract: The paper describes a design of a timber assorting line which has been intended for a sorting at the back of double-wheel angle saw D9. The basic information about the possible applications and design of timber sorters are described in introduction of this paper. In next part, the attention is paid to the working principle of a designed device together with a definition of material parameters, with which the device can work. Constructional design of individual devices which are the members of the assorting line, are described in more details. The main part of this paper deals with the design of the assorting manipulator and roll train. Designed sorter shows an alternative solution to sorting at the back of the saw D9 and it expands the possibilities of nowadays assorting systems.

Key words*: manipulation, assorting manipulator, roll train*

INTRODUCTION

In nowadays saw technologies, the timber assorting systems are still used more often. The assorting system applications represent the basic condition for achievement of a full automated manufacturing process, which is the main reason for their using in practice. Using of these devices allow to remove a hard monotonic human work and ensure the smooth running of a manufacturing process.

The timber sorter represents an additional device for a timber assortment on the individual products. These devices are designed and modified to the concrete requirements. Among the most important initial requirements belong:

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- minimum and maximum length of a graded timber,
- minimum and maximum dimension of a timber cross-section,
- number of graded groups,
- required work tact of the sorting,
- required dimensions of a sorter.

Selection and design of a suitable sorter for specified requirements is very important and difficult process. In practice, there are sorters which can work either continuously at the back of the saw, or the sorter is made as an external device. In the case of continuous sorters, the most difficult requirement is to meet the required work tact which is given by feed velocity of the saw. The external sorters are often used in the case of a limited space at the production hall, where is a lack of space for the timber sorter placement directly at the back of the saw. Disadvantage of this solution is the necessity to transport of a sawed group of the timber towards assorting line and the necessity to solve a timber batching.

This paper deals with the design of a sorter which has been intended for continuous work at the back of double-wheel saw D9 from StrojCad Company. Designed device is intended for a timber grading to the individual groups according to its cross-section. This device represents an alternative of existed assorting systems which StrojCad Company uses at the back of the saw. In Fig. 1, the assorting lines from StrojCad Company are shown.

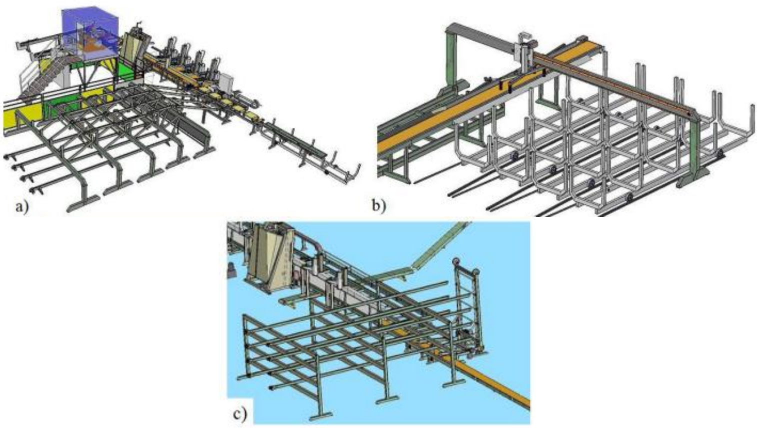

Figure 1. The timber assorting lines from StrojCad Company
a) the transverse sorter with a jib and an extension chain conveyer,
b) the assorting manipulator, c) the terrace timber sorter

MATERIAL AND METHODS

Design of the assorting line is based on the technical parameters of double-wheel saw D9 (Fig. 2). This saw represents a new generation of a double-wheel trunk saw with a movable clamping carriage and the possibility of a variable change of the sawed dimensions length. The saw is characteristic of a stationary cutting mechanism which is created by two rotary saw, perpendicular to each other, where one rotary saw is oriented in horizontal direction and the second one is oriented in vertical direction. Represented sawing method allows us to create a finished edged timber in a high quality by only one transit of piece through the cutting mechanism. The saw is managed by one operator who has the opportunity to interactively choose the suitable cutting scheme which takes into account parameters of a trunk as well as parameters of a required timber (Fig. 3).

Figure 2. Double-wheel angle saw D9

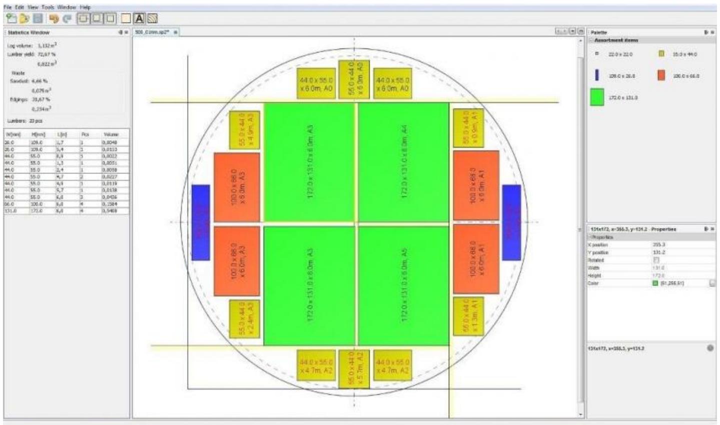

Figure 3. A cutting scheme

For a design of the assorting line, the highest effect from all technical parameters has a possible length range of processed trunk. The length of a cutting trunk directly affects the time of cutting and so required tact of assorting line work. Represented saw allows us to cut a billet with the range of lengths $l_r = 2 \div 8.3$ m. Minimum time of cutting which is important for a design of device is the lowest at cutting of the billet with the lowest length ($l_r = 2$ m). Cutting time also depends on kind of the cutting billet (soft or hard wood). From these information is clear, that minimum times of cutting will be different for hard and soft wood. The saw is able to cut the billet from hard wood with minimum length $l_r = 2$ m, which corresponds with minimum time of cutting $t_m = 5$ s. Sawing soft wood, there is not cut the billet which is shorter than $l_r = 4$ m, which corresponds with time of cutting $t_m = 8$ s.

One of the main aims of this paper is to provide a solution of the timber sorting which allows us to sorting in the biggest range. From this reason, we have focused on the timber length in range $l_r = 4 \div 8.3$ m.

The work principle of the designed sorter line is based on the motion combinations of different transport and manipulation devices which create a compact unit. The assorting manipulator which performs a process of sorting by its motion is a central part of device. The main part of the assorting manipulator is a shear mechanism which provides a lift of the graded billet into required height by its motion. Range of lift is divided into three height levels, where each one represents a different assorting group. Maximum value of lift is h_{max}= 1200 mm, which is the value for grading into the third height level. For grading into the first height level, there is required to perform the lift h_1= 305 mm and into the second level h_2 = 745 mm. In practice, a hydraulic drive or mechanical drive unit is used for ensure the shear mechanism lifting. A linear hydraulic with a velocity of a piston disengagement v_h= 0.25 m·s^{-1} was used for lifting of the shear mechanism in described solution. For achievement of required maximum lifting, determination of the piston disengagement value is required. Necessary value of the hydraulic piston disengagement was computed according to the following equation:

$$x = \sqrt{l^2 - m^2} - l_1 \qquad (1)$$

where:

l [mm] - length of a shear jib (distance of jib pin axes),
m [mm] - distance of jib pins at down position of mechanism,
l_1 [mm] - distance of jib pins at maximum lifting.

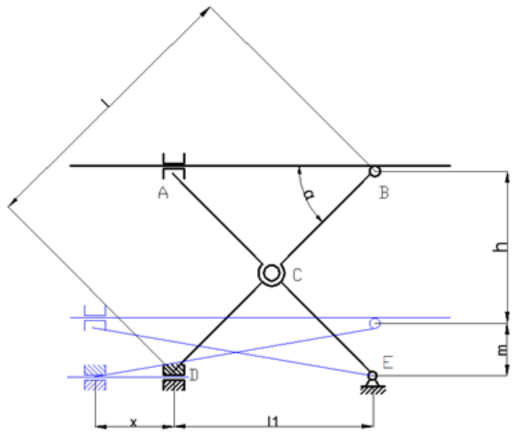

Figure 4. A kinematic scheme of the shear mechanism

Construction of designed shear mechanism consists of bottom welded construction (1), shear jibs (2), top welded construction (3) and linear hydraulic (4). The shear jibs are able to linear motion on one side which is represented by a linear line; on the second side, they are pinned. Due to the stability increase, fit of the shear jibs is designed in order to their asymmetry against to its centre in bottom position of the manipulator and their symmetric position at maximum lifting (Fig. 5).

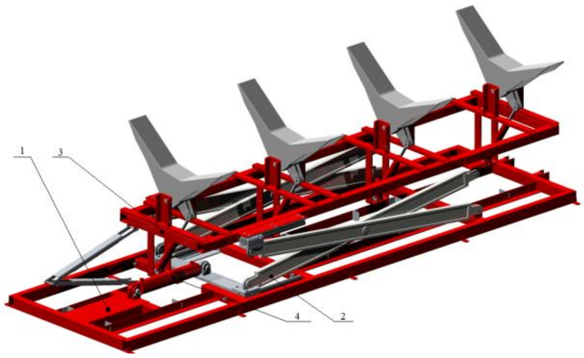

Figure 5. The assorting manipulator

The second important part of the assorting manipulator is a tipping device which is situated at the top of construction. The tipping device consists of a working spoon and linear hydraulic. The working spoon is able to rotate around the rotation axis in angle $\alpha_L = 60°$ by linear hydraulic. Fully, four working spoons with own drive are situated in a row in construction of the shear mechanism. Span between the working spoons is chosen in order to grade the timber with the lowest length $l_r = 2$ m. A possibility of the working spoon rotation in two sides allows us to grade the timber at three different height levels into six groups. When the shear mechanism obtains a required height, the tipping device is taken into motion. Subsequently, the working spoon is rotated according to the grade requirement on the one side or on the other side. Rotating the spoon, an inclined plane appears, where the graded billet is taken into motion by own gravity and it slides to line which transports it into appropriate collecting basket (Fig. 6).

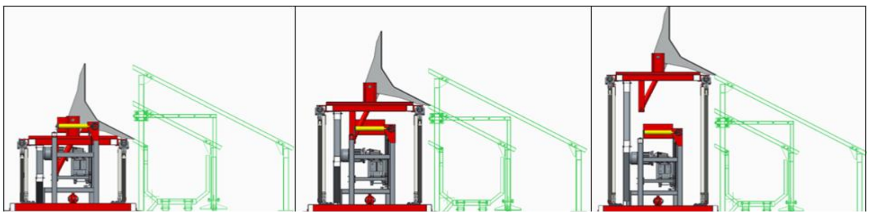

Figure 6. A timber grading into individual height levels

In next part of this paper, we deal with a problem of the billet transport from a conveyer to the assorting manipulator. The billet should be transported over the working spoons. The roll train is the best way of this transport. This roll train is divided into four parts and it is situated directly in the assorting manipulator. Owing to the simple plug of the working spoon under rolls level, construction of the conveyer is divided into individual spans. Individual parts are powered by electric motor and chain gear. Due to the accurate position of the rolls against to geometric centre of the working spoons, individual parts of the conveyer are centred by trips (Fig. 7).

Using of “Rollerdrive” rolls, which would abbreviate the construction of the roll train, was also taken into account at the design of a conveyer power. Due to their low power, using of these rolls could not be possible.

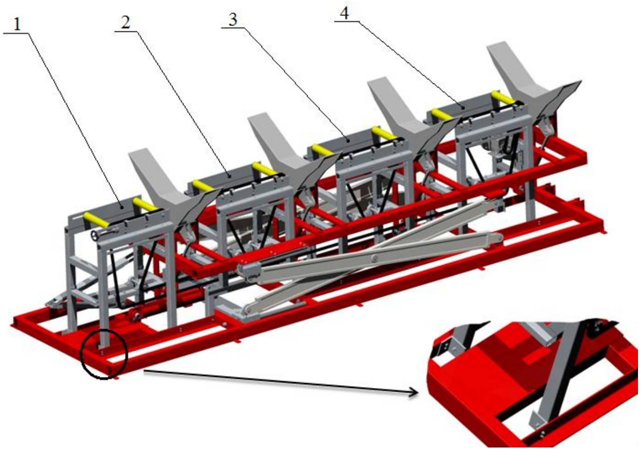

Figure 7. A constructional solution of the roll train

The most important parameter for design of the conveyer was dimension of the billet which can appear at output of the saw D9. Also, the length and cross-section of the billets have a variable character. Due to this, there was necessary to determine critical dimensions of the timber from overall possible range which directly affect the span and stiffness of the rolls. The lowest length of the billet which can appear at output of the saw was the most important property from the view of the conveyer rolls span. Maximum cross-section and length of the billet are important properties from the view of the rolls stiffness. Span of the rolls was chosen according to the rule of minimum three rolls under the shortest piece of the billet which has had length l_r = 2 m.

In next part of this paper, we deal with the design of individual parts of the assorting manipulator. During the work, the manipulator is loaded by the billet gravity which is the subject of manipulation at this moment. At computation, we considered with a gravity of the biggest billet *G* which can be processed by the saw D9. Determination of the manipulator critical positions, in which maximum load appears, is necessary from the view of individual parts design. Firstly, the reaction forces at the top construction by the tipping device were computed in position at the angle of spoon rotation α_L = 0° and α_L = 60°. The billet gravity *G* was evenly divided into each spoon.

A diagrammatic drawing of the tipping device, considering the billet gravity in a position at the angle of spoon rotation α_L = 60°, is in Fig. 7-a. In next step, the reaction forces in connections C and D were computed at the angle of spoon rotation α_L = 0° and α_L = 60° which were applied as loaded forces F_G at member of the shear mechanism (4) (Fig. 7-b). Subsequently, the reaction forces in connections A and B were computed at member (4). These reaction forces were used as loading forces of the shear mechanism jibs in next step of computation. The reaction forces, appeared in individual connections of the jibs, were computed in four positions of the mechanism, concretely at the values of lifting h_0 = 0 mm, h_1 = 305 mm, h_2 = 745 mm and h_{max} = 1245 mm. Due to the knowledge of a force course at hydraulic motor F_h which was necessary to fix the shear mechanism in required position, computation of the reaction forces was performed in different positions of the mechanism. The equations of a static equilibrium at the jibs were being solved according to the following equation:

$$\begin{pmatrix} 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 \\ \frac{l}{2}\cdot\cos\alpha & 0 & -\frac{l}{2}\cdot\sin\alpha & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 \\ \frac{l}{2}\cdot\cos\alpha & 0 & \frac{l}{2}\cdot\sin\alpha & 0 & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} R_{Cy} \\ R_{Ey} \\ R_{Cx} \\ R_{Ex} \\ R_{Dy} \\ F_h \end{pmatrix} = \begin{pmatrix} R_{Ay} \\ 0 \\ R_{Ay}\cdot l\cdot\cos\alpha \\ R_{By} \\ -R_{Bx} \\ -R_{By}\cdot l\cdot\cos\alpha - R_{Bx}\cdot l\cdot\sin\alpha \end{pmatrix} \tag{2}$$

where:

l [m] - length of the shear jib,

α [°] - angle between the shear jib and horizontal plane,

F_h [N] - force at hydraulic motor, necessary to fix the mechanism in required position,

R_{xi} [N] - reaction force in xth point and in ith direction of the shear jibs.

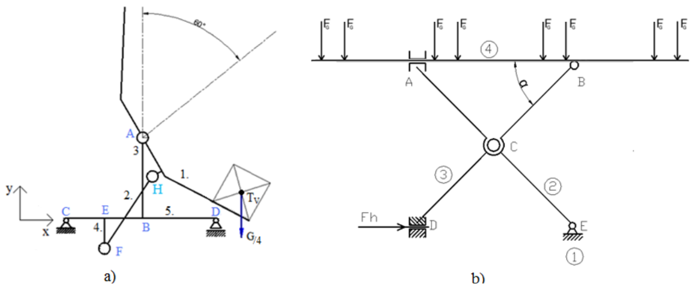

Figure 8. A diagrammatic drawing of loading at the shear mechanism and tipping device

RESULTS AND DISCUSSION

The main aim of the assorting line design was to find a solution which will represents an alternative method of sorting and will allow us to grade the timber in the highest range. It is possible to grade the timber in overall length range from the view of construction dimensions at the designed assorting system. Work tact of the assorting manipulator t_p is also another important parameter which affects a possible dimension range of the graded timber. Due to meet the condition of the sorter continual work, maximum work tact t_p should be lower than the lowest time of the saw cutting. Work tact t_p represents the time which is required to grading and subsequent backspacing of the manipulator into a default position. Work tact of designed device is t_{pmin} = 8 s at the chosen velocities of individual drives. During this time, the device picks up the billet into the second assorting group; upsets the spoon; stays in this position for the time t = 1 s and subsequently it returns into a default position.

After sorting into six assorting groups, it is necessary to perform maximum lift of the shear mechanism on the third height level. Due to this, the time of device work is extended to the value t_{pmin} = 11 s. On the basis of previous times, the sorter is intended for sorting of the billets from soft wood with the length range l_r = 2 ÷ 8.3 m and the billets from hard wood with the length range l_r = 4 ÷ 8.3 m. Sorting the timber with the length l_r = 2 ÷ 5 m, the device allows assortment into four groups and with the length l_r = 6 ÷ 8.3 m it is possible to sort into six groups.

Due to determination of working time of the assorting manipulator for different levels of lifts, determination of the piston extension values in the other positions was also required. Dependence between the lift of the shear mechanism and the piston extension of linear hydraulic was found out by a substitution of the corresponding values into the Eq. 1. This dependence is shown in Fig. 9.

In next part of this paper, a course of needed force F_h which affect to the shear mechanism was found out on the basis of matrix form (2). The force which is required for fixing the mechanism F_h, is maximum at the value of lift h = 0 mm (in a default position). In next lifting of the mechanism, decreasing of required force F_h appears. The course of force F_h in dependence on lift is shown in Fig. 9.

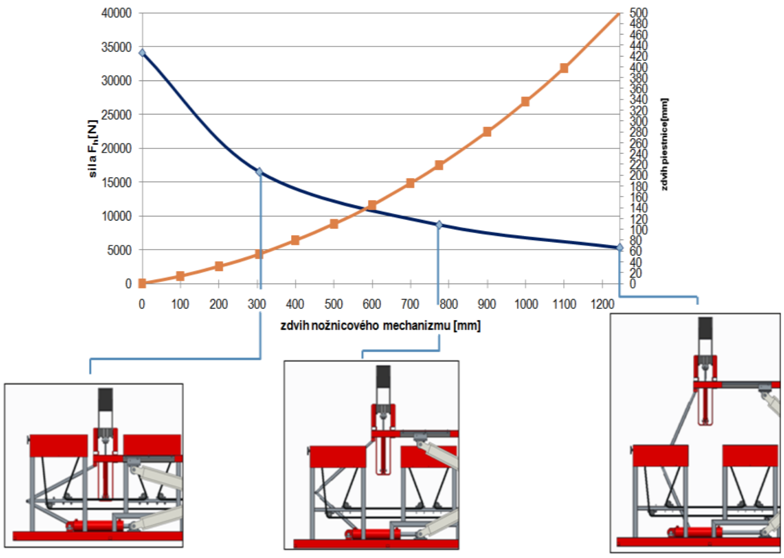

Figure 9. Dependence between the shear mechanism lifting, force F_h and the piston lifting

Table 1. Overview of the resulting reaction forces at the shear mechanism

Force	*[N]*
R_{AY}	*3321,88*
R_{BY}	*4768,17*
R_{BX}	*0,00*
R_{CY}	*-1446,28*
R_{CX}	*-33315,60*
R_{EY}	*4768,17*
R_{EX}	*33315,60*
F_h	*33315,60*

Maximum loading of the shear jibs is at the moment of the mechanism lift height h = 305 mm and the spoon of the tipping device is rotated into a side; there is a billet tipping in the first height level. In this position, non-uniform loading of the jibs on the left and right side appears. It is clear, that the jibs are more loaded on the side of the spoon tilting. The values of resulting reaction forces are shown in Tab. 2.

CONCLUSIONS

Constructional solution of the timber assorting line which is described in this paper can be modified according to the concrete requirements. In dependence on requirements, there is a possibility to modify the size of individual lift and to achieve a change of number of the assorting groups. Due to the decrease of device width, there is a possibility to use the sorting only at one side, for example in the case of its application in halls which are characterized by a low width. In represented constructional solution, the timber is transported from the assorting manipulator into the collecting baskets. In many saw technologies, mechanical transport of the timber from a sorter to a stacker is required. In these cases, the collecting baskets can be replaced by suitable means of transport, which can transport the assorting timber to the stacker. By this solution, it is possible to achieve a full automatic manufacturing process.

Also, the work principle of this sorter allows us to find the use in the other industrial branches after performing the suitable adjustments.

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SORTIRANJE TRUPACA ZA DVOSTRUKU TESTERU D9

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Sažetak: U radu je opisana konstrukcija linije za sortiranje trupaca koja je namenjena za sortiranje pozadi dvostruke ugaone testere D9. Osnovne informacije o mogućim primenama i konstrukciji sortirača trupaca su opisane u uvodu ovog rada. U sledećem delu pažnja je posvećena principu rada konstruisanog uređaja zajedno sa definicijom parametara materijala sa kojima uređaj može da radi. Konstruktivna rešenja pojedinih mehanizama koji čine liniju sortiranja su detaljnije opisani. Glavni deo ovog rada bavi se konstrukcijom manipulatora za sortiranje i valjkastim transporterom. Konstruisani sortirač pokazuje alternativno rešenje za sortiranje iza testere D9 i proširuje mogućnosti današnjih sistema sortiranja.

Ključne reči: *manipulacija, manipulator za sortiranje, valjkasti transporter*

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FIELD EVALUATION OF TRACTOR MOUNTED SOIL SENSOR FOR MEASUREMENT OF ELECTRICAL CONDUCTIVITY AND SOIL INSERTION / COMPACTION FORCE

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Abstract: Soil properties like electrical conductivity and soil compaction due to its correlation with other soil properties like soil texture, water content, cat ion exchange capacity (*CEC*), drainage conditions, organic-matter level, depth to clay pans, salinity, and subsoil characteristics that affect crop growth and its productivity were found to be important properties of soil. To observe the effect of electrical conductivity and insertion force, a tractor operated soil sensor (Make Veris Technology, USA) was used for measurement of electrical conductivity and insertion force (compaction) of soil in the field. Tractor mounted soil sensor probe was having a soil *EC* contacts and a load cell to measure the electrical conductivity and insertion force, respectively by pushing the probe into the soil. Experiments were conducted at two fields of departmental research farm of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. In field no. 1, the average electrical conductivity measured by tractor mounted soil sensor varied from 8.5 to 9.6 $mS{\cdot}m^{-1}$ having coefficient of variance 26.8% at soil moisture content of 26% (wb). In field no.2, the average electrical conductivity measured by tractor mounted soil sensor varied from 15.75 to 23.28 $mS{\cdot}m^{-1}$ with CV 12.1%. For Lab measurement of soil *EC*, coefficient of variance (CV) was found to be 10.9 % with average *EC* value of 20.62 $mS{\cdot}m^{-1}$. Overall insertion force for field no 1 was 1953.44 kPa at 0.2 m depth which suddenly increased up to 2864.06 kPa when depth was increased to 0.4 m which is 46% more than at 0.2 m depth.

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Overall insertion force for field no 2 was 8085.71 kPa observed at 0.2 m depth which increased up to 9704.96 kPa when depth was increased to 0.6 m which was 20% more as compared to insertion force at 0.2 m soil depth.

Key words*: tractor mounted soil sensor, soil electrical conductivity, insertion force, soil compaction*

INTRODUCTION

Green revolution changed Indian agriculture scenario and Punjab had major contribution in this revolution. Use of fertilizers, pesticides, insecticides, high yielding, semi-dwarf and short duration varieties, and advanced machines helped in agriculture growth. Rice-wheat cropping system became popular in Punjab. But due to continuous high usage of fertilizers, pesticides, heavy machinery and cropping pattern, lot of soil properties are affected. Further, declining water table, compaction of soil, and increase in salinity of soil are some other problems faced by farmers due to long and excessive usage of chemicals, machinery and water [1] [2] [3]. In Punjab, puddling is done before transplanting the rice seedlings resulting in creation of hard pan in soil. This hard pan is not broken with normal cultivation due to which water logging takes place in low areas in succeeding wheat crop, thereby decreasing its yield. Excessive and prolonged usage of rotary ploughs especially with L-blade for many years caused compaction of soil and formation of hard pan in the top soil which affect the crop growth and production.

Different soil properties like soil electrical conductivity, soil pH, soil temperature due to its effect on biological process like seed germination, seeding emergence and growth, root development, nutrient and water uptake porosity, and soil strength or compaction affect the crop growth considerably [4]. Out of these properties, soil electrical conductivity due to its correlation with other soil properties like soil texture, water content, cation exchange capacity (*CEC*), drainage conditions, organic-matter level, depth to clay pans, salinity, and subsoil characteristics that affect crop productivity and soil strength due to influence by soil water content, texture and structure are important soil properties [5]. Soil electrical conductivity (*EC*) is a measurement that correlates with other soil properties like *EC* is commonly expressed in milli-siemens per meter ($mS \cdot m^{-1}$). In Punjab, North Eastern undulating sub region is having *EC* 0.14-0.80 $dS \cdot m^{-1}$, Piedmont alluvial plain is having *EC* 0.15-0.80 $dS \cdot m^{-1}$, Central alluvial plain is having *EC* 0.14-1.60 $dS \cdot m^{-1}$ and South west alluvial plain is having *EC* 1.6-1.8 $dS \cdot m^{-1}$ (Kumar et. al. 2008). Soil compaction or strength property also influences the crop growth and its yield. If soil compaction/strength is less than 1 MPa (10.2 $kg \cdot cm^{-2}$) it indicates that roots grow through soil without difficulty and soil physical quality is good. If soil strength is between 1-3 MPa it indicates that root growth may become restricted and soil physical quality is moderate. If soil strength is greater than 3 MPa it indicates that root growth is retarded except through cracks and old root channels and soil physical quality is poor.

Hence, it is important to measure the soil properties to reduce their influence on crop yield. In India, soil electrical conductivity (*EC*) is mostly measured by laboratory analysis. To determine *EC* in laboratory, the soil solution is placed between two electrodes of constant geometry and distance of separation [6]. Laboratory process is laborious and large number of samples has to be taken for single field analysis which is a time consuming process. Machinery available in advanced countries to measure *EC* like soil *EC* mapper (Veris 3100) is bulky and costly. Indian farmers also do not have any access to this kind of equipment. Similarly, the measurement of soil strength with cone penetrometer and manual penetrometers is laborious process by manually pushing the cone into the soil media and recording individual reading obtained at specified intervals and maintains a constant penetration rate during cone pushing into the soil. Thus, to overcome the difficulty in the measurement of Electrical Conductivity (*EC*) and strength of soil, a tractor mounted *EC* mapper along with soil strength measurement can help farmers to collect more information in lesser time about their field so that they can manage their fields effectively.

By using the tractor operated *EC* mapper along with soil strength measurement, *EC* of soil can be directly measured in field which in turn can save a lot of time and resources of farmers. The effect of agricultural machinery usage and rice-wheat cropping pattern on soil compaction can be analyzed. Farmers can determine hard pan in their field and can perform suitable action to break hard pan, which will help in decreasing water logging problem. Hence, considering the above mentioned points, the present study is undertaken with the objectives to evaluate the existing soil sensor for measurement of electrical conductivity and compaction of soil and to compare the system for measurement of conductivity with laboratory method.

MATERIAL AND METHODS

This part deals with the various materials used and methods applied for conducting the experiments like measurement of soil *EC* and compaction in the field, measurement of soil *EC* in the laboratory.

Measurement of soil *EC* and soil compaction in the field

Tractor operated soil sensor. Tractor operated soil sensor (Make Veris Technology) shown in Fig. 1, was used for measurement of electrical conductivity and insertion force (compaction) of the soil in the field and Fig. 2 shows the line diagram of soil sensor.

Figure 1. Real and field view of tractor mounted probe type soil sensor

Soil Sensor is mounted on the tractor with the hydraulic system through the hydraulic lines to activate the system and electrical supply is given to the machine through the battery of the tractor. It should be insured that all the connections must be connected properly; no leakage of hydraulic oil should be there at the connecting points. When hydraulic hoses and power supply wires connected properly, the data logger of machine is connected to the laptop by USB port.

Data of soil *EC* and insertion force is geo-referenced through a GPS connected with the soil sensor and depth is recorded for each measurement in centimeter increments. It goes up to 100 cm depth. The rack-and-pinion hydraulic side-shift provides lateral motion, and the extended cylinder moves the probe forward or backward—all controlled manually, through accessible lever controls. The heavy-duty probe is constructed of 1” (2.54 cm) diameter probe rod.

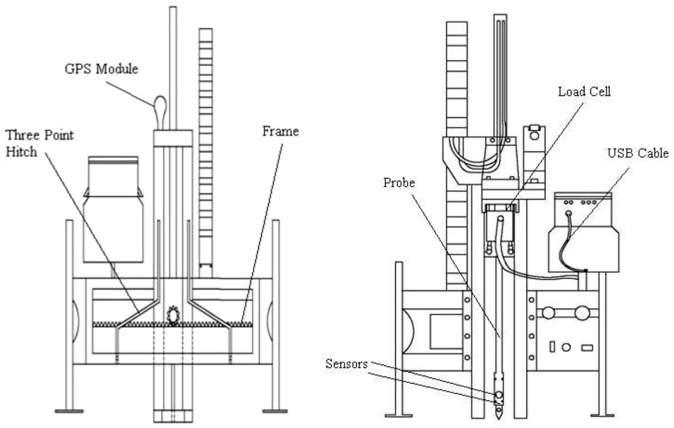

Figure 2. Front and rear view of tractor mounted soil sensor

Measurement of soil EC. Tractor mounted soil sensor is having a probe which can be inserted into the soil through tractor hydraulic system. At the bottom of the probe there is a cone-tip with soil *EC* contacts for collecting dipole *EC* data as shown in Fig. 3. Soil *EC* data along with its geo-referenced location was directly coming to laptop attached with it.

Figure 3. EC contacts on the probe of soil sensor

Measurement of soil compaction. Tractor mounted soil sensor probe is also having a load cell to measure the insertion force required to push the probe into the soil. Data of insertion force or compaction of the soil along with its geo-referenced location is saved.

Data Logging. Before collection of data using sensor, check the indication or light of *EC* port, depth port and GPS system turned green, which ensure that the laptop is properly connected to the machine and machine is ready to operate. The probe of the machine was lowered manually by operating the lever. When the probe just touches the soil, the log button in the software was clicked which starts the data logging. The depth control should be operated continuously without any interruption. Probe measures the electrical conductivity up to 100 cm depth. When the lever was stopped operating, the software stops taking readings by saving data automatically into the computer as an excel sheet format. The data was transferred to the computer using surfer 7.0 software and Arc-GIS 8.3 with spatial and 3D analyst extension.

Calibration of soil sensor EC in the laboratory. In this method the *EC* is measured by *EC* meter installed in the soil testing laboratory of the university. For measuring the soil *EC* in the laboratory, Soil samples were collected from all the marked points in the selected fields. The samples were taken up to the average depth of the probe. Approximately 200g of soil samples were collected and completely dried for further preparation of soil samples. The soil solution was prepared by having 20g of soil and adding 40 ml of water making soil volume ratio as 1:2. For mixing the soil and water properly, solution was stirred with the help of glass rod. Soil solution was ready to measure the *EC* data after keeping it for 24 hrs at room temperature.

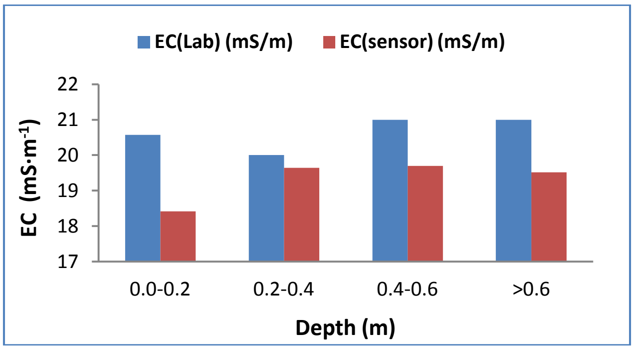

Figure 4. Electrical conductivity measured in lab and with tractor mounted sensor at different soil depths

To measure the soil *EC* in laboratory, the electrode was dipped into the prepared soil solution and *EC* of the samples was determined which was shown on the digital *EC* meter. The unit of *EC* is $mS{\cdot}m^{-1}$. Industrial conductivity probes often employ an inductive method having advantage of fluid not wetting the electrical parts of the sensor. Here, two inductively coupled coils were used. One was the driving coil produced a magnetic field with accurate voltage supply. The other formed a secondary coil of a transformer. The liquid passing through a channel in the sensor formed one turn in the secondary winding of the transformer. The induced current was the output of the sensor.

Conductivity electrode was placed into a standard solution of 0.005 *M KCl*. Electrode was agitated using up and down movement to create proper electrode contact with solution. After agitation, the meter should read 0.72 ± 0.04 mmho·cm^{-1} (0.72 ± 0.04 dS·m^{-1}). Agitate the probe again and re-read the standard solution. Both the first and second readings should be the same value if the probe is in good contact with the solution. Otherwise adjust it for *EC* value 0.72 mmho·cm^{-1}. For accurate measurement of soil *EC* data, Electrode was washed with pure water.

Fig. 4 showed that the values of soil *EC* measured by lab method was observed to be more as compared to the *EC* values measured by soil sensor at 0.0-0.2 m depth of soil. This may be due to the reason that salts are more likely to accumulate and remain near the soil surface up to 10 cm of depth and the salts cannot be leached from the root zone and accumulate on the surface of the soil. The change in soil *EC* was observed in top 20 cm of depth in field no 1 having cotton as harvested crop but corresponding change was in only 10 cm of depth in field no 2 having wheat as harvested crop.

Selection of fields. For conducting the experiment, two fields were selected at departmental research farm of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. Field 1 was selected after the harvesting of cotton crop and data was collected at different locations in the month of December, 2013. Field 2 was selected after the harvesting of wheat crop and data was collected at different locations in the month of May, 2014.

RESULTS AND DISCUSSION

The present study was undertaken to measure the electrical conductivity and compaction of soil by using tractor mounted soil sensor. Various results obtained from the study undertaken and their discussions are presented under this part.

Measurement of soil electrical conductivity

The trend of electrical conductivity with respect to different soil depths at different Geo-referenced locations of field 1 is represented by bar graph as shown in Fig. 5. It is observed that the average electrical conductivity measured by tractor mounted soil sensor varied from 8.5 to 9.6 mS·m^{-1} at average soil moisture content of 26% (wb) (Fig. 4). Coefficient of variance of the measured *EC* data was found to be 26.8 %. Fig. 4 shows that initially when probe of the soil sensor was inserted into the soil up to 0.2 m depth than average electrical conductivity was observed to be 8.5 mS·m^{-1} and further increased to 9.4 mS·m^{-1} at the soil depth of 0.2-0.4 mS·m^{-1}. The trend of graph was further changed as the probe inserted in to the soil at depth 0.4-0.6 m and value of electrical conductivity for that depth was decreased to 8.6 mS·m^{-1} and further increased to 9.6 mS·m^{-1} at depth more than 0.6 m. This may due to the reason that salts are more likely to accumulate and remain near the soil surface. The salts cannot be leached from the root zone and accumulated on the soil surface.

The average soil electrical conductivity of field 2 at different Geo-referenced locations measured by two methods i.e. laboratory and soil sensor is given in Table 2 and profile electrical conductivity of selected points is shown in Fig. 5. It is indicated from the table that in field 2 average electrical conductivity measured by tractor mounted soil sensor varies from 15.75 to 23.28 mS·m^{-1} and for lab measurement it varies from 17 to 23 mS·m^{-1}. For Lab measurement of soil *EC*, coefficient of variance (*CV*) was found to be 10.9% with average EC_L value of 20.62 mS·m^{-1} and for *EC* measurement with tractor mounted soil sensor; the *CV* was 12.1% with EC_S having a value of 19.11 mS·m^{-1}. The average relative error in measurement of *EC* using tractor mounted soil sensor was found to be 9.13% as compared to the lab method.

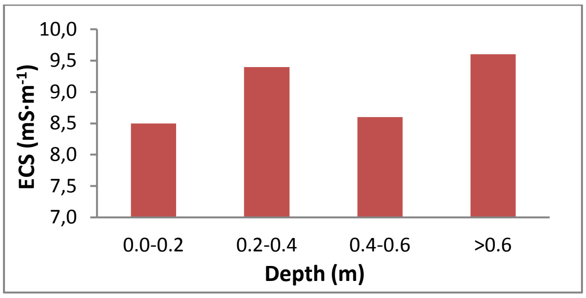

Figure 5. Electrical conductivity measured by sensor at different soil depths

Table 2. Average electrical conductivity measured by soil sensor (EC_S) and in laboratory (EC_L) of different data points with their Geo-referenced location for field 2

Data points	Geo-referenced location	EC_L (mS·m^{-1})	EC_S (mS·m^{-1})	Relative error (%)
1	75.8188N-30.90999E	19	19.1	0.5
2	75.8191N-30.91001E	18	17.38	3.4
3	75.8191N-30.90989E	21	22.83	8.7
4	75.8190N-30.90988E	19	19.54	2.8
5	75.8188N-30.90988E	23	22.9	0.4
6	75.8186N-30.90986E	21	19.4	7.6
7	75.8185N-30.90983E	22	18.5	15.9
8	75.8185N-30.90968E	23	23.28	1.2
9	75.8187N-30.90968E	17	17.67	3.9
10	75.8188N-30.90969E	21	17.53	16.5
11	75.8192N-30.90957E	18	16.49	8.3
12	75.819N-30.90956E	19	15.75	17.1
13	75.8188N-30.90955E	22	18.78	14.6
14	75.8187N-30.90953E	19	17.27	9.1
15	75.8185N-30.90952E	24	21.07	12.2
16	75.8185N-30.90937E	24	18.25	23.9
Average value of EC		20.62	19.11	-
Coefficient of variance (CV)		10.9	12.1	-
Average relative error (%) between EC_S and EC_L				9.13

It's clear from the data that at some points the *EC* values sensed by soil sensor does not correlate with the values of *EC* determined from the lab analysis of soil, but at some points correlate well with each other. The reason behind it may be that in saline soil like in field no 2, the two sets of data are typically well-correlated, but in non-saline fields there is often no statistically significant correlation. Because when a soil sample is put into solution or a saturated paste, conductance through alternating layers of soil particles and along surfaces of soil particles are virtually eliminated. But conductance through salts in solution dominates the conductivity. In non-saline fields, conductance through alternating layers of soil particles, along surfaces of soil particles and conductance through continuous soil solution contribute significantly to the overall *EC* signal. In saline fields, conductance through continuous soil solution dominates the signal response in the field.

Measurement of insertion force or soil compaction

Soil insertion force (compaction) at different soil depths of selected locations in field 1 is graphical presented in Fig. 6. It is evident from the data that at all locations when probe was inserted into the soil there was gradual increase in the insertion force or soil compaction with the depth. When probe was at 60 cm depth, the change in insertion force was increased up to 50 - 100% as compared to the insertion force at the shallow depth i.e. 20 cm. But overall insertion force data for field no 1 showed that 1953.44 kPa insertion force was observed at 20 cm depth which suddenly increase up to 2864.06 kPa at 0.2-0.4 m soil depth which was 46% more than at 0.2 m soil depth. It indicates that there is a hard pan at about 30 cm below the surface which increases insertion force up to 58.5% more as compared to the insertion force at 0.2 m depth.

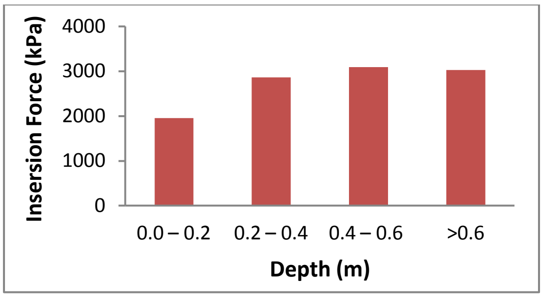

Figure 6. Insertion force (compaction) at different depths of soil in field 1

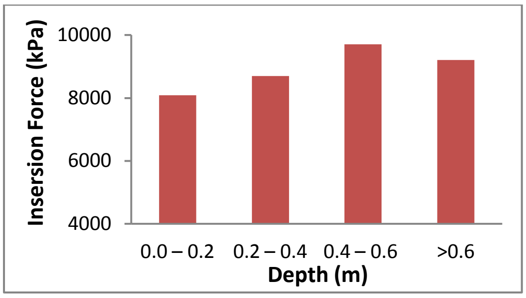

Figure 7. Insertion force (compaction) at different depths of soil in field 2

Soil insertion force (compaction) at different depths of selected location in field 2 is given in Fig. 7. It is evident from the data that at all locations when probe was inserted into the soil there was gradual increase in the insertion force or soil compaction with the depth. When probe was at 0.6 m depth, the change in insertion force was increased up to 20% as compared to the insertion force at the shallow depth i.e. 0.2 m. But overall insertion force data for field no 2 showed that 8085.71 kPa insertion force was observed up to 0.2 m depth which increased up to 9704.96 kPa at 0.6 m soil depth.

CONCLUSIONS

The following conclusions were drawn from the conducted experiments:

- In field no. 1, the average electrical conductivity measured by tractor mounted soil sensor varied from 8.5 to 9.6 mS·m^{-1} having coefficient of variance 26.8% at soil moisture content of 26% (wb).
- In field no.2, the average electrical conductivity measured by tractor mounted soil sensor varied from 15.75 to 23.28 mS·m^{-1} with CV 12.1% and average EC_S value of 19.11 mS·m^{-1}.
- For Lab measurement of soil *EC*, coefficient of variance (CV) was found to be 10.9 % with average EC_L value of 20.62 mS·m^{-1}.
- On an average, the relative error in measurement of *EC* using tractor mounted soil sensor was found to be 9.5 % as compared to the lab method.
- Overall insertion force for field no 1 was 1953.44 kPa at 0.2 m depth which suddenly increased up to 2864.06 kPa when depth was increased to 0.4 m which is 46% more than at 0.2 m depth.
- Overall insertion force for field no 2 was 8085.71 kPa observed at 0.2 m depth which increased up to 9704.96 kPa when depth was increased to 0.6 m which was 20% more as compared to insertion force at 0.2 m soil depth.
- Hard pan occurs at 0.15-0.20 m of soil depth for a wheat harvested field and for cotton harvested field it occurred at 0.3 m soil depth.

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POLJSKA OCENA TRAKTORSKOG SENZORA ZA MERENJE ELEKTRIČNE PROVODLJIVOSTI I SILE PRODIRANJA / SABIJENOSTI ZEMLJIŠTA

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Sažetak: Elektroprovodljivost i sabijenost su izdvojene kao posebno važne karakteristike zemljišta zbog svog odnosa sa drugim njegovim svojstvima, kao što su tekstura, sadržaj vode, kapacitet razmene katjona (*CEC*), uslovi drenaže, sadržaj organske materije, dubina glinovitih slojeva, salinitet i ostale karakteristike koje utiču na porast i produktivnost useva. Za merenje efekta električne provodljivosti i sabijenosti korišćen je traktorski zemljišni sensor (Make Veris Technology, USA). Senzor ima kontakte i ćeliju za merenje elektroprovodljivosti i sile prodiranja ubadanjem sonde u zemlju. Ogledi su izođeni na dve ogledne parcele Instituta za poljoprivredne i pogonske mašine. Na parceli br. 1, srednja izmerena elektroprovodljivost iznosila je od 8.5 do 9.6 $mS\cdot m^{-1}$, sa koeficijentom varijacije od 26.8%, pri vlažnosti zemljišta od 26%. Na parceli br. 2, srednja izmerena elektroprovodljivost iznosila je od 15.75 do 23.28 $mS\cdot m^{-1}$, sa koeficijentom varijacije od 12.1%. Za laboratorijska merenja elektroprovodljivosti, koeficijent varijacije iznosio je 10.9 %, sa srednjom vrednošću od 20.62 $mS\cdot m^{-1}$. Srednja sila prodiranja na parceli br. 1 bila je 1953.44 kPa na dubini od 0.2 m, a zatim je naglo porasla na 2864.06 kPa sa povećanjem dubine na 0.4 m, što je 46% više nego na 0.2 m.

Srednja sila prodiranja na parceli br. 2 bila je 8085.71 kPa na dubini od 0.2 m, a povećala se na 9704.96 kPa sa povećanjem dubine na 0.6 m što je 20% više nego na 0.2 m.

Ključne reči: *traktorski zemljišni sensor, električna provodljivost zemljišta, sila prodiranja, sabijenost zemljišta*

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PERFORMANCE EVALUATION OF CI ENGINE ON DIESEL-ETHANOL-BIODIESEL FUEL BLENDS

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Abstract: The studies were conducted to standardize the level of constituents to obtain stable diesel-ethanol-biodiesel microemulsions prepared using anhydrous ethanol (200° proof) and aqueous ethanol of 195°, 190°, 185°, 180° and 175° proof and soybean biodiesel under wide ambient temperature range. A total of twenty blends of ethanol-diesel-biodiesel were prepared and their temperature stability in the range of 0-45 ^{0}C was studied in an interval of 5^0 starting from 45^{0}C. Based on full range temperature stability, four microemulsions (v/v) 200^0[1:0.053:0.14], 200^0[1:0.0.053:0.26], 190^0[1:0.11:0.62], 180^0 [1:0.25:1.54], diesel: ethanol: biodiesel were selected to study engine performance. On the basis of experimental study it was concluded that 200^0[1:0.053:0.35] diesel: ethanol: biodiesel microemulsion replacing 28.75 % diesel can be used in CI engine without any need for engine modification.

Key words: *biodiesel, microemulsions, proof of ethanol, surfactant*

INTRODUCTION

The world is presently facing the twin crisis of fossil fuel depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based oil resources. World oil production is currently at about 4000 MMT (*million metric ton*) and is expected to reach 5200 MMT by 2030. By 2030, India will need three to four times as much as energy as we currently

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use, if our economy is to grow at 8 to 9 % a year. By 2030, we may need from 350 MMT to 500 MMT of oil a year, depending on our growth rate and the policies we follow. Our domestic production of crude is expected to be around 35 MMT. India's import of 300 MMT to 450 MMT will constitute 6 to 9 % of global production, up from less than 3 % today [1]. This necessitates developing and commercializing fossil-fuel alternatives from bio-origin. The fuels of bio-origin can provide a feasible solution to this worldwide petroleum crisis**.** Among the various alternative fuel options, ethanol has been singled out to be the most promising and prospective solution to the energy crisis of India because of large cellulosic biomass and sugarcane availability for its production.

As CI engines play an important role in developing economics which often are dependent on agriculture, ethanol diesel blends become all the more relevant [5]. The efforts made by some of the leading institutions in the country have shown that there is an advantage of using ethanol-diesel blends leading to 10 % to 15 % increase in power due to improved air utilization, efficiency and lesser pollution in certain range. 41% reduction in particulate matter and 5% NOx emission with 15% ethanol–-diesel blends are reported [6]. Net savings of 20% CO_2 emissions (46.7MMTy^{-1}CO2 equivalent) was achieved in Brazil due to ethanol and bagasse substitution from fossil fuel [7].Therefore, blending of ethanol even in small quantity could give beneficial results. The major drawback in e-diesel is that ethanol is immiscible in diesel over a wide range of temperatures. The amount of diesel replacement in the form of blend is limited with the occurrence of phase separation (immiscibility of ethanol with diesel) in the blend**.** Commercially available ethanol of 180°–160° proofs (10–20% water content) cannot be blended directly in diesel due to their distinct phase separation from diesel. The engine adjusted to ignite such fuel will produce less power, if ethanol separates from diesel [8].To overcome the problem of phase separation while preparing the blended fuel by using lower proof of ethanol or higher amount of diesel substitution, micro emulsification is the best technique, as it increases water tolerance capacity. The amount of diesel substitution can be increased to a great extent by the preparation of alcohol–diesel microemulsion using biodiesel as blending agent [9]. In view of the above scope for use of alternate fuels, a study was planned to formulate different diesel:ethanol:biodiesel microemulsions and thereafter study the performance of CI engine on stable formulated fuels.

MATERIAL AND METHODS

Micromulsified fuels. The microemulsions of different ethanol proofs with diesel were prepared at room temperature (25^{0}C) by simple splash blending using biodiesel as blending agent and then were kept at a temperature of 45, 40, 35, 30, 35, 30, 25, 20, 15, 10, 5 and 0 ^{0}C for 8 h at each temperature. The microemulsions that were found stable in the entire temperature range were selected for study of engine performance (Table 1).

Experimental Set-up. The test engine set-up used for its performance evaluation on above mentioned stable fuels consisted of the following facilities:

- A Kirloskar make, 3.73 kW, constant speed engine.
- A SAJ-Froude make, EC–15 model eddy current dynamometer with electronic controller to load the engine

- A SAJ-Froude make, SFV–75 model electronic volumetric fuel consumption measuring unit.
- A Nucon make, model 4900 hydrocarbon analyzer.
- A Nucon make, model 500, nitric oxide analyzer.

A Nucon make, model 500, nitrogen dioxide analyzer

Table 1. Microemulsified fuels selected for engine performance evaluation

Diesel: Ethanol: Biodiesel Microemulsions	*Diesel replacement (%)*
200^0 [1:0.053:0.14]	*21.81*
190^0 [1:0.110:0.62]	*42.86*
180^0 [1:0.250:1.54]	*64.21*
200^0 [1:0.053:0.35]	*28.75*
Diesel: Ethanol: Biodiesel Microemulsions	*Diesel replacement (%)*
2000 [1:0.053:0.14]	*21.81*
1900 [1:0.110:0.62]	*42.86*
1800 [1:0.250:1.54]	*64.21*
2000 [1:0.053:0.35]	*28.75*

Test engine. A Kirloskar make AV1 model, constant speed, four stroke, single cylinder, direct injection compression ignition engine was selected for the study. The engine is commonly used in agricultural operations as well as a prime mover in electric generators for domestic purposes.

Engine Performance Test. The fuel consumption test of the engine was conducted in accordance with IS: 10000 [P: 8]: 1980 [7]. The fuel consumption test was carried out on fuel types shown in Table 1. The engine was run for at least three minutes on each of the load conditions and thereafter various measurements were made at respective loads. The performance of the engine on selected stable fuels was evaluated at the following load conditions:

- No load
- 20% of the rated load
- 40% of the rated load
- 60% of the rated load
- 80% of the rated load
- 100% of the rated load
- 110% of the rated load

The following parameters were measured during the fuel consumption test**:**

- Engine speed [min^{-1}]
- Brake power [kW]
- Fuel consumption [$l \cdot h^{-1}$]
- *UBHC* emission [%]
- NO emission [ppm]
- NO_2 emission [ppm]

The brake specific fuel consumption, brake thermal efficiency, brake mean effective pressure and energy input of the engine was also calculated

The engine speed (min^{-1}) as displayed by the electronic controller unit of eddy current dynamometer was recorded during the course of experiment at different loading conditions of the engine.

The brake power developed by the engine was calculated using the following equation:

$$BP = \frac{NT}{C} \tag{1}$$

where:

BP	[kW]	- engine brake power,
T	[Nm]	- engine torque,
N	[min^{-1}]	- engine speed,
C	[-]	- dynamometer constant = 9549.305

The fuel consumption was measured with the help of a SAJ-Froude make, SFV-75 model electronic volumetric fuel consumption measuring unit. The fuel to the engine was allowed to pass through the 25 ml pipette. The time taken for the consumption of 25 ml fuel was noted by means of a timer provided with the unit. The brake specific fuel consumption was calculated by using the relationship as given below:

$$BSFC = \frac{V_{cc} \cdot \rho \cdot 3{,}6}{BP \cdot t} \tag{2}$$

where:

$BSFC$	[kg·kWh^{-1}]	- brake specific fuel consumption,
V_{cc}	[cm^3]	- volume of fuel consumed = 25,
ρ	[g·cm^{-3}]	- density of fuel,
t	[s]	- time taken to consume 25 cm^3 of fuel.

The brake thermal efficiency of the engine at different operating conditions was determined using the equation as given below:

$$\eta_t = \frac{K_s}{HV \cdot BSFC \cdot 100} \tag{3}$$

where:

η_t	[%]	- brake thermal efficiency,
K_s	[-]	- unit's constant = 3600,
HV	[kJ·kg^{-1}]	- gross heat of combustion.

The brake mean effective pressure (BMEP) of the engine at different loads was calculated using the relationship given below:

$$BMEP = \frac{2 \cdot BP \cdot k_c}{L \cdot A \cdot N \cdot n} \tag{4}$$

where:

$BMEP$	[Pa]	- brake mean effective pressure,
k_c	[-]	- constant = $60 \cdot 10^{12}$,
L	[mm]	- stroke length,
A	[mm^2]	- cross sectional area of piston,
n	[-]	- number of cylinders.

The energy input (Q) per hour to the engine at different brake load conditions was calculated using the following relation:

$$Q = CV \cdot \rho \cdot FC \tag{4}$$

where:
Q [MJ·h^{-1}] - energy input,
CV [MJ·kg^{-1}] - calorific value of fuel,
FC [l·h^{-1}] - fuel consumption.

Unburnt hydrocarbon measurement. A Nucon make, model 4900 hydrocarbon analyser was used for the measurement of unburnt hydrocarbon in the exhaust gases. The analyser has an electrochemical sensor and indicated the percent unburnt hydrocarbon in the exhaust gas. The measurements were made at different load conditions for each of the selected fuel types.

Nitric oxide measurement. A Nucon make, nitric oxide analyser, model 500-NO was used for the measurement of nitric oxide in engine exhaust gases. An exhaust gas sample drawn through an air pump operating on 230V AC was fed to the analyser for the measurement of nitric oxide content in exhaust gases.

Nitrogen dioxide measurement. The nitrogen dioxide content in engine exhaust gases emanating from burning of different fuel sample was measured with the help of a Nucon make, series 500 analyser.

RESULTS AND DISCUSSION

All the selected microemusions were studied for engine performance with diesel as baseline fuel to compare the results. The main results obtained are mentioned below.

Engine Parameters

Brake mean effective pressure of the engine at no load, 20, 40, 60, 80, 100 and 110% brake load on selected fuel types is shown in Tab. 2**.** It is observed from the data that there is a linear relation between brake mean effective pressure and brake load on various fuel types

Brake power developed by the engine on selected fuel types at no load, 20, 40, 60, 80, 100 and 110% brake loads i.e. at corresponding brake mean effective pressures and at corresponding engine speeds is shown in Tab. 2**.**

Table 2. Brake mean effective pressures of selected fuel types at different load conditions

Brake load (%)	Brake mean effective pressure (bar)	diesel: ethanol: biodiesel microemulsions							
		200^0[1:0.053:0.14]		190^0[1:0.11:0.62]		180^0[1:0.25:1.54]		200^0[1:0.053:0.35]	
		Engine speed (min^{-1})	Brake power (kW)	Engine speed (min^{-1})	Brake power (kW)	Engine speed (min^{-1})	Brake power (kW)	Engine speed (min^{-1})	Brake power (kW)
No L	-	1566	0.00	1530	0.00	1544	0.00	1571	0.00
20	1.1	1530	0.77	1505	0.76	1522	0.77	1545	0.78
40	2.2	1527	1.52	1496	1.49	1507	1.50	1530	1.52
60	3.25	1521	2.28	1488	2.23	1495	2.24	1521	2.28
80	4.3	1519	3.02	1481	2.95	1487	2.96	1517	3.02
100	5.4	1507	3.74	1478	3.67	1480	3.67	1512	3.75
110	5.9	1477	4.04	1460	3.99	1458	3.98	1475	4.03

It is evident from the table that engine developed marginally less brake power on the microemulsions compared to diesel at lighter load conditions. For the higher load conditions i.e. at 100 and 110% load, the brake power on microemulsions was marginally higher than the diesel. This result is consistent with the finding of Meiring *et,al.* [8] which states that the power reduction in lighter load region occurs due to reduced heat content of microemulsions and increase in ignition delay with alcohol when light loads are encountered.

Based on results on brake power developed by the engine on diesel and different microemulsions, it can be said that the microemulsions tested had similar power producing capabilities as diesel, though the amount of diesel replacement by microemulsions varied from 21.81 to 64.21%.

Fuel consumption. Tab. 3a shows the observed fuel consumption ($l \cdot h^{-1}$) of the engine at different brake meaneffective pressures (brake loads) on diesel and four selected microemulsified fuels. The relationship between the fuel consumption of the engine and brake mean effective pressure on different fuel types is presented in Fig. 1. It is evident from the figure that the fuel consumption of the engine gradually increased with increase in brake load and was found maximum at 110% brake load on all fuel types.

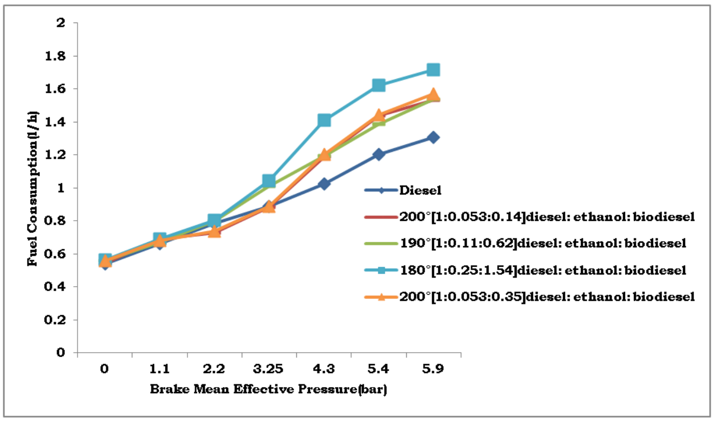

Figure 1. Fuel consumption at different brake mean effective pressures on selected fuel types

It is also evident from the figure that the fuel consumption of the engine on diesel was lowest at all the brake mean effective pressure conditions compared to the four microemulsions tested. This may be due to reason that the calorific values of tested microemulsions were 4 to 12% less than that of diesel.

Brake specific fuel consumption of the engine on diesel at rated load (engine developing *BMEP* of 5.4 bar was found 0.270 $kg \cdot kWh^{-1}$. Brake specific fuel consumption increased with the increased ethanol substitution and same has been reported by *Chaplin and Janius* [9].

The data from Tab. 3b also shows that the drop in the brake specific fuel consumption of the engine was at a higher rate upto 80% brake load (i.e. up to *BMEP* of 4.3 bar). Less change in the *BSFC* of the engine was observed between 80% and 110% brake loads. This is due to the reason that increase in brake power of the engine from

80% to 110% brake load was less as compared to increase in brake power between no load and 80% brake load. It is also evident from the figure that the *BSFC* of the engine at higher brake mean effective pressures was comparably higher on 180^0[1:0.25:1.54] diesel: ethanol: biodiesel compared to other microemulsion fuels.

Table 3. Engine performance paramaters on diesel and selected fuel types

Brake Load(%)	*No Load*	*20*	*40*	*60*	*80*	*100*	*110*
BMEP (bar)	*-*	*1.1*	*2.2*	*3.25*	*4.3*	*5.4*	*5.9*
a) Fuel consumption ($l \cdot h^{-1}$)							
Diesel	*0.541*	*0.662*	*0.783*	*0.887*	*1.026*	*1.205*	*1.309*
*200^0[1:0.053:0.14] **	*0.547*	*0.693*	*0.729*	*0.885*	*1.191*	*1.439*	*1.533*
*190^0[1:0.11:0.62] **	*0.561*	*0.67*	*0.801*	*1.012*	*1.193*	*1.39*	*1.54*
*180^0[1:0.25:1.54] **	*0.563*	*0.692*	*0.804*	*1.045*	*1.41*	*1.622*	*1.715*
*200^0[1:0.053:0.35] **	*0.560*	*0.680*	*0.739*	*0.888*	*1.202*	*1.442*	*1.571*
b) Brake specific fuel consumption ($kg \cdot kWh^{-1}$)							
Diesel	*-*	*0.705*	*0.428*	*0.324*	*0.285*	*0.27*	*0.272*
*200^0[1:0.053:0.14] **	*-*	*0.751*	*0.4*	*0.324*	*0.329*	*0.321*	*0.317*
*190^0[1:0.11:0.62] **	*-*	*0.742*	*0.452*	*0.382*	*0.34*	*0.319*	*0.325*
*180^0[1:0.25:1.54] **	*-*	*0.764*	*0.456*	*0.397*	*0.405*	*0.376*	*0.366*
*200^0[1:0.053:0.35] **	*-*	*0.732*	*0.408*	*0.327*	*0.334*	*0.323*	*0.327*
c) Brake thermal efficiency (%)							
Diesel	*-*	*10.21*	*16.83*	*22.18*	*25.26*	*26.69*	*26.49*
*2000[1:0.053:0.14] **	*-*	*10.13*	*19.01*	*23.49*	*23.61*	*23.7*	*23.63*
*1900[1:0.11:0.62] **	*-*	*10.29*	*16.87*	*19.98*	*22.42*	*23.94*	*23.5*
*180^0[1:0.25:1.54] **	*-*	*10.11*	*16.95*	*19.47*	*19.52*	*20.55*	*20.08*
*200^0[1:0.053:0.35] **	*-*	*10.22*	*18.33*	*22.88*	*22.94*	*23.17*	*22.86*
d) Energy input ($MJ \cdot h^{-1}$)							
Diesel	*22.47*	*27.50*	*32.52*	*36.84*	*42.61*	*50.05*	*54.37*
*200^0[1:0.053:0.14] **	*21.6*	*27.36*	*28.78*	*34.94*	*47.02*	*56.82*	*60.53*
*190^0[1:0.11:0.62] **	*22.27*	*26.6*	*31.8*	*40.17*	*47.36*	*55.18*	*61.14*
*180^0[1:0.25:1.54] **	*22.32*	*27.43*	*31.87*	*41.42*	*55.89*	*64.29*	*67.98*
*200^0[1:0.053:0.35] **	*22.62*	*27.47*	*29.86*	*35.88*	*48.56*	*58.26*	*63.47*

** diesel : ethanol : biodiesel (V/V) microemulsions;*
ppm=parts per million;
BMEP= brake mean effective pressure

Brake thermal efficiency. It was observed that on an average, brake thermal efficiency on aqueous microemulsions was higher than that on diesel. This may be because of high heat of vaporization of alcohol which results into excessive cylinder cooling and therefore increased brake thermal efficiency at high loads.

Fuel energy input to the engine increased with increase in brake mean effective pressure and was observed highest at 110% brake load (i.e. *BMEP* of 5.9 bar) on all fuel types tested. The result of input fuel energy present in Tab. 3d shows that the maximum energy input at rated load was 64.29 $MJ \cdot h^{-1}$ on 1800[1:0.25:1.54] diesel : ethanol : biodiesel microemulsion. This may be because of high fuel consumption of this microemulsified fuel.

Exhaust emissions of the engine

Unburnt hydrocarbons. It is observed from the Tab. 4a that at lower brake mean effective pressures the microemulsions showed much higher *UBHC* emission as compared to that of diesel. The result is in accordance with the previous study [10] which reported increased *HC* emission for ethanol-diesel emulsions at part loads..The higher level ethanol blends generate greater *UBHC* emissions, and those with higher biodiesel level generate less *UBHC*. Due to its reduced cetane number ethanol will ignite later and will not burn completely, increasing in this way the unburned *HC* level from the exhaust gases [11]. It was also observed that the emission of *UBHC* was less on aqueous microemulsions as compared to anhydrous microemulsion at higher loads. The water content in aqueous microemulsions is responsible for reduced *UBHC* emission [12].

Table 4. Exhaust emissions of the engine on diesel and selected fuel types

Brake Load(%)	No Load	20	40	60	80	100	110
BMEP(bar)	-	1.1	2.2	3.25	4.3	5.4	5.9
a) Unburnt Hydrocarbons (%)							
Diesel	0.04	0.03	0.03	0.01	0.04	0.12	0.21
200^0[1:0.053:0.14]	0.04	0.03	0.07	0.11	0.13	0.12	0.16
190^0[1:0.11:0.62]	0.06	0.06	0.1	0.09	0.08	0.11	0.2
180^0[1:0.25:1.54]	0.03	0.07	0.07	0.04	0.08	0.09	0.17
200^0[1:0.053:0.35]	0.04	0.02	0.05	0.07	0.11	0.12	0.2
b) NO_2(ppm)							
Diesel	23.4	47.8	86.8	92.4	61.3	53	40.2
200^0[1:0.053:0.14]	25.2	49.3	86.8	92.4	67.3	67.2	50.1
190^0[1:0.11:0.62]	22.2	44.2	90.6	115.3	115.01	84.3	77.2
180^0[1:0.25:1.54]	42.6	61.3	125.4	190.6	188.3	100.2	74.3
200^0[1:0.053:0.35]	19.2	32.2	77.6	105.3	102.46	99.3	99
c) NO (ppm)							
Diesel	70.7	132.3	216.8	307.3	170	154.2	160
200^0[1:0.053:0.14]	112.3	146.8	297.3	424.5	194.2	200.5	330.4
190^0[1:0.11:0.62]	90.2	210.3	330.4	520.6	627.3	260.2	360.3
180^0[1:0.25:1.54]	100.36	300	410.2	400.2	460.12	690.3	580
200^0[1:0.053:0.35]	70.2	140.3	247.4	497.3	204	190	238.33

Nitrogen dioxide. It is evident from the data presented in Tab. 4b that NO_2 emission from the engine on all microemulsions was found lower than diesel fuel under no load to 60% load (i.e. upto 3.2 bar *BMEP*). NO_2 emission increased sharply beyond 60% load for all microemulsions. NO_2 emission was found more for diesel : ethanol : biodiesel emulsions as compared to diesel. This may be probably because of the higher oxygen content and better combustion of biodiesel fuels, and as a consequence, the combustion temperature increases, as reported by researchers[13] [14].

Nitric oxide. The emission of NO from the engine on diesel varied in the range 70.7 to 407.3 ppm at various brake mean effective pressures while for all microemulified fuels it was found higher than diesel. Presence of oxygen molecule in ethanol causes an increase in combustion temperature thereby resulting in increased NO_x emissions [15] [16]. It was also observed that microemulsions having lower proof of ethanol produced less NO emissions. This is because of the reason that water decreases the flame temperature and, consequently, decreases the formation of thermal NOx**.**

CONCLUSIONS

- From the experimental findings it can be concluded that microemuslions tested had similar power producing capabilities as diesel, though the amount of diesel replacement by microemulsions varied from 5.94 to 64.21%.
- Based upon the engine performance test results it is imperative that 200^0[1:0.053:0.35] diesel : ethanol : biodiesel microemulsion replacing 28.75 % diesel may be recommended for use in CI engine without any engine modification.

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OCENA PERFORMANSI DIZEL MOTORA PRI UPOTREBI DIZEL-ETANOL-BIODIZEL MEŠAVINE GORIVA

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Sažetak: Istraživanja su sprovedena da bi se standardizovao nivo sastojaka u cilju dobijanja stabilnih mikroemulzija dizel-etanol-biodizel, pripremljenih upotrebom dehidriranog etanola (čistoća 200°) i hidriranog etanola čistoće 195°, 190°, 185°, 180° i 175° i biodizela od soje pri širokom opsegu ambijentalnih temperatura. Ukupno dvadeset mešavina dizel-etanol-biodizel je pripremljeno i ispitivana je njihova temperaturska stabilnost u opsegu od 0-45°C, u intervalima od po 5°, počevši od 45°C. Na osnovu punog opsega temperaturske stabilnosti izabrane su četiri mikroemulzije dizel-etanol-biodizel (v/v): 200^0[1:0.053:0.14], 200^0[1:0.0.053:0.26], 190^0[1:0.11:0.62], 180^0 [1:0.25:1.54], za ispitivanje performansi motora. Na osnovu eksperimentalnog ispitivanja zaključeno je da se mikroemulzija dizel-etanol-biodizel 200^0[1:0.053:0.35] može upotrebiti kao zamena za 28.75% dizel goriva u dizel motoru bez ikakvih modifikacija na motoru.

Ključne reči: *biodizel, mikroemulzije, čistoća etanola, surfaktant*

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ESTIMATION OF BEST COMBINATION OF LOW COST LINING MATERIALS TO REDUCE SEEPAGE LOSSES FROM RESERVOIR

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***Abstract**:* Makhamalabad farm, one of the farm of K. K. Wagh College of Agricultural Engineering and Technology, Nashik, was facing a problem of seepage loss from reservoirs having high infiltration rate of 317 $mm \cdot day^{-1}$ and thus the reservoir was unable to store the water for long period. Therefore, the present research work was undertaken with the objective to make the soil strata impervious to avoid seepage losses from the reservoir. A laboratory model was made, for measuring infiltration rate of low cost lining materials. Infiltration rate of individual lining materials like black soil, river soil, cow dung and gypsum were first determined and then the infiltration rate of combination of lining materials in various sequence of lining materials was determined. Among the individual lining materials, gypsum had lowest infiltration rate of 5.12 $mm \cdot day^{-1}$ than other lining materials. Therefore gypsum has proved to be the best material for lining, in case of individual material with a cost of *Rs* 7.50 per m^2. It was also observed that, the infiltration rate from combination of lining materials with the sequence of gypsum placed at bottom layer, then followed by river soil, black soil and cow dung gave the lowest infiltration rate of 1.14 $mm \cdot day^{-1}$ as compared to other sequence of combination of lining materials. The cost of this combination of lining materials was *Rs* 27 per m^2 area which is lower as compared to per m^2 cost of *PE* film i.e. *Rs* 30.00 used for lining pond or reservoir.

Key words: *seepage loss, reservoir, infiltration rate, gypsum, lining materials, PE film*

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INTRODUCTION

Rain water is the cheapest and purest source of water. Harvesting of the water in pond, lakes, wells, tanks and reservoirs helps to preserve this water so that it can be put to varied uses later on. One of the most effective ways of water management is through Pond/Canal lining.

Pond sealing or lining is the process of installing a fixed lining of impervious material or mechanically treating the soil in a pond to impede or prevent water loss. Vast amounts of water are lost through seepage, especially where the soil is gravelly and porous [1].

It is estimated that 70% of water is lost between the storage and usage point. Many states have been experiencing drought resulting in shortage of water, particularly during the summer months. Lining of canals reduces seepage losses. The conventional methods for farm pond and canal lining are use of cast-in-situ concrete, bricks, stone-slabs, precast tiles, precast concrete slabs etc.

Ponds can serve as storm water management detention facilities, add visual aesthetics and create an environment for wildlife. These reservoirs and ponds are located in a variety of soil types which exhibit a wide range of seepage characteristics. Because of seepage, the water level of the reservoirs and tanks depletes rapidly, seepage losses not only means loss of useful water but also lead to other problems such as breach in the embankment, water logging and increased salinity in adjacent areas. With appropriate lining of reservoirs, ponds, canals the seepage loss can be minimized.

By lining the canal, the velocity of the flow can be increased because of the smooth canal surface. For example, with the same canal bed slope and with the same canal size, the flow velocity in a lined canal can be 1.5 to 2 times that in an unlined canal, which means that the canal cross section in the lined canal can be smaller to deliver the same discharge. Before the decision is made to line a canal, the costs and benefits of lining have to be compared. By lining the canal, the velocity of the flow can increased because of the smooth canal surface.

Makhamalabad Farm of K. K. Wagh College of Agricultural Engineering and Technology, Nashik was facing a problem of seepage loss through existing reservoirs, therefore it was unable to store water in those reservoirs even during rainy season and it was waste of money in constructing those reservoirs. Therefore, the research work was conducted, to solve the seepage loss problem by testing the infiltration rate of different materials (river soil, black soil, gypsum and cow dung etc.), selecting the best combination of different materials to reduce the seepage loss & then compare the cost of selected lining materials with *PE* film.

MATERIAL AND METHODS

The present investigation was carried out in October 2013 in Irrigation and Drainage Engineering Laboratory, K. K. Wagh College of Agricultural Engineering and Technology, Nashik. A laboratory model for measuring infiltration rate was made to estimate the best combination of low cost lining materials, used to reduce seepage of water from reservoir/pond. Initially, soil sample from one of reservoir of Makhamalabad farm was collected and then the chemical properties such as pH, *EC*, sodium content and texture of the soil were determined. Then by using laboratory model, infiltration rate of individual and combination of different lining material was determined. Following materials were used for making a model:

1. Hollow cylindrical bisleri tank (17.48 litre capacity)
2. Stand
3. Sieve
4. Polythene bag
5. Measuring cylinder

Construction of Laboratory model

Initially, the stand (cast iron) for supporting bisleri tank was made. Then Bisleri tank was cut from the top and bottom, to make the hollow cylindrical tank. The circular ring made of cast iron was covered with sieve of mesh size (2 mm) and was kept on stand to give support to hollow cylindrical tank. At the bottom of the stand, plastic bag was attached to collect the outflow of water from hollow cylindrical tank. The Laboratory model consisted of three sections viz top section, middle section and bottom section, in which top section contains water, middle section consists of lining materials and bottom section will collect the outflow of water [4].

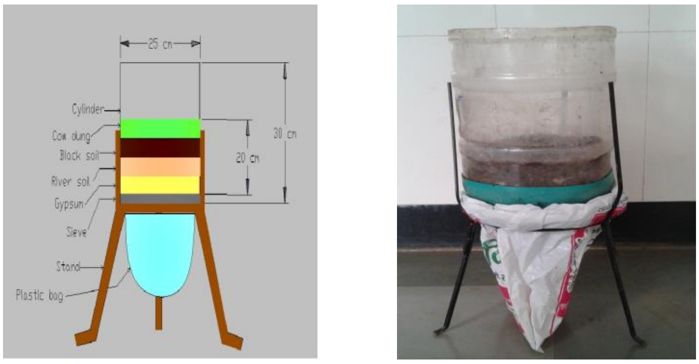

Figure1. Laboratory model for measuring infiltration rate

After making the laboratory model, the lining materials were filled in the cylinder in layers, each having thickness of 5 cm. Then water was spread on lining materials and compaction of lining material was done [5]. The measured quantity of water was added into top section of model and then the water was allowed to pass through different lining materials until water has stopped infiltrating into the bottom section. Plastic bag was attached to the base of the middle section to collect infiltrated water. The water collected in bottom section was measured with the help of measuring cylinder, which is nothing but outflow of water infiltrated from lining material.

The low cost easily available materials were used for lining such as river soil, black soil, gypsum and cow dung etc. River soil and black soil contains high amount of clay, so they have low permeability at optimum moisture content [2] and hence river and black soil were selected as the lining materials. The addition of organic material such as livestock manure [5] can reduce seepage also the organic material cause anaerobic condition resulting in slime growth which plugs passages and its heavy application is required to effectively reduce seepage [3], therefore cow dung was used as one of the lining material.

Table1. Specification of Laboratory Model

Particulars	*Specification*
Inner diameter of cylinder	*25 cm*
Height of cylinder	*30 cm*
Thickness of cylinder	*2.1 Mm*

Initially, infiltration rate of individual material was measured and in similar manner lining materials in different sequences were combined and their infiltration rates were determined. Also then texture, *EC*, pH and sodium content of river & black soil were determined using standard procedures.

RESULTS AND DISCUSSION

The texture of soil sample (field soil) from the reservoir of Makhamalabad farm was determined and it was found that the field soil content 62.8% gravel, 34.25% coarse sand, 2.07% fine sand and 0.87% clay, which meant that the field soil was very porous in nature resulting in heavy loss of water due infiltration & seepage from the sides & bed of reservoir.

Then the chemical properties of lining materials were determined as shown in Tab. 1 and it was found that the field soil was acidic in nature, river soil was normal to saline in nature and black soil was acidic in nature. The sodium content in black soil was more (374.5 ppm) than river soil (335.1) and field soil (129.59 ppm) *EC* of all three soils was normal, indicating that salinity affects are negligible.

Table 2.Chemical properties of lining material

Soil type	*pH*	*EC (mhos·cm^{-1})*	*Sodium (ppm)*
Field soil	*5*	*0.4*	*129.59*
River soil	*6.13*	*0.39*	*335.1*
Black soil	*5.74*	*0..50*	*374.5*

The infiltration rate of individual lining material was determined as shown in Tab. 2. It was observed from Tab. 2. and Fig. 2. that field soil had very high infiltration rate (317.05 mm·day^{-1}) than river soil (22.10 mm·day^{-1}), cow dung (20.51 mm·day^{-1}), black soil (12.69 mm·day^{-1}) and gypsum (5.12 mm·day^{-1}). Also it was found that gypsum had very low infiltration rate of 5.12 mm·day^{-1}.

Then the infiltration rates of combination of lining materials in different sequences were determined and the best combination of lining material was found as shown in Tab. 3. in which the infiltration rate was minimum (1.14 mm·day^{-1}).

In this best combination of lining material cow dung was placed in first layer, followed by black, river soil and gypsum.

Table 3. Infiltration rate of individual lining material

Materials	*Thickness (cm)*	*Inflow (ml)*	*Outflow (ml)*	*Time (h)*	*Infiltration rate (mm·day^{-1})*
Field soil	*5*	*1000*	*980*	*2*	*317.05*
Black soil	*5*	*1000*	*990*	*48*	*12.69*
River soil	*5*	*1000*	*970*	*27*	*22.10*
Cow dung	*5*	*1000*	*800*	*24*	*20.51*
Gypsum	*5*	*1000*	*200*	*24*	*5.12*

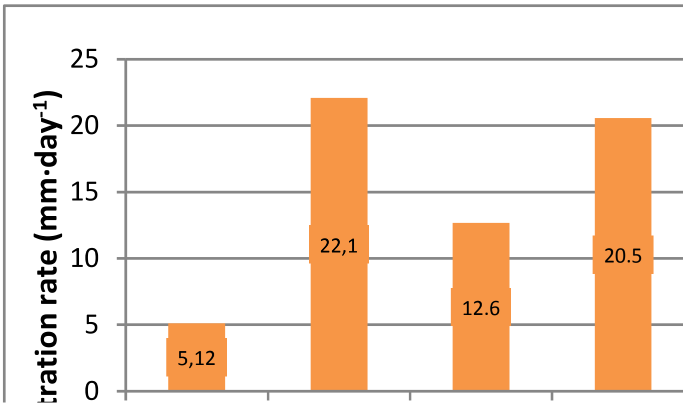

Figure 2. Infiltration rates of individual lining

Table 4. Best combination of lining material

Sr. No.	*Combination*	*Thickness (cm)*	*Inflow (ml)*	*Outflow (ml)*	*Time (h)*	*Infiltration rate (mm·day^{-1})*
1.	*Cow dung*	*20*	*1000*	*180*	*24*	*1.14*
2.	*Black soil*					
3.	*River soil*					
4.	*Gypsum*					

CONCLUSIONS

Sodium content in soil affects the infiltration rate, infiltration rate decreases with increase in sodium content of soil. Therefore, the infiltration rate of black soil (12.69 mm·day^{-1}) was low as compared to the river soil (22.10 mm·day^{-1}) and field soil (317 mm·day^{-1}).

From the present investigation, it was concluded that gypsum had lowest infiltration rate (5.12 mm·day^{-1}) as compared to other materials used for lining. Therefore gypsum has proved to be the best material for lining, in case of individual material with a cost of *Rs* 7.50 per m^2.

The best combination of lining material was cow dung used as in first layer, followed by black soil, river soil and gypsum. The cost of this combination was *Rs* 27.00 per m^2, which was lower than the cost of *PE* film i.e. *Rs* 30.00 per m^2.

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OCENA NAJBOLJE KOMBINACIJE JEVTINIH MATERIJALA OBLOGA ZA SMANJENJE GUBITAKA CURENJEM IZ REZERVOARA

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Sažetak: Farma Makhamalabad ima problem gubitaka zbog curenja rezervoara sa visokim stepenom infiltracije od 317 $mm \cdot dan^{-1}$, tako da rezervoar nije u stanju da skladišti vodu na duži period. Zato je izvedeno istraživanje sa ciljem postizanja nepropusnosti zemljišta radi izbegavanja gubitaka curenjem iz rezervoara. Napravljen je laboratorijski model za merenje infiltracije jevtinih materijala za obloge: crnica, rečni supstrat, goveđa balega i gips. Među njima, gips je imao najmanji stepen infiltracije od 5.12 $mm \cdot dan^{-1}$ i ocenjen je kao najbolji materijal za oblogu, sa cenom od *Rs* 7.50$\cdot m^{-2}$. Takođe je utvrđeno da je infiltracija kombinovane obloge od gipsa u donjem sloju, na koji su dodati slojevi od ostalih materijala bila najmanja i iznosila 1.14 $mm \cdot dan^{-1}$ u poređenju sa ostalim kombinacijama. Cena ove kombinovane obloge bila je *Rs* 27$\cdot m^{-2}$, što je jevtinije od *PE* filma (*Rs* 30.00$\cdot m^{-2}$) koji je korišćen za oblaganje lagune ili rezervoara.

Ključne reči: *curenje, rezervoar, infiltracija, gips, materijali obloga, PE film*

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POTENCIJAL ŽETVENIH OSTATAKA ULJANE REPICE U SRBIJI

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Sažetak: Slama uljane repice potencijalni je izvor obnovljive energije, ali i značajan izvor organske mase u zemljištu. Količina žetvenih ostataka, slame, koja je na raspolaganju, po hektaru, nije dovoljno poznata. Prekomerno skidanje žetvenih ostataka može da izazove negativne posledice u pogledu plodnosti zemljišta, uklanjanje nutrijenata, organskog ugljenika u zemljištu i erozije vetra. Cilj istraživanja bio je da se utvrdi ukupna količina žetvenih ostataka uljane repice, količine, koje mogu da se uberu i količine nadzemnih žetvenih ostataka, kao podloge za donošenje mera za očuvanje plodnosti zemljišta. Prikupljeni su uzorci nadzemne mase osam reprezentativnih sorti sa tri lokacije, 2013. godine (koja je bila sa umerenom sušom) i šest sorti sa jedne lokacije 2014. godine (u toku koje je bila umerena do ekstremna vlažnost). Uzorci biljaka su podeljeni na delove: zrno, stabljika i mahune. Utvrđen je žetveni indeks, prinos i relativni prinos žetvenih ostataka. Stabljike su podeljene u sekcije po visini, izmerene mase i kreiran dijagram kumulativne mase po visini. Za uobičajeni postupak ubiranja slame, presovanjem, ocenjena je količina žetvenih ostataka, koja može da se ubere za dve odabrane visine rezanja. Prosečan žetveni indeks u sezoni 2013. bio je 0,34, dok je u 2014. bio niži i iznosio je 0,29. Procenat žetvenih ostataka, koji može da se ubere bio je između 35 i 51 % od ukupne biljne mase nadzemnih žetvenih ostataka. Tehnički prinos pri lošim klimatskim uslovima bio je za oko 46 % niži, što bi trebalo da se uzme u obzir u slučaju planiranja raspoložive količine. Procenjeno je da bi energetski potencijal, uzimajući u obzir i očuvanje plodnosti zemljišta, uljane repice mogao da bude 1,1 do 2,0 Mg ha^{-1}. Nadzemna masa žetvenih ostataka može, uz primenu obrade zemljišta bez

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Razvoj novih sorti i poboljšanje tehnologija proizvodnje uljanih biljnih vrsta za različite namenem (TR 31025), Ministarstvo prosvete, nauke i tehnološkog razvoja

prevrtanja, da osigura zaštitu zemljišta od erozije vetra i doprinese očuvanju plodnosti zemljišta, organske mase i organskog ugljenika. Žetveni ostaci uljane repice mogu da budu dobra podloga za sprovođenje upravljanja organskom materijom, primenom odgovarajućeg plodoreda, te da se koriste za kompenzovanje organske materije koja se iznosi ubiranjem žetvenih ostataka drugih biljnih vrsta, na primer, pšenice, soje i kukuruza. Buduća istraživanja trebalo bi da budu usmerena ka oceni primenljivosti žetvenih ostataka repice za očuvanje plodnosti zemljišta.

Ključne reči: *uljana repica, žetveni ostaci, energija, zemljište*

UVOD

Uljana repica (*Brassica napus* L.) je treća u svetu po značaju, kao industrijska – uljana biljna vrsta. Pre svega, ubraja se u veoma važnu vrstu energetskog bilja, jer njeni delovi – seme – stabljika i ostali nusproizvodi semena, kao što je esterifikovano ulje, hladno ceđeno ulje, pogača, mogu da se koriste kao obnovljivi izvor energije. Takođe, ulje repice može da se koristi kao sirovina za motorna ulja, ulja za transmisije i hidraulične sisteme i antikorozivnih maziva sa povoljnijim osobinama od onih mineralnog porekla [10].

Najvažniji deo biljke je seme, koje sadrži 40-48 % ulja i 18-25 % proteina. Pored korišćenja kao jestivog ulja, u poslednje dve decenije najviše se koristi za proizvodnju biodizela. Prema [11], uljana repica učestvuje sa čak 84 % u sirovinskoj bazi ukupne svetske proizvodnji biodizela, za razliku od suncokretovog, odnosno sojinog ulja, koji učestvuju sa 13 %, odnosno 1 %, respektivno. Navodi se da je potrebno da se posveti veća pažnja širenju ove biljne vrste, pri čemu su najveće rezerve za povećanje površina u centralnoj Srbiji, na nivou od oko 150.000 ha.

U svetu je, u sezoni 2013/2014, s uljanom repicom različitih sorti (ozima, proletnja, gorušica i neke međuforme), bilo zasejano oko 35 miliona hektara [2], pri čemu je, prema [14], ubrano oko 72,5 miliona Mg semena sa prosečnim prinosom 2 Mg ha^{-1}. U Srbiji je 2012. godine, s oko 2,6 miliona hektara pod ratarskim usevima, prema [15], s uljanom repicom zasejano svega oko 8.250 ha (0,3 %) i požnjeveno oko 20.000 Mg semena, sa prosečnim prinosom 2,78 Mg ha^{-1}, značajno manje nego prethodne godina (15.350 ha, 44.500 Mg i 2,9 Mg ha^{-1}, respektivno). U istom periodu je, na primer, u Češkoj Republici prema [16], koja ima približno istu površinu pod ratarskim usevima kao Srbija, oko 2,5 miliona hektara, s uljanom repicom je bilo zasejano oko 400.000 ha (16 %), a u Slovačkoj Republici, sa oko 1,4 miliona hektara, zasejano je oko145.000 ha (10 %), [18]. Takođe, u Nemačkoj, vodećoj članici EU u pogledu proizvodnje biodizela, na oko 10,7 miliona ha pod ratarskim usevima bilo zasejano oko 1,4 miliona ha uljane repice (13 %), [17]. Razlog zašto se uljana repica u sveta gaji značajno više nego kod nas je zbog korišćenja njenog semena za, pre svega, proizvodnju biodizela, a i za druge potrebe u poljoprivredi i industriji, što je već navedeno na početku ovog rada, a što ukazuje na opravdanost politike favorizovanja njenog gajenja.

Žetveni ostaci sastoje se od korenovog sistema, stabljika sa grančicama i ostacima mahuna (slama). Oni se u Srbiji, po pravilu, nakon žetve semena, usitnjeni inkorporiraju u zemljište. U Nemačkoj, na primer, prema [8], za prosečan prinos zrna oko 3,5 Mg ha^{-1} na poljima, posle ubiranja zrna, ostaje oko 10 Mg ha^{-1} nadzemnih žetvenih ostataka u formi slame, odnosno, ako se uzme u obzir ukupna zasejana površina, oko 14 miliona Mg biomase. Od toga, velika količina usitnjene slame, oko 50 %, ostavlja se na poljima kao supstrat za formiranje humusa. Preostalih 50 %, oko 7 miliona Mg, se ubere i odnosi sa njiva kako bi se upotrebilo, na primer, kao prostirka na farmama, za proizvodnju izolacionog materila, pa i kao gorivo.

Obnovljivi izvori energije sve više dobijaju na značaju, pa se u tom smislu razmatra i mogućnost većeg korišćena žetvenih ostatak uljane repice. Prema [8] donja toplotna moć suve mase slame je 17,1 MJ kg^{-1}, što je na nivou žetvenih ostataka većine ratarskih biljnih vrsta. Najčešće se razmatra korišćenje slame za sagorevanje, ali se čine pokušaji i drugačijeg energetskog korišćenja, na primer, za proizvodnju lignoceluloznog bioetanola [3], mada takav postupak nije dostigao komercijalnu zrelost.

U Srbiji, uglavnom, ne postoji praksa ubiranja slame uljane repice i njenog korišćenja, posebno kao obnovljivog izvora energije. Jedan od razloga je sigurno to što danas preovlađuje gajenje sa manjim brojem biljaka, koje su više, sa debljim stabljikama. Pored toga, u našim klimatskim uslovima stabljika se često lomi, te je manje pogodne za presovanje.

Uklanjanje biljnih ostataka uljane repice sa njive može da ima negativne efekte, jer biljni ostaci sadrže makro i mikro hraniva i izvor su organske materije i organskog uljenika [12]. Oni doprinose poboljšanju strukture i plodnosti zemljišta, smanjenju vodene i vetro erozije i zato njihovo uklanjanje treba da se sprovodi na održiv način. Prema [7], uklanjanje biljnih ostataka posle žetve tokom vremena u zemljištu dovodi do smanjenja količine azota za oko 3 kg ha^{-1} god^{-1} i organskog ugljenika za oko 40–90 kg ha^{-1} god^{-1} po Mg ubranih biljnih ostataka, a Sekulić i dr. [13] su ukazali, na osnovu analize sadržaja organske materije, tj. bilansa organskog ugljenika (*SOC*), žetveni ostaci mogu da se uklanjaju samo na zemljištima na kojima nema deficita humusa. Sa druge strane, Allmaras et al. [1] smatraju da odnošenje nadzemnih delova biljnih ostataka ne utiče značajno na smanjenje sadržaja organskog ugljenika u zemljištu, jer se najveći deo, do 80 %, nalazi u korenu i rizosferi. Blum et al. [4], takođe su proučavali primenu biljaka kao izvora energije i uticaj na plodnost zemljišta. Prema navodima, žetveni ostaci uljane repice ubrajaju se u najizdašnije u pogledu količine organske materije, te bi gajenjem repice u plodoredu omogućilo kompenzaciju za odnošenje žetvenih ostataka drugih biljnih vrsta.

Da bi se obezbedila efikasna zaštita od klimatskih uticaja, vetra, vode, zemljište treba da ima 30 % do 50 % svoje površine pokriveno biljnim ostacima, poželjno učvršćenih za zemlju [9]. ASAE EP291.3 definiše minimalnu količinu biljnih ostataka useva, koji obezbeđuju zaštitu zemljišta od vetro erozije [19]. Ona je ekvivalentna vrednosti 1.100 kg ha^{-1} SGe (small grain equivalent), pri čemu su Hickman and Schoenberger [5] ustanovili dijagrame, koji omogućavaju određivanje specifične vrednosti za žetvene ostatke pšenice, kukuruza, soje i suncokreta.

Cilj istraživanja bio je da se utvrdi ukupni prinos nadzemnih žetvenih ostataka uljane repice, a zatim i da se oceni količina žetvenih ostataka koja može da se ubere, kao i količina koja ostaje na njivi. Na osnovu tih podataka moguće je da se proceni potencijal biomase, kao i da se daju podloge za definisanje održivog korišćenja žetvenih ostataka uljane repice.

MATERIJAL I METODE RADA

U radu je korišćena sledeća terminologija:

1. Teoretski potencijal – ukupna nadzemna masa žetvenih ostataka; utvrđen merenjem.
2. Tehnički potencijal – količina žetvenih ostataka koja može da se ubere; ocenjen na bazi postupka ubiranja, i uz razmatranje, pre svega očekivanih gubitaka.
3. Održivi potencijal – količina žetvenih ostataka koja može da se ubere, a da se ne ugrozi plodnost zemljišta; u radu dati podaci za ocenu ovog potencijala.

4. Energetski potencijal – količina žetvenih ostataka koja bi mogla da se upotrebi kao energent ili sirovina za goriva; dobija se tako da se od održivog potencijala oduzme količina koja bi se koristila za druge svrhe, na primer, prostirku.

U okviru istraživanja utvrđivani su teoretski i tehnički potencijal žetvenih ostataka. Za definisanje održivog potencijala date su podloge, a ocenu bi sprovodili stručnjaci za ovu oblast, uzimajući u obzir brojne uticaje.

Tokom sezone ubiranja zrna ozime uljane repice 2013. i 2014. godine, u fazi zrelosti zrna, uzeti su uzorci ukupne nadzemne mase. Na osnovu vrednosti standardizovanog indeksa padavina (SPI), prema podacima Republičkog hidrometeorološkog zavoda Srbije, Odeljenje za agrometeorologiju, za teritoriju Vojvodine u 2013. godini su uslovi bili umereno sušni, a u 2014. umereno do ekstremno vlažni. U 2013. uzeti su uzorci osam reprezentativnih sorti: Jasna, Zorica, Jelena, Branka, Champlain, Triangle, Turan, Banaćanka, sa 3 lokacije, a 2014. šest sorti: Jasna, Zorica, Jelena, Branka, Slavica i Banaćanka, sa jedne lokacije. Sve lokacije bile su u Vojvodini sa sličnim agroekološkim uslovima, a svi uzorci su uzeti na gazdinstvima sa primenom savremene tehnologije proizvodnje.

Sa svake parcele, od svake sorte, uzeto je pet nasumično raspoređenih uzoraka ukupne nadzemne biljne mase sa jednog kvadratnog metra. Svaki uzorak podeljen je na sledeće delove: zrna, stabljike i mahune. Izmerena je njihova masa sa tačnošću 0,1 g. Obavljeno je merenje sadržaja vlage svih delova u skladu sa ASAE S352.2 [20] za zrno i ASAE S358.2 [21] za ostale delove biljke. Prinos suve materije svih delova izračunat je na osnovu izmerene mase i sadržaja vlage. Izračunati su žetveni indeks (*ŽI*) i udeo prinosa mase stabljike i mahuna u odnosu na masu zrna.

Stabljike su sečene na pet delova: do 10 cm, 10–20 cm, 20–30 cm, 30–40 cm i preko 40 cm i izmerena je masa svakog dela, te na osnovu toga fromirani dijagrami raspodele mase, zbirnog masenog udela po visini.

Na osnovu iskustava u praksi, pretpostavljeno je da može da se ubere samo stabljika, dok mahune pikap uređaj presa ne podiže. Visina sečenja kosionog uređaja je obično je u dijapazonu 20 do 30 cm, pa su pri proračunu mase koja može da se ubere u obzir uzete ove dve vrednosti. Na osnovu visine reza i dijagrama koji prikazuje zbirni maseni udeo, utvrđene su količine stabljike koje ostaju na strnjištu. Pretpostavljeno je da su gubici pri presovanju 10 % u svim slučajevima. Takođe je poznato da su gubici zrna pri ubiranju uljane repice obično u dijapazonu 5 do 10 % (minimalno oko 3 %). Pošto su razmatrani uspešni proizvođači, usvojena je, za proračun mase koja na polju ostaje u obliku zrna, 6 %.

Proračun procene pokrivenosti polja ukupnim nadzemnim žetvenim ostacima uljane repice posle žetve, da bi se postigao maksimalan otpor eroziji vetra i vode, obavljen je prema [9]. Za sva merenja sprovedena je statistička analiza radi određivanja standardnog odstupanja rezultata (*SD*).

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Rezultati ispitivanja udela nadzemnih delova uljane repice prikazani su u Tab. 1.

Prosečni prinos zrna, suve materije, u 2013. godini bio je 2,79 Mg ha^{-1}, a u 2014. za oko 20 % viši, 3,29 Mg ha^{-1}, što je posledica povoljnijih klimatskih uslova.

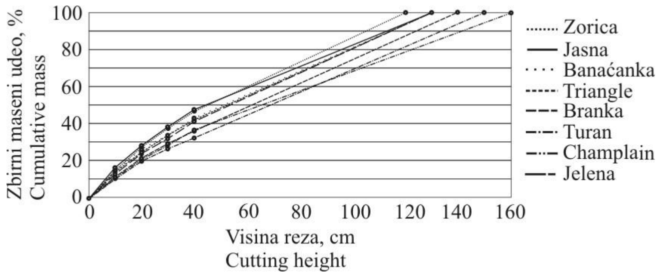
Prosečan žetveni indeks 2013. bio je 0,34, a 2014. iznosio je 0,29. Ovi podaci dobro se slažu sa onim vrednostima koje navodi Hühn [6] za deset sorti uljane repice, najmanja 0,223, a najviša 0,340. Srednja vrednost je 0,285, što se dobro poklapa sa vrednostima dobijenim merenjem, u ovom radu.

Na Sl. 1 prikazan je zbirni maseni udeo stabljika uljane repice po visini (visina reza kosionog aparata) u sezoni 2013, a na sl. 2 u 2014.

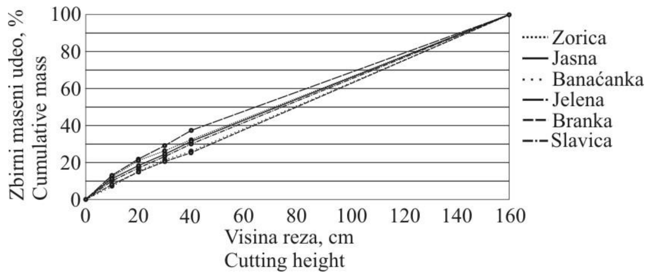
Tabela 1. Biološke karakteristike nadzemnog dela uljane repice (vrednosti mase su date za suvu materiju) u sezonama 2013. i 2014. godine
Table 1. Biological characteristics of the aboveground parts of rapeseed (mass for dry matter), seasons 2013 and 2014

Zrno – *Grain*										
Sorta *Variety*	W* (%)		Prinos *Yield,* (Mg ha^{-1})		SD prinos *SD Yield,* (Mg ha^{-1})		ŽI** (–)		SD ŽI (–)	
	Sezona – *Season*									
	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.
Jasna	5,47	7,32	2,56	2,58	0,30	0,52	0,36	0,29	0,01	0,04
Zorica	6,02	7,55	1,87	2,92	0,17	0,49	0,33	0,29	0,01	0,03
Jelena	5,62	7,41	2,35	2,70	0,37	0,65	0,32	0,30	0,01	0,01
Branka	6,04	8,28	3,43	4,11	0,60	0,66	0,36	0,30	0,01	0,02
Slavica	NP***	7,52	NP	3,83	NP	0,98	NP	0,30	NP	0,02
Champlain	5,62	NP	4,01	NP	0,73	NP	0,33	NP	0,01	NP
Triangle	6,49	NP	2,32	NP	0,33	NP	0,33	NP	0,02	NP
Turan	5,63	NP	3,59	NP	0,79	NP	0,35	NP	0,02	NP
Banaćanka	5,29	8,17	2,22	3,58	0,26	1,23	0,30	0,28	0,01	0,02
Prosek, *Average*	5,77	7,71	2,79	3,29			0,34	0,29		
SD****	0,36	0,37	0,72	0,58			0,02	0,01		
Stabljika – *Stalks*										
Sorta *Variety*	W* (%)		Prinos *Yield,* (Mg ha^{-1})		SD prinos *SD Yield* (Mg ha^{-1})		Udeo mase prema zrnu *Yield relative to grain* (%)		SD udeo mase prema zrnu *SD Yield relative to grain* (%)	
	Sezona – *Season*									
	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.
Jasna	10,6	12,3	2,8	4,6	0,3	0,4	111	177	3,3	46
Zorica	14,3	11,8	2,4	4,9	0,2	0,8	130	169	10,8	24
Jelena	10,6	11,3	2,8	4,0	0,4	0,8	122	148	3,0	6
Branka	12,2	13,3	3,3	6,2	0,4	0,8	97	151	7,7	13
Slavica	NP	13,6	NP	6,1	NP	0,9	NP	159	NP	21
Champlain	10,7	NP	4,8	NP	0,6	NP	120	NP	8,4	NP
Triangle	10,9	NP	2,4	NP	0,2	NP	105	NP	9,2	NP
Turan	10,3	NP	3,7	NP	0,5	NP	103	NP	9,4	NP
Banaćanka	10,5	12,6	2,9	6,5	0,3	1,8	131	182	4,4	23
Prosek, *Average*	11,2	12,5	3,2	5,4			115	164		
SD	1,3	0,8	0,7	0,9			12	13		
Mahune – *Hulls*										
Sorta *Variety*	W* (%)		Prinos *Yield,* (Mg ha^{-1})		SD prinos *SD Yield,* (Mg ha^{-1})		Udeo mase prema zrnu *Yield relative to grain* (%)		SD udeo mase prema zrnu *SD Yield relative to grain* (%)	
	Sezona – *Season*									
	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.	2013.	2014.
Jasna	12,7	11,6	1,6	1,8	0,1	0,15	65	72	5,1	12,0
Zorica	11,5	13,2	1,3	2,3	0,1	0,69	69	78	2,4	14,7
Jelena	11,5	12,3	2,1	2,2	0,2	0,51	89	80	4,6	3,2
Branka	11,7	15,7	2,8	3,3	0,4	0,47	83	81	2,4	7,7
Slavica	NP	12,6	NP	2,8	NP	0,57	NP	73	NP	7,1
Champlain	10,5	NP	3,3	NP	0,6	NP	8	NP	7,0	NP
Triangle	10,7	NP	2,2	NP	0,3	NP	94	NP	7,3	NP
Turan	10,4	NP	2,9	NP	0,4	NP	81	NP	9,7	NP
Banaćanka	10,9	12,0	2,2	2,8	0,3	0,76	98	78	4,9	9,0
Prosek, *Average*	11,3	12,9	2,3	2,5			83	77		
SD	0,7	1,3	0,6	0,5			11	3,4		

* *W – sadržaj vlage, moisture content, ** ŽI – žetveni indeks, harvest index, *** NP – nema podataka, no data, **** SD – standardno odstupanje, standard deviation*

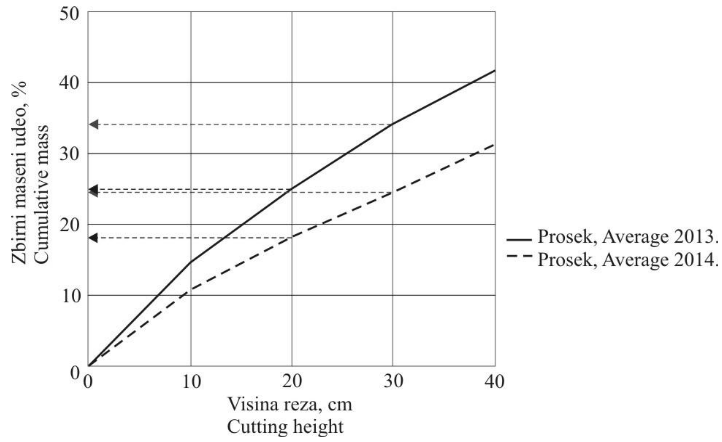


Slika 1. Zbrini maseni udeo stabljika uljane repice po visini, sezona 2013.
Figure 1. Cumulative mass of rapeseed stalks by height, season 2013



Slika 2. Zbrini maseni udeo stabljika uljane repice po visini, sezona 2014.
Figure 2. Cumulative mass of rapeseed stalks by height, season 2014

Krive zbirnog masenog udela, slične su za većinu ispitivanih sorti. Jedino sorte Jasna i Zorica pokazuju značajnije razlike u pogledu veće mase delova stabljike, koje su do 30 cm visine od tla, u sezoni 2013, zbirni maseni udeo 39,8 i 39,7 %, respektivno, a sorta Turan zbog manje mase delova stabljike, zbirni maseni udeo 27,7 %. Sezone 2014. najviše mase delova stabljike do 30 cm visine od tla imala je sorta Jelena, zbirni maseni udeo 29,3 %, a najmanje sorta Branka, zbirni maseni udeo 20,9 %.



Slika 3. Zbirni maseni udeo stabljika uljane repice po visini, prosek merenja 2013. i 2014.
Figure. 3. Cumulative mass of rapeseed stalks by height, average of samples in 2013 and 2014

Prosečne vrednosti zbirnog masenog udela svih ispitanih sorti i lokaliteta u zavisnosti od visine reza, za obe sezone ispitivanja, prikazane su na sl. 3. Sezone 2013. bila je uočljiva razlika u visinama stabljika, koja je u proseku iznosila 136 cm, u odnosu na sezonu 2014. kada je bila 160 cm (na dijagramu je prikazan dijapazon do visine 40 cm).

Prosečna visina stabljika bila je 2013. ispod 1,4 m, a 2014. su sve sorte imale visinu oko 1,6 m. Udeo mase stabljika, koja ostaje na strnjištu, iznosio je, u sezoni 2013, u proseku 24,8 % za visinu reza 20 cm i 33,8 % za visinu reza 30 cm, a u 2014. iznosio je 18,0 % i 24,6 %, redom.

Na osnovu prosečnih vrednosti za sve uzorke u sezoni 2013. i 2014. izračunata je ubrana masa, tehnički potencijal i masa koja ostaje na polju, Tab. 2.

Tabela 2. Prosečne vrednosti za ubranu masu i masu koja ostaje na polju
Table 2. Average values for harvetable and on field remained mass

Sezona - *Sesson*		2013.	2014.
Ukupni nadzemni deo žetvenih ostataka/stabljike *Total above ground mass of crop residues/stalks* (Mg ha^{-1})		5,5/ 3,2	7,9/ 5,4
Masa koja se ubire za visinu reza	20 cm	2,2	4,0
Harvestable mass for cutting height (Mg ha^{-1})	30 cm	1,9	3,7
Udeo ubrane mase u odnosu na ukupnu	20 cm	40	51
Percentage of harvested in total mass (%)	30 cm	35	47
Masa koja preostaje na polju (Mg ha^{-1})	20 cm	3,3	3,9
On field remained mass	30 cm	3,6	4,2
Preostala masa uključujući i gubitak zrna	20 cm	3,5	4,1
Remained mass including grain losses (Mg ha^{-1})	30 cm	3,8	4,4

Ubrana masa, odnosno tehnički potencijal, bila je u 2013. godini 1,9 do 2,2 Mg ha^{-1}, a u 2014. 3,6 do 4,0 Mg ha^{-1}. Ovi podaci ukazuju na značaj potencijala slame uljane repice, ali i o uticaju vremenskih prilika na potencijal, pa tako i na sigurnost snabdevanja slamom uljane repica.

Za slamu strnih žita i kukuruzovinu se orijentaciono računa da je energetski potencijal u proseku oko jedne trećine od teoretskog. To nije primenljivo za slučaj repice, jer se kod nje, zbog ranije navedenih razloga, žetveni ostaci češće koriste za obogaćivanje zemljišta organskom materijom. Načelno bi moglo da se računa sa četvrtinom ili čak petinom teoretskog potencijala. To bi, za razmatrane sezone, 2013. i 2014, bilo oko 1,4 i 1,1 Mg ha^{-1}, odnosno 2,0 i 1,6 Mg ha^{-1}, računajući četvrtinu i petinu respektivno. Ovakvi prinosi podrazumevaju i povremeno ostavljanje celokupne količine slame, kao meru za unošenje organske materije u zemljište.

Pri nepovoljnim klimatskim uslovima, kao što je bilo sezone 2013, tehnički potencijal umanjen je za 45 i 47 %, za visinu reza 20 i 30 cm, respektivno. Ovo bi trebalo da se uzme u obzir kao pokazatelj sigurnosti snabdevanja, ukoliko bi se slama uljane repice koristila kao izvor energije, ili sirovina za proizvodnju biogoriva.

Masa koja preostaje na polju (suva materija), sezone 2013. bila je 3,3 i 3,6 Mg ha^{-1}, a 2014. iznosila je 3,9 i 4,2 Mg ha^{-1}, za visinu reza 20 i 30 cm respektivno. Na osnovu proračuna procene pokrivenosti biljnim ostacima uljane repice prema [9], posle žetve zrna na polju je ostalo, u sezoni 2013. 81 i 85 % biljnih ostataka za visinu košenja 20, odnosno 30 cm, respektivno, a u sezoni 2014. 89 % i 92 %, respektivno. Pokrivenost se smanjuje u zavisnosti od primenjene obrade zemljišta [5]. Tako bi za primenu razrivača umanjenje bilo za 30 %, a pri primeni oranja 90 %. Ukoliko se primenjuje prolećna setva, trebalo računati i sa umanjenjem usled dejstva padavina i vetra, množenjem sa 0,9. Za slučaj primene razrivača do trenutka sprovođenja prolećne setve pokrivenost polja bila bi 51 do 58 %. Dakle, u svim slučajevima iznad 30 %, te je ostvarena zaštita od vetro erozije. Ukoliko bi se primenjivalo oranje, to ne bi moglo da se ostvari.

ZAKLJUČAK

Slama uljane repice u Srbiji bi mogla da postane obnovljivi izvor energije ili sirovina za biogoriva. Značajno ograničenje za njeno ubiranje je to što se osušena slama lomi, te je otežano presovanje. Slama uljane repice je prema mnogim izvorima pogodna kao izvor organske materije, pa i organskog ugljenika. Ukoliko se primenjuje u plodoredu sa pšenicom i kukuruzom, čiji se žetveni ostaci uklanjaju, pogodno je da se slamom uljane repice nadoknadi odneta organska materija. Naravno, da bi efekti bili povoljni, potrebno je da se ovakvo upravljanje žetvenim ostacima sprovede u konsultaciji sa stručnim licima.

Ispitivanje količine žetvenih ostataka, koje je sprovedeno 2013, u nepovoljnim klimatskim uslovima, te 2014. godine pri povoljnim klimatskim uslovima, rezultiralo je podacima o žetvenom indeksu, tehničkom prinosu i uticaju na zaštitu od erozije vetra. Prosečan žetveni indeks bio je 0,34 i 0,29 za 2013. i 2014. respektivno. Tehnički potencijal, suva masa žetvenih ostataka koja može da se ubere, u 2013. iznosila je 2,2 i 1,9 Mg ha^{-1}, a 2014. 4,0 i 3,7 Mg ha^{-1}, za visinu reza 20 i 30 cm respektivno. Ubrani prinos iznosio je 35 do 51 % od ukupnih nadzemnih žetvenih ostataka.

Procenjeno je da bi energetski potencijal bio u dijapazonu 1,1 do 2,0 Mg ha^{-1} suve mase. Utvrđeno je da je prinos, odnosno tehnički potencijal pri nepovoljnim klimatskim uslovima bio za 45 do 47 % niži, što bi trebalo da se uzme u obzir pri planiranju korišćenja kao obnovljivog izvora goriva, ali i organske materije za zemljište.

U svim slučajevima, uz sprovođenje obrade zemljišta bez prevrtanja, moglo bi da se ostvari da tokom zime po površini polja ostane dovoljno žetvenih ostataka za zaštitu od erozije vetra, dakle, pokrivenost površine više od 30 %.

Žetveni ostaci uljane repice mogli bi da budu dobar izvor za nadoknađivanje obrane organske mase drugih biljnih. Ova uloga uljane repice trebalo bi da se u budućnosti elaborira i nađe njeno mestu u plodoredu.

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POTENTIALS OF RAPESEED CROP RESIDUES IN SERBIA

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Abstract: Rapeseed straw is potential source of renewable energy, but important source of soil organic matter as well. The amount of crop residues, available for energy use, per hectare, is not well known. Excessive offtake of crop residues can be followed by reduction of soil fertility, removal of nutrients, organic carbon and wind erosion. The objective of the investigation was to define total and harvestable amount of crop residues – straw, and amount that remain on the field, which can be background for the calculation of soil fertility preservation. In 2013 (climatic conditions characterized as moderate dry) samples of aboveground mass of eight varieties were collected from three locations, and in 2014 (characterized as moderate to extreme humid) six varieties for one location. The samples were divided into: grain, stalks and hulls. It has been defined yield of fractions and calculated harvest index. The stalks were split along their lengths, parts measured and created cumulative mass distribution. For common harvest procedures have been defined harvestable mass, potential, for two selected cutting heights. Average harvest index was in 2013 0.34, and in 2014 lower, 0.29. Percentage of harvestable mass was between 35 and 51 % of total aboveground residual mass. Harvestable yield was in 2013 about 46 %, due to less favorable climatic conditions. This should be considered by the planning of any use of this material as energy source. It was assessed that the energy potential of rapeseed straw, including measures for preservation of soil fertility, is 1.1 to 2.0 Mg ha^{-1}, in average. On field remained residual mass can ensure, if proper tillage is applied, protection of wind erosion and increase of soil organic matter and soil organic carbon. It is concluded that rapeseed straw can be used for soil amelioration if adequate crop rotation is applied, and can compensate offtake of residues of other crops, e.g. wheat straw and corn stover. Future investigation should be oriented toward this utilization of rapeseed straw.

Key words: *rapeseed, crop residues, energy, soil*

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ENGINEERING PROPERTIES OF RICE

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Abstract: Engineering properties of rice is essential for designing of storage bin. The physical properties of rice (ADT-43) namely, size, shape, thousand grains mass, aspect ratio, surface area, volume, bulk density, true density and porosity at moisture content ranging from 11.55 to 26.84% (db) were determined using standard techniques for development of ozone based storage bin. In this case, thousand grains mass, surface area and volume increased from 10.70 to 14.59 g, 14.58 to 16.94 mm^2 and 3.78 to 4.76 mm^3, respectively, with an increase in moisture content from 11.55 to 26.84% (db). Geometric mean diameter, sphericity, aspect ratio, true density and porosity increased from 2.30 to 2.48 mm, 0.45 to 0.46, 33.10 to 34.66%, 961.89 to 975.24 $kg \cdot m^{-3}$ and 26.97 to 29.66%, respectively, with an increase in moisture content from 11.55 to 26.84% (db). These properties are very essential for designing of different parts of ozone based storage bin.

Key words*: rice, engineering properties, storage bin, moisture content, porosity*

INTRODUCTION

Rice (*Oryza sativa L.)* is most commonly consumed cereals and stable food for more than half of the Indians population. It is also a good source of riboflavin, thiamine, dietary fiber and niacin. In India, where 80% of the produced rice is consumed; it contributes 60-90% of the calories of Indian diet. ADT 43 is one of the most popular varieties of rice in Tamil Nadu due to high yielding performance. The insects are easily infesting the rice during storage. Temperature and moisture content of the grain provide the basis for extension of storage period, alternatively upon further processing of grain. According to the Food and Agriculture Organization of the United Nations (FAO), more

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than 20% of the world's harvested grain is spoiled every year. The major part of this loss is caused by insects and mould activity [1]. It reduces the market value and export potential of the rice. Hence there is a need to design a storage bin to manage the insects during storage. Therefore the engineering properties of rice are very essential for designing a storage bin. The marketing value of rice is depending on its physical qualities like infestation percentage, grain weight, moisture content, damaged rice and discolored rice (%) after the harvesting.

The percentage of whole grain is the most important parameter for the rice processing industry. If the machinery and operations are improperly designed may results rice kernel cracking and breakage and consequently a low marketing price. The knowledge of the engineering properties of the agricultural products is of fundamental importance during the storage chamber design and operating different equipments used in post harvesting processing operations of these products [2]. Physical and mechanical properties are important for design and development of bulk storage chamber and fumigation bin. Angle of repose and static coefficient of friction can be useful in design of storage bin hoppers. The information related to porosity is a paramount importance for studies involving fumigant movement through the bulk grain. In addition, together with moisture content and porosity are the basic parameters for studying the storage of agricultural products and drying and to reduce the quantity and quality loss of the agricultural material until its processing and marketing time. A rice grain bed with low porosity will have greater resistance to ozone fumigant movement during the fumigation process, which may lead to the need for higher power to drive the aeration fans or create the vacuum inside the fumigation bin.

Engineering properties of rice grains are required for designing of machines like thresher, cleaner, grader, separator, hulling, milling, scouring and packaging equipments. It is also essential for design and development of storage chamber and fumigation bin. The engineering properties like, angle of repose and coefficient of friction is play a major role in the designing of feed hopper in storage bin and it decides the bin wall thickness. Density and volume of the cereal grains are the important physical properties for designing of storage chamber at a required capacity. Hence, the moisture dependent engineering properties of cereals are essential for to reduce the quantitative and qualitative losses occur from harvesting to consumption.

For rice kernels it can be seen that increased in moisture content causes increases the lateral and vertical pressure on storage bin walls. Because the increase in pressure requires an increase in the thickness of storage bin wall results costs of construction increase. The objective of this study was to investigate the some engineering properties of rice (ADT 43) in relation to designing parameters of storage bin.

MATERIAL AND METHODS

Raw materials. Rice (ADT-43) was obtained from local mill, Coimbatore, India and used for the study. The rice was cleaned by using destoner and specific gravity separator to remove all foreign materials.

Sample preparation. The initial moisture content of rice was determined using hot air oven at 130˚C until a constant weight was reached [3]. The initial moisture content of rice was found to be 11.55% (db). In order to achieve the desired moisture levels for the study, rice samples were conditioned by adding calculated quantity of water. The samples were kept in a refrigerator at 4±2°C for a period of 5 days for the moisture to distribute uniformly throughout the rice grains. The moisture contents of the rice samples were equilibrated to 11.55, 13.79, 18.63, 22.75 and 26.84% (db). The required quantity of rice sample was withdrawn and equilibrated at room temperature (30±2°C) before conducting different tests [4].

Size and shape. To determine the average size of the rice grains, 100 grains were randomly picked and their three linear dimensions namely, length (*L*), width (*W*) and thickness (*T*) were measured using a Mitutoyo digital vernier calliper having a least count of 0.01 mm. Arithmetic mean diameter (D_a) and geometric mean diameter (D_g) of the rice grains were calculated by using the following relationships [5].

$$D_a = \frac{(L + W + T)}{3} \tag{1}$$

$$D_g = (LWT)^{\frac{1}{3}} \tag{2}$$

where:

D_a	[mm]	- arithmetic mean diameter,
D_g	[mm]	- geometric mean diameter,
L	[mm]	- length,
W	[mm]	- width,
T	[mm]	- thickness.

The aspect ratio (R_a) was calculated as:

$$R_a = \frac{W}{L} \tag{3}$$

Shape of rice grains can be expressed in the terms of sphericity (ϕ). It was found to be cylindrical. Sphericity of rice grain was calculated using the following formula [5]:

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \tag{4}$$

Thousand grains mass. One thousand rice kernels from each sample were randomly picked and weighted using digital electronic balance having an accuracy of 0.01 g.

Surface area and volume. The surface area of rice grain was found by using the following relationship:

$$S = \frac{\pi C L^2}{2L - C} \tag{5}$$

where:

$$C = \sqrt{WT} \tag{6}$$

Rice volume (*V*) was calculated using the following equation:

$$V = \frac{\pi C^2 L^2}{6(2L - C)} \tag{7}$$

Density. Bulk density is the ratio of mass of rice grains (*M*) to its total (bulk) volume (*V*). It was determined by filling a known volume of container with rice grains and gently tapped without compact the grains during filling.

$$\rho_b = \frac{M}{V} \tag{8}$$

The true density of rice kernel is defined as the ratio of mass of rice to solid volume occupied. The rice volume was determined using toluene displacement technique.

Porosity. Porosity (ε) of rice grain is the ratio of the volume of internal pores in between the grains to its bulk volume. It was determined using following equation [6, 7]:

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) * 100 \tag{9}$$

where:

ε [%] - porosity,

ρ_b [kg·m^{-3}] - bulk density,

ρ_t [kg·m^{-3}] - true density.

Data analysis. All the tests ware repeated for three times to determine mean value of engineering properties. The data were analyzed statistically using AGRES software (7.01) and regression equation using Microsoft Excel software. The treatments and their interactions were compared at $p \leq 0.01$ and $p \leq 0.05$ level using least square deference test.

RESULTS AND DISCUSSION

Size distribution pattern. Per cent distributions of rice grain dimensions at a moisture content of 11.55% (db) measured. About 88 % of rice had a length from 5.03 to 5.12 mm, about 92 % of rice had a width ranging from 1.69 to 1.72 mm and about 89% of rice had a thickness ranging from 1.39 to 1.44 mm. Minimum, maximum and mean values of the three principal dimension of rice at different moisture contents are presented in Table 1. The data indicated that size of the rice kernel increased with an increase in moisture content from 11.55 to 26.84% (db). The length, width and thickness of rice grains increased from 5.05 to 5.39 mm ($p \leq 0.01$), 1.70 to 1.87 mm ($p \leq 0.01$) and 1.42 to 1.52 mm ($p \leq 0.05$), respectively, with increase in moisture content from 11.55 to 26.84% (db). The changes in the size of rice kernel with increase in moisture content may be due to hygroscopic nature. A greater increase was found to be width (8.93%), thickness (6.76%) and length (6.29%). Tab..2 shows the regression analysis of the experimental data showed a linear correlation between length, width and thickness with moisture content at high coefficient of determination (R^2).

Table.1. Minimum, maximum and mean values of axial dimensions of rice at different moisture contents

M.C.	*Length (mm)*				*Width (mm)*				*Thickness (mm)*			
(db)	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*
11.55	*4.98*	*5.32*	*5.05*	*0.12*	*1.63*	*1.76*	*1.70*	*0.11*	*1.33*	*1.49*	*1.42*	*0.09*
13.79	*5.07*	*5.36*	*5.23*	*0.07*	*1.64*	*1.79*	*1.73*	*0.14*	*1.31*	*1.54*	*1.46*	*0.04*
18.63	*5.16*	*5.41*	*5.31*	*0.14*	*1.71*	*1.84*	*1.80*	*0.06*	*1.36*	*1.58*	*1.49*	*0.03*
22.75	*5.14*	*5.48*	*5.36*	*0.09*	*1.72*	*1.89*	*1.83*	*0.08*	*1.42*	*1.67*	*1.50*	*0.14*
26.84	*5.17*	*5.59*	*5.39*	*0.11*	*1.74*	*1.98*	*1.87*	*0.13*	*1.44*	*1.69*	*1.52*	*0.08*

M.C. - Moisture content ; S.D. - Standard deviation

Mean diameters. Geometric mean diameter and arithmetic mean diameter of rice kernel at different moisture contents are shown in Fig. 1. From the figure, it is seen that the mean diameters of rice kernel increased with increase in moisture content, and established a linear and positive relationship with regression equation of the form:

$$D_g = 0.0112M + 2.1974, (R^2 = 0.9404) \tag{10}$$
$$D_a = 0.0128M + 2.6028, (R^2 = 0.9353) \tag{11}$$

where:
M [%] - moisture content of rice kernels (db).

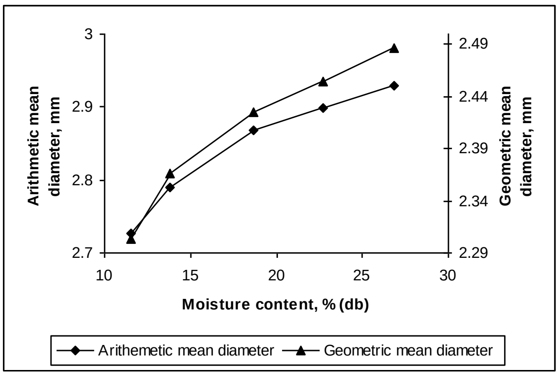

Figure 1. Effect of moisture content on arithmetic and geometric mean diameter of rice

High coefficient of determination (R^2 > 0.93) indicated the best fit of regression equations. The changes in the mean diameters of rice kernel with increase in moisture content might be due to swelling of rice by absorbing moisture [8]. The increase in moisture content from 11.55 to 26.84% (db) increased the arithmetic and geometric mean diameter of rice kernel from 2.72 to 2.92 mm ($p \leq 0.01$) and 2.30 to 2.48 mm ($p \leq 0.01$), respectively. A greater increase was found to be geometric mean diameter (7.33%) as compared to arithmetic mean diameter (6.93%) with increase in moisture content from 11.55 to 26.84% (db).

Aspect ratio. From the Fig.2, it is seen that aspect ratio of rice grain increased from 33.10 to 34.66% ($p \leq 0.05$) with increase in moisture content from 11.55 to 26.84% (db). Thus, the lower values of the aspect ratio indicate a difficulty in getting the kernels to roll than that of spheroid grains [2]. However, it slides on their flat surfaces. This tendency to either roll or slide should be necessary in the design of hoppers for fumigation and storage bin. The increase in aspect ratio with increase in moisture content was reported by Ghadge and Prasad [2] for rice. This confirms the findings of present study. The relation between moisture content and aspect ratio is linear (Tab. 2.).

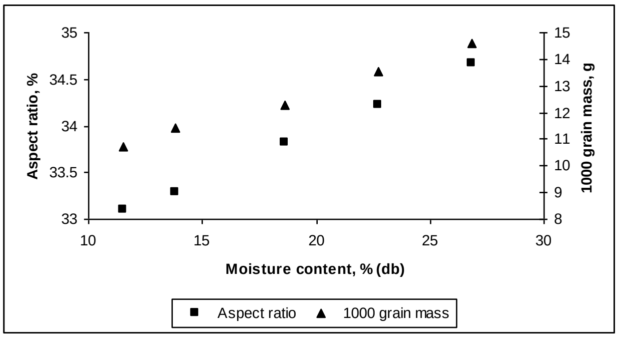

Figure 2. Effect of moisture content on aspect ratio and 1000 grain mass

Mass of thousand grains. Fig. 2 depicted that mass of 1000 rice kernels was found to be increase from 10.70 to 14.59 g ($p \leq 0.01$) with increase in moisture content from 11.55 to 26.84% (db), respectively. The increase in the mass of 1000 rice kernels with increase in moisture content might be due to hysteresis effect of rice kernels. Similar results of effect of grain moisture on thousand grains mass were reported for ridge gourd seed [9] and moth gram [10]. These reported results confirmed the findings of present study. The thousand grain mass is a useful index to “milling outturn” in measuring the relative amount of foreign or dockage material in a given lot of cereal grain, and the amount of immature and shriveled kernels [11].

Shape. The shape of rice was measured in terms of sphericity at different moisture contents are shown in Fig. 3. From the figure, it is seen that the mean value of sphericity increased from 0.455 to 0.460 as the moisture content increased from 11.55 to 26.84% (db), respectively. It indicate that sphericity of rice was significant ($p \leq 0.05$) as the moisture content increased from 11.55% to 26.84% (db). The changes in the sphericity of rice with increase in moisture content might be due to increase in its dimensions namely length, width and thickness. The increase in sphericity upon increase in moisture was reported for barley grains [12] and *Telfaria Occidentalis* seeds [13]. This confirms the findings of the present study. From the Tab. 2, it is seen that a linear relationship exists between moisture content and sphericity of rice grain.

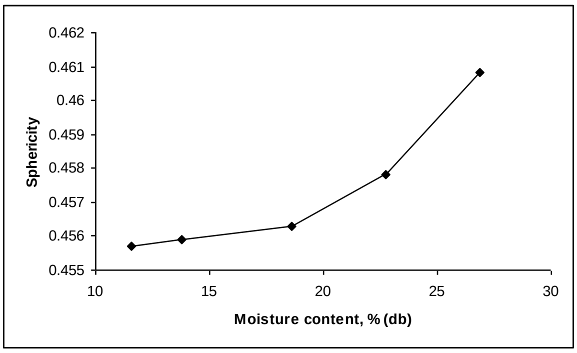

Figure 3. Effect of moisture content on sphericity of rice

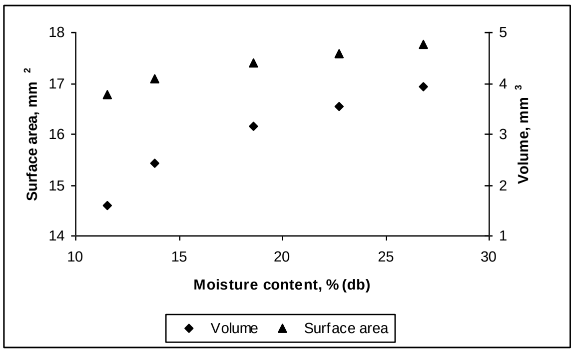

Figure 4. Effect of moisture content on surface area and volume of rice

Surface area. The surface area of rice grain increased linearly from 14.58 to 16.94 mm^2 ($p \leq 0.05$) with increase in moisture content from 11.55 to 26.84% (db) (Fig. 4).

The variation of moisture content and surface area can be expressed mathematically as given in Tab. 2. High R^2 value shows the best fit of equation to the experimental values. The changes in the surface area of rice grain with increase in moisture content may be due to increase in length, width and thickness of rice kernel with increase in moisture content. Similar trends were reported by [14] and [15] for onion seed and linseed, respectively.

Volume. The relationship between volume and moisture content of rice kernel is shown in Fig. 4. The volume of rice grain increased from 3.78 to 4.76 mm^3 ($p \leq 0.01$) as the moisture content increased from 11.55 to 26.84% (db). Similar results were reported by [8] reported an increase in volume with increase in moisture content for onion seed. The linear relationship exists between moisture content and volume followed a regression equation is given in Tab. 2.

Densities. The bulk density of rice grain at different moisture contents are shown in Fig.5. The grains bulk density at different moisture contents varied from 712 to 676 kg·m^{-3}, which indicates a decrease in bulk density with an increase in moisture content from 11.55 to 26.84% (db). That is, 56.96% increase in moisture content resulted in 5.26 per cent decrease in bulk density. The effect of moisture content on bulk density of rice grains showed a significant increase ($p \leq 0.01$) with increasing moisture content. The decrease in bulk density with an increase in moisture content is mainly due to the fact that an increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk [12]. A similar decreasing trend in bulk density has been reported by [7] for paddy and [16] for pea seed. This confirmed the findings of present study. Regression analysis shows that bulk density is linearly dependent on moisture content and it is negatively correlated.

True density of rice kernel slightly increased with increase in moisture content (Fig. 5). It increased from 961 to 975 kg·m^{-3} with an increase in moisture content from 11.55 to 26.84% (db). That is, 56.96% increase in moisture content resulted in only 1.38 per cent increase in true density. Increasing moisture content had a significant effect ($p \leq 0.05$) on true density of rice. The increase in true density is due to decrease in volume of the kernel at higher moisture content levels. Regression analysis shows (Table. 2) that true density is positively correlated and depicts the linear dependency of true density on moisture content.

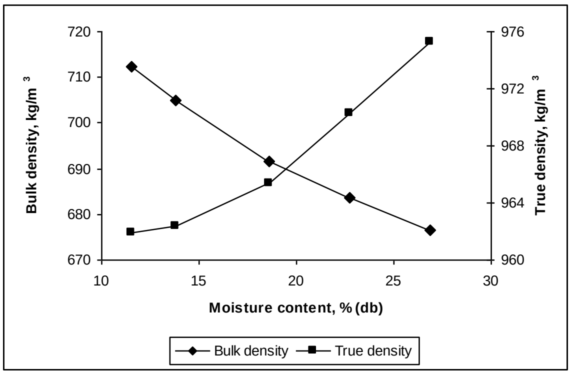

Figure 5. Effect of moisture content on density of rice

Porosity. The effect of moisture content on porosity of rice grain is shown in Fig. 6. From the figure, it was observed that porosity of rice grains increased from 26.97 to

29.66 ($p \leq 0.05$), when the moisture content was increased from 11.55 to 26.84% (db), respectively. The increase in porosity with increase in moisture content might be due to increase in shape and size of rice kernel. From the results, it is seen that, 56.96% increase in moisture content, porosity increased only about 9.06 per cent. The porosity of rice grain followed a linear relationship with moisture content and followed the regression equation (Tab. 2). Similar trend was observed in [14] for onion seed.

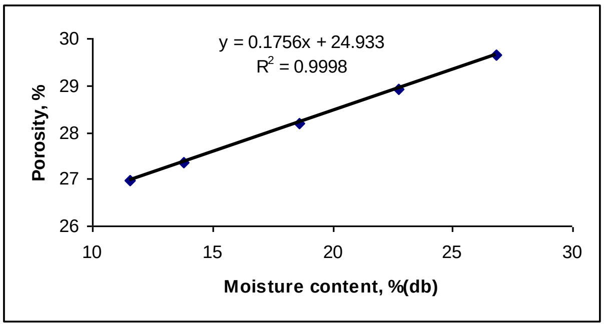

Figure 6. Effect of moisture content on porosity of rice

Table 2. Engineering properties of rice (ADT-43) as a function of moisture content

Engineering properties	*Relationship with moisture content*	*Coefficient of determination (R^2)*
Length (mm)	*0.0197M + 4.9023**	*0.8340*
Width (mm)	*0.0109M + 1.587*	*0.9730*
Thickness (mm)	*0.0061M + 1.363*	*0.9359*
Aspect ratio (%)	*0.1028M + 31.896*	*0.9992*
Thousand grain weight, g	*0.2504M + 7.8261*	*0.9943*
Sphericity	*0.0003M + 0.4515*	*0.8366*
Surface area (mm^2)	*0.0610M + 3.1829*	*0.9556*
Volume (mm^3)	*0.1444M + 13.226*	*0.9375*
Bulk density (kg·m^{-3})	*-2.3212M + 737.23*	*0.9858*
True density (kg·m^{-3})	*0.9307M + 948.92*	*0.9013*
Porosity (%)	*0.1756M + 24.993*	*0.9998*

**M-Moisture content, % (db)*

CONCLUSIONS

Moisture content of rice grains is one of the most important factors influence the storage period of rice. The information on engineering properties of rice (ADT-43) is essential for designing a storage bin and processing equipments. Moisture dependent engineering properties namely size, shape and 1000 grains mass increased with increase in moisture content. The surface area of rice grain increased linearly from 14.58 to 16.94 mm^2 ($p \leq 0.05$) with increase in moisture content from 11.55 to 26.84% (db). The volume of rice grain increased from 3.78 to 4.76 mm^3 ($p \leq 0.01$) as the moisture content increased from 11.55 to 26.84% (db). The grains bulk density at different moisture contents varied from 712 to 676 kg·m^{-3}. True density increased from 961 to 975 kg·m^{-3} with an increase in moisture content from 11.55 to 26.84% (db). The porosity of rice grains increased from 26.97 to 29.66 ($p \leq 0.05$), when the moisture content was increased from 11.55 to 26.84% (db).

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TEHNIČKA SVOJSTVA ZRNA PIRINČA

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Sažetak: Tehnička svojstva pirinča su osnova za projektovanje skladišnog rezervoara. Sledeća svojstva pirinča (ADT-43): dimenzije, oblik, masa hiljadu zrna, površina, zapremina, gustina mase, stvarna gustina i poroznost, pri vlažnosti od 11.55 do 26.84% (db), određivane su standardnim tehnikama za razvoj ozonskog skladišnog rezervoara. U ovom slučaju, masa hiljadu zrna, površina i zapremina porasli su sa 10.70 na 14.59 g, 14.58 na 16.94 mm^2 i 3.78 na 4.76 mm^3, redom, sa povećanjem sadržaja vlage sa 11.55 na 26.84% (db). Geometrijski srednji prečnik, sveričnost, stvarna gustina i poroznost su se povećali sa 2.30 na 2.48 mm, 0.45 na 0.46, 33.10 na 34.66%, 961.89 na 975.24 $kg \cdot m^{-3}$ i 26.97 na 29.66%, redom, sa povećanjem sadržaja vlage sa 11.55 na 26.84% (db). Ova svojstva su osnov za konstruisanje različitih delova ozonskog skladišnog rezervoara.

Ključne reči*: pirinač, tehnička svojstva, skladišni rezervoar, sadržaj vlage, poroznost*

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COMPARATIVE PERFORMANCE OF WIND AND ELECTRIC PUMPS FOR IRRIGATION

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Abstract: Wind energy technology may turn out to be the best alternative compared to the use of hydro electric power for pumping water for irrigation in certain parts of Ghana during the dry season. This paper focuses on evaluating the performance of wind and electric pump through the mounting of an experiment in order to do a comparative evaluation of the investment cost of running the two energy-based pumping systems in the Keta District which provides one of the best wind regimes in Ghana. Farmers in these coastal communities may have engaged in the use of wind energy for water pumping but for its high initial cost. Despite the high initial cost farmers could form cooperative societies in order to run a wind energy pumping system. The high electricity tariff paid every month for power consumption deters majority of the farmers using hydro electricity technology for pumping. A total investment cost of ¢4095.80 per hectare was incurred by farmers using the electric power whilst ¢929.80 per hectare by those using the wind power technology for every farming season. A difference of ¢3166.00 could be saved for other uses by farmers practicing the wind energy technology.

Key words*: wind, electricity, pumps, irrigation, energy, performance*

INTRODUCTION

There is increasing demand for water for domestic purposes and crop irrigation as a result surface water is becoming very scarce worldwide [1]. Though diesel, petrol and sometimes kerosene powered pumps have traditionally been used to pump water [1], electric and wind energy are emerging as attractive sources of energy for water pumping for irrigation and domestic use. Most of the worlds energy needs is met by fossil and nuclear power plants, however the global search and the rise in the cost of conventional fossil fuel is making supply-demand of electricity product almost impossible especially in some remote areas [2]. Wind energy systems for irrigation and milling have been in

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use since ancient times and at the beginning of the 20th century it is being used to generate electric power. Windmills for water pumping have been installed in many countries particularly in the rural areas [2]. Wind power is able to feed both energy production and demand in the rural areas. It is used to run a windmill which in turn drives a wind generator or wind turbine to produce electricity [3]. Wind turbine has significant benefit in the areas where there is a shorter rainy season and hence demand for pumped water. After installing wind turbine water pumps in a farm, one can raise higher value crops throughout the year and also supply water to the livestock [4].

There are various energy alternatives, which may be non-renewable options such as clean coal, nuclear, and renewable options such as hydroelectric, biomass / biofuels, geothermal, thermal energy conversion, wave, tidal, wind, solar, and other [5], however Solar and wind are renewable and non-polluting, and is optional alternative resources for power generation [6]. Also the awareness in saving of direct energy has grown rapidly in this sector due to continues increase in energy prices (for example fuel) in the last couple of years [7].

For the purposes of this research, much emphasis is laid on the supply of irrigation water for vegetable production; and thus focused on comparing and choosing the most economically viable and affordable pumps operated on wind and electric energy sources for vegetable production in the Anloga community in the Keta District of the Volta Region of Ghana.

Description of Research Area. Geographically, Keta District is located in the southern sector of the Volta Region of Ghana. The District lies within longitude 0.3°E and 1.05°E and latitude 5.45°N and 6.005°N. It is sandwiched between two major surface water bodies – the Keta lagoon and the Gulf of Guinea. It is a flat land full of sandy soil owing to its proximity to the Keta beach.

The indigenous Anlo communities basically engage in vegetable production and salt winning on commercial scale since time immemorial. They mainly produce shallot, pepper, tomato and okro. More often than not, some of these farmers cultivate other crops such as corn, cassava and coconut on subsistence bases.

Wells are drilled to a depth of about 1-9 m to provide water for irrigation. Buckets and/or watering cans are used to draw water manually from the wells. These buckets of water are sprinkled manually on the vegetable beds two times a day (morning and evening) as a form of irrigation. Where pumps are used, rubber hoses are used for irrigation. In this case pressure is exerted on the open end of the hose with the fingers by way of apparently reducing the diameter. This action mimics rainfall or sprinkler discharges.

Problem Statement. Recent power rationing exercise in the country due to the unavailability of enough water in the Akosombo dam to generate effectively the needed hydro-electric power also affects power supply to the pumps. This situation is a setback on constant supply of water to the crops. A wind speed of 5.8 $m \cdot s^{-1}$ for the critical season in the community can supply the energy needs of 0.25 kJ to the windmill for irrigating the desired areas [8], however the initial cost of setting a wind energy driven pump for irrigation also presents a constraint.

Objectives. The prime objective of this paper is to compare the economic operation of the wind and electric pump (capital/investment and operation costs) of the for vegetable production in the farming communities of the Keta District in the Volta Region of Ghana as a basis for making informed decision on profitable irrigation.

MATERIAL AND METHODS

Relevant parameters on a windmill installed on pilot basis with a distance of 250 m away from the sea to provide power for pumping water from 9 m deep borehole for irrigation was measured as energy source for pumping of water in the area understudy.

Secondary data from the Ghana Energy Foundation [8] indicating that the windmill operates under a pressure of about 20.69 $N \cdot m^{-2}$ and discharges minimum water of about 12 $m^3 \cdot s^{-1}$ during the critical farming season (September/October) was obtained. Water is pumped into 10.91 l storage tank raised 2.7 m above the ground. This quantity of water is used to irrigate 0.5 ha of land everyday by drip system of irrigation. The stored water is discharged directly to the root zone of crops by gravity through the laterals to the emitters which are laid directly beside the crops.

In addition, well structured questionnaire were designed and randomly administered to ten of farmers in the area to solicit responses on their farm land sizes, income generated and the investment involved in using energy sources such wind and electric in pumping water to irrigate their respective farm lands. The data obtained was then subjected to critical cost analysis.

RESULTS AND DISCUSSION

Cost Analysis

The Fig. 1 indicates ten randomly selected farmers with total investment cost / expenditure against the corresponding farm size.

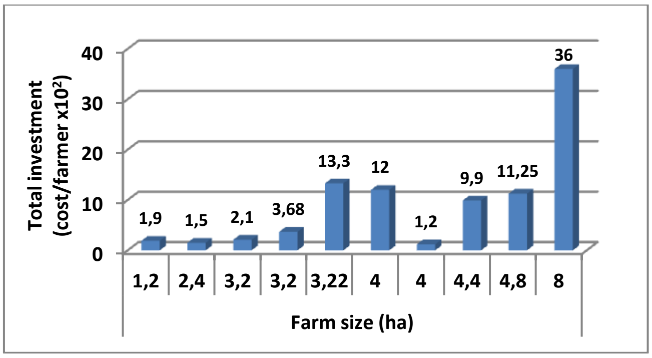

Figure 1. A graph of total investment cost against farm size

From Fig. 1, the larger the farm size, the greater the investment cost. Thus where all conditions seemed equal, a farmer with a farm size of 4 ha is required to invest a total amount of ¢15193.34 whilst a farmer with farm size of 4.4 ha and 8 ha needed to invest a total of ¢22212.7710 and ¢96402.70 respectively. Farm sizes 3.2, 3.22, 4, 4.4 and 4.8 ha showed certain disparities that can be explained. The differences in the total investment cost of the farm sizes are due to unequal initial investment cost invested by the farmers. It can also be attributed to the following: differences in the quantity of electric power consumed; differences in the number of centrifugal pumps purchased. Thus a farmer could purchase one pump which cost ¢260.00 for a sizeable hectares of land where as the other farmer could use three pumps which cost a total of ¢750.00 on a similar farm size. The difference in the number of sprinkler heads and hence the cost of sprinklers.

Cost Analysis of the two Farming Practices as at 2013/2014

From the interviews, farmers who engaged in both the modern sprinkler and drip irrigation farming usually lease a hectare of land for ¢25.00. They are obliged to repay the rent after one year of farming. This implies that farmers who might have engaged more than a hectare of land are indebted to pay proportional amount which corresponds to the acquired farm size. For a farm size of 2 ha, the farmer pays 2 by ¢25.00 per annum (¢50.00). As at July, 2014, a borehole was drilled at a cost of ¢100.00. For a hectare of land, a total of ¢125.00 was spent on purchasing vegetable seedlings. In effect the total capital cost was ¢250.00. A farmer practicing sprinkler irrigation farming system is likely to spend a total of ¢2666.00 as the system cost. In that cost of PVC materials (main pipelines, lateral pipelines and riser pipes) amount to a total of ¢2250.00 per hectare. One rotating impeller sprinkler as at July, 2014 cost ¢12.00. A research interview conducted showed that 13 sprinkler heads operate a hectare of land. A centrifugal pump also cost ¢260.00.

Table 1. Electric powered (sprinkler) technology

Element Data		
A hectare of Land/annum	*Capital cost (¢)*	*25.00*
A Borehole		*100.00*
Vegetable Seedling/ha		*125.00*
Total		*250.00*
Cost of PVC Materials/ha	*System cost (¢)*	
Main Pipe Lines		*1250.00*
Lateral Pipe Lines		*1000.00*
13 Rotating Impeller Sprinkler		*156.00*
A 50mm diameter Centrifugal Pump		*260.00*
Total		*2666.00*
Land Clearing/ha	*Operational cost (¢)*	*50.00*
Labour		
Cost/Person/Hour		*0.6000*
Cost/Person/Month		*100.80*
Cost/Person /Year (for 6 Month)		*604.80*
Repair & Maintenance		
Pump Repairs/year		*200.00*
Well Repairs/year		*25.00*
Cost of Electric Power Consumed		
Pumping Cost/ha/Month		*50.00*
Pumping Cost/ha/Year		*300.00*
Total		*1179.80*
Total Investment Cost		*4095.80*

It is obvious that the same element data are available in both the electric and wind-powered technology. Under the wind powered technology, the total capital cost is also ¢260.00. A total of ¢7473.00 was invested as the system cost under this technology. The system cost included drip materials, 11 m^3 water storage tank and the windmill. The overall cost of the drip materials/ha was ¢3000.00 and that of the water storage tank was ¢1323.00. The windmill was purchased at the total cost of ¢3150.00. This cost included a clearance charge of 2% of the purchasing price of $3500.00 (US).

Table 2. Wind powered (drip) system

Element data		
A hectare of land/annum	*Capital cost (¢)*	*25.00*
A borehole		*100.00*
Vegetable seedling/ha		*125.00*
Total		*250.00*
Drip materials/ha (main & lateral lines, emitters and filters)	*System cost (¢)*	*3000.00*
11 m^3 water storage system		*1323.00*
Windmill		*3150.00*
Total		*7473.00*
Land clearing (pouching)/ha	*Operational cost (¢)*	*50.00*
Windmill installation		*6.00*
Reservoir installation		*100.0*
Labour		
Cost/person/hour		*6000.00*
Cost/person/month		*100.80*
Cost/person /year (for 6 months)		*604.80*
Repair & maintenance		
Pump repairs/year		*0*
Well repairs		*25.00*
Cost of electric power consumed		
Pumping cost/acre/month		*0*
Pumping cost/acre/year		*0*
Total		*839.80*
Total Investment Cost		*8562.80*

The operation cost of the windmill system encompassed the following elements: land clearing (plowing), windmill installation, reservoir installation, labor and repair and maintenance cost. Labor cost included the expenditure on a laborer per working season (6 months) per year. Repair and maintenance included borehole repairs. Only a small or no amount of money may be spent on the repair of the windmill. From Tab. 2, cost of land clearing (plowing) per hectare, windmill installation and reservoir installation are shown. Total cost of labor per working season (6 months) per year is ¢604.80. The overall cost of operations of this system of farming was ¢839.80. The total investment cost of the wind powered (drip) technology was ¢8562.80.

Assessment of the Financial Performance of Farmers

Profitability ratio is used to critically assess the performance of most farmers who are involved in using the electric power for irrigation compared the wind powered (windmill) technology. The Fig.2 is a graphical representation of the financial performance of farmers against the corresponding farm size in hectares cultivated.

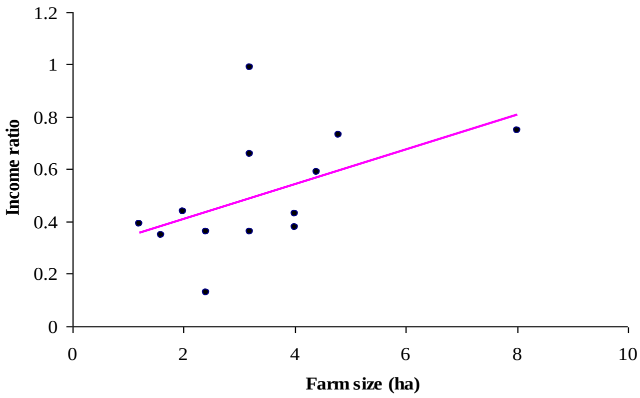

Figure 2. A graph of income ratio against farm size

Fig. 2 illustrates the relationship between the income ratio and the farm size. An indication of correlation coefficient, r = 0.503 proved that there is a strong positive relationship between the income ratio and the farm size. Correlation coefficient, r, also known as Pearson product moment correlation coefficient (PPMC) from a sample data is the measure of the strength and direction of a linear relationship between two variables [8]. From Fig. 2, a larger farm size correlate with a larger income ratio. The income ration 0.38, 0.35, 0.44, 0.99, 0.63, 0.39, 0.75, 0.59, 0.73, 0.66 and 0.43 clearly presupposed that there is significant amount of income generated per farm size.

Table 3. Demonstration of the relationship between income ratio and farm size

Farm size, F (ha)	*Income ratio, IR*	*FIR*	F^2	IR^2
4	0.38	1.52	16	0.1444
1.6	0.35	0.56	2.56	0.1225
2	0.44	0.88	4	0.1936
3.2	0.99	3.168	10.24	0.9801
3.2	0.63	2.016	10.24	0.3969
2.4	0.13	0.312	5.76	0.0169
1.2	0.39	0.468	1.44	0.1521
8	0.75	6	64	0.5625
4.4	0.59	2.596	19.36	0.3481
4.8	0.73	3.504	23.04	0.5329
3.2	0.66	2.112	10.24	0.4356
4	0.43	1.72	16	0.1849
2.4	0.36	0.864	5.76	0.1296
$\sum F=44.4$	$\sum IR= 6.83$	$\sum FIR= 25.72$	$\sum F^2= 188.64$	$\sum IR^2= 4.2001$

Unlike the electric pump, the wind pump has a life span of 30 – 50 years. One wind pump can be used efficiently and effectively for several years to serve not less than 5 ha of farmland. In this regard farmers who engaged the use of wind pump would not have to border their heads on the purchase of more wind pump every farming season. The purchase, installation and repairs of water storage reservoirs, the drip materials and cost of drilling boreholes are non-perennial/non-seasonal practices since the already purchased and installed items can serve their purpose for several years. Elements such as the wind pump and the water storage reservoir have their service life longer than 5 years compared to the electric powered system where the life span of the centrifugal pump is not more than 5 years. A non-consideration of the fixed system costs (drip materials, windmill, water storage tank and installations) would bring the total investment cost of the wind powered system considerably down from ¢8562.80 to ¢929.80 as indicated on the Tab. 4.

The correlation coefficient, r is calculated as follows:

$$r = \frac{n\left(\sum FIR\right) - \left(\sum F\right)\left(\sum IR\right)}{\sqrt{\left[n\left(\sum F^2\right) - \left(\sum F\right)^2\right]\left[n\left(\sum IR^2\right) - \left(\sum IR\right)^2\right]}}$$

$$= \frac{13(25.72) - (44.4)(6.83)}{\sqrt{\left[13(188.64) - (44.4)^2\right]\left[13(4.2001) - (6.83)^2\right]}} \tag{1}$$

$$= \frac{31.108}{61.8449}$$

$$\therefore r = \underline{\underline{0.503}}$$

Table 4. Subsequent seasonal cost analysis of the wind powered system

Element data		
A hectare of land/annum	*Capital cost (¢)*	*25.00*
A borehole		*100.00*
Vegetable seedling/ha		*125.00*
Total		*250.00*
Drip materials/ha (main & lateral lines, emitters and filters)	*System cost (¢)*	*0.00*
11 m^3 water storage system		*0.00*
Windmill		*0.00*
Total		*0.00*
Land clearing (pouching)/ha	*Operational cost (¢)*	*50.00*
Windmill installation		*0.00*
Reservoir installation		*0.00*
Labour		
Cost/person/hour		*0.60*
Cost/person/month		*100.80*
Cost/person /year (for 6 months)		*604.80*
Repair & maintenance		
Pump repairs/year		*0.00*
Well repairs		*25.00*
Cost of electric power consumed		
Pumping cost/acre/month		*0.00*
Pumping cost/acre/year		*0.00*
Total		*679.80*
Total Investment Cost		*929.80*

A difference of about ¢3166 is saved compared to the practice of the electric powered technology.

Studies show that the Poldaw windmill locally manufactured in Ghana by MoFA could be purchased at the cost of ¢5000 [6]. This seemed a huge expense for a single farmer to bear. In a more reasonable and economically strategic way, co-operative groups could be formed by the local farmers in a group of ten for instance. These co-operative groups could purchase the windmill by way of individual contributions, accessing bank loans, or by any other governmental or nongovernmental assisted funds to that effect.

CONCLUSIONS

Although the electrically powered system has gained ground in the communities, many farmers are unable to use the technology. Some of the problems they face are the high cost of electric power consumptions, instability of the system as a result of the on-going intensive power rationing exercise and the short service life of the centrifugal pumps (2 to 5 years). In general, the relatively high investment cost deters most farmers from fully embracing the practice.

Recommendations. The high system cost (GH¢7473) of the windmill technology seemed to prevent most farmers from considering the wind as an alternative source of energy for vegetable production. To overcome this fear, it is recommended that farmers form co-operative societies, so they can purchase the locally manufactured Poldaw wind pump at a current cost of ¢5000. For economic and agronomic reasons, the system of irrigation which reduces strain on the part of farmers and moreover, boosts the income generation of both the farmers and the manufacturers of the irrigation materials is the wind powered technology. This technology is also environmentally friendly.

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UPOREDNE PERFORMANSE PUMPI ZA NAVODNJAVANJE NA ELEKTRIČNI I VETRO POGON

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Sažetak: Tehnologija energije vetra može da postane najbolja alternativa hidro električnom pogonu pumpi za navodnjavanje određenih delova Gane tokom sušne sezone. Ovaj rad se bavi ocenom performansi pumpi sa vetro i električnim pogonom kroz ogled u kome se uporedno ispituju investicioni troškovi rada pumpnih sistema sa ova dva pogona u oblasti Keta, koji ima najbolje režime vetra u Gani. Farmeri u ovim obalnim zajednicama su pokušali upotrebu vetro-pogona za vodene pumpe, ali sa velikim inicijalnim troškovima. Uprkos visokim troškovima, farmer mogu da osnuju kooperative da bi pokrenuli system pumpi sa vetro-pogonom. Visoka cena električne energije koju plaćaju svakog meseca odvraća većinu farmera od upotrebe hidro-električne tehnologije za pumpanje. Ukupna investicija kod farmera koji su koristili elektro pogon je iznosila ¢4095.80 po hektaru, dok je kod farmera koji su koristili vetro pogon u svakoj sezoni investicija iznosila ¢929.80 po hektaru. Razlika od ¢3166.00 se može uštedeti i upotrebiti za druge namene.

Ključne reči*: vetar, električna struja, pumpe, navodnjavanje, energija, performanse*

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OCENA EMISIJE GASOVA S EFEKTOM STAKLENE BAŠTE LANCA SNABDEVANJA KUKURUZOVINE

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Sažetak: U okviru istraživanja su, za različite scenarije lanca snabdevanja kukuruzovinom namenjene za proizvodnju biogasa, određene vrednosti emisija gasova s efektom staklene bašte i ocenjen njihov uticaj na doprinos globalnom zagrevanju. Osnovna razlika između scenarija proizilazi iz načina ubiranja kukuruzovine i to silažnim kombajnom i formiranjem velikih četvrtastih i valjkastih bala. Ustanovljeno je da se lanac snabdevanja sa primenom silažnog kombajna rezultuje najvišom vrednošću uticaja, koja iznosi 70 i 85 kg $CO_{2\ ekv}\ Mg_{SM}^{-1}$, za visok i nizak prinos kukuruzovine respektivno. Za lanac sa ubiranjem u formi četvrtastih bala, te vrednosti iznose 62 i 68 kg $CO_{2\ ekv}\ Mg_{SM}^{-1}$, a za valjkaste bale 61 i 67 kg $CO_{2\ ekv}\ Mg_{SM}^{-1}$. Od analiziranih gasova s efektom staklene bašte, dominantan uticaj ima ugljen-dioksid. Smanjenje prinosa kukuruzovine, usled suše, nepovoljno se odražava na lanac snabdevanja, pre svega zbog dužine puta pri ubiranju i transportu.

Ključne reči: *kukuruzovina, biogas, gasovi s efektom staklene bašte, LCA*

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Projekat "Razvoj malih biogas postrojenja – doprinos održivom razvoju ruralnih oblasti u AP Vojvodini", finansiran od Autonomne pokrajine Vojvodine, Pokrajinski sekretarijat za nauku i tehnološki razvoj

UVOD

Korišćenje obnovljivih izvora energije (OIE) poput biogasa, podstiče se sa ciljem smanjenja zavisnosti društva od fosilnih goriva, kao i smanjenja negativnih uticaja na životnu sredinu. Jedna vrsta negativnog uticaja su emisije gasova koji doprinose efektu staklene bašte (*Greenhouse Gases - GHG*). Brojne ocene uticaja emisija GHG pri proizvodnji biogasa ukazuju na manji uticaj u poređenju sa uticajem konverzije energije iz fosilnih goriva [9], te je podsticanje ove tehnologije opravdano. U okviru samog ciklusa proizvodnje biogasa, značajan doprinos krajnjim vrednostima uticaja ima deo koji se odnosi na, uslovno rečeno, proizvodnju supstrata, tj. lanac snabdevanja supstratom. Tako se uticaj emisija GHG pri proizvodnji biogasa iz otpadnih materija karakterišu povoljnijim vrednostima u odnosu na, recimo, proizvodnju iz energetskog bilja [8], pri čemu izbor vrste otpadne materije takođe može značajno da utiče. U [1] utvrđeno je da korišćenje slame u poređenju s otpadnim materijama poput organske frakcije komunalnog otpada, ima povoljnije vrednosti u pogledu uticaja emisija GHG. Korišćenje kukuruzovine za proizvodnju biogasa je i dalje u razvoju, usled čega nije objavljena ni jedna referenca gde se proizvodnja biogasa iz kukuruzovine ocenjuje u pogledu uticaja emisije GHG na principima ocene životnog ciklusa (*Life Cycle Assessment – LCA*). Takva ocena podrazumevala bi da se u okviru životnog ciklusa razmotri i lanac snabdevanja kukuruzovine. U literaturi je identifikovano svega nekoliko ocena lanca snabdevanja kukuruzovine, ali u sklopu životnog ciklusa proizvodnje bioetanola. Primer predstavlja [15] gde autori, u okviru lanca snabdevanja kukuruzovine razmatraju samo ubiranje i odnošenje hraniva čime izostavljaju druge faze, poput transporta, koje mogu imati značajan uticaj na vrednost uticaja emisija GHG. Predmet istraživanja [4, 6] je metodski pristup u okviru ocene životnog ciklusa bioetanola iz kukuruzovine, tačnije princip primene alokacije u okviru lanca snabdevanja kukuruzovine. Karakteristično za navedene reference je što ne razmatraju mogućnosti da sam lanac snabdevanja kukuruzovine može biti organizovan tako da, na primer, uključuje upotrebu različitih vidova mehanizacije pri ubiranju. Na taj način izostaje uvid u to da li su izborom lanca snabdevanju moguća unapređenja u pogledu emisije GHG. Takođe, jedino se u [15] u okviru senzitivne analize razmatraju drugačije vrednosti prinosa kukuruzovine utvrđujući da ne postoji značajna razlika. Međutim, usled nedovoljnog objašnjenja samog metodskog pristupa, uticaj prinosa kukuruzovine na emisije GHG ostaje nepoznanica.

Cilj ovog rada je da se oceni uticaj emisije GHG različitih lanaca snabdevanja kukuruzovine namenjene za proizvodnju biogasa na globalno zagrevanje. Zadatak je da se primeni ocenjivanje na principima LCA, definisanim u [18, 19]. Takođe treba da se utvrdi smanjenja prinosa kukuruzovine.

MATERIJALI I METODE RADA

Osnove ocene uticaja emisije GHG

Lanac snabdevanja kukuruzovine, čija je funkcija obezbeđivanje sirovine za proizvodnju biogasa, obuhvaćen je granicama sistema i predstavlja predmet ocene uticaja emisije GHG na principima LCA. Funkcionalna jedinica u okviru sistema definisana je kao 1 Mg_{SM} (*suva materija – SM*) kukuruzovine. Lanac snabdevanja obuhvata sledeće faze: formiranje zboja tokom ubiranja zrna, ubiranje, odnošenje hraniva u sastavu kukuruzovine, utovar i uskladištenje, transport, skladištenje, priprema za preradu. Na ovaj način obuhvaćeni su svi postupci koji se odnose na kukuruzovinu do momenta kada počinje priprema za proizvodnju biogasa. Gajenje kukuruza nije uključeno u granice sistema, kao kod sličnih ocena [4, 6], te nije bilo potrebe za korišćenjem alokacije, jer je kukuruzovina smatrana za otpadni tok pri proizvodnji zrna. Granicama su obuhvaćeni i procesi karakteristični za materijalne ulaze koji se odnose na energiju za proizvodnju goriva, mineralnih hraniva, potrošnog materijala, ali i materijalne ulaze poput mehanizacije i skladištenog prostora.

Za definisanje materijalnog toka, korišćene su vrednosti prinosa kukuruzovine pri različitim agro-klimatskim uslovima u Vojvodini i to u uslovima umerene suše i ekstremne suše, uz ravnotežni sadržaj vlage kukuruzovine, preuzete iz [3]. Korišćene su vrednosti ukupnog prinosa kukuruzovine, 10,8 i 5,3 $Mg_{SM}\,ha^{-1}$, za uobičajene i redukovane prinose u Vojvodini/Srbiji.

U okviru inventarisanja, razmatrane su emisije sledećih GHG: ugljen-dioksida, azot-suboksida, sumpor-heksafluorida, azot-trifluorida, nemetanskih volatilnih organskih jedinjenja (NMVOC) i metana. Sprovedena je ocena u odnosu na kategoriju uticaja „globalno zagrevanje“, a rezultati su iskazani u vidu kg $CO_{2\,ekv}\,Mg_{SM}^{-1}$ kukuruzovine. Kao metod za ocenu uticaja emisija GHG, korišćen je „*CML2001 - Apr. 2013, Potencijal globalnog zagrevanja (GWP 100 Godina), bez biogenog ugljenika*“. Ocena je sprovedena korišćenjem softvera *GaBi 6*.

Definisanje lanca snabdevanja

U okviru istraživanja, pri formiranju inventara LCA, jednog od koraka u okviru LCA, definisano je kakvu formu lanac (lanci) snabdevanja kukuruzovine treba da imaju. Procesi od interesa i karakteristični tokovi u okviru modela korišćeni su iz baze podataka Ecoinvent 2.2 i GaBi professional + Extension database 12. Ukoliko je bilo potrebno, identifikovani procesi od interesa prilagođeni su tako da odgovaraju definisanom scenariju, a te vrednosti navedene su u radu. Ukoliko procesi od interesa nisu identifikovani u okviru pomenutih baza podataka, pristupilo se njihovom definisanju pri tome prateći princip objašnjen u [7].

Pri definisanju lanca snabdevanja kukuruzovine, vođeno je računa da smanjenje produktivnosti pri žetvi zrna ne sme da je više od 10 %; povećanje gubitaka zrna ne sme da je više od 0,5 %; povećanje sadržaja pepela kukuruzovine ne sme da je više od 5 %. Na pomenute zahteve, faze u okviru lanca snabdevanja koje imaju uticaja su formiranje zboja i ubiranja kukuruzovine. Analizom dostupne literature [12, 13, 14, 16], u okviru koje se predlažu tri pristupa organizacije ovih faza: sa jednim prohodom, dva i više prohoda na polju, ustanovljeno je da postupak sa dva prohoda daje najpovoljnije rezultate u skladu sa postavljenim zahtevima, ali i u pogledu efikasnosti ubiranja kukuruzovine i potrošnje goriva. On podrazumeva da se u toku žetve zrna kukuruza, sprovodi i formiranje zboja, dok se u drugom prohodu sprovodi ubiranje kukuruzovine.

Za potrebe ocene, u okviru faze formiranja zboja pretpostavljena je primena tehničkog rešenja na kombajnu koji u toku žetve zrna formira zboj od usitnjene kukuruzovine [12, 16]. Potrošnja goriva pri žetvi zrna dodatno je uvećana za 32,7 % usled primene sitnilice žetvenih ostataka i *Cornrower*-a [16]. Međutim, kako se rad sitnilice žetvenih ostataka može smatrati za deo sistema gajenja kukuruza, praktično je u oceni korišćena samo potrošnja goriva za rad *Cornrower*-a za formiranje zboja. Od dodatne potrošnje goriva, 20 % je smatrano za posledicu rada *Cornrower*-a. Kako je inicijalna potrošnja kombajna oko 28 L ha^{-1} [20], proizilazi da je potrošnja goriva uslovljena radom *Cornrower*-a oko 2 L ha^{-1}.

U okviru faze ubiranja kukuruzovine razmatrana su tri načina ubiranja i to: korišćenjem silažnog kombajna, baliranjem velikih četvrtastih (u nastavku teksta koristiće se termin četvrtaste bale) i valjkastih bala [12, 13]. Pri ubiranju korišćenjem silažnog kombajna, za potrošnju goriva usvojena je vrednost 14,5 L ha^{-1} pri dužini sečenja od približno 6 mm, uz efikasnost ubiranja od 61 % [13]. Gustina ubrane kukuruzovine u vidu silaže u tom slučaju iznosi približno 68 kg_{SM} m^{-3} [10]. Kada je u pitanju baliranje, [10] navode različite gustine ubrane kukuruzovine u zavisnosti od sadržaja vlage, te se za potrebe ove analize usvaja da su gustine četvrtastih i valjkastih bala 110 i 90 kg_{SM} m^{-3} respektivno. Efikasnost ubiranja iznosi 41 %, a za dimenzije su usvojene vrednosti 120/90/260 cm, odnosno ϕ180/150 cm. Usled redukovanog prinosa, potrošnja goriva je korigovana za dodatnih 25 %, zbog dužeg puta za formiranje bala.

Ubiranjem kukuruzovine odnosi se količina hraniva koju je neophodno nadoknaditi, te se samim tim potrebna dodatna količina hraniva uključuje u granice sistema i u ukupni bilans emisije GHG uključuju emisije nastale kao posledica njihove nadoknade. Kako se smatra da azot sadržan u kukuruzovini nije lako dostupan biljkama tokom sledećih sezona [2], uzeto je u obzir da se praktično odnose samo fosfor i kalijum u formi aktivnih materija. Vrednosti odnošenja fosfora i kalijuma u formi P_2O_5 i K_2O iznose 2,35 odnosno 14,0 kg Mg_{SM}^{-1} kukuruzovine [2]. Pretpostavljeno je da se one nadoknađuju u formi jediničnog superfosfata i kalijum-nitrata.

Faza utovara i uskladištenja podrazumeva, u slučaju korišćenja silažnog kombajna za ubiranje, paralelno kretanje traktora sa silažnim kombajnom uz potrošnju goriva od 5 L h^{-1} [20]. U slučaju baliranja, ova faza podrazumeva rad na utovaru i istovaru bala.

Pri transportu kukuruzovine, razmatran je traktor sa prikolicom. U skladu sa načinom ubiranja, pretpostavljene su i različite nosivosti prikolica. Pri ubiranju u vidu silaže, pretpostavljen je transport silažnom prikolicom zapremine 35 m^3. U slučaju četvrtastih bala, pretpostavljeno je nošenje 15 bala (10 u prvom i 5 u drugom redu, paralelno postavljenih u odnosu na uzdužnu osu prikolice), a u slučaju valjkastih 14 (8 u prvom redu i 6 u drugom, normalno postavljenih na uzdužnu osu prikolice). Na taj način, ostvarene su nosivosti prikolica od 2,34, 4,65 i 4,76 Mg_{SM}, respektivno za pomenute forme ubrane kukuruzovine. Kao reprezentativno transportno rastojanje (radijus) usvojeno je 20 km, s tim što je pri redukovanom prinosu transportno rastojanje uvećano za dodatnih 20 %.

Za potrebe definisanja faze skladištenja kukuruzovine u slučaju njenog ubiranja u vidu silaže, usvojeno je skladištenje u silo jami dimenzija 30x18 m, sa dva bočna zida visine 3 m i debljine 0,2 m, izrađenih od armiranog betona sa zapreminskim udelom armatura od 5 %. Za korisnu zapreminu silo jame usvojena je vrednost od 70 % ukupne, a pretpostavljeno je da silaža nakon sabijanja traktorom ima gustinu od 80 kg_{SM} m^{-3}. Za debljinu donje ploče silo jame usvojeno je da je 0,2 m i smatrano je da je izrađena samo od betona. Takođe je pretpostavljeno korišćenje dve zaštitne poli-etilenske folije dimenzija 30x10 m, specifične mase 220 g m^{-2} [21]. Smatrano je da silo jama ima životni vek 20 godina, dok je za foliju usvojeno, na osnovu navoda proizvođača, 10 godina. U okviru faze skladištenja, pretpostavljen je i rad traktora koji sabija kukuruzovinu, pri čemu troši 6 L h^{-1} dizel goriva [20]. U slučaju ubiranja kukuruzovine u vidu četvrtastih bala, skladištenje je definisano na otvorenom uz korišćenje zaštitne cerade. Za oblik kamare usvojeno je ređanje bala u tri vrste sa po četiri bale po visini, uz jednu dodatnu balu u srednjoj vrsti radi formiranja krova, nagiba cerade [10]. Pretpostavljeno je korišćenje namenske cerade dimenzija 12,5x9,8 m specifične mase 130 g m^{-2} i veka trajanja 5 godina [21]. U slučaju ubiranja kukuruzovine u vidu valjkastih bala, usvojen je identičan vid skladištenja kao i kod četvrtastih, sa tim što oblik kamare ima formu piramide sa tri bale u prvom redu. Za potrebe ovog istraživanja usvojeno je da gubici SM, pri skladištenju za sve scenarije iznose 4 % od inicijalne vrednosti.

Faza pripreme za procesiranje kukuruzovine u slučaju ubiranja u formi silaže, podrazumeva transport traktorom sa prednjim utovarivačem zapremine kašike 1,6 m^3 i ukupnom trajanju te operacije od 3 minuta po jednom zahvatu uz potrošnju goriva od 5 L h^{-1} [20]. Kod ubiranja u vidu bala, transport traktorom podrazumeva korišćenje prednjeg utovarivača u vidu viljuške. S obzirom da je granicama sistema usvojeno da kukuruzovina treba da je u formi neophodnoj za procesiranje u fermentoru (ili opciono nekim vidom predtretmana), usvojena je dodatna operacija dezintegracija bala sa mašinom uz sitnjenje, uz potrošnju električne energije 11 kWh Mg_{SM}^{-1} kukuruzovine [5].

Kako su razmatrana tri načina ubiranja kukuruzovine i dve vrednosti prinosa, ukupno je ocenjivano šest scenarija za lanac snabdevanja kukuruzovine i to: UP-SK, RP-SK, UP-ČB, RP-ČB, UP-VB, RP-VB (UP–uobičajen prinos, RP–redukovani prinos; SK–silažni kombajn; ČB–četvrtaste bale; VB–valjkaste bale).

REZULTATI ISTRAŽIVANJA I DISKUSIJA

U okviru rezultata neće biti prikazani rezultati inventarisanja, već ocene uticaja emisije razmatranih gasova izraženim u vidu kg $CO_{2\,ekv}$ Mg_{SM}^{-1}. U tabeli 1 su date vrednosti za analizirane scenarije. Od razmatranih GHG, kao dominantan gas odgovoran na rezultate uticaja je ugljen-dioksid. Sa vrednošću uticaja između približno 55 i 80 kg $CO_{2\,ekv}$ Mg_{SM}^{-1} u zavisnosti od posmatranog scenarija, značajno je uticajniji od ostalih gasova poput npr. metana čija vrednost je oko 2,5 odnosno 3,5 kg $CO_{2\,ekv}$ Mg_{SM}^{-1}. Primetna je manja vrednost uticaja u slučaju metana za scenarije sa silažnim kombajnom koji su posledica manjih emisija metana usled nekorišćenja polietilenskih veziva kao u slučaju lanca snabdevanja sa baliranjem kukuruzovine. Azot-suboksid i NMVOC imaju još manji uticaj i vrednosti za oba gasa i analizirane scenarije ne prelaze 0,7 kg $CO_{2\,ekv}$ Mg_{SM}^{-1}. Emisije gasova poput sumpor-heksafluorida i azot-trifluorida registrovane su u tragovima, te u tabelu nisu unešene.

Posmatrano preko udela pojedinačnog gasa ukupnoj vrednosti ocene uticaja, emisije ugljen-dioksida odgovorne su za između 92 i 95 % ukupnog uticaja, zavisno od analiziranog scenarija. Uticaj emisije metana za sve razmatrane scenarije je niži od 6 %, dok je udeo emisija azot-suboksida i NMVOC-a nešto niži od 1 %.

Za ukupne vrednosti uticaja, scenario sa silažnim kombajnom karakteriše se višim vrednostima od scenarija sa baliranjem. Vrednost ocene uticaja za scenario sa korišćenjem silažnog kombajna i pri uobičajenom prinosu kukuruzovine iznosi približno 70 kg $CO_{2\,ekv}$ Mg_{SM}^{-1}, dok u slučaju redukovanog prinosa, ta vrednost raste za približno 20 % i iznosi oko 85 kg $CO_{2\,ekv}$ Mg_{SM}^{-1}. Približne vrednosti za scenarije sa drugačijim načinom baliranja ukazuju na mali značaj izbora načina baliranja. U slučaju uobičajenog prinosa, vrednost uticaja emisije GHG iznosi oko 61 kg $CO_{2\ ekv}$ Mg_{SM}^{-1}, odnosno 67 kg $CO_{2\ ekv}$ Mg_{SM}^{-1} pri redukovanom prinosu kukuruzovine.

Tabela 1 Uticaj analiziranih gasova, jedinjenja i ukupni, u kg $CO_{2\ ekv}$ Mg_{SM}^{-1}

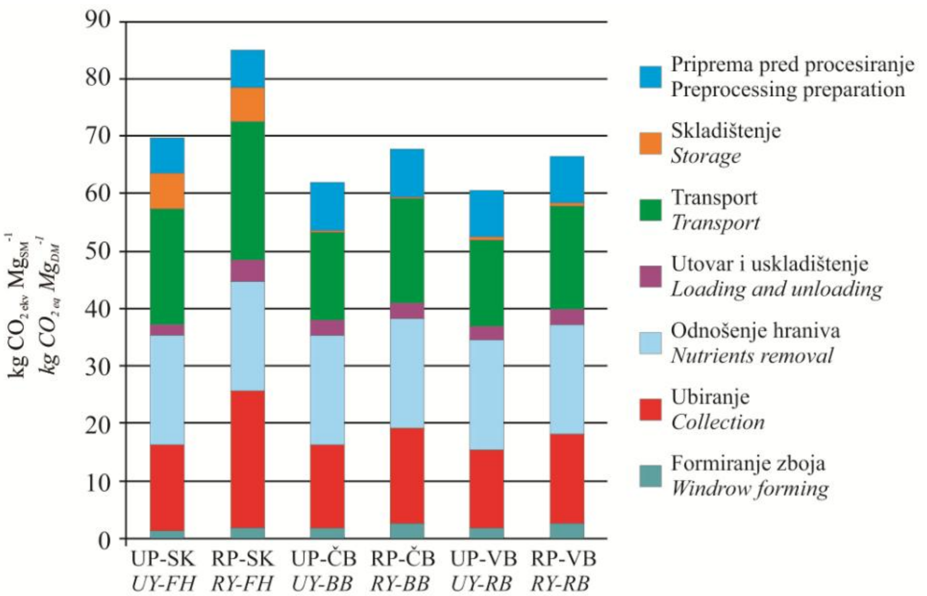
Table 1 Impac of analyzed gasses, compunds and total, in, kg $CO_{2\ eq}$ Mg_{DM}^{-1}

Jedinjenje *Compound*	Scenario *Scenario*					
	UP-SK *UY-FH*	RP-SK *RY-FH*	UP-ČB *UY-BB*	RP-ČB *RY-BB*	UP-VB *UY-RB*	RP-VB *RY-RB*
Ugljen-dioksid *Carbon dioxide*	66,2	80,7	57,4	63,1	56,2	61,9
Azot-suboksid *Nitrous oxide*	0,6	0,7	0,5	0,6	0,5	0,5
NMVOC	0,6	0,7	0,5	0,6	0,5	0,5
Metan *Methane*	2,4	2,8	3,5	3,6	3,4	3,6
Ukupno *Total*	69,7	84,9	61,9	67,8	60,6	66,5

UP – uobičajen prinos; RP – redukovan prinos; SK– silažni kombajn; ČB – četvrtaste bale; VB – valjkaste bale
UY – common yield; RY – reduced yield; FH – forage harvester; BB – big rectangular bales; RB – round bales

Posmatrano po pojedinačnim fazama u okviru lanca snabdevanja, faze ubiranja, odnošenje hraniva i transporta su dominantne, slika 1. U okviru faze ubiranja, emituje se oko 15 kg $CO_{2\ ekv}$ Mg_{SM}^{-1} pri svim scenarijima, dok je samo pri korišćenju silažnog kombajna pri redukovanom prinosu ta vrednost viša i iznosi oko 24 kg $CO_{2\ ekv}$ Mg_{SM}^{-1}. Razlog za to je generalno veća potrošnja goriva pri korišćenju silažnog kombajna u poređenju sa scenarijima sa baliranjem, te pri redukovanom prinosu to povećanje potrošnje ima primetan uticaj. Faza odnošenja hraniva odgovorna je za uticaj od približno 19 kg $CO_{2\ ekv}$ Mg_{SM}^{-1}. Pri transportu silaže, usled manje mase kukuruzovine koja se transportuje u poređenju sa balama, ostvaruje se i povećan uticaj emisije GHG usled veće potrošnje goriva za transport iste mase kukuruzovine. To povećanje iznosi oko 5 kg $CO_{2\ ekv}$ Mg_{SM}^{-1} kod scenarija sa uobičajenim prinosom, odnosno 9 kg $CO_{2\ ekv}$ Mg_{SM}^{-1} pri redukovanom. Transport valjkastih bala je sa vrednošću uticaja od približno 15 kg $CO_{2\ ekv}$ Mg_{SM}^{-1} najefikasniji vid transporta. Što se tiče ostalih faza, uticaj usled utovara i uskladištenja ne prelazi 3 kg $CO_{2\ ekv}$ Mg_{SM}^{-1}, a izvesno je povećanje uticaja pri utovaru silirane kukuruzovine pri redukovanom prinosu s obzirom na duže vreme potrebno da se prikolica napuni silažom. Pri skladištenju silirane kukuruzovine, usled korišćenja silo jame, odnosno građevinskih materijala, uticaj emisija GHG je veći nego pri skladištenju kukuruzovine u vidu bala. Emisije u okviru faze pripreme za procesiranje rezultat su potrošnje dizel goriva tokom rada traktora i potrošnje električne energije pri radu dezintegratora bala. Emisije usled potrošnje goriva su u slučaju silirane kukuruzovine veće u okviru ove faze zbog manje ostvarene nosivosti pri transportu kukuruzovine od mesta skladištenja do mesta procesiranja, u poređenju sa baliranom kukuruzovinom. Vrednosti uticaja su između 6 i 8,5 kg $CO_{2\,ekv}$ Mg_{SM}^{-1}, zavisno od posmatranog scenarija.

Izraženo u vidu međusobnog doprinosa pojedinačnih faza u okviru lanca snabdevanja kukuruzovine ukupnom uticaju, faze formiranja zboja i utovara i uskladištenja doprinose najmanje ukupnom uticaju. Te faze ne doprinose sa više od 4 % posmatrano pojedinačno za svaku fazu. Za sve načine ubiranja kukuruzovine, doprinos ukupnom uticaju faze ubiranja je približno isti i kreće se u opsegu od 22 do 24 %. Jedino se ubiranje silažnim kombajnom pri redukovanom prinosu karakteriše većom vrednošću koja iznosi 28 %. Transport se karakteriše najvećim udelom koji je između 25 i 30 %. Pri skladištenju silirane kukuruzovine, doprinos uticaju emisija GHG ove faze je oko 8 %, dok pri skladištenju doprinos nije veći od 1 %. U fazi pripreme pred procesiranje, pri baliranoj kukuruzovini, doprinos iznosi oko 13 %, a u slučaju silirane kukuruzovine svega oko 8 %.



UP – uobičajen prinos; RP – redukovan prinos; SK– silažni kombajn; ČB – četvrtaste bale; VB – valjkaste bale

UY – common yield; RY – reduced yield; FH – forage harvester; BB – big rectangular bales; RB – round bales

Slika 1. Ukupne vrednosti uticaja emisija GHG za analizirane scenarije

Figure 1. Total values of GHG emission impact assessment for analyzed scenarios

ZAKLJUČCI

Poređenjem vrednosti ocene uticaja za tri razmotrena lanca snabdevanja kukuruzovinom koji se razlikuju u načinu ubiranja kukuruzovine, primetno je da se baliranjem kukuruzovine ostvaruju povoljniji rezultati. Dominantan razlog za to je efikasniji način transporta ubrane kukuruzovine, odnosno veća nosivost koja je omogućena za baliranu kukuruzovinu. Kako je u ovom istraživanju korišćena jedna vrednost transportnog rastojanja, treba imati u vidu da bi njenim povećanjem emisije GHG bile značajno veće, te se time fazi transporta i njenoj optimizaciji mora pridati značajna pažnja ukoliko se teži scenariju sa što manjim vrednostima emisija GHG. Iako je na osnovu rezultata primetno da su i u fazi skladištenja emisije manje pri baliranju, skladištenje silirane kukuruzovine bez silo jame nego samo u vidu gomile ili eventualno u silažnim vrećama (ukoliko se pokaže da je to ekonomski opravdano), vrednost emisija se može značajno smanjiti. Unapređenja u okviru faze pripreme pred procesiranje, pre svega smanjenjem potrošnje energije bi logično bile poželjne, ali s obzirom na njihov mali doprinos ukupnim emisijama, ne bi značajno doprinele poboljšanju rezultata ocene uticaja emisija GHG. U okviru ostalih faza snabdevanja kukuruzovinom, zbog niskog doprinosa ukupnoj vrednosti ocene uticaja, unapređenja verovatno nisu moguća. Izvesno je jedino da bi korišćenje tehničkog rešenja *Cornrower* za formiranje zboja u pogledu emisija GHG bilo izuzetno povoljno. Nepovoljni agro-klimatski uslovi koji za rezultat imaju redukovanje prinosa kukuruzovine negativno utiču i na rezultate ocene uticaja emisija GHG, što treba imati u vidu pri razvoju strategija ubiranja kukuruzovine. Povećanje vrednosti uticaja pokazalo se manje u slučaju baliranja i iznosilo je oko 10 % u poređenju sa povećanjem u slučaju siliranja za koju je ta vrednost iznosila nešto manje od 20 %. Stoga je opravdano prednost pri planiranju strategija dati scenarijima koji podrazumevaju baliranje kukuruzovine.

Za nastavak istraživanja predlaže se, pored ocene uticaja emisija GHG, razmatranje i drugih kategorija uticaja na životnu sredinu. Kako je faza transporta kukuruzovine razmatrana samo za jedno transportno rastojanje, u okviru budućih istraživanja sprovešće se razmatranje uticaja transportnog rastojanja na krajnje rezultate ocene uticaja. Kao krajnji zadatak postavljeno je razmatranje celokupnog životnog ciklusa i posledičnih uticaja na životnu sredinu proizvodnje biogasa iz kukuruzovine.

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GHG EMISSIONS OF CORN STOVER SUPPLY CHAIN

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Abstract: Within this investigation, different scenarios for supply chains of corn stover intended for biogas production were evaluated in terms of emissions of the greenhouse gasses and their impact to global warming. A primary difference between the scenarios was due to application of different stover collection techniques i.e. forage harvester, baling of big rectangular and round bales. It was found that the supply chain, which includes the application of forage harvester for stover collection is characterized by the highest value of impact, approximately 70 and 85 kg $CO_{2\,eq}\,Mg_{DM}^{-1}$, respectively for the usual and reduced corn stover yield. For the supply chain which includes baling of big rectangular bales, these values are around 62 and 68 kg $CO_{2\,eq}\,Mg_{DM}^{-1}$, and for the baling of round bales, values are 61 and 67 kg $CO_{2\,eq}\,Mg_{DM}^{-1}$. Among the analyzed greenhouse gases emissions, the dominant impact is due to the emissions of carbon dioxide. The reduction of the corn stover yield, caused by extreme drought, is followed by higher GHG emissions, first of all due to longer distances during harvest and transportation.

Key words: *corn stover, biogas, GHG emissions, LCA*

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PRODUCTION OF BIOETHANOL FROM POTATOES WASTES AS AN ALTERNATIVE FUEL

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Abstract: Production of ethanol from biomass is one way to reduce both the consumption of crude oil and environmental pollution. The current research focused to produce the bioethanol from crop wastes. The study carried out in Agricultural Engineering Department and Agric. Botany Department at faculty of Agriculture, Kafrelsheikh University. The main objective in this part of the current study is producing the bioethanol from potato wastes to applicable in the engine of the farm machine. The experiment was carried out in aerobic batch digester and bioreactor after potato tubers wastes pretreatment with *Bacillus subtilis* (E34) as amylolytic bacteria for 7 days. The bioreactor system consists of three main units. The first unit was ethanol reactor which represents the main unit of the fermentation process and the second is the agitating unit required to enhance the fermentation process and to increase the efficiency of ethanol production for all treatments. Third unit is the collector tank; it is consisted of the 8 liters capacity tank with input and output valves. The output valve used to measure the pH values for different ethanol production. The 10 liters of water that was feeding in solution of potatoes wastes was heated to 30°C. Bioethanol fermentation was conducted in reactor. The yeast *Saccharomyces cerevisae* was used for fermentation process in dried form. The inoculum was used at 50 g from dried *Saccharomyces cerevisae* were used to inoculate 3 l from the pretreated potato wastes. The pH of the medium was adjusted to 4.5. All experiments were incubated at 30°C under different stirring speeds (30, 120 and 200 min^{-1}) in the reactor for 7 days. The values of the percentage of bioethanol production increased and reached to the maximum values after 18 hour of

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elapsed time for 30 min^{-1}, 120 min^{-1} and 200 min^{-1} agitation rotational speeds. The maximum values of bioethanol production percentage were 37.8%, 44.45% and 68.68% after 18 hour elapsed time for 30, 120, 200 min^{-1} respectively. On the other hand, the increase of agitation speed from 30 to 200 min^{-1} tends to increase the percentage of bioethanol production. The energy requirement of volume bioethanol production increased due to increase of the agitation speed from 30 min^{-1} to 200 min^{-1}. The highest value of energy requirement was 5.9 Wh at 200 min^{-1} after 24 hours for bioethanol production. The lowest energy requirement for agitation was 8.7 Wh at 30 min^{-1} after 2 hours. Bioethanol production increased and reached to 70.9% at 18 hour of duration time for bioreactor compared to 65% bioethanol percent after 18 days for batch reactor.

***Key words**: bioethanol, production, wastes, energy*

INTRODUCTION

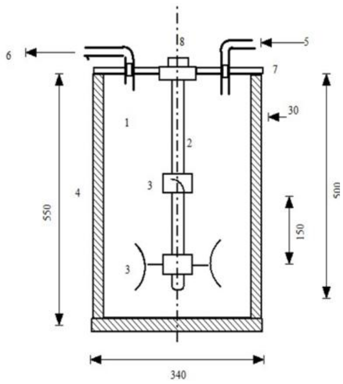
The alcohols such as methanol (CH_3OH), ethanol (C_2H_5OH), propanol (C_3H_7OH), and butanol (C_4H_9OH) can be used as alternate motor fuels. The combustion heats of alcohols are lower than those of hydrocarbons due to higher oxygen contents. Practically, any of the organic molecules of the alcohol family can be used as a fuel. However, only methanol and ethanol fuels are technically and economically suitable for internal combustion engines (ICEs) [3]. Ethanol has been used in Germany and France as early as 1894 by the then incipient industry of internal combustion engines. Brazil has utilized ethanol as a fuel since 1925. World production of biofuels is dominated by three countries or regions: the US 43%, Brazil 32% and, less so, the European Union 15% [4]. This will continue to be the case, not only because of respective government policies on biofuels addressing, to various degrees, climate change mitigation, energy security and rural development, but also because of the huge areas of productive land which are needed to provide biomass feedstocks for any significant biofuel production. [10] stated that the every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years.” However, fossil fuels were predominantly used for automobile transportation throughout the last century, obviously due to their lower production cost. As an automotive fuel, hydrous ethanol can be used as a substitute for gasoline in dedicated engines. Anhydrous ethanol, on the other hand, is an effective octane booster when mixed in blends of 5 to 30% with no engine modification requirement. [12] stated that potatoes are the second most used food in the world. Potatoes are starchy crops which do not require complex pre-treatments. [11] and [2] stated that although, it is also a high value crop, but 5 to 20% of crops that are waste potato by-products from potato cultivation could be utilized for bio-ethanol production. [20] indicated that moreover, during processing of potato, particularly in the potato chip industry, approximately 18% of the potatoes are generated as waste. Therefore, the waste from potato industry can also be utilized as growth media for the fermentation processes for the production of ethanol as it has high starch content. The wastes of potato industry are currently being utilized as animal feed. [16] stated that the starchy materials require a reaction of starch with water (hydrolysis) to break down the starch into fermentable sugars (scarification). Hydrolysis is carried out at high temperature (90 to 110°C);

however, at low temperatures, it is also possible and can contribute to energy savings. [17] showed that to convert starch into the fermentable sugars, either acid hydrolysis or enzymatic hydrolysis needs to be performed. Each has their own set of advantages and disadvantages for use. Enzyme hydrolysis is generally chosen even though high cost of enzymes and initial investment because of high conversion yield of glucose. [13] stated that however, production of ethanol from waste potato still needs to be optimized because limited research has been conducted about the utilization of potato waste for ethanol production. [6] showed that different wastes of potato industry can be a good carbon source for yeast during alcohol fermentation by studying waste from potato chips industry (98.67% total carbohydrate) and different potato cultivations (starch content in a range of 11.2% to over 19.3%), respectively. [1] stated that the biodiesel can be a good substitute as it is a renewable source and can be a partial diesel substitute to boost the farm economy; reduce uncertainty of fuel availability by efficiently using it in small portable engines in rural areas for agricultural work and make fuel availability to the farmers and self-reliant. [9] 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. [18] showed that the ethanol produced is obtained from agricultural or agriculture-related feed-stocks. Of these, sugar-based feed-stocks account for approximately 42%, and non-sugar feed-stocks (mainly starch-based ones) for about 58% of the ethanol volume produced. [8] showed that the hydrolysis inoculated with the best combination of nutrients and fermentation was carried out at various temperatures namely 25, 30, 35 and 40°C. Ethanol content in fermented samples was estimated after 48 h of incubation. The pH of hydrolysis was adjusted to different levels and it was fermented after supplementation with the best combination of nutrients after inoculating with 10% inoculum (v/v). The fermentation was carried out at 35°C for 48 h. [7] observed that production of ethanol by *S. cerevisiae* y-1646 was favored at 35°C temperature and reached its maximum value (5.29 $g \cdot l^{-1}$) after 36 h. At 37°C, ethanol production was reduced to 4.38 $g \cdot l^{-1}$. [15] observed that maximum ethanol content of 56.8 $g \cdot l^{-1}$ was recorded after 48 h of fermentation at 30°C. However, at temperature 35, 37 and 40°C, the corresponding values were 53.6, 50.0 and 46.0 $g \cdot l^{-1}$, respectively showing a decline with increase in temperature of fermentation.

MATERIAL AND METHODS

The experimental system consists of three main units after potato tubers wastes pretreatment with *Bacillus subtilis (E34)* as amylolytic bacteria for 7 days. The first unit was ethanol reactor which represents the main unit of the fermentation process and the second is the agitating unit required to enhance the fermentation process and to increase the efficiency of ethanol production for all treatments. Third unit is the collector tank; it's consisted of the 8 l capacity tank with input and output valves. The output valve used to measure the pH values for different ethanol production. Spectorphotometer Dr. Beruno LANGE GmbH type LPG 089 was used to measure the concentration of ethanol and its specification showed as follow. Fig. 6 showed Spectorphotometer. The pH meter

KEDID Ph/ORP-6658H was used to measure the pH value during the fermentation process to obtain the proper situation of fermentation. The reactor was manufactured in the laboratory of Agricultural Engineering Department, Kafr El Sheikh University. The dimensions of reactor were 28 cm diameter and 55 cm height that correspond 6 l. The cover of the reactor was made of a circuitous stainless steel with thickness of 1 mm. The cover of the reactor equipped with a hole as the outlet of the ethanol liquid. The cover was fixed in the reactor by 5 bolts. A rubber gasket was fitted between the cover and the vessel to provide an ethanol. However the system was isolated by Wool thermal with 30 mm thickness as shown in Fig. 1.



1-reactor, 2-main rotor of the agitator, 3-blades of the agitator 4-thinks of the isolator material, 5-inlet of biomass, 6-outlet of bio-ethanol, 7-caver from plastic and steel, 8-fixed point of the electric motor, 9-dimension with mm

Figure 1. The diagram of reactor to produce the bio-ethanol

Source of microorganisms

One bacterial strain (*Bacillus subtilis* (E34) as amylolytic bacteria) was obtained from prof. Dr. Elsayed B. Belal professor of agricultural microbiology, Dep. of Agric. Botany, Fac. of Agriculture, Kafrelsheikh University and these bacterial strains was isolated in previous study as efficient starch degrading bacterial strain [5]. B. *subtilis* (E34) was cultivated in nutrient liquid medium. 250 ml nutrient liquid medium was inoculated with 2 ml of a cell suspension of *B. subtilis (E34*) (nutrient broth medium, 108 cfu·ml^{-1}) was incubated at 30°C and 150 min^{-1} for 3 days. The cultures were incubated at 30°C and 150 min^{-1} for 3 days. Thereafter, 250 ml from bacterial strain culture (108 cfu·ml^{-1}) was applied on aqueous pretreated potato wastes (1kg of crushed potato wastes: 9 liters of water for 7 days under room temperature (28°C) in reactor.

Experimental and procedures

The current study was conducted to investigate of the ability of the potatoes waste as a source of bioethanol production. The crops waste industries in Egypt are the main source of environmental pollution. The main objective in this part of the current study is producing the bioethanol from potato wastes to applicable in the engine of the farm machine. The experiment was carried out in aerobic batch digesters. The 10 liter of water that was feeding in solution of potatoes wastes was heated to 30°C. Bioethanol fermentation was conducted in reactor. The yeast S. *cerevisae* was used for fermentation process in dried form. The inoculum was used at 50 gm from dried *S. cerevisae* were used to inoculate 3 liter from the pretreated potato wastes. The pH of the medium was adjusted to 4.5. All experiments were incubated at 30°C under different stirring speeds (30, 120 and 200 min^{-1}) in the reactor for 7 days. The ethanol content was measured after 7 days fermentation [5]. The samples were collected at different elapsed time: 2, 3, 10, 18, 23 and 24 hours, to detect and determine the concentration of bioethanol by using the photometer Dr. Beruno LANGE GmbH type LPG 089. The colorimetric method was used to detect the bioethanol as follows: 1 ml of the fermented wash was taken in 500 ml pyrex distillation flask containing 30 ml of distilled water. The distillate was collected in 50 ml flask containing 25 ml of potassium dichromate solution (33.76 g of $K_2Cr_2O_7$ dissolved in 400 ml of distilled water with 325 ml of sulphuric acid and volume raised to 1 liter). About 20 ml of distillate was collected in each sample and the flasks were kept in a water bath maintained at 62.5°C for 20 min. The flasks were coaled to room temperature and the volume raised to 50 ml. 5 ml of this was diluted with 5 ml of distilled water for measuring the optical density at 600 nm using spectrophotometer [5]. A standard curve was prepared under similar set of conditions by using standard solution of ethanol containing 2 to 14% (v/v) ethanol in distilled water and then ethanol content of each sample was estimated [21]. The experiment was conducted again without the use of the enzyme where it began the process of production after 15 days and continued until 30 days.

RESULTS AND DISCUSSION

The result focused on the bioethanol production from the crop waste specially the potatoes waste. Regarding to adding bacteria to activate the fermentation process in bioreactor, as well as reducing the time required for ethanol production (fermentation time or elapsed time). The result indicated that the highest values of ethanol production were obtained after eighteenth day's elapsed fermentation time in batch reactor. The ethanol production from batch reactor was produced without any edition of engineering treatment such as the agitation process under laboratory conditions. The increasing of fermentation time or elapsed time tends to increase the ethanol production. The fermentation time was 18 days that produced the maximum ethanol percentage values. On the other hand the production of ethanol after 18 days goes to decrease. This result may be due to decrease glucose that converts to ethanol as shown in Fig. 2. It noticed that production of the bioethanol process started after two hours from elapsed time with agitated at different rotational speed 120 min^{-1} and 200 min^{-1} as shown in Fig. 3. The values of the percentage of bioethanol production increased and reached to the maximum values after 18 hour of elapsed time for 30 min^{-1}, 120 min^{-1} and 200 min^{-1} agitation rotational speeds. The maximum values of bioethanol production percentage were 37.8%, 44.45% and 68.68% after 18 hours elapsed time for 30, 120, 200 min^{-1}, respectively. On the other hand, the increase of agitation speed from 30 to 200 min^{-1} tends to increase the percentage of Bio-ethanol production. The above result may be due to the effect of agitation system in bioreactor that tends to improve the distribution of the microorganisms during the fermentation process. During the 18 hours fermentation time, the bioethanol percent increased by increasing the duration time. On the other hand, after 18 hours of fermentation time the bio-ethanol percent tends to decreased. This result may be due to the toxic effect of ethanol on S. *cervesiae*. It could be recommended that the starch of potatoes most be feeding in the bioreactor to obtain the continually bioethanol production after 18 hours of fermentation time.

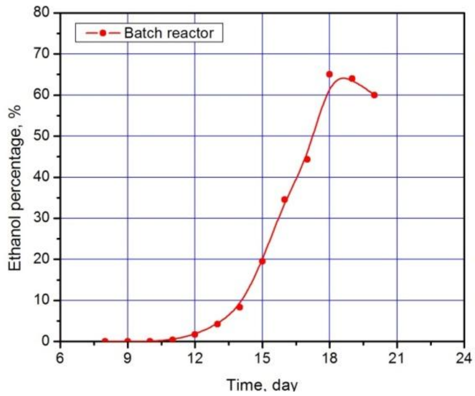


Figure 2. Effect of the fermentation time on ethanol production from batch reactor

Energy requirement for ethanol production

Fig. 4 presents that the effect of rotational speed for agitation system and operation duration time on the energy requirement for bioethanol production. It is clearly that, the energy requirement of volume bioethanol production increased due to increase of the agitation speed from 30 min^{-1} to 200 min^{-1} The highest value of energy requirement was 5.9 Wh at 200 min^{-1} after 24 hours for 10 letter media to produce bioethanol . The lowest energy requirement for agitation was 8.7 Wh at 30 min^{-1} after 2 hours. Theoretically, it could be calculated the maximum energy requirement for agitation to produce one ton of bioethanol, it may be about 0.84 $kWh \cdot t^{-1}$. Also, the energy requirement for heating one liter of water was 0.16 Wh. The energy requirement for pretreatment of waste potatoes was 0.3 $kWh \cdot kg^{-1}$. As well as the total energy to produce one ton of bioethanol under laboratory conditions may be around 1 kWh.

Comparison between bioreactor and batch reactor

Fig. 5 displays the ethanol percentage from bioreactor and batch reactor. It's clearly that Bio-ethanol production increased and reached to 70.9% at 18 hour of fermentation time for bioreactor compared to 65% bioethanol percent at 18 days for batch reactor. The bioreactor with agitation system and controlled temperature may be tends to produce the high values of ethanol production in short time compared the batch reactor. The highest values of the volume ethanol production increased due to increase the rotational speed of the agitation system. The highest percentage production of ethanol was 71% at speed of 200 min^{-1} for bioreactor.

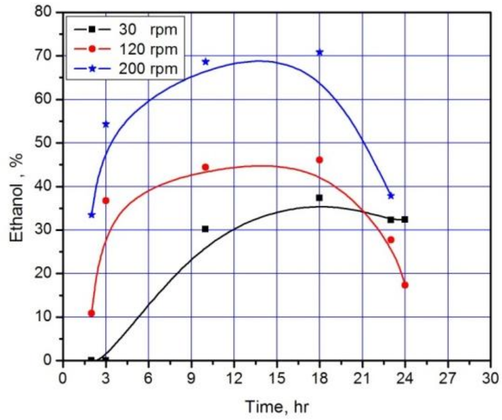


Figure 3. Effect of rotational speed of the agitation system and duration time on the ethanol percentage production

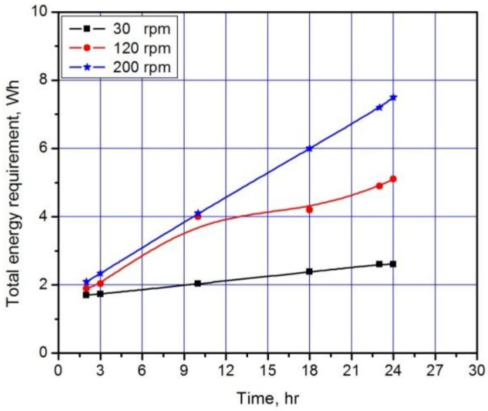


Figure 4. Effect of agitator rotational speed of motor and operation time on the energy requirement

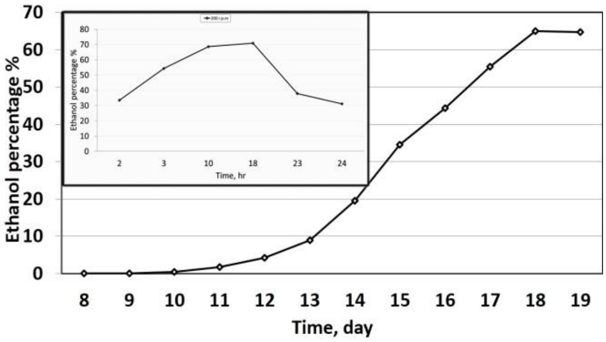


Figure 5. Ethanol percentage production from bioreactor and batch reactor

By comparing the elapsed fermentation time the bioreactor goes to reduce the elapsed time compared to the batch reactor. It noticed that the production of the bioethanol process from bioreactor started after two hours but the production of the ethanol process from batch reactor started after eleven days as shown in Fig. 5.

CONCLUSIONS

It could be summarized that the Bacilace E34 with agitated the potatoes starch tends to increase the ethanol production and reduce the fermentation time into the reactor. The above results may be due to the agitation made a good distribution of the E34 in the starch of potatoes. It's clearly that Bio-ethanol production increased and reached to 70.9% at 18 hour of fermentation time for bioreactor compared to 65% bioethanol percent at 18 days for batch reactor. The increasing of rotational speed tends to increase energy requirement to produce the bioethanol.

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PROIZVODNJA BIOETANOLA KAO ALTERNATIVNOG GORIVA IZ OSTATAKA KROMPIRA

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Sažetak: Proizvodnja etanola iz biomase je jedan od načina za smanjenje potrošnje sirove nafte i zagađenja okoline. Skorija istražuvanja se odnose na proizvodnju bioetanola iz biljnih ostataka. Ova studija je izvedena na Institutima za poljoprivrednu tehniku i poljoprivrednu botaniku Poljoprivrednog fakulteta Univerziteta Kafrelsheikh. Osnovni cilj ovog dela istraživanja je proizvodnja bioetanola iz ostataka krompira, koji će moći da se koristi u motorima poljoprivrednih mašina. Ogled je izveden u aerobnom digestoru i bioreaktoru posle prethodnog tretmana ostataka krompira amilolitičkom bakterijom *Bacillus subtilis* (E34) u trajanju od 7 dana. Sistem bioreaktora sastoji se od tri glavne jedinice. Prva je etanolski reaktor, u kome se odvija glavni deo procesa fermentacije. Drugi je aktivaciona jedinica koja pojačava fermentaciju i povećava efikasnost produkcije etanola u svim tretmanima. Treća jedinica je kolektorski rezervoar; on se sastoji od tanka kapaciteta 8 litara sa ulaznim i izlaznim ventilima. Izlazni ventil ujedno i meri pH vrednosti proizcedenog etanola. 10 litara vode, koja se dodaje u rastvor ostataka krompira, je zagrevano na 30°C. Fermentacija bioetanola je izvođena u reaktoru. Za fermentaciju je korišćen suvi kvasac, glivica soja *Saccharomyces cerevisae*. 50 g suvog *Saccharomyces cerevisae* je upotrebljeno za inokulaciju 3 litra prethodno tretiranog otpada krompira. pH vrednost je bila podešena na 4.5. U svim ogledima, inkubacija je na 30°C, pod različitim brzinama podsticanja (30, 120 i 200 min^{-1}) u reaktoru trajala 7 dana. Procentualne vrednosti produkcije bioetanola rasle su dostigle maksimume posle 18 časova pri aktivacionim brzinama rotacije od 30 min^{-1}, 120 min^{-1} i 200 min^{-1}. Maksimalne procentualne vrednosti produkcije bioetanola iznosile su 37.8%, 44.45% i 68.68% posle 18 časova, pri aktivacionim brzinama rotacije od 30, 120, 200 min^{-1}, redom. Sa druge strane, povećanje aktivacione brzine sa 30 na 200 min^{-1} ima tendenciju povećanja procenta produkcije bioetanola. Zahtevi za energijom pri proizvodnji veće zapremine bioetanola su se povećali zbog povećanja aktivacione brzine sa 30 min^{-1} na 200 min^{-1}. Najveća potrošnja energije bila je 5.9 Wh pri 200 min^{-1} posle 24 časa proizvodnje etanola. Najmanja potrošnja energije za aktivaciju bila je 8.7 Wh pri 30 min^{-1} posle 2 časa. Produkcija bioetanola porasla je i dostigla 70.9% posle 18 časova u bioreaktoru, u poređenju sa 65% bioetanola posle 18 dana u digestoru.

Ključne reči: *bioetanol, proizvodnja, otpad, energija*

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TEMPUS PROJECT PRESENTATION

Project title: BUILDING CAPACITY OF SERBIAN AGRICULTURAL EDUCATION TO LINK WITH SOCIETY Acronym: "CaSA"

Part 2. NEED ANALYSIS AND TRAININGS

544072-TEMPUS-1-2013-1-RS-TEMPUS-SMHES
(2013 – 4604 / 001 - 001)
Sub programme:
Structural Measures, Action Higher Education and Society

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INTRODUCTION

This is a presentation of the CaSA project and the role it plays in linking research and innovation with knowledge improvement in agriculture. CaSA is a national project, coordinated by The University of Belgrade, Faculty of Agriculture.

It belongs to the TEMPUS sub-program Structural measures and the Action Higher education and society. These two benchmarks point out what are the main objectives of the project: to improve quality and availability of vocational agricultural education; to strengthen competences of educators; to create a National Repository for Agricultural Education (NaRA) [3].

Basic course is strengthening links between higher education (HE) and society by building capacity of Serbian:

- University teachers from Faculties of Agriculture (FA)
- Agricultural secondary school (AMS) teachers
- experts in Extension services (ES)

to improve teachers' competences in pedagogic skills and provide in-service vocational training courses.

Specific objectives of the project are:

- SO1 - Improvement of quality and availability of vocational agricultural education
- SO2 - Strengthening of professional and pedagogical competences of educators
- SO3 - Creation of the "open source" repository for educators in the area of agricultural education

Creation of a National Repository for Agricultural Education (NaRA) - a repository for online courses and teaching resources to ensure project sustainability and networking of all stakeholders in agricultural education.

There are 13 partners contributing to the project, 10 Serbian and 3 EU partner institutions. Serbian partners are 5 agricultural faculties from Belgrade, Novi Sad, Kragujevac, Novi Pazar and Sremska Kamenica, as well as Association of Agricultural Middle School in the area of agriculture, food processing and food production, Institute for Science Application in Agriculture responsible for in-service training of agricultural advisors, 2 NGO training organization (Education Forum and Balkan Security Network) and the Ministry of Education, Science and Technological Development of the Republic of Serbia. EU partners are universities from Timisoara (Romania), Maribor (Slovenia) and Foggia (Italy)

All project activities are grouped into 11 work packages.

The project lasts for 3 years (01/12/2013 - 30/11/2016) and aims to build the capacity of main holders of Serbian agricultural education: university teachers, teachers in agricultural middle schools and agricultural advisors working in extension services.

The CaSA project's main achievement will be the creation of a NaRA, available as an electronic platform that should enable the sustainability of the project and connection of stakeholders involved in all levels of agricultural education and training in Serbia. This repository will include: information necessary for teaching traditional courses as well as online courses for professional development of Agricultural Middle Schools and experts in extension services; databases of results obtained by research; selected and recorded classes of interactive teaching; selected parts of courses realized and/or developed within the project, prepared in the form of online video tutorials and posted together with additional teaching contents; and other relevant contents added to the repository based on authorized decisions of the NaRA Advisory Board.

All project participants have agreed and signed the Constituent agreement on project implementation and NaRA management.

NEED ANALYSIS AND TRAININGS

Those issues were structured through a lot of activities in different work packages. In the following part are presented the activities, including planned and realized deliverables.

WP 2 - Infrastructural support for NaRA functioning / Development of resources
WP leader, project secretary: Goran Topisirović, UB, Belgrade, Serbia

A2.2. Training of IT administrators at every faculty/university for maintenance of the platform

Training of 5 IT administrators from every faculty was planned, to be trained in Belgrade by EF expert Milos Bajcetic for managing and using Moodle e-Learning software and maintaining distance learning platforms, as well as solving typical problems of users.

IT administrators were trained on May 22nd and 23rd 2014 at the Faculty of Agriculture in Belgrade. Trainer was Milos Bajcetic, Education Forum expert for Moodle e-Learning software application, maintenance of distance learning platforms, solving typical problems of users, etc. 5 IT responsible persons from each university/faculty and IPN were present and attended the training. The training included the following topics: 1st day - Moodle – Administration; Basics about Moodle LMS; Necessary infrastructure; Installation; Basic system settings; Users administration (identity check); 2nd day - Moodle - Administration II; Administration of courses; Courses structure and format; Sections and blocks; Activities and resources; Add-ons (plug-ins).

WP 3 - Improvement of competences of university teachers
WP leader: Ana Pešikan, EF, Belgrade, Serbia

A3.1. Training of university teachers in ATL

Active teaching/learning is an accredited teaching methodology created by experts from EF, applicable and adapted for both school and University level. It consists of 2 trainings: basic and supervision seminar, between the two - a period of at least 30 days is needed, since in that period EF experts analyze teaching scenarios and give advices for improvement, thus preparing the second seminar. 60 university teachers from all 5 Universities will be trained in ATL. They will be trained in 2 groups

The activity started by construction of two questionnaires on academics beliefs about the nature of learning/teaching process. As foreseen in CaSA application this activity started with the basic ALT seminars (in Belgrade and Cacak) followed by a supervisory training (in Novi Sad and Novi Pazar), held at least a month after the basic, in the meantime assignments given to participants were analysed and corrected. The training was realized in 2 groups: one group consisted of UTs from Belgrade and Novi Sad and the second of UT from Educons, SUNP and UNIKG. 65 UTs were trained.

A3.2. Training of university teachers in academic skills

In continuation of the 2nd ATL seminar, on the 4th day University teachers will be trained in academic skills: how to conduct quality research, prepare a project proposal and good quality research paper, how to present research results and other academic skills. 60 university teachers from all 5 Universities will be trained in academic skills.

Two courses for university teachers were held as follows: at Novi Sad University targeting academics from University of Novi Sad, Belgrade and several from Educons; at Novi Pazar State University (targeting academics from University of Novi Pazar, Kragujevac (Cacak) and Educons University. The courses covered scientific writing, presentation skills and project proposal writing.

A3.3. Training of university teachers in methodology of creating vocational courses in e-Learning format

University teachers (UT) will be trained to create vocational courses in eLearning format using Moodle software. This training will be held for 3 days in face to face format and additional 2 days online training. They will be trained together with AMS teachers, at each University both university teachers and AMS teachers will be trained simultaneously at Universities: at UB (15 UT+12 AMS), UNS (15 UT+12 AMS), SUNP (10 UT+12 AMS), UNIKG (10 UT+12 AMS), EDUCONS (10 UT + 12 AMS) i.e. 5 groups.

This activity was held and completed by the end of 2014. As planned UTs and secondary school teachers (AMS) teachers were trained together. AMS teachers were divided in 5 groups and each training was held at 5 Serbian agricultural faculties. In total 122 AMS and UT were trained.

WP 4 - Modernization of teaching contents
WP leader: Snežana Tanasković, UNIKG, Čačak, Serbia

A4.1. Need analysis for knowledge refreshment

Report on the analysis of the needs for knowledge refreshment. This will require questionnaires preparation (will be done by BSN and ME, with assistance of IPN and AMS), their distribution (done by IPN and AMS), and finally analysis before report preparation (done by BSN and ME).

The activity started by the study visit to UM. Three representatives of the Institute for Science Application in Agriculture (IPN) and one representative of the Ministry of Education, Science and Technology Development (ME) participated in the Study visit to Faculty of Agriculture and Life Science, University of Maribor to compare experience in extension services and eLearning practices as well as other aspects of agricultural education and help Serbian partners in defining TNA.

Two detailed and broad questionnaires for training needs analysis for two target groups (secondary school teachers and advisors) were prepared in collaboration with project partners.

The registration on a website is needed to access the questionnaires that are in Serbian language. The results of the TNA for 2 groups: advisor and AMS teachers were presented in January 2015 at the workshop in Cacak. Response rate was high. Results were analysed with the assistance of IPN. Results were discussed with the participation of all beneficiaries at the meeting in Cacak which served for fine tuning of the final version of the TNA report. It was discussed to what extent TNA can be useful to training providers and to what extent should be complimented by other information sources. Also, a potential to further develop TNA as a service to NaRA users was elaborated. One of the conclusions of the discussion was that the skill gap assessments in Agriculture on national level is missing and that practice of conduction TNA regularly can contribute to the development of Agricultural education policy in general. Due to the need to strengthen the role of EU partners at the project, it was decided to send the results of TNA, after being presented at the Cacak workshop to EU partners who gave their comments in a form of external review. The final document is prepared. TNA is a comprehensive and detailed document of 42 pages. The SC agreed that TNA will be the first brochure to be published in CaSA, and is available for download on NaRA. The whole brochure “Need analysis for knowledge refreshment of agricultural school teachers and extension service advisors in agriculture” can be found at http://arhiva.nara.ac.rs/handle/123456789/582.

WP 5 - Improvement of competences of AMS teachers
WP leader: Vidoje Vukašinović, AMS, Požarevac, Serbia

A5.1. Training of AMS teachers in ATL

The already explained active teaching/learning consists of 2 trainings: basic and supervision seminar, between the two - a period of at least 30 days is needed, since in that period EF experts analyze teaching scenarios and give advices for improvement, thus preparing the second seminar. 60 AMS teachers, 12 from 5 different AMS will be trained in ATL. They will be trained in 2 groups, according to the same training scheme as in 3.1.

Dates were decided in Cacak. Basic ATL seminars took place in February-March 2015 in Cacak and Sremska Kamenica. Supervisory ATL took place April 2015 in Novi Pazar and Sremska Kamenica.

A5.2. Training of AMS teachers in e-learning

60 AMS teachers will be trained in eLearning in 3 groups, together with university teachers as explained in 3.3.

Trainings was held in October - December 2014. AMS teachers trained with UT (Activity 3.3)

WP 6 - Improvement of competences of experts in extension services
WP leader: Snežana Janković, IPN, Belgrade, Serbia

A6.1. Training of agronomists in extension services in using e-learning platform

Agronomists, experts from extension services will be trained in using e-learning platform. They will be trained in 3 groups of 20 trainees, i.e. 60 agronomists will be trained in Belgrade.

A6.2. Training of agronomists in extension services in communication and project proposals preparation skills

Agronomists, experts from extension services will be trained in communication skills in order to acquire communication ability with farmers/ agricultural producers. They will also acquire project proposals preparation skills. This is foreseen as days 2 and 3 of the same Belgrade training that will start with the first day of using eLearning platform training. This training will be held by BSN and University professors.

IPN prepared, together with lecturers and submitted a detailed proposal for the module on e-learning and the module on communication and project proposals preparation skills to the Council for Agricultural Advisory and Applied Research of the Ministry of Agriculture and Environmental Protection for approval as one of the modules in the 2015 training plan for advisors. The proposal was accepted in December 2014.

According to the initial idea of the project, it was planned for 60 advisors from 34 Extension Offices to participate in the project (approximately two per station). IPN prepared a call and 69 advisors applied (list sent to project officer). Before the start of trainings 13 advisors more applied. Since increasing of number of advisors didn’t affected budget they were invited to participate. In total, 82 participants from 34 Extension were recruited and trained in three groups in March 2015 in IPN in Belgrade. They attended training and achieved activities 6.1 and 6.2. This is considered by the SC as added value of the project.

WP 8 - Quality assurance control of project activities
WP leader: Sofija Pekić Quarrie, SUNP, Novi Pazar, Serbia

A8.1. Development of questionnaires for training courses evaluation

A Report on the creation of the Quality Control Body created during the first gathering of all partners. This body will be responsible for monitoring project achievements.

Prof. Sofija Pekic Quarrie, WP8 leader led a Creation of the QC body at the Kickoff. It was decided that all trainings should be covered by questionnaires and their analyses; QA of vocational courses will be done by detailed peer review by EU experts. QA body monitoring and evaluation comprises: recruitment of teachers, training, feedback from trained AMS and ES. Selection of topics will be based on need analysis, TNA (ME representatives in the QA body). Members of the QC body were suggested and approved.

A8.2. Analysis of training courses feedback questionnaires

Questionnaires for training courses evaluation will be developed in 3 occasions during project lifetime. Questionnaires will be developed by 2 psychologists experts from EF and one from BSN.

Questionnaires were developed for University teachers (ATL, academic skills and e-learning), AMS teachers (ATL and e-learning), and advisors (project proposal preparation, communication skills and e-learning). Also, IPN has performed pre and post testing for all advisors, training participants.

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