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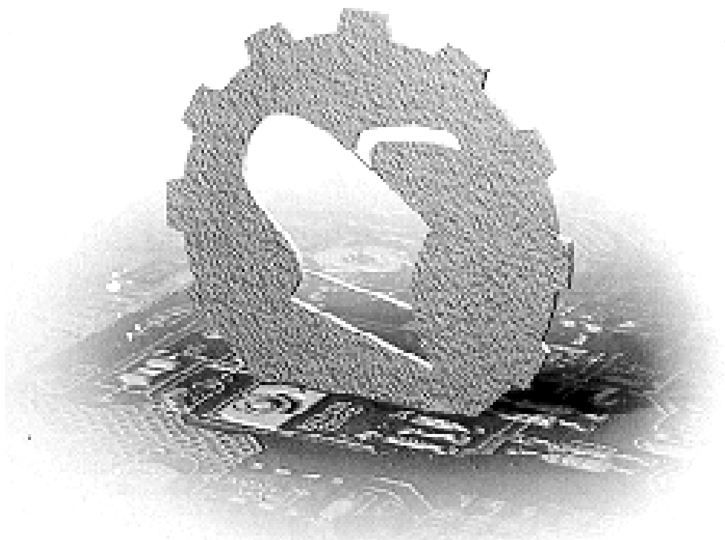

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ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
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THE IMPORTANCE OF MAKING A RATIONAL BUSINESS DECISION OF TOP MANAGEMENT IN AGRICULTURAL COMPANIES IN THE REPUBLIC OF SERBIA

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Summary: The importance of making a rational business decision by top management in agricultural enterprises should be viewed as an ongoing process. The process of rational business decision-making is of special importance for the business of companies that carry out most of their business in activities that do not have a high degree of capital turnover, i.e. in activities that depend on the great influence of natural factors on production such as agriculture. The authors point out that the process of making a rational business decision begins with making a valid management decision by top management. The implementation of a valid business decision in all parts of the company is of great importance to be implemented immediately because any delay in its implementation costs the company. The IT sector of the company can help speed up the implementation of the business decision of the top management, because it has the technical conditions to immediately include innovative business decisions in the business system in all sectors in the agricultural company. As a special support for the implementation of business decision-making is the previous adoption of a valid organizational scheme in the company.

Key words: *business decision making, IT, sector, enterprise.*

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INTRODUCTION

Top management in agricultural companies should have determination in terms of applying new business principles and innovative approaches in the business decision-making process [1], [2], [3]. Management processes by the top management should be based on the application of realistic and rational business decision making [4], [5] in all parts of the company.

This is of great importance when functionally connecting the sectors of enterprises that essentially have to function as one whole that will achieve an increase in production, turnover or services.

Functional improvement of business decision-making by top management has to link real control primarily in the processes of real agricultural production.

In addition, as part of the performance of other functions such as trade or when performing some kind of service by an agricultural company, the importance of making valid business decisions is noticed, because it achieves the end result on the market. In addition to making valid business decisions by top management, he can use and apply in his business a whole range of new methods by which he will be able to enable future business decision-making. Business decision-making is very much related to the application of numerous international standards [6], [7], [8].

Business decision-making is closely related to the establishment of online controls and internal audit in regular business processes [9], [10].

In addition, top management should adopt a general management plan in the company, i.e. business decision-making is followed by business management in an agricultural enterprise [11], [12], [13].

The goal of real and business decision-making based on valid decision-making is based on making valid business decisions that will enable better business results in the business of an agricultural company. Business decision-making affects the increase of business security within the regular business of agricultural companies.

In this paper, the authors draw attention to the importance of real decision-making and making real business decisions, which is of great importance for achieving the final results of business activities.

ESTABLISHMENT OF INTERNAL CONTROL IN AGRICULTURAL ENTERPRISES

The system of making business decisions by which the management of companies will be performed in a safe way inevitably leads to the implementation of internal control and internal audit in the regular operations of the company.

In order to establish systems to improve business decision-making in business, it is necessary to establish a system of internal controls and internal audits at all levels of management in the agricultural enterprise.

In the presentation in Figure 1, the authors presented some of the possible established control mechanisms by which it is realistically possible to improve the business of an agricultural enterprise.

The application of these solutions is possible in transition economies, which is of great importance, especially for countries moving towards accelerated development, such as the Republic of Serbia.

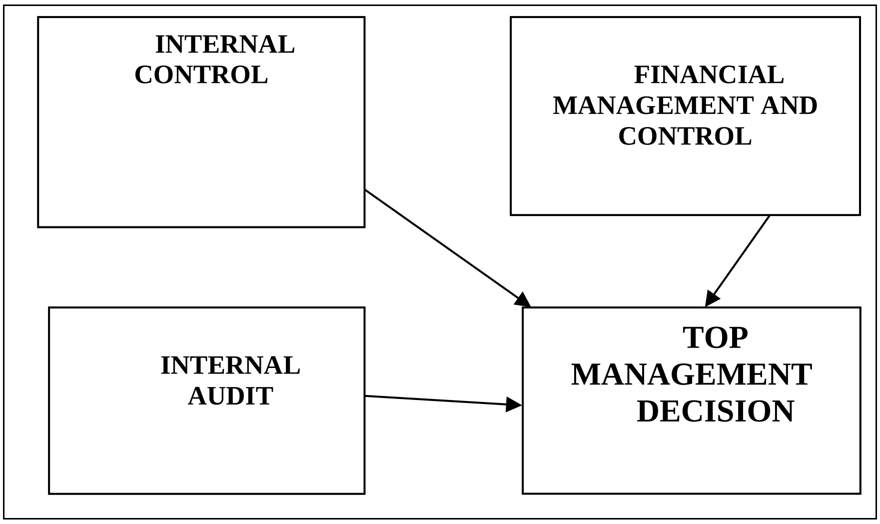

Figure 1. Development of software solutions in the system of "good practice" in agricultural enterprises

1. Review of the formation of one of the forms of control in the decision-making of an agricultural company in the Republic of Serbia

The formation of one of the forms of control in agricultural companies can also be shown through the influence on the decisions of the top management of the company through the formulas:

Formed Internal Audit + Impact of the work of internal audit = Decision of top management

FIA + IIA = TME (1)

Internal control formed + Influence of **internal control work = Decision of top management**

FIC + IIC = TME (2)

Formed financial management and control + Impact of work financial management and control = Decision of top management

FFMC + IFFMC = TME (3)

(where the symbols represent: (FIA = formed internal audit; FIC = formed internal control, FFMC = formed financial management and control).

2. Review of the formation of one of the forms of control in the decision-making of an agricultural company in the Republic of Serbia

The authors point out that based on the gradation, the introduction of 3 forms of internal control mechanisms can be observed, and therefore the gradation of the introduced forms can be performed.

1. **TME = IC** (initial level = implementation of internal control mechanisms in the company's business),
2. **TME = IA** (Intermediate level = implementation of internal control mechanisms in the company's operations with the work of the formed internal audit in the company)
3. **TME = IC + IA + FFMC** (High level = fully implemented internal control mechanism in the company's operations in the system of financial management and control).

The authors point out that the safest business in agricultural companies is realized in the case when the decisions of top management are based on the formed financial management and control in companies.

3. Establishment of Control in financial reporting in agricultural enterprises in the Republic of Serbia

Controls and financial statements in agricultural enterprises should ensure that:

• show users whether the overall financial activities of that fiscal year were conducted in accordance with regulations;

• help users to better understand the nature, size and scope of the company's activities, as well as its financial condition;

• help customers understand and assess how the company finances its activities;

• help users to understand and evaluate the effects of the company's activities;

• help customers determine whether the company has achieved its goals,

• whether the costs have been correctly identified;

• provide users with information on the quantitative aspects of the company's income statement.

Users of financial statements include:

• employees in companies; • external business partners such as creditors, suppliers and customers;

• economists, analysts and special interest groups;

• the media.

• financial statements include work that should be: understandable, relevant, reliable, material (significant), timely, consistent, comparable,

• balance sheet, including assets, liabilities and reserves;

• cash flow, which documents the sources and use of funds;

• notes to the financial statements that include a description of the accounting principles and methods used,

• other explanations as appropriate, which may include performance indicators.

THE IMPORTANCE OF ESTABLISHING AN INTERNAL AUDITOR IN AGRICULTURAL COMPANIES

The importance of establishing an internal auditor in agricultural companies is reflected in the fact that top management wants to establish less business risk for the company itself in its regular operations.

The authors gave a presentation of possible reports of internal auditors with the most characteristic advantages and disadvantages that arise on that occasion. The authors pointed out the main advantages and disadvantages of the reports submitted to the top management, and the presentation itself is given in Table 1.

Table 1. Methods of presenting the internal auditor's report

Method of submitting financial reports	Advantages	Deficiency
Presentation	• Interactive • Flexible • Easier acceptance • Helps to consider more difficult issues and solutions • May increase the chance of implementing measures • Contributes to focusing on priority issues Internal audit can affect the way measures are taken	• Not all evidence can be presented • It can lead to difficulties in presenting complex data which can lead to misunderstandings • Presentation skills and active participation of two people are required • Good preparation is required • The possibility of domination of one person or a particular problem • The user can still request a report
Standard report	• Good for detailed reporting and complex data • Can provide general information and context • Evidence is immediately available to the reader Some users find reports more "authoritative"	• Require more preparation time • Long reports may remain unread and sometimes difficult to accept • They may be presented late due to delays in preparation

In addition to the internal auditor's reporting methods to the top management, they should take into account the sampling frequency so that the financial and other reports are close to the optimum reporting to the required audits performed by internal auditors for the top management of the agricultural enterprise.

In the following, the authors in Table 2 give an overview of the sampling frequency as a basis for obtaining a valid internal audit opinion, which they submit to the top management.

Table 2. Sample size observed through different lengths of time

Frequency	Sample size	
	Systems that are of key (material) importance for financial statements	Systems that are subject to cyclical checks
Daily reporting	30	18
Sunday	5	5
Monthly	2	4

DISCUSSIONS

Management in agricultural enterprises is performed in the conditions of continuous existence of weaknesses and risks for the general business of the agricultural enterprise. For that reason, it is necessary to eliminate the risk to the business of the agricultural company. In order to be able to realistically implement this in the business of the company, top management introduces control mechanisms of business in all parts of the company, i.e., in all sectors of the company.

The importance of the introduction of internal control and internal audit by the top management of the company is provable and can be applied in a large number of primarily medium-sized companies in agriculture.

The establishment of controls can be done and can have an effect only if the top management of the company realistically respects the expert opinion of the internal auditor as well as the person who performs internal control in the company.

CONCLUSION

Agricultural enterprises managed by top management can detect more system weaknesses (enterprises) only if they introduce control mechanisms in all parts of the enterprise. In this paper, the authors emphasized the importance of introducing internal control and internal audit by top management of companies, and presented the results in the form of Table 1-2, which can serve as a realistic basis for financial and other reporting in a large number of medium-sized companies areas of agriculture in the Republic of Serbia. The control can be carried out, first of all, taking into account the expert opinion of the internal auditor, who should perform essential sampling on all parts of the enterprise in order to establish even control of the business functions of the agricultural enterprise.

Finally, it is important to point out that there is no such system of internal control and internal audit that would provide perfect results every time, in the presentation of Figure 1 the authors gave an overview that it is possible to introduce financial management and control, but it should be noted that this type of control used in large systems, ie more used in large agricultural enterprises. Finally, the authors point out that any control that is carried out results in the creation of certain costs that must be taken into account by the top management in the projections in order not to burden the overall business with unnecessary costs.

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ZNAČAJ DONOŠENJA RACIONALNE POSLOVNE ODLUKE TOP MENADŽMENTA U POLJOPRIVREDNIM PREDUZEĆIMA U REPUBLICI SRBIJI

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Sažetak: Značaj donošenja racionalne poslovne odluke od strane top menadžmenta u poljoprivrednim preduzećima treba posmatrati kao trajni proces. Proces racionalnog poslovnog odlučivanja je od posebnog značaja za poslovanje preduzeća koje svoj pretežni deo poslovanja ostvaruju u delatnosti koja nema visok stepen obrta kapitala odnosno u delatnostima koje zavise od velikog uticaja prirodnih faktora na proizvodnju poput poljoprivrede. Autori ističu da proces donošenja racionalne poslovne odluke započinje donošenjem važeće upravljačke odluke od strane top menadžmenta. Implementacija validne poslovne odluke u svim delovima preduzeća je od velike važnosti da se primeni odmah jer svako odugovlačenje sa njenom primenom košta preduzeće. „IT" sektor preduzeća može da pomogne bržoj implementaciji poslovne odluke top menadžmenta, jer isti raspolaže tehničkim uslovima da odmah može da uključi inovativne poslovne odluke u sistem poslovanja u svim sektorima u poljoprivrednom preduzeću. Kao posebna podrška implementacije primene poslovnog odlučivanja je prethodno donošenje validne organizacione šeme u preduzeću.

Ključne reči: *poslovno odlučivanje, „IT", sektor, preduzeće.*

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EVALUATION OF THE PHYSICO-MECHANICAL PROPERTIES OF POLYESTER/CORN STALK COMPOSITE

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Abstract: In this study, corn stalk/polyester composites were prepared using molding techniques at several percentage filler loadings per weight and the physio-mechanical properties were studied. The composite showed moderate improvement in tensile strength 13.582MPa for 3% corn stalk which was the highest. The composite also reported the highest values for impact strength 744.90(J/m^2) and flexural strength 23.947MPa, respectively for filler loading of 3% corn stalk and 93% polyester and 2% corn stalk and 98% polyester composite samples. The significant strengths recorded can be attributed to the good surface intermingling bonding between the corn stalk fillers and the polyester matrix. The study also revealed that, density of the composites decreased with increase in filler loading and the density dropped from 0.116 g/cm^3 to 0.108g/cm^3. The composites recorded increase in water uptake with increasing filler loading. The results showed that the highest water absorption rate was at 5% corn stalk loading which had maximum water absorption of 4.55% by the composite samples. The physio-mechanical properties of the composites indicate that it can be useful in applications which require moderate strengths. These composites could be considered as a potential way of utilizing agricultural waste materials and as sustainable resources for manufacturing of structural materials such as particle board, partitioning panels, ceiling boards thereby reducing the amount of agricultural wastes and eliminating the pollution caused by burning of corn stalk waste.

Key words*: Corn Stalk, Tensile Strength, Polyester, Impact Strength, Water Adsorption, Agricultural Wastes, Composites, Density*

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INTRODUCTION

Composites are materials composed of two or more different materials with the properties of the newly formed materials become superior to the properties of individual material that make up the composites. Hence by this definition, a blend or mixture of any agricultural waste and plastic materials can be considered composites [1]. Agricultural wastes are by-products of agricultural produce especially after harvest. It can be husk, straw, cobs, stalk or fiber as for the maize plant [2]. The studies of agricultural wastes which are, in essence natural fibers, made into composites have attracted limitless consideration from academicians and industrialists for their excellent properties such as; improved mechanical strength, excellent water and oxygen barrier, dimensional stability, thermal, wear, chemical or corrosive resistance, etc., [3]. In practical applications, agricultural wastes fiber reinforced thermoplastic composites are gaining significant roles in building and automobile industries, and other consumer applications [4]. More so, the inherent quality outputs of waste plastic composites such as low cost, renewability, biodegradability, low specific gravity, availability, high strength and non-abrasiveness proffer the use of agricultural waste plastic composites in variety of practical applications [5]. Underutilized and discarded agricultural wastes are most importantly rich resources of lignocelluloses materials and some typical example are millet, rice, wheat, corn straw, corn stalk, cocoa husk, corncobs and fiber [6]. Though there are limited numbers of research studies on some of the agricultural wastes on millet husk, corn husk and rice husk reinforced plastic composites [7], more work has to be done on the other agricultural wastes which constitute the plant such as corn stalk, etc. Considering the generality of lignocelluloses fibers in the reinforced plastic composites, major setback in using these fibers is the relatively poor compatibility with hydrophobic thermoplastics, which often lead to poor mechanical properties [4]. However, agricultural waste as a filler and reinforcement in thermoplastics are popular [8]. The research in this area now competes with that in inorganic materials such as glass filler, carbon filler, clay etc. [9]. Thus, these inorganic filler materials most likely produce residues with toxic byproducts during manufacturing process. Generally, natural fiber polymer composites such as wood plastic composite seem to be incompatibile between hydrophilic and hydrophobic thermoplastic matrix [10]. Apart from the fact that agricultural wastes are low in cost, there is particular interest nowadays on its effects to the environment and especially, its biodegradability properties. To actualize the scale up production of agricultural waste plastic composites by the formation and synthesis of these filler fibers, various methods are required which involve mixing of filler husks at different filler loading per weight [4].

Polyester was used as the composite matrix and are naturally occurring chemicals, such as in the cut in of plant cuticles, as well as synthetics such as polybutyrate. Natural polyesters and a few synthetic ones are biodegradable, but most synthetic polyesters are not. The material is used extensively in clothing [11]. According to the polyester's chemical structure, it can have the properties and behave as a thermoplastic or thermoset [12]. Hardeners are a beneficial way to cure polyester resins. The most popular and one of the earliest uses of polyester were to make polyester suits which were in vogue in the 70s. Polyester clothes were very popular due to its strength and tenacity and also used to make ropes in industries [13].

This study seeks to add value to agricultural waste of maize plant, increase the economic strength of the maize plant and hope to increase the exploitation of maize plant for composite production instead of allowing them to decay or decompose. Corn waste is more than 50% of the entire maize plant which consists of the stalk, leaf, cob, husk with the husk accounting for 10% of the dry corn waste [14]. Thus, this study presents agricultural wastes (corn stalk) as a reinforcement resource in composite production with a view to create cheaper composite materials that can be viable for a wide variety of products such as paper, textiles, fibre-based materials and wood-based panels (fibreboards and particleboards).

MATERIAL AND METHODS

Materials

Polyester Resin is a liquid which will cure to a solid when the hardener is added. It has been specially formulated to cure at room temperature. The hardener, Methyl Ethyl Ketone Peroxide (MEKP) is added to cure, or harden the resin. MEKP hardeners for polyester resin often referred to as catalyst and available in small plastic tubes or bottles with graduated measurements marked on them. Hardeners are measured in drops or fractions of teaspoons for most lay-up or repair jobs.

Corn-stalk is most at times used as animal feed, artificial sugar, paper and fuel. Corn stalk is composed of cellulose (42%), lignin (13%), ash (4.2%) and other materials (41%). In this work, modalities have been developed to extract fibres from stalk of the maize plant by mechanical and chemical processes. The extracted fibres are rough and harsh, chopped and used for forage or left on the field for animal bedding [15]. Research shows that corn stalks can be used in many applications including human consumption and as a source of industrial raw material for the production of oil, alcohol and starch [16, 17]. It can also be used to make reasonably good particleboard and fiberboard [18, 19].

Methods

The raw materials used in this research were collected from farms in Umudike, Abia State, Nigeria which are freshly harvested. They were gathered and pruned to leave only the corn stalk. The corn stalk was sorted, cleaned and sun dried for days at approximately 30°C – 35°C. Crushing of the corn stalk was done using a medium two flywheel plastic crushing machine to reduce them to smaller sizes. Polyester was purchased from Onitsha, Anambra State, Nigeria. The whiskers were extracted into strands by hand manually and were cut to average length of about 2-3 inches; the whiskers were treated with sodium hydroxide (NaOH) and saline solution for one hour respectively.

They were later washed with water in which acetic acid was added and also washed severally with clean tap water which was dried in an oven at 100ºC for two hours. A mould measuring 30cmx 20cm x8mm was made available, and the polyvinyl acetate was used as mould release agent. The polyester resin was cured with cobalt naphthenate as the accelerator and methyl ethyl ketone peroxide as the catalyst. The gel time was between them was 10 – 15 minutes.

Each sample was mixed with appropriate mass fraction of polyester resin and appropriate mass fraction of corn stalk before casting inside the mould. They are kept at room temperature to cure effectively and demoulded after 2 days.

Table 1. Sample Mixture of Corn Stalk/Polyester Composites

Sample Specimen (SS)	Percentage Mass of Polyester (%)	Percentage Mass Of Corn Stalk (%)	Actual Mass of Polyester (g)	Actual Mass of Corn Stalk (g)
Control Sample	100	0	552	0
Sample A	95	5	546.48	5.52
Sample B	90	10	540.96	11.04
Sample C	85	15	535.44	16.56
Sample D	80	20	529.92	22.08
Sample E	75	25	524.40	27.60

After demoulding, a rip saw was used to cut the samples according to the appropriate test sample geometry and were smoothened with sandpaper. For tensile tests, specimen geometry (l x b x h) was 25cm x 2cm x 8cm and flexural test specimen geometry was 10cm x 2cm x 8cm.

(a) (b) (c)

Plate 1. Picture of (a) cured composite, (b) Cutting of composite into test sample geometry and (c) Corn Stalk/Polyester Composite Test Samples ready for testing.

Testing for Physical Properties

Water absorption and density of composite samples were used to characterize the physical properties. The expressions for testing for water adsorption and density are given below.

$$\left[\frac{(w_2 - w_1)}{w_1} x100\right] \qquad (1)$$

where

w_1 = dry weight of composite;

w_2 = wet weight of composite

$$\rho = \frac{m}{V} \qquad (2)$$

where
ρ = density;
m = mass of test sample;
V = volume of test sample

Testing for Mechanical Properties

Universal Test Machine at the Materials Strength Laboratory in University of Nigeria Nsukka was used to perform tensile test (according to ASTM standard D638) and flexural test (according to ASTM D790) while the impact strength was computed. The machine was operated at a uniform cross head speed of 50.00mm/min. The applied load that caused the material to fail under tensile and flexural testing was recorded and used to compute the tensile and flexural strengths from established relationships. These relationships can be found in [20–22] and impact strength was computed from the expression below.

$$G_c = \frac{U}{A}(J/m^2) \quad (3)$$

where is:
G_c = Impact Strength;
U = Energy of Fracture (Joules);
A = Area of test sample (m^2).

RESULTS AND DISCUSSION

Results of Physical Properties Tests

The results of the tests conducted to characterize the physical properties are outlined in Tables 2 and 3 whereby plots are generated in order to discuss the findings.

Table 2. Results of water absorption test of corn stalk/polyester composite samples

Sample Specimen (SS)	Hours	Corn Stalk %	Polyester %	Initial Weight (g)	Final Weight (g)	Water Absorption, w_a (%)
Control Sample	4	0	100	219.2	219.2	------
Sample A	4	1	99	109.1	110.7	1.47
Sample B	4	2	98	121.3	123.9	2.14
Sample C	4	3	97	122.1	125.1	2.46
Sample D	4	4	96	132.7	135.8	2.34
Sample E	4	5	95	63.8	66.7	4.55

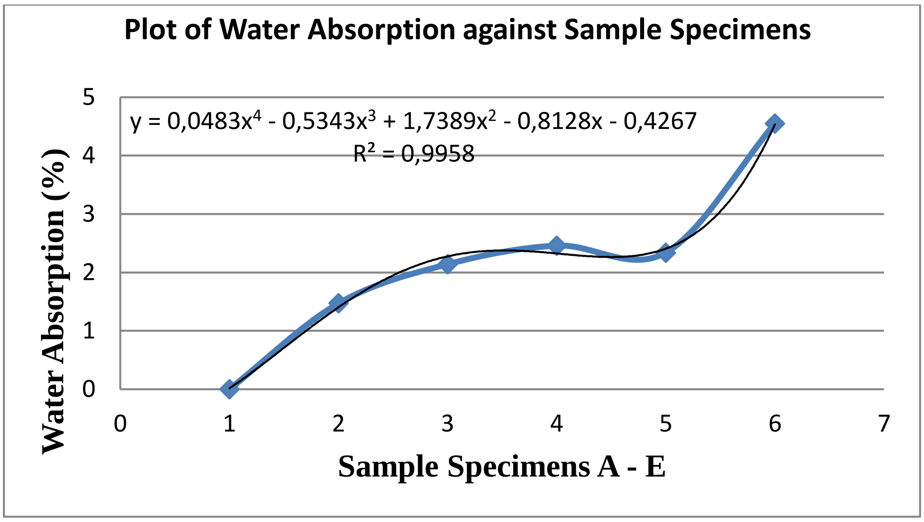

Figure 1. Plot of water absorption (%) against Sample Specimens

Table 2 and Fig. 1 presents the percentage water intake by corn stalk /polyester composite at different mass filler fractions after immersion in water for 4 hours. The Control Sample has zero percent water intake because it has no corn stalk whiskers and the polymer molecules are hydrophobic in character i.e. they do not contain any polar group as such, the polymer does not easily bond to water molecules explaining its ability to stay dry [23]. The plot shows a steady rise from 1% corn stalk filler mass fraction in polyester matrix with 5% mass fraction having the highest water being absorbed. This confirms that water absorption rate increases as corn stalk filler mass fraction increases though there was a little reduction between 4% cornstalk filler mass fraction (Sample D) and 5% cornstalk filler mass fraction (Sample E). The water absorption profile in the different compositions of cornstalk/polyester has a very good correlation and given as

$$Wa = 0.048\ SS^4 - 0.5343\ SS^3 + 1.7389\ SS^2 - 0.812 \quad (4)$$
$$(R2) = 0.9958$$

Water absorption affects the mechanical behavior of the composites and has already been established that the water absorption degenerates the tensile behavior of the polymer matrix composites [24]. Due to the established water absorption by the cornstalk/polyester composites of different percentage mass fractions, the composite becomes suitable for applications, such as particle boards, devoid of moisture.

Table 3. Computed results of density of corn stalk/polyester composite samples

Sample Specimen (SS)	Corn Stalk (%)	Polyester (%)	Mass (g)	Volume (cm^3)	Density, *D* (g/cm^3)
Control Sample	0	100	22.34	151.3	0.148
Sample A	2	98	11.12	103.4	0.108
Sample B	4	96	12.36	113.9	0.109
Sample C	6	94	12.45	110.2	0.113
Sample D	8	92	13.53	117.4	0.115
Sample E	10	90	13.02	112.2	0.116

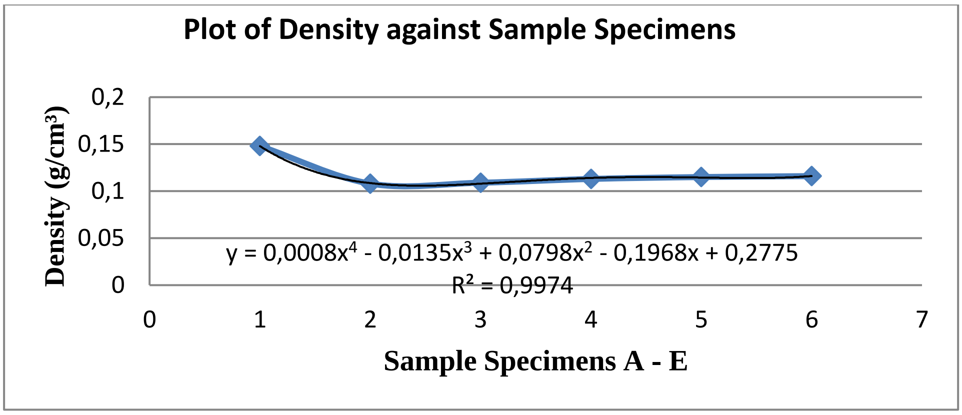

Figure 2. Plot of density against Sample Specimens

The plot on Fig. 2 is obtained from Table 3 and it shows the variation of the cornstalk/polyester composite densities as a result of the increasing cornstalk filler mass fractions. The decrease in the densities of the cornstalk/polyester composite as the cornstalk filler mass fraction increases can be caused by air trapped within the cornstalk filler reinforcement material. After curing, micro voids may be formed in the composites along cornstalk whiskers due to the fibres orientation which has adverse effect on the general properties of composites and this reduces the density of the composite. However, natural fibres are known to be light weight which explains when the filler content increases, density of the composites decreases. This is in line with the result obtained by [25]. The density profile has a good correlation and represented by the equation

$$D = 0.0008\ SS^4 - 0.0135\ SS^3 + 0.0798S^2 - 0.1968\ SS - 0.27758 \quad (5)$$

(R2 = 0.9974)

The density of the composites also show a steep decrease with varying ratio of the fillers though there was a reversal from Sample B to Sample E but the density is less than Sample A. These results of density imply that these composites can replace non-natural filler composites because of their light weight [26].

Results of Mechanical Tests

The results of the tests conducted to characterize the mechanical properties are outlined in Table 4 and plots are generated in order to discuss the findings.

Table 4. Results of tensile strength of corn stalk/polyester composites samples

Sample Specimen (SS)	Corn Stalk (%)	Polyester (%)	Tensile Strength, (*TS*) (N/mm^2)	Flexural Strength, (*FS*) (MPa)	Impact Strength, (*IS*) (J/m^2)
Control Sample	0	100	22.204	63.167	882.00
Sample A	1	99	10.560	23.699	526.80
Sample B	2	98	12.267	23.947	708.10
Sample C	3	97	13.582	20.590	744.90
Sample D	4	96	7.622	20.113	416.10
Sample E	5	95	8.337	21.933	664.50

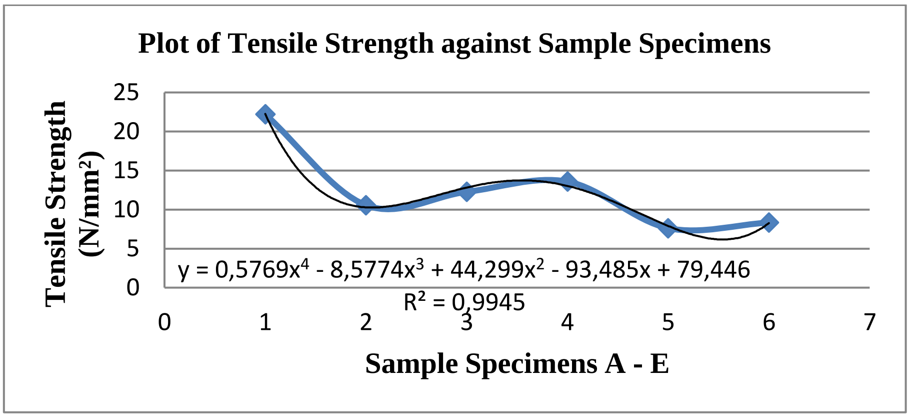

Figure 3. Plot of Tensile Strength against Sample Specimens

Table 4 gives the values of the tensile and flexural tests conducted and impact strength computed. Figure 4 is the plot characterizing the tensile strength of the different filler compositions. The pristine polyester had a higher tensile strength than all composite samples. The inculcation of corn stalk filler loadings greatly reduces the tensile strength. The increase in mass fractions of cornstalk filler reinforcement in polyester matrix further decreases the tensile strength of the composites. There was a steep decrease from 0% mass fraction to 1% mass fraction and next, a steady increase in tensile strength through 2% mass fraction to 3% mass fraction. Tensile strength decreased from here to 4% mass fraction and tipped up a little to 5% mass fraction. The decrease in tensile strength observed in these composites could be attributed to agglomerate formation and stress centers in the composites which originate and initiate cracks on application of stress. The tensile strength alternating (increase and decrease) behavior can also be attributed to the extent of fibre-matrix interfacial adhesion. Tensile strength profile is presented by this equation and correlation value

$$TS = 0.5769\ SS^4 - 8.5774\ SS^3 + 44.299\ SS^2 - 93.1485SS - 79.446 \quad (6)$$
$$(R^2) = 0.9945$$

Its strength is satisfactory for useful applications such as pharmaceutical shelves, particle board and partition wall.

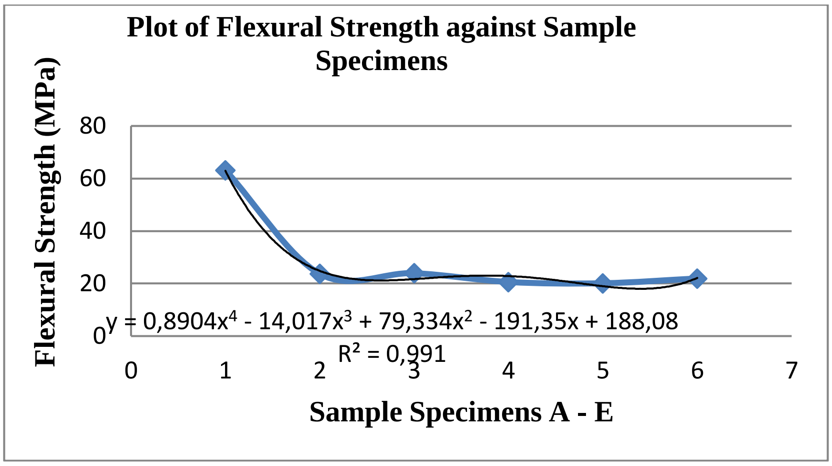

Figure 5. Plot of Flexural Strength against Sample Specimens

From the plot of the flexural strength of cornstalk/polyester composite as seen in Figure 5, the cornstalk/polyester composite again decreases below the pristine polyester which had higher flexural strength than all composite samples. It was observed that the flexural strength of the composites decreases with increasing filler mass fractions which were also similar to the tensile behavior. This could be due to poor intermolecular interaction and adhesion between the polyester matrix and the cornstalk whiskers. Similar results were obtained by [27] in his study on some mechanical properties of polyester filled with the seed shell of sunflower and water melon.

The flexural strength profile for the different mass fractions of cornstalk/polyester composite is present by equation and correlation value

$$FS = 0.8904\ SS^4 - 14.017\ SS^3 + 79.334\ SS^2 - 191.35SS - 188.08 \quad (7)$$
$$(R^2) = 0.991$$

The decline in flexural strength can be due to formation of agglomerates which created stress centres in the composites contributing to in mechanical failure properties of the composites [28].

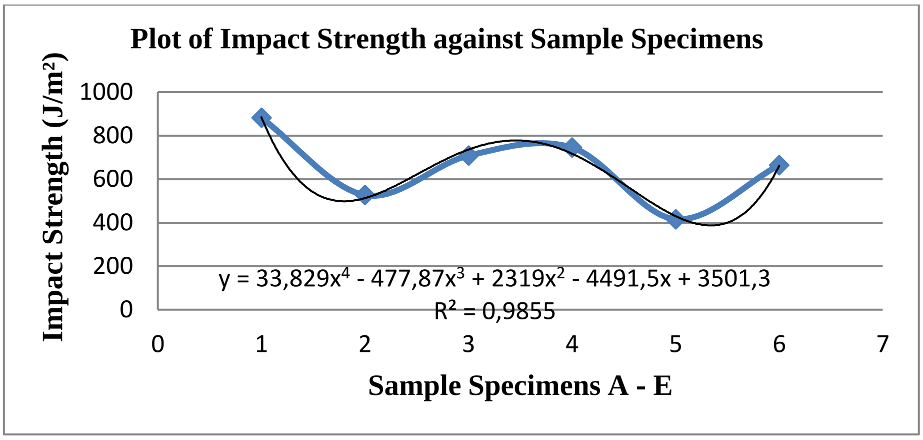

Figure 6. Plot of Impact Strength against Sample Specimens

The computed impact strength of the cornstalk/polyester composite depicts a different behavior compared to the tensile and flexural strengths. Pristine polyester also had higher impact strength than all composite samples. The tests proved that the cornstalk/polyester composites have ability to withstand shock loading or absorb mechanical energy under impact loading and stresses. The impact strength value decreases with increasing filler mass fractions from 0% to 1% mass fractions and increases from 1% to 3% mass fractions. However, another reduction was observed from 3% to 4% mass fractions and increment from 4% to 5% mass fractions of cornstalk filler reinforcement. The impact strength profile and correlation value are

$$FS = 0.8904\ SS^4 - 14.017\ SS^3 + 79.334\ SS^2 - 191.35SS - 188.08 \quad (8)$$
$$(R^2) = 0.991$$

It has been reported that high fibre content increase the probability of fibre agglomeration which results in regions of stress concentration requiring less energy for crack propagation [29, 30]. The decrease in impact strength can be attributed to saturation of the polyester resin by the fillers, thus, preventing proper bonding of the fillers to form strong adhesion forces. The results reveal that the cornstalk/polyester composites can withstand medium energy impact without fracturing. Improvements in absorbing energy by the composites could be enhanced with better interaction of the filler and matrix. A deviation was reported in similar work on production and properties of sweet potato flour/HDPE composites which shows decrease in impact strength with increase sweet potato powder as reported by [25].

CONCLUSION

This study investigated the successful preparation and investigation of the physico-mechanical properties of corn stalk/ polyester composites. Also, a means of discarding agricultural waste (corn stalk) as a resource for new material by adding value to them was proferred.

The water absorption behavior of the cornstalk/polyester composites at different filler mass fractions followed similar trend in other reported research. Water absorption revealed huge influence on the physico-mechanical properties of cornstalk/polyester composites. A four hour immersion in water revealed that the water absorption by the cornstalk/polyester composites increased as the cornstalk filler mass fractions were also increasing and similar results were observed by [31]. The cornstalk/polyester composite densities decreased with increasing cornstalk filler mass fractions.

The mechanical properties of the cornstalk composites revealed, essentially, that the introduction of cornstalk fillers in a polyester matrix reduced the tensile strength, flexural strength and impact strength of the cornstalk/polyester composites below the tensile strength, flexural strength and impact strength of pristine polyester matrix (i.e. 100% polyester resin). This is in contrary to the description of composites stated in the introduction of this paper. The results reported makes cornstalk filler unlikely suitable for polyester resins or maybe unsuitable for all polymer matrices or resins. Poor cornstalk fillers and polyester matrix interfacial adhesion can be the reason for the decline in tensile, flexural and impact strengths of the cornstalk/polyester composites.

Furthermore, the results also show that density of the cornstalk/polyester composites decrease considerably with varying percentage of cornstalk filler mass fractions and provide moderate interaction and interfacial bonding between the cornstalk fillers and the polyester matrix.

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PROCENA FIZIČKO-MEHANIČKIH OSOBINA KOMPOZITA POLIESTER-KUKURUZ

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Apstrakt: U ovom radu, kompozit u sastavu stabljika kukuruza-poliester su pripremljeni tehnikom oblikovanja sa nekoliko procenata opterećenja materijala za ispunu prema masi . Proučavana su fizičko-mehaničke osobine ovog materijala .
Kompozit je pokazao umereno poboljšanje zatezne čvrstoće od 13,582 MPa za 3% stabljike kukuruza, što je bilo najviše.
Kompozit je takođe imao najveće vrednosti čvrstoću na udar od 744,90 (J/m^2) i na savijanje od 23,947 MPa, respektivno za punjenje od 3% stabljike kukuruza i 93% poliestera i 2% stabljike kukuruza i 98% poliester materijala.
Značajno zabeležena vrednost otporosti materijala može se pripisati dobrom površinskom međusobnom vezivanju između materijala stabljike kukuruza i poliestera kao osnove.
Studija je takođe pokazala da se gustina kompozita smanjivala sa povećanjem količine materijala za punjenje, i vrednost gustine novog materijala je smanjena sa 0,116 g/cm^3 na 0,108 g/cm^3.
Kompoziti su zabeležili povećanje vrednosti upijanja vode sa povećanjem opterećenja materijala punioca. Rezultati su pokazali da je najveća stopa apsorpcije vode bila pri opterećenju stabljike kukuruza od 5%, što je imalo maksimalnu apsorpciju vode od 4,55% kod kompozitnih uzoraka.
Fizičko-mehaničke osobine materijala kompozita ukazuju da on može biti koristan u aplikacijama koje zahtevaju umerene vrednosti na čvrstoću.

Ovi kompozitni materijali mogu se smatrati potencijalnim načinom iskorišćavanja poljoprivrednog otpadnog materijala i održivim resursima za proizvodnju konstrukcijskih materijala kao: iverice, pregradne ploče, plafonske ploče čime se smanjuje količina poljoprivrednog otpada i eliminiše zagađenje izazvano sagorevanjem stabljike kukuruza.

Ključne reči: *Stabljika kukuruza, zatezna čvrstoća, poliester, udarna čvrstoća, adsorpcija vode, poljoprivredni otpad, kompoziti, gustoća*

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A COMPARATIVE STUDY ON ENERGY USE OF RICE (*Oryza sativa* L.) CULTIVARS UNDER MECHANIZED CROPPING SYSTEMS IN WEST OF TURKEY

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Abstract: The study was performed energy analysis of mechanized rice production for two rice cultivars under a region, named Çanakkale, in West Turkey. The indicators are energy use efficiency, specific energy, energy productivity and net energy. The cultivars of rice commonly grown in the region are listed in two groups: native and high yield hybrid. Primary data were obtained through field survey with farmer's interviews face to face with a questionnaire in Biga, Ezine and centre districts, commonly rice cultivation areas in the region. Secondary data and energy equivalents were obtained from available literature using collected data of the production period of 2020–2021. Analysis of data showed that averagely diesel had the highest share within the total energy inputs as 46.46% and 45.72% for native and hybrid, respectively, followed by chemical fertilizers with 24.19%, and 23.80%, especially nitrogen. Water input was the third highest share with 11.29% and 11.60% for native and hybrid, respectively. Machinery input had fourth share in total, but it showed similar percentage with around 8.00% in both cultivars because of receiving similar machinery operations. Another high input was pesticides with around 4.00% because herbicides using is very high, especially for annual and perennial sedges and broadleaf weeds. Labour is the optimum level because of cultivation practices are usually performed by mechanical power. Net energy was found higher in hybrid cultivar with 101.41MJ ha^{-1} due to higher grain and straw yield than native with 84.01 MJ ha^{-1}. The energy use efficiency and energy productivity of nature cultivar were 2.3 and 0.12 kg·MJ^{-1}, respectively, corresponding to increases of 2.5 and 0.13 kg·MJ^{-1}in hybrid. With appropriate agronomic measures in rice production in the study area, higher yield of hybrid cultivar would necessarily lead to an increase in energy productivity and gain.

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Key words: *Energy analysis, energy indicators, rice cultivars*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the important principal food crops that feeds more than half of world's population. Rice production areas in world cover around 162 million hectares comprising about 11% of all arable lands which annually produces approximately 758 million ton [1]. The main producer countries are Chin, India, and other Asian countries while Turkey is ranked at thirty-seven.

China is the largest rice producer in the world with 211 million tons production volume per year, and India comes second with 159 million tons yearly production.

Although, worldwide agriculture production has defeated the population growth [2], still there is a challenge to providing feed for huge population with sustainability and so, it felt urgent need of find mitigation and adaptation practices to minimize the impact of crop cultivation on climate change, especially rice provides food a half of the world population, particularly in developing countries subjected to intense demographic growth [3].

In Turkey, due to the low of subsidies, farmers have taken on more costs for fuel as well as chemical fertilizer and electricity for irrigation, particularly for rice production which is one of the important crops among cereals. Meanwhile, rice consumption and then its production has steadily been increasing in the country although wheat is the main crop. In annual, rice production in the country was reported to be more than 920 thousand tons [4] with 116 thousand hectares with 7930 kg ha^{-1} on average yield depending on cultivar. Marmara Region, one of the considerable rice production areas of the country, produces more than 71 percentage of total rice production. Osmancık-97 and Baldo are the well-known nature cultivars among farmers and consumers and have dominated the region for many years. However, new hybrid cultivars such as Cammeo, Galileo, Ronaldo, and Luna are catching farmers' attention in term of high yield and milling rates. Nonetheless, the country still has rice importing with more than 225 thousand tons per year. Therefore, efforts are required to increase the production of rice sustainably, but effective energy use is needed to reduce production costs and preserving fossil resources and decreasing environmental pollution. South of the Marmara Region of the country, especially Çanakkale, is one suitable region for rice production in terms of favourable climate and abundant water resources according to many other parts. The region keeps fourth rank with 11348 hectares (9.3%) in rice production at national level. The mechanization degree is showing high level in the application of farm machinery for rice production, but it varies due to variations in climate, culture, technology adaptation, cropping systems, crop season, farming conditions and seed cultivars. Optimal use of improved farm machinery coupled with optimal use of other recommended resources allow an increase in rice yield up to potential levels.

Energy is used in every stage of the crop production process agriculture, from soil tillage to harvesting as well as drying and storage stage. Therefore, identifying sustainable rice cultivation methods using cultivar with different yields is crucial to ensure food security for a growing population. Energy is also a key input of agriculture and agriculture production positively correlated with energy input. In recent years, energy input in agriculture, like fuel and electricity, has been highly affected by changes in country energy policy.

The energy analysis of agricultural ecosystems is a promising approach to assess the energy efficiency, and their impact on environment [5].

On the other hand, the countries like Turkey, energy consumption in agriculture is much lower than the other sectors, energy use as both input and output of agricultural sector is a very important issue due to its large agricultural potential and rural area. Also, energy consumption in such areas based on farm conditions (size of crop area), farmer's social considerations such as level of education, and energy inputs including fertilizer, water, etc. Studies on this aspect help in identifying or developing more energy efficient technologies, with low adverse environmental impacts and improvement in natural resource conservation. So, many studies were devoted on exploring yield performance and nitrogen use efficiency of different methods of rice production under rainfed and controlled irrigation. Nonetheless, few studies have been conducted to determine energy efficiency of rice cultivation with different cultivars in similar or different agro-ecologies conditions. But very few studies compared different rice cultivar due to yield. In this study, we hypothesized that rice production with hybrid cultivar reduces the energy use and increase net energy comparing and nature. The objective of this study was to identify a cultivar with optimum energy consumption that had maximum productivity, energy use efficiency and low environmental impacts.

MATERIALS AND METHODS

Study area and climate

The study was carried out in Çanakkale region, South of the Marmara Region of west Turkey (Figure 1). The region is located between 39°27′-40°45′ Lat. N and between 25°40′-27°30′ Lon. E, covering a total area of 993318 hectares, cropping area of 331633 hectares and a rice cropping area of 383367 decare, which is a total of 7.52% of the rice areas in the country. Topographic elevations vary between 0 and 100 metre above sea level (Figure 1). Agriculture in the region is intensively irrigated, mechanized and input-intensive (Figure 1). Rice is usually cultivated under continuous flooding irrigation with full water control, despite the introduction of drip irrigation in recent years. The climate of the study area is semiarid subtropical with extreme summers and severe cold winters. The northern parts of the region experience cold weather, whereas the southern parts experience tropical weather. Summer is from May to September, and winter is from October to April. Annual mean of maximum summer temperature is about 28°C (in August) according to the long-term period, and annual mean of minimum winter temperature is 6 °C (in January) (Figure 2). The annual total rainfall is varying from 460 mm to 715 mm according to years, and about 65% of annual rainfall events occur from December to May (Figure 3).

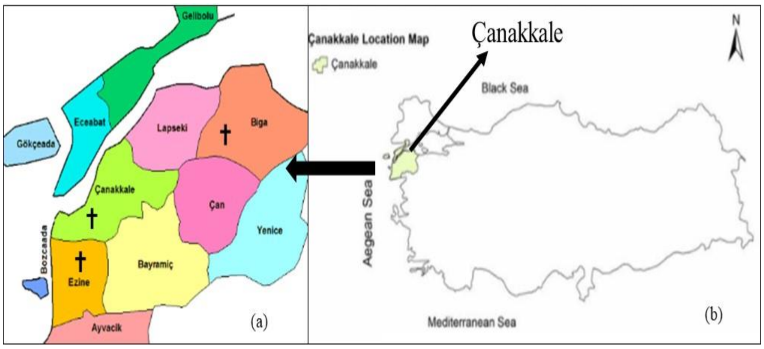

Fig. 1. Location of the study area in the country (b).,
farms in surveyed three-district (a).

In this area, rice is usually grown under mechanized system, but human labour is still using in some cultivation practices. In general, the average farm size is very small in the area. The most of rice farmers have 20 to 30 decare (1 decare =1000 m^2), area for the rice production. Only a few farmers have 1000 to 2000 decare size. The cultivars of rice commonly grown in the region are listed in two groups as native (*Baldo, Osmancık-97, Yatkın*) and hybrid (*Cameo*, *Vasco*, *Luna*) cultivars. Farmers usually prefer hybrid cultivars which open new options and flexibility under prevailing weather conditions. They may also enhance land use efficiency following winter season because crops stay for short duration in field and leaving enough time for the succeeding crops during autumn and winter season. These cultivars also are increasing crop productivity and probability per unit area because cost is one of the major goals of agriculture farming. The study was conducted from only three districts of the region, named is Biga, Ezine and center (Figure 1). Data were collected from 65 farmers in three districts by a questionnaire. Observations and surveys were performed face to face with farmers during production season of 2020-2021. Farms were determined by using Neyman method by Yamane [6] with following equation.

$$n = \frac{N^2 \ x \ s^2 \ x \ t^2}{(N-1)\, d^2 + (s^2 \ x \ t^2)} \qquad (1)$$

Where, n, the required sample size; N, the number of rice farmers in the target population; s, the standard deviation; t, the t-value at 95% confidence limit (1.96); d, the acceptable error. In addition to the data collected by the questionnaire, the secondary data used in the study were collected from the previous studies [7] and publications by some institutions such as TUIK (Turkish Statistical Institute), and other government agencies, Çanakkale Directorate of Provincial Agriculture and Forestry. the questionnaire included all kinds of inputs such as seed, fertilizer, pesticides, fuel, and water, supplied to the crop and use of different power sources such as human and agricultural machinery as well as output of farms as the yield of main product (grain) and by-product (straw).

The first, all inputs and outputs for rice production were determined, quantified and entered into Microsoft Excel spreadsheets, and then transformed into energy units and expressed in MJ ha^{-1}.

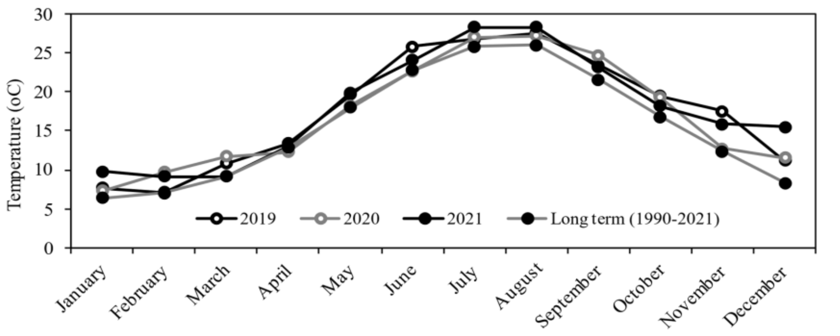

Fig. 2. Average temperature according to months for three years and long-term

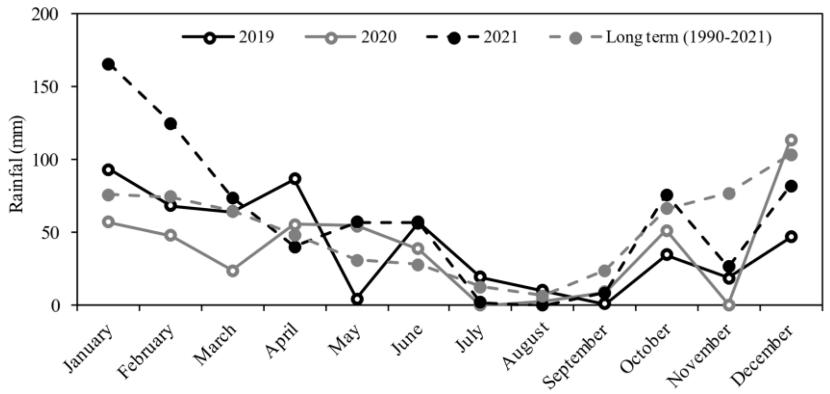

Fig. 3. Rainfall distribution according to months for three years and long-term period

Rice production

There are different farming practices in the area for rice production due to seasonal soil tillage and seedbed preparation in autumn following by previous crop harvest time, and in spring season. A brief description of these soil preparation practices is presented in Table 1 and 2 for autumn and spring season, respectively. Field operations began with disposal of the straw by soil incorporation or removal from the field. Tillage may be done in fall or may be postponed until spring under wet conditions, but generally begins as early as possible.

Tillage with mouldboard plough is carried out in 20 to 25 cm depth followed by shallow tillage performed with a disk harrow or a field cultivator, and rotovator. Soil levelling is done with leveller blades after the first ploughing under dry conditions.

The laser is usually used in larger farms and allows a uniform water depth within the basin. Before flooding the field, the fertilizer and pre-emergence herbicide are applied and incorporated into the soil with a spike-tooth harrow followed by pressing of the soil with the leveller to press soil surface before seeding. Seeding is done by seed drill with iron wheel, while some farmers also broadcast pre-soaked seed (ungerminated) with centrifugal fertilizer broadcaster into water.

Seed rate is 200 kg per hectare for long-large grain size cultivars and it is 170-180 kg per hectare for medium grain type and 150 kg for small grain cultivars. Under both season tillage practices, different soil tillage equipment is used for the first deep tillage operation (Table 1, 2), for example mouldboard plough and disc harrow are usually used in autumn where mouldboard plough and chisel are performed in spring season. Other equipment is used in both season with different times such as disc harrow, spring cultivator, rotovator, centrifugal fertilizing broadcaster, soil lever, sprayer, laser, and seed drill. Farmers are preferred autumn time practices because of operation time is very limited in spring to prepare the seedbed on time for seed drill practice. For this reason, in this study, the applications in the autumn model-1 were taken to determine energy input and output. Weed control, one of the major challenges toward rice production in the study area, is often performed by sprayer before seeding. Some characteristics of agricultural machinery such as field speed, field efficiency and working widths required for the effective field capacity were obtained from the equipment commonly used in the study area.

Table 1 Agricultural practices in autumn rice production systems and their estimated fuel consumption, model-1

Time	Machinery	Practice	Fuel ($l\ ha^{-1}$)
Second week November	Mouldboard plough	Soil tillage at 20-25 cm	40
Second week April	Heavy cultivator	Incorporation crossing soil tillage	10
Third week April	Heavy disc harrow	Breaking soil clods-3 times	30
Fourth week April	Spring cultivator	Incorporation crossing soil tillage-2 times	20
First week May	Vertical rotovator	Breaking soil clods	20
First week May	Laser	Levelling	45
First week May	Centrifugal fertilizer	Applying fertilizer	2
First week May	Spike-tooth harrow	Mixing on soil surface-3 times	12
First week May	Leveller	Pressing soil surface before seeding	2
First week May	Mounted sprayer	Applying the pre-seeding herbicides	2
Second week May	Seed drill with iron wheel	Seeding	2
First week October	Combine	Harvesting	18

Table 2. Agricultural practices in spring rice production systems and their estimated fuel consumption, model-2

Time	Machinery	Practice	Fuel ($l\ ha^{-1}$)
Second week April	Mouldboard plough	Deep soil tillage	40
Fourth week April	Chisel (curved arm)	Incorporation deep soil	10
Fourth week April	Heavy cultivator	Incorporation crossing soil tillage	10
First week May	Heavy disc harrow	Breaking soil clods-2 times	20
First week May	Laser	Levelling	45
First week May	Centrifugal fertilizer	Applying fertilizer	2
First week May	Spike-tooth harrow	Mixing on soil surface-3 times	12
First week May	Leveller	Pressing soil surface before seeding	2
First week May	Mounted sprayer	Applying the pre-seeding herbicides	2
First week May	Seed drill with iron wheel	Seeding	2
First week October	Combine	Harvesting	18

Nitrogen and phosphorus fertilizer with zinc compound are usually used for rice crop in the country as well as in the region. Soils have enough available potassium, therefore no-potassium application is done for rice crop. Fertilizer rate is $N_{150}P_{80}Zn_{15}$ per hectare. Nitrogen is applied in three times; the first, second, third parts are at the pre-planting, tillering, panicle initiation, respectively. Under irrigation with continuous flooding, nitrogen is applied in the form of ammonium sulphate or urea. All phosphorus and zinc are used at the pre-planting. Rice harvesting time varies from September 15 to October 30 in the study area at 45 to 50 days after flowering. Early harvesting may reduce the head yield of rice owing to the presence of immature kernels as well as grain yield in unit area. Late harvesting may also reduce grain yield in unit area because of grain shattering and lodging. Rice is directly harvested with combine and the crop is dried to a storable moisture of 13 to 14 percent.

Energy analysis procedures

The energetic efficiency of the agricultural system has been evaluated by the energy rate between output and input. Human labour, machinery, diesel fuel, chemical fertilizers and pesticides, seed, water, electricity, etc., and output values such as rice grain and straw yield have been used to estimate the energy rate. Energy equivalents shown in Table 3 were used for estimating the input and output energy. Agricultural energy consumption may be divided into four energy categories: direct, indirect, renewable, and non-renewable. Direct energy is defined as the energy used to power (diesel fuel as thermal) the agricultural machines used in the soil tillage and preparation or harvesting stages [8], and manual. Indirect energy comprises of energy inputs in manufacturing of machinery and raw materials such as chemical fertilizers, pesticides, seed and transportation. Non-renewable energy includes machinery, chemical fertilizers, pesticides, and diesel fuel while renewable energy includes seed, water, and human labour. A complete inventory of all inputs (fuels, fertilizers, seed, pesticides, human labour, irrigation water and, machinery power) and outputs of both rice grain and straw yields were recorded from the surveyed forms. Energy inputs in different studies were computed by multiplying the inputs with the corresponding energy coefficients and summation of all these components. For this study, the energy coefficients were taken from the literature (Table 3), but they varied in different studies due to differences in calculations and spatial and temporal system boundaries.

Due to this, the results of different studies are not comparable. So, the energy coefficient values from different studies conducted in similar environments were used in the present study (Table 3).

Manual energy input was determined by multiplying the number of persons engaged in an operation by the man hour requirement [9].

The energy contribution from male (E_m) and female (E_f) labour were estimated using equation (1) and (2), respectively.

$$E_m = 3.6\ (0.075 \times N \times T) \quad (1)$$
$$E_f = 3.6\ (0.065 \times N \times T) \quad (2)$$

Where, T is the useful time spent by the person per unit operation.

N shows the number of persons involved in an operation at the maximum continuous energy consumption rate of 0.30 kW and conversion efficiency of 25%, respectively.

Table 3 Energy coefficients of different agricultural inputs and outputs

Particulars	EC (MJ unit^{-1})*		Reference
A. Inputs			
1.Human labour	1.96	MJ man h^{-1}	[10]
2.Machinery**	62.70	MJ kg^{-1}	[11]
2.1. Tractor	138	MJ kg^{-1}	[12]
2.2. Chisel plough	149	MJ kg^{-1}	[12]
2.3 Mouldboard Plough	180	MJ kg^{-1}	[12]
2.4. Disc harrow (heavy)	149	MJ kg^{-1}	[12]
2.5. Spring cultivator	148	MJ kg^{-1}	
2.6. Seed drill	133	MJ kg^{-1}	[12]
2.7. Centrifugal fertilizer	129	MJ kg^{-1}	[12]
2.8. Mounted sprayer	116	MJ kg^{-1}	[12]
2.9. Combine	116	MJ kg^{-1}	[12]
3.Diesel***	56.31	MJ l^{-1}	[12]
4.Chemical fertilizer			
4.1. Nitrogen (N)⸸	78.1	MJ kg^{-1}	[12]
4.2. Phosphate (P_2O_5)⸸⸸	17.4	MJ kg^{-1}	[12]
4.3. Zinc (Zn)	8.40	MJ kg^{-1}	[13]
5.Pesticide			
5.1. Insecticides	184.63	MJ kg^{-1}	[14]
5.2. Herbicides	255	MJ kg^{-1}	[14]
5.3. Fungicides	115	MJ kg^{-1}	[12]
6.Water for irrigation	1.02	MJ m^{-3}	[11]
7.Seed	14.57	MJ kg^{-1}	[12]
8.Electricity	11.93	MJ kWh^{-1}	[12]
B. Outputs			
1.Grain (rice)	14.57	MJ kg^{-1}	[14]
2.Straw (rice)	12.50	MJ kg^{-1}	[14]

*Energy coefficients; **excluding self-propelled machines; ***including cost of lubricants; ⸸,production (69.5) and PTA (packaging, transportation, application, 8.6); ⸸⸸production (7.6) and PTA (packaging, transportation, application, 9.8); ⸸⸸⸸,production (6.4) and PTA (packaging, transportation, application, 7.3).

Diesel (thermal) energy (E_d) was estimated by multiplying the quantity of total fuel used in different farm operations by its lower heating value for rice crop production [9]. The diesel energy input was determined using the following equation (3):

$$E_d = 47.8 \times D \tag{3}$$

Where,

E_d, the diesel energy consumed (MJ);

47.8, the calorific (lower heating) value of diesel fuel (MJ l^{-1});

D, the quantity of diesel fuel consumed per unit operation (l).

The machinery input energy (indirect) was calculated by computing the production energy of tractors and agricultural machines per unit area using the following equation (4).

$$E_m = \frac{M \times E}{L \times C_e} \quad (4)$$

Where,
E_m, total machinery input energy for agricultural machinery in the lifetime allocated to one hectare (MJ ha^{-1});
M, the mass of tractor and machinery (kg);
E, the energy coefficient to manufacture, transport and repair (for tractor, 76 MJ kg^{-1} and farm machinery, 111 MJ kg^{-1}) (transport and repair) (Table 3);
L, the economic life of tractor and machinery (h);
Ce, the effective field capacity of farm machinery (ha h^{-1}).

Fuel consumption in different tillage operations depends on depth and width of ploughing, soil type, moisture content, tractor size, and the equipment used (Table 1, 2). So, fuel consumptions in different tillage operations, which were done with different tillage implements drawn by a 45 HP two-wheel drive tractor, were estimated.

$$C_e = \frac{V \times W \times E_f}{10} \quad (5)$$

Where,
W, the working width (m);
V, the working speed (km h^{-1});
E_f, the field efficiency. Chemical energy input was obtained from the quantity of fertilizer and herbicides (kg) used.

The NPK 20:20:0 fertilizer was the most widely used in the study area, and sometimes combined with Zn. The energy equivalent for a kilogram of NPK fertilizer was obtained from the rate of its elements (N P K) in a 50 kg bag of the fertilizer. The total chemical energy input was calculated by multiplying the quantity of fertilizer used by its energy equivalent value as shown in equation (6). Also, the chemical energy input from pesticides (especially herbicides) was obtained using equation (7).

$$E_{fert} = \sum_{n=1}^{n} \left(\frac{N x N_{eqv}}{AP} + \frac{P_2O_5 x P_{eqv}}{AP} + \frac{K_2O x K_{eqv}}{AP} \right) \quad (6)$$

Where,
E_{fert}, the chemical energy fertilizer;
N_{eqv}, the energy equivalent value of N;
P_{eqv}, the energy equivalent value of P_2O_5;
K_{eqv}, the energy equivalent value of K_2O; N, the compound fertilizer rate applied percentage of N ingredient (kg); P_2O_5, the compound fertilizer rate applied percentage of P_2O_5 ingredient (kg); K_2O, the compound fertilizer rate applied percentage of K_2O ingredient (kg);
AP, the planted area (ha); n, the compound fertilizer for applied time nth.

$$E_{herb} = H_{herb} \times H_{eqv} \quad (7)$$

Where,
E_{herb}, the chemical energy herbicide;
H_{herb}, the quantity of herbicide used (kg);
H_{eqv}, the energy equivalent value of herbicide.

Biochemical energy sources are the amount of energy stored in the rice seed. The biological energy input in rice production was calculated using equation (8).

$$E_{bio} = Q_{seed} \times Q_{eqv} \quad (8)$$

Where, Q_{seed}, the quantity of seed planted (kg ha^{-1}) and
Q_{eqv}, the energy equivalent of rice (MJ kg^{-1}).

Canal water is not used in any of the studied farms, therefore, only well water was calculated. The energy required for pumping water (E_{ir}) from a well was calculated using the following equation (9).

$$E_{ir} = r \times g \times H \times \frac{Q}{Ep} \times Eq \quad (9)$$

Where,
r, water density (1000 kg m^{-3});
g, the acceleration due to gravity (9.80 m s^{-2});
H, total depth of dynamic head (m);
Q, the volume of water required for one season (m^3 ha^{-1});
Ep, the pump efficiency (80%);
Eq, total power conservation efficiency (20%).

Transmission and production efficiencies were also considered for estimation of irrigation energy. Transportation to storage facilities was done with tractor and trailer. The energy input in transportation consists of thermal, manual, and mechanical energy. Energy required (MJ) in transportation (E_{trans}) was estimated by measuring the time involved in the operation which include time spent on loading and off-loading the rice in equation (10).

$$E_{trans} = 4.8 \times D + 3.6\,(0.075 \times N \times T) + \frac{M \times E}{L \times C_e} \quad (10)$$

Land preparation, planting, weeding, fertilizer application and harvesting were done mechanically in all the farms questioned. For land preparation, the amount of fuel consumed by the tractor in litres per hectare and the time taken by the operator to perform the operation were recorded.
The energy required (MJ) for each field practice (land preparation, planting, weeding, fertilizer application, harvesting, transportation) was obtained from equation (11). The technical properties of all farm equipment were presented in Table 3

$$E_{field-practice} = 3.6\ (4.8 \text{ x } D) + 3.6\ (0.075 \text{ x } N \text{ x } T) + \frac{M \text{ x } E}{L \text{ x } C_e} \quad (11)$$

The amount of output energy (MJ ha^{-1}) is estimated by multiplying the rice and straw yield (kg ha^{-1}) by rice and straw energy equivalent (MJ kg^{-1}) as mentioned in Table 3). Total output energy of rice was estimated as a sum of the total energy from grain and straw yield in equation (12).

$$E_{output} = Q_{\text{grain-yield}} \text{ x } Q_{grain-eqv} + Q_{\text{straw-yield}} \text{ x } Q_{straw-eqv} \quad (12)$$

Where,
$Q_{\text{grain-yield}}$ is the quantity of grain yield (kg ha^{-1});
$Q_{\text{grain-eqv}}$ is the energy equivalent of rice grain (MJ kg^{-1});
$Q_{\text{straw-yield}}$ is the quantity of straw yield (kg ha^{-1});
$Q_{\text{straw-eqv}}$ is the energy equivalent of rice straw (MJ kg^{-1}).

Based on the total energy equivalents of the inputs and outputs, energy use efficiency, energy productivity, specific energy and net energy were used to evaluate the performance of energy usage in rice farms They were calculated using the following equations (13-17) as suggested in literature [15, 16]. Net energy refers to the difference between the energy consumed in producing a product and the sum of energy gain from the product. The energy rate describes the relationship in a production process between energy outputs and inputs. Energy productivity is also an important indicator for evaluating the energy use efficiency, and the amount of economic output for each unit of energy consumed. Specific energy is the energy consumed to produce a unit mass of a product.

$$\text{Net energy (MJ ha}^{-1}) = \text{Total energy output} - \text{Total energy input} \quad (13)$$

$$\text{Energy use efficiency (energy rate)} = \frac{\text{Total energy output (MJ ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})} \quad (14)$$

$$\text{Energy productivity (kg MJ}^{-1}) = \frac{\text{Grain and straw yield (kg ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})} \quad (15)$$

$$\text{Specific energy (MJ kg}^{-1}) = \frac{\text{Total energy input (MJ ha}^{-1})}{\text{Grain and straw yield (kg ha}^{-1})} \quad (16)$$

$$\text{Energy profitability} = \frac{\text{Net energy (MJ ha}^{-1})}{\text{Total energy input (MJ ha}^{-1})} \quad (17)$$

RESULTS AND DISCUSSION

Energy consumption is one of the important indicators of crop performance and environment sustainability; higher energy use efficiency with less input is required for improving livelihood security of millions of rural household practicing rice cultivation.

Energy requirement and its production potential largely depend on inputs used, it is also affected by crop the cropping systems, cultivation practices, and type. The total energy requirement of the system was significantly varied with the methods of establishment and rice cultivars (Table 4). Good levelling of the soil to be cultivated rice seed germination of seedlings, healthy growth, weed control and weed enhancement of the effectiveness of pesticides is very important. Soil levelling is done in small parcels with levelling blades, in larger parcels with lightweight graders, or with a laser machine. With the use of laser, a 20% increase in yield is achieved. During the studies in the farms, the amount of rice produced per hectare during the 2020-2021 production season was calculated as an average of 8990 and 8000 kg for hybrid and nature, respectively. Grain energy output was directly related to the productivity. Hence, the highest grain energy output was observed in the hybrid cultivar (130,830 MJ ha^{-1}) compared to nature (117,600 MJ ha^{-1}) (Table 4). This was mainly because of higher yield in hybrid cultivar (8990 kg ha^{-1}) than that of nature (8000 kg ha^{-1}). This was also expressed by the farmers participated questionnaire that they cleared particularly the hybrid cultivars provided more rice grain yield as well as high profits. In addition, hybrid cultivars have higher grain yields per unit area due to their higher resistance to pests than natural cultivars. Similar results were observed in total energy output including crop straw. The total energy output for hybrid and nature cultivars were calculated as 168,330 and 148,850 MJ ha^{-1}, respectively (Table 4). However, it is stated that generally the farmers do not collect the crop residues at the end of a crop season since these were returned to the soil. The energy equivalents were same for both the cultivars, which imply that there was no effect on the grain energy returns. The weight of straw harvested is 1.2 times higher (3000 kg ha^{-1}) in hybrid cultivar than nature (2500 kg ha^{-1}), therefore the straw contains large amount of energy, which is much higher (37,500 MJ ha^{-1}) than the energy of nature cultivar (31,250 MJ ha^{-1}) straw. The energy output for straw increased by 6250 MJ with using hybrid cultivars while correspond value was 13,230 MJ for grain (Table 4).

The highest energy inputs for both type cultivars were the fuel around 45%, but it was higher with 46.46% in nature compared to hybrid with 45.72% (Table 4). The results of study indicated that fuel input plays an important role in energy input for rice production. In particular, fuel consumption in tillage and harvesting is more than in other operations in rice production. In general, there is a considerable reason for high diesel consumption in the study area due to old machineries and irrigation pumps. One of the main reasons for high consumption of diesel fuel is a temporal depreciation of machinery particularly in the tractors and tillage equipment.

In order to improve the energy consumption as well as reduction of diesel fuel in rice producing system, it is powerfully suggested that the machinery's efficiency is increased with new machineries and equipment such as tractor, tillage and irrigation pumps.

The total energy equivalent of the chemical fertilizer consumption was ordered as second component among energy inputs and constituted 15,928 MJ ha^{-1} of the total energy input for both cultivars with 23.80% and 24.19% rate for hybrid and nature cultivar, respectively. Analysis of data showed that energy input of nitrogen fertilizer has the highest share (around 91%) within all chemical fertilizers. It has been reported that the energy input of chemical fertilizer has the biggest share of the total energy input in crop production while machinery had the most significant impact on rice production.

Similarly, several researchers reported that the energy used by fertilizers represented a major part of the total input energy around 40-70% of total compared with other input requirements [14, 17].

In most previous rice production studies, fertilizer accounted for the largest share of total energy input, with the energy input of nitrogen ranking top among all fertilizers[9], which agrees with the findings of the present study (Table 4). Fertilizer, fuel, and water were the three highest energy inputs and accounted for 81.78% of total energy input, regardless the cultivar. Hence, to reduce total energy input for rice production, it is essential to control fertilizer, fuel, and water inputs. Consume energy for irrigation water was the same in both rice cultivars and consist of approximately 12.00% (Table 4). Irrigation water and its operation consumed the maximum energy on rice farm due to the higher water requirement of rice crop and the electrical energy is mainly utilized by motor pumps to run irrigation pump set. Similarly, Pimentel and Pimentel [18] reported that irrigation energy requirement for rice production in the United States of America is 8949.6 MJ ha^{-1} (18.10%) of the total energy requirement. However, Alipour. et al. [19] found that in rice study the irrigation energy had the highest share with 38.84% which is higher than what was obtained in this study. Since fertilizer and fuel are closely related to the profitability of rice production, farmers are highly receptive to integrated machinery and nitrogen-saving technologies that can achieve high energy-use efficiency. In general, reducing diesel fuel and fertilizer consumption, mainly nitrogen, is important for energy management in this study area. Reducing chemical fertilizer use on rice fields, it does not only provide financial benefits to farmers, but it also can reduce environmental pollutions. Consequently, farmers pay less attention to water-efficiency measures, resulting in negative environmental impacts [20]. Therefore, it is essential to adopt water-saving irrigation methods to reduce irrigation water input and ultimately total energy input. Fertilization management, integrating a legume into the crop rotation, chopped residues and other soil managements can reduce the chemical fertilizer energy requirements [21, 22]. Therefore, it is necessary to focus more on fertilizer, fuel consumption than other factors to effectively reduce energy consumption in rice production.

Table 4 Energy (MJ ha^{-1}) input-output analysis for two cultivars of the rice production

Input	Hybrid		Nature	
	(MJ ha^{-1})	Percentage (%)	(MJ ha^{-1})	Percentage (%)
Human labour	997.96	1.49	997.96	1.52
Diesel fuel	30592	45.72	30592	46.46
Machinery	5575	8.33	5575	8.47
Chemical fertilizer	15928	23.80	15928	24.19
Pesticides	2220	3.32	2220	3.37
Electricity	900	1.34	900	1.37
Seed	2940	4.39	1864	2.83
Water	7764	11.60	7764	11.79
Total energy input	66916	100.00	64842	100.00
Output	168330		148850	
Rice	130830	77.72	117600	79.01
Straw	37500	22.28	31250	20.99

According to the data collected from all questioner farms, pesticides consumption was 2220 MJ ha^{-1}, especially comes from herbicide use to control common weeds such as watergrass (*Echinocloa spp*.) which is the most competitive and difficult weed to control in rice fields in the area. Annual and perennial sedges and broadleaf weeds are also the most important infested weeds in the rice production fields. Regardless of the cultivar, labour consumed around 2% energy, whereas least energy was utilized for labour. Energy share from human labour for rice fields of the study area was as 1.49% and 1.52% of related total energy inputs for hybrid and nature cultivar, respectively. Most of the human labour in rice production was used in the soil seedbed preparation, irrigation and harvesting although most of the machine power was used in the seedbed preparation, harvesting (in many farms) and irrigation operation. The source of human labour in the questioned farms is either from family members or hired labours. In contrast, [23] reported that the contribution of human labour in rice production was approximately 46% of the total in Sikkim State of India because many agricultural practices were performed by human. The energy input of electricity was calculated 900 MJ ha^{-1} (Table 4). In this study, due to water being pumped from deep wells, water channel and supply need for consumption of the electricity energy was very high. A high percent of this energy in the studied area could be attributed to use of irrigation pumps of low efficiency despite the low electricity price in the country where electric energy used in agriculture is produced mainly from renewable sources, especially water which highly considers energy consumption for both cultivar production (Table 4). This input is in line with others [24] who show generally account for a considerable share of total energy input. Seed only represented 4.39% and 2.83% of total energy requirement in studied area, for hybrid and nature cultivar, respectively. There was a significant difference among two seed cultivars in respect to energy consumption of seeds due to higher cost of purchase for hybrid, although it has high quality. However, the required quantity of seed will reduce by using high quality seeds. In addition, qualified seed will help to reduce the eventuality of pests and weeds infestation, reduce the energy needed in for weeding and chemical application and increase yield.

The key indicators to compare the efficiency of energy resources in a cropping system are net energy, energy use efficiency (energy rate), energy productivity and specific energy. Energy use efficiency (energy rate), specific energy, energy productivity, and net energy in the study are presented in Table 5. Energy use efficiency or energy rate represents energy output per 1 MJ energy input, which is an important indicator of crop production efficiency. The energy use efficiency above 1.0 showed energy being used efficiently, high energy use efficiency is attributed to lower input usage. Reducing the quantity of agrochemical inputs with high energy costs and effective use of energy resources are critical for energy saving in modern crop production. Additionally, increasing crop yield by using improved seed cultivars such as hybrid is also required. With respect to the data analysis, the energy use efficiency varied from 2.3 for nature cultivar to 2.5 for hybrid with greater yield.

In contrast, others [25] reported that the energy use efficiency of rice cultivated predominantly through manual was lower with 1.72 and decreased to 1.63 following greater mechanization.

However, the lower inputs of resources such as fertilizer and machinery use in Iran rice production led to lower rice yields, which was the most significant difference between the rice production systems of Iran and this region of western Turkey. Similarly, different rice cultivars have been found to respond differently to energy use efficiency [15], while some rice cultivar yielded more grain than the others [26]. This could be also due to differences in agricultural and climatic conditions, and rice cultivar between the studies. Similarly reported that different rice cultivars responded differently to the growing methods [27]. Similar to the present study, [28] obtained energy use efficiency of 2.8 in energy consumption analysis for selected crops in different regions of Thailand despite the low grain yield with 2593 kg ha^{-1} as compared to 8000 and 8990 kg ha^{-1} obtained from this study for nature and hybrid cultivars, respectively. Low efficiency of rice production in the present study comparable to Kosemani and Bamgboye [9] in Nigeria (6.6) and Khan et al. [5] in Australia (6.7) was a result of low grain and straw yield of rice in the study area. They reported that high energy use efficiency was due to low input energy with 14,813 MJha^{-1} because of many practices are performed bay human. In this study, results demonstrated that energy use in rice production is not efficient and on the other hand is detrimental to the environment due to mainly excess input use. Therefore, reducing inputs would be helpful to optimize rice fields by more efficient fertilizer application and diesel in rice production. By increasing the annual yield of rice production and/or decreasing the energy consumption, especially diesel fuel energy, rice production in this area will be efficient. Management systems with a legume as a previous crop have been reported as having a greater energy use efficiency than those with a cereal as the preceding crop [21].

Table 5. Energy indicators of two rice cultivars produced in the study area

	Unit	Hybrid	Nature
Energy use efficiency (energy rate)	-	2.5	2.3
Energy productivity	kg MJ^{-1}	0.13	0.12
Specific energy	MJ kg^{-1}	7.4	8.1
Net Energy	MJ ha^{-1}	101,414	84,008

The energy productivity indicates the amount of rice produced per MJ of energy consumed and it is a measure of the environmental effects associated with the production of crops. The energy productivity is calculated as 0.13 kg MJ^{-1} and 0.12 kg MJ^{-1} for hybrid and nature cultivar, respectively. These values suggested that 0.13, and 0.12 kg of rice were produced when 1 MJ of energy was used for hybrid and nature cultivars, respectively. There was an increase in energy productivity from hybrid to nature cultivars, indicating that more kilograms of rice were produced per unit energy (1 MJ) input in hybrid cultivar. These are lower than the value of energy productivity of 0.45 kg MJ^{-1} reported by [9]; the low productivity in this study was due to the use of high input energy. They reported that the high energy productivity was due to low energy input by 14813 MJ ha^{-1} as compared to this study 66,916 MJ ha^{-1} and 64,842 MJ ha^{-1} for hydride and nature cultivars.

Specific energy is an indicator which shows how much energy was used to produce one unit of disposable product (Table 5). The specific energy of rice production was 7.4 and 8.1 MJ kg^{-1} for hybrid and nature cultivar, respectively. For producing 1 kg of rice, 7.4 and 8.1 MJ of energy was spent in hybrid and nature cultivar, respectively.
This means that each kg of rice produced with hybrid cultivar will save approximately 0.7 MJ compared with the nature cultivar of rice production. Specific energy decreased in nature than hybrid cultivar, indicating that more energy was used in the production of rice in hybrid than nature one.

Similar to the output energy, the same trend was followed in net energy. The net energy for rice production was approximately 17% greater in hybrid (101,414 MJ ha^{-1}) than nature (84,008 MJ ha^{-1}). Considering this indicator, a considerable difference was recorded between hybrid and natural cultivars. This indicator, which was determined for both cultivars, was found to be lower than the net energy obtained in Nigeria of 82,733 MJ ha^{-1} in small farms [9]. Low net energy values obtained from this study was attributed to low grain and straw yields of rice.

CONCLUSIONS

It is possible to conclude that the energy rate can be increased by raising the crop yield and by decreasing energy input consumption. The results of the study confirmed the importance of diesel fuel and chemical fertilizer consumption on total energy input in the study area. It seems to be possible to reduce energy use, especially fuel and fertilizer, by using better management and more efficient methods such as legume crop rotation. For improving energy efficiency in the study area, the farmers should be educated regarding the optimal use of inputs such as fertilizers, chemicals, and irrigation water as well as technologies. In addition, local agricultural institutes have an important role to inform the farmers with respect to more efficient use of energy resources and providing more sustainable agricultural production systems in the region. Further, results of this study revealed that hybrid cultivar had higher grain and straw yield than nature, and increased output energy. Analysing all impacts, hybrid rice cultivar is a sustainable and very feasible alternative to nature in the region, as it increases energy use efficiency, and net energy due to higher grain and straw yield, which is directly to the productivity, and requires low specific energy used to produce one unit of the product.

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KOMPARATIVNA STUDIJA ENERGETSKOG KORIŠĆENJA KULTIVATORA ZA PIRINAČ (*Oriza sativa* L.) KOD MEHANIZOVANOG SISTEMA GAJENJA NA ZAPADU TURSKE

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Apstrakt: U prikazanom istraživanju je izvršena energetska analiza mehanizovane proizvodnje pirinča (*Oriza Sativa* L.) za dve sorte pirinča u regionu pod nazivom Çanakkale, u zapadnoj Turskoj.
Indikatori su efikasnost korišćenja energije, specifična energija, energetska produktivnost i neto energija. Sorte pirinča koje se obično uzgajaju u regionu navedene su u dve grupe, kao: autohtoni i hibrid visokog prinosa.

Primarni podaci su dobijeni putem terenske ankete sa farmerima licem u lice i upitnikom u okruzima Biga, Ezine i centralnim okruzima, obično u oblastima za uzgoj pirinča u regionu. Sekundarni podaci i energetski ekvivalenti dobijeni su iz dostupne literature korišćenjem prikupljenih podataka za period proizvodnje 2020–2021.
Analiza podataka pokazala je da dizel gorivo ima prosečno najveće učešće u ukupnim uloženim energentima sa 46,46% i 45,72% za autohtoni i hibridni uzorak pirinča, a zatim slede hemijska đubriva sa 24,19% i 23,80%, posebno azot (N).
Unos vode je bio treći najveći uticajni parametar sa 11,29% i 11,60% za autohtone i hibridne uzorke pirinča, respektivno.
Mašinski input je ukupno imao uticaj na četvrtom mestu, ali je pokazao sličan procenat sa oko 8,00% kod obe sorte pirinča zbog upotrebe sličnih mašinskih operacija.
Drugi visok uticaj na rezultate je primena pesticida od približno 4,00% jer je upotreba herbicida veoma visoka, posebno zbog jednogodišnjih i višegodišnjih i širokolisnih korova.
Upotrebljena količina energije ima optimalan nivo jer se kultivacija obično izvodi mehaničkom elementima.
Utvrđeno je da je neto utrošena energija veća kod hibridnih sorti pirinča sa 101,41 MJ ha^{-1} zbog većeg prinosa zrna i slame nego kod authotone sorte sa 84,01 MJ ha^{-1}. Efikasnost korišćenja energije i energetska produktivnost autohtone sorte iznosile su 2,3 i 0,12 kg·MJ^{-1}, respektivno, što odgovara porastu od 2,5 i 0,13 kg·MJ^{-1} kod hibridne sorte.
Uz odgovarajuće agronomske mere u proizvodnji pirinča na istraživanom području, veći prinos hibridne sorte trebai nužno da dovede do povećanja energetske produktivnosti i prinosa.

Ključne reči: *Energetska analiza, energetski indikatori, sorte pirinča*

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EFFECTS OF SOIL AND WATER CONSERVATION MEASURES ON THE ENVIRONMENT: A REVIEW

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Abstract: The preservation and sustainable development of soil and water resources is one of the basic principles for the development of the environment. Soil degradation was a significant global issues during the 20th century and remains of high importance in the 21st century as it affect the environment, agronomic production, food security, and quality of life. This review provides an extensive review information on soil conservation strategies or methods and their applications. Based on this, the most promising soil conservation technologies are identified to improve the management and conservation of soil resources. This review also aims to provide general characteristics of soil and water loss, explore the relationship between soil and water conservation and sustainable development, and to provide relevant methods for soil and water conservation.

The result of this review shows that measures focused on soil and water conservation by ridging, constructing earth bunds and terraces, mulching, multiple cropping, fallowing, and tree planting. Mulching, crop management, and conservation tillage are appropriate technologies for conserving sandy soils of high erosivity and low water holding capacity. Leguminous cover crops and residue management reduce the impact of rain.

These measures also reported to enhance the levels of soil organic matter and nutrients, especially nitrogen, which is generally limited in tropical soils. Intercropping of compatible species is recorded as a promising cropping system, as cultures with different rooting patterns and growth cycles can promote nutrient recycling and suppress weeds.

Key words*: mulching, terracing, conservation tillage, soil, ridging, crop management*

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INTRODUCTION

Soil and water conservation is a comprehensive subject on the study of reasonable exploration and utilization of water resources. The preservation and sustainable development of soil and water resources is one of the basic principles for the development and sustainability of any environment. According to [1] there is a direct proportion between the water and nutrient absorbed by plants and soil capacity of the root system. A highly extended roots which is affected by soil structure can help plants to absorb nutrients needed.

The preservation and sustainable development of soil and water resources is one of the basic principles for the development any country. The United Nations predict that 1.8 billion people will experience absolute water scarcity in less than 5years, and worry that by 2025, two out of three persons will be living in water stressed region [2]. Already, every five persons worldwide cannot access their basic everyday water resources [2]. This is a fact recently witnessed in Cape Town, South Africa which is in dire need of water with serious rationing of the commodity. Water will be a renewable resource, but its capacity to renew itself depends on how it is managed. Restoration of degraded soil calls for the application of certain management and conservation measures and the undertaking of much needed precautions. Measures such as contour cultivation, tied ridging, terracing, strip cropping, dense vegetation and planting of cover crops, mulches, fast growing species and integrated cropping system, provision of alternative fuel sources, check structures, protected watersheds, proper land preparation and ploughing, application of fertilizer, amendments and organic manures and drainage systems are quite often mentioned as the techniques which help to protect and improve the soil [3].

Soil and land management practices such as tillage and cropping practices, directly affect the overall soil erosion problem and solution on a farm. When crop rotations or changing tillage practices cannot effectively control erosion on a field, a combination of measures might be considered necessary. For example, contour ploughing, strip cropping, or terracing may be considered. The most practiced measures involves: (1) Agronomic such as plant/soil cover, conservation farming , contour farming (2) Vegetative; such as planting barriers (vegetative strips), live fences, windbreaks (3) Structural; such as terraces, banks, bunds, cut off drains, barriers and lastly (4) Overall management; such as area closures, selective clearing.

Terraces

A terrace is an embankment or ridge of earth constructed across a slope to control runoff and minimize soil erosion [4]. A terrace reduces the length of the hill-side slope, thereby reducing sheet and rill erosion and prevent formation of gullies. Research have shown that soil loss by erosion is proportional to the length of slope to the 0.5 power [5; 6]. Doubling the length of slope increases erosion about 1.4 times. By shortening the length of slope, terraces contribute greatly to reducing soil loss. About 70 per cent of the soil disturbed by splash erosion moves downhill. Terraces produce a barrier to partially stop this downhill movement of soil. A great part of the splashed soil is deposited in the terrace channel (Fig 1).

Terracing, however, cannot be justified on crop land that can be protected by less expensive conservation measures. Agronomic measures such as contour tillage, crop rotation, and strip cropping are sufficient on many slopping areas.

These measures alone may furnish enough protection where rainfall intensities are low, the soil absorbs the rainfall rapidly or are erosion-resistant, and the slopes are gentle. Agronomic control measures may give a partial control, and they can be successfully reinforced with terracing [7]. Terraces should always be supplemented with the best possible cropping practices, since they fail to hold the soil adequately when used alone [8].

Fig 1.Illustration of bench terraces, [5]

Levelled bench terraces and earth banding on existing slopes are common earth structure used in soil and water conservation. Sometimes, and especially in the highlands, steps are constructed across hillsides and strips of crop residues are covered with soils dug from above. The resulting incorporation of organic matter increases soil fertility and enhances infiltration [9] through macro porosity as well as increased water retention in soils [10; 11]. The challenge however, is the high labour requirement in their construction and maintenance [12]. [13] observed highest maize yields in terraced compared to all other conservation measures in sloping land.

For instance in Kenya, there are three major principles on conservation agriculture practiced in Kenya; minimal soil disturbance, permanent soil cover and crop rotations [2]. Soils under conservation agriculture tend to considerably improve their soil organic matter content after applying the technology for several years. Soil organic matter can be considered as the most important soil fertility and quality factor influencing other soil properties such as macro porosity, infiltration, water holding capacity or soil structure. In conservation agriculture, only minimal or no soil tillage is applied and involves crop seeding without mechanical seedbed preparation and minimal or no soil disturbance since the harvest of the previous crop [12; 1].

Contour Farming

Contouring farming is the practice of conducting all field operations such as ploughing, planting, and cultivating land across the slope, rather than up and down the slope [14].

The small ridges and plant stems in the plant stems in the contoured rows hold water and thus prevent runoff and soil erosion [14]. The ridges are most effective in row crops, but the water holding ability of the ridges, supplemented by plant stems, makes contouring valuable for small grains. This practice is the simplest and easiest of all the mechanical soil conservation measures. When contouring is used alone on steeper slopes or under conditions of high rainfall intensity and soil erodibility, there is an increased hazard of gullying because of breaching of rows. Breaches cause cumulative damage as the volume of water increases with each succeeding row. The effectiveness of contouring is also reduced by changes in infiltration capacity of the soil due to surface sealing. Depressing storage is reduced after the tillage operations cease and settlement take place. Studies have shown that contour cultivation together with good grassed waterways reduced watershed runoff to 75 to 80 percent at the beginning of the season. This reduction dropped as low as 20 percent at the end of the year, with an annual average reduction in runoff, due to contouring, of 66 percent. For best results on steeper slopes contouring should supplement other conservation practices like strip cropping, terracing or bunding [15].

Strip Cropping

Strip cropping is the practice of growing alternate strips of close-growing and intertilled crops in the same field [9]. Strip cropping (Fig 2) of maize, oats and hay on the field. Crops have been grown in association with one another for centuries. In fact, crop mixture probably represents some of the first farming systems [16]. Complex crop mixture have been recognized as being important in the sub tropics and temperate zones, primarily in labor intensive cropping system.

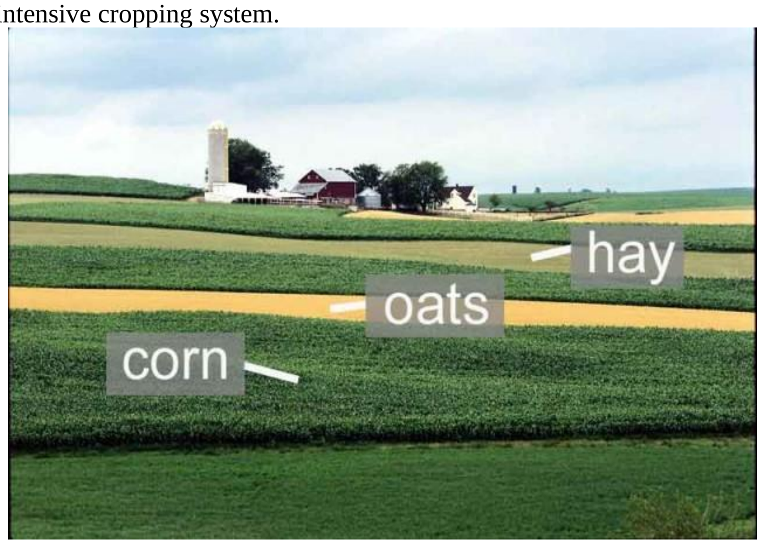

Fig 2. Strip cropping of corn, oats and hay on an agricultural field, [9].

This is a more intensive soil conservation practice than contouring, but is not as intensive as terracing or bunding. It is quite often used in conjunction with terracing or bunding. Strip cropping is not a single practice; it is a combination of several good farming practices, particularly crop rotations, contour farming and cover cropping. It may also include conservation tillage operations and stubble mulching. When strip cropping is combined with contour tillage or terracing, it effectively divides the length of the slope, checks the velocity of runoff, filters out soil from the runoff water and facilitates absorption of rain. The growing of perennial grass in the rotation provides protection for a part of the field at times when the intertilled strips are bare.

Strip-cropping to control soil erosion against runoff, derives its effectiveness mainly from the following two reasons: (a) reducing the runoff flow through close growing sod strips, (b) increasing the infiltration rate under cover conditions. The reduction in runoff velocity between the row strips is because of making obstruction in the flow path [17; 14]. The obstructions created by row crops are also responsible to dissipate the kinetic energy of flowing water, as a result the flow velocity at the downstream section get reduced sufficiently, which causes deposition of soil particles over the soil surface.

The crops grown in strips not only reduce the flow velocity of water over the surface, but also encourage the water intake rate of the soil, which might be due to the following reasons: (1) the crops provide an obstruction in flow path of surface water, that is water gets additional time to stand between the rows. By this virtue, a large amount of water infiltrated into the soil, as result the depth of water causing runoff generation is reduced significantly, and thereby the soil loss also get reduced accordingly; (2) the root system of the crops makes the soil more porous causing more amount of water is absorbed by the soil, and thus reduces the runoff and soil loss; (3) the water also gets additional intake path along the roots of the plant, which creates a similar effect on runoff and soil loss.

When strips are laid with varying degree of divergence from the contour, then effectiveness of strip-cropping is influenced by the soil types, degree and length of land slopes, previous erosion. The effect of soil type is imposed by all those soil properties, which are responsible to increase water intake capacity. From field investigations it has been found that 2 to 3 times greater soil loss is from the soil having moderately heavy to heavy sub-soil than the soils with light textured sub-soil for the same slope conditions [18]. The degree and length of land slope have pronounced effect on soil loss. The reason may be justified as: the erosive power of flowing surface water is increased due to increase in slope inclination, as a result the certain range, the erosion also increases, accordingly, but at greater length there start sediment deposition due to reduction in runoff volume and its velocity. The combine effect of slope and its length is more significantly on soil loss. In addition to control the soil erosion/soil loss, the strip cropping is also very effective to maintain the soil fertility; and creating effects on several good farming practices including crop rotation, contour cultivation, proper tillage, stubble mulching, cover cropping, mainly.

Erosion reduction by strip cropping on hillsides

Another dimension of strip cropping is the use of annual small grains or perennial hay crops in alternating strips with corn or soybeans.

In addition, crop rotations, residue management and conservation practices all contributes to the maintenance of productive top soil on erosive hillsides. Water-induced soil erosion is retarded by introducing small grain or meadow/legume crops as part of alternative farming systems [16].

Crop Rotation

Crop rotation is defined as the practice of growing a sequence of plant species on the same soil [19]. Crop rotation is characterized by a cycle period, while crop sequence is limited to the order of appearance of crops on the same piece of land during a fixed period [20]. Crop rotation (Fig 3) is along used concept in models to represent the temporal dimensions of cropping plan decisions. The succession of crops in a given area has effects on production and consequently on cropping plan decisions, the traditional approach developed by agronomists was to derive cropping plans from the crop proportions in crop rotation. Some authors have argued that the reproducibility of a cropping system over time is only ensured when crop choices are derived from crop rotation. Cropping plan decisions consequently require one to look back and forth in time [20].

Fig 3. Crop rotation a way to boost yield and increase profit, [21]

Crop rotation can be more effective for controlling the soil erosion when accompanied with strip-cropping system. It can be used on the same piece of land by growing tilled crops, small grain crops, hay crops or grasses either under strip-cropping system or in a separate field system.

In the areas, where perennial grasses and legumes are not feasible to grow, then the row crops of small grain and annual legume crops can be grown in the strips. It is a general rule that, no two cultivated strips should have the same planting or harvesting dates.
The sequence of crops should be in such a manner, that there could be formed a dense-fibrous root system to hold the soil and retard the erosion, until the roots are broken under tillage operations. All these activities under crop rotation add the organic matter in the soil, thereby the physical condition of the soil gets improved, and ultimately the soil absorbs more water and also increases the capability to resist the erosion [19; 22].

Cover crops for soil fertility and erosion control

Cover crops are fundamental sustainable tools used to manage soil quality [23; 24], water, weeds, pests, diseases and diversity in an ecosystem. Keeping the soil covered is a fundamental principle of conservation agriculture. Crop residues are left on the soil surface to protect soil surface after harvesting or during kill-down when the cover crops are slashed and left in the field at flowering [10;11]. Effects of cover crops are positive when managed to improve infiltration and reduce evaporation [11]. Cover crops have an influence on physical soil properties such as water relationships, aggregation, infiltration capacity, bulk density, soil temperature and hydraulic conductivity. Cover crops influence soil water content through reduced surface evaporation due to mulch effect and increased infiltration and retention of precipitation [2; 10; 11].
Judicious use of cover crops residues, either incorporated in the soil or placed on soil surface can help maintaining adequate infiltration rates [25; 26; 27; 28], preventing soil surface crusting [29; 30; 31; 32; 33], improving soil aggregation [34; 35; 36; 37; 38; 39], and aeration in the soil [40]. [41] found that final infiltration into the soil were increased from 2.3 to 5.3 cm/hr when 2.2 Mg/ha of wheat straw was mulched on the surface (Fig. 4). [42] reported that runoff from tropical Nigerian soil was five times greater where crop residues where ploughed under other than for no-tillage system with crop residues remaining on the soil surface. [43], modeling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions, observed that even small amounts of surface residue are effective at reducing water loss and increasing yield. Some cover crops have been shown to suppress weeds, reduce nematode loads, improve soil fertility, reduce water leaching and control erosion. Mulch's impact in reducing the splash effect of the rain, decreasing the velocity of runoff, and hence reducing the amount of soil loss has been demonstrated in many field experiments conducted on several Nigerian research stations [25; 44; 45; 46; 47; 48].

Fig. 4. Application of mulch in agriculture, [25].

Conservation Tillage

Conservation tillage describes the method of seedbed preparation that includes the presence of residue mulch and an increase in surface roughness as key criteria [49; 50; 44]. The practice therefor ranges from reduced or no-till to more intensive tillage depending on several factors, such as climate, soil properties, crop characteristics, and socioeconomic factors [51].

Tillage is a fundamental practice in agricultural management. It can be defined as a method of working the soil either physically, chemically, mechanically or biologically to create suitable conditions for seedling germination, establishment and growth [52]. Conservation tillage embraces not only primary cultivation practices based on ploughing or soil inversion, but also secondary operations directed at land preparation and sowing or planting. Conservation tillage typically involves inversion tillage which disturbs the soil to a depth of 20-30cm, redistributes soil layers and expose subsurface horizons to oxidation [50; 53; 52].

Minimum Tillage

Minimum tillage describes a practice where soil preparation is reduced to the minimum necessary for crop production and where 15% to 25% of residues remain on the soil surface [54; 55]. The sustainable development of agriculture has stated that there is no universally applicable system for soil tillage because of the local differences, especially climate and soil type and also the technical level of endowment. Reduces establishment costs, saves time, and reduces soil erosion, nutrient leaching and fuel use. Improves soil structure and builds organic matter.

Although not all fields will be suitable for minimum tillage. It depends on the level of compaction and surface residue. Less resistance to root growth, improved structure, less soil compaction by the reduced movement of heavy tillage vehicles and less soil erosion compared to conventional tillage [51].

Zero Tillage

Zero tillage (Fig. 5) is characterized by the elimination of all mechanical seed bed preparation except for the opening of a narrow strip or hole in the ground for seed placement.

The surface of the soil is covered by crop residue mulch or killed sod [56].

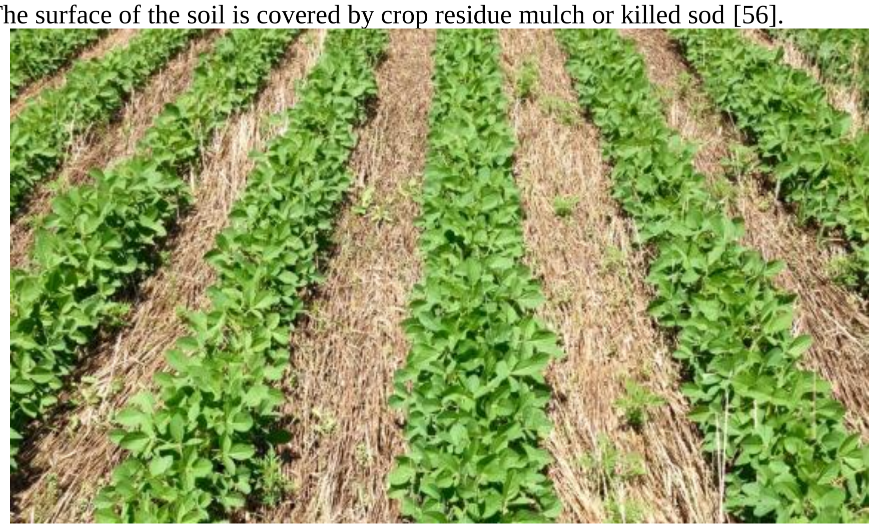

Fig 5. Zero tillage Agriculture

Research on quantifying the effects of different tillage operations on runoff and erosion were conducted by [51]. He recorded that soil loss was 42 times higher from the ploughed watershed than from the no till watershed. Other erosion measurement on soil loss were made by [57]. The result clearly show the suitability of conservation tillage as an effective soil erosion control measures through the protective effect of residue mulch.

CONCLUSIONS

Investigations focusing on the influence of different tillage methodologies performed manually or mechanically on soil properties and crop yield are numerous. According to these studies, no till and mulch farming are sustainable management technologies for humid and sub-humid tropics, whereas rough ploughing, ridging, and mulching are appropriate techniques for the semi-arid regions. Different tillage operations are necessary in locations with unfavorable climatic conditions or problematic soils. However, high labour intensity, time consuming, regular inspections, high consumption of scarce farmland, and large amount of construction materials required are factors that hinder farmers from installing or maintaining terraces.

Literature on investigation into drainage systems is scarce. The implementation probably needs special knowledge of the water regime of the area and the construction of waterways. Structural barriers made of stones or vegetation installed along contour lines are another mechanical erosion control measures. As they operate as filters, they may not reduce the runoff amount but retard its velocity and hence encourage sedimentation, increase infiltration, and facilitate the formation of natural terraces [51]. References on the use of stone lines installed as barriers on the field were not found in this review. In general, mechanical measures are effective soil conservation technologies as they reduce soil loss. But as the installation and maintenance is usually labor intensive, these structures are not likely to be adopted by farmers. According to various literatures reviewed, soil conservation measures should be site specific depending on the local factors such as topography, soil texture, water regime, and farming system. Conservation tillage, mulching, crop management are some of the appropriate technologies for conserving sandy soils of high erosivity and low water holding capacity. These measures also enhance the levels of soil organic matter and nutrients such as nitrogen, which is generally in short supply in tropical soils. From literature reviewed, alley cropping is regarded as an effective erosion control measure but is not practiced on farms in Nigeria as this technology is very labor intensive and the benefits on soil fertility did not yield the expected returns on investment. Research on minimum tillage has shown its beneficial effect on chemical, physical, and biological soil properties. However, the application of minimum tillage is problematic on soils with poor drainage, compacted layers, surface crust that still require periodic soil preparation to enhance infiltration. Minimum tillage and no-till are effective erosion control measures on coarse and medium texture soil with good drainage, whereas ridge tillage is advantageous in areas with low or variable rainfall, shallow soils and where root and tuber crops are cultivated.

Conservation tillage operations that use the effect of surface covers or increase roughness to reduce erosion risks ought to be chosen according to factors such as rainfall, crop, and depth, texture, and drainage conditions of the soil.

Permanent mechanical methods for conserving the soil are rare, as implementation and maintenance are labor, time and cost intensive and success is visible only after long periods. Water resources development will go a long way to mitigate some of the extreme climate condition that can adversely affect the soil negatively.

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EFEKTI MERA ZAŠTITE ZEMLJIŠTA I VODE NA ŽIVOTNU SREDINU: PREGLED

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Apstrakt: Očuvanje i održivi razvoj zemljišta i vodnih resursa jedan je od osnovnih principa razvoja životne sredine. Degradacija zemljišta je bila značajno globalno pitanje tokom 20. veka i ostaje od velikog značaja u 21. veku jer utiče na životnu sredinu, poljoprivrednu proizvodnju, sigurnost hrane i kvalitet života.

Ovaj pregled pruža opsežne informacije o strategijama ili metodama očuvanja zemljišta i njihovoj primeni.

Na osnovu ovoga, identifikovane su najperspektivnije tehnologije očuvanja (zaštite) zemljišta za poboljšanje upravljanjem i očuvanjem resursa zemljišta. Ovaj pregled takođe ima za cilj da pruži opšte karakteristike gubitka površina zemljišta i vode, istraži vezu između očuvanja zemljišta i vode i održivog razvoja i tako pruži relevantne metode za očuvanje zemljišta i vode.

Rezultat ovog pregleda pokazuje da su mere bile usmerene na očuvanje zemljišta i vode kroz eliminaciju nagiba, izgradnju terasa i traka, malčiranje, združene useve, zatravljivanje površina i sadnju pojasa sa drvećem.

Malčiranje, upravljanje usevom i konzervacijska obrada zemljišta su odgovarajuće tehnologije za očuvanje peskovitih zemljišta pretežno sa visokim stepenom mogućnosti pojave erozije i malog kapaciteta zadržavanja vode. Pokrovni usevi sa mahunarkama i upravljanje biljnim ostacima smanjuju uticaj padavina u pojedinim predelima.

Ove prikazane agrotehničke mere takođe pokazuju povećavanje sadržaja organske materije i hranljivih materija u zemljištu, posebno azota, koji je generalno u malim procentima prisutan u tropskim zemljištima. Zajedničko gajenje kompatibilnih vrsta je zabeleženo kao obećavajući sistem useva, jer biljne kulture sa različitim načinima ukorenjivanja i ciklusima rasta mogu promovisati recikliranje hranljivih materija i efikasno suzbiti pojavu korova.

Ključne reči: *Malčiranje, terase, konzervacijska obrada, zemljište, banak, upravljanje usevom*

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DESIGN AND DEVELOPMENT OF A MULTI-TASKS MOTORIZED GINGER RHIZOMES JUICE EXPRESSION MACHINE

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Abstract. Manual ginger juice expression processes are tedious, unhygienic, and inefficient, affecting the quality and quantity of ginger juice extracted. Extraction by chemical means is complex, expensive, and requires high skill to operate. The developed motorized ginger juice expression machine performs two distinct unit operations: size reduction and separation processes. Major components of the machine include the feeding unit, pulverizing unit, juice expression unit, juice drainage point, waste outlet, frame, and power transmission system. The machine is powered by 2 H.P., 1400 rpm and 1 H.P., 1430 rpm prime movers, and the V-belts and pulley assembly speed are 646 rpm and 240 rpm, respectively. The developed expression machine offers an affordable and simple method of processing fresh ginger minimizing loss in ginger rhizome quantity and quality, and ultimately reducing postharvest losses.

Keywords: *Ginger, expression, extraction, machine, oleoresin, juice.*

INTRODUCTION

Ginger (*Zingiber officinale roscoe*) is produced from the plant rhizome and belongs to the family of *Zingiberaceae*. It has essential value for its oil, such as oleoresin and gingerol, used in the beverage industry, bakery, pharmaceutical, culinary and cosmetic preparation [1,2]. [3] published that the percentage composition of volatile oil and non-volatile extract of ginger from Nigeria was given as 2.5% and 6.5%, respectively, which resulted in the high demand for Nigerian ginger in the international market.

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Although, [4] reported that the quality of Nigerian dried ginger has been declining due to poor mechanization in ginger production and processing. Thus, resulting in the attendant mould growth and loss of some important ginger qualities, Nigeria to command the cheapest price in the world market [5,6]. There is a low percentage of oleoresin content per unit volume of ginger due to extended harvest, long storage period, over-drying, and re-drying due to dampness [7,8]. Also, when drying ginger at a high temperature, it denatures the protein content and alters the organoleptic attributes through loss of aroma and colour [9,10]. However, the deterioration of active ingredients in dried ginger reduces its economic value and utilization in the industries. [11] enunciated that pulverization and expression as unit operations can be done using traditional or modern methods, though the former is relatively primitive and favours low capacity output, and is susceptible to increasing the microbial load on the crushed ginger [12,13]. Ginger juice obtained from the mechanical expression of pulverized ginger rhizomes offers a value-added ginger product that will increase farmers' market opportunity [14,15].

Farmers do not generally adopt the chemical extraction method of processing ginger due to the high cost and complexity of the equipment used in the extraction [16]. The ginger extract obtained from this process usually has some elements of impurity resulting from dissolved chemicals used in the extraction [17,15]. Other methods of ginger processing are traditionally done by a manual method such as mortar, pestle, and hand pressing, but this process is described as tedious, unhygienic, and inefficient. Thus, affecting the quality and quantity of ginger juice available in the Nigerian market. The wet extraction process, otherwise known as hot water or steam extraction used traditionally by women in rural communities for processing varieties of oil-bearing biological materials, falls short of the standard, especially in quality [18,15]. The mechanical expression of ginger juice via pulverized ginger rhizomes offers a value-added ginger product that will increase the satisfaction of consumers over convenient food consumption and increase the market opportunity for entrepreneurs and farmers [19,20]. A motorized ginger juice expression machine aimed at processing ginger at the shortest possible time after harvest and increasing the retention level of the active ingredients in ginger was developed to meet up with the high market demand for ginger juice due to its nutritional and medicinal values, reduce the amount of loss of oleoresin and volatile oil in ginger during processing.

MATERIALS AND METHOD

The study was carried out at the general engineering workshop of Agricultural and Bioresources Engineering Department Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria, located at Latitude 5º 28" 3 N and 7º 32" 56 E.

Design Considerations

The following were considered in developing the multi-tasks ginger juice expression machine

1. For durability and prevention of oxidation and corrosion, stainless steel sheet was used for the construction except for the frame (where galvanized steel was used) because it does not react with juice from the ginger rhizomes, which contain oleoresin and volatile oil.

2. The hopper design was based on the recommended average angle of repose (34.60) and the coefficient of friction on stainless steel of fresh whole ginger rhizome (0.57) to ensure the flow of ginger rhizomes in the hopper
3. Static and dynamic stresses resulting from direct loading, bending, and torsion was considered in the shaft design.
4. The cost of construction materials was considered by using locally available materials.
5. Variable pitch and tapered screw shaft (auger) were used to ensure maximum conveyance and pressing of the pulverized ginger rhizomes.

Description of the motorized ginger juice expression machine

The developed motorized ginger juice expression machine consists of the following major components: feeding unit, pulverizing unit, juice expression unit, juice outlet, waste outlet, frame, and power transmission system. The developed machine is shown in Figures 1 and 2.

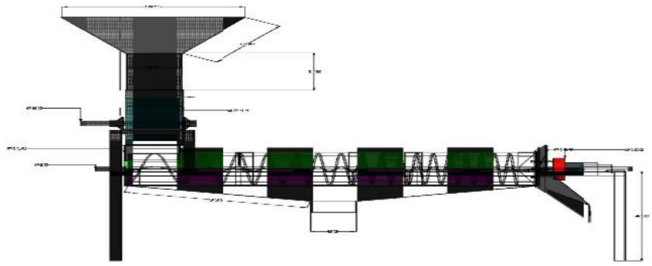

Fig 1. Orthographic drawing of the developed motorized ginger rhizomes juice expression machine

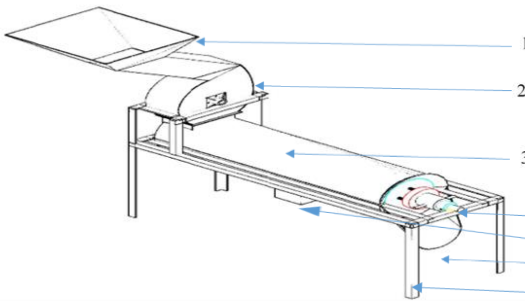

Fig 2. Isometric view of the motorized multi-tasks ginger juice expression machine.

1. Frame

The two design factors considered in determining the material required for the frame are weight and strength. The frame was constructed with 38 mm×38 mm×3 mm mild steel angle iron. The frame provides firm support for the entire assembly. Based on anthropometric considerations, the overall dimensions of the frame were chosen as 610 mm×390 mm×790 mm.

2. Feeding unit

The hopper is a stationary part and, mounted onto the machine, forms the feeding chute through which sliced ginger rhizomes are fed into the grating unit by gravity [21]. The hopper's passage hole (85 mm×55 mm) was large enough to prevent choking of the product. The hopper was made of stainless steel and a rectangular pyramid shape.

3. Grating unit

The grating unit consisted of a wooden shaft wrapped with a rough stainless plate attached to a pulley through a metal shaft. The grater will rotate and hence shred the ginger rhizomes into smaller sizes in operation. That will be conveyed by gravity to the position where it enters the expression unit through the lower hopper.

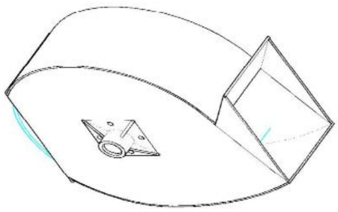

Fig 3: Isometric view of the grater

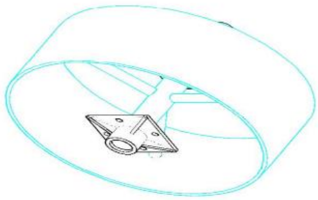

Fig 4: Skeletal view of the grating chamber

Expression unit

The ginger juice expression unit consisted of a tapered cylindrical barrel covering a perforated tapered cylindrical drum housed a screw shaft [22]. The screw shaft is the main component of the juice expression unit. The screw shaft comprises a stainless shaft with a tapered helical screw of variable pitch.

The pitch of the screw flights gradually decreased towards the discharge end to increase the pressure on the pulverized ginger rhizome as it's been carried through the barrel.

The barrel is perforated to allow expressed juice to escape, and the diameter of perforation is 1mm. Thus, the pressed ginger residue (chaff) passes through the waste discharge point in the barrel outlet.

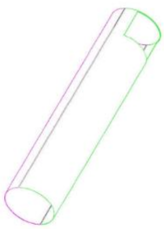

Fig 5. Expression barrel

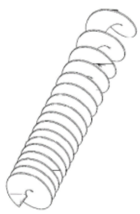

Fig 6. Expression screw

Power transmission system

The power transmission system comprises the prime mover (electric motor), shaft, reduction gear, pulleys, and belt. The power was provided by 2 H.P., 1400 rpm, and 1 H.P., 1430 rpm prime movers. The V-belts and pulley assembly were used to transmit the power to the pulverizing and expression units at a speed of 646 rpm and 240 rpm, respectively. The prime movers were mounted on a slotted plate on the frame to facilitate the belt tension adjustment.

Design Calculations for the developed machine components

The component design calculation for the motorized ginger juice expression machine is given below:

(1) Pulverizing shaft speed

Equation (a) was used to determine the pulverizing shaft speed given by [23]

$$N_1 D_1 = N_2 D_2 \qquad \text{(a)}$$

Where:
N_1 = speed of driving motor, rev min^{-1};
N_2 = speed of the pulverizing shaft, rev min^{-1};
D_1 = diameter of the driving pulley, m;
D_2 = diameter of the driven pulley, m..

(2) Pressure on the barrel

The limiting (maximum) pressure (P_b) the barrel can withstand is estimated using the Equations (b) and (c) as given by [24] and [23]:

$$P_b = \frac{t\delta_a}{D_i} \qquad \text{(b)}$$

$$\delta_a = 0.27t\delta_o \qquad \text{(c)}$$

Where:
δ_a = allowable stress, MPa;
δ_o = yield stress of barrel material, MPa;
t = barrel thickness, mm;
D_i = internal diameter of barrel, mm.
t = 2 mm, δo = 215 MPa; at feed point,
D_i = 80 mm, and at the discharge point, D_i = 65 mm.

Design of screw shaft for the expression unit

The screw shaft was made using a code equation (d) given by [23] and [24]:

$$d^3 = \left(\frac{16}{\pi S_s}\right) \times [(K_b M_b)^2 + (K_t M_t{}^2)]^{1/2} \qquad \text{(d)}$$

Where:

d = diameter of the shaft; mm;
M_t = torsional moment; Nm;
M_b = maximum bending moment; Nm;
K_b = combined shock and fatigue factor applied to bending moment;
K_t = combined shock and fatigue factor applied to torsional moment;
S_s = Allowable shear Stress, MPa.
For rotating shafts subjected to apply load with minor shocks only, values for suddenly K_t and K_t was given as 1.5.

For shafts with allowance for keyways as given by [23].

$S_s = 42 \times 10^6 Nm^{-2}$
A stainless steel rod of diameter 30 mm was selected, considering bearings.

Screw pitch (P_s)
Determination of the pitch of the screw shaft in Equation (f) below is given by [25] and [26] as:

$$P_s = \pi tan\varphi d_{sm} \quad \text{(f)}$$

Where:
φ = lead angle, (°);
d_{sm} = mean diameter of the shaft, mm.
The screw has a variable pitch with maximum and minimum lead angles as 26° and 10°, respectively.

Screw thread design
The screw shaft is essentially a tapered screw conveyor with the volumetric displacement decreasing from the feed end of the barrel to the discharge end [22]. In this way, the pulverized ginger is subjected to pressure, which expels juice as it is propelled forward during the screwing process. The screw threading system was designed as a step up shaft diameter and decreasing screw depth using the expression in Equation (g) as given by [23]:

$$U_n = a + (n - 1)d \quad \text{(g)}$$

Where; U_n = screw depth at the discharge end, mm;
a = screw depth at the feed end, mm;
n = no screw turns;
d = common difference between subsequent successive screw depths.
Given that U_n = 16 mm, a = 24 mm, n = 8; then d ≈ 2 mm.

Design for capacity of the machine
The expressing capacity of the fabricated machine was determined using a modified form of the Equation (h) given by [25] as:

$$Q_P = 60 \times \frac{\pi}{4}({D_{ms}}^2 - {d_s}^2)P_{ms}\rho N_s\Phi \quad \text{(h)}$$

Where:
Q_P = theoretical capacity of the expressing unit, kg s-1;
D_{ms} = mean screw diameter;
d_s = shaft diameter;
ρ = crop density, kg m-3;
P_{ms} = mean screw pitch, mm;
Ns = shaft speed, rev min-1; Φ = filling factor.

The pulverizing capacity of the machine was determined using a modified form of Equation (i) given by [23] as:

$$Q_P = 60 \times \frac{\pi}{4}\left(D_s{}^2 - d_P{}^2\right) P_s \rho N_P \Phi \quad \text{(i)}$$

Where;
Q_P= theoretical capacity of the pulverizer, kg s^{-1};
D_s = screw diameter, mm;
d_P = pulverizing shaft diameter;
ρ = crop density, kg m^{-3};
P_s = screw pitch, mm;
N_P = pulverizing shaft speed, rev min^{-1};
Φ= filling factor.

Design for the power requirement of the machine

The power required by the machine for expressing juice was determined using Equation by [26] :

$$P_e = Q_{ve} L_s \rho g F \quad \text{(j)}$$

Where
P_e = power required for expressing,
W; Q_{ve} = evolumetric capacity, m3 s $^{-1}$;
L_s = length of screw shaft, mm; g = acceleration due to gravity, m s^{-2};
F = material factor.

The power required by the machine for pulverizing was determined using Equation (k) by [27] adapted as:

$$P_P = Q_{ve} L_p \rho g F \quad \text{(k)}$$

Where:
Pp = power required for pulverizing, W;
Q_{ve} = evolumetric capacity, m3 s^{-1} ;

Ls = length of pulverizing shaft, mm;
g=acceleration due to gravity, m s^{-2}.

The total power requirement (Pt) of the machine was computed using Equation (l) by [27]:

$$P_t = P_e + P_P \quad (l)$$

The power of the electric motor required to drive the machine was estimated from Equation (m) given by [27] as:

$$P_m = \frac{P_t}{\eta} \quad (m)$$

Where:
P_m = power of electric motor;
η =drive efficiency (%)

Working principle of the developed ginger juice expression machine
The developed machine performs two distinct unit operations: size reduction and separation processes. The ginger rhizomes are fed into the grater through the hopper. The ginger rhizomes are comminuted by shredding at the grating unit. The screw shaft of the expression unit crushes, presses, and conveys the product that comes from the grating unit in such a way that juice is squeezed out of the grated rhizomes.
The expression is achieved by the action of the screw shaft in squeezing the grated ginger rhizomes against each other and on the surface of the screw.
The movement of the materials along the line of travel of the perforated cylindrical barrel also expresses the juice along the line of travel. The fluid expressed is drained through the juice channel into the juice outlet from where it is collected while the residual waste is collected at the waste outlet.

RESULTS AND DISCUSSION

Construction of the juice expression machine
The motorized juice expression machine was designed for the large-scale production of any ginger juice but can also be used to extract other oil-bearing agricultural products [28,29]. This production involves facing, turning, boring, milling, welding, cutting, tapping, fillings, paintimg, etc. This can be carried out in any large/medium-sized workshop with average machining and fabrication facilities. Other components such as bearings, electric motors, V-belts, bolts/nuts, etc., were sourced for in the local market. The essential workshop facilities required for the production of the machines are lathe machine, milling machine, welding machine, hand grinding machine, drilling machine, M10 tap, and file.
The quality of construction is an essential factor in the overall performance of any machine [7,30]. This fact was given due consideration in selecting the production processes and sequences of operation in the fabrication of the machine.

CONCLUSION

The motorized ginger juice expression machine has been developed as an easily affordable technology that is very suitable for the environment, energy efficient, and versatile on ginger. It is fully developed to incorporate all stages of ginger rhizome processing; this machine can revolutionize ginger rhizome processing in the country and has the potential for adaptation into a large industrial facility.

Recommendations

The motorized ginger juice expression machine is recommended for large-scale ginger juice expression in rural and urban communities. Further experimental tests such as performance evaluation could be carried out on the ginger juice expression machine.

Conflict of Interest

The Authors have no conflict of interest

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DIZAJN I RAZVOJ MAŠINE SA MOTOROM SA VIŠE OPERACIJA ZA CEĐENJE SOKOVA OD KORENA ĐUMBIRA(*Zingiber officinale roscoe*)

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Abstrakt: Procesi ručnog ceđenja soka od đumbira su monotoni, nehigijenski i neefikasni, što utiče na kvalitet i količinu ekstrahovanog soka (*Zingiber officinale roscoe*).
Ekstrakcija hemijskim putem je složena, skupa i zahteva veliko iskustvo i visoku veštinu za ovaj proces.
Razvijena mašina sa motorom za ceđenje soka od đumbira obavlja dve različite operacije: smanjenje zapremine korena đumbira i proces odvajanja.
Glavne komponente mašine uključuju jedinicu za punjenje, jedinicu za usitnjavanje, jedinicu za ispuštanje soka, cev za odvod soka, izlaz za otpad, okvir i sistem za prenos energije. Mašinu pokreću motori od 2 KS, 1400 o/min i 1 KS, 1430 o/min, a brzina klinastih kaišnika i remenice je 646 o/min i 240 o/min, respektivno.
Razvijena mašina za ekspresiju nudi pristupačan i jednostavan metod obrade svežeg đumbira koji minimizira gubitak količine i kvaliteta korena đumbira i na kraju smanjuje gubitke nakon ubiranja.

Ključne reči: *Đumbir, ekspresija, ekstrakcija, mašina, uljna smola, sok.*

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ДВИГАТЕЛЕЙ ВНУТРЕННЕГО СГОРАНИЯ: -ПЕРСПЕКТИВЫ ПРИМЕНЕНИЯ СВОБОДНОПОРШНЕВОГО ДВИГАТЕЛЯ В СЕЛЬХОЗТЕХНИКЕ

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Анотация: в статье расмотрены различные принципиальные схемы поршневого двигателя внутреннего сгорания (ДВС) и приведены их основные недостатки, в частности, низкий коэффициент полезного действия (КПД), который в зависимости от типа современных ДВС колеблется от 0,25 до 0,5. Для повышения этого показателя продолжается поиск более совершенных схем ДВС. С этой целью предложена новая принципиальная схема свободно-поршневоого двигателя внутренного сгорания (СПДВС), в которой передача мощности осуществляется гидроприводом, в результате коэффициент полезного действия (КПД) увеличивается на 30 до 40 % .

Ключевые слова: *двигатель внутренного сгорания (ДВС), свободно-поршневой двигатель внутренного сгорания (СПДВС), коеффициент полезного действия (КПД), кривошипно-шатунный механизм (КШМ), цилиндр, поршень, коленчатый вал, шатун, гидропривод*

ВВЕДЕНИЕ

Человечество тесно связано с энергетикой и применяемым в ней взаимопревращением различных видов энергий: механической, электрической и тепловой.

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В настоящее время потребность населения земли в энергии ежедневно растёт.
Одними из первых потребителей носителей энергии в жидком и газовом виде являются двигатели внутренного сгорания с кривошипно-шатунным механизмом (ДВСКШМ), мощность и количество которых с каждым годом растёт и соответственно увеличивается потребление топлива. Если 30 лет назад, когда для автомобиля считался нормальным расход 15 литров бензина на 100 км пути, человечеству хватало 60 миллионов баррелей нефти в сутки, то теперь нужно уже выше 90 миллионов баррелей в сутки [1,2].

Современнный двигатель внутреннего сгорания (ДВС) „не самый выдающийся продукт“. Это значит, что его можно и нужно совершенствовать до бесконечности. Это - слова президента венчурного фонда семьи Рокфеллер Venrock [3,4]. В действительности коэффициент полезного действия КПД - (η) современных бензиновых ДВСКШМ составляет только $\eta = 25\%$, дизельных $\eta = 40\%$, а в дизелах типа турбонаддува $\eta = 50 - 53\%$ [5,6]. Т. е. из топлива, которое мы заливаем в баки, больше его половины расходуется напрасно и приносит вред природе. В целях повышения КПД ДВСКШМ ведутся научно-исследовательские работы по разным напрвлениям. На сегодняшний день известны разные принципиальные схемы ДВС[7,8], в которых кривошипно-шатунный механизм (КШМ) выполнен в различных вариантах (рис. 1). Однако основным недостатком различных видов КШМ, в частности КШМ в ДВС (рис. 1, А, Б, В, Г, Д, Е, Ё, З) является то, что в процесе работы ДВС, разнообразно меняется плечо h (Рис. 2), создаваемое коленчатым валом (коленвалом), на которое (плечо) приложена сила, развиваемая на дне поршня, что создаёт крутящий момент, передаваемый на выходной вал ДВСКМ.

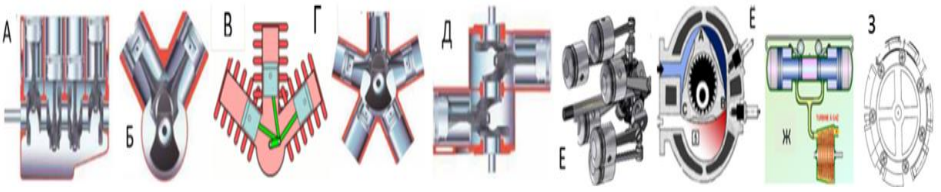

Рис. 1. Различные схемы поршневых ДВС: А. однорядный; Б. V-образный; В.W-образный; Г. звездообразный; Д. оппозитный; Е. аксиальный, Ё. роторнопоршневой, Ж. свободнопоршневой генератор газа (С.Г.Г.), З. кольцевой.

В результате за счёт меняющей величины плеча, с которой шатун действует на коленвал в ДВС с КШМ имеем значительные потери КПД ≈ 40 % [9].

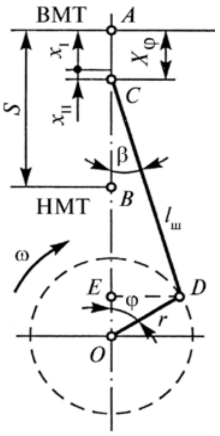

Рис. 2. OD – радиус коленвла, DE – h - плечо коленвала, DC – шатун

Причём, когда поршень находится в верхней мёртвой точке (ВМТ) и в камере сгорания создаётся максимальное значение давления P_z, в это время плечо h созданное коленчатым валом (КВ) относительно продольной оси цилиндра, становится равным 0 (нулю), соответственно, развиваемый момент на КВ равен нулю. При вращении КВ, когда плечо h становится наибольшим - равным радиусу коленчатого вала, то давление Pв в цилиндре приближается к её низшему значению, становится ниже $0,3P_z$ и, соответственно, момент, приложенный на КВ, небольшой. Это – одна из основных причина снижения КПД в ДВСКШМ.

Кроме этого при увеличении h увеличивается трение между рабочими элементами ДВСКШМ, которое также снижает КПД ДВСКШМ. Другой основной причиной механических потерь мощности ДВС в КШМ кроме изменчивой величины плеча силы шатуна являются потери на силы трения в КШМ.

ЦЕЛЬ

Повышение КПД ДВС. Рассмотрение возможностей его применения в сельхозтехнике.

МАТЕРИАЛЫ И МЕТОДЫ

Рассмотрение различных видов ДВС, которые были разработаны с целью повышения КПД, анализ их положительных и отрицательных сторон, создание конструкции ДВС с повышенным КПД.

Для устранения выще изложенных недостатков и некоторого улучшения рабочего процесса ДВС, разработаны разные конструкции ДВСКШМ (рис. 1, Б, В, Г, Д и Ж). В V-образном ДВС(рис. 1, Б) поршни раположены V-образно, что несколько уравновешивает и уменьшает продольную базу ДВС, сравнитнльно с однорядным расположением поршней. В W-образном и зведообразном ДВС (рис. 1, В, Г) также улучшены указанные показатели (уравновешенность и продольная база); В оппозитном ДВС (рис.1,Д) повышена уравновешенность ДВС; в аксиальном ДВС (рис. 1, Е), шатуны связаниы с тариелькой, которая совершает синусоидольные движения, которые потом превращаются во вращательное движение специальным волновым механизмом. В последнее время разрабатаваются ДВС, в которых для передачи движения от поршней к рабочим узлам используется зубчато-реечная передача [9], однако эти разработки не достигли уровня внедрения их в практику.

Поэтому независимо от разнообразных подходов к кривошипно-шатунным механизмам, этот недостатки - низкий КПД из-за вариабельности плеча h КВ относительно продольной оси цилиндра и большие механические потери на трение в КШМ - остаются почти неизменными и нерешёнными.

В канце 60-х и в начале 70-х годов прошлого века, патент Ванкеля куплен 11 ведущими автопроизводителями мира. в том числе компанией „NSU" и концерном „Mazda", в мире выпушено 37204 экземпляров роторнопоршневого (рис.1 Ё) ДВС (РПДВС). Преимуществом этих двигателей является: простота конструкции, маленькие габариты и удельная металлоёмкость, однако они имеют и ряд недостатков:

1. Маленький моторесурс 200 тыс. км. [10, 11], а другие указывают 50-60 тыс. км., [12,13];
2. Дороговизна РПДВС, так как её изготовление требует высокотехнологичного материала и точнейшего оборудования для изготовления;
3. Замена масла следует делать каждые 5 тыс. км.;
4. Большой расход топлива;
5. Высокая токсичность выхлопнвых газов;
6. Огромная склонность к перегреву;
7. Частая замена уплотнителей камер сгорания из –за большого воздействия ротора.

Эти недостатки отрицательно решили судьбу пройзводства РПДВС.

Для усовершенствования ДВС продолжается поиск, с этой целью в Россиской Федерации запатентован кольцевой ДВС (рис. 1, З),и способ передачи движения к силовому агрегату [14], в котором с целью устранения недостатков кривошипшо-шатунного механизма данный механизм отсутствует, цилиндры и поршни выполнены кольцеобразными, поршни жёстко соединены с кольцеобразными штоками, на внутренней стороне которых созданы пазы с зубьями для зубчатой передачи, зубья штоков сцеплены с маленькими зубчатыми колесами, которые в свою очередь сцеплены с централным зубчатым колесом. Во время работы кольцеобразные поршни с кольцеобразными штоками перемещаются по кругу в одном направлении, передавая вращательное движение через зубчатую передачу на маленькие зубчатые колёса и через них на большое центральное зубчатое колесо с выводним из ДВС валом.

Недостатком этой конструкции ДВС является то, что при её работе поршни вынужденно перемещаются по кольцу, при этом создаются центробежные силы, которые прижимают поршни к наружной стороне кольцеобразного цилиндра. Кроме того, возникают большие силы трения на зубчатых передачах между кольцеобразными штоками и маленькими зубчатыми колесами, что снижает КПД ДВС.

Свободнопоршневой двигатель внутреннего сгорания (СПДВС) (рис. 1 Ж) по сравнению с ДВС с кривошипно-шатунным механизмом имеет ряд преимуществ [15].

Первый проект свободнопоршневого двигателя внутренного сгорания - свободнопоршневой газогенератор (СПГГ), разработали для пройзводства газо-воздушной смеси для приведения в действие турбины, он использовался в газовых энергетических установках в качестве генератора рабочего тела (газа) в 1922-1924г. Эты проекты были осуществлены в 50-х гг прошлого века, мощность которых составлял 750-3500 квт и применялись на небольших судах. Этот СПГГ по конструктивному исполнению схож с дизельным компрессором, представляет одноцилиндровый двухтактный ДВС с противоположно движущимися поршнями, которые жестко связаны с поршневым компрессором. Компрессор является наддувочным агрегатом, давление наддува составляет 0,6-0,7 Мпа. Воздух во время выдувки цилиндра смешиваетсся с газом. Газо-воздушная смесь поступает в газовую турбину. Продукты сгорания или их смесь с воздухом на выходе имеет температуру $400 \div 500^0$C а давление 4-5 кг/см^2. Это сравнительно низкие параметры рабочего тела позволили создать дешевую и экономичную газовую турбину мощностью 10-59 МВт. КПД достигает 40%. На одну газовую турбину могут работать несколько СПГГ. Силовые газотурбинные установки с СПГГ применяют в различных отраслях промышленности, на транспорте и в энергетике [16, 17].

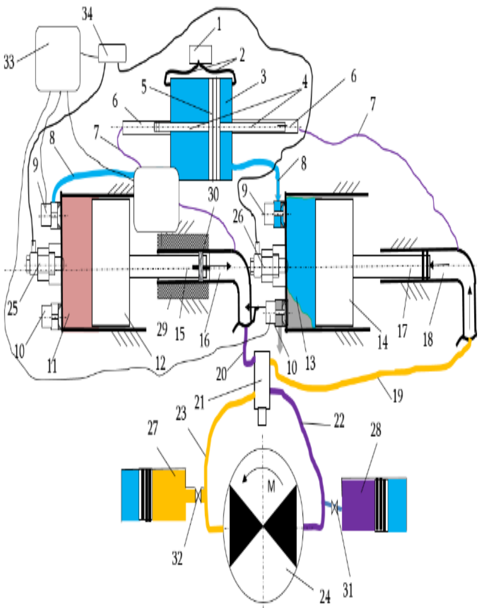

Рис. 3. Принципиальная схема СПДВС :

1 Воздушный фильтр; 2 и 8. Воздухопровод;
3. Цилиндр дла поддувки воздуха;
4. Гидроцилиндры с двухсторонными штоками;
5. Воздухоподдувочный поршень;
6,16,18.Камеры плунжеров высокого давления;
7,19,20,22 Гидравлические трубопроводы высокого давления;
9, 10 Впускные и выпускные клапаны;
11, 13 Цилиндры; 12 и14 Поршни;
15, 17 Плунжеры; 21 Распределитель;
23 Гидравлические трубопроводы низкого давления,
24 Гидромотор; 25 и 26 Форсунки,
27,28 Гидроаккумуляторы;
29 Индуктивная катушка,
30 Кольцевой постоянный магнит,
31, 32 Регулируемые краны,
33 Пульт управления,
34 Топливный насос высокого давления.

Недостатками СПДВС являются трудность привода газораспределения и её синхронизация. Для устранения данного недостатка автор Мируашвили В. разработал новую принципиальную схему свободнопоршневого ДВС (СПДВС) с гидроприводом (рис.3) [18], на которую выдан патент на изобретение и в котором возможно осуществить безступенчатую регулируемую и синхронную поддувку в цилиндры, интенсивность которой автоматически меняется в зависимости от нагрузки СПДВС. Пневматическая энергия, полученная от сгорания топлива в данном СПДВС, превращается в гидравлическую энергию, подаваемую к гидроприводу в виде постоянного потока гидравлической жидкости (гидроносителя) высокого давления.

Предложенный СПДВС работает следующим образом: Перед пуском СПДВС ротор гидромотора 24 приводится во вращение от стартера (на рисунке не указан) и гидромотор 24 создаёт поток гидроносителя, который через автоматический распределитель 21 подаётся поочередно в гидроцилиндры 16 и 18 и в камеры 6 с расположенным в них двухсторонным штоком 4. Когда поток гидроносителя направлен в гидроцилиндр 18, он одновременно воздействует на плунжер 17 и на плунжер 4 и поршень 5 нагнетает воздух из цилиндра 3 в цилиндре 11, так как это не требует большого усилия. После этого, от гидромотора 24 гидроноситель подаётся в камеру 16 и плунжером 15 поршень 12 перемешается к высшей мёртвой точке (ВМТ) и в камере 11 осуществляется такт сжатия. В этом время поршень 14 перемешается к низшей мёртвой точке (НМТ), т. е. поршни 12 и 14 одновременно и почти с одинаковой скоростью перемещаются в противоположных направлениях. При подходе (приближении) поршня 12 к ВМТ-е, из форсунки 25 осуществляется впрыск топлива. При впрыске топлива в цилиндр 11 осуществляется сгорание горючей смеси и начинается такт расширения, при этом плунжером 15 и поршнем 12 гидроноситель нагнетается через трубопроводы высокого давления 20, 22 и гидрораспределитель 21 к гидромотору 24. Когда гидромотор начинает работать от подаваемого из камер 16 и 18 гидроносителя, нагрузка на стартер уменьшается и стартер под действием пружины автоматически отключается. В дальнеишем в цилиндрах 11 и 13 поочередно меняются такты сжатия и расширения, поршни 12 и 14 совершают движения в противоположном направлении и силы инерции, вызванные от переменно направленного движения поршней 12 и 14 взаимно гасятся, тем самым полностью уравновешивается СПДВС. Скорости поршней 12 и 14 не всегда соответствуют частоте (скорости) вращения гидромотора, т. е. пройзводительность гидроносителя плунжерами 15 и17 не всегда соответствует расходу гидроносителя гидромотором, и это различие погашается гидроаккумуляторами 27 и 28. Подобные ДВС могут состоять как из одно-спаренных цилиндров, так и двух, трёх и т. д. (неограниченного количества) спаренных цилиндров, что предоставляет большие возможности подобным СПДВС.

РЕЗУЛЬТАТЫ

1. Проведён анализ конструкций известных ДВСКШМ и СПДВС приведены их конструктивные недостатки;

2. Проанализированы их рабочие процессы и выявлены их основные недостатки;

3. Приведена совершенно новая принципиальная схема СПДВС и её описание в статике и в динамике;

4. Для увеличения КПД ДВС предложена комбинация СПДВС с гидромотором и проведено её сравнение с ДВСКШМ.

В ДВС с КШМ львиная доля механических потерь мощности приходится на трение в КШМ., на цилиндропоршневую группу (ЦПГ) 39%, на коленвал и шатун 24 %[19]. Другие авторы [20,21] приводят несколько отличающиеся показатели механических потерь в процентах, приходящих на ЦПГ и коленвал с шатуном. Но все они приближаются к вышеуказанным значениям и колеблются в пределах ±5% от этих величин.
Например, в другом источнике [20] общие механические потери по разным узлам двигателя распределены следующим образзом (Таб.1):

Таб. 1 Меньшие значения механических потерь относятся к двигателям
с искровым зажиганием, большие – к дизелям.

Общие механические потери на трение:	До 75 %
Поршневых колец и поршня:	42 -50 %
Подшипников коленчатого вала:	16 -19 %
механизма газораспределения:	4 -6 %

Как видно из Таб. 1., большая часть механических потерь на трение приходится на КШМ: на поршневые кольца и поршни от 42 до-50%, подшипников коленчатого валв от 4 до 6%.

При этом значительная часть механических потерь в КШМ приходится на ЦПГ, что обьясняется тем, что в процессе работы шатун с большой силой N, перпендикулярной к стенке цилиндра поршня, (Рис. 4) прижимает поршень то к одной, то к противополжной стенке цилиндра, что существенно увеличивает силу трения и соответственно – механические потери [22].

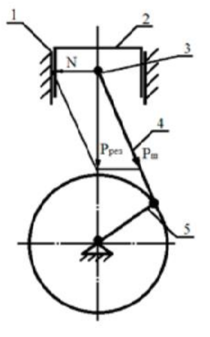
Рис. 4.

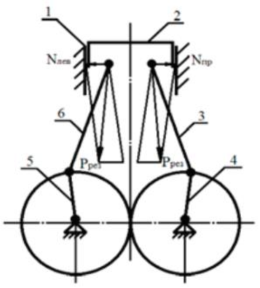
Рис. 5

Причём чем меньше длина шатуна, тем больше эта боковая сила (N), однако увеличение длины шатуна увеличивает габариты, вес и металлоёмкость ДВС. Более половины механческих потерь мощности в ЦПГ вызвано усилением силы трения за счёт прижатия поршня к боковой стенке цилиндра.

Кроме того в момент перехода поршня через ВМТ (высшая мёртвая точка) и НМТ (низшая мёртвая точка) изменяется направление действия боковой силы, в результате поршень перемещается от одной стенки поршня к другой – происходит перекладка поршня. Это вызывает удар поршня о стенку цилиндра, сопровождающийся характерным звуком. Износ ДВС (поршней и цилиндров) приводит к увеличению зазора между поршнем и стенкой цилиндра и усилению этого вредного явления.

От ударных нагрузок на стенки юбки поршня и цилиндра могут пройзойти разрушение юбки поршня и трещины в цилиндрах.

Проблема эта настолько серьёзная, что для её решения придумли двухвальный двигатель, где поршень подвижно соединён с с двумя шатунами и через них – с двумя коленвалами (Рис. 5).

Боковые силы N, с которыми шатуны действуют на поршень в двухвальном двигателе, взаимно уравновешивают друг друга и тем самым повышение силы трения за счёт прижатия поршня к стенке цилиндра не происходит. Однако добавление ещё одного шатуна и коленвала значително усложняет конструкцию и увеличивает металлоёмкость, габариты ДВС, добавляется сила трения ещё одного коленвала.

В СПДВС отсутствует повышение силы трения и механических потерь мощности за счёт сильного прижатия шатуном поршня к стенке цилиндра, отсутствуют потери КПД и крутящего момента за счёт меняющей величины плеча (момента) силы шатуна, действующего на коленвал, нет самого коленвала и шатуна и соответственно силы трения и механических потерь мощности, которые мы получаем в коленвале и шатуне, нет перекладки поршня и связанных с ней вредных явлений.

Однако первостепенной проблемой , стоящей на пути широкого использования СПДВС является снятие мощности с такого двигателя, который механически представляет собой замкнутую систему, подключение к поршню, который перемещается с высокой частотой.

В современных гидромоторах КПД достигло высокого уровня (достигает 95%), а СПДВС ещё в середине прошлого века использовался в качестве насоса.

Именно поэтому с целью повышения КПД ДВС предложена описанная выше комбинация СПДВС с гидромотором [18], с решением проблемы привода газораспределения и её синхронизации.

Применение СПДВС с передачей движения через гидроноситель на гидромотор позволяет значительно увеличить КПД за счёт снижения механических потерь мощности на трение и на меняющую величину плеча шатуна.

В СПДВС с гидроприводом мы вместо потерь в КШМ имеем потери в гидромоторе и гидравлических трубопароводах, по которым гидроноситель подаётся к гидромотору.

По существующим в литературе данным КПД в гидромоторе достигет 95 % и больше [23]. Соответственно потери мощности в гидромоторе составит 5 %, ещё 5 % потери мощности можно отнести на трение гидроносителя в гидравлических трубопроводах. Исходя из вышеизложенного выигрыш КПД в СПДВС с гидроприводом по сравнению с ДВС с КШМ может составить ≈ 30-40 % в зависимости от конкретного СПДВС, ДВС и гидромотора.

ДИСКУССИЯ

К недостаткам СПДВС относятся сложность пуска и регулирования, неустойчивость работы на частичных нагрузках (с развитием микропроцессорных систем управления последний недостаток стал неактуальным).
Основной сложностью и недостатком же СПДВС, причем это касается всех его типов, является то,что отсутствие в конструкции каких-либо вращающихся частей (что с одной стороны является большим преимуществом, т.к. упрощает конструкцию и уменьшает габариты двигателя) создает трудность для классического привода газораспределения и её синхронизации через распределительный вал (Рис. 5, должность 15).

В предложенном выше СПДВС [18], защищено патентом, упрощена система подачи горючей смеси, газораспределения и её синхронизация, что достигается тем, что устройство для подачи горючей смеси выполнено в виде свободнопоршневого насоса двойного действия с рабочими приводными полостями, последние из которых сообщены с насосными камерами.

ЗАКЛЮЧЕНИЕ

Одним из путей уменьшения себестоймости сельскохозяйственных (с/х) продуктов является уменьшение энергетических и трудовых затрат. Для достижении этой цели, научно-исследовательские работы идут по следующим направлениям:

1. Увеличение ширины захвата с/х мащин;
2. Применение комбинированных агрегатов, при которого одним проходом агрегата выполняется несколко селскохозяйтсвенных (с/х) операции.

Оба направления требуют увеличения тягового усилия и мощности, вследствие чего происходит увеличение массы тракторов. Последнее вызывает уплотнение почвы и тем самым ухудшение её структуры, что является причиной уменьшения урожайнности. Для успешного решения представленной задачи, тракторостройтелям и заводам с/х машин предлагаем на тракторах и с/х машинах установить СПДВС с гидромотором, который обладает меньшей массой. даёт возможность, при номинальной частоте цикла СПДВС с гидромотором безступенчато менять скорость перемещения агрегата, простым соединением (без карданной или цепной передачи) – гидро- трубопроводами и шлангами осуществить передачу энергии на каждое опорное колесо, снабдить их - колеса , а также другие рабочие (движущие) узлы тракторов и с/х машин (расположенные в любой точке рамы с/х мащин в зависимости от проводимих на них (машинах) технологических процесов) отдельными гидромоторами (что облегчается компактностью гидромоторов), связанными с гидросистемой трактора, и привести их во вращение, колебание и другие виды движения.

В СПДВС уменьшаются габариты и металлоёмкость двигателя вседствие отсутствия вращающихся частей, расход топлива вследствие повышения мощности, инерционные нагрузки на детали двигателя,токсичность выхлопных газов вследствие лучшего обогащения газовой смеси воздухом и, следоательно, кислородом. Упрощается конструкция - по сравнению с классическим двигателем - с ДВСКШМ СПДВС обладает на 40 % меньшим количеством элементов [15].
Всё это повышает эффективность применения СПДВС в различных машинах и агрегатах, в том числе и сельскохозяйственных.

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IMPROVING EFFICIENCY OF INTERNAL COMBUSTION ENGINE: PERSPECTIVES OF APPLICATION FREE PISTON ENGINE IN AGRICULTURAL ENGINEERING.

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Abstract: The article discusses various schematic diagrams of a reciprocating internal combustion engine (ICE) and shows their main disadvantages, in particular, low efficiency, which, depending on the type of modern ICE, ranges from 0.25 to 0.5.
To increase this indicator, the search for more advanced ICE schemes continues. For this purpose, a new schematic diagram of a free-piston internal combustion engine (FPICE) is proposed, in which power is transferred by a hydraulic drive, as a result, the efficiency increases from 30 to 40%.

Keywords: *internal combustion engine (ICE), free-piston internal combustion engine (FPICE), efficiency, crank mechanism, cylinder, piston, crankshaft, connecting rod, hydraulic drive*.

POBOLJŠANJE EFIKASNOSTI MOTORA SA UNUTRAŠNJIM SAGOREVANJEM: -PERSPEKTIVE PRIMENE MOTORA SA SLOBODNIM KLIPOM (FPICE) U POLJOPRIVREDNOM INŽENJERSTVU

Apstrakt: U ovom radu se razmatraju različiti šematski dijagrami klipnog motora sa unutrašnjim sagorevanjem (SUS).
Prikazani su njihovi glavni nedostaci, posebno niska efikasnost, koja se u zavisnosti od tipa savremenog SUS, kreće od 0,25 do 0,5.
Da bi se povećao ovaj indikator, potraga za naprednijim SUS šemama se nastavlja.
Zbog toga je predložen novi šematski dijagram motora sa unutrašnjim sagorevanjem sa slobodnim klipom (SKSUS), gde se snaga prenosi hidrauličnim pogonom.
Kao rezultat, SKSUS se povećava za 30 do 40%.

Ključne reči: *motor sa unutrašnjim sagorevanjem (SUS), motor sa unutrašnjim sagorevanjem sa slobodnim klipom (SKSUS), efikasnost, kolenasti mehanizam, cilindar.*

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COMPARATIVE EXPLORATION OF MECHANIZED SYSTEMS FOR PALM BROOM PRODUCTION

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Abstract: Performance and economic capabilities of two distinct mechanized systems for processing brooms from coconut and oil palm leaflets were surveyed in this study to determine the best technology to advance/adopt for commercialization. The systems are abrasive roller and knife edge aided peeling based machines while peeling efficiency, processing time/throughput, payback period and benefit cost ratio constitute the parameters weighed. Results revealed the knife edge based peeling systems as most viable even though the abrasion process based system performs with high throughput. This because it's peeling efficiency of 96% is above the minimum acceptable rate of 95% and that of the abrasion process system (94%) is less. This, implies 5% scraps/reworks associated with abrasive aided peeling system which amount to post peeling operation of sorting. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process.

The payback and benefit cost rating of knife edge aided system amounts to 0.8 and 2.45 respectively while 1.69 and 1.76 constitutes the respective ratings of abrasion process based machines.

In addition, the knife edge aided processing system peels both fresh and dry palm leaflets while the abrasion peeling system handles dry leaflets only. Hence, adoption of knife edge aided peeling process is recommended for advancing broom production from palm leaflets.

***Key words**: Abrasive, broom bristle, knife edge, machine, palm leaf, peeling*

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INTRODUCTION

Broom is a bound organic or synthetic bristle basically used for sweeping floors and some auxiliary ornamental, political and religious purposes [1, 2]. Organic broom bristles from oil and coconut palm leaflets are common in Nigeria due to their effective dirt, dust and wears absorption and moisture-resistant features as well as abundance of these palms in this region [3, 4]. Bristle production from the palm leaf involves peeling or scraping off the leaf's blade from its petiole (stalk) using sharp knife edged objects (such as knife and razor) or abrasives [5. 6]. The separated stalk constitutes the broom bristles. This separation process can be by manual or mechanized operations. The campaign for phasing out manual palm leaflets peeling due its high drudgery and risk features is not receiving adequate attention expected despite the successful development of mechanized systems for producing broom from the palms by [3, 7, 8, 9]. This is because of the palm broom processors' problem of choosing among the two distinct mechanisms of abrasive and knife edge aided peeling process based on which the machines were developed. The innovation of [3] peels off the lamina from the midrib of dry oil palm leaflets by abrasion when its rotating abrasive-covered drum rubs the leaflet against a half pipe whose internal surface have been lined with abrasive as shown in Fig. 1. The leaf blade debris falls off through the mesh-chute while the bristles are collected in a trough with their 'head' in a chuck. Although this machine performed efficiently, binding the bristles into a handy broom still necessitated a manual effort that quelled its adoption commercially by stakeholders. Hence its improvement by integrating bristles tying/weaving units to it by [9] as shown in Fig. 2. The tying unit consists of a strapping pin attached to the chuck which holds and winds the rope around the broom bristles under the spring tension and recoil spool comprising a rope, recoil spring and a reel/spool.

The midrib separation machine (Fig. 3) developed by [7] peels coconut leaflets. It consists of vertical placed batch of one spiked and two non-spiked rollers which rotates in opposite direction to scrap off the blades of the leaflets fed into it. The need for both fresh and dry palm leaflets peeling mechanism led [8] to develop a knife edged aided peeling module which was later integrated to a tethering machine for processing broom from coconut and oil palm leaflets as shown in Fig. 4. This integrated peeling-tethering machine consisting a set of rollers, palm leaflets inlet, stripper and tethering unit. The rollers feed the leaf to the stripping a mild steel blade which peels the leaf blade off from its stalk before ejecting the sticks into the tethering unit for tying by electromechanical means.
Although, records indicated successful performance of these innovative peeling mechanisms for broom bristle production from palm leaflets, their mass production is still pending due to non-organization of their techno-economic viability data for effective comparison.

Hence, the dominance of manual peeling in this sector and ever increasing scarcity of brooms made from coconut and oil palm leaflets in our markets [8]. Since, adequate comparative knowledge of technical and economic viability of alternate innovations is vital for their adoption for both specific and general applications, this study presents the comparison of abrasion and knife edge peeling based coconut and oil palm broom processing systems.

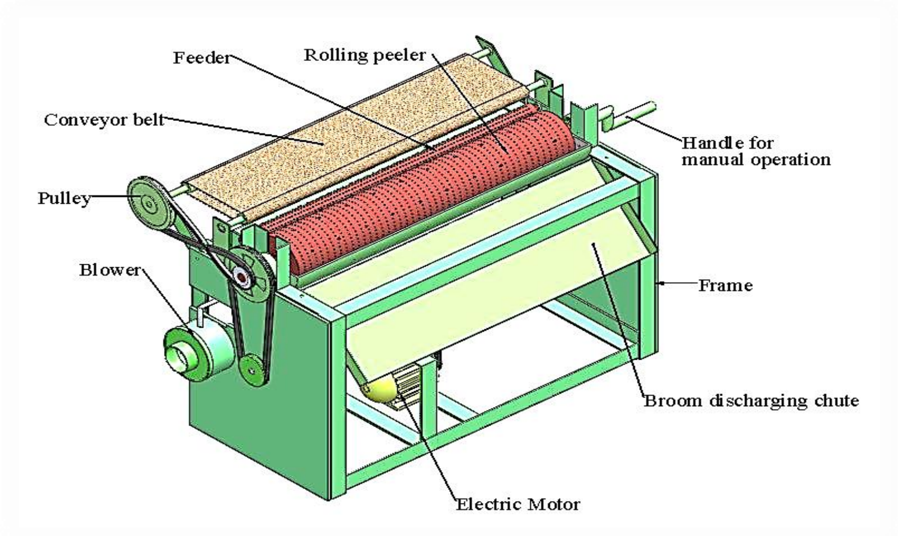

Fig. 1. Palm frond broom peeling machine, [3].

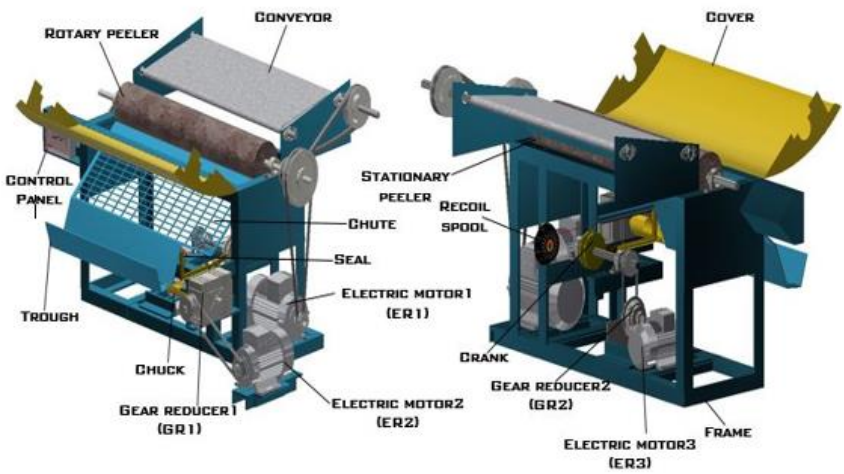

Fig. 2. Oil palm broom processing machine, [9].

Fig. 3. Novel machine to separate midribs from coconut leaflets, [7].

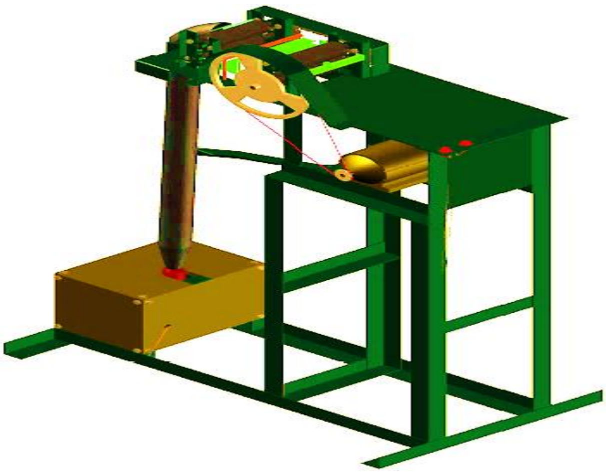

Fig. 4. Integrated broom peeling-tethering processing machine, [8].

MATERIAL AND METHODS

This study involves comparative viability assessment of the two distinct machines for producing brooms from coconut and oil palm leaflets from the records of [3, 7, 8, 9, 10, 11]. This is to determine the best for advancement. The systems parameters weighed include peeling efficiency, processing time/throughput, payback period and benefit cost ratio of the recent developed coconut and oil palm broom processing innovations. Throughput (TP) of each system constitutes the total number of palm leaflets it processed per unit time while the peeling efficiency (η) entails percentage ratio of the well processed broom bristles and number of palm leaflets processed within a given time expressed mathematically as follows [9].

The investment decision pointers of benefit cost ratio (BCR) and payback period (P_b) applied to assess the economic viabilities of the broom processing machines were determined from Equations (3) and (4) based useful life of five years and prevailing economic indicators/market prices of materials in Abia State of Nigeria between from 2014 to 2021. The decision criteria include that the payback period of each machine must be less than five years while the peeling efficiency and benefit cost ratio must be greater than 95% and 1 respectively for its acceptance.

$$TP \text{ (brooms/h)} = \frac{n}{t} \quad (1)$$

$$\eta(\%) = \frac{n-n_s}{n} \times 100 \quad (2)$$

$$P_b = \frac{C_i}{B_n} \quad (3)$$

$$BCR = \frac{PVB}{PVC} \quad (4)$$

Where:
n is the quantity of palm leaflets processed while n_s constitutes defectives (which consists of those that the lamina were not properly removed and/or broken ones) while C_i, B_n, PVB and PVC constitute the initial investment cost and average annual net benefit (cash inflow), present values of benefits and costs of the machine.

RESULTS AND DISCUSSION

The results of this investigation shown in Table 1 revealed the knife edge aided peeling process adopted by [8] in developing broom processing machine as most viable even though the abrasive aided processing systems performed with high throughput. This because it's peeling efficiency of 96% is above the minimum acceptable rate of 95% and that of the abrasion process system (94%) is less. This, implies 5% scraps/reworks associated with abrasive aided peeling system which amount to post peeling operation of sorting. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process. The high cost of production induced by this post peeling operation is obvious from the high payback period and low benefit cost ratio of this system compared the knife edged aided process. Furthermore, the knife edge aided processing system peels both fresh and dry palm leaflets while the abrasion peeling system handles dry leaflets only. Hence, the knife edge aided peeling process based broom processing machine is apt for advancing broom production from palm leaflets.

Table 1. Comparative analysis of mechanized palm broom processing systems

Evaluation parameters	Abrasive roller peeling based system	Knife edge peeling based system
Peeling efficiency (%)	94.00	96.00
Throughput (Kg/h)	6311.00	2016.00
Payback period	1.69	0.80
Benefit cost ratio	1.76	2.45
Nature of Leaf processed	Dry	All

CONCLUSIONS

The study revealed that broom processing machine developed based on knife edge aided peeling mechanism is most viable for advancing broom production from palm leaflets. This because of its high peeling efficiency and benefit cost ratio as well as low payback period ratings over abrasion based peeling systems. Hence, its general adoption and mass production is highly recommended to reduce drudgery and waste of palm leaflets in this country as well as scarcity of coconut and oil palm brooms.

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UPOREDNO ISTRAŽIVANJE MEHANIZOVANIH SISTEMA ZA PROIZVODNJU METLI OD GRANA PALMI

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Apstrakt: U ovoj studiji ispitane su performanse i ekonomske mogućnosti dva različita mehanizovana sistema za izradu osnove metli (pogledati https://www.researchgate.net/publication/303805658) od listova (ogranaka) kokosovog oraha i uljane palme. Tako bi se odredila najbolja tehnologija za unapređenje/usvajanje proizvodnje za komercijalnu namenu.

Ovi sistemi su mašine za ljuštenje sa abrazivnim metalnim rotirajućim valjcima i noževima sa sečivom. Efikasnost ljuštenja, vreme/protok biljne mase u toku obrade, period vraćanja mase, odnos troškova i koristi predstavljaju merene parametre.

Rezultati istraživanja pokazuju da su sistemi za ljuštenje zasnovani na oštrici noža lako izvodljiviji, iako je ovaj sistem zasnovan na procesu abrazivnog delovanja valjka on radi sa velikim učinkom. To je zato što je efikasnost ljuštenja od 96%, iznad minimalne prihvatljive stope od 95% .

Efikasnost sistema kod procesa abrazivnog delovanja valjka je manja (94%). Ovo podrazumeva pojavu 5% otpadaka u preradi koji su povezani sa sistemom za ljuštenje sa abrazivnoim delovanjem valjka, što može da predstavlja i izdvojenu operaciju sortiranja nakon ljuštenja.

Visoki troškovi proizvodnje izazvani operacijom ljuštenja su očigledni zbog dugog perioda vraćanja materijala i niskog odnosa troškova i koristi ovog sistema u poređenju sa procesom rada sa noževima na bubnju .

Ocena korisnog dejistva kod sistema sa sečivima noža iznosi 0,8 i 2,45, dok vrednosti 1,69 i 1,76 predstavljaju odgovarajuće ocene mašina zasnovanih na procesu abrazivnog delovanja valjaka.

Pored toga, sistem za obradu sa ivicom noža ljušti sveže i suve listove palmi, dok sistem za ljuštenje pomoću abrazivnog delovanja valjaka obrađuje (odstranjuje) samo suve delove biljke palme.
Stoga se preporučuje u ovom ispitivanju usvajanje procesa ljuštenja uz pomoć oštrica noža za unapređenje efikasnosti proizvodnje metli od ogranaka palme.

Ključne reči: *abrazija, osnov metle, ivica noža, mašina, palmin list, ljuštenje*.

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A STUDY OF ROTARY DRUM MOWER BLADE WEAR AND ITS EFFECTS ON FORAGE PRODUCTIVITY

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Abstract: Egyptian clover (*Trifolium alexandrinum*) is the main and oldest cultivated winter forage leguminous crop in Egypt. It occupies about one third of the cultivated area with average of 1.63 million Feddan (Feddan= 4200 m^2). With an estimated productivity of about 42.03 million tons of green fodder [7]. In last years, the forage mower conditioner machine used in Egypt to cutting the Egyptian clover crops. The mean objectives of the current research were evaluated the new and wear blades attached in the rotary drum mower conditioner. As well as, study the effect of new and wear blades on the productivity of green fodder under local conditions. The current research carried out in the Sakha Research Station, Egypt during session 2016/2017. The drum mower conditioner was operated by tractor to cut the Berseem Egyptian clover forage crops (Sacha-4) at three different moisture content 65.4%, 57.3 and 46.2 % (d.b.) at second cutting of Berseem (*Trifolium alexandrinum*). The results indicated that, the average maximum value was 4.96 ton/fed compared with 2.42 ton / fed for Alfalfa moisture content 56.3 %. This result indicated that the wear old blade or wear knife may be going to reduce the productivity as 49.9%. The average maximum value of fuel consumption was 23.04 l/fad compared to 15.4 l/fed for Berseem Egyptian clover forage crops (Sacha-4) moisture content 65.7 %. This result indicated that the old blade or wear knife may be going consumed low values of fuel consumption per L/fed.

This result indicated that the old blade or wear knife may be going reduce the PTO power. The average values of clover forage crops of power requirement were 28.83 hp, 24.9 hp, and 25.0 hp for old knife compared with 47.67 hp, 39.8 hp and 38.27 hp for new blade at 65.7 %, 57.3 % and 46.2 % moisture content respectively.

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The aim of the present research is evaluated the performance of new and wear blades attached in the rotary drum mower conditioner. As well as, study the effect of new and old blades on the productivity of green fodder under local conditions.

Keywords*: Drum mower, wear, forage cutting machine*

INTRODUCTION

Forages are important compared with other agricultural crop and require as much inputs, care, and management. Livestock products are as important in our food chain as cereals. It is not possible to increase the area under fodder so, it is imperative that forage crops become an important component of cropping systems. Integration will add to the availability of fodder but help the alternative crops if leguminous forages are grown. Berseem, Egyptian clover (*Trifolium alexandrinum*) has achieved the distinction of being designated "king of forages". Wild in the Levant and domesticated in Egypt in antiquity it has been a base of Egyptian farming, both as fodder and for soil fertility maintenance. Under Egyptian conditions cross-pollination in traditional cultivars, *Trifolium alexandrinum* and *T. repins* was up to 82 % in the presence of bees. Currently there are 200-300,000 acres of Alfalfa planted in Egypt and acreage is rising each year year [27]. Vertical axis mowers avoid many of the complications of reciprocating machines by cutting the crop with freely pivoting blades attached to rotating [28]. The pivoting action of the blades allows them to swing away from rocks and other obstacles. In all rotary mowers, the crop is unsupported during cutting. Thus for a clean cut, the force of cutting must be absorbed by the rigidity of the plant's stem and its neighbors–there is no counter shear to hold the stem in place. There are two types of vertical axis rotary mowers, disc and drum. Drive mechanisms in disc mowers are located beneath the cutting blades, so crop flows more easily through the machine. This is believed to reduce energy requirements for crop conveyance. Blades may be counter rotating to leave the material in distinct bands or co-rotating for uniform distribution across the cutting width. Drum mowers have their drive mechanism above the blades, and crop is required to pass in the narrower spaces between or under the drums, resulting in higher energy requirements. The combination of the mowers revolution and forward velocity causes the blade to move in a cycloid path. The ends of blades may be beveled so that the flat portion of the blade does not push into standing crop as the machine advances [28]. In general, the tangential velocity of the blade is much greater than the forward velocity of the mower, so the oblique angle of cutting is near zero. This reduces the number of stems that slide forward and off the blade's edge, since the cutting surface is oriented perpendicular to the direction of travel. Cutting of plant stems is believed to occur when the pressure caused by the blade reaches a critical value from 9 to 30 N/mm^2 for most plant materials. Cutting results in multiple modes of tissue failure. Initial knife penetration results in localized plastic deformation, followed by significant buckling as the knife advances.

The turgor pressure of moist stems will often resist initial compression in high speed cutting. As the knife continues to advance the fibers composing the stem are deflected and eventually fail in tension.

The plant stem is deformed and compressed ahead of and to the sides of the knife. These compression effects alone may account for 40-60% of total cutting energy [28], [4,5] cites a power requirement of 5.0 kW/m of rotary cutting width.

The power requirement for rotary mower conditioners is 8.0 kW/m. Other studies report even higher energy requirements, with 11 to 16 kW/m consumed by the mower at 15 km/h [28] and [26] uggests the following relationship for the power requirements of a rotary mower:

$$P_{mow} = \left(P_{Ls} + E_{sc} v_f\right) w_c \quad \ldots\ldots\ldots \tag{1}$$

Where is :

P_{mow}= total power requirement of mower, kW

P_{ls}= specific power loss due to friction, kW/m

E_{sc}= specific cutting energy, kJ/m^2

V_f = forward velocity of mower, m/s

W_c = width of mower, m

Specific power losses (Pls) range from 1.5 - 4.0 kW/m, with drum mowers experiencing higher losses than disc-type [26]. Specific cutting energy (Esc) ranged from 1.5 - 2.1 kJ/m2, depending on blade sharpness. Energy losses in rotary mowers are identified as windage, mower drag, friction within the drive train, and friction with the stubble beneath the blades. Author [25]. mentioned that the general formulas for the energy requirements of a flail mower as follow:

$$P_{mow} = c_1 + c_2\, m_f \quad \ldots\ldots\ldots \tag{2}$$

Where is :

mf = mass feed rate of crop material, kg/s

C1= constant power requirement, kW

C2 = feed rate energy requirement, kJ/kg

Typical values for $C_1$and C_2 are 10 kW and 4.0 kJ/kg. In addition to flail mowers, other horizontal axis mowers have been developed and tested, such as a compound helical cutter bar [12]. Cutting of plant stems is believed to occur when the pressure caused by the blade reaches a critical value from 9 to 30 N/mm2 for most plant materials. Cutting results in multiple modes of tissue failure. Initial knife penetration results in localized plastic deformation, followed by significant buckling as the knife advances. Initial plant penetration is strongly influenced by the fineness of the blade, which is defined by the rake angle, Increasing the oblique angle tends to change the nature of cutting from impact to slicing [28]. Slicing cuts generally require less energy, but increase the tendency for crop material to slide along the blade.

Serrated blades increase friction between the blade and stem, reducing the tendency for material to slide out of the cutting area. Friction between the cutting blade and the underside of the blade was considered a part of the cutting energy, as in in [11].

Since cutting force was not monitored, it was not possible to distinguish these parasitic losses from the energy required to sever the stalk.

OBJECTIVES

The aim of the present research is evaluated the performance of new and wear blades attached in the rotary drum mower conditioner. As well as, study the effect of new and old blades on the productivity of green fodder under local conditions.

MATERIAL AND METHODS

The current research conducted in the Sakha Research Station, Egypt during session 2018/2019. The tractor model Fiat 5560 with engine power 65 hp used to operate the drum mower conditioner model Celmak-Mechanical. The drum mower has 165 cm width to cut the Berseem Egyptian clover forage crops Sacha-4 at three different moisture content 65.4%, 57.3 and 46.2% (d.b.) at second cutting of Berseem (*Trifolium. alexandrinum).*
The different trails tests for cutting the Berseem Egyptian clover forage crops Sacha-4 (Alfa-Alfa) were operated at two different total averages operating times 7 hour and 8 hours. The total cutting area for Berseem Egyptian clover forage crops Sacha-4 (Alfa-Alfa) to evaluate different blades was arranged between 10 feddan to 18 feddan. The wear blades were used knives at the end of the operating cutting session and the dimension of the new and wear blade presented as shown in figure 1.

Operating forward speed was adjusted at 4.8 km/h for all trails testes conditions by adjusting the hand throttle control fuel paddle. The cutting height was adjusted at 8 cm from the ground. The three hitch point in hydraulic system was operated at fixed position to control of the cutting height at 8 cm for forage Berseem Egyptian clover forage crops Sacha-4. The energy requirement of rotary drum mower was calculated by using equation 2 for all trail testes conditions. As well as, a tractor with trailer was used to transfer the forage and the total production mass stem was measured after every trail of cutting alfa-alfa by using weight balance of a trailer in Sacha research center. The total productivity or farm capacity of machine calculated by divided the total mass production on the total cutting area. Also, the specific fuel consumption (SFC) was estimated by using the following equation:

SFC= fuel consumption with liter/total cutting area with fedden

ASABE Standards [3],[4] are widely used for estimating fuel consumption for determining cost of operations. The most widely used relationship for estimating fuel consumption in gallons per hour (gal/h) is;

$$Q_{AVG} = a' \cdot P_{PTO} \quad \ldots \qquad (3)$$

Where as:
QAVG = average diesel consumption (gal/h),
PPTO = rated PTO power (hp),
a′ = 0.044 gal/hph.

The value of the coefficient a' was estimated to submit the average diesel consumption with (l/h). The equation 3 used to estimate the total rated PTO power for wear and new blades at different trial testes conditions. The fuel consumption was measured by using the graduated cylinder and stop watch.

Wear is a process of gradual removal of a material from surfaces of solids subject to contact and sliding. Damages of contact surfaces are results of wear. They can have various patterns (abrasion, fatigue, ploughing, corrugation, erosion and cavitation). The wear depth profile of a surface is a useful measure of the removed material. The wear depth can be estimated with the aid of wear laws, [24]. Derived in this study, constitutive equations of anisotropic wear are extensions of the Archard law of wear,

The amount of wear can be specified in terms of direct or indirect quantities. Indirect quantities are often used in technical assessments of the lives of machinery and in practical engineering.

Direct wear quantities specify the change in mass, geometrical dimensions or volume of the wearing body.

The wear could be illustrated as follows:
- wear amount:
- mass loss (kg)
- linear dimensional change (m)
- volume loss (m^3)
- wear resistance = (1/wear amount), m^{-1}, m^{-3}, and kg^{-1} … (4)
- wear rate= (wear amount/sliding distance or time) (m/m, m^3/m, kg/m, m/s, m3/s, kg/s) Author [14]. (5)

The primary measurement from which these quantities are derived is usually mass loss, dimensional change or volume loss, although other methods can also be used.

The two different knives wear blade and new blade were constructed and used under field condition at the above three moisture contents. The differences between the weight of new and old blades was in both dimensions and materials of the blades was measured. The average weight was 50.61g for wear blades and 103.2 g for new blades. The weight loss of blade was 52.59 g (0.0526kg). As well as, the dimensional sliding distance change and volume loss were 0.0278 m and 0.0062 m^3 respectively.

The equation 4 and 5 used to calculate the wear rate and wear resistance. The average wear rate in rotary drum was 18.92 kg/m (0.0526 kg/0.0278 m) or 8.48 kg/m^3 for constructed old blades. Also, the wear resistance rate in rotary drum was for constructed old blades 19.23 kg^{-1} for constructed old blades.

Table 1: The technical specification of Mechanical drum mower conditioner

Model Celmak - Mechanical drum mower 165 cm.	dimension
Cutting width	1650 mm
Number of drums	2
Number of cutting blades	6
Tractor power	30 kW
Length	2 750 mm
Width	990 mm
Height	1 100 mm
Weight	400 kg
Working capacity	1.5 ha/h
P.T.O	540 rpm
Skid plates	6 mm

Fig. 1. The wear blades or old blades used in Mechanical drum mower conditioner

RESULTS AND DISCUSSION

The result indicated that the wear knife or old blades in mechanical drum mower conditioner tends to decrease the total production and productivity of Berseem Egyptian clover forage crops Sacha-4 (*Trifolium alexandrinum*) as shown in table 2. As well as, the productivity (ton / fed.) will be decrease when using the wear blade during the operation. Figure 2 illustrated the effect of wear blade on the production of cutting Berseem Egyptian clover forage crops Sacha-4 under three moisture contents. The average maximum productivity of Berseem Egyptian clover forage crops Sacha-4 value was 4.96 ton/fed compared to 2.42 ton / fed for moisture content 56.3 %. This result indicated that the old blade or wear knife may be going to reduce the percentage of productivity as 49.9%.

The average values of Berseem Egyptian clover forage crops Sacha-4 yield were 2.63 ton/fed, 2.42 ton/fed, and 2.18 ton/fed for wear knife at 65.7 %, 57.3 % and 46.2 % moisture content respectively.

Also, the average values of Berseem Egyptian clover forage crops Sacha-4 yield were 4.3 ton/fed, 4.98, and 4.11 ton/fed for new blade mower drum conditioner 65.7 % , 57.3 % and 46.2 % moisture content respectively.
Figure 3 and table 3 illustrated that the effect of wear knife or blades in drum mower conditioner on feeding rate at different trails conditions. The wear blade tends to reduce the feeding rate of Berseem Egyptian clover forage crops Sacha-4 during the operation as shown in table 3. As well as, the feeding rate will be increasing when using the new blade compared to wear blade. Figure 3 illustrated the effect of blade wear on the feeding rate of cutting Berseem Egyptian clover forage crops Sacha-4 for three moisture content. The average maximum value of feeding rate was 9.42 ton/h compared to 4.71 ton/h for Berseem Egyptian clover forage crops Sacha-4 moisture content 65.7%.
The average values of feeding rate Berseem Egyptian clover forage crops Sacha-4 were 4.71 ton / h , 3.72 ton / h, and 3.75 ton / h for old knife at 65.7 % , 57.3 % and 46.2 % moisture content respectively. Also, the average values of feeding rate of cutting Berseem Egyptian clover forage crops Sacha-4 were 9.42 ton / h, 7.45 ton/h and 7.06 ton/h for new blade mower drum conditioner 65.7 %, 57.3 % and 46.2 % moisture content respectively.
Table 2 illustrated that the effects of wear blades in mechanical drum mower conditioner on the fuel consumption L/fed at different trails conditions. As well as, the fuel consumption may be it is an indicator to know the wear in blades of mower conditioner. Figure 4 illustrated the effect of blade wear on the fuel consumption of cutting Berseem Egyptian clover forage crops Sacha-4 for three moisture content. The average maximum value of fuel consumption was 3.14 L/fed compared to 4.26 for both old and new blade at moisture content 65.7 % of Berseem Egyptian clover forage crops. This result indicated that the old blade or wear knife may be going consumed low values of fuel consumption per L/fed. As well as, the average values of Berseem Egyptian clover forage crops Sacha-4 were 3.14 L/fed, 2.86 L/fed and 3.2 L/fed for old knife at 65.7 %, 57.3 % and 46.2 % moisture content respectively. Also, the average values of fuel consumption were 4.26 L/fed, 3.75 L/fed and 4.28 L/fed for new blade mower drum conditioner 65.7 %, 57.3 % and 46.2 % moisture content respectively. The fuel consumption may be used as indicator to change the blades in mower conditioner. Table 3 illustrated that the effects of wear blades in mechanical drum mower conditioner on PTO power requirement at different trails conditions. As well as, the PTO power requirement may be reduced due to increasing of the wear blades in conditioner. Figure 4 illustrated the effect of blade wear on the PTO power requirement of cutting Alfalfa for three moisture content. The average maximum value of PTO power requirement was 47.67 hp compared to 28.83 hp for both new and old blades respectively at moisture content 65.7 %. This result indicated that the old blade or wear knife may be going to reduce the PTO power and it means that the blades most be changing. The average values of cutting the Berseem Egyptian clover forage crops Sacha-4 of power requirement were 28.83 hp, 24.9 hp, and 25.0 hp for old knife at 65.7 %, 57.3 % and 46.2 % moisture content respectively. Also, the average values of power requirement for cutting Berseem Egyptian clover forage crops Sacha-4 were 47.67 hp, 39.8 hp and 38.27 hp for new blade mower drum conditioner 65.7 %, 57.3 % and 46.2 % moisture content respectively.

CONCLUSIONS

The result indicated that the old or wear knives tend to reduce the performance of rotary drum mower production. The average maximum value was 4.96 ton/fed. Compared to 2.42 ton / fed for Alfalfa moisture content 56.3 %.
The result indicated that the old blade or wear knife may be going to reduce the PTO power. As well as, the fuel consumption may be it is an indicator to know the wear in blades of mower conditioner. The reduction of productivity and specific fuel consumption l/fed may be used as an indicator to change the blades in drum mower conditioner.

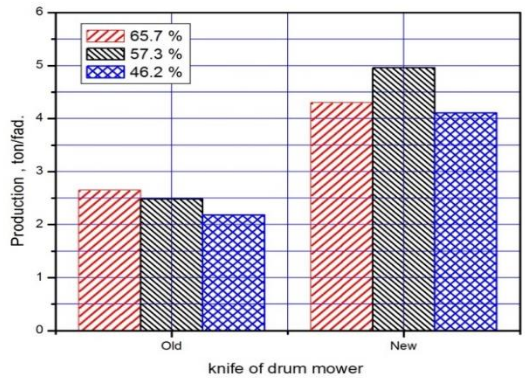

Figure. 2. The effect of old blades used in mechanical drum mower conditioner on the productivity of cutting

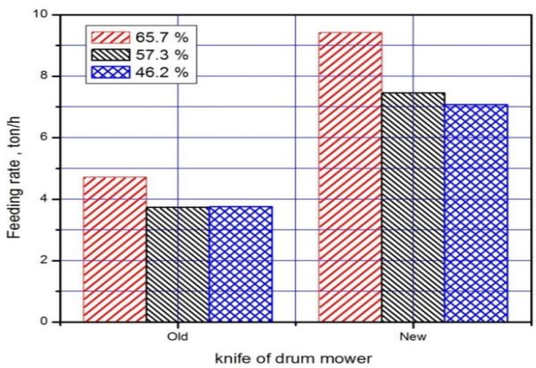

Figure 3. The effect of old blades used in mechanical drum mower conditioner on the feeding rate of cutting forage Alfalfa

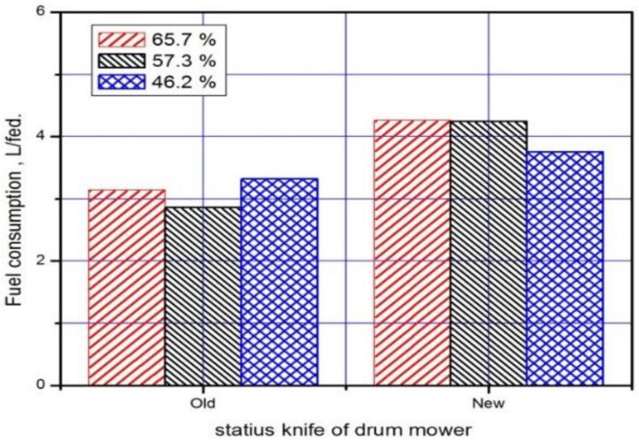

Fig. 4: The effect of old blades used in mechanical drum mower conditioner on the fuel consumption L /fed of cutting forage Alfalfa

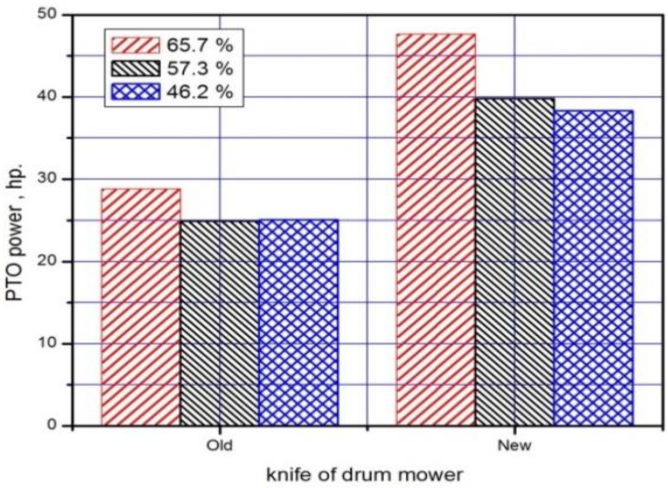

Fig. 5: The effect of old blades used in mechanical drum mower conditioner on PTO power requirement of cutting forage Alfalfa

Table 2: Display the measured data for old and new knife in drum rotary mower conditioner Model Celmak

Trails	Blade	MC, %	Oper. time, hr	Total cutting area, fad	Total production, ton	Productivity, ton/fed
T1	old	65.4	7	18	36.32	2.02
T2	old		7	10	37.77	3.78
T3	old		7	12	22.32	1.86
T4	old		7	12	35.47	2.95
T1	old	57.3	8	12	32.23	2.69
T2	old		8	12	28.47	2.37
T3	old		8	12	30.24	2.52
T4	old		8	12	32.34	2.69
T5	old		8	12	28.16	2.35
T1	old	46.2	7	12	23.32	1.94
T2	old		7	12	26.04	2.17
T3	old		7	12	25.60	2.13
T4	old		7	12	25.24	2.10
T5	old		7	12	27.84	2.32
T6	old		7	12	26.36	2.20
T1	New	65.4	7	18	72.64	4.04
T2	New		7	16	75.53	4.72
T3	New		7	12	44.64	3.72
T4	New		7	15	70.93	4.72
T1	New	57.3	8	12	64.45	5.37
T2	New		8	12	56.93	4.74
T3	New		8	12	60.47	5.04
T4	New		8	12	64.67	5.39
T5	New		8	12	56.31	4.69
T1	New	46.2	7	12	46.64	3.89
T2	New		7	12	52.08	4.34
T3	New		7	12	51.20	4.27
T4	New		7	12	50.48	4.21
T5	New		7	12	55.68	4.64
T6	New		7	12	52.72	4.39
T7	New		7	12	39.04	3.25

Table 3: Display the effect of wear knife blades in vertical rotary disc mower to mower the alfaalfa crop (*Trifolium alexandrinum*) on power requirement, fuel consumption

Trails	Blade	MC, %	feeding rate, ton/h	sp fuel consumption, L/fed	FC, L/h	PTO Power, hp
T1	old	65.4	5.19	2.87	2.57	30.75
T2	old		5.40	2.85	1.43	31.58
T3	old		3.19	2.88	1.71	22.75
T4	old		5.07	2.85	0.71	30.27
T1	old	57.3	4.03	3.13	1.50	26.11
T2	old		3.56	3.15	1.50	24.23
T3	old		3.78	3.16	1.50	25.12
T4	old		4.04	3.12	1.50	26.17
T5	old		3.52	3.16	1.50	24.08
T1	old	46.2	3.33	3.34	1.71	23.33
T2	old		3.72	3.34	1.71	24.88
T3	old		3.66	3.31	1.71	24.63
T4	old		3.61	3.32	1.71	24.42
T5	old		3.98	3.32	1.71	25.91
T6	old		3.77	3.34	1.71	25.06
T1	New	65.4	10.38	4.28	2.57	51.51
T2	New		10.79	4.28	1.43	53.16
T3	New		6.38	4.28	1.71	35.51
T4	New		10.13	4.23	0.71	50.53
T1	New	57.3	8.06	4.26	1.50	42.23
T2	New		7.12	4.26	1.50	38.47
T3	New		7.56	4.26	1.50	40.24
T4	New		8.08	4.26	1.50	42.34
T5	New		7.04	4.26	1.50	38.16
T1	New	46.2	6.66	3.75	1.71	36.65
T2	New		7.44	3.75	1.71	39.76
T3	New		7.31	3.72	1.71	39.26
T4	New		7.21	3.75	1.71	38.85
T5	New		7.95	3.75	1.71	41.82
T6	New		7.53	3.75	1.71	40.13
T7	New		5.58	3.75	1.71	32.31

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PROUČAVANJE SEČIVA NOŽEVA ROTACIONE KOSAČICE I NJIHOVI EFEKTI NA PROIZVODNJU ZELENE MASE

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Apstrakt: Egipatska detelina (*Trifolium alexandrinum*) je glavna i najstarija gajena zimska krmna leguminoza u Egiptu. Zauzima oko jedne trećine obradivih površina sa prosekom od 1,63 miliona fedana (feddan=4.200 m^2), a procenjenim prinosom od oko 42,03 miliona tona zelene mase [7].

Poslednjih godina mašina za kondicioniranje zelene mase u Egiptu je kosačica sa vertikalnim rotacionim bubnjevima sa noževima, koja se uspešno koristi za košenje deteline. Srednji ciljevi trenutnog istraživanja su procenjeni na novim i istrošenim noževima kosačice postavljenih na vertikalne rotacione bubnjeve

Takođe, proučen je uticaj novih i istrošenih rotacionih noževa na prinos zelene stočne hrane u lokalnim uslovima.

Trenutno istraživanje sprovedeno u istraživačkoj stanici Sakha, Egipat u toku perioda 2016/2017. Kosačica je agregatirana na traktor i obavljeno je košenje egipatske deteline Berseem (tip Sacha-4) sa tri različita sadržaja vlage 65,4%, 57,3 i 46,2% (w.b.).

Urađeno je drugo košenje deteline tipa Berseem (*Trifolium alexandrinum)*. Rezultati su pokazali da je prosečna maksimalna vrednost prinosa iznosila 4,96 tona u poređenju sa 2,42 tone za Alfalfa sa sadržajem vlage od 56,3 %.
Ovaj rezultat je pokazao da staro sečivo rotacionog noža zbog istrošenosti, habanja smanjuje produktivnost za 49,9%. Prosečna najveća vrednost potrošnje goriva iznosila je 23,04 L/fad za košenje deteline tipa *Trifolium alexandrinum*, u poređenju sa 15,4 L/fad za egipatsku detelinu Berseem (tip Sacha-4) sa sadržajem vlage 65,7 %.
Rezultat ukazuje da staro sečivo ili nož ima manje vrednosti potrošnje goriva u L/Fed, kao i da staro sečivo ili nož zbog habanja smanjuje dobijenu snagu izlaznog vratila PTO.
Prosečne vrednosti zahtevane snage traktora (KS) za košenje deteline bile su 28,83; 24,9 i 25,0 za stari nož pri 65,7 % sadržaju vlage, u poređenju sa 47,67; 39,8 i 38,27 za novo sečivo i sadržaj vlage 65.7 %, 57.3 % i 46.2 % respektivno..

Cilj ovog istraživanja je procena performansi novih i istrošenih noževa postavljenih na rotacione bubnjeve kosačice. Takođe, proučavan je uticaj novih i starih noževa na prinos zelene stočne hrane u lokalnim uslovima.

Ključne reči: *kosačica sa bubnjem, habanje, mašina za sitnjenje stočne hrane*

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