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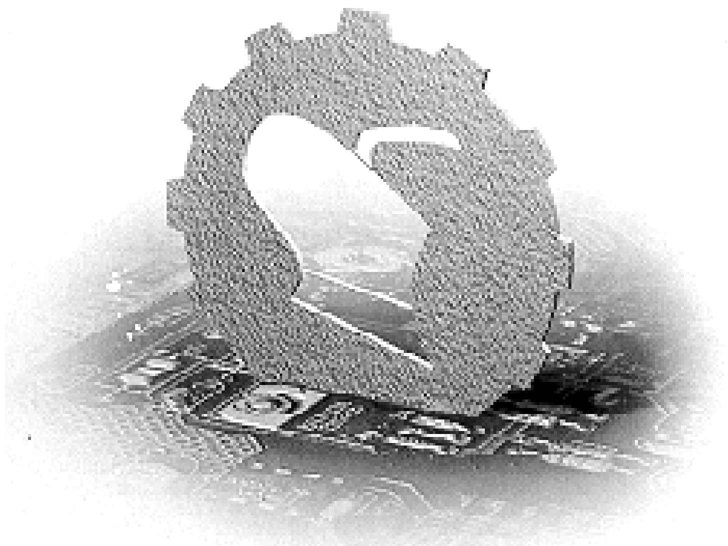

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THE USE OF SOLAR PLANTS FOR CROP SEEDS DRYING

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Abstract: A grain drying complex based on solar energy, including a grain storage with a built-in solar drying system and a drum solar dryer for grain, is proposed. The construction and principle of operation of the grain drying complex is described. The basis of each of the solar drying systems of the complex is the presence of two solar collectors, one of which provides heating of the drying agent at the inlet into the drying chamber, and the second – heating of the used drying agent in the exhaust pipe to increase its flow rate and, accordingly, the intensification of grain drying. Availability of gravel or water heat accumulators allows to carry out the process of grain drying or grain storage, at night and under adverse weather conditions without the risk of self-heating. The optimum capacity of the gravel accumulator is 0.5-0.75 m^3 per 1 m^2 of solar collector area. Drum solar dryer provides guaranteed drying of a grain batch for 6-7 hours of the day time and a grain batch for the night time. It was found that the optimum thickness of the grain layer in the drying process is 50-70 cm and specific load is up to 100 kg of grain per square meter of the horizontal solar collector area.

Key words: *Solar plant, moisture, solar dryer, drying chamber, air exchange, grain storage*

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INTRODUCTION

Drying is an important, but very energy-consuming technological process of post-harvest processing of agricultural crops seeds. For example, for final grain drying various types of dryers with the average flow of liquid fuel up to 100 kg/h or gas 70 kg / t and the preset capacity of electric motors about 50 kW are used. When using existing installations, grain drying accounts for 85 to 97% of the total energy consumption for its processing [1].

With small production volumes of grain seeds and vegetable crops the use of high-temperature dryers is not economically justified. The use of simple floor dryers with electric air heating requires large amounts of electricity and manual labor.

To reduce energy costs, solar plants are most often proposed [2-8]. They are simple in design and can be used as independent drying units and for preheating the drying agent in high-temperature dryers.

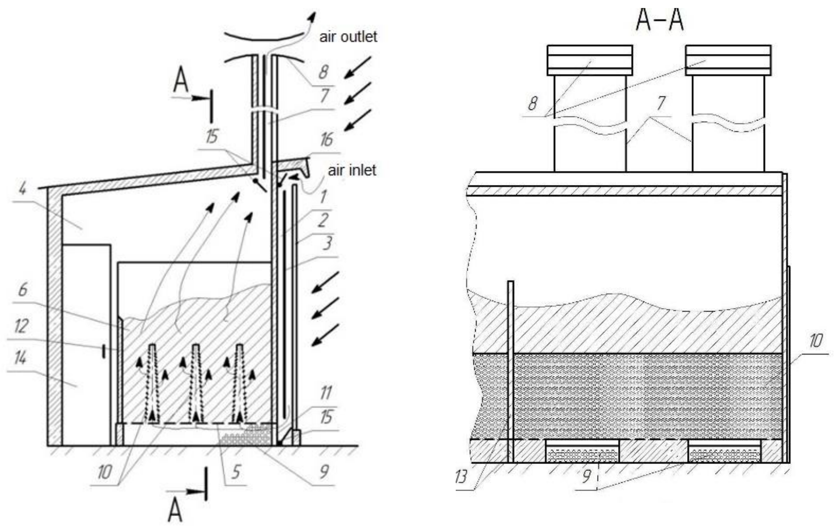
Due to the large variety of solar plant designs, research is needed to determine the optimal technological schemes of solar dryers for agricultural crops seeds [9-11].

MATERIAL AND METHODS

To combine the technological operations of energy-saving drying and grain crops storage a prototype grain drying complex based on an alternative energy source was created and tested. It includes a section of a grainery with built-in solar drying system (fig. 1) and a drum-type grain solar dryer (fig. 2).

Solar dryer-grain storage has (fig. 1) a vertical solar collector 1 with a translucent cover 2 and light-absorbing surface 3, drying chamber 4 with a perforated deck 5 for placing on it dried grain 6, and exhaust pipe 7 also in the form of a solar collector with deflector 8. Gravel accumulator 9 is placed under the decking 5. The perforated air-distribution channels 10 are on the decking 5. Their quantity and height are chosen in such a way that the distance between them and from the top of the channel to the surface of the dried material was about the same. This ensures the passage of the drying agent through the entire thickness of the grain (optimally from 50 to 70 cm). Under-deck space is connected with the vertical solar collector 1 by means of openings 11 in the wall of the grain storage [12].

Division of the drying chamber and the floor space into compartments for drying, for example, different varieties or types of crops by longitudinal 12 and transverse 13 partitions. Along the compartments a technological corridor runs, at the ends of which the gate 14 is located. Air exchange regulation in the grain storage is done by means of shutters 15. In order to reduce sailing, exhaust pipe 7 with a height sufficient to overcome the hydraulic resistance of the grain layer and reverse thrust in the solar collector (optimally – one and a half times the height of the solar collector 1), is made in separate sections. Entrance slot in the upper part of the solar collector 1 is covered with a grid from insects and rainfall canopy 16 of the roof. The walls, roof and gates of the grain storage must be thermally insulated and sealed so that there is no air suction, bypassing the solar collector 1.



a)

b)

c)

d)

Figure 1. Grain storage with built-in solar drying system:
a – basic diagram; b – general view; c – the grain storage sections; d – section view with temperature sensor.
1 – vertical solar collector; 2 – translucent cover; 3 – light-absorbing surface;
4 – drying chamber; 5 – perforated decking; 6 – dried grain; 7 – exhaust pipe;
8 – deflector; 9 – gravel accumulator; 10 – perforated air-distribution channels; 11 – openings in grain storage wall; 12 – longitudinal partition; 13 – transversal partition; 14 – door; 15 – shutters; 16 – roof canopy

The drying process during storage proceeds as follows. Due to the draft arising in the exhaust pipe 7, the ambient air enters through the input slot under the canopy 16 into the solar collector 1, where it is heated and through openings 11 is distributed in the space under the floor, simultaneously heating the gravel accumulator 9. Perforated decking 5 and air distribution channels 10 evenly distribute heated air in the mass of dried grain 6. The humidified air after passing through the grain layer is removed through the exhaust pipe 7 and deflector 8. At night time drying continues due to the heat given by the gravel accumulator. To regulate the air exchange depending on the environmental parameters and the condition of the grain mass, dampers 15 are used.

Drum solar dryer (fig. 2) provides, if necessary, drying of individual grain batches, both when the grain comes from the field and during its storage [13].

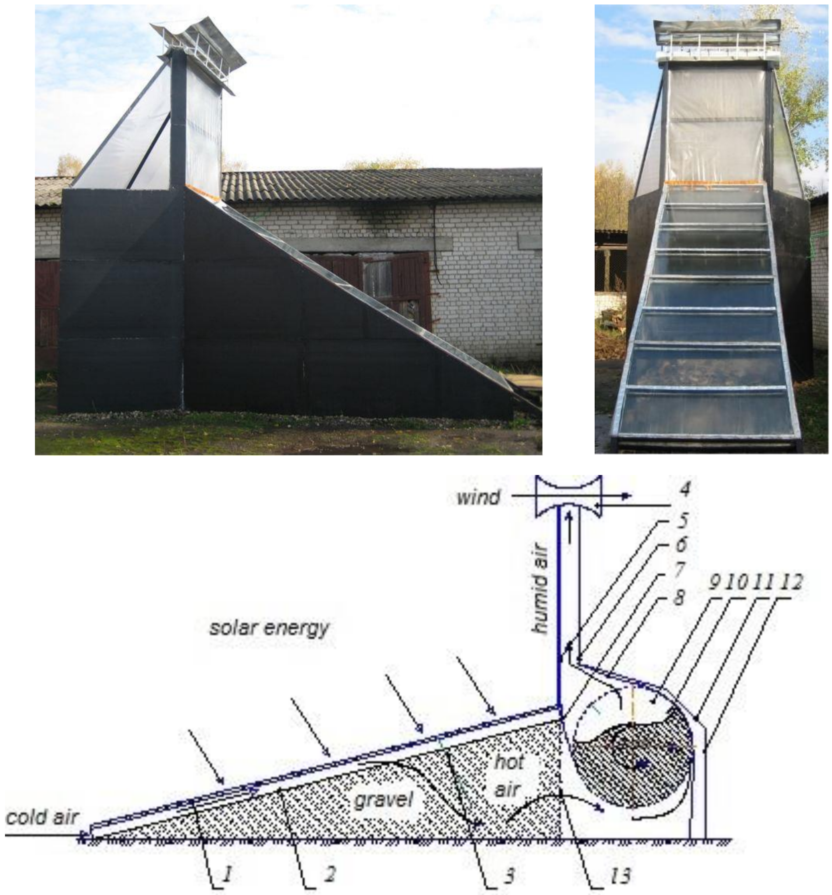


Figure 2. General view and scheme of drum solar dryer:
1 – inlet collector with double transparent coating; 2 – gravel heat accumulator; 3 – partition; 4 – exhaust pipe deflector; 5 – double transparent coating; 6 – rear heat-receiving wall; 7 – front rubber apron; 8 – rear rubber apron; 9 – drying drum;
10 – shovels; 11 – top cover; 12 – bottom cover; 13 – grid

The solar dryer consists of the inlet collector with double transparent coating 1, gravel heat accumulator 2 with the volume of 0.5-0.75 m^3 per 1 m^2 of the collector area. The heat accumulator has partition 3, which serves to organize the passage of air through the gravel. The upper blackened layer of gravel serves as a heat-receiving surface. To strengthen the draft there is a deflector 4 of the exhaust pipe, which is the vertical solar collector formed by transparent coating 5 and the rear heat-receiving wall 6.

Rubber aprons 7 and 8 are installed in the drying chamber to organize the flow of heated air. Drying drum 9 is installed in supports and has covers for loading and unloading of grain.

The drum has blades 10, which are used to mix the drying product. To load the drum, the drying chamber has opening covers 11 and 12. The drum is driven in rotation by a motor through the reducer. The chamber is separated from the collector by grid 13.

The solar dryer works in the following way. The drum is filled with grains to 3/4 of its volume. The air from outside enters the drying chamber, passing through the gap between the transparent covering of the inlet collector and the surface of the gravel, enveloping the partition and being heated.

The excess heat is absorbed by the gravel. The air enters the chamber through the grid 13. Aprons 7 and 8 slide over the surface of the drum and organize the air flow as shown in fig. 2 – from the bottom of the drum through it and then up into the exhaust collector, where it is additionally heated and goes upwards, forming a draft. If there is wind, the draft is increased by the deflector, which also prevents water from entering the drying chamber when it rains.

A disadvantage of a solar dryer is the lack of mechanization means of loading and unloading of dried material. This disadvantage can be eliminated by a designed solar dryer designed in different way (fig. 3), [14].

Mechanized solar dryer-storage unit works as follows. The material to be dried by means of the loading conveyor 9 is fed into the drying chamber 11. Guide tray 10 provides the material to the gap between the ends of perforated air channels 12 and the walls of the exhaust pipe 6. This provides consistent uniform distribution of material in the drying chamber on the surfaces of the perforated air distribution channels 12. In this case the sluice valves 14 are in a closed state, preventing the flow of material from the drying chamber 11 into the discharge channels 13.

Under the influence of solar energy, the incoming atmospheric air (drying agent), consistently passes through the retractable film solar collector 1 with blackened coating and inclined solar collector 2 with translucent protection and is heated. At the same time the water in the water heat accumulator 3 is heated. Then the drying agent streams through the main air channel 4 and discharge channels 13 into the perforated air distribution channels 12 with open shutters 14, penetrates into the layers of the dried material, moistens and is exhausted through the exhaust pipe 6 into the atmosphere.

The shutters 14 allow closing the supply of the drying agent in the corresponding perforated air distribution channels 12 when the drying chamber 11 is not completely filled. This prevents the free outlet of the drying agent into the exhaust pipe 6, bypassing the material layer.

At insufficient draft in the exhaust pipe 6 the exhaust fan 8 is switched on. Increasing the heating of the drying agent and accordingly the drying speed is provided by increasing the area of the heat-receiving surface with horizontal extending solar collector 1 as well as by regulating the amount of water in the water heat accumulator 3.

At reduction of water volume in the accumulator more solar energy goes on heating of the drying agent that increases speed of drying and vice versa. The maximum volume of water in the water heat accumulator is required to ensure drying of the material at night. The water heat accumulator 3 is filled via the expansion tank 5 and emptied via the drain cock 20.

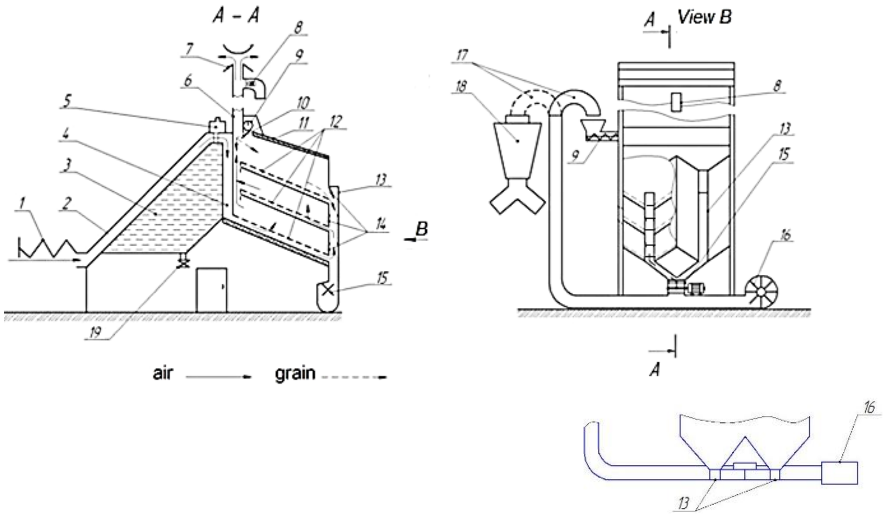


Figure 3. Solar dryer-grain storage:
1, 2 – sliding film and inclined solar collectors; 3 – water heat accumulator;
4 – main air channel; 5 – expander tank; 6 – exhaust pipe; 7 – deflector;
8 – exhaust fan; 9 – loading auger conveyor-distributor; 10 – guide channel;
11 – drying chamber; 12 – perforated air distributing channels; 13 – discharge channels; 14 – shutters; 15 – sluice valve; 16 – pneumatic conveyor; 17 – rotary deflector; 18 – cyclone; 19 – drain cock

To discharge the dried material, the sluice valves 14 are opened. The material under the gravity is poured into the discharge channels 13 and further through the sluice gate 15 into the pneumatic conveyor 16. The rotary deflector 17 directs the material either back to the loading auger conveyor 9 for material recirculation or to the unloading cyclone 18 and further to processing or permanent storage.

RESULTS AND DISCUSSION

The drum solar dryer was tested for drying wheat, rye, barley, oats, buckwheat, grain legumes, as well as herbs, mushrooms, fruits and marshmallows. Tests of solar dryers and grain store showed that the presence of a permanent natural draught at the expense of the solar collector exhaust pipe provides preservation of wet grain even under adverse weather conditions. In the absence of the sun the solar dryers operate for some time due to the heat stored in the gravel or water accumulator.

The optimum capacity of the gravel accumulator is 0.5-0.75 m^3 per 1 m^2 of solar collector area. Duration of drying depends on humidity of grain and solar activity.

On a bright sunny summer day, 1 m^2 of the collector can give up to 1 kW of heat output. During short summer rains, the grain in the solar dryer is sheltered from the rain, and drying continues due to the heat stored in the accumulator. Heating temperature of the drying agent does not exceed 70 ^{0}C, and the temperature of grain heating does not exceed 40 ^{0}C, which corresponds to the drying mode of seed grain.

The drum dryer provides guaranteed drying of grain batch for 6-7 hours of day time and grain batch for the night time. Specific load is up to 100 kg of grain per square meter area of the horizontal solar collector. In this case drying of grain batch with different humidity is provided. It also should be noted that in two hours after drying some increase in humidity of the grain is not observed, in contrast to the floor dryer and drum dryer with electric air heating.

Improving the efficiency of solar dryer drum as compared to existing models, provided by the optimal organization of air movement in the dryer through the lower inclined solar collector and gravel heat accumulator, the presence of the upper vertical solar collector in the form of an exhaust pipe, as well as deflector, significantly increasing the draft in the dryer.

The design of the dryer provides grain drying also at night time by accumulating heat energy during the day in the gravel accumulator and releasing it at night time. Gravel accumulator and increased draft in the exhaust pipe prevent the formation of condensation in the dryer and increase the humidity of grain during the rainy season. This makes it possible to store moist grain in the dryer during such a period without the danger of its self-heating. An important advantage of mechanized solar dryer-grain storage is the possibility of recirculation of grain, which accelerates drying and provides its uniformity for the entire grain batch.

CONCLUSIONS

With large volumes of grain production, it is advisable to dry wet seeds by a combined method in two stages, involving preliminary removal of moisture in solar dryers, and then bringing the grain to the required conditions using high-temperature dryers. Division of the drying process into two stages will reduce moisture removal in high-temperature dryers, which will increase their carrying capacity by 1.5-2.0 times, and will significantly reduce energy costs for drying of grain.

When using only solar dryers, the total volume of drying drums or chambers should be equal to half of the daily volume of incoming wet grain. Additional drying of grain in the process of its storage in the solar dryer- granary is also possible.

In case of serial production of drying chambers in the form of separate modules it is possible to provide the required productivity of the offered drying complex.

The most rational use of solar dryers is for drying of small seed grain batches, seeds of vegetable and herbaceous crops, as well as for heat treatment of seeds before sowing.

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UPOTREBA SOLARNIH POSTROJENJA ZA SUŠENJE SEMENA USEVA

Aleksey Kupreenko[1], Khafiz Isaev[1], Yury Kuznetsov[2], Stanislav Mikhailichenko[1], Igor Kravchenko[3], Larisa Kalashnikova[4]

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Sažetak: Predložena konstrukcija postrojenja za sušenje zrna žitarica je bazirana na korišćenju solarne energije, koja uključuje skladište žitarica sa ugrađenim solarnim sistemom za sušenje i bubanj solarnu sušaru za zrna žita.

Opisana je konstrukcija i princip rada postrojenja za sušenje zrna. Osnova svakog od solarnih sistema za sušenje je prisustvo dva solarna kolektora. Jedan obezbeđuje zagrevanje vazduha-medijuma za sušenje na ulazu u komoru za sušenje, a drugi zagrevanje korišćenog vazduha-medijuma za sušenje u izduvnoj komori, cevi za povećanje protoka, i zbog toga, intenziviranje sušenja zrna.
Dostupnost akumulatora toplote (voda ili šljunak) omogućava izvođenje procesa sušenja ili skladištenja zrna, noću i pod nepovoljnim vremenskim uslovima bez rizika samozagrevanja. Optimalni kapacitet akumulatora (šljunak) je 0,5-0,75 m^3/m^2 površine solarnog kolektora. Solarna sušara sa bubnjem obezbeđuje garantovano sušenje šarže zrna tokom 6 do 7 sati dnevno i šarže zrna noću.
Utvrđeno je da je optimalna debljina sloja zrna u procesu sušenja 50 do 70 cm i specifično opterećenje do 100 kg /m^2 horizontalne površine solarnog kolektora.

Ključne reči: *Solarno postrojenje, vlaga, solarna sušara, komora za sušenje, razmena vazduha, skladištenje zrna*

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MODELING OF TILLAGE OPERATION PARAMETERS FOR DRAFT AND POWER REQUIREMENT FOR THREE TILLAGE IMPLEMENTS IN A LOAMY SOIL

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Abstract: Tillage is the basic operation in agriculture and its energy requirements represent a considerable portion of the energy utilized in crop production. The trials were achieved using five tractor speeds (3.6, 5.4, 7.2, 9.0 and 10.8 km/hr) and five tillage depths (10, 15, 20, 25 and 30 cm) to determine implement speed at different tillage depths for 3-bottom disc plough, spring tine cultivator and offset disc harrow on loamy soil. The design of the experiment used were two factors, five levels factorial of Central Composite Rotatable Design of Response Surface Method. Selected models were analyzed using ANOVA at $\alpha_{0.05}$ and also validated. The high values of the coefficient of determination for all the selected models and the reasonable agreement between the predicted and actual values of draft and power requirement for all the tested implements show that the generated model equations can be used for predictive purposes for draft and power requirement.

Keywords: *Draft, power requirement, tillage, loamy soil, modeling*

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INTRODUCTION

Agricultural mechanization is considered to be the main factor that contributes to the total energy inputs in agricultural system and tillage and it is an area where massive power is utilized. The three items that are involved in tillage are; the source of power, the soil and the implement, [7].

Studied [2], the influence of speed and depth on the draft of a chisel plough; an offset disc harrow, a mouldboard and a disc plough on sandy, loamy soil in the field. They observed a significant increase in the draft for all the implements with an increase in depth.

The specific drafts of four tillage implements were also affected significantly by speed and depth. Accessed the influence of the geometric factors of flat tillage tools on their draft, cutting efficiency and loosening of moist clay soil [5]. They observed increases in the draft with width, depth, and rake angle of the tools. Estimated the draft and vertical forces [6], soil deformation and normal pressure distribution on four geometrically similar subsoilers using the finite method.

The four subsoilers investigated have a combination of a vertical shank with 15, 23 and 31^0 included chisels and a 75^0 rake angle shank with 15^0 inclined chisels. They reported that a subsoiler with a shank angle of 75^0 and a chisel angle of 15^0 had the least draft.

Studied [8], the influence of plough speed on the formation of stress on the Steyr tractor using quarter-bridge strain gauge circuit with temperature compensation. It was discovered that stress on these parts of the three-point linkage system increased when the speed of plough goes up. The values of the average stress acquired were relatively higher when compared with the yield stress of 0.23 kN/m^2 of the bracket material.

Researched [4]. draft and fuel requirements measurement using tractor on-board. It was discovered that the model outputs of the operations for mouldboard plough, chisel plough, field cultivator, row crop planter and grain drill for the draft requirements do not differ significantly from the field data. There was a very close association between the preliminary draft and the predicted draft for the experiment of the implements. The model output of the disc harrow operations for the draft requirement is statistically different from the field data. The model outputs of the implements for the fuel requirements do not differ significantly from the field data.

There was a very close association between the experimental fuel requirement and the predicated fuel requirement for the implements.

Investigated [1], the effect of depth and speed on the fuel consumption of some commonly used farm tractors in selected states of southwestern Nigeria and reported that increase in ploughing depth and ploughing speed increases tractor fuel consumption. Also, fuel consumption varies with different states in southwestern Nigeria due to the variation in the soil and climatic conditions.

They reported further that ploughing depth is the most impactful factor in the determination of tractor fuel consumption during the ploughing operation.

The objectives of this study are to develop model equations using tillage depth and tractor speed as operating parameters and also carryout statistical analysis.

MATERIALS AND METHODS

Study location

The study was conducted at Use Offot located in Uyo Local Government Area of Akwa-Ibom state, Nigeria.

Tractor and tillage implements

The specification of the tractor used in all the field experiments is presented in Table 1. A set of primary and secondary tillage implements comprising of a 3 – bottom disc plough, an offset disc harrow and a spring tine cultivator were used in this research work for evaluating draft and power requirements over a wide range of tractor speeds and tillage depths. These implements are representative of the standard primary, and secondary tillage implements most commonly used for seedbed preparation in Akwa – Ibom State and the study location. They were owned by the Department of Agricultural and Food Engineering, University of Uyo. Implement specifications are given in Table 2.

Table 1. Specifications of tested tractor

Specification	Swaraj tractor, model 978 FE
Effective output (hp)	72(53.7 kW)
Type of Engine	4 – cylinder
Type of Fuel	Diesel
Type of steering system	Power assisted
Type of injector pump	In – line injector
Fuel tank capacity (L)	98
Lifting capacity (kg)	1250
Rated engine speed (rpm)	2200
Type of cooling system	Water – cooled
Country of manufacture	China
Front tyres (size)	6.0 – 16
Inflation pressure (kPa)	360
Rear tyres (size)	14.9 – 28
Inflation pressure (kPa)	180

Table 2. Specifications of implements used during the field test

S/No	Item	Disc Plough	Tine Cultivator	Offset disc harrow
1.	Type (Hitching)	Fully mounted	Fully mounted	Fully mounted
2.	Number of bottoms / discs/ Share blade	3	-	14
3.	Number of tines	-	11	-
4.	Width of tine (cm)	-	6	-
5.	Type of disc blade	Plane concave	-	Plane Concave
6.	Diameter of bottom/disc (cm)	65.3	7	62
7.	Spacing of discs/share blade (cm)	68	10	22.5
8.	Rake angle (°)	35	49	36
9.	Width of implement (cm)	116	66	105
10.	Actual width of cut (cm)	95.1	54.1	91.5
11.	Disc angle (°)	45	-	25
12.	Tilt angle (°)	20	-	15
13.	Weight of implement (kg)	360	266	305

Determination of draft

The draft of all the tillage implements was determined using the equation as given by [3]:

$$D = \frac{W}{Z} + \frac{c\left(\frac{bd}{sin\beta}\right) + \rho bdv_o^2 sin\delta / sin\,(\delta+\beta)}{Z(sin\beta + \mu cos\beta)} \quad \ldots\ldots\ldots\ldots (1)$$

Where,

D = Draft of tillage implement, N

W = Weight of soil, N

C = Soil cohesion, kPa

μ = coefficient of internal soil friction

β = angle of the forward failure surface, $[°]$

V_o= speed of operation, m/s

$$Z = \frac{cos\delta - \mu' sin\delta}{sin\delta + \mu' cos\delta} + \frac{cos\beta - \mu sin\beta}{sin\beta + \mu cos\beta} \quad \ldots\ldots\ldots\ldots (2)$$

μ'= coefficient of internal soil – metal friction

Determination of power requirement

The equation below was used for the determination of the power requirement.

$$P = DV_o \quad \ldots\ldots\ldots\ldots (3)$$

Where,

P = power requirement, kW

Experimental Design

The effects of tillage depth and tractor speed on draft and power requirements were examined. The two independent variables considered are very vital parameters affecting draft and power requirements. The design of the experiment used was two factors, five levels, factorial central composite rotatable design (CCRD) of response surface methodology.

For each independent variable, the levels were chosen based on past reports by different researchers on tillage operations using various implements since there is no knowledge on optimization of these parameters on draft and power requirements. Five levels of tillage depths (10, 15, 20, 25 and 30 cm) and tractor speeds (3.6, 5.4, 7.2, 9.0 and 10.8 km/h) were chosen.

An experimental plot of 100 m long by 50 m wide was used for each implement. A plot of 50 m by 50 m (Figure 3.7) was used as a practice area before the beginning of the experimental runs to enable the tractor and the implement to reach the selected tractor speed and tillage depth. Tillage depth was measured as a vertical distance from the top of the undisturbed soil surface to the implements deepest penetration using a steel measuring tape (Figure 3.8). The different tractor speeds (3.6 – 10.8 km/h) were achieved by selecting appropriate gears and adjusting engine throttle at engine speeds of 1600 – 2000 rpm while the tillage depths of (10- 30 cm) were achieved by using tractor depth controller through its quadrant. Time taken for each implement to travel a distance of 100 m was taken and recorded. The distance was divided by the time taken to obtain the implement travel speed.

Model selection for the Dependent Variables

In selecting a model, the polynomial with the highest order and the additional terms in the polynomial are significant, and the model is not aliased, lack-of-fit is not significant, and the maximization of the "Adjusted R^2" and the "predicted R^2" were considered. The cubic model is aliased and cannot be selected, and when the coefficient of determination (R^2) is maximum, and the value of standard deviation is minimum. A Design Expert (version 11.0.1) software package for the design of experiments was utilized to study and to generate model equations for the dependent variables which are draft and power requirement.

RESULTS AND DISCUSSION

Soil analysis test for the study location

Analysis of soil test was carried out at the study location for the three tillage implements. The results of the analysis test for mechanical properties of the soil is presented in Tables 3.

Table 3. Mechanical properties of the soil at the study location for the tillage implements

Soil Parameter	Values		
	3-Bottom Disc Plough	Spring Tine Cultivator	Off-set Disc Harrow
Soil Composition	%	(%)	(%)
Sand	41	41	41
Silt	35	35	35
Clay	24	24	24
Classification	Loam	Loam	Loam
Average Bulk density	(g/cm^3)	(g/cm^3)	(g/cm^3)
	1.32	1.32	1.32
Average Moisture content	(%)	(%)	(%)
	13.9	16.2	15.0

Experimental test results

The average summary of the experimental results for the two-factor, five levels factorial Central Composite Rotatable Design (CCRD) of the response surface methodology (RSM) for draft and power requirement are presented in Tables 4 and 5.

Table 4. Experimental results for draft using three implements on loamy soil

S/N	Factor 1	Factor 2			
	D_T (cm)	S_T (km/h)	D (kN)-3BDP	D (kN)-STC	D (kN)-ODH
1	10	7.2	1.19	0.12	1.02
2	15	5.4	1.78	0.20	1.53
3	15	9.0	1.91	0.22	1.68
4	20	3.6	2.53	0.28	2.16
5	20	7.2	2.69	0.30	2.27
6	20	7.2	2.67	0.30	2.27
7	20	7.2	2.69	0.30	2.28
8	20	7.2	2.69	0.30	2.27
9	20	7.2	2.68	0.30	2.27
10	20	10.8	2.77	0.31	2.34
11	25	5.4	3.46	0.40	3.04
12	25	9.0	3.65	0.42	3.16
13	30	7.2	4.64	0.54	3.97

D_T = Tillage Depth (cm); S_T = Tractor Speed (km/h); D = Draft (kN);
3BDP = 3-Bottom Disc Plough; STC = Spring Tine Cultivator; ODH = Offset Disc Harrow

Table 5. Experimental results for power requirement using three implements on loamy soil

S/N	Factor 1	Factor 2			
	D_T (cm)	S_T (km/h)	PR (kW)-3BDP	PR (kW)-STC	PR (kW)-ODH
1	10	7.2	2.28	0.20	1.88
2	15	5.4	2.24	0.28	2.09
3	15	9.0	3.55	0.47	3.52
4	20	3.6	1.94	0.18	1.49
5	20	7.2	4.19	0.39	3.10
6	20	7.2	3.97	0.38	3.06
7	20	7.2	4.11	0.39	3.14
8	20	7.2	4.16	0.39	3.04
9	20	7.2	4.02	0.38	3.08
10	20	10.8	5.04	0.48	3.81
11	25	5.4	3.52	0.49	4.25
12	25	9.0	5.98	0.73	5.59
13	30	7.2	6.58	0.66	4.92

D_T = Tillage Depth (cm); S_T = Tractor Speed (km/h); PR = Power Requirement (kW);
3BDP = 3-Bottom Disc Plough; STC = Spring Tine Cultivator; ODH = Offset Disc Harrow

Model selection for the tillage operation using draft as the response at the study location

The comparison of the linear, 2FI, quadratic and cubic models for the draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location is presented in Tables 9, 10 and 1 respectively. Considering the model with the maximum R^2 value and the minimum standard deviation (with preference given to R^2), quadratic, quadratic and quadratic models were selected to predict the draft of tillage operation for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively. The final regression equations for the draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow are given in equations 4, 5 and 6 as:

$$D_{3-BDP} = -0.022 + 0.069D_T + 0.044S_T + 0.0017D_TS_T + 0.0023{D_T}^2 - 0.0028{S_T}^2\ (R^2 = 0.9995) \ldots\ldots(4)$$

$$D_{STC} = -0.044 + 0.0086D_T + 0.0099S_T - 2.80 \times 10^{-18}D_TS_T + 0.00030{D_T}^2 - 0.000037{S_T}^2\ \ R^2 = 0.9991) \ldots\ldots\ldots..(5)$$

$$D_{ODH} = -0.19 + 0.064D_T + 0.068S_T - 0.00083D_TS_T + 0.0023{D_T}^2 - 0.0015{S_T}^2\ (R^2 = 0.9994)\ldots\ldots\ldots(6)$$

Where;
D_{3-BDP} = Draft for 3-bottom disc plough, kN
D_{STC} = Draft for spring tine cultivator, kN
D_{ODH} = Draft for offset disc harrow, kN
D_T = Tillage Depth, cm
S_T = Tractor Speed, km/h

Table 6. Model comparison for the draft for 3-bottom disc plough at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.0982	0.1030	0.0256	0.0260
R^2	0.9893	0.9894	0.9995	0.9996
Mean	2.72	2.72	2.72	2.72
Adjusted R^2	0.9872	0.9859	0.9991	0.9991
C.V.	3.61	3.79	0.9413	0.9547
Predicted R^2	0.9709	0.9706	0.9963	0.9607
PRESS	0.2624	0.2657	0.0336	0.3549
Adequate precision	72.95	60.23	197.82	169.41

Table 7. Model comparison for the draft for spring tine cultivator at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.0131	0.0138	0.0042	0.0028
R^2	0.9869	0.9869	0.9991	0.9997
Mean	0.3069	0.3069	0.3069	0.3069
Adjusted R^2	0.9843	0.9825	0.9984	0.9993
C.V.	4.26	4.49	1.36	0.9075
Predicted R^2	0.9663	0.9648	0.9915	0.9655
PRESS	0.0044	0.0046	0.0011	0.0045
Adequate precision	65.79	54.05	145.66	192.21

Table 8. Model comparison for the draft for offset disc harrow at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.0938	0.0987	0.0246	0.0228
R^2	0.9869	0.9869	0.9994	0.9996
Mean	2.33	2.33	2.33	2.33
Adjusted R^2	0.9843	0.9826	0.9989	0.9991
C.V.	4.03	4.24	1.05	0.9805
Predicted R^2	0.9669	0.9658	0.9950	0.9562
PRESS	0.2221	0.2293	0.0338	0.2934
Adequate precision	65.78	54.11	177.63	164.77

FI = Factorial Interaction; Std. Dev. = Standard deviation; C.V. = Coefficient of Variation; PRESS = Predicted Sum of Square.

The ANOVA for the selected models for the draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location is presented in Tables 9, 10 and 11 respectively.

For 3-bottom disc plough, the probability value of 0.0001 (Table 9) of the model is less than the selected α-level of 0.05. This implies that the selected model is significant. The probability values of 0.0001, 0.0001 and 0.0001 (Table 9) of the model expressions are less than the selected α-level of 0.05. This indicates that the model terms are significant. In view of this, D_T, S_T and ${D_T}^2$ are significant model expressions.

This denotes that the tillage depth and tractor speed have significant influence on the draft for 3-bottom disc plough at the study location with tillage depth having the more significant influence on the draft force. It was pointed out that the model was significant with an adequate coefficient of determination (R^2 = 0.9995).
The high coefficient of determination implies that there is an excellent correlation among the tillage depth and tractor speed.
This value shows that the model for the draft for 3-bottom disc plough at the study location can explain 99.95 % of the total variability in the responses.

For spring tine cultivator, the probability value of 0.0001 (Table 10) of the model is smaller than the selected α-level of 0.05. This specifies that the selected model is significant. The probability values of 0.0001, 0.0002 and 0.0001 (Table 10) of the model expressions are less than the selected α-level of 0.05. This indicates model expressions are significant. In line with this, D_T, S_T and $D_T{}^2$ are the significant terms. This shows that the tillage depth and tractor speed all have a significant influence on the draft for 3-bottom disc plough at the study location with tillage depth having the more significant influence on the draft. It was also seen that the model was significant with the coefficient of determination (R^2 = 0.9991), implying excellent correlations between the tillage depth and tractor speed. This value designates that the response model (draft) for spring tine cultivator at the study location can describe 99.91 % of the variability of the responses.

For offset disc harrow, the probability value of 0.0001 (Table 11) of the model is less than the selected α-level of 0.05. This specifies that the selected model is significant. The probability values of 0.0001, 0.0001 and 0.0001 (Table 11) of the model expressions are smaller than the selected α-level of 0.05. This shows that the model expression is significant. In view of this, D_T, $S_T$and $D_T{}^2$ are the significant terms. This denotes that the tillage depth and tractor speed all have a significant effect on the draft for 3-bottom disc plough at the study location with tillage depth having the greater influence on the draft. It was pointed out that the model was significant with the coefficient of determination (R^2 = 0.9994). This value specifies that the model for the draft for offset disc harrow at the study location can explain 99.94 % of the variability of the responses.

Table 9. Analysis of Variance for response surface quadratic model for the draft for 3-bottom disc plough at the study location

Source of Variation	Sum of Squares	Df	Mean Square	F-Value	p-value
Model	9.02	5	1.80	2753.39	< 0.0001
D_T	8.88	1	8.88	13545.51	< 0.0001
S_T	0.0533	1	0.0533	81.40	< 0.0001
D_T x S_T	0.0009	1	0.0009	1.37	0.2795
$D_T{}^2$	0.0749	1	0.0749	114.33	< 0.0001
$S_T{}^2$	0.0019	1	0.0019	2.88	0.1336
Residual	0.0046	7	0.0007		
Lack of Fit	0.0043	3	0.0014	17.78	0.0089
Pure Error	0.0003	4	0.0001		
Cor Total	9.02	12			

Table 10. Analysis of Variance for response surface quadratic model for the draft for Spring tine cultivator at the study location

Source of Variation	Sum of squares	Df	Mean Square	F-Value	p-value
Model	0.1306	5	0.0261	1496.62	< 0.0001
D_T	0.1281	1	0.1281	7344.30	< 0.0001
S_T	0.0008	1	0.0008	47.76	0.0002
D_T x S_T	0.0000	1	0.0000	0.0000	1.0000
$D_T{}^2$	0.0013	1	0.0013	75.16	< 0.0001
$S_T{}^2$	0.0000	1	0.0000	1.85	0.2165
Residual	0.0001	7	0.0000		
Lack of Fit	0.0001	3	0.0000		
Pure Error	0.0000	4	0.0000		
Cor Total	0.1307	12			

Table 11**.** Analysis of Variance for response surface quadratic model for draft for offset Disc harrow at the study location

Source of Variation	Sum of squares	Df	Mean Square	F-Value	p-value
Model	6.70	5	1.34	2223.17	< 0.0001
D_T	6.59	1	6.59	10922.13	< 0.0001
S_T	0.0331	1	0.0331	54.85	0.0001
D_T x S_T	0.0002	1	0.0002	0.3731	0.5606
$D_T{}^2$	0.0726	1	0.0726	120.32	< 0.0001
$S_T{}^2$	0.0006	1	0.0006	0.9418	0.3641
Residual	0.0042	7	0.0006		
Lack of Fit	0.0041	3	0.0014	69.02	0.0007
Pure Error	0.0001	4	0.0000		
Cor Total	6.71	12			

[a]Significance; D_T represents tillage depth (cm); S_T represents tractor speed (km/h)

Model selection for the tillage operation using power requirement as the response at the study location

The comparison of the linear, 2FI, quadratic and cubic models for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location is presented in Tables 12, 13 and 14 respectively. Considering the model with the maximum R^2 value and the minimum standard deviation (with preference given to R^2), quadratic, linear and linear models were selected to predict the power requirement of tillage operation for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively. The final regression equations for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow are given in equations 4.31, 4.32 and 4.33 as:

$PR_{3-BDP} = 0.056 - 0.16D_T + 0.50S_T + 0.032D_TS_T + 0.0033{D_T}^2 - 0.047{S_T}^2$ $(R^2 = 0.9875)$……….. (7)

$PR_{STC} = -0.39 + 0.023D_T + 0.048S_T (R^2 = 0.8424)$……………………………………(8)

$PR_{ODH} = -2.60 + 0.17D_T + 0.34S_T \quad (R^2 = 0.8357)$ …………………………………(9)

Where:
PR_{3-BDP} = Power Requirement for 3-bottom disc plough, kW
PR_{STC} = Power Requirement for spring tine cultivator, kW
PR_{ODH} = Power Requirement for offset disc harrow, kW
D_T = Tillage Depth, cm
S_T = Tractor Speed, km/h

Table 12. Model comparison for power requirement for 3-bottom disc plough at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.3926	0.3667	0.2002	0.1719
R^2	0.9314	0.9461	0.9875	0.9934
Mean	3.97	3.97	3.97	3.97
Adjusted R^2	0.9176	0.9281	0.9786	0.9842
C.V.	9.89	9.24	5.05	4.33
Predicted R^2	0.8362	0.8454	0.9032	0.4123
PRESS	3.68	3.47	2.17	13.20
Adequate precision	21.76	20.63	34.21	34.41

Table 13. Model comparison for power requirement for spring tine cultivator at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.0683	0.0715	0.0717	0.0815
R^2	0.8424	0.8445	0.8783	0.8879
Mean	0.4169	0.4169	0.4169	0.4169
Adjusted R^2	0.8109	0.7927	0.7914	0.7309
C.V.	16.38	17.15	17.21	19.54
Predicted R^2	0.6716	0.4956	0.1405	-11.9822
PRESS	0.0972	0.1494	0.2545	3.84
Adequate precision	14.12	11.68	10.33	7.72

Table 14. Model comparison for power requirement for offset disc harrow at the study location

Models	Linear	2FI	Quadratic	Cubic
Std. Dev.	0.5139	0.5415	0.5447	0.6012
R^2	0.8357	0.8358	0.8708	0.8876
Mean	3.31	3.31	3.31	3.31
Adjusted R^2	0.8028	0.7811	0.7785	0.7302
C.V.	15.55	16.38	16.48	18.19
Predicted R^2	0.6540	0.4639	0.0650	-12.0195
PRESS	5.56	8.62	15.03	209.29
Adequate precision	13.92	11.44	10.01	7.77

Note: FI = Factorial Interaction; Std. Dev. = Standard deviation; C.V. = Coefficient of Variation; PRESS = Predicted Sum of Square.

The ANOVA for the selected models for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location is presented in Tables 15, 16, and 17 respectively.
For 3-bottom disc plough, the probability value of 0.0001 (Table 15) of the model is less than the selected α-level of 0.05. This implies that the selected model is significant. The probability values of 0.0001, 0.0001, 0.0239 and 0.0080 (Table D15) of the model terms are less than the selected α-level of 0.05.

This specifies that the model terms are significant. In line with this, D_T, S_T, $D_T \times S_T$, and ${S_T}^2$ are significant model terms. This indicates that tillage depth and tractor speed have significant influence on power requirement for 3-bottom disc plough at the study location with tillage depth having the more significant influence on the power requirement. It was established that the model was significant with an acceptable coefficient of determination ($R^2 = 0.9875$). The high coefficient of determination indicates that there is an excellent correlation between the tillage depth and tractor speed. This value shows that the model for power requirement for 3-bottom disc plough at the study location can explain 98.75 % of the total variability in the responses.

For spring tine cultivator, the probability value of 0.0042 (Table 16) of the model is less than the selected α-level of 0.05 and it implies that the chosen model is significant. The probability values of 0.0008 and 0.0043 (Table 16) of the model terms are less than the selected α-level of 0.05. This indicates that the model terms are significant. In view of this, D_T and S_T are the significant model terms. This indicates that the tillage depth and tractor speed have significant influence on power requirement for 3-bottom disc plough at the study location with tillage depth having the more significant influence on the power requirement. It was pointed out that the model was significant with the coefficient of determination ($R^2 = 0.8424$), which implies an excellent correlation between the tillage depth and tractor speed. This value shows that the model for power requirement for spring tine cultivator at the study location can describe 84.24 % of the variability of the responses.

For offset disc harrow, the probability value of 0.0001 (Table 17) of the model is less than the selected α-level of 0.05 and it shows that the selected model is significant. The probability values of 0.0002 and 0.0019 (Table 17) of the model terms are less than the selected α-level of 0.05. This specifies that the model terms are significant. In line with this, $D_T$and $S_T$are the significant model terms. This implies that the tillage depth and tractor speed have a significant influence on power requirement for offset disc harrow at the study location with tillage depth having the greater influence on the power requirement. It was also established that the model was significant with the coefficient of determination ($R^2 = 0.8357$). This value shows that the model for power requirement for offset disc harrow at the study location can explain 83.57 % of the variability of the responses.

Table 15. Analysis of Variance for response surface quadratic model for power requirement for 3-bottom disc plough at the study location

Source of Variation	Sum of squares	Df	Mean Square	F-Value	p-value
Model	22.17	5	4.43	110.64	< 0.0001
D_T	12.63	1	12.63	315.08	< 0.0001
S_T	8.28	1	8.28	206.68	< 0.0001
D_T x S_T	0.3306	1	0.3306	8.25	0.0239
$D_T{}^2$	0.1522	1	0.1522	3.80	0.0923
$S_T{}^2$	0.5398	1	0.5398	13.47	0.0080
Residual	0.2806	7	0.0401		
Lack of Fit	0.2460	3	0.0820	9.48	0.0273
Pure Error	0.0346	4	0.0087		
Cor Total	22.45	12			

Table 16. Analysis of Variance for response surface linear model for power requirement for Spring tine cultivator at the study location

Source of Variation	Sum of squares	Df	Mean Square	F-Value	p-value
Model	0.2494	2	0.1247	26.73	< 0.0001
D_T	0.1610	1	0.1610	34.51	0.0002
S_T	0.0884	1	0.0884	18.95	0.0014
Residual	0.0467	10	0.0047		
Lack of Fit	0.0465	6	0.0078	258.56	< 0.0001
Pure Error	0.0001	4	0.0000		
Cor Total	0.2961	12			

Table 17. Analysis of Variance for response surface linear model for power requirement for Offset disc harrow at the study location

Source of Variation	Sum of squares	Df	Mean Square	F-Value	p-value
Model	13.43	2	6.72	25.43	0.0001
D_T	8.86	1	8.86	33.54	0.0002
D_T	4.58	1	4.58	17.32	0.0019
Residual	2.64	10	0.2641		
Lack of Fit	2.64	6	0.4392	296.77	< 0.0001
Pure Error	0.0059	4	0.0015		
Cor Total	16.07	12			

[a]Significance; D_T represents tillage depth (cm); S_T represents tractor speed (km/h)

Validation of a model for tillage operations for the draft at the study location

A test run under the obtained optimal tillage operating parameters for draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location was carried out in order to evaluate the precision of the quadratic, quadratic and quadratic models for draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively. A reasonable agreement between the observed and predicted values for the draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow was obtained from the parity plot among the predicted and the actual values (Figures 1, 2, and 3). There is a high link (R^2 = 0.9995; 0.9991; and 0.9994 for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively) between the projected and experimental values for draft which specified that the expected values and experimental values are in satisfactory agreement which means that the data fixed well with the model and contributed to the reasonable evaluation of response for the tillage operation in the range of tillage operating parameters studied.

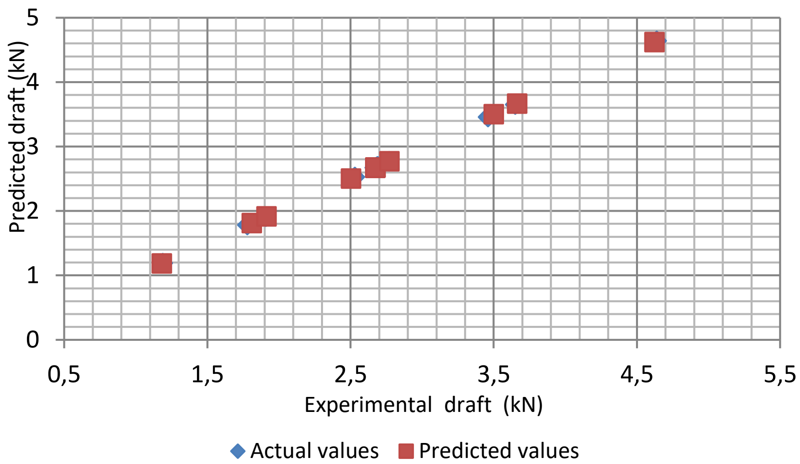

Figure 1. Predicted and actual values for draft (kN) for 3-bottom disc plough (3-BDP) at the study location

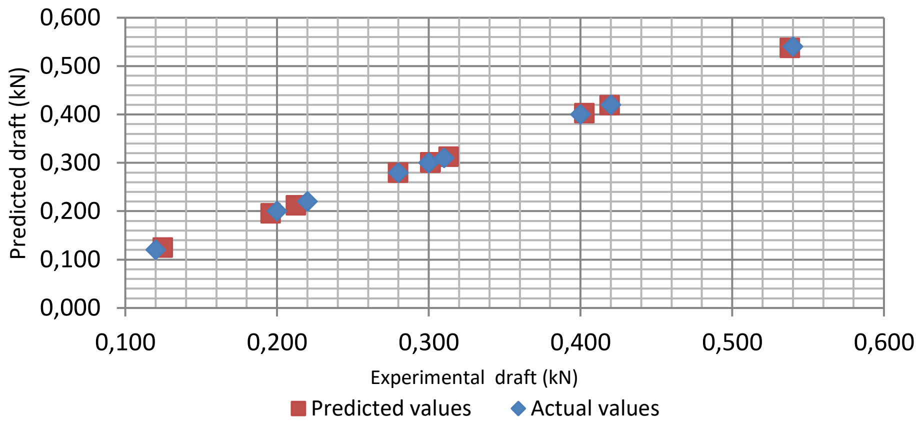

Figure 2. Predicted and actual values for draft (kN) for Spring tine cultivator (STC) at study location

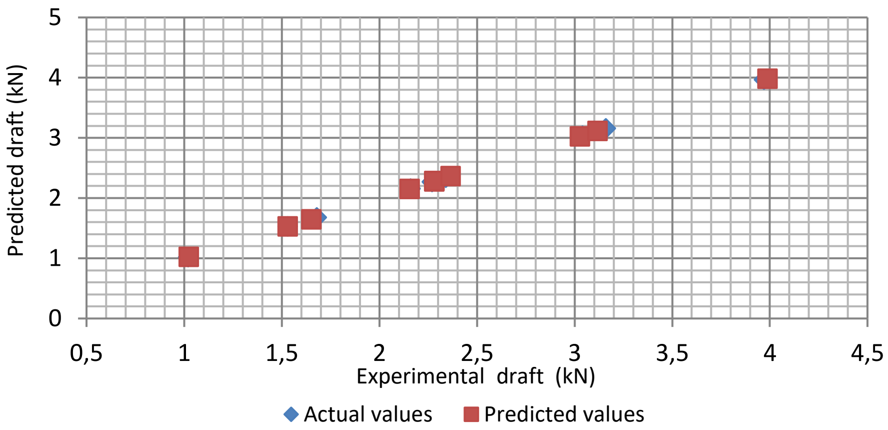

Figure 3. Predicted and actual values for draft (kN) for Offset disc harrow (ODH) at the study location

Comparing the experimental and predicted results (Table 20, 21 and 22) for the optimum draft for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location. It was observed that the deviations between the experimental and predicted values of the draft were low and ranged between 0.01 to 0.10 for 3-bottom disc plough, 0.01 to 0.10 for spring tine cultivator, and 0.01 to 0.10 for offset disc harrow, respectively.

This indicate that the predicted and the experimental values are in close agreement and the generated model can be used satisfactory to predict the draft (kN) for the tillage operation.

Table 20. Experimental, Predicted, Residual, and Standard residual Values of draft for 3-bottom disc plough (3-BDP) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	1.1900	1.1835	0.0065	0.55
2	15	5.4	1.7800	1.8113	-0.0313	-1.72
3	15	9.0	1.9100	1.9146	-0.0046	-0.25
4	20	3.6	2.5300	2.5052	0.0248	2.12
5	20	7.2	2.6900	2.6748	0.0152	0.65
6	20	7.2	2.6700	2.6748	-0.0048	-0.21
7	20	7.2	2.6900	2.6748	0.0152	0.65
8	20	7.2	2.6900	2.6748	0.0152	0.65
9	20	7.2	2.6800	2.6748	0.0052	0.22
10	20	10.8	2.7700	2.7719	-0.0019	-0.16
11	25	5.4	3.4600	3.5013	-0.0413	-2.27
12	25	9.0	3.6500	3.6646	-0.0146	-0.80
13	30	7.2	4.6400	4.6235	0.0165	1.40

Table 21. Experimental, Predicted, Residual, and Standard residual Values of draft for Spring tine cultivator (STC) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	0.12000	0.12463	-0.00463	-2.42
2	15	5.4	0.20000	0.19575	0.00425	1.43
3	15	9.0	0.22000	0.21241	0.00759	2.55
4	20	3.6	0.28000	0.27963	0.00037	0.20
5	20	7.2	0.30000	0.30103	-0.00103	-0.27
6	20	7.2	0.30000	0.30103	-0.00103	-0.27
7	20	7.2	0.30000	0.30103	-0.00103	-0.27
8	20	7.2	0.30000	0.30103	-0.00103	-0.27
9	20	7.2	0.30000	0.30103	-0.00103	-0.27
10	20	10.8	0.31000	0.31296	-0.00296	-1.55
11	25	5.4	0.40000	0.40241	-0.00241	-0.81
12	25	9.0	0.42000	0.41908	0.00092	0.31
13	30	7.2	0.54000	0.53796	0.00204	1.07

Table 22. Experimental, Predicted, Residual, and Standard residual Values of draft for Offset disc harrow (ODH) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	1.0200	1.0238	-0.0038	-0.33
2	15	5.4	1.5300	1.5308	-0.0008	-0.05
3	15	9.0	1.6800	1.6508	0.0292	1.67
4	20	3.6	2.1600	2.1554	0.0046	0.41
5	20	7.2	2.2700	2.2803	-0.0103	-0.46
6	20	7.2	2.2700	2.2803	-0.0103	-0.46
7	20	7.2	2.2800	2.2803	-0.0003	-0.02
8	20	7.2	2.2700	2.2803	-0.0103	-0.46
9	20	7.2	2.2700	2.2803	-0.0103	-0.46
10	20	10.8	2.3400	2.3654	-0.0254	-2.26
11	25	5.4	3.0400	3.0275	0.0125	0.72
12	25	9.0	3.1600	3.1175	0.0425	2.44
13	30	7.2	3.9700	3.9871	-0.0171	-1.52

Validation of a model for tillage operations for power requirement at the study location

A test run under the obtained optimal tillage operating parameters for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location was carried out in order to evaluate the precision of the quadratic, linear and linear models for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively. A reasonable agreement between the observed and predicted values for power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow was found from the parity plot among the predicted and the actual values (Figures 4, 5 and 6).

There is a high connection (R^2 = 0.9875; 0.8424; and 0.8357 for 3-bottom disc plough, spring tine cultivator and offset disc harrow respectively) among the projected and experimental values for power requirement which indicated that the predicted values and experimental values agreed satisfactorily which shows that the data fixed well with the model and gave a reasonable estimate of response for the tillage operation in the range of tillage operating parameters studied.

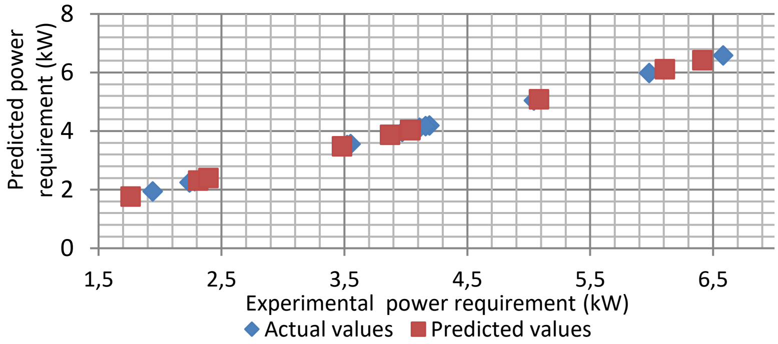

Figure 4. Predicted and actual values for power requirement (kW) for 3-bottom disc plough (3-BDP) at the study location

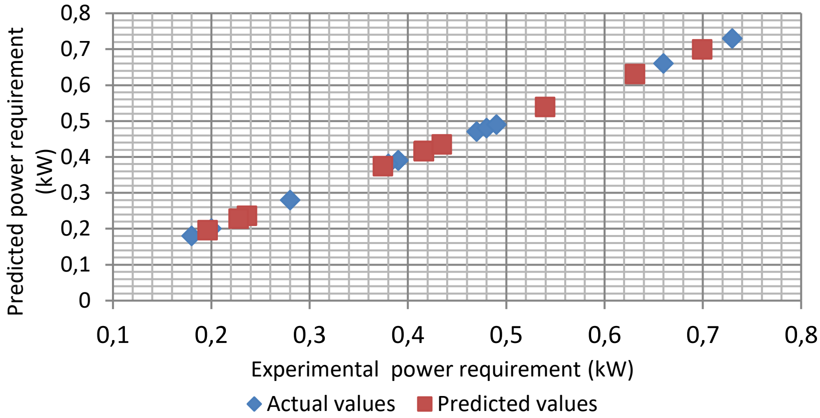

Figure 6. Predicted and actual values for power requirement (kW)
for Offset disc harrow (ODH) at the study location

Comparing the experimental and predicted results (Table 23, 24 and 25) for the optimum power requirement for 3-bottom disc plough, spring tine cultivator and offset disc harrow at the study location. It was observed that the deviations between the experimental and predicted values of the draft were low and ranged between 0.01 to 0.12 for 3-bottom disc plough, 0.01 to 0.08 for spring tine cultivator, and 0.01 to 0.44 for offset disc harrow, respectively. This indicate that the predicted and the experimental values are in close agreement and the generated model can be used satisfactory to predict the power requirement (kW) for the tillage operation.

Table 23. Experimental, Predicted, Residual, and Standard residual Values of power requirement for 3-bottom disc plough (3-BDP) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	2.280	2.309	-0.029	-0.31
2	15	5.4	2.240	2.393	-0.153	-1.07
3	15	9.0	3.550	3.480	0.070	0.49
4	20	3.6	1.940	1.759	0.181	1.98
5	20	7.2	4.190	4.034	0.156	0.86
6	20	7.2	3.970	4.034	-0.064	-0.35
7	20	7.2	4.110	4.034	0.076	0.42
8	20	7.2	4.160	4.034	0.126	0.69
9	20	7.2	4.020	4.034	-0.014	-0.08
10	20	10.8	5.040	5.082	-0.042	-0.46
11	25	5.4	3.520	3.870	-0.350	-2.46
12	25	9.0	5.980	6.106	-0.126	-0.89
13	30	7.2	6.580	6.412	0.168	1.83

Table 24. Experimental, Predicted, Residual, and Standard residual Values of power requirement for spring tine cultivator (STC) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	0.2000	0.2361	-0.0361	-1.10
2	15	5.4	0.2800	0.2278	0.0522	1.02
3	15	9.0	0.4700	0.3745	0.0955	1.87
4	20	3.6	0.1800	0.1961	-0.0161	-0.49
5	20	7.2	0.3900	0.4162	-0.0262	-0.40
6	20	7.2	0.3800	0.4162	-0.0362	-0.55
7	20	7.2	0.3900	0.4162	-0.0262	-0.40
8	20	7.2	0.3900	0.4162	-0.0262	-0.40
9	20	7.2	0.3800	0.4162	-0.0362	-0.55
10	20	10.8	0.4800	0.5394	-0.0594	-1.81
11	25	5.4	0.4900	0.4345	0.0555	1.09
12	25	9.0	0.7300	0.6311	0.0989	1.94
13	30	7.2	0.6600	0.6994	-0.0394	-1.20

Table 25. Experimental, Predicted, Residual, and Standard residual Values of power requirement for offset disc harrow (ODH) at the study location

S/N	D_T (cm)	S_T (km/hr)	Experimental values	Predicted values	Residual values	Standard Residual
1	10	7.2	1.880	1.960	-0.080	-0.32
2	15	5.4	2.090	1.806	0.284	0.73
3	15	9.0	3.520	3.086	0.434	1.12
4	20	3.6	1.490	1.694	-0.204	-0.82
5	20	7.2	3.100	3.307	-0.207	-0.42
6	20	7.2	3.060	3.307	-0.247	-0.50
7	20	7.2	3.140	3.307	-0.167	-0.34
8	20	7.2	3.040	3.307	-0.267	-0.54
9	20	7.2	3.080	3.307	-0.227	-0.46
10	20	10.8	3.810	4.164	-0.354	-1.42
11	25	5.4	4.250	3.569	0.681	1.76
12	25	9.0	5.590	4.759	0.831	2.14
13	30	7.2	4.920	5.397	-0.477	-1.91

CONCLUSION

Model equations were generated with a satisfactory high coefficient of determination (R^2) for the two factors and responses on clay loam soil. The high coefficient of determination of the responses showed excellent correlation between tillage depth and tractor speed which would make the models suitable for predictive purposes on a clay loam type of soil.

The Analysis of Variance (ANOVA) for the selected models for all the implements showed that the models chosen are significant.

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MODELIRANJE OPERATIVNIH PARAMETARA OBRADE ZA PLAN POTREBNE SNAGE ZA TRI RADNA TELA U OBRADI ILOVASTOG ZEMLJIŠTA

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Sažetak: Obrada zemljišta oranjem je osnovna operacija u poljoprivredi gde energetske potrebe predstavljaju značajan deo potrošene energije koja se koristi u biljnoj proizvodnji.

Probe su izvedene korišćenjem pet brzina kretanja traktora (3,6; 5,4; 7,20 9,0 i 10,8 km/h) i pet dubina obrade zemljišta (10, 15, 20, 25 i 30 cm) da bi se odredila optimalna brzina kretanja traktora sa različitim priključkom i dubinama obrade zemljišta za: diskosni plug (3 radna tela-diska), kultivator sa opružnim motičicama i teška tanjirača.

Zemljište prema mehaničkom sastavu je pretežno ilovastog mehaničkog sastava. Dizajn eksperimenta ima dva faktora: faktorsku analiza sa pet nivoa, i metodu određene površine (CCRD). Odabrani modeli su analizirani korišćenjem testa ANOVA sa 0,05 i takođe su validirani.

Visoke vrednosti koeficijenta determinacije za sve odabrane modele i određeno slaganje između predviđenih i stvarnih vrednosti dubine rada i potrebne snage traktora za sve testirane priključne mašine, pokazuju da se generisane jednačine modela mogu koristiti u svrhe predviđanja plana potrebne snage vučne mašine (traktora) za određene priključne mašine.

Ključne reči: *Plan, potrebna snaga, obrada, glinovito zemljište, modeliranje*

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DETERMINANTS OF MOBILE PHONES USAGE FOR AGRICULTURAL PURPOSES AMONG ARABLE CROP FARMERS IN IWO ZONE OF OSUN STATE, NIGERIA

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Abstract: This study examined the socio-economic factors underlining arable crop famers' use of mobile phones for agricultural-related purposes in Iwo Agricultural Development Program (ADP) Zone of Osun State. Multistage sampling procedure was used to select 150 arable crop farmers from whom primary data were collected with structured interview schedule. Data obtained was analyzed using descriptive statistics and ordinary least square regression analysis. Findings from this study revealed that most frequently used applications include voice call (99.3%), calendar (96.7%), calculator (96%) and torch light (95.3%). Most of the farmers strongly consented that mobile phones facilitated timely access to needed services ($\bar{X}$ = 4.74), eased production decision making ($\bar{X}$ = 4.54), enhanced increased income and profit ($\bar{X}$ = 4.50) and accessing personalized information about new farming techniques ($\bar{X}$ = 4.44). Major constraints identified for limiting the usage of phones for agricultural purposes were poor internet access ($\bar{X}$ = 3.73), inadequate electricity to charge t he mobile phone ($\bar{X}$ = 3.55), poor network access ($\bar{X}$ = 3.54) and high charges on services ($\bar{X}$ = 3.41). Gender (β= 4.337; P< .01), level of education (β= 16.358; P< .01), years of farming (β= 0.513; P<.05), information sources (β= 0.645; P<.01) all jointly had positive influence on farmers' use of mobile phones for agricultural information. It was recommended that higher capacity of female and arable crop farmers with lower level of education should be energized to utilize their mobile phones for enhancing their production activities.

Keywords: *Determinants, mobile, communication, agricultural information, farming*

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INTRODUCTION

Information and Communication Technologies (ICT) particularly the use of mobile phones have immensely penetrated every field of life like education, business, commerce, and agriculture [1]. Mobile phone-based communication has rapidly grown in the recent past and became the most used communication tool among all ICTs of the current age. Recent statistics showed that 62.9 percent of the global population already owns a mobile phone with 4.68 billion users on the planet [2]. As such, mobile phones now represent one of the most exciting forms of ICTs particularly in the context of developing nations. The use has opportune speeding up ways in which people get, exchange, and or manipulate information. Specifically, [3] posited that mobile phones have enabled farmers to focus and extract useful and up-to-date information from social and business networks. However, the exploration of other features is still largely limited among rural dwellers, where in the use for making voice calls remains the principal function owing to widespread rural illiteracy and the fact that the calling price system is believed to give more value for money than other features [4], [5].

The exact number of mobile phone users in Nigeria is hard to pin down, currently; estimates from different sources put the number of smartphone users in Nigeria at roughly 25-40 million and its forecasted to grow to more than 140 million by 2025 [2]. There is evidence that rural incomes have been increasing with the use of ICTs to access information [6]. However, there are challenges in making ICT platforms available to a large number of the rural population who are engaged in agriculture and these have to be tackled through public policy in the context of rural development and incentives for investments in rural areas [7]. As such, there is no solely accepted model which is the most effective in access of agricultural information. Fortunately Africa is witnessing a phenomenal increase in mobile phone acquisitions and when they are combined with other ICT platforms like radio the impact on agriculture can be very high [7]. While access to various mobile networks is increasing, it is not yet certain how rural farmers' agricultural activities are aided with mobile phones usage. More so, there is dearth of empirical evidence on the possible effects of the variations in their socio-economic attributes on the usage of the applications for their agricultural activities. In view of these, this study aimed at evaluating the influence of socio-economic factors on arable crop farmers' use of mobile phones in Iwo Agricultural Development Project (ADP) Zone of Osun State. The specific objectives of the study were to

I determine farmers level of usage of mobile phone applications in their agricultural activities,

II examine the benefits derived by farmers from the usage of phone applications for their agricultural activities,

III analyze the socio-economic factors influencing arable crop farmers' use of mobile phones for agricultural information, and

IV assess the constraints facing farmers on use of their mobile phones for agricultural purposes.

MATERIAL AND METHODS

Study Area: This study was carried out in Iwo zone of Osun State, Nigeria. The area is one of the three (3) Agricultural Development Project (ADP) zones namely, Osogbo, Iwo and Ife/ Ijesha in the state. Iwo zone covers an area of 245 km^2 and has a population of 191,348 people (National Population Commision (NPC), 2006). There are seven Local Government Areas (LGAs) in the zone namely; Iwo, Irewole, Ejigbo, Ayedire, Ayedaade, Isokan and Ola-Oluwa. The people are primarily of Yoruba descent and their major economic activity revolves round agriculture

Source and type of data: Primary data were used for this study. The primary data were obtained with the aid of well-structured questionnaire and unstructured interview. The questionnaire was structured to capture data on socio-economic variables, farmers' use of mobile phone applications in agricultural activities, information on phone applications used in agricultural activities, agricultural benefit of using mobile phone applications, and the constraints that hinder the use of mobile phones by the farmers in the study area.

Sampling techniques and data collection: Multi-stage sampling procedure was used in selecting farmers for this study. The first stage involved purposive selection of three (3) Local Government Areas (LGAs) with highest record of arable crop production from ADP office. Thereafter, five (5) communities were randomly selected from each of the LGAs to make fifteen (15) communities. An average of ten (10) respondents was chosen randomly from each of the fifteen (15) communities to make a total of one hundred and fifty (150) arable crop farmers sampled for the study.

Analytical techniques and models: The study employed analytical tools based on the stated objectives. They include descriptive statistics, inferential statistics, and ordinary least square regression. The descriptive statistics tools used were mean, standard deviation, frequency counts and percentages which were applied to describe socio-economic characteristics of the farmers. Two-sample t-test as an dinferential statistics tools was used to test the stated hypothesis while ordinary least squares multiple regression model was applied to establish the factors influencing arable crop farmers' use of mobile phones for agricultural information.

Ordinary least squares multiple regression model: The perceived effect of poverty and their determinants were fitted into four functional forms. These models were explicitly specified as follows;

Linear function:

$$Y = f\,(b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5\,x_5 + b_6x_6 + b_7x_7 + b_8\,x_8 + e) \quad (1)$$

Exponential function:

$$LnY = f\,(b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5\,x_5 + b_6x_6 + b_7x_7 + b_8\,x_8 + e) \quad (2)$$

Semi – log function:

$$Y = f(b_0 + b_1 lnx_1 + b_2 lnx_2 + b_3 lnx_3 + \ldots\ldots + b_5 lnx_5 + b_6 lnx_6 + b_7 lnx_7 + b_8 lnx_8 + e) \quad (3)$$

Double-log function:

$$LnY = f(b_0 + b_1 lnx_1 + b_2 lnx_2 + b_3 lnx_3 + \ldots\ldots + b_6 lnx_6 + b_7 lnx_7 + b_8 lnx_8 + e) \quad \ldots(4)$$

Where Y = Total score of phone applications used in agricultural activities.

X_1= Age of the arable crop farmers in years

X_2 = Gender (dummy = 1 if male, 0 = if otherwise)

X_3 = Level of education (No formal Education = 0, Primary School attempted = 2, Primary School completed = 3, Secondary School attempted = 4, secondary School completed = 5, tertiary School = 6)

X_4 = Household size from nominal value of member of the household

X_5 = Years of residence in years

X_6 = Farming experience in years

X_7 = Social capital in total scores of participation in social organization

X_8 = Information sources measured as total number of sources used in receiving information on arable crop farming

b_1 – b_8 are the co-efficient parameters to be estimated

e = stochastic error variable

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Crop Farmers

Table 1 shows the average age of the respondents as 49.98± 9.577 years, with majority been male (76.7%), and mostly married (90.7%). This distribution indicates that majority of the farmers in the study area were still in their middle ages and can be able to adopt the use of mobile phones easily. with average number of years spent in school more than 6, by implication these suggested that majority of the farmers in Nigeria may not have passed through a tertiary school education to attain a high qualification, but have an educational background and as such are literate enough to make use of a mobile phone. The table also revealed the farming experience (4.72 years ± 10.213) in years, with household size of 5.

Table 1. Socioeconomics characteristics of crop farmers (Source: Field Survey Data, 2020.)

Variables	Frequency	Percentage (%)	Mean ±SD
Age			
20 – 39	23	15.3	
40 – 59	94	62.7	49.98± 9.577
60 – 79	33	22.0	
Gender			
Male	115	76.7	
Female	35	23.4	
Marital Status			
Single	3	2.0	
Married	136	90.7	
Divorced	5	3.3	
Widowed	6	4.0	
Education Level			
No Formal Education	7	4.7	
Primary school	13	8.7	
SSCE/GCE	58	38.6	
Diploma/NCE	12	8.0	
HND/B.Sc.	53	35.3	
M.Sc.	6	4.0	
Ph.D.	1	0.7	
Farming Experience (years)			
1 – 10	71	47.3	
11 – 20	35	23.3	4.72 years ± 10.213
21 – 30	39	26.0	
>30	5	3.3	
Household Size (persons)			
1 – 4	75	50.0	
5 – 8	75	50.0	
Farm size (Ha)			
0 – 4	80	53.3	
5 – 9	64	42.7	
10 – 14	4	2.7	15.27 years ± 2.652
>14	2	1.3	
Land Acquisition			
Owner	144	96.0	
Leased	6	4.0	

Farmers' uses of mobile phone in agricultural activities

Farmers' uses of mobile phone in agricultural activities are presented in Table 2. The results show that the applications used daily by most farmers phones were that of voice call (99.3%), calendar (96.7%), calculator (96%), torch light (95.3%), WhatsApp (68%) and Facebook (67%). These applications were found to be used virtually every day by most of the farmers and as such they could be pin-pointed as the main phone applications frequently employed for facilitating farmers agricultural activities. Substantial use of radio, browsers and camera were also indicated as used daily by 48.7%, 33.3% and 22.8% of farmers. On the hand, multi-media messaging and other social media applications including 2go, Instagram and twitter were indicated as grossly unused by the farmers. The findings of this study agrees with [8] who discovered that making phone calls ranked highest in the use of phone by the farmers in Nigeria.

Table 2. Distribution of Farmers' uses of mobile phone in agricultural activities

Ser.No	Phone Applications used in agricultural activities	Frequency of use in agricultural activities					
		Daily (%)	Weekly (%)	Forthrightly (%)	Monthly (%)	Not at all (%)	Rank
1	Short Message Service (SMS)	8	3.3	0.7	34.7	53.3	10th
2	Voice call	99.3	0.67				1st
3	Multi Media Message (MMS)					100	
4	Browsing and Surfing	33.3	2			63.7	7th
5	Radio	48.7	1.3	4.7	1.3	44	6th
6	Voice recording	18.67	1.3	0.7	4	75.3	9th
7	Camera	22.8	9.4		3.4	64.4	8th
8	Calendar	96.7	0.7			2.7	2nd
9	Calculator	96	0.7			2.7	2nd
10	Torchlight	95.3		4.7			3rd
11	Alarm/reminder	8.7	2	0.7	16	72.7	11th
13	Google app for downloading other apps.	0.7	1.3		16	82	14th
14	Games	2	0.7	1.33	4	92.6	13th
15	Music	6	1.3		6.7	86	12th
16 A B C D E F F	Social apps. WhatsApp Facebook Instagram 2go Twitter Telegram	 68 67.3 67. 3				 32 32.7 100 100 100 100 100	 4th 5th
17	Google map	0.7			1.3	98	15th

Source: Field Survey Data, 2020.

Agricultural benefits of using Mobile Phone applications

Results in Table 3 shows the farmers' mean ratings of the agricultural benefits of mobile phone usage. The results show that most of the farmers strongly consented that mobile phones facilitated timely access to needed services ($\bar{X}$ = 4.74), eased production decision making ($\bar{X}$ = 4.54), enhanced increased income and profit ($\bar{X}$ = 4.50) and accessing personalized information about new farming techniques ($\bar{X}$ = 4.44). These benefits ranked 1st, 2nd, 3rd and 4th respectively among the agricultural benefits derived by farmers for using mobile phones. Other benefits include; gaining access to weather forecast information ($\bar{X}$ = 4.38), improving farm productivity ($\bar{X}$ = 4.37), access to updated price information ($\bar{X}$ = 4.35), increasing connectivity with other stakeholders ($\bar{X}$ = 4.35), reducing travel hours and costs ($\bar{X}$ = 4.35), facilitating local market chains ($\bar{X}$ = 4.34), making procurement of agricultural input easy ($\bar{X}$ = 4.31), improving supply management ($\bar{X}$ = 4.31), enable giving real time feedback of agricultural activities ($\bar{X}$ = 4.31), improving management of agricultural resources ($\bar{X}$ = 4.30), saves money, energy and time ($\bar{X}$ = 4.11).

These results confirmed that farmer's use of phones facilitated their timely access to inputs, market information and enabled better management of their production activities and thereby greater productivity. Undoubtedly, time saving and cost reduction potentials of phones use in farm production logistics are of innumerable importance in agribusiness management. This is because arable crops production is extremely time-sensitive, thus the farmers who use mobile phones would be better off in operating their farm activities and empowered to guard against products perishability and spoilage in the marketing process. Overall, these confirm that attested to the beneficial importance of phones use for agricultural activities and business.

Table 3. Mean scores of farmer's benefits of owning mobile phones in the study area

Benefits	Mean ($\bar{X}$)	Standard Deviation (SD)	Rank
Facilitate timely access to needed es Services	4.74	0.44	1st
Make production decision making Easy	4.54	0.526	2nd
Enhanced increased Income and profit	4.50	0.515	3rd
Getting personal Information about new farming techniques	4.44	0.66	4th
Gaining access to Weather Forecast information	4.38	0.739	5th
Improves Farm Productivity	4.37	0.689	6th
Gives access to updated information on market price	4.35	0.645	7th
Enabling e connectivity with consumers and Traders	4.35	0.533	8th
Reduce need for travel and Costs	4.35	0.604	9th
Facilitate Local Market Chains	4.34	0.674	10th
Make Procurement of Agricultural inputs Easy	4.31	0.634	11th
Enable improved Supply Management	4.31	0.615	12th

Continued Tab.3.			
Enable giving real-Time Feedback on Agricultural Activities	4.31	0.677	13th
Improve Management of Agricultural Resources	4.3	0.621	14th
Save Money, Energy and Time	4.11	0.77	15th
use for Entertainment	3.27	0.962	16th

Source: Field Survey Data, 2020.

Factors influencing arable crop farmers' use of mobile phones for agricultural information

Table 4 presented the result of the regression analysis on the factors influencing arable crop farmers' use of mobile phones for agricultural information. The coefficient of multiple determination (R^2) shows that 66.0% of the variation in arable crop farmers' use of mobile phones is been explained by the included independent variables in the model. The coefficient of R^2 and F statistics which is significant at $p < 0.01$ shows that the exponential model is well fitted. The results in Table 5 show that age of the arable crop farmers, gender, level of education, years of farming, and information sources were the factors influencing arable crop farmers' use of mobile phones for agricultural information in the study area.

There is a positive relationship between the coefficient of gender and the arable crop farmers' use of mobile phones for agricultural information and the variable was statistically significant at 1% level of significance. This result implies that for every unit increase in male, we expect a 4.337 units increase in the use of mobile phones by the arable crop farmers with a predicted score of 4 points higher in males than females. This result reveals that male arable crop farmers make use of their phones for agricultural purposes than the females. This finding is similar to the viewpoint of [9] that confirmed a significant categorical relationship between the gender of respondents and their intention to use mobile phones in agriculture.

The results in Table 5 reveal that level of education has a positive and significant relationship with farmers' use of mobile phones for agricultural information at $p < 0.01$ critical level. This indicates that a year increase in the year of tertiary education will increase the arable crop farmers' use of mobile by 16.358 units with a predicted score of 16 points higher in tertiary education than other levels of education. This result is expected as higher level of education tends to enhances farmers' inquisitiveness to explore phone in sourcing information on modern techniques of crop farming and marketing. However, this result contradicts with findings of [8] that posited that educational qualification does not significantly contribute to the prediction of farmers' use of mobile phones for agricultural information in Nigeria.

The coefficient of years of farming experience was positive and statistically significant at 5% level of significance. This implies that a unit increase in the years of farming experience tends to increase the arable crop farmers' use of mobile by 0.513 units. This result disagrees with the similar study of [8] that confirmed that years of farming experience was not a significant factor determining the farmers' use of mobile phones for agricultural information in Nigeria.

Sources of receiving information on arable crop farming show a positive relationship with farmers' use of mobile phones for agricultural information and statistically significant at $p < 0.01$ critical level.

It implies that a unit increase in the sources of receiving information on arable crop farming will increase the arable crop farmers' use of mobile phones by 0.645 units. This result reveals that a farmer that has more sources of receiving information on arable crop farming tends to use mobile phone to access information more than the farmer that has few sources of information.

Table 4. Mean scores of constraints that hinder the use of Mobile Phones in the study area

Constraints	Mean ($\bar{X}$)	Standard Deviation (SD)	Rank
Problem in understanding phone features	2.61*	0.940	7th
Limited skill to the use of phone	3.23*	0.991	5th
Inadequate electricity for charging of phone	3.55*	0.764	2nd
Non-availability of helpline	2.55*	0.691	9th
Inadequate money for phone recharge/ data purchase	2.43	0.572	11th
High Charges on services	3.41*	0.956	4th
Poor Network connection	3.54*	0.841	3rd
Poor Internet Access	3.73*	0.853	1st
High cost of repair of faulty phone	2.85*	0.918	6th
Non-availability of Phone repairer in this vicinity	2.55*	0.765	8th
accessibility of recharge voucher	2.46	0.765	10th
Unavailability of phone accessories	2.11	0.608	13th
Inability to Read and Write (Illiteracy)	2.45	1.020	12th

* Serious Constraints

Source: Field survey Data, 2020.

CONCLUSION AND RECOMMENDATION

This study affirmed arable crop farmer's deployment of mobile phones for facilitating agricultural activities. It was shown that voice call, calendar, calculator torchlight and radio were the most frequently used in the course of agricultural activities. The findings revealed that farmer's use of phones facilitated timely access to inputs, market information and enabled better management of their production activities and thereby greater productivity. Furthermore, socio-economic characteristics including gender, education, farming experience and number of information source explored by the farmers are key determinants of farmer's use of the phones for agricultural purposes. As such, the male farmers were flagged with higher tendency to deploy phones usage for agricultural purpose just as farmers with tertiary education excelled others accordingly.

Higher farming experience was found to stipulate increased use of phones for enhancing the production processes just as the multiplicity of information sources explored by farmers attracted greater phone usage for the agricultural processes.

The factors influencing arable crop farmers' use of mobile phones for agricultural information in the study area include age of the arable crop farmers, gender, level of education, years of farming, and information sources. In spite of the efficacy of mobile phone use for agribusiness, farmers will always be frustrated and eventually underutilize the technology especially when necessary infrastructure and enabling environment are lacking. Therefore, government and other stakeholders should provide adequate infrastructural facilities, especially electricity also internet providers should make available to farmers low tariff and internet access availability. As such, it was concluded that arable crop farmer's exploration of mobile phones for facilitating their agricultural productivity is substantially underlined by the gender, education level, year of experience as well as number of sources accessed for agricultural information reception. Given this, it was recommended that higher capacity of female and arable crop farmers with lower level of education should be energized to utilize their mobile phones for enhancing their production activities. Also, rural telephone expansion with quality of service is needed in Nigeria by the government and telephone service providers. Also, policy focus should be geared towards low tariff plans for farmers, stable electricity in the rural areas, and training on the use of mobile phone features.

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DETERMINANTE KORIŠĆENJA MOBILNIH TELEFONA ZA POLJOPRIVREDNE NAMENE KOD FARMERA U IWO ZONI DRŽAVE OSUN, NIGERIJA

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Sažetak: Ova studija je ispitala socio-ekonomske faktore koji naglašavaju upotrebu mobilnih telefona kod farmera proizvođača ratarskih kultura za poljoprivredne svrhe u zoni Programa poljoprivrednog razvoja oblasti Iwo (ADP) u državi Osun, Nigerija. Višestepena procedura uzorkovanja je korišćena za odabranih 150 farmera-ratara kod kojih su prikupljeni primarni podaci sa strukturnim rasporedom intervjua. Dobijeni podaci su analizirani korišćenjem deskriptivne statistike i regresione analize najmanjeg kvadrata. Nalazi ove studije su pokazali da najčešće upotrebljene aplikacije uključuju: pozive glasom (99,3%), kalendar (96,7%), kalkulator (96%) i svetlo sa mobilnog telefona (95,3%). Većina farmera se jednoglasno složila da su mobilni telefoni olakšali: blagovremeni pristup potrebnim uslugama ($\bar{X}$=4.74), lakše donošenje odluka o proizvodnji ($\bar{X}$=4.54), povećali prihod i profit ($\bar{X}$=4.50), poboljšali pristup personalizovanim informacijama o novitetima poljoprivredne tehnike ($\bar{X}$=4.44).

Glavna ograničenja identifikovana kod upotrebe mobilnih telefona u poljoprivredi bili su: loš kvalitet pristupa internetu ($\bar{X}$=3.73), neadekvatna/nepristupačna električna energija za punjenje mobilnog telefona ($\bar{X}$ = 3.55), loš pristup mreži ($\bar{X}$ = 3.54) i visoka naplata usluga mobilnih operatera ($\bar{X}$ = 3.41). Ispitani su i pol farmera (β= 4.337; P< .01), stepen obrazovanja (β= 16.358; P< .01), godine bavljenja poljoprivrednom proizvodnjom ili iskustvo (β= 0.513; P<.05), izvori informacija (β= 0.645; P<.01).

Svi navedeni parametri su zajedno uticali pozitivno na upotrebu mobilnih telefona za poljoprivredne informacije kod farmera.

Preporuka istraživanja je da se podstakne viši stepen korišćenja mobilnih telefona kod farmera sa nižim stepenom obrazovanja u procesu unapređenja poljoprivrednih aktivnosti.

Ključne reči: *Determinante, mobilni, komunikacija, poljoprivredne informacije, poljoprivreda*

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EFFECT OF SOLAR DRYING ON PROXIMATE COMPOSITION OF TWO VARIETIES OF GINGER RHIZOMES FOR BLANCHED AND UNBLANCHED TREATMENTS

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Abstract: Ginger (*Zingiber officinale Roscoe*) of two verities UG I ('Tafin-Giwa', a yellowish variety with plump rhizomes) and UG II ('Yatsun-Biri', a black or dark variety with small compact rhizomes), were analysed to identify its proximate composition. The effects of drying as a processing technique on ginger were investigated with respect to the proximate composition of the produce. The UG I and UG II were collected, sorted (whole, peeled and unpeeled) and (slice, peeled and unpeeled), and were subjected to Unblanched and Blanched (50℃ at 3,6 and 9 min respectively) treatments and dried using solar dryer for a period of one month. The initial moisture content of UG I and UG II were 71.12% and 72.47% respectively, the final moisture content were reduced to 7.02% SUP (Unblanched) and 5.52% SUP (Blanched at 9 min) for UG I, while that of UG II were 4.82% SP (Unblanched) and 5.85% WUP (Blanched at 3 min). For Carbohydrate content, 61.38% was noted to be the lowest level at Unblanched (Whole peeled), and 68.37% indicates higher CHO content at Blanched 50℃ at 9 min (Split Unpeeled) treatments for UG I samples. Similarly, for UG II, CHO's presence was low at 56.01% for Unblanched (Whole peeled) and high at 76.32% for Blanched on the temperature of 50°C at 9 min (Whole peeled) treatment. Ash content was observed to be low at 4.68% for Blanched 50℃ at 3 min (Split Unpeeled) and high at 6.47% for Unblanched (Whole peeled) treatment for UG I samples, and 3.82% low for Blanched on the temperature of 50°C at 9 min (Split peeled) with higher ash content of 7.69% Unblanched (Split Unpeeled) treatment for UG II samples.

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UG I and UG II samples determination for Crude fibre was observed at 4.64% for Blanched on the temperature of 50°C at 9 min (Whole Unpeeled) and 6.25% at Unblanched (Whole peeled) treatment, 3.72% Blanched on the temperature of 50°C at 9min (Split peeled) and 8.89% at Unblanched (Whole Unpeeled) treatment, respectively. Determination of fat content, at UG I and UG II samples, it was observed that fat content are less at 7.41% for Blanched on the temperature of 50°C at 9 min (Whole Unpeeled) and 3.10% for Blanched on the temperature of 50°C at 9 min (Whole peeled) treatments, respectively. Higher fat content presences were observed at 9.00% for Unblanched (Whole peeled) and 9.78% for Unblanched (Whole Unpeeled) treatments, respectively. Crude protein content shows that its presence was higher at 9.79% for Unblanched (Whole peeled) UG I and 11.75% for Unblanched (Whole Unpeeled) treatment UG II. While it was less at 8.32% Blanched on the temperature of 50°C at 9 min (Whole Unpeeled) UG I and 6.32% Blanched on the temperature of 50°C at 9 min (Split peeled) treatment UG II. The solar drying is effective in sufficient moisture removal and also for the enhancement of some nutritional composition of the produce (Ginger rhizoms).

Keywords: *Drying, Ginger, proximate, composition, blanched, unblanched.*

INTRODUCTION

Ginger (*Zingiber officinale Roscoe*) is an herbaceous perennial crop, grown as an annual crop for its spicy underground rhizomes. The plant has fibrous roots that emerge from the branched rhizomes. Closely grouped, unbranched, pseudostems or overial shoots are produced from the rhizomes. The pseudostems reach a height of 50 – 120 cm. The simple, lanceolate, and smooth leaves are alternate and about 25 cm long. Ginger is asexually propagated from portions of the rhizome. The flowers of ginger are usually sterile and rarely set seed [1]. The shoot, leaf and the stem emit pleasant aroma. The anchorage roots are succulent and when squeezed exude appreciable fluid and emit aroma similar to the one from the other plants parts [2]; [3]. Over 25 varieties of ginger are grown worldwide. Varieties differ in the size of the rhizome, flower, aroma, pungency, colour and fiber content [1]. Nigerian ginger is darker in colour, min. in size and has more pungent taste when compared to others. Cochin ginger is usually larger, well scraped, contains more starch and breaks with a shorter fracture. African ginger is darker in colour, more pungent in taste and has less flavor than Jamaica ginger [4]. Two main varieties are grown in Nigeria. Umudike ginger I (UG I) known as the ''black yellow ginger'' and Umudike ginger II (UG II) known as the ''black'' ginger. The stem cluster of the yellow ginger is fat and robust, resembling the elephant's foot hence the name ''Taffin-giwa''. Similarly, the black ginger because of its shriveled and slander nature typical of the monkey's finger, it is called ''Yatsun biri'' [2]; [3].

Fresh ginger contains 80.9% moisture, 2.3% protein, 0.9% fat, 1.2% minerals, 2.4% fibre and 12.3% carbohydrates [4, 5]. The minerals present in ginger are iron, calcium and phosphorous. It also contains vitamin such as thiamine, riboflavin, niacin and vitamin C. The composition varies with the type, variety, agronomic conditions, curing methods, drying and storage conditions [5].

The branching fleshy rhizome composed of 40-60% starch, 10-40% yellow colour volatile oil responsible for its flavour and the remaining percentage for protein, mineral matter and fiber content [6]. Table 1 comprises of the nutrient/metabolic content of freshly harvested black and yellow ginger rhizome.

Table 1. Nutrient/Metabolic Constituents of Freshly Harvested Ginger Rhizome, [7]

S/N	Nutrient/Metabolite	Yellow (Tafin Giwa)	Black (Yatsun biri)
1	Moisture (g/100g)	78.00	80.90
2	Starch (g/100g dry weight)	55.8	57.19
3	Total reducing sugars (g/100g dry weight)	4.80	3.68
4	Crude protein (g/100g dry weight)	17.15	10.15
5	True protein (g/100g dry weight)	3.18	1.84
6	Total free amino acids (g/100g dry weight)	5.27	4.38
7	Crude fiber (g/100g dry weight)	3.24	4.77
8	Total lipids (g/100g dry weight)	2.74	3.61
9	Total ash (g/100g dry weight)	7.75	7.35
10	Acid –insoluble ash (g/100g dry weight)	2.00	2.00
11	Total carotenoids (mg-carotene/100g dry weight)	6.64	5.41
12	Ascorbic acid (g/100g dry weight)	1.23	1.30
13	Ginger oleoresin (g/100g dry weight)	5.61	6.26

The main objective of this research is to determine the effect of Solar drying on proximate composition of two verities of ginger rhizomes (UG I and UG II), for Blanched and Unblanched treatment. Proximate analysis is referred to as the partitioning of compounds in a feed into six categories based on the chemical properties of the compounds. The six categories are moisture, ash, crude protein, crude lipid, crude fibre and nitrogen-free extracts (digestible carbohydrates).

MATERIAL AND METHODS

Research Materials

A costarred bowl (4 kg) of two ginger varieties, namely Umudike Ginger I and Umudike Ginger II (UG I and UG II), were purchased, respectively from the National Root Crop Research Institute, (NRCRI) Umudike, Abia State. 4 kg of UG I and UG II was cleaned and separated into groups. One of the groups was peeled and splitted with a sharp stainless steel knife The UG I and UG II split and whole, (peeled and unpeeled) was blanched with the aid of Electric water bath in the Soil and Water Laboratory, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State. Ginger rhizomes were blanched (3, 6 and 9 min.), on the temperature of 50°C. Each group with various treatments were subjected to solar drying in sequence. The unblanched UG I and UG II split and whole, (peeled and unpeeled) was also subjected to solar drying for about a period of one month, before taken to the laboratory for proximate analysis. All treatments were done at 10mm thickness of UG I and UG II rhizome.

Chemical analysis

The dried UG I and UG II Samples were subjected to proximate analysis. The proximate composition of the samples UG I and UG II with various treatments, in respect to moisture, protein, fat, ash, fibre and carbohydrate percentage, were determined following the standard methods of association of official analytical chemists [8].

The UG I and UG II dried samples, were ground into fine powder, using a milling machine. The powdered samples were sieved through mesh 300 μm sieve and stored in air-tight cellophane bag as stock sample in a refrigerator, until required for analysis [9]. Thermal drying method was used in the determination of moisture content of the samples [9]; [10].

Moisture content determination

Moisture was determined by the loss in weight of samples dried with solar and cabinet dryers respectively. The percentage moisture content was calculated by computing the loss in weight on drying as a fraction of the initial weight of sample used and multiplied by 100.

$$Mc\ (\%) = \frac{Wo}{Wi} \times 100 \qquad \text{.........(1)}$$

Where Wo = loss in weight (g) on drying and Wi = initial weight of sample (g)

Crude fat content determination

Crude fat content determination of the sample was done using soxhlet type of the direct solvent extraction method. Crude fat represents total fat in most samples. At the extraction end, the solvent was evaporated and the flask dried in the oven (at 60℃). The flask was then cooled and reweighed. The percentage Crude fat (lipid) was calculated using the formula:

$$CL\ (\%) = \frac{Mex}{Mg} \times 100 \qquad \text{.........(2)}$$

Where Mex = mass of extract (g) and Ms = mass of sample used (g)

The Ash content determination

The Ash content was determined using the ignition method by burning the sample in a muffle furnace at 600℃ for 2 hrs. The percentage ash content was calculated using the formula:

$$Ash\ (\%) = \frac{Ma}{Ms} \times 100 \qquad \text{.........(3)}$$

Where Ma = mass of ash (g) and Ms = mass of sample used (g)

Determination of Crude protein

Determination of Crude protein was done by determining the total organic nitrogen, using the macro-Kjeldhal method. This method determination digestion, distillation and titration. The technique determined the amino nitrogen of the sample, after which the total organic nitrogen was then calculated using the formula:

$$\%\ TON = \frac{TV \times NE \times TVd}{Ms \times Vd} \times 100 \qquad \text{.........(4)}$$

Where:
Tv = Titre value, NE = mg of nitrogen equivalent to molarity of acid,
TVd = total volume to which digest was diluted, Ms = mass of the sample (g)
Vd = volume of digest distilled.

Determination of Carbohydrate content

Determination of Carbohydrate content of the sample was estimated by 'differences' [10]. In this, the sum of the percentages of all the other proximate components was subtracted from 100.

Total CHO (%) =100 - (% moisture + % crude protein % crude fat + % ash).........(5)

RESULTS AND DISCUSSION

Results

The results obtained in the study and results of the proximate analysis are presented in Table 2. It shows the variation range of values for Solar dried samples of UG I and UG II proximate analysis results for blanched and unblanched treatments respectively.

Table 2. Proximate (nutrients) contents of UG I and UG II varieties of Ginger rhizome, with various treatments for Solar dried samples

	UG I					UG II			
	WP	WUP	SP	SUP	UNBLANCHED	WP	WUP	SP	SUP
% MC	7.13	7.10	7.06	7.02		5.71	5.94	4.82	4.98
% CP	9.79	9.75	9.70	9.60		8.44	11.75	7.97	11.54
% FAT	9.00	8.95	8.95	8.86		8.67	9.76	8.46	9.53
% CF	6.23	6.19	6.15	6.10		7.08	8.89	7.05	8.80
% ASH	6.47	6.43	6.43	6.32		6.22	7.63	6.23	7.69
% CHO	61.38	61.58	61.71	62.10		63.88	56.01	65.47	57.46
					BLANCHED @ 3 min				
% MC	6.09	6.28	6.15	6.35		6.20	5.85	7.11	6.94
% CP	8.99	8.72	8.79	8.61		6.65	6.97	6.57	7.90
% FAT	8.17	7.73	7.95	7.96		3.40	3.58	3.34	3.49
% CF	5.23	4.94	5.19	4.96		3.98	4.32	3.94	4.26
% ASH	5.86	5.79	5.82	4.68		4.17	4.36	4.08	4.39
% CHO	65.66	66.54	66.10	66.44		75.60	74.92	74.94	73.02
					BLANCHED @ 6 min				
% MC	6.14	6.33	6.22	6.42		6.31	5.99	7.26	7.14
% CP	8.76	8.57	8.64	8.48		6.50	6.81	6.45	7.77
% FAT	8.02	7.58	7.88	7.81		3.27	3.46	3.22	3.31
% CF	5.00	4.77	4.96	4.83		3.85	4.22	3.82	4.19
% ASH	5.72	5.55	5.68	5.54		4.06	4.27	3.91	4.22
% CHO	66.36	67.20	66.62	66.92		76.01	75.25	75.34	73.37
					BLANCHED @ 9 min				
% MC	6.24	6.43	6.32	5.52		6.47	6.15	7.36	7.27
% CP	8.62	8.46	8.51	8.32		6.44	6.75	6.34	7.66
% FAT	7.87	7.43	7.79	7.66		3.12	3.34	3.16	3.15
% CF	4.87	4.64	4.83	4.70		3.74	4.13	3.74	4.00
% ASH	5.58	5.41	5.54	5.40		3.93	4.18	3.82	4.16
% CHO	66.82	67.63	67.01	68.37		76.30	75.45	75.58	73.66

Note: WP – Whole peeled; MC – Moisture content; WUP – Whole unpeeled; CP – Crude protein; SP – Split peeled; CF – Crude fibre; SUP – Split unpeeled and CHO – Carbohydrate

Discussions

The proximate analysis experiment for both UG I and UG II, with various treatments, indicates higher values in percentage for unblanched UG I, and UG II. The results in the Table 2 show an increase in content of, ash, crude fiber, crude protein, fat, and carbohydrate. While the results for the blanched treatments of UG I and UG II show a reduction in percentage moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate.

The initial moisture content of UG I and UG II were 71.12% and 72.47% respectively, the final moisture content were reduced to 7.02% SUP (Unblanched) and 5.52% SUP (Blanched at 9 min) for UG I, while that of UG II were 4.82% SP (Unblanched) and 5.85% WUP (Blanched at 3 min).

For Carbohydrate content, 61.38% was noted to be the lowest level at Unblanched (Whole peeled), and 68.37% indicates higher CHO content at Blanched at 50℃ at 9min (Split Unpeeled) treatments for UG I samples. Similarly, for UG II, CHO's presence was low at 56.01% for Unblanched (Whole peeled) and high at 76.32% for Blanched at 50℃ at 9min (Whole peeled) treatment.

Ash content was observed to be low at 4.68% for Blanched at the temperature of 50℃ at 3min (Split Unpeeled) and high at 6.47% for Unblanched (Whole peeled) treatment for UG I samples, and 3.82% low for Blanched at the temperature of 50℃ at 9min (Split peeled) with higher ash content of 7.69% Unblanched (Split Unpeeled) treatment for UG II samples.

UG I and UG II samples determination for Crude fibre was observed at 4.64% for Blanched at the temperature of 50℃ at 9 min (Whole Unpeeled) and 6.25% at Unblanched (Whole peeled) treatment, 3.72% Blanched at the temperature of 50℃ at 9 min (Split peeled) and 8.89% at Unblanched (Whole Unpeeled) treatment, respectively.

Determination of Fat content, at UG I and UG II samples, it was observed that Fat content are less at 7.41% for Blanched at 50℃ at 9min (Whole Unpeeled) and 3.10% for Blanched 50℃ at 9min (Whole peeled) treatments, respectively. Higher fat content presences were observed at 9.00% for Unblanched (Whole peeled) and 9.78% for Unblanched (Whole Unpeeled) treatments, respectively.

Crude protein content shows that its presence was higher at 9.79% for Unblanched (Whole peeled) UG I and 11.75% for Unblanched (Whole Unpeeled) treatment UG II. While it was less at 8.32% Blanched at the temperature of 50℃ at 9min (Whole Unpeeled) UG I and 6.32% Blanched at the temperature of 50℃ at 9min (Split peeled) treatment UG II. This study's findings agreed with earlier r at the temperature of eports on ginger's proximate composition [9].

CONCLUSIONS

The results obtained in this research, can be concluded that the proximate composition for both UG I and UG II, indicates higher values in percentage for the unblanched treatment, which shows increased moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate.

While that of blanched treatments, shows a reduction in percentage moisture content, ash content, crude fiber, crude protein, fat, and carbohydrate. The solar drying is effective in sufficient moisture removal and also for the enhancement of some nutritional composition of the produce (Ginger rhizoms).

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UTICAJ SOLARNOG SUŠENJA NA PROSEČNI SASTAV DVA VARIJETETA KORENA ĐUMBIRA ZA BLANŠIRANE I NEBLANŠTANE TRETMANE

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Sažetak: Đumbir (*Zingiber officinale Roscoe*) sa dva varijeteta: UG I (Tafin-Giva, žuta sorta sa izrazitim korenom) i UG II (Yatsun-biri, crna ili tamna sorta sa malim kompaktnim korenom) je analiziran kako bi se utvrdio njihov neposredni sastav.
Uticaj efekta sušenja kao tehnike prerade na koren đumbira ispitivani su obzirom na neposredni sastav proizvoda.

Uzorci UG I i UG II su sakupljeni, sortirani (celi, oljušteni i neoljušten) i (isečen, oljušten i neoljušten) i podvrgnuti tretmanima neblanširani i blanširani (kuvanje na 50°C na 3,6 i 9 min.) i osušeni u solarnoj sušari u periodu od mesec dana.
Početni sadržaj vlage UG I i UG II iznosio je: 71,12%, odnosno 72,47%, a konačni sadržaj vlage smanjen je na 7,02% SUP i 5,52% SUP (blanširan do 9 min.) za UG I, dok je sadržaj UG II bio 4,82% SP (neblanširano) i 5,85% WUP (blanširano za 3 min.). Sadržaj ugljenih hidrata, 61,38% je zabeležen kao najniži nivo kod neblanširanog uzorka (ceo oljušten koren), a 68,37% ukazuje na veći sadržaj CHO u blanširanom uzorku na 50 °C za 9 minuta (isečeno, neoljušteno) za uzorke UG I.
Slično opisanom, za UG II, prisustvo CHO je bilo nisko od 56,01% za neblanširani (celi, oljušten) i visoko od 76,32% za blanširan na 50°C za 9 min. (celi, oljušten). Uočeno da je sadržaj pepela nizak pri 4,68% za kuvani uzorak 50°C za 3 min. (isečen, neoljušten) i visok od 6,47% za neblanširan (ceo koren, oljušten) tretman za uzorke UG I, i 3,82% za blanširan 50°C za 9 minuta (isečen, oljušten) sa većim sadržajem pepela od 7,69% tretmana neblanširan (neoljušten uzorak) za uzorke UG II.
Utvrđivanje sastava UG I i UG II uzoraka za sirova vlakna primećeno je na 4,64% za blanširane na 50°C za 9 min. (celi neoljuštni uzorci) i 6,25% za neblanširane (cele oljušteni uzorci) tretmane, 3,72% blanširane na 50°C za 9 min. (isečen, oljušten) i 8,89% na tretmanu nekivano (celo neljušteno).
Određivanje sadržaja masti, na uzorcima UG I i UG II, primećeno da je sadržaj masti manji kod 7,41% za blanširane uzorke na 50°C u 9 min. (celi neoljšten) i 3,10% za blanširane 50°C u 9 minuta (celi oljušteni uzorci), respektivno. Prisustvo većeg sadržaja masti primećeno je za 9,00% za tretmane neblanširani (celi, oljušteni), odnosno 9,78% za tretmane neblanširani (celi, neoljšteni).
Sadržaj sirovih proteina pokazuje da je njihovo prisustvo bilo veće od 9,79% za neblanširani (celi, oljušteni uzorak) UG I I za 11,75% za neblanširani (celi neoljušten) tretman UG II. Iako je bilo manje na 8,32% blanširan 50°C za 9 min. (celi, neoljušten) UG I i 6,32% kuvani na 50 °C za 9 min. (isečen, oljušten) kod tretmana UG II.
Sušenje na suncu je efikasno u dovoljnom uklanjanju vlage, a takođe i za poboljšanje nekih hranljivih sastojaka korena đumbira.

Ključne reči: *Sušenje, đumbir, približan sastav, blanširan, neblanširan.*

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SYNTHESIS OF ACRYLATED EPOXIDIZED BIOBASED RESIN FROM GROUNDNUT SEED OIL

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Abstract: In this study, groundnut seed oil was epoxidized in situ using hydrogen peroxide (30%) and formic and acetic acid. The reaction conditions were monitored at a temperature of 70ºC, stirring speed of 750 rpm and time of 6 hours. After epoxidation, a further modification was done using acrylic acid in the presence of hydroquinone at a temperature of 120ºC. Comparatively, peroxyformic acid performed more effectively than the peroxyacetic acid during epoxidation with an iodine value (26.4 gl/100g oil) and oxirane content(3.27%). FTIR analysis of the raw, epoxidized, and acrylated groundnut seed oil indicates that they were suitably functionalized.

Keywords*: Groundnut seed oil, epoxidation, acrylation, formic acid, acetic acid.*

INTRODUCTION

The use of petroleum-based feedstock in the manufacture of polymers has experienced some levels of decline in recent years due to the spiralling prices and high rate of depletion of the stocks. Furthermore, the unhealthy effect of polymer wastes on the environment resulting from its non-biodegradability is of great concern. This has inspired researchers to investigate sources of renewable natural materials as an alternative source of monomers for the polymer industry, which could substitute for the petroleum-based monomers for the manufacture of polymers, hence the need to develop biobased resins from plant seed oils [1-4].

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Plant seed oils are essential raw materials in the formation of bio-based thermosets.

Different researchers have worked extensively on plant seed oil such as sunflower oil, soybean oil, groundnut seed oil and linseed oil due to their high iodine value and fatty acid profile (oleic, linoleic and linolenic acids) contained [5-7].

Vegetable oils containing unsaturated fatty acids triglycerides can be suitably epoxidized and further modified to biobased resins. These C=C bonds are the reactive sites for the modifications [20]. Studies have revealed that rubber seed oil, soya bean oil, sesame seed oil, melon seed oil and groundnut seed oil containing high unsaturated fatty acid triglycerides can be modified through several chemical processes [8-12].

Wool and Sun [13]. reported on various synthetic pathways by which an epoxidized plant oil can be suitably functionalized using acrylic acid to give acrylated epoxidized triglycerides and maleic anhydride to give malenized triglycerides.

Groundnut is a principal oilseed crop that is cultivated on a large scale throughout the world. It is an annual crop principally for its edible oil and protein-rich kernel seeds, borne in pods that develop and mature below the soil surface [14]. In India, 80% of the groundnut produce is crushed to extract oil and accounts for 36.10% of the total oil production. Groundnut seed contains 44 – 56% oil and 22 – 30% protein on a dry seed and is a rich source of mineral (Phosphorous, calcium, magnesium and potassium) and vitamins E, K and B group [15]. The fatty acid composition consist of Iodine value (g/100 g) = 85; oleic acid (18:1) = 46.8%, linoleic acid (18:2) = 33.4. This composition makes the oil amenable to various chemical modification; it can be successfully epoxidized and further modified [12].

The use of bio-based resins has helped reduce fossil fuel consumption, and they have been utilized in the production of various products, such as inks, paints, coatings, and plastics. Also, it has been used in the production of technical materials for housing (doors, window frames, hot tubs and composite decking), for aerospace (aero craft wings, tails, propellers, and interior), boats, bathtubs, pools, storage tanks and in the manufacture of vehicle parts [10, 16-18]. This paper, therefore, adds value to groundnut seed oil by synthesizing epoxides and acrylates from its oil, which could be used as a substitute to the non-renewable ones made from petrochemical sources that have adverse effects on the environment. Table 1., below represents the fatty acids (oleic, linoleic and linolenic acids) present in groundnut seed oil.

Table 1. Composition of unsaturated fatty acids present in melon seed oil and their molecular weights, [12].

Groundnut seed oil	
Fatty acids	Composition (wt%)
Oleic acid	53.0
Linoleic acid	32.0
Linolenic acid	-

MATERIAL AND METHODS

Materials

Magnetic heater with a stirrer, Three-necked round bottom flask, Thermometer, Condenser, Feed funnel, Stirring bulb, measuring cylinder, weighing balance, Separation funnel, Rotary evaporator. Groundnut seed oil was used as raw material, Formic acid (85 wt%), Acetic acid (85 wt%), Hydrogen peroxide (30 wt%), Sodium Carbonate, Distilled water, Acrylic acid, Hydroquinone powder, Toluene, Sodium sulphate.

Methods

Epoxidation procedure

(35 g) of groundnut seed oil was measured and placed in the three-necked round bottom flask, 2.43 g of formic acid was added to the flask, and the mixture was stirred continuously for 30 min. Then 16.15 g of 30% aqueous hydrogen peroxide was added drop-wise to the reaction mixture as an oxygen donor while stirring. The mole ratio of the components used was 1:1.5:0.5, H_2O_2: HCOOH. After the complete addition of hydrogen peroxide, the mixture was heated under reflux and maintained at a temperature of 70^oC with rapid stirring. The rapid stirring was maintained throughout the experiment to achieve fine dispersion of oil and avoid high peroxide concentration zones that could lead to an explosive mixture. Samples were collected hourly from the set-up for analysis. The collected samples of epoxidized melon seed oil (EMSO) were then washed with a solution of 10 g of sodium carbonate mixed in 200 ml of distilled water to remove the free fatty acids and other unwanted components. The 10 g of Na_2CO_3 was first dissolved in 100 ml of distilled water before the remaining 100 ml was finally added, mixed with the sample and separated using a separation funnel. Subsequent extraction was used to recover the remaining samples after washing.

Synthesis of Acrylated epoxidized groundnut seed oil AMMSO)

35 g of epoxidized melon and groundnut seed oil was heated at room temperature, acrylic acid (4.89 g) containing hydroquinone (0.013 g of 0.25 wt% acrylic acid) was added after 30 min. The reaction mixture was heated under reflux from 8 to 12 hours under constant stirring. The obtained product, Acrylated epoxidized groundnut seed oil, was then isolated.

Characterization of groundnut seed oil

The pure, epoxidized, and acrylated groundnut seed oil was characterized using Fourier Transform Infrared (FTIR) Spectroscopy Technique to determine surface functional groups present. The FTIR analyses were carried out on the samples using Shimadzu FT-IR-8400S Spectrophotometer with a resolution of 4 cm^{-1} in the range of 400 - 5000 cm.

Analytical techniques
Iodine value

Wiji's method of the Association of Oil Chemists determined the iodine value of the test oil sample. First, 0.5g of the sample was poured into a conical flask. Next, 10ml of carbon tetrachloride was added to the oil and shook to allow the oil to dissolve. Also, 20 ml of Wiji's iodine solution was later added to the mixture, stirred vigorously, stoppered and kept in the dark for 30 minutes. Subsequently, 15 ml of potassium iodide solution followed by 100 ml of distilled water was added. The mixture was titrated against 0.01N sodium thiosulphate solution. A reagent black was titrated as well.

The iodine value of epoxidized samples was calculated after analysis using the formula in eq. (1).

$$IV = \frac{(B-S)\times M\times 12.69}{W} \qquad \text{………………… (1)}$$

Where:
IV = Iodine value of samples
S = Volume of $Na_2S_2O_3$ used for sample (ml),
B = Volume of $Na_2S_2O_3$ used for blank (ml),
W = Weight of sample used (g),
M = Molarity of the $Na_2S_2O_3$ used.

Oxirane Oxygen content

The percentage of the oxirane oxygen was determined by the direct method established by using a hydrobromic acid solution in glacial acetic acid. First, the content of oxirane oxygen (O.O.) was calculated according to the consumed amount of the halogen atom.

The Oxirane Oxygen Content of the analyzed samples was calculated using the formula in eq. (2).

$$OV = \frac{(B-S)\times M\times A_O\times 100}{1000W} \qquad \text{………………… ………. (2)}$$

Where:
S = Volume of NaOH used for sample (ml)
B = Volume of NaOH used for blank (ml)
M = Molarity of the NaOH used
W = Weight of sample used (g)
A_o = Atomic weight of oxygen

RESULTS AND DISCUSSION

Table 2. Iodine and oxirane values of the epoxidized samples

Samples	Iodine value (g /100 g of oil)	Oxirane value (%)
Epoxidised groundnut seed oil with acetic acid	26.92	2.00
Epoxidised groundnut seed oil with formic acid	26.4	3.27

The iodine value and oxirane oxygen content are essential parameters in the characterization of epoxidized vegetable oils [19]. While the iodine value indicates the remaining unsaturated fatty acid triglyceride present after the epoxidation reaction, the oxirane oxygen content indicates the epoxy groups incorporated in the products. From the results presented in Tab. 2, it was observed that the epoxidized groundnut seed oil with formic acid had better-functionalized samples than the oil epoxidized with acetic acid. With formic acid, the iodine value was obtained as 26.4 g/100 g oil, which is lower than 26.92 g/100g oil for acetic acid and the oxirane value of 3.27% was obtained for samples where formic acid was used. This is a higher than 2.00% value result obtained for samples where acetic acid was used. Although the oil samples were epoxidized successfully with both formic and acetic acids as used in this study, the results indicated that formic acid gave a better performance than acetic acid for the epoxidation process of groundnut seed oil. This result agrees with the findings of [19]

Figure 1. FT-IR analysis of a raw sample of groundnut oil

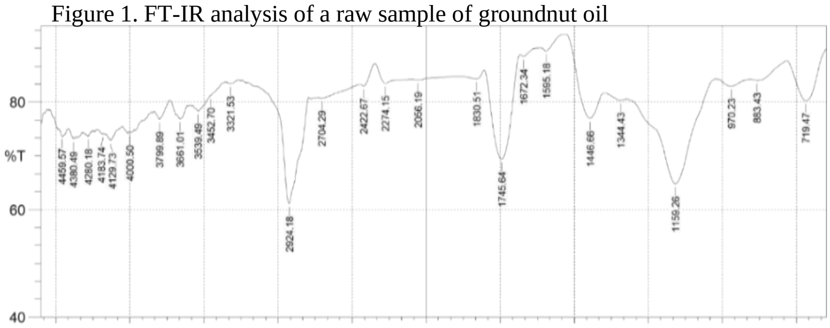


Figure 2. FT-IR analysis of epoxidized groundnut oil sample with acetic acid

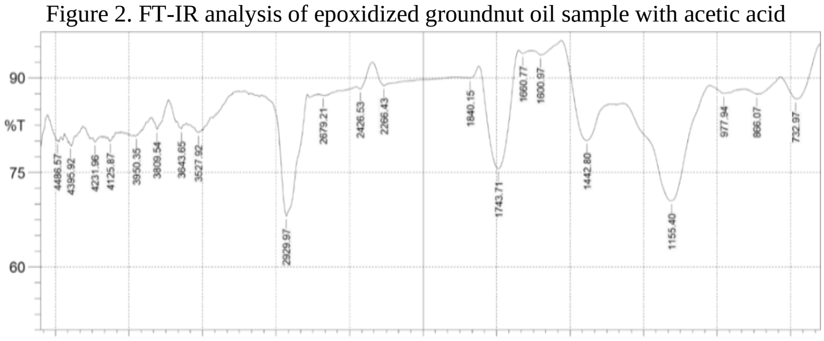


Figure 3. FT-IR analysis of epoxidized groundnut oil sample with formic acid

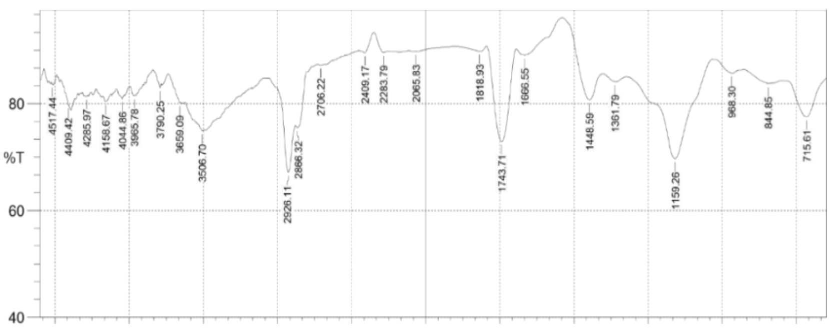


Figure 4. FT-IR analysis of acrylated epoxidized groundnut oil sample with acetic acid

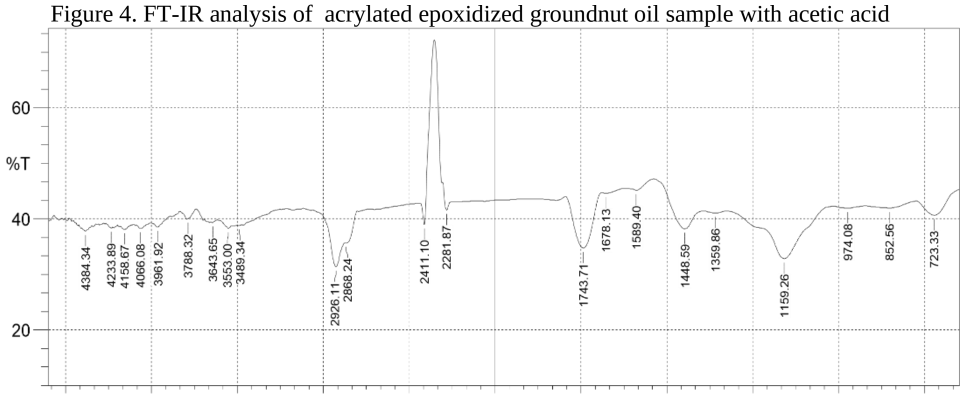
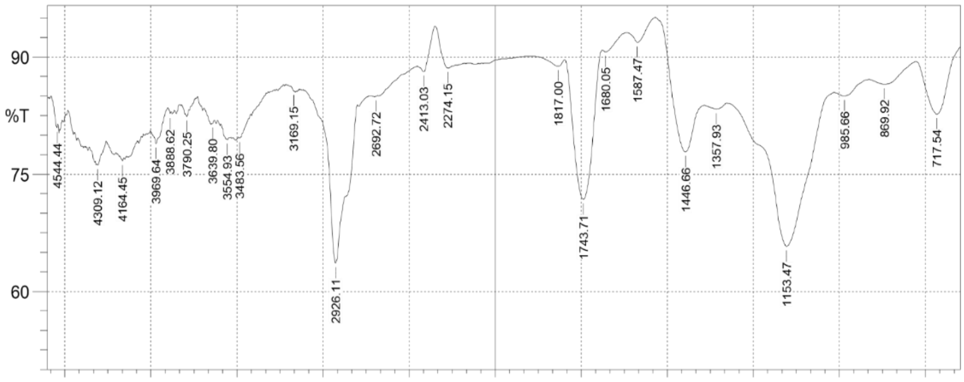


Figure 5: FT-IR analysis of acrylated epoxidized groundnut oil sample with formic acid



Discussion

From results of the FT-IR spectra as presented in Fig. 1-5, the presence of carbon-carbon double bonds (C=C) were observed in the untreated groundnut seed oil, which was indicated by the appearance of peaks at 3500cm^{-1} and 3000 cm^{-1} as shown in Fig. 1, this indicates the functionality of the oil. As presented in Fig. 2 in the acetic acid epoxidized groundnut seed oil, the absorption band for the epoxy group was indicated by the single peak at 3527.92 cm^{-1}. For the same oil epoxidized with formic acid, the peak was also indicated at 3506.70 cm^{-1}; this shows a close margin between both carboxylic acids, indicating their suitability in the epoxidation process. Fig. 3 shows that the oils were suitably epoxidized in both cases, and these results were achieved after six hours (6 h) reaction time, stirring speed of 750 rpm and 70^{0}C temperature.

The I.R. spectra for the acrylic acid modified samples revealed acrylic group indicated by the peak at 3489 cm^{-1} for the acrylated epoxidized groundnut seed oil with acetic acid and 3483 cm^{-1} for the acrylated oil epoxidized with formic acid, as shown in Fig. 4 and Fig.5, respectively. These peaks were observed to be absent in both the epoxy resin and the pure, unmodified groundnut seed oil, which was an indication that the epoxy groups in the epoxidized oils have been converted to acrylated groups after the acrylation process was carried out on the epoxidized groundnut seed oil, this result is in agreement with the findings of [20].

CONCLUSIONS

The results obtained during this study found that groundnut seed oil is a good starting material for oil epoxy synthesis. Although there may be competition with food needs because of its edibility, increasing pressure on supply, consolidating on this research would upscale its production and increase its diversification in other areas of application. Under the same reaction conditions of temperature 70ºC, stirring speed of 750 rpm, and time of 6 hours, peroxyformic acid was observed to be more efficient for in situ epoxidation than peroxyacetic acid.

However, both carboxylic acids gave good results during the process of epoxidation and acrylation of the oil.

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SINTEZA AKRILOVANE EPOKSIDOVANE BIOBAZIRANE SMOLE OD ULJA SEMENA KIKIRIKIJA

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Sažetak: U ovoj studiji ulje semena kikirikija je epoksidovano in situ pomoću vodonik-peroksida (30%) mravlje i sirćetne kiseline. Uslovi reakcije praćeni su na temperaturi od 70 °C, brzini mešanja od 750 o/min i vremenu trajanja od 6 sati.
Posle epoksidacije, izvršena je naredna modifikacija upotrebom akrilne kiseline u prisustvu hidrohinona na temperaturi od 120°C.
U poređenju sa navedenim tretmanima, peroksiformna kiselina se pokazala efikasnijom od peroksiocetne kiseline tokom epoksidacije sa jodnom vrednošću (26,4 gl/ 100 g ulja) i oxiran sadržajem (3,27%).

FTIR analiza sirovog, epoksidovanog i akrilovanog ulja semenki kikirikija ukazuje na to da semenke kikirkija funkcionalno odgovaraju ovom procesu .

Ključne reči: *Ulje semena kikirikija, epoksidacija, akrilacija, mravlja kiselina, sirćetna kiselina.*

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A REVIEW OF NUTRIENT POTENTIALS OF COMPOSTED MUNICIPAL SOLID WASTES FOR AGRICULTURAL USE

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Abstract: The article reviewed the application of compost to the plants in providing essential macro-nutrients such as Nitrogen (N), Potassium (K) and Phosphorus (P), and micro-nutrients, ie. Iron (Fe), magnesium (Mg), copper (Cu), Zinc (Zn), and Boron (B) and enhances microbial activity. Nutrients are released slowly due to strong association of compost with organic matter. This property makes compost an excellent alternative to inorganic fertilizers as leaching and volatilization losses are reduced. Over-reliance on the use of chemical fertilizers has been associated with declines in soil physical and chemical properties and crop yield, and significant land problems, such as soil degradation due to over exploitation of land and soil pollution caused by high application rates of fertilizers and pesticide application. The reduction in the use of chemical fertilizers and supplementing the same through organic manure such as urban compost, otherwise known as municipal solid waste (MSW), Farm yard manure (FYM), poultry manure (PM), etc., become necessary to sustain productivity, profitability and to maintain soil health. Application of FYM is practiced for many years but it has become scarce due to scanty population of livestock, therefore urban compost is one of the alternative sources of organic manure.

Key words: *Nutrients, organic matter, municipal solid waste, compost, crop yield*

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INTRODUCTION

Municipal Solid Waste (MSW) compost contains a large fraction of organic N that could be potentially beneficial to agricultural soils. A typical MSW compost application of 20 t/acre (20 t/ha in EU) can contain from 300 to 500 lb N/acre (app. 10 to 25 kg N/ha in EU). Land application of MSW compost has to be managed properly in order to optimize crop growth. Composting MSW involves managing environmental conditions to accelerate the biological oxidation of organic waste components resulting in a product with potential benefits for agricultural soils [1, 2].

Composting MSW is seen as a method of diverting organic waste materials from landfills while creating a product, at relatively low-cost, that is suitable for agricultural purposes [3, 4]. The trend may be accentuated by a combination of economic and environmental factors, aimed at reducing municipal landfill capacity; avert costs associated with land-filling and transportation of materials; adoption of legislation to protect the environment; minimizing the use of commercial fertilizers; increasing the capacity for the recycling of household waste, and so on. With rising interest in organic agriculture, the production of organic-grade MSW compost for agriculture is also gaining popularity because of its positive effect on biological, physical, and chemical soil properties [5].

[6] reported that waste materials, and materials derived from wastes, possess many characteristics that can improve soil fertility and enhance crop performance. These materials can be particularly useful as amendments to severely degraded soils associated with mining activities. The use of composted municipal solid waste contains high organic matter which can be absorbed by plants [7] and improves soil quality [8]. Soil organic matter consists of a variety of simple and complex carbon compounds and thus provides food for a variety of organisms. It provides much of the cation exchange and water-holding capacities of surface soils [9].

Municipal solid waste exerts a positive influence on physical and chemical soil properties such as porosity, aggregate stability, water holding capacity, cation exchange capacity, and releases nutrient generally [10]. However, there are concerns about potential public health hazards from the presence of pathogens and pollutants such as trace metals and organic contaminants [11]. Furthermore, the bioavailability of these non-essential heavy/trace metals could pose serious health and environmental problems to the inhabitants of the vicinity of the dumpsites.

1. Physical and Chemical Properties of Waste Dumpsite Soils/ Nutrients

Experiment conducted by an environmental student of Federal College of Land Resources Technology, Owerri [12] has shown the effect of solid waste (municipal waste) dumped on soil properties. The results indicated that soils from waste dumpsite have greater appreciable better chemical properties against those found in Non-waste dumpsite. This indicates the usefulness of some environmental waste as raw materials for organic fertilizers [12].

Waste dumpsite soils contain a number of favorable characteristic for agriculture such as macro-nutrients, micro-nutrients and some heavy metals heavy metals [12,13].

Nitrogen (N)

Nitrogen is one of the macro nutrients of the soil. Nitrogen is a key plant nutrient; crucial in forming nucleic acids and proteins, important for photosynthesis, cell wall composition, cell reproduction, energy and nutrient storage [14]. Nitrogen is a major macro-nutrient needed for growth and development of plants. It is fixed into the soil through the activities of nitrogen-fixing bacteria and some plants through their root nodules.

This important element exists in many forms in the soil system, transforming from one to another as influences by various complex chemical and biological processes [14]. Organic N, a component of soil OM in the form of decaying plant litter and soil organisms, and inorganic nitrate and ammonium are the most common forms of N found in the soil.

Nitrate is the preferable chemical from for the absorption of the plants. However, this is a very mobile chemical form. In order to minimize the rise of groundwater contamination, [15] recommended the use of stable organic amendments (with a more stabilized organic matter, which could produce a lower content of leachable Nitrogen forms. Risks are also minimized by planting rainfall crops and particularly choosing crops with a high demand for Nitrogen such as wheat or maize.

After the application of MSW compost to the soil, nitrogen is transformed into mobile forms, which can be accumulated in the soil, absorbed by plants, or released into the atmosphere or water system. The amount of nitrogen released into the soil solution determines the form of nitrogen availability to the plant and, consequently, the yield. If MSW is poor in nitrogen or the rate C/N is inadequate for the mineralization of the organic matter, additional sources of nitrogen are need. [16] found that the low availability of compost-N means that supplementary nitrogen in the form of inorganic fertilizer may have to be added together with compost in order to enhance N availability to crops. They observed that inorganic fertilizer (NPK) and a mixture of MSW compost and inorganic fertilizer produce higher yields than MSW compost alone.

Phosphorus

Phosphorus is a fundamental crop macronutrient that is required by plants for early plant growth, development of reproductive organs, crop maturity and root development [17]. Phosphorus is a necessary component of key molecules in plant growth including nucleic acids, phospholipids and adenosine triphosphate (ATP). Therefore, plants need a consistent supply of P to reach their potential yield [18]. The P content of natural soil materials are usually less than 1mg kg^{-1} [19,20].

A review paper by [21] on soil P dynamics reveals that, following P application in the form of manure, inorganic fertilizer and/or alternative organic products, plant available soil P increases as a function of physical and chemical soil properties. Specifically, theses plant available forms of P are most available within a pH range of 6 – 7 [22] and are influences by soil soluble Al, Fe, Ca and OM [21].

Various organic forms of P exists in the soil, representing 20 – 80% of the TP [18] and can symmetrically contribute to the P nutrition of plants [23]. The turnover of organic P in the soil is ultimately determined by both the rates of immobilization and mineralization [23].

Some authors observed that MSW compost effectively supplies phosphorus to soil with its concentration increased when increasing application rates. MSW composts provide equivalent amounts of phosphorus to soil as mineral fertilizers [24, 25].

Some reports observed that MSW compost provided equivalent amount of P to soil as mineral fertilizers. Low mineralization rates of P were seen immediately after application, but after a residence time of 3 months, MSW compost provided sufficient P for plant growth. A 10-50% of total P in compost was available both the first and second year after application [26, 27]. I n an experiment in plots in a quarry restoration, where 3 kg/m3 of MSW were applied to a substrate composed by limestone outcrop from the rejection of the quarry' an increment of nutrients associated to the composition of the composted MSW was obtained. In the plots in which MSW was applied' an important increase in the soil content of N-Kjeldahl, available P, and the rest of macro- and micronutrients was found, favouring the plant growth [28].

[29] studied the effect that 13 years of applying three different composted organic amendments have had on soil quality, Greenhouse Gas (GHG) emission, and the dynamics of its microbial communities 15 days after the annual application. They found that total Nitrogen increased with respect to the control by amending with organic fractions of Municipal Solid Waste. Organic amendment application resulted in higher levels of phosphorus and potassium in the soil. They concluded that significant higher organic matter contents, total N, P and K contents, on the soil when compared to the control validate the fact that organic waste-based fertilizers contribute to enhanced soil fertility.

It has been reported that MSW compost has a high capacity to supply P to plants given the compost is mature since the concentration of P in MSW compost tended to increase with composting time. Some research suggested that excess P was applied to soil when MSW compost was applied to meet N requirements [30]. At high MSW compost application rates (>200 $Mgha^{-1}$), to supply adequate N, download movement of P was observed [31].

Potassium (K)

Potassium is another main source of nutrients for plant growth. A long-term study of MSW compost demonstrated that K was available in MSW compost as in mineral K fertilizers [26]. In a study conducted by [26, 27], of the total K in MSW compost, 36 – 48 % was found to be available for plant. Another study revealed that soil K concentrations are increased even when very low rates of MSW compost are used [32]. Increased K constant of the following was reported for soils treated with MSW compost. pp. blueberries, Swiss chard, boot-stage barley, alfalfa, and cock foot [33, 34, 35, 36, 37].

A study conducted by [38], Potassium level in the field soil was generally found to be high when enriched compost was applied to the field. Individual applications of enriched compost in the soil were observed to have maximum level potassium content, when compared to mineral fertilizer application alone. [34] have reported that potassium content in soil was increased with increasing dose of compost application.

[39] made similar observation that there was enhancement in soil available potassium content from the comparative studies on the effects of combining mineral fertilizers with compost materials with respect to those observed when mineral fertilizers alone were applied. [39] found that municipal waste leachate markedly increased the amount of available macro (N,P,K) and micronutrients (Fe, Mn, Zn and Cu) in soil and rice plant.

Effects of other Plant Essential Nutrients

Some other essential plant nutrients or elements of interest and concern are. pp. calcium, magnesium, sulphur. A survey of selected MSW composts in the US found that Calcium, Ca was one of the major elements in the product, present at concentrations above 10 gkg^{-1}. Municipal Solid Waste compost has been reported to increase total and extractable soil Ca concentrations compared to fertilizer treatments [40]. Increased soil Ca concentrations, however, did not result in increased plant uptake of Ca by blueberries, Swiss chard, and basil (*Ocimumbasilium L.*) [35].

Furthermore a survey of MSW facilities in the U.S shared that the average Magnesium, Mg content of MSW compost was less than 5gkg^{-1}, ranging from 1.8 to 4.4 kg^{-1} [41]. Municipal Solid Waste compost increased total soil Mg concentration when compared to an unamended control soil, which in turn increased Swiss chord and basil Mg concentrations [35]. Soil Mg concentrations were also increased when MSW compost was applied to a poorly drained soil when compared to control, fertilizer, gypsum and manure plots [37]. Magnesium concentrations in blueberry leaves were also seen to increase with MSW compost and that was proportional to the application rate [37].

In another study MSW compost was applied at 0, 50, 100, and 150 kg plant available Nha^{-1} the first year (approximately, 0.75, 150, and 225 $Mgha^{-1}$), followed by half the amount the following year. His study found that soil Mg concentrations increased when compared to manure applications to barely Mg concentrations appeared to decline with increased compost addition and wheat Mg (*Triticumaestivum*, L) concentration rate but declined at the highest application rate [34].

In a study conducted by [31], MSW compost was found to increase soil sulphur, S concentrations, though the levels decreased with time probably due to the downward movement of the elements in the soil profile. However, other studies reveal fertilizer to be more effective in increasing soil S concentration when compared to MSW compost [42].

Effect of pH (Soil Reaction)

Perhaps the most outstanding characteristics of the soil solution is its reaction that is, the soil pH. pH determines the amount of hydrogen present in a soil sample and ranges from 0 – 14. Low pH indicated sour of soil. High pH is salty soil [43, 44]. Thus, acid soils have a pH below 7 and alkaline soils have a pH above 7 (Magdalene, 2017). The most important effect of pH in the soil is an ion solubility, which in turn affects microbial and plant growth [45].

A pH range of 6.0 to 6.8 is ideal for most crops because it coincides with optimum solubility of the most important nutrients. Some minor elements (e.g, Iron) and most heavy metals are more soluble at lower pH. This makes pH management important in controlling movement of heavy metals (and potential groundwater contamination) in soil [46, 47]. Increased soil pH is considered as a major advantage when MSW compost is used [25]. Low pH has been associated with the release of soluble Al, which can inhibit root development. Low soil pH may also result in nutrient deficiency. Bases such as Ca, Mg, and K becomes more susceptible to leaching loss [48].

Effect of Electrical Conductivity and Salt

The amount of soluble salts in a sample is expressed in terms of electrical conductivity (EC) and measured by conductivity meter. Plants are negatively affected by excess salts in soils and Na can be detrimental to soil structure. Soil salination as a consequence of leachate disposal also implies exotexicological effects on plants and soil organisms [49].

Soil salination has negative effect on microbial respiration, especially when Na^+ and/or Cl^- are involved. Microbial activity and the cycling of nutrients may be inhibited. Furthermore, high salinity in newly restored sites may favour salt tolerant species and may alter the succession of the ecosystem [50].

[50] reported that besides minimizing the salt input by a proper dilution rate of leachate, the impact of salts can be reducing if salts were eluted away from the rooting zone. The traditional concept of leaching involves the pending of water to achieve more or less uniform salt removal from the entire soot zone [51].

[52] proposed the concept of leaching requirement. It is the excess amount of water in addition to evapotranspiration, required to leach salts out of the rooting zone to maintain an acceptable salt content. The volume of irrigation can be calculated based on evapotranspiration, salinity of the diluted leachate and the crop tolerance [50]. Leaching requirement (L.R) is given by [53].

$$L.R = \frac{ECw}{(5ECe - ECw)}$$

Where:

ECw is the electrical conductivity of irrigation water,

ECe is the average salt concentration of saturated extract. The depth of water required to leach the salts from the root zone is given by $D_a = ET/(1 - L.R)$ where, D_a represent the depth of water required to leach the salts and ET is the evapotranspiration rate [53].

Although the application of excess water can mitigate salination problem, plants would be severely impaired when the soil is water-logging with high salinity water, especially with leachate. Excessive water should be drained out of rooting zone. Moreover, planting salt-tolerant species (e.g *Hibiscus tiliaceus)* can lower the adverse impact to vegetation in episodic drought conditions due to hot dry weather or a breakdown of the irrigation system [50].

Effect of Soil Organic Matter (OM)

Estimates of soil organic matter are frequently based on organic carbon. The organic carbon content of soils includes the remains of plants, animals and micro-organism in all stages of decomposition. Carbon is a major element of soil organic matter that is readily measured quantitatively. Estimates of soil organic matter are frequently based on organic carbon. Values of organic carbon content of soils may be expressed in 5 or g/kg. Organic carbon can be converted to total organic matter by multiplying by the factor 1.729. Soil containing less than 15 organic carbons is considered low in organic matter [12].

Several studies have revealed that the application of MSW compost increase soil organic matter content and soil C/N ratio to levels greater than those of unamended soil [54, 55, 56, 36].

Thus, Municipal Solid Waste compost had a high water holding capacity because of its organic matter content which in turn improved the water holding capacity of the soil (57].

Furthermore, application rates of 30 and 60 $Mgha^{-1}$ of MSW composts increased the aggregate stability of soil through the formation of cationic bridges thereby, improving the soil structure [57].

[58,59] found that improved soil properties following that application lasted for several years and the quantity of microbial biomass C was greater for compost than control or inorganic fertilizer. [60] found higher soil OM levels in previously applied compost treatment plots than the control and OM levels increased with compost application rate.

Soil Cation Exchange Capacity (CEC)

A soil's CEC is the capacity for it to exchange of cations between it and its solution and is linearly related to the per cent clay and OM [22]. Cation exchange capacity is strongly correlated to soil electrical conductivity (EC), a measure of soluble ions (salts) in the soil, and Municipal Solid Waste compost application has been found to increase soil EC levels in relation to feedstock and facilities composting procedures. Other studies have identified soil EC levels to be related to application rates and that soil EC increases as more compost or manure is applied due to its high OM content [61, 62].

Exchangeable Cation (EC) is one of the important soil chemical properties which influence the soil fertility. Soil scientists are very interested in the cation exchange properties of soils because the distribution of the exchangeable cations indicates the relative abundance and availability of some major nutrient elements such as Ca, Mg and K in soils. For Nigerian Soils, a cation content of about 2 Cmol/kg (2 meq/100g soil) is considered adequate for Ca and Mg while for K, 0.2 Cmol/kg (0.2 meq/100g soil) and above is good [12].

Effect of Iron

The range of Fe that has been detected in MSW compost is 5.3 – 34.9 gkg^{-1} according to a study by [32]. The application of MSW compost did not tend to increase soil and plant Fe contractions. In another study, MSW compost applied at 100 and 35-140 $Mgha^{-1}$ did not increase available soil Fe concentration nor did clover and blueberry leaves, respectively, showed increase Fe concentration compared to a control [33].

Effect of Micronutrients and Trace Elements (Heavy Metals)

Most Municipal and Industrial wastes contain heavy metal. Heavy metal is used to cover a number of metals and their ions which are mostly of high density and belong largely to the group of "transition elements" of the periodic table. Some of these metals are also termed "Trace elements or Micro-nutrients" in agriculture stressing their relatively low abundance in normal soils. The fact is that they tend to be essential for plant growth [63].

The contamination of soil by heavy metal can cause adverse effects as human health, animals and soil productivity [64] and depending on the tendency of the contaminants, they end up either in water held in the soil matrix or leached to the underground water.

Contaminants like Cadmium (Cd), Copper (Cu), Nickel (Ni), Lead (Pb) and Zinc (Zn) can alter the soil chemistry and have an impact on the organisms and plants depending on the soil for nutrition.

Research conducted by [65, 66, 67, 68, 69, 70] found out that plants grown on municipal dumpsites soil accumulated higher concentrations of the metals than those on rural dumpsites.

The studies further revealed that plants grown on dumpsites soils bio-accumulated higher metal concentrations than their counterparts obtained from normal agricultural soils.

2. Composted Municipal Solid Waste (MSW) for Agricultural Purposes

Compost is increasingly used in agriculture as a soil conditioner but also as fertilizer [71]. Composting MWS is seen as a method of diverting organic waste materials from landfills while creating a product, at a relatively low-cost that is suitable for agricultural purposes. Composting MSW reduces the volume of the waste, kills pathogens that may be present, decreases germination of weeds in agricultural fields and destroys malodorous compounds [72]. It used the biological system of microbes in the compost to breakdown or transform contaminants in soil/water [73].

When MSW compost was applied to soil at application rate of 20 and 80 Mgha-1, the major structural units of humic acid in MSW compost were incorporated into the humic acids in the soil [56]. The change in soil structure persisted and was structurally changed 9 years after the initial application [56]. Repeated application of MSW compost consistently increased soil organic matter content and soil C/N ratio to levels greater than those of unamended soil [54, 55, 56, 36]. Municipal solid waste compost had a high water holding capacity because of its organic matter content, which in turn improved the water holding capacity of the soil [57].

Furthermore, application of 30 and 60 $Mgha^{-1}$ of MSW compost increased the aggregate stability of soil through the formation of cationic bridge hereby improving the soil structure [57]. Another study also revealed that the addition of mature MSW compost in this case to a silt loam, increased aggregate stability [74].

Composting transforms organic by-products into drier, more uniform and biologically stable products that can act as slow-release sources of plant-available nutrients [75, 76]. MSW compost may consist of various combinations of household and/or commercial wastes including but not limited to. pp. food, kitchen and yard wastes, municipal sewage sludge, sawdust, paper products, biosolids, etc. municipal Solid Wastes (MSW) composed of about 45% of the wastes dumped in landfills [50]. Certain components of soil organic matter are largely responsible for the formation and stabilization of soil aggregates [77].

Finally, composting has seen well established and it is currently used to provide a final product, which can act as a soil conditioner or fertilizer. Compost contains major plant nutrients such as N, P, K and macronutrients [78, 79].

3. Dumpsite soil Biological Properties/Microbial Activity

Soil ecology is increasingly being used to evaluate soil quality. It is thought that soil microbial properties are most sensitive to changes in the soil environment [80, 81]. Biomass N, C, and S showed increases in the soil immediately, after compost addition are far up to 1 month, while biomass P showed an increasing trend for 5 months.

Application of 2.5, 10, 20 and 40 $Mgha^{-1}$ MSW compost increased soil microbial biomass C and soil respiration (an index of general metabolic activity of soil micro-organisms) when compared to a control [82].

[83, 38] also observed that significantly higher amounts of total N and C and soluble organic carbon C which were found in the composts had the effect for increased microbial population. Another measure of soil microbial health is the activity of soil enzymes involved in the transformation of the principal nutrients [55].

4. Dumpsite soils and plant growth

Municipal solid waste compost is high in organic matter (OM) content, has a low bulk density [84], and research has shown that it has the ability to improve soil properties [25] and the growth and yield of vegetables [60, 33], with evidence of positive residual effects [85]. Soil organic matter also contains large quantities of plant nutrients that act as a slow-release nutrient store-house, especially for nitrogen [9]. The use of composted organic wastes produces changes in soil physical, chemical, and biological properties and can enhance plant growth after its application [86].

Nutrient availability to plant is strongly influenced by organic and inorganic amendments that usually increase the amount of carbon and other nutrients, especially nitrogen. Organic matter is added to soil by the incorporating of plant materials, animal residue manure, sewage sludge or municipal waste. Amendments not only influence soil fertility, but can also affect the composition and activity of soil organisms [87]. [88] also reported that municipal solid waste has the ability of improving soils that have been cropped for many years, but which may be deficient in nutrients such as Boron, Zinc, Copper, and municipal solid waste compost mitigate such deficiencies. [89, 90] also added that crop residues contain considerable quantities of major crop nutrients as well as being source of organic matter.

The chemical properties of the waste material also have significant impacts on crop performance. For example, high nitrogen content favours fast-growing grass species which is often desirable for reclamation and revegetation projects [91]. Nevertheless, the application of composted waste to agricultural soils requires caution due to the possibility of food chain contamination and negative effects on soil microbiology, particularly rhizobia [91].

Studied, [71] the effect of Lunenburg's MSW compost on strawberries and concluded that it significantly increased soil Mehlich III extractable phosphorus (M3P) concentrations. These concentrations were found to increase with increasing MSW compost application rates. Fruit quality and yields were found to be reduced as a result of N deficient compost supplying inadequate amounts of N to the strawberries.

Positive residual effects from FYM and MSW composts have also been identified, such as increased soil organic matter (OM) content, nutrient availability and uptake by crops, and can be superior to those of residual manure and inorganic fertilizer applications. [34] investigated the residual effect of previous additions of MSW compost and found greater uptake by annual ryegrass and residual availability of N and P compared to previous manure applications. They also identified that repeated compost applications increased soil OM content and that grass yields increased with compost application rate [85].

CONCLUSION

Investigation of nutrients potentials of municipal solid waste compost, physico-chemical soil properties at dumpsites and surrounding area were reviewed.
Definite patterns of higher values of soil properties at dumpsite soil than counterparts at surrounding or control soil were reviewed both in open dumpsites in developing and in developed economies.

Solid waste dumpsites have been reviewed to be rich in organic matter content which is the source of most of the nitrogen and phosphorus which enhances soil fertility and promote plant growth. The nutrients potentials of the dumpsite soils were reported to be higher in all works reviewed compared to the control locations. This may not be unconnected to the composition of the organic wastes which are mainly from agricultural and farmyard sources. Moreover, the activities of soil organisms in the decomposition of these wastes may have accounted for the rich nutrient contents of the dumpsite soils compared to the natural soils (control locations).

This review buttresses the fact that Composts represent an important resource to maintain and restore soil fertility, especially in those areas/ fields or soils where the organic matter contents have declined. However, the application of composted waste to agricultural soils requires caution due to the possibility of food chain contamination and negative effects on soil microbiology, especially rhizobia.

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PREGLED HRANLJIVIH POTENCIJALA KOMPOSTIRANOG KOMUNALNOG OTPADA ZA UPOTREBU U POLJOPRIVREDI

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Sažetak. U radu je prikazana primena komposta za biljke u obezbeđivanju najvažnijih makronutrijenata. pp. azota (N), kalijuma (K) i fosfor a(P), i mikronutrijenata, kao. pp. gvožđa (Fe), magnezijuma (Mg), bakra (Cu), cinka (Zn) i bora (B) i poboljšavanju mikrobne aktivnost.

Hranljive materije se sporo oslobađaju zbog jake povezanosti komposta sa organskom materijom. Ova osobina predoređuje kompost za odlično alternativno neorgansko đubrivo jer su smanjeni mnogobrojni gubici ispiranja određenih sastojaka.
Prekomerna upotreba hemijskih đubriva povezana je sa promenom (padom) dobrih (povoljnih) vrednosti papametara fizičkih i hemijskih osobina zemljišta i prinosa useva, kao i značajnim problemima zemljišta, kao što je degradacija usled prekomerne eksploatacije i zagađenja zemljišta prouzrokovano visokim procentima primene hemijskih đubriva i neogovornom primenom pesticida.
Smanjenje upotrebe hemijskih đubriva i dopuna putem organskog đubriva kao što je gradski kompost, koji se dobija od komunalnog čvrstog otpada (KČO), i đubriva sa farmi krupnih životinja (FKŽ), ili farmi živine (FŽ), i slično, postaju neophodna za održavanje. produktivnosti, profitabilnosti i dobrog zdravlja zemljišta.
Primena (FKŽ), praktikuje se dugi niz godina, ali postaje sve ređe zbog oskudnog ili smanjenog stočnog fonda.
Zato je kompost od komunalnog čvrstog otpada (KČO), jedan od dobrih alternativnih izvora organskih đubriva.

Ključne reči: *Hranljive materije, organska materija, komunalni čvrsti otpad, kompost, prinos useva*

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OPREMLJENOST I ANGAŽOVANOST MEHANIZACIJE NA PORODIČNOM POLJOPRIVREDNOM GAZDINSTVU

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Sažetak: Ispitivana je opremljenost i angažovanost traktora i priključnih mašina na primeru prosečnog porodičnog gazdinstvu u Srbiji. Istraživanja su obavljena na registrovanom poljoprivrednom gazdinstvu Šiljić u selu Selevcu opština Smederevska Palanka. Porodično gazdinstvo Šiljić raspolaže ukupno sa 5,4 ha korišćenog poljoprivrednog zemljišta. Na gazdinstvu je u proizvodnoj 2019/2020. godini bila je posejana pšenica na 2 ha i po 1 ha kukuruz, suncokret i tritikale.
Na površini od 0,4 ha je okućnica i bašta. Od mehanizacije, gazdinstvo Šiljić poseduje traktor IMT-558, plug, tanjiraču, drljaču, prskalicu i prikolicu, koje su nabavljene 1979. godine. U upotrebi je stara mehanizacija. Registrovano porodično gazdinstvo Šiljić je nedovoljno opremljeno mehanizacijom. Korišćenjem dvoosovinskog traktora snage 42,65 kW i 5 priključnih mašina, obrađuje se 5,4 ha, pa energetska opremljenost iznosi 8,5 kW/ha. Traktor je najviše angažovan u proizvodnji kukuruza 10,0 h/ha, zatim suncokreta 9,5 h/ha, tritikala 8,33 h/ha, a najmanje pšenice 7,4 1 h/ha efektivnog rada. Na gazdinstvu je na površini od 5 ha od ukupno 42,66 sati rada, traktor najviše korišćen u osnovnoj obradi zemljišta 17,0 h ili 3,1 h/ha. Traktor je angažovan i u predsetvenoj pripremi zemljišta tanjiračom 9 h (1,8 h/ha) i drljačom 7 sati (1,4 h/ha), u transportu 5,33 h (1,07 h/ha), u aplikaciji pesticida sa prskalicom 4,33 h (0,87 h/ha).

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Pored ukupnog efektivnog rada pri sprovođenju određenih agrotehničkih mera u proizvodnji ratarskih kultura, traktor je angažovan 7,30 sati za odlazak i povratak sa parcele (pomoćno radno vreme).

Potrošnja goriva u osnovnoj obradi zemljišta iznosila je 18 l/ha, u predsetvenoj pripremi tanjiračom 10 l/ha, drljačom 5l/ha i u primeni pesticida i transportu proizvoda 5 l/ha.

Ključne reči: *Porodično gazdinstvo, opremljenost mehanizacijom, angažovanost traktora i priključnih mašina, potrošnja goriva.*

UVOD

Jedan od osnovnih uslova za ekonomski uspešnu proizvodnju ratarskih kultura na porodičnim poljoprivrednim gazdinstvima u Srbiji je njihova opremljenost i racionalno korišćenje poljoprivredne mehanizacije. Prema popisu poljoprivrede iz 2012. godine u Republici Srbiji ima ukupno 628.555 porodičnih gazdinstava koja obrađuju 2.816.424 ha korišćenog zemljišta. Prosečno porodično gazdinstvo u Republici Srbiji raspolaže sa 4,48 ha poljoprivrednog zemljišta usitnjenog u 5 parcela od 90 ari. Ukupan broj dvoosovinskih traktora koji se koriste u Republici Srbiji na porodičnim gazdinstvima je 405.728 traktora, od kojih je 94,87% starije od 10 godina. Pored traktora gazdinstva R.Srbije poseduju 2.421.065 priključnih mašina, od kojih je 93% starije od 10 godine (RZS 2012.).

Porodična gazdinstva u R.Srbiji nisu dovoljno opremljena sa dvoosovinskim traktorima svega 0,64 traktora po gazdinstvu. Sa jednim dvoosovinskim traktorom prosečne snage motora od 32,27 kW (43,52 KS) obrađuje se 6,99 ha zemljišta ca 5,89 priključnih mašina [17].

Energetska opremljenost porodičnih gazdinstava u R.Srbiji je 2,89 (kW/ha), a prosečna starost traktora je 17,5 godina. Prosečno korišćenje tratora [13], na porodičnim gazdinstvima je 421 h/god.

Registrovano poljoprivredno gazdinstvo Šiljić (selo Selevac) predstavlja prosečno gazdinstvo u Srbiji koje se bavi ratarskom proizvodnjom, gde se jedan deo prinosa prodaje na tržištu, a drugi deo koristi za pripremu smeše za ishranu svinja.

Obim angažovanosti mehanizacije i utrošak energije zavisi od izbora kulture koja se seje i setvene strukture, primenjene agrotehnike gajenja, tipa, osobina, uslova i vremena obrade zemljišta.

Cilj istraživanja je da se ustanovi opremljenost prosečnog porodičnog poljoprivrednog gazdinstva Šiljić poljoprivrednom mehanizacijijom i na osnovu setvene strukture i sprovedenih agrotehničkih mera u procesu proizvodnje pšenice, kukuruza, suncokreta i tritikala utvrdi njena angažovanost. Data je i ukupna potrošnja goriva tokom izvođenja agrotehničkih operacija u proizvodnji ratarskih kultura na Gazdinstvu.

MATERIJAL I METOD RADA

Istraživanja u ovom radu su obavljena metodom studije slučaja na primeru porodičnog gazdinstva Šiljić iz sela Selevca, koje se nalazi na 18 km udaljenosti od Smederevske Palanke u Podunavskoj oblasti.

Osnovni podaci o veličini gazdinstva Šiljić dobijeni su iz direktnog intervjua na osnovu koga je utvrđeno: postojeće stanje mehanizacije, raspoloživo zemljište, setvena struktura i prosečni prinosi gajenih ratarskih kultura.

Ukupna angažovanost mehanizacije praćena je direktnom evidencijom rada i potrošnje goriva na gazdinstvu Šiljić tokom proizvodnje pšenice, kukuruza, tritikala i suncokreta u sezoni 2019/2020. godine.

Angažovanost mehanizacije na gazdinstvu Šiljić utvrđena je merenjem efektivnog radnog vremena (efektivan rad) i pomoćnog radnog vremena. Vreme koje je utrošeno za odlazak traktora i priključne mašine od ekonomskog dvorišta gazdinstva Šiljić do parcele evidentirano je kao pomoćno radno vreme. Efektivno radno vreme čine sve agrotehničke operacije u proizvodnji pšenice, kukuruza, tritikala i suncokreta. Utrošak radnog vremena meren je ručnom digitalnom štopericom. Količina goriva za obavljanje svih radnih operacija utvrđena je zapreminskom metodom nalivanjem dizel goriva u rezervoar traktora.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Porodično poljoprivredno gazdinstvo Šiljić bavi se ratarskom proizvodnjom i uzgojem svinja i prasadi. Sve poslove vezane za poljoprivrednu proizvodnju na Porodičnom gazdinstvu obavljaju tri člana porodice (otac, majka i sin). Prosečna poljoprivredna gazdinstva u R. Srbiji sve teže ekonomski opstaju baveći se isključivo poljoprivredom. Zbog toga osnovni prihodi na ovom gazdinstvu ne ostvaruju se samo iz poljoprivredne delatnosti, nego i dodatnim radom dva člana porodice (otac i sin). Porodično gazdinstvo Šiljić raspolaže ukupno sa 5,4 ha obradivog korišćenog poljoprivrednog zemljišta podeljenih u 5 parcela (Tabela 1), od toga 92,59 % ili 5 ha su oranice, a ostalo 0,4 ha su okućnica i bašta. Površine pod oranicama podeljene su u 4 parcele, od kojih su tri parcele od 1 ha, a jedna od 2 ha. Parcele su od ekonomskog dvorišta udaljene 3,5 km i povezane su asfaltnim putem. Prema veličini zemljišnog poseda, usitnjenosti, broju i veličini parcela porodično poljoprivredno gazdinstvo Šiljić pripada prosečnim poljoprivrednim gazdinstvima u R.Srbiji, koje raspolaže sa 4,48 ha poljoprivrednog korišćenog zemljišta usitnjenog na 5 malih parcela od 90 ari [18].

Slična poljoprivredna struktura zemljištnog poseda [15], [17], [8], [14], [10] postoji samo u Crnoj Gori 4,60 ha, Sloveniji, Grčkoj 6,4 ha. Isti Autori navode da su mnogo veća Gazdinstva Šiljić u: Portugaliji 8 ha, Italiji 9,3 ha, Zapadnoj Turskoj 10 ha, Španiji 22 ha, Nemačkoj 28,9 ha, Francuskoj 44,8 ha i Velikoj Britaniji 109,7 ha.

Tabela 1. Setvena struktura na porodičnom gazdinstvu Šiljić u sezoni 2019/2020
Table 1. Sowing structure on the family Farm Šiljić at the season 2019/2021

Kultura *Crop*	Površina (ha) *Area (ha)*	Prosečan prinos (t) *Average yield (t)*
Pšenica *Wheat*	2,0	4,9
Kukuruz *Maize*	1,0	8,0
Suncokret *Sunflower*	1,0	3,0
Tritikale *Triticale*	1,0	5,5
Okućnica i bašta *Backyard and garden*	0,4	-

Tabela 2. Raspoloživa mehanizacija na porodičnom gazdinstvu Šiljić
Table 2. Available mechanization on the family Farm Šiljić

Vrsta mehanizacije *Type of Mechanization*	Proizvođač *Manufacturer*	Tip mašine *Type ofMachine*	Broj komada *Num. of Pieces*	Godina proizvodnje *Year of Production*
Traktor *Tractor*	IMT Beograd	IMT -558	1	1979.
Plug *Plough*	IMT Beograd	IMT -577	1	1979.
Tanjirača *Disc harrow*	Lemind-Leskovac	TT-24/210	1	1980.
Drljača *Harrow*	IMT Beograd	IMT-611-4	1	1980.
Prskalica *Sprayer*	Jessernigg Austrija	Jessernigg 600	1	1983.
Prikolica *Trailer*	IMT Beograd	IMT 628.9	1	1980.

Porodično poljoprivredno gazdinstvo Šiljić, selo Selevac, Republika Srbija u proizvodnoj 2019/2020. godini je posejalo kulture: pšenice, kukuruza, suncokreta i tritikale. Najveći prinosi su ostvareni kod kukuruza od 8,0 t/ha, tritikale 5,5 t/ha, pšenica 4,9 t/ha, a najmanji prosečni prinosi su kod suncokreta 3,0 t/ha. (Tabela 1.)
Ovo porodično gazdinstvo poseduje mehanizaciju prema prikazu u Tabela 2.

Prema popisu poljoprivrede u Podunavskoj oblasti registrovano je 19.101 porodičnih poljoprivrednih gazdinstava koja koriste 73.336 ha, poseduju 13.781 dvoosovinska traktora (0,72 traktora/gazdinstvu) od kojih je 95,84% starije od 10 godina. Na teritoriji Opštine Smedervska Palanka registrovano je 6.747 poljoprivrednih gazdinstava koja obrađuju 27.782 ha korišćenog zemljišta sa 4.861 dvoosovinska traktora od toga 603 starije od 10 godina. Selo Selevac ima ukupno 831 registrovanih gazdinstava i 623 dvoosovinska traktora koji obrađuju ukupno 3.164 ha korišćenog zemljišta sa 3.059 priključnih mašina.

Na osnovu navedenih statističkih podataka može se zaključiti da u Podunavskoj oblasti porodična gazdinstva poseduju 0,72 dvoosovinska traktora /gazdinstvo, a jedan traktor obrađuje 5,32 ha korišćenog zemljišta. Slična je situacija i na teritoriji opštine Smederevska Palanka (0,72 traktora/gazdinstvo) i 5,71 ha po traktoru.

U selu Selevcu je 0,75 traktora/gazdinstvo koji obrađuju 5,1 ha korišćenog zemljišta sa 4,91 priključne mašine. To je prema broju traktora po farmi više od Mađarske (0,25), Portugalije (0,51), Italije (0,59), Srbije (0,64), a manje od Poljske (0,77), Crne Gore (0,84), Turske (0,99), Austrije (1,32), Slovenije (1,47), Francuske (1,58), Velike Britanije (2,05), kao i Hrvatske-Osječko Baranjske županije (3,3) traktora po farmi [17], [15], [8], [9], [19], [14], [10].

Tabela 3. Energetska opremljenost porodičnog Gazdinstva Šiljić sa mehanizacijom
Table 3. Energy equipment of family Farm Šiljić with mechanization

Traktor (kom.) *Tractor (pieces)*	Snaga traktora (kW) *Tractor power (kW)*	Energetska opremljenost (kW/ha) *Energy equipment (kW/ha)*	Obradiva površina po traktoru (ha) *Number of ha per tractor (ha)*	Broj priključnih mašina po traktoru (kom.) *Number attached machines per tractor (pieces)*	Obradiva površina po mašini (ha) *Number of ha per attached machines (ha)*
1	42,65	8,5	5,0	5	1

Opremljenost gazdinstva traktorima i odgovarajućim priključnim mašinama po asortimanu uslovljen je mnogim faktorima: veličina poseda, konfiguracija terena, struktura i obim proizvodnje, ekonomska moć gazdinstva i raspoloživa mehanizacija na tržištu. Registrovano porodično gazdinstvo Šiljić (selo Selvac) sa dvoosovinskim traktorom snage 42,65 kW obrađuje 5,4 ha sa 5 priključnih mašina i sa energetskom opremljenošću od 8,5 kW/ha (Tabela 3).

Poređenja radi, u Vojvodini na privatnom sektoru energetska opremljenost je 3,54 kW/ha, a na jedan traktor prosečne snage 40 kW dolazi 15,83 ha poljoprivrednog zemljišta. Korišćenje mehaničke snage traktora u Americi je 0,783 kW/ha, u Evropi 0,694 kW/ha, u Turskoj 2,42 kW/ha, u Poljskoj 4,9 kW/ha [1], [17], [8], [10]. U Srbiji jedan dvoosovinski traktor prosečne snage motora od 32,00 kW (43,52 KS) obrađuje 6,99 ha zemljišta sa 5,89 priključnih mašina u Turskoj 7,26, i Crnoj Gori sa 1,85 priključnih mašina po traktoru [17], [10], [14].

Tabela 4. Angažovanost mehanizacije u prizvodnji pšenice, kukuruza, suncokreta i tritikala
Table 4. Engagement of mechanization in the production of wheat, corn, sunflower and triticale

Kultura *Crop*	Pšenica (2 ha) *Wheat (2 ha)*		Kukuruz (1 ha) *Maize (1 ha)*		Suncokret (1 ha) *Sunflower (1 ha)*		Tritikale (1 ha) *Triticale (1 ha)*	
Agrotehnička mera *Agrotecnical Measure*	ER* EW*	PRV** AWT**	ER* EW*	PRV** AWT**	ER* EW*	PRV** AWT**	ER* EW*	PRV** AWT**
Oranje *Ploughing*	5,5	0,33	3,5	0,33	4,5	0,33	3,5	0,33
Priprema zemljišta *Soil Preparation*	3,0	0,33	2,0	0,33	2,0	0,33	2,0	0,33
Priprema zemljišta *Soil Preparation*	2,5	0,33	1,5	0,33	1,5	0,33	1,5	0,33
Primena herb. i folijarna ishrana *Application of Herbicides and Foliar Nutrition*	1,83	0,33	1,0	0,33	0,83	0,33	0,67	0,33
Transport *Transport*	2,0	0,68	2,0	0,68	0,67	0,33	0,66	0,33
Ukupna angažovanost traktora *Total Tractor Engagement*	14,83	2,0	10,0	2,0	9,5	1,65	8,33	1,65

*Efektivan rad (h); **Pomoćno radno vreme (h)
* Effective Work (h); ** Auxiliary Working Time (h)

Analizirano gazdinstvo Šiljić, u ovom radu, poseduje traktor i mehanizaciju koja je vrlo stara. Traktor IMT-558, a i ostale mašine nabavljene su 1979. godine i na gazdinstvu se koriste preko 42 godine. U Srbiji je 95% traktora starije od 10 godina [17].

Poređenja radi registrovani traktori u Hrvatskoj su 91,8% stariji od 10 godina, a prosečna starost registrovanih traktora u Sloveniji je 21 godina [15]. U Turskoj je 54%, traktora starije od 24 godine, a u Zapadnoj Turskoj je samo 12 % traktora starije od 20 godina [14]. U Crnoj Gori je 52% traktora starije od 20 godina, a 8,4% mlađe od 10 godina [10]. U Mađarskoj je prosečna starost traktora do 2013. godine bila 18,3, a u 2016. godini starost je 12 godina [9].

Analiza korišćenja traktora i mehanizacije gazdinstva Šiljić pokazuje da postoje značajne razlike u nivou između gajenih kultura po pojedinim grupama radova tj agrotehničkim merama (Tabela 4).

Traktor je najviše angažovan u proizvodnji kukuruza 10,0 h/ha, zatim suncokreta 9,5 h/ha, tritikala 8,33 h/ha, a najmanje pšenice 7,41 h/ha efektivnog rada. Rezultati prikazani u radu su u saglasnosti sa istraživanjima [5]. o angažovanosti traktora i mehanizacije u proizvodnji pšenice (7,03 h/ha) i kukuruza (24 h/ha), a veći od vrednosti koje navode u proizvodji suncokreta (7,85 h/ha). Isti autor [6], navode da je traktor u proizvodnji suncokreta korišćen 13,03 h/ ha, što je više od rezultata prikazanih u radu.

Struktura obima korišćenja traktora u proizvodnji 2019/2020 godine na Gazdinstvu na površini od 5 ha, pokazuje da je traktor od ukupno 42,66 sati ili 8,23 h/ha najviše korišćen sa plugom u osnovnoj obradi zemljišta u oranju 17,0 sati, ili 3,1 h/ha, zatim za predsetvenu pripremu zemljišta sa tanjiračom 9 sati ili 1,8 h/ha, drljačom 7 sati ili 1,4 h/ha. Na gazdinstvu je traktor najmanje korišćen sa prskalicom za zaštitu bilja od bolesti i štetočina, uništavanje korova i folijarno đubrenje svega 4,33 sati ili 0,87 h/ha (Tabela 5). Rezultati prikazani u radu o angažovanju traktora u osnovnoj obradi zemljišta u oranju su manji (3,85 h/ha) od onih koje navodi [6].

Tabela 5. Ukupna angažovanost mehanizacije porodičnog gazdinstvu Šiljić u sezoni 2019/2020
Table 5. Total engagement of mechanization on the family Farm Šiljić at the season 2019/2020

Primenjena mehanizacija *Applied Mechanization*	Efektivno radno vreme (h) *Effective Working Time (h)*	Efektivno radno vreme (h/ha) *Effective Working Time (h/ha)*	Pomoćno radno vreme (h) *Auxiliary Working Time (h)*	Ukupno radno vreme (h) *Total Working Time (h)*
Traktor *Tractor*	42,66	8,23	7,30	49,96
Plug *Plough*	17,0	3,1	1,32	18,32
Tanjirača *Disc harrow*	9,0	1,8	1,32	10,32
Drljača *Harrow*	7,0	1,4	1,32	8,32
Prskalica *Sprayer*	4,33	0,87	1,32	5,65
Prikolica *Trailer*	5,33	1,07	2,02	7,35

Prema [13] i [17], prosečno godišnje korišćenje traktora na porodičnim gazdinstvima u Srbiji je 421 sat. U Mađarskoj na malim farmama koje se bave ratarskom proizvodnjom angažovanost traktora je od 400 do 500 sati godišnje [12].

Istraživanj u ovom radu pokazuju da je traktor na gazdinstvu Šiljić nedovoljno iskorišćen, sa samo 50 sati godišnje, što je 8 puta manje od proseka u R.Srbiji.

Tabela 6. Prosečna potrošnja goriva po agrotehničkim merama
Table 6. Average fuel consumption by agrotechnical measures

Agrotehnička mera *Agrotechnical Measure*	Potrošnja goriva (l/ha) *Fuel consumption (l/ha)*
Oranje *Ploughing*	18
Tanjiranje *Disc-Harowing*	10
Drljanje *Harowing*	5
Primena pesticide *Application of Pesticides*	5
Transport proizvoda *Transport of Products*	5
Ukupno *Total*	43

Na porodičnom gazdinstvu Šiljić izvodi se klasična obrada zemljišta dvobraznim nošenim plugom i traktorom IMT 558 snage motora 42,6 kW (58 KS) na dubini do 25 cm i utrošeno je 18 l/ha (Tabela 6). Količina goriva utrošena za osnovnu obradu zemljišta pri oranju u našim istraživanjima je približna potrošnji goriva (20,79 l/ha) koju navodi [7] u proizvodnji kukuruza i pšenice. Rezultati o potrošnji goriva u oranju u radu su manji u odnosu na utrošak goriva (33,4 l/ha) koje navodi [11] u prizvodnji ozimog ječna, kao i utrošak goriva koje navodi [3] u proizvodnji kukuruza (39,75 l/ha) i ozime raži (32,36 l/ha). Razlika u povećanoj potrošnji goriva može se tumačiti različitim uslovima rada, osobina zemljišta, vlažnosti zemljišta, stanju i podešenosti pluga itd. Prema [4], potrošnja goriva zavisi od konstrukcije motora, ali i za isti motor se menja u zavisnosti od režima rada. Kako navodi [16], jedan od razloga za povećanu potrošnju goriva može da bude i ugao predpaljenja motora, gde su varijacije snage motora prouzrokovale promenu potrošnje koja je iznosila u oranju od 4,01- 6,86 kg/h dizel goriva (D-2).

Predsetvena priprema zemljišta obavljena je nošenom tanjiračom sa četiri sekcije pri čemu je utrošeno 10 l/ha. Navedeni rezultati istraživanja o potrošnji goriva u pripremi zemljišta sa tanjiračom su u saglasnosti sa istraživanjima (9,95 l/ha i 10,48 l/ha) koje navode autori [11] i [7]. Rezultati istraživanja u radu o potoršnji goriva za pripremu zemljišta su manji od potrošnje goriva sa traktorom iste snage sa tanjiračom (15,57 l/ha) i drljačom (7,34 l/ha) koju navodi [3] u proizvodnji kukuruza.

Radi bolje pripreme zemljišta u proizvodnji ratarskih kultura na gazdinstvu je pored tanjirače korišćena i klinasta drljača pri čemu je potrošeno 5 l/ha dizel goriva. Navedene vrednosti istraživanja su manje u odnosu na potrošnju goriva sa drljačom za pripremu zemljišta u proizvodnji heljde (7,68 l/ha) i ozime raži (7,84 l/ha) [2], kao i 6,93 l/ha u proizvodnji pšenice i kukuruza [7].

ZAKLJUČAK

Porodično gazdinstvo Šiljić spada u prosečna gazdinstva u R.Srbiji sa 5,4 ha obradivog poljoprivrednog zemljišta usitnjenog na ukupno 5 parcela.

U setvenoj strukturi u proizvodnoj 2019/2020. godini zastupljeni su kukuruz, tritikale i suncokret sa po 1 ha, pšenica sa 2 ha i 0,4 ha povrće za sopstvene potrebe.

Jedan deo proizvedenog zrna prodaje se na tržištu zadruzi, a drugi deo se koristi u pripremi krmne smeše za ishranu svinja.

U organizaciji i realizaciji proizvodnje ratarskih kultura za gazdinstvo Šiljić u ovom radu koristi se sopstvena mehanizacija i to: traktor 558, plug, drljača, tanjirača, prskalica i prikolica, nabavljeni 1979. godine. Vrlo je mala angažovanost sopstvene mehanizacije za izvođenje agrotehničkih mera u proizvodnji ratarskih kultura. Na godišnjem nivou traktor je ukupno angažovan sa svega 50 sati rada i to za oranje, predsetvenu pripremu zemljišta, primenu pesticida i transport.

Za izvođenje agrotehničkih mera u proizvodnji ratarskih kultura u sezoni 2019/2020. godine traktor je ukupno radio 42,66 sati (efektivno vreme) sa odgovarajućim priključnim mašinama i još 7,30 sati provedenih u transportu, odnosno u dolasku i povratku sa parcele (pomoćno vreme). Na godišnjem nivou traktor je ukupno angažovan svega 50 sati rada ili 8,23 h/ha i to za oranje 3,1 h/ha, predsetvenu pripremu zemljišta 3,2 h/ha, primenu pesticida 0,87 h/ha i transport 1,07 h/ha.

Na gazdinstvu Šiljić (selo Selevac, Republika Srbija) u proizvodnji ratarskih biljaka potroši se ukupno 43 l/ha i to najviše za oranje 18 l/ha, zatim za tanjiranje 10 l/ha, i 5 l/ha za drljanje, primenu pesticida i transport.

U cilju većeg i boljeg angažovanja traktora na gazdinstvu Šiljić u ovom radu je planirana nabavka: jedne sejalice za strna žita, jedne sejalice za okopavine, jednog rasipača mineralnih đubriva i jedan setvospremač.

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EQUIPMENT AND ENGAGEMENT OF MECHANIZATION ON THE FAMILY AGRICULTURAL FARM

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Abstract: The equipment and engagement of tractor and attached machines were examined on the example of the average family farm Šiljić in Serbia.

The research was performed on a registered agricultural farm in the village of Selevac, municipality of Smederevska Palanka. The family farm Šiljić has a total of 5,4 ha of used agricultural land. In production season 2019/2020 wheat was sown on 2 ha and 1 ha of maize, sunflower and triticale each. On the area of 0,4 ha is a backyard and garden. The farm owns a tractor IMT-558, a plough, a disc harrow, a harrow, a sprayer and a trailer, purchased in 1979. The old machinery is in use. The registered family farm Šiljić is insufficiently equipped with mechanization.

With a two-axle tractor with a power of 42.65 kW and 5 attached machines cultivates 5.4 ha, so the energy equipment is 8.5 kW/ha. The tractor is mostly engaged in the production of corn 10,0 h/ha, sunflower 9,5 h/ha, triticale 8,33 h/ha and the least is wheat 7,41 h/ha of effective work. On the farm Šiljić, on the area of 5 ha, out of a total of 42,66 hours of work, the tractor was mostly used in the basic tillage 17,0 h or 3,1 h/ha. The tractor is also engaged in pre-sowing soil preparation with a disc harrow 9 h (1,8 h/ha) and a harrow 7 hours (1,4 h/ha), in a transport 5,33 h (1,07 h/ha), in the application of pesticides with a sprayer 4,33 h (0,87 h/ha). In addition to the total effective work in the implementation of certain agro-technical measures in the production of field crops, the tractor was hired at 7,30 hours to leave and return from the plot (auxiliary working hours). Fuel consumption in basic tillage was 18 l/ha, in pre-sowing preparation with a disc harrow 10 l/ha, harrow 5 l/ha and 5 l/ha in the application of pesticides and transport of products.

Key words: *Family farm, mechanization equipment, engagement of tractors and attached machines, fuel consumption.*

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PERFORMANCE EVALUATION OF A MOTORIZED GINGER RHIZOMES PEELING MACHINE

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Abstract: A 5kg motorized Ginger rhizome (*Zingiber Officinale Roscoe*) peeling machine was designed, developed and tested. Three moisture contents (70%, 75% and 80% wb), three feed rates (54 kg/h, 68 kg/h and 73 kg/h) and three peeling speeds (230 rpm, 270 rpm and 300 rpm) were used for the performance evaluation of the machine. A $3 \times 3 \times 3$ factorial experiment in a randomized complete block design (RCBD); replicated two times was used to study the effects and interactions of the three factors (moisture content, feed rates and peeling speed) on the performance parameters (peeling efficiency, peeling capacity and percent damage). Relationship between performance parameters and the influencing factors were determined using multilevel factorial design and response surface methodology for the graphical analyses. The study showed that peeling efficiency increased from 82.3% to 88.5% with an increase in moisture content from 70% to 80%, a decrease in feed rate from 73 kg/h to 54 kg/h and an increase in peeling speed from 230 rpm to 300 rpm. Peeling capacity increased from 2.4 kg/h to 11.64 kg/h with an increase in moisture content from 70% to 80%, a decrease in feed rate from 73 kg/h to 54 kg/h and an increase in peeling speed from 230 rpmto300 rpm. Percent damage increased from 6.3% to 14.4% with a decrease in moisture content from 80% to 70%, an increase in feed rate from 54 kg/h to 73 kg/h and an increase in peeling speed from 230 rpm to 300 rpm. The analysis of variance (ANOVA) result showed that the interaction of moisture content, feed rate and peeling speed had significant effect on peeling efficiency, peeling capacity and percent damage at $p<0.05$ level. For a maximum peeling efficiency, peeling capacity and minimum percent damage, an optimum moisture content of 75%, feed rate of 68 kg/h and peeling speed of 270 rpm were recommended for use.

Key words: *Ginger rhizomes, performance evaluation, peeling capacity, peeling efficiency.*

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INTRODUCTION

Peeling of Ginger (*Zingiber Officinale Roscoe*) is an important unit operation where fully matured rhizomes are scraped with bamboo-splits having pointed ends, to remove the outer skin before drying to accelerate the drying process [1]. Although Ginger cultivation in Nigeria started in 1927 [2]. Peeling which is one of the unit operations in its local processing is still being done predominantly by traditional method (manual scraping with knife) which is labour intensive, full of drudgery and it equally exposes the hand to injury. Primary processing of Ginger rhizomes involves operations such as washing, slicing/splitting/peeling and drying [3]. Dried Ginger is produced from mature rhizome, since the flavour and aroma become much stronger as the rhizome matures. Rhizomes of dried Ginger may be left whole, peeled, split or sliced into smaller pieces to speed up drying [4]. Deep scraping with knife needs to be avoided to prevent damage to oil-bearing cells present just beneath the outer skin. Excessive peeling results in reduction of essential oil content in dried product [4]. Few industries that process Ginger in the country make use of imported machinery due to non-availability of simple locally developed machines for its processing and this has adversely affected the production and marketing of Ginger in Nigeria, in spite of its great economic potentials.

[1] developed a concentric drum brush type Ginger peeler with a capacity to peel 7 kg per batch. The optimum operating conditions for peeling Ginger were obtained at drum load of 7 kg, for inner drum speed of 45 rpm, outer drum speed of 20 rpm and for a peeling duration of 15 minutes. The peeling efficiency was 61% and the corresponding material loss was 5.33%. A brush type Ginger peeling machine with two continuous brush belts moving vertically in opposite direction was reported by [5]. The maximum peeling efficiency obtained for the brush type Ginger peeling machine was 84.3% at a belt speed of 85 rpm having a belt spacing of 1 cm. [6] reported the development of an abrasive brush type Ginger peeling machine consisting of two continuous vertical belts provided with 32-gauge steel wire brush, 2 cm long and having a peeling zone of 135 cm, had a maximum peeling efficiency of 85%.

Despite all the developments relating to Ginger peeling machine, the farmers still fall back to the manual method of peeling. In recognition of the constraints imposed by manual method of peeling Ginger, there is need to develop a motorized Ginger peeling machine that will be developed locally. This study therefore reports on the performance evaluation of a locally developed motorized Ginger rhizomes peeling machine.

MATERIALS AND METHODS

The study was conducted at the Postharvest Technology Laboratory, Department of Agricultural and Bioresources Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

Description of Developed Ginger Rhizome Peeling Machine

The motorized Ginger peeling machine consist of the following components: frame, feeding unit, pulley and belt drive, shoe pad, arm, shaft, crank shaft, cranking mechanism, discharge chute and gate. Figures 1and 2 shows the pictorial and isometric views of the developed motorized Ginger rhizomes peeling machine.

Fig. 1. Developed Ginger rhizomes peeling machine

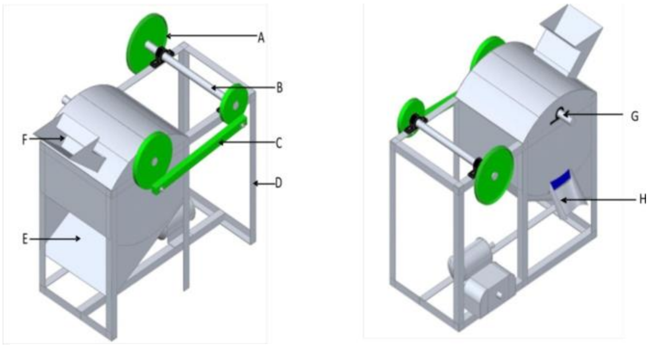

Fig. 2. Isometric view of the developed ginger rhizomes peeling machine Legend: A-Puley, B-Puley shaft, C-Connecting rod, D-Frame, E-Discharge shute, F-Hopper, G-Shoe pad shaft, H- Discharge gate

Frame

The frame holds all the components of the Ginger peeling device. It is designed to withstand torsional and vibrational forces. It has a length of 800 mm, width of 400 mm and a height of 830 mm.

Feeding unit (Hopper)

The hopper feeds the Ginger rhizomes into the peeling chamber where rhizomes are subjected to abrasive force from the abrasive shoe pad through the shaft rotation. It has a dimension of 300 mm by 230 mm and inclined at an angle of 40^0.

Pulley and belt drive

The pulleys which have diameter sizes of 85 mm, 250 mm and 300 mm transmits the mechanical energy from the shaft of the combustion engine to the shaft of the Ginger rhizome peeler.

Shoe pad

This is a not machine component that comes into direct contact with the Ginger rhizomes and provides the frictional force for peeling. The shoe pad (362 mm by 118 mm) is made-up of wire gauze material which has a rough surface. This material is attached to a flat bar using bolts and nuts for ease of replacement.

Arm

The arm is the component of the machine which carries the shoe pad for the peeling. It is joined to the shaft by welding. It has a hollow pipe which is welded to the shaft and then a solid part which slides inside the hollow pipe in order to alter the clearance. The solid arm (200 mm length and 10 mm diameter) is held firmly to the hollow pipe by screw after adjusting to the suitable clearance. The adjustment is to accommodate for the variation in the sizes of the Ginger rhizomes.

Shaft

The shaft of the Ginger rhizome peeling machine which has a length of 620 mm and a diameter of 25 mm transmits the mechanical energy that will be transmitted from the combustion engine through the pulley and belt drive system to the oscillating shoe pad.

Connecting rod

This transmits rotary motion given to the shaft by the motor to oscillating motion of the shoe pad which has a length of 480 mm and diameter of 15 mm.

Discharge chute

Discharge chute is an extension of the peeling unit whereby the peels of the Ginger rhizomes are discharged under gravity as they are being peeled. It has a dimension of 115 mm length, 300 mm width and an angle of inclination of 65^0.

Discharge gate

The discharge gate is a casing of 80 mm length and 305 mm width covering the peeling chamber which is inclined at an angle of 46^0 so that during the peeling operation the rhizomes do not splatter, rather its being opened after the operation for collection of the peeled Ginger rhizomes.

Working Principle of the Developed Ginger Peeling Machine

The kinematics upon which the machine works is the principle of quadric-crank mechanism. This principle converts rotary motion to oscillatory motion, whereas the force application for peeling uses the principle of attrition or shearing force principle. The shoe pad which comes in contact with the Ginger has conical projection on its surface. The machine prime mover is a 2.25 kW petrol internal combustion engine. The shoe pad is attached to an adjustable arm which is then attached to the shaft. The shaft is connected to the cranking mechanism through a connecting rod. As the pulley makes a rotary motion, this motion is converted to the oscillatory motion of the shaft, the arm and the shoe pad which are attached rigidly together. The shoe pad and the peeling chamber have a clearance which depends on the geometric mean diameter of the Ginger rhizomes. As the rhizomes are trapped in between the abrasive shoe pad and the abrasive peeling chamber; and the shoe pad performs an oscillating motion, the rhizomes are being peeled due to the friction between the Ginger and the abrasive surface of peeling chamber; Ginger and abrasive surface of the shoe pad and as well friction among the rhizomes. The peels fall through the openings on the peeling chamber through the discharge chute while the peeled Ginger rhizomes are collected from the discharge gate.

Experimental Procedure

Ginger rhizomes used for this study was sourced from Ntigha market in Isialangwa Local Government Area of Abia State, Nigeria. The rhizomes were cleaned and prepared ready for peeling. The machine was set into operation and allowed for 2 minutes before a known weight of Ginger rhizomes were fed into the peeling chamber through the hopper. The time taken together with the peeling shaft speed were noted and recorded. The peeled Ginger and peels were collected and weighed independently. The feed rate and moisture content were also determined. Each test carried out was replicated two times and at three levels of speed, moisture content and feed rate. The peeling speed, feed rate and moisture content were taken as independent parameters for this study. Three levels of peeling speed termed S_1, S_2 and S_3 (230, 270 and 300 rpm) were chosen in order to determine the optimum speed required for peeling Ginger rhizomes. Three levels of feed rate were also taken as F_1, F_2 and F_3 (54, 68 and 73 kg/h). Also, three levels of moisture content were taken as M_1, M_2 and M_3 (70, 75 and 80% wb).These parameters gave a $3 \times 3 \times 3$ factorial experiment replicated two times. This gave a total of 27 treatment combinations and 54 numbers of observations. The values obtained were used to calculate the performance parameters.

Performance Evaluation Parameters

The performance evaluation carried out on the developed Ginger peeling machine was assessed using the following parameters given by [6]:

$$F_R = \frac{Q_f}{t} \qquad \text{.......... (1)}$$

Where,

F_R = feed rate (kg/h)

Q_f = mass of Ginger rhizomes fed into the machine (kg)

t = time to finish the feeding (h)

$$\eta_p = \frac{(W_{sf} - W_{sm})}{W_{sf}} \times 100\% \qquad \text{......... (2)}$$

Where,

η_p = peeling efficiency of Ginger peeler (%)

W_{sf} = weight of skin on fresh Ginger (kg)

W_{sm} = weight of skin removed by hand trimming after mechanical peeling (kg)

$$C_p = \frac{Q_t}{t} \qquad \text{.......... (3)}$$

Where,

C_p = peeling capacity (kg/h)

Q_t = mass of Ginger rhizome peeled (kg)

t = time taken for peeling (h)

$$P_d = \frac{(W_1 - W_{sf}) - (W_2 - W_{sm})}{W_1} \times 100\% \qquad \text{......... (4)}$$

Where,

P_d = damage of Ginger (%)

w_1 = total weight of Ginger before peeling (kg)

w_2 = total weight of Ginger after mechanical peeling (kg)

W_{sf} = weight of skin on fresh Ginger (kg)

W_{sm} = weight of skin removed by hand trimming after mechanical peeling (kg)

Statistical analysis

Data obtained during performance evaluation of the machine were subjected to the Analysis of Variance (ANOVA) for the test of significance of experimental factors and their interactions. ANOVA for each factor was done using Minitab version 17.0 software package and a significance level of ($P<0.05$) was used for all the analyses. Relationship between performance parameters and the influencing factors were determined using multilevel factorial design and response surface methodology for the graphical analyses.

RESULTS AND DISCUSSION

Effect of Interaction of Experimental Factors on Peeling Efficiency

Peeling efficiency as shown in Fig. 3 increased from 82.9% to 88.5%with an increase in feed rate and decrease in moisture content. According to Fig.4, peeling efficiency increased from 82.3% to 87.8% with a decrease in moisture content and an increase in peeling speed which could be as a result of the increased friction between the rhizomes. [1] reported a maximum Ginger peeling efficiency of 62.86% when the outer drum speed was 25 rpm, the inner drum speed was 45 rpm and the peeling duration was 15 minutes at a constant drum load of 6 kg of Ginger. Also, the peeling efficiency decreased from 88.2% to 84.2% with an increase in feed rate and a decrease in peeling speed as shown in Fig. 5. There was significant effect in the interaction of moisture content, feed rate and peeling speed on peeling efficiency at $p<0.05$ level as presented in Table 1. [5] reported a maximum peeling efficiency of 84.3% in a vertical brush type Ginger peeling machine when the belt speed was 85 rpm at belt spacing was 1 cm. [7] reported that during abrasive peeling of potatoes in an abrasive drum type peeler, peeling efficiency increased with time. Similarly, peeling efficiency also increased with the increase in drum speed. This agrees with this study.

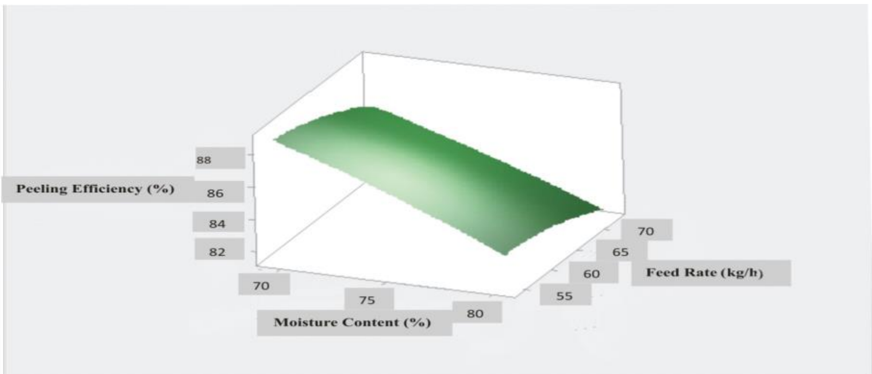

Fig. 3. Surface plot of interaction of moisture content and feed rate on peeling efficiency

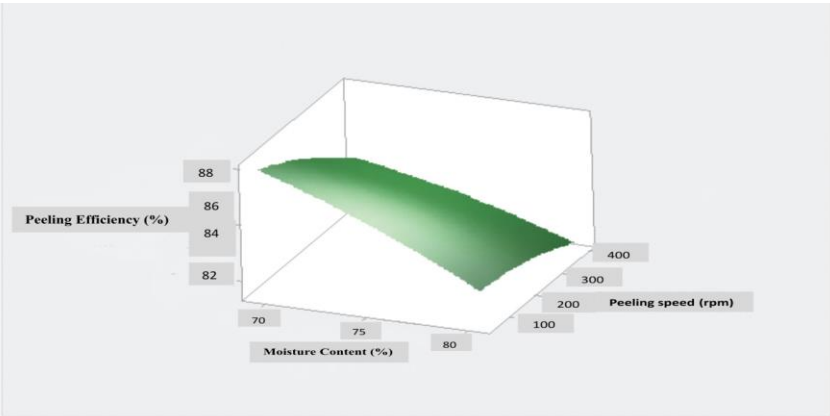

Fig. 4. Surface plot of interaction of moisture content and peeling speed on peeling efficiency

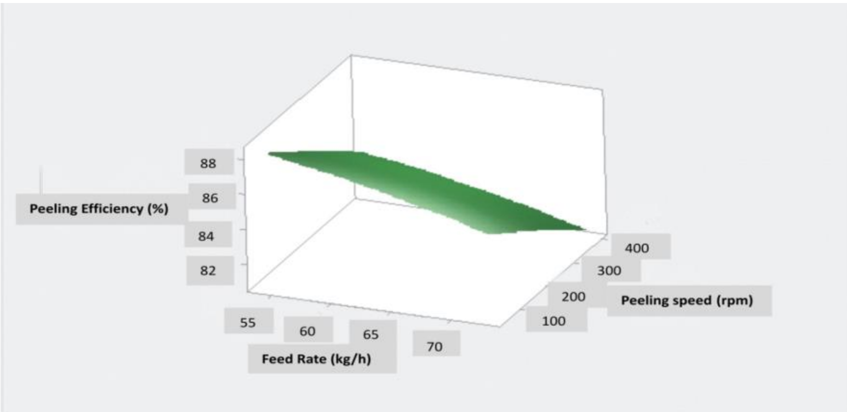

Fig. 5. Surface plot of interaction of feed rate and peeling speed on peeling efficiency

Tab 1. ANOVA for the effects of moisture content, feed rate and peeling speed on peeling efficiency

Source of Variation	DF	SS	MS	F-value	P-value
MC	2	8.61	4.31	2.07	0.1458^{NS}
FR	2	18.32	9.16	4.40	0.02218^{NS}
PS	2	4.60	2.30	1.11	0.3441^{NS}
MC*FR	4	11.85	2.96	1.42	0.2542^{NS}
MC*PS	4	7.27	1.82	0.88	0.4889^{NS}
FR*PS	4	7.97	1.99	0.96	0.4453^{NS}
MC*FR*PS	8	41.72	5.22	2.51	0.03507^{S}
Error	27	56.06	2.08		
Total	53	156.71			

Keynote:
MC - Moisture content; FR - Feed rate; PS - Peeling speed; DF- Degree of freedom; SS - Sum of squares; MS - Mean of squares; S - Significant; NS - Not significant

Effect of Interaction of Experimental Factors on Peeling Capacity

Figure 6 showed that the peeling capacity increased from 9 kg/h to 10.9 kg/h with an increase in feed rate and a decrease in moisture content. The peeling capacity as well decreased from 7.2 kg/h to 2.4 kg/h with a decrease in moisture content and a decrease in peeling speed (Fig. 7) which was due to a decrease in friction among the rhizomes. Also, peeling capacity increased from 3.2 kg/h to 9.8 kg/h with an increase in peeling speed and decrease in feed rate (Fig. 8) which was due to the amount of Ginger fed into the machine and also increase in friction due to increase in speed. In Table 2, the analysis of variance (ANOVA) showed that the interaction of moisture content, feed rate and peeling speed had a highly significant difference on peeling capacity at $p<0.05$ level. [8] reported that the average throughput capacity of cocoa yam peeling machine was highest (112.92 kg/h) at the operational speed of 933 rpm which was the most efficient for the operation of the machine.

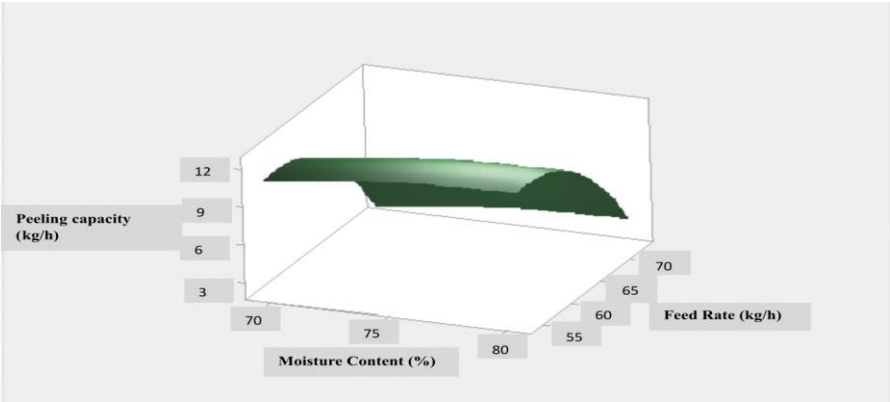

Fig. 6. Surface plot of interaction of moisture content and feed rate on peeling capacity

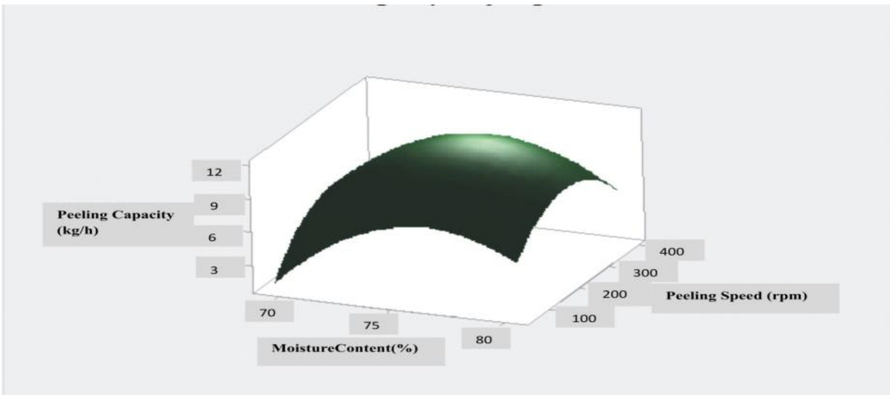

Fig. 7. Surface plot of interaction of moisture content and peeling speed on peeling capacity

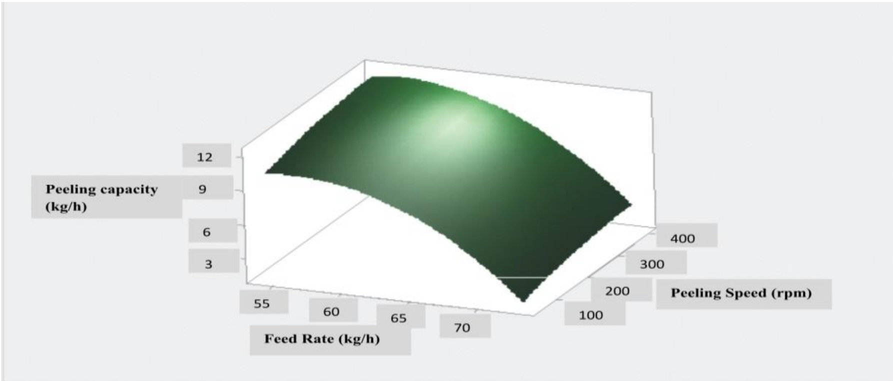

Fig. 8. Surface plot of interaction of feed rate and peeling speed on peeling capacity

Tab 2. ANOVA for the effects of moisture content, feed rate and peeling speed on peeling capacity

Source of Variation	DF	SS	MS	F-value	P-value
MC	2	0.60	0.30	115.38	0.00001^{S}
FR	2	305.76	152.88	58800	0.00001^{S}
PS	2	0.18	0.09	34.62	0.00001^{S}
MC*FR	4	0.58	0.145	55.78	0.00001^{S}
MC*PS	4	0.11	0.0275	10.58	0.00001^{S}
FR*PS	4	0.10	0.025	9.62	0.00001^{S}
MC*FR*PS	8	0.15	0.0188	7.23	0.00001^{S}
Error	27	0.07	0.0026		
Total	53	307.63			

Keynote:
MC - Moisture content; FR - Feed rate; PS - Peeling speed; DF- Degree of freedom;
SS - Sum of squares; MS - Mean of squares; S - Significant; NS - Not significant

The percent damage increased from 7.5% to 13.5%with an increase in moisture content and increase in feed rate as shown in Fig. 9. [1] observed a maximum material loss of Ginger at 6.15% when the outer drum speed was 25rpm, inner drum speed of 45 rpm and peeling duration of 15 minutes when the drum load was constant at 6 kg of Ginger.
At same time, the percent damage increased from 6.3% to 3.4% with an increase in peeling speed and increase in moisture content as shown in Fig. 10. [5] reported a substantial increase of flesh loss of Ginger when the speed was increased from 65 to 85 rpm.
Also, percent damage decreased from 14.4% to 6.9 %with a decrease in feed rate and a decrease in peeling speed as shown in Fig. 11. [6] reported a material loss of 3.27% in an abrasive brush type Ginger peeling machine when the peeling efficiency was 85.56%.
In Table 3, the analysis of variance (ANOVA) proved that the interaction of moisture content, feed rate and peeling speed had significant effect on percent damage at $p<0.05$ level.

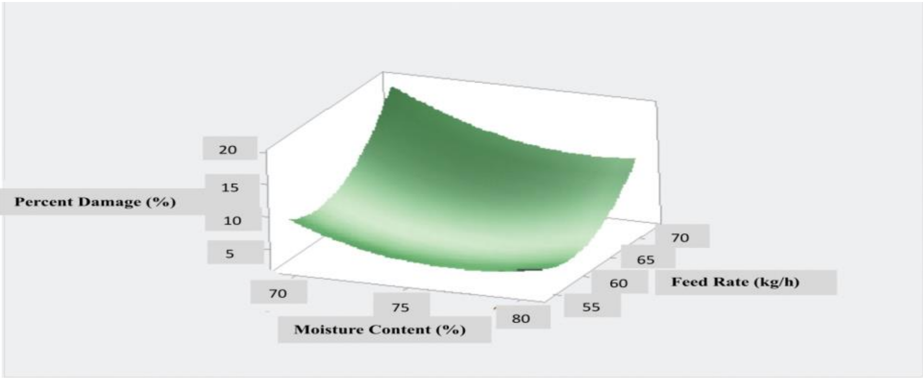

Fig. 9. Surface plot of interaction of moisture content and feed rate on percent damage

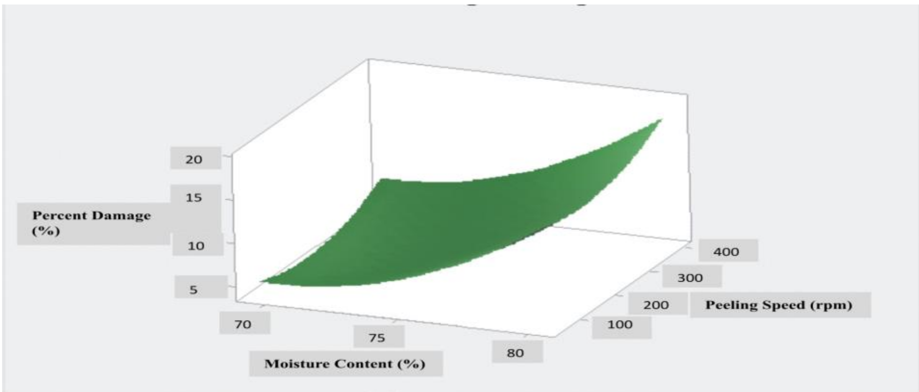

Fig. 10. Surface plot of interaction of moisture content and peeling speed on percent damage

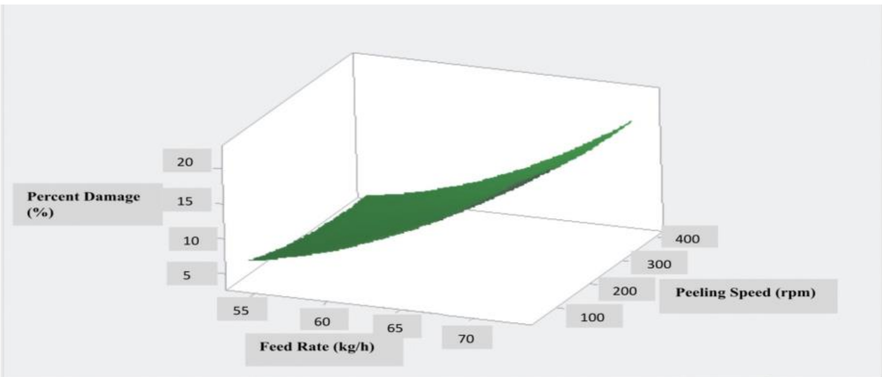

Fig. 11. Surface plot of interaction of feed rate and peeling speed on percent damage

Tab 3. ANOVA for the effects of moisture content, feed rate and peeling speed on percent damage

Source of Variation	DF	SS	MS	F-value	P-value
MC	2	84.94	42.47	151.68	0.00001^{S}
FR	2	291.34	145.67	520.25	0.00001^{S}
PS	2	3.74	1.87	6.68	0.0044^{S}
MC*FR	4	104.84	26.21	93.61	0.00001^{S}
MC*PS	4	4.99	1.25	4.46	0.00676^{S}
FR*PS	4	3.60	0.90	3.21	0.02802^{S}
MC*FR*PS	8	14.06	1.76	6.29	0.00013^{S}
Error	27	7.58	0.28		
Total	53	526.20			

Keynote:
MC - Moisture content; FR - Feed rate; PS - Peeling speed; DF- Degree of freedom;
SS - Sum of squares; MS - Mean of squares; S - Significant; NS - Not significant

CONCLUSIONS AND RECOMMENDATION

Conclusions

The following conclusions can be drawn based on the results of this study:

1. A motorized Ginger rhizomes peeling machine made from readily available materials was designed and developed. The machine is cheap and within the buying capacity of local farmers.
2. Peeling efficiency increased from 82.3% to 88.5% with an increase in moisture content from 70% to 80%, a decrease in feed rate from 73 kg/h to 54 kg/h and an increase in peeling speed from 230 rpm to 300 rpm.
3. Peeling capacity increased from 2.4 kg/h to 1.64 kg/h with an increase in moisture content from 70% to 80%, a decrease in feed rate from 73 kg/hto54 kg/h and an increase in peeling speed from 230 rpm to300 rpm.
4. Percent damage increased from 6.3% to14.4% with a decrease in moisture content from 80% to 70%, an increase in feed rate from 54 kg/h to 73 kg/h and an increase in peeling speed from 230 rpm to 300 rpm.
5. The interaction of moisture content, feed rate and peeling speed had significant effect on peeling efficiency, peeling capacity and percent damage at $p<0.05$ level.

Recommendation

For a maximum peeling efficiency, peeling capacity and minimum percent damage, an optimum moisture content of 75%, feed rate of 67 kg/h and peeling speed of 270 rpm were recommended for use.

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OCENA PERFORMANSI MAŠINE SA MOTOROM ZA LJUŠTANJE GINGER KORENA

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Sažetak: Dizajnirana, razvijena i testirana mašina sa motorom za ljuštenje korena đumbira u količini od 5 kg (Ginger) (*Zingiber Officinale Roscoe*).

Ispitivanje obuhvatilo tri vrednosti: sadržaja vlage (70%, 75% i 80% wb), brzine dodavanja (54 kg/h, 68 kg/h i 73 kg/h) i broja obrtaja rotora sa sečivom za ljuštenje korena (230 o/min, 270 o/min i 300 o/min), za ocenu performansi mašine. Trofaktorski eksperiment (3×3×3), sistem randomizovani kompletni blok dizajn (SRKBD) sa dva ponavljanja, korišćen za proučavanje efekata i interakcija tri faktora (sadržaj vlage, brzina uvlačenja krtole i brzina ljuštenja) na parametre performansi (efikasnost, kapacitet i % oštećenja) Ginger korena. Odnos između parametara performansi i faktora uticaja utvrđen je korišćenjem višefaktorskog dizajna i metode određene površine za grafičke analize.

Studija je pokazala da se efikasnost ljuštenja korena đumbira povećala sa 82,3% na 88,5% sa promenom sadržaja vlage sa 70% na 80%, smanjenjem brzine punjenja od 73 kg/h na 54 kg/h i povećanjem broja obrtaja rotora za ljuštenje od 230 o/min na 300 o/min.

Kapacitet ljuštenja korena je povećan od 2,4 kg/h na 11,64 kg/h uz povećanje sadržaja vlage od 70% na 80%, smanjenjem količine punjenja prijemnog koša od 73 kg/h na 54 kg/h i povećanjem brzine rotora za ljuštenje od 230 o/min na 300 rpm.

Oštećenje (%) korena đumbira (Ginger) je povećano sa 6,3% na 14,4% sa smanjenjem sadržaja vlage od 80% na 70% i sa povećanjem brzine dodavanja (punjenje) masom korena sa 54 kg/h na 73 kg/h, i povećanjem broja obrtaja rotora sa sečivom za ljuštenje Ginger korena od 230 o/min na 300 o/min.

Rezultat analize varijanse (ANOVA, softverski paket Minitab, ver. 17.0) pokazuje da interakcija faktora: sadržaj vlage, brzina uvlačenja i brzina ljuštenja ima značajan uticaj na efikasnost ljuštenja, kapacitet ljuštenja i procenat oštećenja Ginger korena (đumbira) na nivou tačnosti $p<0,05$.

Za maksimalnu efikasnost ljuštenja, kapacitet ljuštenja i minimalni procenat oštećenja, preporučeni su: optimalni sadržaj vlage 75%, brzina uvlačenja mase korena đumbira 68 kg/h i broj obrtaja rotora sa sečivom za ljuštenje Ginger (đumbir) korena (*Zingiber Officinale Roscoe)* od 270 o/min.

Ključne reči: *Ginger koren, procena performansi, kapacitet ljuštenja, efikasnost ljuštenja.*

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CROP - MACHINERY MANAGEMENT SYSTEM FOR FIELD OPERATIONS AND ADOPTED PLANNING TECHNIQUES FOR PLANTATION SUGAR CANE PRODUCTION

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Abstract: Major objectives of farm mechanization are to maximize production at minimum risks and optimum cost of equipment usage by good management planning and operation of machines to carry out sequence crop production operations for the whole farming system. Hence this study was needed at Sunti Golden Sugar Company, Nigeria to determine cost of equipment use and select appropriate tractor power and machinery for the crop cultivation, crop establishment, weed control, cane harvesting and transporting to the store for post- harvest processing for future target of 4,770 ha of sugar cane farm. Based on agricultural farm size, field operational planning factors like soil, weather/environmental conditions, each implement matched with appropriate tractor size was calculated. Costs of equipment use, ownership and operational costs for implements and tractors were also calculated. A well-drawn cropping field operations calendar was very important for crop and operational sequencing was recommended and was put in-place since the operations overlaps with multi-periods. As part of the recommendation, during the planned equipment downtime, major repairs and maintenance were to be carried out before critical field operation's period to improve pre-field and in-field efficiency for effective equipment and field operational planning and management. Determined are the values of each implement field capacity within allotted time available, actual number of implement/tractor power required, fuel and oil consumption per unit time for the sugar cane cultivation, harvesting and transporting operations at the sugar cane farm. Also appropriate earthmoving and earthwork equipment for road, irrigation and drainage structural works were also selected.

Key words*: Cropping calendar, machinery, management, operational, sequencing*

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INTRODUCTION

Agricultural mechanization is all forms of mechanical assistance at all levels of sophistication which usually involves injection of capital and is labour augmenting.

Agricultural mechanization must be seen in the context of a broad agricultural development strategy whose objectives are likely to be agricultural productivity in order to increase the sector's contribution to economic growth and security; increase rural welfare, income, employment, living standards and poverty alleviating; achieving social modernization, attitudes and behavior. Mechanization level decisions need to consider number one, farm power requirements to increase agricultural productivity and secondly appropriate technology that is cost effective, choice consistent with resources availability, social and economic objectives, [1]. Agricultural operation maximum profitability is possible with good knowledge of agricultural machinery management to eliminate costly mistakes for optimum system cost, [2].

Farm mechanization major objectives are to maximize production at minimum risks by good management planning and operation of machines to carryout sequence crop production operations for the whole farming system [3]. This requires study of relationship and identification of crop to be cultivated, operations, machines and weather which can control machine capacity in-term of width, speed, and field efficiency also selecting appropriate implement within time availability, operation and crop [3]. The goal of good crop-machinery management is to have a system that is flexible enough to adapt broad range of weather, soil and crop conditions at minimal long-run costs and production risks, [4].

Factors to be considered are machine performance to carryout operations, machinery running/operational costs, machinery size selection, operational timeliness like tillage, planting and harvesting dates effect on production, field capacity of machine, matching tractor power and implement size, operational scheduling for optimum output, [4].

MATERIAL AND METHODS

Characteristics of the study areas

Sunti Golden Sugar Estate is a subsidiary of Flour Mills of Nigeria Plc which is a 15,000 ha of acquired fadama land located at northern side of River Niger, southern part of Jebba Dam Hydroelectric Power Station, Niger State, Nigeria. Figure 1 is the layout of the estate features.

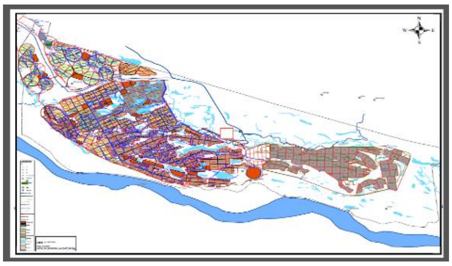

Fig.1. Features layout of the estate, Source: Sunti Golden Sugar Etsate map, 2018.

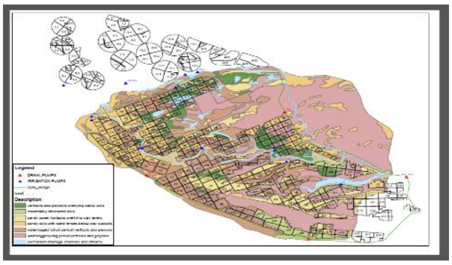

Fig.2. Soil map of the estate, Source: Sunti Golden Sugar Estate map, 2018.

Presently only about 4,770 ha of the land acquired was found suiTab. for sugar cane cultivation, 930 ha is the total land surface area covered by small lakes and channels of water. The remaining 9,300 ha of land was found not sui Tab. for sugar cane cultivation because of the soil high water Tab. level. The top soil depth ranged between 30 cm to 40 cm while available sugar cane varieties root depth is from 50 cm to 150 cm. Figure 2 is the soil map of the estate.

Agricultural Field Operations Planning.

The followings are the relevant information needed but most of it was not available from captured data for the current and previous cropping seasons:

- Field operational management hierarchy
- Take off time of cropping seasons and previous was required.
- Intended ratooning field to be cultivated, that is, size/season (ha/year).
- What was accomplished for ratooning (ha).
- Intended new field to be cultivated size/season (ha).
- What was accomplished for newly developed field (ha).
- Targeted plowing/harrowing operation (ha).
- Targeted row marking operation (ha).
- Targeted cane planting operation (ha).
- Targeted herbicide application operation (ha).
- Targeted fertilizer application operation (ha).
- Targeted soil moulding/forming of ratoon fields.

How much of these targets were achieved at specified time for the current and previous seasons?

What are the observed factors that resulted for not meeting the targeted operation for the current and previous seasons, for example:

- Field too wet and delayed machine operation (h) due to rainfall.
- Idle time travelling to field location (h).
- Machine clogged and sank in mud time which delayed operation (h).
- Average time spent in filling fertilizer box for application (h).
- Average time spent in filling sprayer with water and mixing chemical (h).
- Method and planting operation (h).
- Method and harvesting operation (h).
- Cane harvesting (h).
- Cane loading (h).
- Cane transportation to the factory (h).

Tillage implements rating size and width

- Rome harrow of disc size 711 mm (28'') and 5.6 m to 5 m width.
- Rome plow of disc size 914 mm (36'') and 2.55 m width for old ratoon and 1,067 mm (42") and 2.55 m width for newly developed land.
- Three row ridger of disc size 711 mm (28") and 5.5 m width.
- Single row ridger of disc size 711 mm (28'') and 1.2 m width.

Figures 3 and 4 are some of the tillage implements, while Figure 5 is a field prepared and was being planted with sugar cane at the study site during 2018 cropping season.

Fig. 3. A rome plow for deep plowing operation

Fig. 4. A soil moulding/forming implement

Fig. 5. Field being manually planted by both female and male laborers

Fig. 6. Crawler tractor mounted with raking Blade for land developmet windrowing, raking and root de-stumping

Land Development, Earth Works, Civil, Roads Equipment

Figure 6 is one of the crawler tractor mounted with equipment used for land clearing, raking and root de-stumper which was as well mounted with A Rome blade for tree felling and earth moving/work operations.

Irrigation and drainage system assessment

Factors for major source of water for the irrigation system in the estates and also major drainage channel to discharge excess water from fields for both irrigation and drainage assessment:

- Water available/storage for irrigation system were from abundance of scores of lakes/channels.
- Irrigation types in relation to soil classification.
- Sprinkler system (ha)/depth of application/irrigation scheduling.
- Rain gun system (ha) /depth of /irrigation scheduling.
- Availability of enough primary, secondary and tertiary lines, risers and sprinkler heads.
- Availability of labour to change lines, maintain/repair and operate pumps.
- Pivot system (ha) /depth of application/irrigation scheduling.
- Surface/flood system (ha) /depth of application/irrigation scheduling.
- Pumping capacity for overhead irrigation system, m^3/h.
- Pumping capacity for surface/flood irrigation system, m^3/h.
- Pump station maintenance and supply of fuel and servicing parts.

Fig. 7. One of the lake that is serving as sources of irrigation water/drainage outlet

Fig. 8. Sprinkler irrigation lines being assembled in irrigation workshop

The irrigation application depth requirement for the soil type is 180 mm to 200 mm per irrigation scheduling of 6 hours/day of 6 day circle. Figure 7 is a lake that is serving as one of sources of irrigation water/drainage outlet, Figure 8 is sprinkler irrigation lines being assembled in irrigation workshop, preparing for season's irrigation operation, Figure 9 is a pivot irrigation system, Figure 10 is an earth canal for surface irrigation, Figure 11 is a pump station for surface irrigation, Figure 12 is a completed drainage pump station lifting water above the dyke out of the field and Figure 13 is a fuel bowser for supplying fuel from one pump station to another.

Fig. 9. A pivot irrigation system

Fig. 10. An earth canal for surface irrigation

Fig. 11. Pump station for surface irrigation station

Fig. 12. A completed drainage pump lifting water above the dyke out of the field

Fig.13. A fuel bowser for supplying fuel from one pump station to another

There are several pump stations for irrigation and drainage operations, some with two pumps of 2,200 m^3/s and 220 kW from River Niger, a 410 kW motor pump at Batagi, a single pump to assist some field which is of 87 m^3/h capacity, five pumps in a station of 500 m^3/h, Sabotunga station with four pumps, Sunti station with four pumps, drainage pump station (DPS) 3 station with three giant pumps and DPS 6 with six giant pumps under construction because of serious drainage problem encounter during the raining season.

Machinery Management Procedure

This section dealt with farm equipment requirement determination for implements and source of power, tractor. This was determined by using operations required, area to be covered per unit time and implement type specified for the crop production procedure which consist machinery selection, power requirement and machinery costs [3].

The available period for land preparation at Sunti Golden Sugar was from October to April of the following year with December as break (6 months). The daily field day work starts from 8:00 am to 3:00 pm with one hour break (6 hours) from Monday to Saturday (6 days) and operates four weeks in a month at peak period of operations.

The target area to be covered is 4,770 ha out of 14,070 ha for future expansion on the total land acquired for the sugar cane plantation. The equipment selection was based on yearly ratoon/newly developed replanting of 1,000 ha for ripping, deep plow and row marking fields.

Field machine capacity requirement calculations

Machinery selection procedure was to determine the size and the number of implements and power units required to complete field operations within time available by calculating effective field capacity (ha/h). Required parameters include speed of field operation, field efficiency, available working days and available working hours per day [5].

I. **Field capacity**

Effective field capacity (C_a) on area basis is expressed in ha/h and was calculated using total farm area and total time available to carry out each field operation using eq. (1).

$$C_a = \frac{vwf}{10}\frac{ha}{h} \qquad (1)$$

Where:

v = travel speed, km/h, w = machine working width, m, f = field efficiency,

Or

Effective field capacity was calculated [3] as follows using eq. (2).

$$C_a = \frac{A}{Dxh} \qquad (2)$$

Where:

A = area under operation, ha, D = available working days,

h = available working hours per day, h

From eq. (2) when area A is 1,000 ha for ripping of replanted/newly developed fields:

$C_a = \frac{1,000}{6x6x3x4}$ = 2.31 ha/h

II. **Required width**

For heavy- duty plowing/tandem disk harrow, if field efficiency,

f is 75% and operating speed, v is 7 km/h from eq. (1).

With $C_a = \frac{vwf}{10}$ = 2.31 ha/h

Then, $w = \frac{2.31x10}{7x0.75}$ = 4.40 m

III. **Number of machine(s) required**

Number of machine(s) required M was calculated using eq. (3).

$$M = \frac{W}{MAWW} \qquad (3)$$

Where: M = number of machine required,

$MAWW$ = maximum available working width, m

Effective field capacity C_m on a material basis is expressed in Mg/h using eq. (4)

$$C_m = \frac{vwYf}{10} \qquad (4)$$

Where:

C_a = field capacity, area basis, ha/h (C_{at} when ♌f = 1.0),
C_m = field capacity, material basis, Mg/h (C_{mt} when f = 1.0),
Y = crop yield, Mg/ha.

IV . **Machinery power requirement**

Machinery field operation draft and power requirements are important when selecting tractors and implements because tractors must be of adequate size to meet implement draft requirements. Tractors' engine or self-propelled machines must be large enough to supply the power requirements of the field operations on which this was based, [5].

(a). **Draft requirement calculation** using eq. (5).

$$D = F_i(A + Bv + Cv^2)wd \qquad \text{.......................................(5)}$$

Where:
D = implement draft, F_i = dimensionless texture adjustment factor,
i = 1 for fine, 2 for medium, or 3 for coarse textured soils,
A, B, and C = implement specific constants,
d = tillage depth, cm (use 1.0 for minor tillage tools and seeders),
v – travel speed, km/h.

(b). **Drawbar power calculation** using eq. (6).

$$P_{db} = \frac{Dv}{3.6} \qquad \text{.......................................(6)}$$

Where:
P_{db} = drawbar power, kw

(c). **Power take off (PTO) power determination:**

This can be estimated using Fig. 15.1in [5] where 4WD tractive condition for firm soil = 0.78 and tilled soil = 0.75.
And for self-propelled machines that has rotary power. Power – takeoff (PTO) power required to power the implement from PTO shaft of the tractor or engine. Implement power take-off power can be calculated using eq. (7).

$$P_{pto} = (a + bw + cCm) \qquad \text{...................... (7)}$$

Where:
P_{pto} = power-takeoff rotary power required by the implement, kW,
w = implement working width, m,
Cm = material feed rate on wet basis, t/h, a, b, c = machine spec. constants from Tab. 3
For some machines, drawbar power requirement must be added to the rotary power requirement to obtain the total power requirement.

V . **Cost of equipment use**

Equipment cost of use includes charges for ownership and operation cost. The ownership costs or fixed or overhead costs are usually independent of use but being owned which is termed as fixed cost like depreciation, shelter, interest on capital and inflation, insurance and taxes. Operation costs vary directly with the amount of use called variable cost like repair, maintenance, labour, timeliness, fuel, oil and lubricants, [7].

(a). **Total annual ownership costs:**

Generally speaking, equipment ownership costs include equipment depreciation, interest on the investment, and cost of taxes, insurance and housing or shelter of the equipment. Hence total annual costs can be expressed as follows using eq. (8)

$$C_{os} = \frac{Coa}{Pu} = (1 - S_v)\left[\frac{i(1+i)^L}{(1+i)^L - 1}\right] + \frac{k}{100} \quad \text{.....(8)}$$

Where:
C_{os} = specific annual ownership costs, per year,
C_{oa} (decimal) x purchase price = average annual ownership cost of machine,
S_v = salvage value factor of machine at end of machine life year, L, decimal,
L = machine life, year, i – interest ratio, decimal,
K = annual ownership cost of taxes, housing/shelter, and insurance: normally expressed as a percentage of purchase price, decimal.

Also, this can be estimated using eq. (9) [8].

$$C_o = 100\left[\frac{1-Sv}{L} + \frac{1+Sv}{2}i + k\right] \quad \text{.....(9)}$$

Where:
C_o = ownership cost in %. P_u $(1+i)^L$

(b). **Operating costs:**

Repair and maintenance cost

Repair and maintenance is to keep equipment operational due to wear, part failures, accidents and normal operational determination. Accumulated repair and maintenance costs at a typical field speed can be determined using eq. (10) [9].

$$C_{rm} = (RFI)Pu\left(\frac{t}{1000}\right)^{RF2} \quad \text{.....(10)}$$

Where:
C_{rm} = accumulated repair and maintenance costs, N, $RF1$ and $RF2$ are repair and maintenance factors (Tab. 3 in [9] and (Tab. 15.1 in [5],
Pu = purchase machine list price in current Naira. For rapid inflation rate, the original list price must be multiplied by $(1+i)^n$, where i is the average inflation rate and n is the age of machine,
t = accumulated use of machine, h.
To correct for inflation, the purchase price (Pu) in equation above is multiplied by $(1+i)^n$ i.e Pu = $Pu(1+i)^n$, hence accumulated repair and maintenance costs vary from year to year. Average hourly cost of repair and maintenance can be estimated by estimating the total economic life of the machine in hours, using equation 19 to calculate the total repair and maintenance costs over the life of the machine and dividing the total economic life in hours. One can obtain the average repair and maintenance cost per hectare of area worked by the machine by dividing the average cost by machine capacity, C_a.

Example from equation above, with data in Tab. 15.1 shows that for tractor, total repair and maintenance costs over or divide by the life of a tractor is equal to the purchase price of the tractor.

Fuel consumption

Fuel consumption for diesel engine was calculated using eq. (11) [2]

$$Q_f = 0.226\,Pbd \quad \text{.....(11)}$$

$$Q_{fav} = 0.305\,Ppto$$

Where:
Q_f = fuel consumption, l/h, Q_{fav} = average fuel consumption, l/h

Fuel consumption for a particular operation was calculated using eq. (12) [8].

$$Q_i = Q_s P_T \quad (12)$$

Where:

Q_i = estimated fuel consumption for a particular operation, l/h,

Q_s = specific fuel consumption for given tractor, l/kWh, [9].

Costs of fuel and oil

Any given operation per hectare fuel (or oil) cost was calculated using the following eqs. (13) and (14), [5] :

$$C_s = \frac{P_l Q_i}{C_a} \quad (13)$$

Where:

C_s = per hectare fuel (oil) costs, P_l = price of fuel (oil), N/l,

Q_i – fuel (oil) consumed by engine, l/h,

C_a = effective field capacity during the operation, ha/h.

$$SFC_v = 3.91 + 2.64X - 0.263\sqrt{(173} + 738X) \quad (14)$$

If $X > 0.856$, then $SFC_v = 0.411$ l/kWh

Where:

SFC_v = specific fuel consumption, volume basis, l/kWh,

X = ratio of equivalent PTO power requirement to maximum available PTO power.

Usually, values of X range between 0.2 for spraying operations to 0.85 for primary tillage. Product of SFC and equivalent PTO power needed for the operation gives Q_i and the estimated fuel consumption to perform the operation.

Engine oil consumption

This is estimated as 15% of total fuel cost [9] gives equation for estimating oil consumption of gasoline, diesel and LPG engines. The eq. (15) was used for diesel engines calculated:

$$Q_{io} = \frac{21.69 + 0.59P_r}{1000} \quad (15)$$

Where:

Q_{io} = oil consumption, l/h, P_r = rated engine power, kW.

Total cost of all lubricants can be estimated equal to 10% - 15% of fuel costs.

Labour cost

Labour cost can be estimated for owner-operators from alternative opportunities for use of time. For hired operators, a constant hourly rate is appropriate and for two cases the charges should not be less than a typical community labour rate. Also a portion of the tractor ownership costs must be included in the cost of use of implements.

(c) Timeliness costs:

In agricultural operations, there is an optimum time of the year to perform some field operations and economic penalties are incurred if the operations are performed too early or too late. It is thus economically justifiable to increase machine costs through purchase of a machine of greater capacity when the larger machine will accomplish more timely work. Hence the term timeliness is important when carrying out machinery cost analyses.

Timeliness cost was calculated by using eq. (16) [5].

$$C_t = \frac{K_t\, AYV}{ZTCaPwd} \qquad (16)$$

Where:
C_t = timeliness cost, N/ha,
K_t = timeliness coefficient, fraction of annual crop value lost per day (Tab. 4)
Y = crop yield, t/ha,
A = crop area, ha/year,
V = crop value, N/t,
Z = 2 if operation commences or ends at optimum time, 4 if operation can be balanced evenly about optimum time,
T = expected time available for field work, h/day,
C_a - effective field capacity of machine, ha/h.

Also timeliness cost can be estimated from a timeliness coefficient obtained from [9] clause 8. Annual timeliness cost for an operation was estimated using eq. (17).

$$W = \frac{K_3 A2\, YV}{ZTCaPwd} \qquad (17)$$

Where:
W = annual timeliness cost, N,
K_3 – timeliness coefficient obtained from [9]

Equipment Operational Planning and Control

The tractor power and machinery size for the crop cultivation, crop establishment, weed control up to harvesting and transporting for the post- harvest processing store were determined to match each other in terms of row spacing and established tramline to reduce long time soil compaction problem, [10]. The headland or trace size for appropriate connected tractor and implement length to reduce turning time must be put in-place for each block of field.A well- drawn cropping field operations calendar was very important for crop and operational sequencing and be put in-place since the operations are overlapping with multi-periods. Resources like fuel and oil, equipment spare parts, fertilizer, insecticides, herbicides and their availability are limiting factors to be considered [11].

RESULTS AND DISCUSSION

Based on agricultural field operational planning factors like soil, weather and environmental conditions, appropriate implement matched with tractor calculations were carried out to obtain Tab. 1, Tab.1.1; Tab. 2., Tab. 2.1. and Tab.3.

Tab.1., Tab.1.1., shows the values of each implement field capacity it in allotted time available, actual number of implement/tractor required, ownership and operational costs. Tab.2., and Tab.2.1., show the same calculated cost values of pool of excess implements from which choice could make if need be while Tab.3 is similar calculation for self-propelled equipment for earth works like land clearing/development, road, drainage, irrigation and dyke construction/maintenance works.

From fleet of available prime mover, tractor in the sugar cane plantation, total power required to power the implements were determined for 4,770 ha of sugar cane cultivation, harvesting and transporting operations. Also appropriate earthmoving and earthwork equipment for road, irrigation and drainage work were determined.

As part of the recommendation, during the planned equipment downtime, major repairs and maintenance are to be carried out before critical field operations' period to improve pre-field and in-field efficiency, [2].

To improve machinery performance efficiency, [10], proper breakdowns communication reporting and daily record of every equipment operational record keeping will go a long way to make the machinery selected function well within the determined system.

The company, most of the time, has being responsible for the community road maintenance. Fertilizer and chemical applications are manually and knapsack applied respectively, hence so far, it has not started polluting the environment. Also waste water from the factory is being treated, hence not affecting stream water for now. In future when the company's operation will be fully mechanized, additional safety precautions/measures to control environmental and air pollution must be put in place.

Tab.4., is the cropping calendar of 4,770 ha which was based on crop cultivation operation sequence, soil type and condition, weather condition and Staff public holiday within the cropping season.

With this, the machinery power requirement, optimum size and number of equipment were determined based on total area under cultivation per season. Cropping field operations calendar shows that crop and operational sequencing is very important and hence thereby recommended to be put in-place since the operations are overlapping with multi-periods with peak periods of 1,332 h/month in November to 1,512 h/month in February. There must be adequate machinery management from November to April of the following year if the operational target of cultivating 4,770 ha of sugar cane with the fleet of the equipment and time available must be met as in Tab. 1.; Tab.1.1. and Tab. 2., Tab.2.1.

Table 1. Recommended Machinery and Capacity Operation Requirement for Sunti Sugar cane 4,770 ha

	Implement/Operation											
	Implement Specifications							Owners Costs	Operating /Timeliness Costs			Total Costs
S/ No	Implement/ Equipment Operation/power required, kW	Time avai. mont	Field capacit yare, ha/h	Field capacit materia t/h	Total implem. capacity required width, m or ton.	Num of imp. req.	Estimated Purchase price, (N)	Total annual owners. cost, N/ha	Cost of oil cons. med, N/h	Repair and mainten.c ost, N/ha	Time liness penalty cost, N/ha	Total operating costs N/ha
1	Ripping, Subsoiler/165.56	3	2.31		4.40/3.00	2	6,360,000	1,399.20	51.41	4,699.56	29,739.2 5	34,490.22
2	Deep plow/293.87	4	1.74		3.31/2.50	2	20,400,000	4,488.00	95.62	11,934.0	23,791.4	40,309.02
3	Rome harrow,28'' Dia./5.6m/123.00	4	3.48		6.62/5.60	2	11,200,000	2,464.00	54.14	6,552.00	28,371.2	37,441.39
4	Row marking/38.98	4	1.74		2.84/3.00	1	2,708,500	595.87	32.26	1,644.06	23,791.4	26,063.59
5	Selfpropelled cane planter-ACME 2AZ-2/131.13	4	8.28		23.01/3.0	8	22,250,000	4,895.00	60.48	16,682.9	31,438.6	53,076.98
6	Valtra Mould former-BT MP2/145.83	4	8.28		11.83/3	4	2,504,110	115.49	6.29	318.66	23,791.4	24,231.84
7	Fertilizer Spreader/74.60	2	16.57		33.83/4.5	8	7,500,000	345.91	9.69	1,255.51	31,438.6	33,049.74
8	Row crop cultivator, weeder/67.14	2	16.57		22.09/4.5	5	2,848,500	131.38	7.38	362.47	28,371.2	28,872.48
9	Boom sprayer ALFA 1000/106.81	2	16.57		36.40/18	2	2,970,000	136.98	12.22	432.46	37,490.5	38,072.24
10	JD. Cane Harvester 3520/251.00	4	8.28	578.08	13.77/3	5	80,465,000	3,508.75	25.77	6,778.03	149,962.	160,274.87

Continued Table 1

11	JD Cane loader 6068T/138.00	4	8.89	578.08	333,000/40 ton/h	13	51,198,000	10,649.1	62.21	4,636.80	69,864.3	85,212.53
12	Cane wagon transporter/72.76	4	8.89	578.08	333,000/15 ton/load	33	5,775,000	251.82	7.99	959.50	69,864.3	71,083.65
13	Cane stubble shaver/ratoon manager/86.27	As req.	1.50			As req	2,298,407	1,011.30	45.50	6,870.14	35,491.1	43,418.04
14	Sugar cane sett cutter/ chopper/65.52	As req.	5.55			As req	44,787,727	18,631.7	35.14	52,934.5	12,065.6	83,667.03
15	Bowser- FKWT 3000L/52.20	As req.	3000L/ load		3000L/ load	As req	2,385,000	524.70	30.53	1,030.32		1,585.55
16	Cane loader BM100/74.60	As req.	8.89	578.08		As req	25,000,000	5,200.00	38.02	10,800.0	69,864.3	85,902.36
17	Cane loader Bell/49.00	As req.	5.39	350.33		As req	24,000,000	4,992.00	29.38	10,368.0	115,230.	130,620.17
18	Cane loader 1850/78.00	As req.	8.89	578.08		As req.	40,000,000	8,320.00	39.17	17,280.0	69,864.3	95,503.51

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 1.1. Recommended Machinery Cost of Field Equipment for Sunti Sugar cane 4,770 ha

		Tractor/Prime mover							
		Power Ratings		Owner ship Costs	Operating Costs				Total Costs
S/No	Implement/ Equipment Operation/power required, kW	Equipment/ power, kW	Estimated Purchase price, (N)	Total annual ownership cost, N/ha	Cost of fuel cons., N/ha	Cost of oil cons. N/ha	Repair and maintena. cost, N/h		Total operating costs N/ha
1.	Ripping, Subsoiler/165.56	J. D. tract. 7225J/168.00	48,000,000	10,416.00	2,807.14	52.27	20,736.00		33,959.14
2.	Deep plow/293.87	J.D.Tract, 8970/298.00	88,000,000	19,096.00	7,456.32	114.05	38,016.00		64,682.37
3.	Rome harrow, 28'' Dia./5.6m/123.00	Valtra med. tractor, T171/134.00	30,000,000	6,517.50	3,359.23	58.18	12,960.00		22,894.91
4.	Row marking/38.98	J.D. tract. 2650/58.20	13,000,000	2,886.00	724.03	32.26	5,616.00		9,258.29
5.	Selfpropelled cane planter ACME-2AZ2/131.13	Valtra Tract. T191/141.00	35,000,000	7,603.75	3,162.24	60.48	15,120.00		25,946.47
6.	Valtra Mould former BT-MP2/145.83	J. D.Tract. 4960/149.00	45,000,000	1,962.26	922.75	13.31	4,075.47		6,973.79
7.	Fertilizer Spreader/74.60	Valtra Tract. BM- 125i/98.40	23,480,000	1,026.25	420.72	9.69	2,126.49		3,583.15
8.	Row crop cultivator, weeder/67.14	J.D.Tractor 3350/74.60	17,000,000	791.19	1,025.11	432.78	1,539.62		3,788.70
9.	Boom sprayer ALFA 1000/106.81	Valtra Tract. T171/134.00	30,000,000	1,366.35	412.73	12.22	2,716.98		4,508.28
10.	JD. Cane Harvester 3520/251.00	Self prop./ 251.00	80,465,000	3,508.75	2,048.41	25.77	6,778.03		12,360.96

Continued Table 1.1.

11.	JD Cane loader-6068T/138.00	JD Cane loader6068T/138.00	51,198,000	10,649.18	1,931.93	62.21	22,117.54	34,760.86
12.	Cane wagon transporter/72.76	J.D. Tract. 3350/74.60	17,000,000	791.19	366.27	7.99	1,539.62	2,705.07
13.	Cane stubble shaver/ratoon manager/86.27	Valtra Tract. BM 125i/98.40	23,480,000	9,790.38	2,108.16	46.08	20,286.72	32,231.34
14.	Sugar cane sett cutter/ chopper/65.52	J.D. Tract. 3050/67.60	44,787,727	18,631.70	1,546.56	35.14	52,934.55	73,147.95
15.	Bowser- FKWT 3000L/52.20	John Deere tractor, 2650/58.20	13,000,000	2,886.00	1,594.94	30.53	5,616.00	10,127.47
16.	Cane loader. BM100/74.60	Cane loader BM100/74.60	25,000,000	5,200.00	2,083.97	38.02	10,800.00	18,121.99
17.	Cane loader. Bell/49.00	Cane loader Bell/49.00	24,000,000	4,992.00	824.26	29.38	10,368.00	16,213.64
18.	Cane loader. 1850/78.00	Cane loader 1850/78.00	40,000,000	8,320.00	2,139.26	39.17	17,280.00	27,778.43

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 2. Capacity and Cost of Field Equipment Operation Requirement of Available Additional Machinery from which choice could be made

	Implementation/Operation								
	Implement Specifications					Owner. Costs	Operating /Timeliness Costs		Total Costs
S/No	Implement/ Equipment Operation/power required, kW	Time avail., month	Fiel. cap. area, ha/h	Num of impl. req.	Estimated Purchase price, (N)	Total annual ownersh. cost, N/ha	Cost of oil cons. N/h	Repair and maintenance cost, N/ha	Total operating costs N/ha
1.	Rome plow, 36'' Dia./2.55m/179.00	As req.	1.25	As req.	19,400,000	8,536.00	119.00	22,698.00	24,353.00
2.	Rome plow, 42'' Dia./ 2.55 m/242.50	As req.	1.25	As req.	20,400,000	8,976.00	166.00	23,868.00	33,010.00
3.	Rome harrow, 28'' Dia./ 5.6 m/123.00	As req.	4.20	As req.	11,200,000	4,928.00	94.00	13,104.00	18,126.00
4.	Rome harrow,28'' Dia./5 m/123.00	As req.	3.75	As req.	11,200,000	4,928.00	94.00	13,104.00	18,126.00
5.	3 row Ridger,28'' Dia./ 5.5 m width/67.10	As req.	2.70	As req.	1,359,384	598.13	61.00	1,590.48	2,249.61
6.	Single row ridger mounted on VTR-16, 28'' Dia./1.2 m/48.50	As req.	0.59	As req.	1, 241,767	546.38	50.00	1,452.87	2,049.00
7.	Light duty tract. plow/0.8 m/45.00	As req.	0.39	As req.	1,600,000	704.00	48.00	1,872.00	2,624.00
8.	Medium duty tract.plow/ 01.2 m/74.60	As req.	0.59	As req.	1,800,000	792.00	66.00	2,106.00	2,964.00

Continued Table 2.

9.	Heavy duty tract. plow/1.5 m/97.00	As req.	0.74	As req.	2,200,000	968.00	79.00	2,574.00	3,621.00
10.	Light duty tract. harrow /3.0 m/45.00	As req.	2.25	As req.	2,000,000	880.00	48.00	2,340.00	3,268.00
11.	Medium duty tract. harrow/ 5.0 m/74.60	As req.	3.75	As req.	2,400,000	1,056.00	66.00	2,808.00	3,930.00
12.	Heavy duty tract. harrow/ 6.5 m/97.00	As req.	4.88	As req.	3,000,000	1,320.00	79.00	3,510.00	4,909.00

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 2.1. Capacity and Cost of Field Equipment Operation Requirement of Available Additional Machinery from which choice could be made

	Tractor/Prime mover						
	Power Ratings		Ownership Costs	Operating Costs			Total Costs
S/No	Implement/Equipment Operation/power required, kW	Estimated Purchase price, (N**)**	Total annual ownership cost, N/ha	Cost of fuel con. N/ha	Cost of oil cons. N/ha	Repair and maintence cost, N/h	Total operating costs N/ha
1.	Rome plow,36’’ Dia./2.55m/179.00	68,000,000	29,512.00	13,095.00	184.00	58,752.00	101,543.00
2.	Rome plow, 42’’ Dia./2.55 m/242.50	68,000,000	29,512.00	13,095.00	184.00	58752.00	101,543.00
3.	Rome harrow, 28’’ Dia./5.6 m/123.00	30,000,000	13,035.00	5,832.00	101.00	25,920.00	44,888.00
4.	Rome harrow, 28’’ Dia./5 m/123.00	30,000,000	13,035.00	5,832.00	101.00	25,920.00	44,888.00
5.	3 row Ridger, 28’’ Dia./5.5 m width/67.10	17,000,000	7,548.00	3,576	66.00	14,688.00	25,878.00

Continued Table 2.1.

6.	Single row ridger mounted on VTR-16, 28'' Dia./1.2 m/48.50	13,000,000	5,772.00	2,769.00	56.00	11,232.00	19,829.00
7.	Light duty tract. plow/0.8 m/45.00	13,000,000	5,772.00	2,769.00	56.00	11,232.00	19,829.00
8.	Medium duty tract. plow/1.2 m/74.60	18,000,000	7,488.00	4,071.00	72.00	15,552.00	27,183.00
9.	Heavy duty tract. plow/1.5 m/97.00	23,480,000	9,790.38	3,561.00	80.00	20,286.72	33,717.72
10.	Light duty tract. harrow/3.0 m/45.00	13,000,000	5,772.00	2,769.00	56.00	11,232.00	19,829.00
11.	Medium duty tract. harrow/5.0 m/74.60	18,000,000	7,488.00	4,071.00	72.00	15,552.00	27,183.00
12.	Heavy duty tract. harrow/6.5 m/97.00	23,480,000	9,790.38	3,561.00	80.00	20,286.72	33,718.10

Table 3. Sunti Sugar cane 4,770 ha Recommended Machinery Capacity and Cost of Self-propelled Field Equipment Operation Requirement for Earthworks

	Implement								
	Implement Specifications				Ownership Costs	Operating /Timeliness Costs			Total Costs
S/No	Implement/Equipment/ power required, kW	Eq. cap., area. ha/h	Number of imp. req.	Estimated Purchase price, (N)	Total annual ownership cost, 1000 , N	Cost of fuel consumed, N/h	Cost of oil cons., N/h	Repair and maint. cost, N	Total cost, N/h
1.	Cat. Bulldozer D7G/164.00		As required	150,000,000	31,200.00	7,773.00	119.00	115,200.00	154,292.00
2.	Cat. Bulldozer D8R/245.00		As required	200,000,000	41,600.00	11,694.00	166.00	153,600.00	207,060.00

Continued Table 3.

3.	Amphibious excavator SWEA220/69.60	0.10	As required (50 ha/yr)	48,147,500	10,014.68	2,820.00	63.00	36,977.28	49,874.96
4.	Ditch witch implement RT55/42.00	0.07	As required (25 ha/yr)	25,600,000	5,324.80	1,491.00	47.00	11,059.20	17,922.20
5.	Excavator 325C/141.00	0.08	As required (25 ha/yr)	60,000,000	12,480.00	6,093.00	105.00	46,080.00	64,758.00
6.	Excavator 320L/97.00	0.06	As required (25 ha/yr)	65,000,000	13,520.00	4,617.00	79.00	49,920.00	68,136.00
7.	Excavator JS2052C/106.00	0.07	As required (25 ha/yr)	55,000,000	11,440.00	4,542.00	84.00	42,240.00	58,306.00
8.	Motor grader 140H/138.00		As required	103,846,000	21,599.97	6,567.00	103.00	79,753.73	108,023.70
9.	Compactor VM116drum/85.00	1.47	As require (10 ha/yr)	29,500,000	6,136.00	4,047.00	72.00	12,744.00	22,999.00
10.	Paywheel loader 432ZX/112.00	1.81	As required	49,000,000	10,192.00	5,289.00	88.00	21,168.00	36,737.00
11.	Backhoe loader JCB 3DX/68.60	1.76	As required	45,000,000	9,360.00	3,264.00	62.00	19,440.00	32,126.00
12.	Backhoe loader JCB 3CX/55.00	1.70	As required	40,000,000	8,320.00	2,619.00	54.00	17,280.00	28,273.00
13.	Backhoe loader JCB 4CX/74.60	1.74	As required	48,000,000	9,984.00	3,060.00	66.00	20,736.00	33,846.00

Note please: Nigeria Naira to USD at time of study was N385 to $1.

Table 4. Cropping Calendar for 4,770 ha Sugar cane Cultivation

S/No	Operation	Cover. area, ha	Oct., h	Nov., h	Dec., h	Jan., h	Feb., h	Mar .h	Apr., h	May, h	June h	July, h	Aug., h	Sept., h
1.	Ripping	1,000	72	144	72	144								
2.	Deep plow	1,000	36	144	72	144	144	36						
3.	Harrow	1,000		144	72	144	144	72						
4.	Row marking	1,000		144	72	144	144	72						
5.	Cane planting	1,000		144	72	144	144	72						
6.	Bedforming/ earth-up	4,770		72	72	144	144	144						
7.	Ratoon cane stubble shaver/manager	500		72	72	72	72							
8.	Fertilizer broadcasting	4,770		36	36	36	36	36	36	36	36			
9.	Herbicide spraying	4,770			36	36	36	36	36	36	36	36		
10.	Row crop cultivating/ weeding	4,770				72	72	72	72					
11.	Irrigation/drainage	4,770		As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.	As req.
12.	Cane harvesting	4,770		144	72	144	144	72						
13.	Cane loading	4,770		144	72	144	144	72						
14.	Cane transporting	4,770		144	72	144	144	72						
			108	1,332	792	1,512	1,368	756	144	72	**72**	36		

CONCLUSIONS

This study was able to determine appropriate tractor power matched with machinery for the crop cultivation, crop establishment, weed control up to harvesting and transporting for the post- harvest processing store for 4,770 ha of sugar cane production. This was made possible based on agricultural field operational planning factors like soil, weather and environmental condition, implement and appropriate matching tractor calculations. A well- drawn cropping field operations calendar was very important for crop and operational sequencing and hence recommended since the operations are overlapping with multi-periods. As part of the recommendation, during the planned equipment downtime, major repairs and maintenance were also to be carried out before critical field operations' period to improve pre-field and in-field efficiency for effective equipment and field operational planning and management.

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SISTEM UPRAVLJANJA USEVOM – MAŠINE ZA TERENSKE OPERACIJE I USVOJENE TEHNIKE PLANIRANJA ZA PROIZVODNJU ŠEĆERNE TRSKE

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Apstrakt: Glavni ciljevi mehanizacije farme su maksimiziranje proizvodnje uz minimalne rizike i optimalnu cenu korišćenja mehanizacije i opreme dobrim planiranjem upravljanja i radom mašina za obavljanje pojedinih operacija proizvodnje useva za kompletan sistem . Zbog toga je ova studija bila potrebna kompaniji Sunti Golden Sugar u Nigeriji, da se u budućnosti utvrde na površini farme od 4.770 ha troškovi korišćenja opreme i odgovarajuća snaga traktora sa mašinama za gajenje i negu šećerne trske, kontrolu korova, žetvu trske i transport posle žetve do skladišta i postrojenja za preradu.. Na osnovu veličine/površine farme, faktora operativnog planiranja na terenu kao što su zemljište, vremenske prilike/uslovi okoline, predviđena je svaka priključna mašina koja je usklađena sa odgovarajućom snagom traktora. Takođe su izračunati troškovi korišćenja za priključne mašine i traktor. Prikazan je kalendar svih tehnoloških operacija u polju sa šećernom trskom, koji je veoma važan za useve, a operativni redosled je preporučen i postavljen da se tehnološke operacije ne preklapaju u toku perioda gajenja useva.

Kao deo preporuke, tokom planiranih zastoja mašina, treba uraditi eventualne velike popravke i održavanje mašina pre perioda kritičnih tehnoloških operacija gajenja šećerne trske na terenu kako bi se poboljšala efikasnost planiranja i upravljanja mašinama i opremom u radu.

Utvrđene se vrednosti: učinka svake mašine u okviru predviđenog raspoloživog vremena, stvarno potrebna snaga traktora, potrošnja goriva i ulja po jedinici vremena za uzgoj šećerne trske, žetvu i transport.

Takođe su odabrane potrebne odgovarajuće mašine i oprema za sve dodatne radove sa zemljištem: na putevima, za navodnjavanje ili drenažu.

Ključne reči: *Kalendar useva, mašine, upravljanje, rad, sekvenciranje*

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