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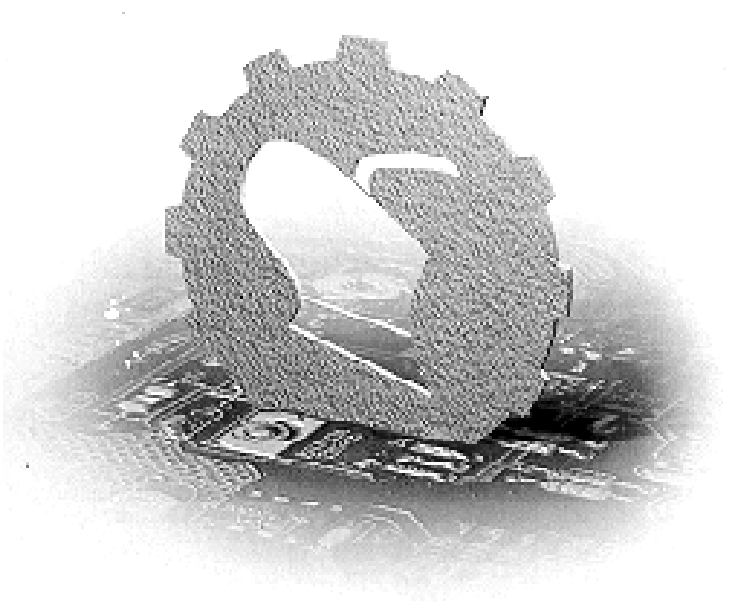

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ECONOMICAL ANALYSIS OF THE MACHINE TECHNOLOGY OF THE CULTIVATION OF DROUGHT-TOLERANT PLANTS FOR RENEWABLE ENERGY PRODUCTION

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Abstract: This study analyses the management of machinery on farms growing sorghum as a drought-tolerant crop, and feedstock for renewable energy production, in addition to the cereals and oilseeds in the classical crop rotation, considering not only field operations but also logistical tasks and machinery usage costs. Furthermore, the machine operation characteristics specific to different farm-level production technologies have also been taken into account.
It can be concluded that the difference between the costs of the small and the large-scale farm size is significant. This all can be explained with the efficiency of the machine exploitation.
In the field of costs there is also a difference between the use of modern and less modern machines. In case of small-scale farm size, with using less modern power-machines a more advantageous cost level can be reached, although the quality of the work and the circumstances of the working must be considered. In case of large-scale farm size, the difference between the operational costs of the less modern and more modern machines decrease significantly, because the operation of the less modern machines is more expensive at larger strain and the high-level constant costs of the modern machines decrease significantly, according to their better exploitation, considering one unit of work.

Key words: *Renewable plant production, farm size, machine fleet management, logistical tasks, machinery cost*

INTRODUCTION

The goal of the research is the technical-economic analysis of the production-technology system of the sweet sorghum that is known as drought tolerant energy plant and nowadays as a promising base material of biotechnological industries [1].

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Work done *by an efficiently developed machine system* is a significant condition of the fruitfulness of farming [2]. The machine prices and the cost of their utilization are extremely high and all these result in extraordinarily high production costs. *Rational machine utilization* is a definitive factor of the efficiency of farming [3].

We have accomplished the examinations by taking power-machines from different quality and cost levels as base.

Through this we have showed that not only the size of the farms effects the amount of the operational costs, but the standard of mechanization too [4].

MATERIAL AND METHODS

The crop plan

The surveys can be conducted by *modelling* the machine working processes of agricultural production. On the base of field crop production, a crop plan including cereal plants for human consumption and for *energy* production purposes, *sweet sorghum* for animal breeding and for *energy* production purposes and oil seeds – as sunflower and the nowadays very popular oilseed rape - appropriate for human consumption and energy production as well and reflecting the special features of production in Hungary has been applied. Depending on farm size the proportion of the crop area of the individual plants has been stipulated in view of the agronomical and production technological conditions. In the sowing plan the ratio of the plants is the following: wheat 40%, sunflower 25%, sweet sorghum 25%, rape 10%.

The sweet sorghum is one of Hungary's plants that is capable to produce the greatest amount of biomass and it's production can be fitted in the conventional alternation of the cereals and industrial plants and the outstanding yields can be ensured at lower costs than other cultures. From the point of view of energetic use, the component of the sweet sorghum that is classed as secondary product, the high sugar content solution that can be pressed from the spears, that is a suitable base material for bioconversion methods. The amount of the productable sugar reaches or exceeds the amount of the glucose that can be produced from cereals grown on a land with the same size. The complex use of the components that can be obtained from the sweet sorghum can significantly increase the reachable profitableness of agriculture [5].

The plant is subtropical, needs hot weather and drought tolerant. It is also called durra or sweet-cane. It was grown in a higher amount between the two world wars. After the II. World War, until the start of the sugar production, the sugar containing syrup pressed and condensed from the plant was used instead of sugar. Nowadays it is mainly used to produce silage fodder, planted with silage corn.

The growing conditions are very advantageous, because the sweet sorghum gives a stable yield even in case of poor water supply (60-70 tons/hectare) [6].

The significance of machine utilization, the machine categories applied, the parameters of model calculations

In the utilization costs of the more and more up-to-date and expensive power machines the proportion of *fixed costs*, especially amortization and maintenance is very high [7]. This expense can be decreased by increasing *utilization*. If the applied means are coupled to the individual field work operations at their effective operation cost – i.e., taking the rate of utilization into account – the effect of *working-hour performance* on costs will become measurable [8].

Basically, the cheapest power machine families used in Hungary on the one hand, and the ones with the highest possible investment cost demand available on the market of agricultural machinery on the other have been the subject of the survey [9, 10].

The basic figures of machine utilization have been determined with the help of the data base of the Hungarian Institute of Agricultural Engineering [11].

The machine cost calculations on which the study is based were made in 2022-2023, and were based on the mechanisation cost data for Hungary in 2021 [12]. In this way, the effects of the significant input material-, and agricultural product price fluctuations in the production year 2022-2023 have not been incorporated into the model.

The *model-calculations* have affected the farm size points of machine stock development in a farm size of 30 and 1000 ha. On this basis we can come to statements affecting a wider segment of the agricultural property structure, resp. to conclusions concerning mechanization and machine utilization [13].

RESULTS AND DISCUSION

The constitution of the machine system in case of the examined farm sizes

The power-machine system that can be ordered to serve the examined farm size of 30 hectares to finish the soil preparation in a good quality consists of the minimal 40 kW output power machine and the attachable soil tilling, nutritive spreading and plant protection working machines.

In case of the 1000 hectares farm size, that is the base of the large-scale examination, the minimum is the tractors with 60-120 kW of output that can be the base of the machine works. The different output-categories are represented by two power-machines in each case. The easier nutritive supply and plant protection tasks are done by the machines with smaller output and the heavier tasks are done by the machines with higher output. The *materials handling to the depot* can also be done by these tractors by using tow-cars to increase the exploitage of the machines.

In case of farm size of 30 hectares, the finishing of the harvesting works as wage work is the most efficient. According to the calculations, on a 1000 hectare sized farm, to reach the acceptable capacity-utilization, one *cereal combine-harvester* can be operated as the property of the farm. The appliance of the self-propelled silage harvester that does the gathering of the sorghum as a property, highly increases the machine costs of the farm, therefore it can be seen in the chapter *results* in details that it is more advantage out to use a self-propelled silage harvester for commission work.

The number of the executed working-hours in function of the power-machine category, the mechanical level and the farm size

The number of the executable working-hours of the power-machines in case of different farm sizes determines the composition to each category of the power-machine system.

In case of the examined *smaller sized farm* (30 hectares) based on our calculations *low exploit age* can be reached to the tractors: maximum 435 working-hours/year.

In case of large farm sizes (1000 hectares) the executed machine working-hours of the farms power-machine fleet, based on our model calculations is 6650 working-hours, from which the tractors represent a major (1100 working-hours/year (power-machine with 60 kW output) and 1700 working-hours/year (power-machine with 120 kW output)) part.

With a clever-chosen cereal harvesting machine at *one thousand hectare* farm size executing about 450-500 working-hours it reaches *significant* exploit age, that results in *acceptable* operational cost. The annual capacity exploitage of the self-propelled silo combine in case of own property is only 150 working-hours, that makes the idea of purchasing the machine as property to think it over.

In case of a 30 hectare sized farm the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 120 working-hours, that is 14,8 working-hours/hectare. This value is slightly higher than the economic average. In case of a 1000 hectare sized farm the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 1675 working-hours, that is 6,7 working-hours/hectare. This marks well that the production of sweet sorghum is a labour-intensive activity, because this value is also higher than the value that is specific to the whole farm. By using *modern machines*, the shown working-hour execution parameters will decrease with 4-5 % [14, 15].

In case of small-scale production, the significant number of shift-hours increases the living work outlay, thereby *increases the employment*. In the farms with this size the use of small output machines is reasonable. However, the proper usage of the small capacity machines is not ensured either, so the significant constant costs induce *higher operational costs* [16].

The analysis of the machine work costs

Applying *low-level* power-machine fleet, the annual machine use cost of a 30 hectare farm that produces sweet sorghum too is 11.785 EUR, that is 393 EUR per hectare.

Applying *modern power-machines* the annual machine use cost is 14.645 EUR, that is 491 EUR per hectare.

Those who work on small sized farm can count with low power-machine utilization, that also has effects on the use costs per working-hour of the tractors.

This value is 19 EUR/working-hours in case of the 40 kW tractors that are usually used in small works. At this production size, the calculated cost of the borrowed used cereal harvester and self-propelled silo combine is 52,5 EUR/working-hours and 72,7 EUR/working-hours.

In case of *modern machines*, the specific cost of the mentioned tractor to a time unit is 24 EUR. The cost of the cereal combine is 73,6 EUR/working-hours. In case of an ensilage cutter, we can also count with the given values, because in the database that we used for the calculations we haven't found two different technical levels from the harvesting machines with these functions.

Considering a 1000 hectare sized farm in case of *low-level* mechanization, taking the above mentioned sowing plan ratios the annual use cost of the machines is 303,5 thousand EUR, that is 303,5 EUR/hectare.

If the use of the self-propelled ensilage cutter machine is not as an own property, then it is *leased work*, the machine use cost of the whole farm is 267,8 thousand EUR. The specific value for a hectare is 267,8 EUR.

With the appliance of *high-level* power-machines the annual machine use cost projected to the whole farm is 339 thousand EUR, specifically 339 EUR/hectare.

It can be observed that the machine cost of sweet sorghum is the highest in every case, compared to the other plant cultures. This is mostly because great volume of the harvesting and crop transporting tasks: at least 60-80 t/hectare of crop has to be harvested and transported to the processing plant.

If the ensilage cutter does it's tasks as *leased work*, the costs decrease. As a result of the calculations, the total machine use cost of the whole farm is 303,5 thousand EUR. Specifically it is 303,5 EUR/hectare.

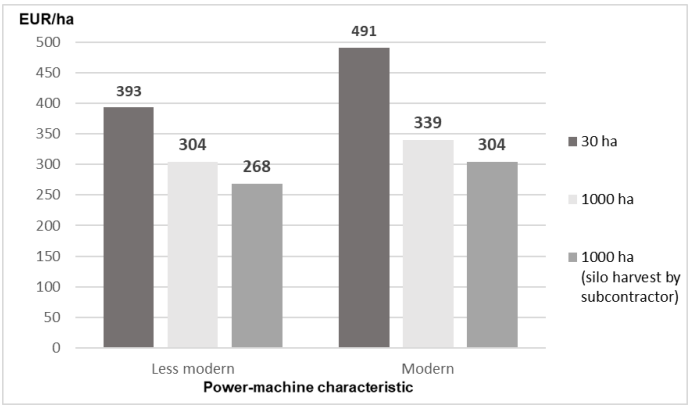

Fig. 1. The specific machine utilisation costs in case of different mechanization levels at farms with the investigated sizes (own editing)

The Figure 1 also shows the previously introduced results, where the upper and lower limit of the machine usage costs are shown in function of the farm size, that are determined considering the use of low-level power-machines and implements and the expensive power-machines that represent the modern machine technologies.

In large-scale production the exploitage of the power-machines is more advantageous. The tractor with 60 kW output works 1100 working-hours and the medium sized universal power-machine with 120 kW output works 1750 working-hours annually. The usage cost of them to one working-hour is 15,7 EUR, and 27,3 EUR.

According to our calculations the use cost of the cereal harvester and self-propelled silo combine as own property is 83 EUR/working-hour, and 243,2 EUR/working-hour. If we borrow the ensilage cutter for work, the cost reduces significantly to 97,4 EUR/working-hour. In case of *modern power-machines* the specific cost of the mentioned tractors to a time unit are 19,7 EUR and 31,4 EUR. The cost of the cereal combine is 93,4 EUR/working-hours. In case of an ensilage cutter as we have mentioned, we can calculate with the above given values.

The operational costs of the work processes of the sweet sorghum production calculated after the computer modelling can be seen on Table 1.

Table 1. The direct machine operation costs of the work processes of the sweet sorghum production

30 ha		Farm size	1000 ha	
Low technical level power-machines	Modern power-machines	Machine features	Low technical level power-machines	Modern power-machines
EUR/ha	EUR /ha	Specific cost	EUR /ha	EUR /ha
23	28,6	Stubble ploughing	15,4	17,6
11,8	14,8	Fertilizer distribution + transport	8	8,3
		Manure spreading + transport	34,9	39,8
23	28,6	Stubble care	15,4	17,6
69,4	78,9	Deep ploughing	33,8	37,5
23	28,6	Plough levelling	15,4	17,6
10,9	13,4	Herbicide spraying	7	7,8
15,5	19,2	Chemical pouring + transport	10,6	12,1
15,5	19,2	Preparation of seedbed	10,6	12,1
22,3	25,9	Sowing + transport	18	19,8
10,9	13,4	Chemical plant protection	7,0	7,8
19,6	23,8	Row cultivation	7,7	9
(65,2)	(65,2)	Harvesting	171 (64,1)	171 (64,1)
(57,1)	(65,3)	Crop transportation to depot	32,9	38,5

The values in brackets show the first-cost of the leased work.

The marked costs in the chart show the direct costs of the machine operation, plus the accessory costs (farm level costs) that increase the discussed values with almost 20%.

The difference between the costs of the small and the large-scale farm size is well-marked. This all can be explained with the efficiency of the machine exploitage. In the field of costs there is also a difference between the use of modern and less modern machines. In case of small-scale farm size, with using less modern power-machines a more advantageous cost level can be reached, although the quality of the work and the circumstances of the working must be considered.

In case of large-scale farm size, the difference between the operational costs of the less modern and modern machines decreases significantly, because the operation of the less modern machines is more expensive at larger strain and the high level constant costs of the modern machines significantly decrease, according to their better exploitage, considering one unit of work.

CONCLUSIONS

Besides the introduced machine costs, we must count with the prices of the input materials of the sweet sorghum production to know the whole cost of the production of the plant. Adding all the cost of the nutrient supply, the seeds and the cost of the pesticide, we face that a minimal input material cost is 600 EUR/hectare. Beside this we must not forget about the cost of the insurance and other supplemental expenses that is connected to the production.

Adding everything, the total production cost of the studied plant per hectare in case of small-scale farm size is minimum 1065 EUR. Examining the large-scale industrial production the costs reduce, but they can not be reduced under the 960 EUR/hectare level.

The introduced operational costs can slightly modificated with the spatial distribution, because for example in a more undeveloped region the lower wages have decreasing effects on the operational costs, compared to the regions where the wages are higher and the job market is more efficient. Furthermore, the feature of the ground, the soil and other factors can slightly have influence on the costs.

The aim of our research work and the exposition of its results is the professional support of the machine investment decisions and the machine utilization practice of the different size farms promoting hereby the creation of the conditions of fruitful farming and rational machine investment decisions.

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EKONOMSKA ANALIZA MAŠINSKE TEHNOLOGIJE GAJENJA BILJAKA OTPORNIH NA SUŠU ZA PROIZVODNJU OBNOVLJIVE ENERGIJE

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Apstrakt: Ova studija analizira upravljanje mehanizacijom na farmama koje uzgajaju sirak kao usev otporan na efekat pojave suše, kao i sirovinu za proizvodnju obnovljive energije, pored žitarica i uljarica u klasičnom plodoredu, uzimajući u obzir ne samo terenske tehničke operacije već i logističke zadatke i troškove korišćenja mašina.
Osim toga, uzete su u obzir i karakteristike rada mašine specifične za različite tehnologije proizvodnje na nivou farme.

Može se zaključiti da je razlika između troškova malih i velikih farmi značajna.
Ovo se sve može objasniti efikasnošću eksploatacije mašine.
U oblasti troškova takođe postoji razlika između upotrebe savremenih i manje savremenih mašina.
U slučaju male farme, korišćenjem manje modernih mašina za pogon može se postići povoljniji nivo troškova, iako se mora uzeti u obzir kvalitet rada i okolnosti rada.
U slučaju velike farme, razlika između operativnih troškova manje modernih i modernijih mašina značajno se smanjuje, jer je rad manje modernih mašina skuplji pri većem opterećenju i visokim konstantnim troškovima modernih mašina. Troškovi mašine se značajno smanjuju, po njihovoj efikasnijoj eksploataciji, obzirom na usvojenu jedinicu rada.

Ključne reči: *Proizvodnja obnovljivih izvora, veličina farme, upravljanje mašinskim parkom, logistički zadaci, troškovi mašina.*

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THE IMPORTANCE OF DETERMINING THE EFFICIENCY OF BUSINESS OF AGRICULTURAL FARMS IN RELATION TO THE USE OF CREDITS IN AGRICULTURE, THE EXAMPLE OF THE REPUBLIC OF SERBIA

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Abstract: The organization of agricultural production in countries such as the Republic of Serbia should be as close as possible to optimality. This can be achieved in different ways. One of the ways to improve the success and efficiency of business should be seen in the search for the most favorable form of obtaining loans from commercial banks. The paper highlights the importance of analyzing three types of loans, namely: a loan for refinancing intended for agriculture, an investment loan intended for agriculture and a loan for working capital intended for agriculture from the perspective of the efficiency of agricultural operations. A Pearson correlation analysis was performed for the observation period 2021-2022. The main conclusion is that there is a connection between the efficiency of agricultural operations with all three forms of taking loans by agricultural farms on a sample of N =149, that is, the obtained results confirmed this ($p<.05$).

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In addition, the study points to the existence of another conclusion, i.e. that the costs related to the taken loans in the observed period have an increase, but they do not have such an impact as the analyzed three forms of loans taken by agricultural holdings, because their impact is in the interval of 0.067 for 2021 to 0.070 in 2022.

***Ključne reči**: Agriculture holding, credit, business efficiency*

INTRODUCTION

The organization of agricultural production requires the holder of agricultural production to be based on the use of valid documentation so that decisions on business activities can be made in accordance with real and realistic business conditions [1-2].

A realistic approach to organizing agricultural production should be such that it gets closer to an organization that will use recognized business standards as much as possible [3], in order to reduce business risk as much as possible [4-6] and essentially improve the system of making business decisions of all decision-makers.

The bearers of agricultural organization, that is, agricultural production, rely to a large extent in their activities on the improvement of the evaluation process [7], but also on the issues of essential improvement of business decision-making in management processes [8-11] in different agricultural systems and forms of organization.

Countries where a more realistic approach to the organization of agricultural production is being developed [12-14], regardless of the type of agricultural production, are paying more and more attention to the real organization of the same, where the establishment of controls within the organization itself, which is essentially engaged in agricultural production, is becoming more and more important in one economy.

The importance of determining business efficiency in agricultural activity has a wide range of opportunities for improving management functions through decision-making by decision-makers [15-19]. One of the ways to improve the management and application of management forms in agricultural farms in relation to the use of loans in agriculture [20-23] which in the long term can have effects on the overall operations of numerous organizational parts in agriculture.

MATERIAL AND METHODS

For the purposes of the study, a survey was conducted in 149 agricultural farms in the Republic of Serbia. The research period referred to 2021-2022. The observation related to the use of three types of loans, namely: loans for re-financing intended for agriculture, investment loans intended for agriculture and loans for working capital intended for agriculture from the aspect of the efficiency of agricultural operations. In addition, data from the final balance sheet for the observation period 2020-2022 were used for expenses related to loans taken during 2021-2022. Only the final research was completed in the period July-August 2023.

Confirmation of the results obtained after the survey was done through Pearson's correlation analysis, with the aim of confirming the existence of a significant connection

between the use of different forms of credit in the business of agricultural farms with the factor of business efficiency.

Statistical processing of data and analyzes were performed using the software IBM SPSS (Statistical Package of Social Science) version 25. The level of 0.05 was used for the threshold value of the existence of significance.

RESULTS AND DISCUSSIONS

Confirmation of the possible connection between the efficiency of agricultural operations and the type of loans received was done using Pearson's correlation analysis.

Testing using Pearson's correlation analysis covered the period from 2021-2022. and that for three forms of credit, as well as for observing the achieved impact on the basis of allocated funds of agricultural farms and the overall impact on business efficiency.

The display after the performed test is given in the display Table 1-2.

Table 1. Presentation of the obtained results of the Pearson correlation analysis related to the efficiency of the agricultural business and the type of lending for 2021.

Serial number	The connection between the form of credit and the costs related to lending to agricultural holdings		Business efficiency
1.	Types of loans	Loan for re-financing intended for agriculture	-0.83
		Investment loan intended for agriculture	-0.69
		Loan for working capital intended for agriculture	-0.85
2.	Allocated funds based on loans taken in the business year 2021	Costs related to loans taken during 2021	-0.067
3.	Agricultural farms (N=149)		

*Statistical significance at the level of 0.05

Table 2. Presentation of the obtained results of the Pearson correlation analysis related to the efficiency of the agricultural business and the type of lending for 2022.

Serial number	The connection between the form of credit and the costs related to lending to agricultural holdings		Business efficiency
1.	Types of loans	Loan for re-financing intended for agriculture	-0.87
		Investment loan intended for agriculture	-0.70
		Loan for working capital intended for agriculture	-0.88
2.	Allocated funds based on loans taken in the business year 2022	Costs related to loans taken during 2022	-0.07
3.	Agricultural farms (N=149)		

*Statistical significance at the level of 0.05

Based on the results of the correlation analysis shown in Table 1-2, it can be concluded that there is a connection between the efficiency of agricultural operations and the three forms of loans taken from commercial banks. However, it can be said that the obtained values ($p<.05$) are significant for all three forms of observed loans, but loans for working capital intended for agriculture has a slightly higher impact value and is moving for 2021 at a value of 0.85, and in 2022 it will be 0.88 .

Allocated funds on the basis of loans taken in the business year 2021 have an impact on business efficiency of 0.067, and in the following year 2022 this impact will continue and amount to 0.070, with a note that this monitoring for both years has a weaker impact than the observed three forms of lending.

Essentially, it can be pointed out that there is a connection between three forms of lending, namely: a loan for re-financing intended for agriculture, an investment loan intended for agriculture and a loan for working capital intended for agriculture in relation to the observation of the efficiency of agricultural operations, this indicates that such a realistic assessment lending represents an important factor for making valid management decisions in the business of agricultural farms in the future, because the realistic and correct setting of lending can affect the improvement of the efficiency of the operations of a large number of agricultural farms.

CONCLUSIONS

Based on the results obtained in the study, it can be concluded that there is a basic conclusion, which is that there is a connection between three forms of lending, namely the observed loans for re-financing intended for agriculture, investment loans intended for agriculture and loans for working capital intended for agriculture in relation to the observation of efficiency of agricultural operations.

In addition, it was determined that there is a slight increase in observed loans in terms of its importance for the entire observation period of 2021-2022.

The third conclusion would be that allocated funds based on loans taken for the same period have an impact on business efficiency, but it is far less than the choice of loans. In the end, the results of the study indicate that there is an importance of a realistic view of lending in the process of making valid decisions by the owners of agricultural farms, because a realistic approach to lending can have a great impact on improving business efficiency.

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ZNAČAJ UTVRĐIVANJA EFIKASNOSTI POSLOVANJA POLJOPRIVREDNIH GAZDINSTAVA U ODNOSU NA KORIŠĆENJE VRSTE KREDITA U POLJOPRIVREDI, PRIMER REPUBLIKE SRBIJE

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Abstract: Organizacija poljoprivredne proizvodnje u zemljama, poput Republike Srbije, treba da bude takva da se približi što više optimalnoj. To je moguće postići na različite načine. Jedan od načina poboljšanja uspešnosti i efikasnosti poslovanja treba posmatrati u traženju najpovoljnijeg oblika dobijanja kredita od strane poslovnih banaka. U radu, je istaknut značaj analiziranja tri vrste kredita i to: kredit za re-finansiranje namenjen poljoprivredi, investicioni kredit namenjen poljoprivredi i kredit za obrtna sredstva namenjen poljoprivredi sa aspekta efikasnosti poslovanja poljoprivrednog gazdinstva. Urađena je Pearsonova korelaciona analiza za period posmatranja 2021-2022.godina. Osnovni zaključak je da postoji povezanost između efikasnosti poslovanja poljoprivrednog gazdinstva sa sva tri oblika uzimanja kredita od strane poljoprivrednih gazdinstava na uzorku od N=149, odnosno dobijeni rezultati su to potvrdili ($p<.05$).

Osim toga, studija upućuje na postojanje i drugog zaključka, odnosno da troškovi vezani za uzete kredite u posmatranom periodu imaju rast, ali oni nemaju takav uticaj kao analizirana tri oblika kredita koje uzimaju poljoprivredna gazdinstva, jer se njihov uticaj kreće u intervalu od 0.067 za 2021., do 0.070 za 2022. godinu.

Ključne reči: *Poljoprivredno gazdinstvo, kredit, efikasnost poslovanja.*

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EFFICIENCY OF AGRICULTURAL MECHANISM MANAGEMENT WITH ADDITIONAL ENGAGEMENT IN AGRICULTURAL FARMS IN THE REPUBLIC OF SERBIA

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Abstract: Increasing the effectiveness of agricultural machinery management can be done in several ways.

In this paper, author highlight the importance of using agricultural mechanization through additional engagement, and that in the largest and most numerous forms of agricultural production organization in the Republic of Serbia, more precisely within agricultural holdings. In the work, five types of agricultural mechanization were observed, in such a way that they were additionally engaged within the scope of the expansion of the basic activity of agricultural farms, within the framework of the development of rural tourism. The main conclusion reached by the authors of the study is that there is a strong influence of the effectiveness of the use of agricultural machinery, which is additionally used to perform work on agricultural farms. This was confirmed after the analysis carried out on the basis of the obtained samples of N=132, where a comparison was made of two forms of use of agricultural mechanization, i.e. standard use in 52 farms with a new form of use, in 80 agricultural farms, i.e. in agricultural farms that used the same agricultural mechanization for business needs, so-called rural tourism.

The views were strengthened based on the obtained results of the comparison of the mentioned two forms of use of agricultural mechanization ($p<.05$) and indicate the importance of additional use of agricultural mechanization in the overall operation of agricultural farms.

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***Key words**: Agricultural economy, business efficiency, agricultural mechanization.*

INTRODUCTION

Business decision-making is the focus of numerous researches, which emphasize the importance of making valid management decisions in entities that operate on a realistic basis [1-3].

Management and decision-making processes are characteristic at all levels of economic management, and some specificities are also present in the organization of farms [4].

In any case, business decision-making should be aligned with internal control factors in business [5-9]. This harmonization was supported by the application of new software solutions, as well as the application of IAS [10-11].

The soil factor is linked to the organization of agricultural production [12]. In addition, correct and realistic reporting to decision-makers is of particular importance [13-15], which can be seen from the overall changes in socio-economic activities in an economy [16].

MATERIAL AND METHODS

In order to prepare this study, the authors collected data from 132 agricultural farms in the Republic of Serbia. This was done in the period August-September 2023.

The observation was done in such a way that data were processed for 52 agricultural farms that use agricultural machinery on their farms in the classic way, as well as for 80 farms that also used agricultural machinery in other supplementary jobs, especially in areas of application of tourism, i.e. within the framework of rural tourism, in order to increase the income of their agricultural holdings.

Within the framework of the research, five forms of agricultural mechanization were analyzed: motor cultivators, chainsaws, small trailers, agricultural tools, other agricultural mechanization.

After that, classical statistical processing of the obtained data was done. Statistical data processing and analysis were done using the software IBM SPSS (Statistical Package of Social Science) version 25. In the work, the t test of independent samples was applied to examine the difference between groups and regression analysis to predict the total income that is achieved by applying agricultural mechanization.

A level of 0.05 was used for the threshold value of significance.

RESULTS AND DISCUSSIONS

The aim of the research was to determine whether there is a significant difference in the efficiency of using two forms of agricultural mechanization within agricultural farms. This was done using a t test.

The t-test of independent samples was used to examine possible differences in the form of agricultural technology engagement.

The presentation of the obtained results is given in Table 1.

Table 1. Presentation of the differences in relation to the value of individual and total value of individual agricultural machinery in two forms of use, as well as the total income realized in agricultural holdings in the Republic of Serbia

Analyzed factors	Agricultural machinery		t	p
	Classic form of use (N=52)	A new form of use within additional jobs (N=80)		
	Middle value			
Motocultivator	19.97 ± 0.60	24.90 ± 0.90	-36.022	<0.0005*
Chainsaw	30.20 ± 0.73	39.91 ± 0.86	-64.231	<0.0005*
Small trailers	11.52 ± 0.46	14.86 ± 0.81	-28.600	0.089*
Agricultural tools	1.52 ± 0.44	4.30 ± 0.47	-30.371	<0.0005*
Other small agricultural machinery	1.40 ± 0.45	2.31 ± 0.44	-10.589	<0.0005*
Total value of agricultural machinery	59.06 ± 0.60	89.00 ± 3.91	-52.249	<0.0005*
Total income	98.00 ± 1.70	139.95 ± 0.90	-156.728	<0.0005*

Note: Statistical significance at the level of 0.05.

Based on the presentation in Table 1, it can be seen that there is a statistically significant difference in 4 types of agricultural machinery, and that the connection is weak in the application of small trailers. The new form of using agricultural mechanization, i.e. when it is also used to perform additional work on the farm, has a higher value among all the analyzed forms of using agricultural mechanization, but also with their use it is possible to achieve higher total incomes.

In the presentation of the second part of the obtained results, the authors applied multiple linear regression. This was done to examine the formation of total income for the agricultural economy, that is, whether it is possible to predict the ratio of the total value of agricultural machinery in relation to the form of use of agricultural machinery. The regression analysis yielded a coefficient of determination of 0.956, on the basis of which it can be seen that the obtained model describes 95.6% of the total variance.

The total value of agricultural mechanization can be predicted on the basis of total income as a statistically significant model was obtained ($F=1376.95$, $p<0.0005$). Based on the results shown in Table 2, it can be seen that income has a significant impact in relation to the total value of agricultural machinery used on agricultural farms.

Table 2. Individual contribution of independent variables to the prediction of the total value of agricultural machinery for use in agricultural holdings

	Beta	t	p
A constant	-	-3.974	<0.0005*
Total income	-2.980	-4.023	<0.0005*

Note: Statistical significance at the level of 0.05.

CONCLUSION

The results obtained in the study indicate that there is a general conclusion that there is a strong connection between the use of agricultural mechanization and the efficiency of its use in agricultural farms in Republic Serbia.

As a further conclusion, the existence of a strong connection between all analyzed types of agricultural mechanization could be drawn, except for the use of small trailers in use on agricultural farms.

Finally, it should be emphasized the existence of a connection with each of the analyzed types of agricultural machinery in terms of the formation of individual contributions of independent variables in relation to the establishment of a connection between the total value of the engagement of agricultural machinery in agricultural farms and the formation of total income.

Better results were achieved by agricultural farms that used additional agricultural machinery in business because we discovered that there is a statistically significant behavior according to the resulting model where we obtained values ($F=1376.95$, $p<0.0005$).

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EFEKTIVNOST UPRAVLJANJA POLJOPRIVREDNOM MEHANIZACIJOM DODATNIM ANGAŽOVANJEM U POLJOPRIVREDNIM GAZDINSTVIMA U REPUBLICI SRBIJI

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Abstract: Povećanje efektivnosti upravljanja poljoprivrednom mehanizacijom može se ostvarti na više načina. U ovom radu Autor ističevažnost korišćenja poljoprivredne mehanizacije, putem dodatnog angažovanja i to u najvećem i najbrojnijem obliku organizacije poljoprivredne proizvodnje u Republici Srbiji, tačnije u okviru poljoprivrednih gazdinstava. U radu je izvršeno posmatranje pet (5) tipov poljoprivredne mehanizacije i to na način da se ista dodatno angažovala u okviru proširenja osnovne delatnosti poljoprivrednih gazdinstava u okviru razvoja seoskog turizma.

Osnovni zaključak studije do koga je došao Autor je da postoji snažan uticaj efektivnosti korišćenja poljoprivredne mehanizacije koja se dodatno koristi za obavljanje poslova na poljoprivrednim gazdinstvima. To je potvrđeno nakon sprovedene analize na osnovu dobijenih uzoraka od N=132, gde je izvršeno poređenje dva oblika upotrebe poljoprivredne mehanizacije, odnosno standardnog korišćenja kod 52 gazdinstva, sa novim oblikom korišćenja, kod 80 poljoprivrednih gazdinstava, odnosno kod

poljoprivrednih gazdinstava koja su koristila istu poljoprivrednu mehanizaciju za potrebe poslovanja tzv. seoskog turizma.

Stavovi su dobijeni na osnovu dobijenih rezultata poređenja pomenuta dva oblika upotrebe poljoprivredne mehanizacije ($p<.05$) i ukazuju na važnost dodatnog korišćenja poljoprivredne mehanizacije u ukupnom poslovanju poljoprivrednih gazdinstava.

Ključne reči: *Poljoprivredno gazdinstvo, efikasnost poslovanja, poljoprivredna mehanizacija.*

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ESTIMATION OF SOME PHYSICAL AND MECHANICAL CHARACTERISTICS OF WHEAT GRAIN AT DEFINITE MOISTURE CONTENT

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Abstract: Physical properties and mechanical properties of grains have importance in design of farm machinery, processing equipment's, handling equipment's, and processing of food and agricultural products. The physical properties must be known to an engineer to design a machine for handling, cleaning, conveying, storing and milling. There are some of important physical properties such as shape, size, volume, density and mechanical properties like angle of repose, static friction coefficient of different grains is necessary for the design of seed drill cum fertilizer, harvester, thresher etc. and food processing units such as separating, handling, storing, drying systems etc. Physical and mechanical properties of grain were estimated at Food Research Lab, Food and Processing Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, (Uttar Pradesh). Therefore,

The objective of present study was to determine some physical and mechanical properties of wheat grain at 9.2 % moisture content such as dimensions (length, width and thickness); equivalent, geometric and arithmetic mean diameter; sphericity; surface area; area of flat and transverse surface; volume; mass of one grain; and then other properties under effect of moisture content variation such as density, thousand kernel mass, coefficient of friction against deferent materials and angle of repose.

The average length, width and thickness of wheat seed were measured 6.25, 4.48 and 3.73 mm at a moisture content of 9.7 % (wet basis) respectively.

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Equivalent diameter and sphericity were calculated at moisture content of 9.7 % were 4.63 mm and 74 %. The bulk density and particle density was estimated 623 and 1215 kg/m^3 at same moisture content while mechanical properties such as angle of repose and static friction were determined 24.6^0 and 0.352 respectively at same moisture level. Therefore, these estimated physical and mechanical properties can be used to design and development of combine tillage and sowing assembly.

***Key words**: Physical properties, Mechanical properties, Wheat*

INTRODUCTION

Physical properties and mechanical properties of grains vital role in the design of farm machines, structures, processing equipment, handling equipment, processing of food and agricultural products. The estimation of some important physical properties such as shape, size, volume, density and mechanical properties like angle of repose, static friction coefficient of different grains is necessary for the design of various separating, handling, storing and drying systems [7]. These physical and mechanical properties are significantly affected by numerous factors such as size, form, superficial characteristics and moisture content of the grain [3]**.**

Wheat is the main cereal crop in India. The total area under the crop is about 29.8 million hectares in the country and become second largest producer of wheat in the world, producing 109.6 million tonnes annually. In recent year 2023, India produced a record 112.74 million metric tons of wheat, up from 107.7 million metric tons in 2022. However, India consumes around 108 million metric tons of wheat annually.

To meet up with domestic requirements, India will need to increase wheat production to 140 million tons by 2050. The major increase in the productivity of wheat has been observed in the states of Haryana, Punjab and Uttar Pradesh. Wheat is mainly preferred for making bread; durum wheat is preferred for making the various types of pasta, while soft red winter wheat and soft white wheat are preferred to making the biscuits and cakes.

MATERIAL AND METHODS

The combined tillage and sowing machinery were designed and developed at Farm Machinery and Power Engineering, Vaugh Institute of Agricultural Engineering and Technology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, (Uttar Pradesh).

Combined tillage and sowing machinery are also named as vertical rotary plough with seed cum fertilizer drill has rotating sharp tines mounted on a vertical shaft and can be attached to the three-point linkage of 18-20 HP tractors. It is powered by PTO and provided with setting of different working depth adjustment. It has two flanges spaced apart some distance and each flange carries two sharp blades.

The physical and mechanical properties of wheat grain are estimated in food research lab located in university campus. These estimated physical and mechanical properties are mainly used to design and development of combine tillage and sowing assembly.

The study view of tillage and sowing machinery and other grain properties estimation in food research lab presented in Fig. 1, 2, 3, 4 respectively.

Fig. 1 Study view of combine tillage and sowing machinery

Fig. 2 Measurement of moisture content of wheat seed grain sample by oven dry method

Fig. 3. Measurement of bulk density of wheat seed grain sample by measuring cylinder

Fig. 4. Measurement of equivalent diameter and sphericity of wheat seed grain by calliper

Selection of Wheat Seed Variety

The wheat seed variety namely HUW-234 is one of popular and still being cultivated on a larger area because of its wide adaptability in adverse situations, excellent chapatti making quality and suitability for rainfed cultivation. The wheat variety HUW-234 (popularly known as Malviya 234) was developed by the Breeding Department of Agriculture and provides an average yield of 31-35 Qtls/ha. This variety normally matures in 126-134 days, contains 10-11 percent protein with good chapatti making quality.

HUW-234 is very famous variety with significant existence in release of several improved wheat varieties among farmers of eastern Uttar Pradesh and grown by them. The main reasons for large success and popularity of HUW-234 among farmers include its adaptation to low resource environment, ability to perform better under abiotic stresses of terminal heat, limited irrigation and variable fertilizer doses and its suitability for planting even after early potato harvesting. Therefore, its suitability in all adverse conditions makes HUW-234 popular amongst farmers. Hence, viewing aspects of multi functionality of this variety, HUW-234 was selected for testing combined tillage and sowing machine during field experiment.

Equivalent diameter

Equivalent diameter can be considered by taking random samples of one hundred wheat seeds were taken out from each level of moisture content. The three major dimensions length (L), breadth (B), and thickness (T) of each seed in the sample were measured using the vernear caliber with accuracy 0.01 mm. The equivalent diameter (De) of seed was calculated by using the following relations given as follow in equation [7].

$$De = (L \times B \times T)^{\frac{1}{3}}$$

Where,

D_e = Equivalent diameter, mm
L = Length of seed sample, mm
B = Breadth of seed sample, mm
T = Thickness of seed sample, mm

Spehericity

Randomly samples of one hundred seeds were taken out for each level of moisture content. The three major dimensions length (L), breadth (B), and thickness (T) of each seed in the sample were measured using the vernear caliber with accuracy 0.01 mm. The sphericity (S) of seed were determined in term of equivalent diameter (De) by using the following relations [7].

$$\mathbf{S = \frac{De}{L}}$$

Where, D_e = Equivalent diameter, mm
L = Length of seed sample, mm

Bulk density

The bulk density was determined by filling a graduated cylinder of 500 ml with the seeds from a height of 15cm at constant rate, and the base of the cylinder was tapped a dozen times on a table [4]. Then, the cylinder was refilled again to its maximum reading (500 ml), the sample was weighed and bulk density was calculated. Each test was done in five replicates.

$$B = \frac{W}{V}$$

Where, B_d = Bulk density of seed sample, kg/m^3
W = Weight of seed sample, kg
V = Volume of seed sample, m^3

Particle density

The particle density was estimated by measuring the actual volume of a known weight of a random seeds sample. The actual volume of the seeds was determined using the toluene displacement method [6]. The particle density for each wheat seeds at each level of moisture content was repeated five times for attending accuracy.

$$\mathbf{P_d = \frac{W}{V_s}}$$

Where, P_d = Particle density of seed sample, kg/m^3
W = Weight of seed sample, kg
V_s = Displaced volume of toluene, m^3

Angle of repose

The angle of repose of the wheat grains was measured using the apparatus developed by [9] and fabricated locally. The dynamic angle of repose was the measured angle between the horizontal and the natural slope of the seeds heap. The height of the heap was measured and the dynamic angle of repose was calculated by the following relationship.

$$\boldsymbol{\theta = \tan^{-1}\left(\frac{2H}{D_p}\right)}$$

Where,
θ = dynamic angle of repose, θ^0
H = heap height of seed, mm
Dp = platform diameter, mm

Static friction coefficient

A static friction coefficient measuring apparatus as described by [8] was designed and fabricated as shown in figure (2) with the box dimensions 26 x 21 x 9 cm to measure the angle of static friction for grains at each moisture content level of wheat varieties on four different material surfaces namely plywood sheet, galvanized iron sheet, stainless steel sheet and rubber sheet.

The angle of inclination (α) was recorded and the static coefficient of friction (μ) was calculated by the following equation. The angle of friction (α) was measured ten times for each selected materials, each level of moisture content and for each wheat varieties.

$$\mu = \tan \alpha$$

Where, μ = Coefficient of friction,

α. = Angle of inclination, θ^0

RESULTS AND DISCUSSION

Estimation of wheat seed physical properties

The wheat seed physical properties were revealed in terms of average seed length, width and thickness, were measured by calipers 6.25, 4.48 and 3.73 mm at a moisture content of 9.7 % (wet basis) respectively. The equivalent diameter and sphericity was calculated on the basis of seed length, breath and thickness at a moisture content of 9.7 % were 4.63 mm and 74 %. The bulk density and particle density was estimated 623 and 1215 kg/m^3 at same moisture content. Mechanical properties such as angle of repose and static friction were determined 24.6^0 and 0.352 respectively at same moisture level.

Table 1. Estimation of various wheat seed physical and mechanical properties

Sr. No.	Seed physical properties	Moisture content (wb), %	Average length, mm	Average breath, mm	Average thickness, mm	Value
1.	Equivalent Diameter, mm	9.7	6.25	4.48	3.73	4.63
2.	Sphericity, %	9.7	6.25	4.48	3.73	74
3.	Bulk density, kg/m^3	9.7	6.25	4.48	3.73	623
4.	Particle density, kg/m^3	9.7	6.25	4.48	3.73	1215
5.	Angle of repose, θ^0	9.7	6.25	4.48	3.73	24.6
6.	Static friction coefficient, c	9.7	6.25	4.48	3.73	0.352

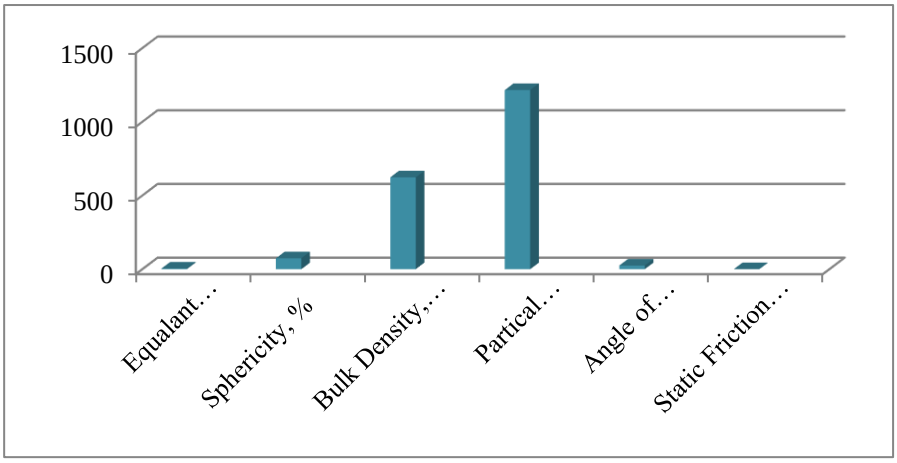

Fig. 5. Variation of the physical and mechanical properties

CONCLUSION

The average length, width and thickness of wheat seed were measured 6.25, 4.48 and 3.73 mm at a moisture content of 9.7 % (wet basis) respectively. Equivalent diameter and sphericity was calculated at moisture content of 9.7 % were 4.63 mm and 74 %.
The bulk density and particle density was estimated 623 and 1215 kg/m^3 at same moisture content while mechanical properties such as angle of repose and static friction were determined 24.6^0 and 0.352 respectively at same moisture level.

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PROCENA NEKIH FIZIČKO-MEHANIČKIH KARAKTERISTIKA PŠENIČNOG ZRNA KOD ODREĐENOG SADRŽAJA VLAGE

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Apstrakt: Fizičke i mehaničke osobine žitarica imaju značaj u projektovanju poljoprivrednih mašina, opreme za preradu, opreme za rukovanje i preradu hrane i poljoprivrednih proizvoda. Fizička svojstva moraju biti poznata inženjeru da bi dizajnirao mašinu za rukovanje, čišćenje, transport, skladištenje i mlevenje.
Postoje neke važne fizičke osobine kao što su oblik, veličina, zapremina, gustina i mehanička svojstva, ugao mirovanja, koeficijent statičkog trenja različitih zrna neophodnih za projektovanje sejalice za đubrivo, kombajna, vršilice itd. i jedinica za preradu hrane kao što su odvajanje, rukovanje, skladištenje, sistemi za sušenje itd.
Fizička i mehanička svojstva zrna su procenjena u laboratoriji za istraživanje hrane, Inženjering za hranu i preradu, Vaugh Institute of Agricultural Engineering and Technologi, Sam Higginbottom Univerzitet za poljoprivredu, tehnologiju i nauku, Praiagraj, (Uttar Pradesh). Zato je cilj ovog istraživanja bio da se utvrde neke fizičko-mehaničke osobine pšeničnog zrna pri sadržaju vlage 9,2% kao što su: dimenzije (dužina, širina i debljina); ekvivalentni, geometrijski i srednji aritmetički prečnik; sferičnost; površina; površina horizontalnog i poprečnog preseka zrna; zapremina; masa jednog zrna; a zatim i druga svojstva pod uticajem varijacije sadržaja vlage kao što su gustina, masa hiljadu zrna, koeficijent trenja u odnosu na različite materijale i ugao mirovanja.

Prosečna dužina, širina i debljina zrna pšenice izmerene su 6,25, 4,48 i 3,73 mm pri sadržaju vlage od 9,7 % (mokra osnova). Ekvivalentni prečnik i sferičnost su izračunati pri sadržaju vlage od 9,7 % i iznosili su 4,63 mm i 74 %. Zapreminska gustina i gustina zrna procenjena je na 623 i 1215 kg/m^3 pri istom sadržaju vlage. Mehanička svojstva kao što su ugao mirovanja i statičko trenje utvrđena na 24,60 odnosno 0,352 pri istom nivou vlage. Zbog toga se ove procenjene fizičko-mehaničke osobine mogu koristiti za projektovanje i razvoj kombinovanih mašina za obradu zemljišta i setvu.

Ključne reči: *Fizička svojstva, mehanička svojstva, pšenica*.

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THE EFFECTS OF SPEEDS, DIGGER LENGTHS AND SPACING ON THE MATERIAL EFFICIENCY OF A GINGER HARVESTER: A RESPONSE SURFACE APPROACH

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Abstract: A developed ginger harvester was studied for its performance during operation using response surface methodology. Some of its parameters like speeds of operation, digger lengths and spacing, were varied to determine their effects on the Material Efficiency of the machine. Three levels of speeds (4,8,12km/hr), three levels of digger lengths (25,30,35cm) and three levels of digger spacing (4,6,8cm) were investigated as they affected the Material Efficiency of the machine. Results showed that the linear effects of speed, the quadratic effects of speed, the quadratic effects of digger lengths and the interactions of speeds and digger lengths were significant to the Material Efficiency of the ginger harvester at 5% probability ($P \leq 0.05$). These effects alone accounted for about 94.14% of the variations in the Material Efficiency of the machine. The response surface curve showed that the material efficiency increased with speed and digger spacing, but decreased with digger lengths. The highest overall Material Efficiency was obtained when the digger lengths were 25cm and the digger spacing was 8cm.

Key words*: Ginger, harvester, response, surface, methodology, material, efficiency.*

INTRODUCTION

Ginger is botanically known as *Zingiber officinale.* It is a flowering spicy plant grown in the tropical regions of the world [1]. Ginger is highly valued in the international market because of its pungent smell and its high oleoresin content.

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The rhizome or ginger root is also commonly used as spice and traditional medicine [2]. Ginger is an herbaceous perennial plant that grows annual pseudo stems or false stems made of rolled bases of leaves. It can grow up to a meter tall and bears narrow leaf blades [3]. It is used as raw material for food, medicine and confectionary industries. Ginger roots are also used for flavoring beverages, seasoning of pies and biscuits. A tonic made from ginger roots can be used as a medical remedy for nausea, motion sickness, arthritis and rheumatism [1].

There are two varieties of ginger commonly grown in Nigeria, namely (i) the yellow ginger, known as UG1 and (ii) the black ginger, known as UG2. The former is consumed as spice, while the latter is important for its essential oils [4]. Ginger harvesting in Nigeria is commonly done manually. The development of a mechanized ginger harvester is an added advantage to ginger production in Nigeria as it will reduce drudgeries involved in the manual methods of ginger production.

Response Surface Methodology (RSM) is essentially a particular set of mathematical, graphical and statistical methods used by researchers to aid in the solution of certain types of problems which are seen in scientific and engineering processes [5-6]. RSM is the most popular optimization method used in recent years because of the ease of application and least number of experimental runs needed to evaluate a process, [7]. The RSM is a powerful optimization tool for design of experiments and it is used in constructing an equation on the input variables that gives the best prediction of the dependent variable (the response). It also requires few experimental data to predict the relationship. It incorporates graphical display of the relationships between the variables and therefore helps to determine the variable levels for the maximum or minimum points of the response studied [8, 9, 10].

MATERIAL AND METHODS

The Description of the Ginger Harvester

A two-row ginger harvester was developed [11]. The harvester consists of shafts, pulley, collector, PTO shaft connector, gear reducer, diggers, rake, and conveyor. It is coupled to a tractor through the 3-point linkage and the power-takeoff shaft (which is the driving unit). The harvester has two wheels and incorporates a rigid steel framework and a collector. During harvest operation, the diggers dig up the ginger rhizomes which are picked up by the rakes and sent to the conveyor to the collector. The isometric, orthographic and picture of the two-row ginger harvester are shown in Figs 1, 2 and 3.

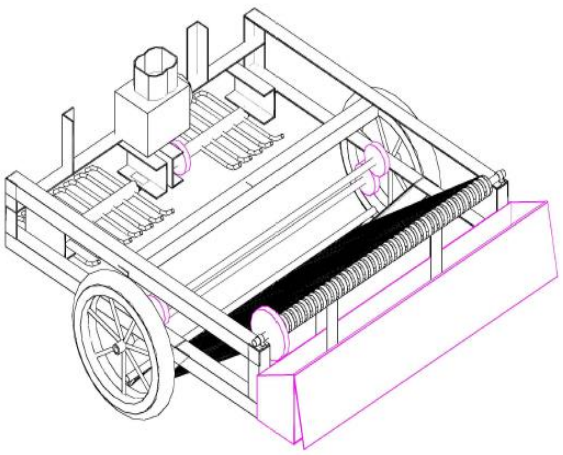

Figure 1. Isometric View of the Ginger Harvester

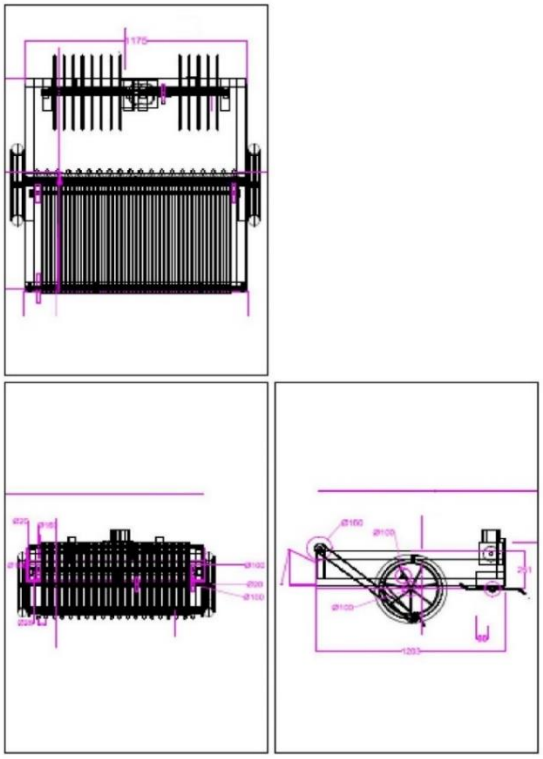

Figure 2. The Orthographic View of the Ginger Harvester

Figure 3. The Developed Ginger Harvester

Experimental Design and Research Methodology

After the development of the machine, it was tested in the field where ready to be harvested ginger crops were grown. Tests involved the effects of speeds, digger lengths and spacing as they affect the Material efficiency of the machine using Response Surface Methodology. The Material efficiency was obtained by modifying the equation by [12], as;

$$ME = {}^{m-l}/_{m} \times 100 \quad \text{..... (1)}$$

Where:

ME =Material Efficiency (%),
m= Total rhizomes in the field (kg) and
l= Unharvested rhizomes (kg).

For the RSM analysis, the regression was done using Minitab 16 software, while the response surface graphs were plotted with MATLAB R2015 software.

In the RSM design the linear, quadratic and interactive effects of speeds of operation, digger lengths and spacing as they affect the response (Material Efficiency) were studied. The experimental variables used in the design and the experimental results of the independent variables on the response are shown in Tables 1 and 2.

Table 1: Experimental Variables and Coding Used in the Design

Independent Variables	Variable Levels		
Speeds X1	4km/hr	8km/hr	12km/hr
Digger Lengths, X2	25cm	30cm	35cm
Digger Spacing, X3	4cm	6cm	8cm
Code Designation	-1	0	1
Dependent Variable (Response)			
Material Efficiency (%) Y			

RESULTS AND DISCUSSION

The experimental variables and coding are shown in Table1, while the experimental results incorporating the independent variables in coded terms are shown in Table 2. The estimated regression coefficients for Material Efficiency against, speed of operation, digger lengths and spacing are shown in Table 3. The analysis of variance for their regression are shown in Table 4.

Table 2. Experimental Results of Independent Variables and Response in Coded Terms

Runs	X1	X2	X3	Y%
1	-1	-1	1	82
2	0	0	0	80
3	0	1	0	92
4	0	0	0	79
5	0	0	0	79
6	1	-1	1	68
7	0	0	-1	82
8	1	1	1	75
9	-1	1	1	65
10	-1	0	0	70
11	0	0	0	80
12	1	1	-1	84
13	0	-1	0	80
14	-1	-1	-1	87
15	1	0	0	55
16	1	-1	-1	60
17	0	0	0	79
18	0	0	0	79
19	-1	1	-1	82
20	0	0	1	84

Table 3. Response Surface Regression: Y versus X1, X2, X3

Term	Coeff	SE Coeff	T	P
Constant	78.964	1.0504	75.178	0.000
X1	-4.400	0.9662	-4.554	0.001
X2	2.100	0.9662	2.173	0.055
X3	-2.100	0.9662	-2.173	0.055
X1^2	-15.909	1.8425	-8.635	0.000
X2^2	7.591	1.8425	4.120	0.002
X3^2	4.591	1.8425	2.492	0.032
X1X2	6.625	1.0802	6.133	0.000
X1X3	2.625	1.0802	2.430	0.035
X2X3	-3.625	1.0802	-3.356	0.007

S= 3.05536 R-Sq =94.14%

The regression equation is:

Y= 78.96-4.4X1+2.1X2-2.1X3-15.91X1^2+7.95X2^2+4.59X3^2+6.63X1.X2+ +2.63X1.X3-3. 63X2.X3

Where,
Coeff = regression coefficients,
SE Coeff = standard error of the regression coefficients
T = Tabulated values of the regression parameters.
P = Probability values of the regression terms.
S = Standard error. R-Sq =(R-squared) is a standardized measure of the goodness of fit of the regression model.

Table 4: Analysis of Variance for Y

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	9	1498.45	1498.45	166.494	17.84	0.000
Linear	3	281.80	281.80	93.933	10.06	0.002
X1	1	193.60	193.60	193.600	20.74	0.001
X2	1	44.10	44.10	44.100	4.72	0.055
X3	1	44.10	44.10	44.100	4.72	0.055
Square	3	705.27	705.27	235.091	25.18	0.000
X1^2	1	369.80	696.02	696.023	74.56	0.000
X2^2	1	277.51	158.46	158.460	16.97	0.002
X3^2	1	57.96	57.96	57.960	6.21	0.032
Interaction	3	511.37	511.37	170.458	18.26	0.000
X1.X2	1	351.12	351.13	351.125	37.61	0.000
X1.X3	1	55.12	55.12	55.125	5.91	0.035
X2.X3	1	105.13	105.13	105.125	11.26	0.007
Residual Error	10	93.35	93.35	9.335		
Lack of Fit	5	92.02	92.02	18.404	69.01	0.000
Pure Error	5	1.33	1.33	0.267		
Total	19	1591.80				

Where,
DF = Degrees of freedom.
Seq SS = Sum of squares.
Adj SS = Adjusted sum of squares
Adj MS =Adjusted mean squares.
F = Value of the restriction test on the regression model.
P = Probability values of the regression terms.

From Table 3, the linear effects of speed, the quadratic effects of speed, the quadratic effects of digger lengths and the interactions of speeds and digger lengths were significant to the Material Efficiency of the ginger harvester at 5% probability ($P \leq 0.05$)
These factors alone accounted for about 94.14% of the variations in the Material Efficiency of the ginger harvester. The analysis of variance Table 4 fully confirmed the results.

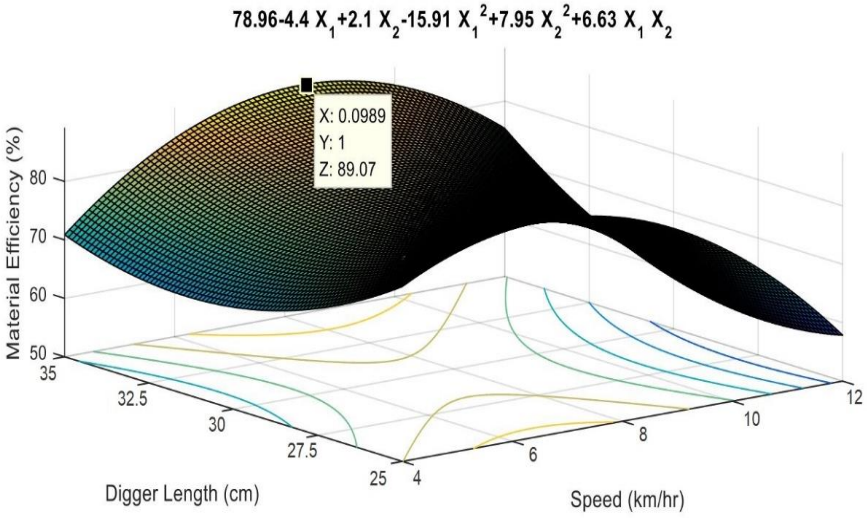

Figure 4. Response Surface Curve of the Effects Digger Lengths and Speeds on the Material Efficiency of the Ginger Harvester

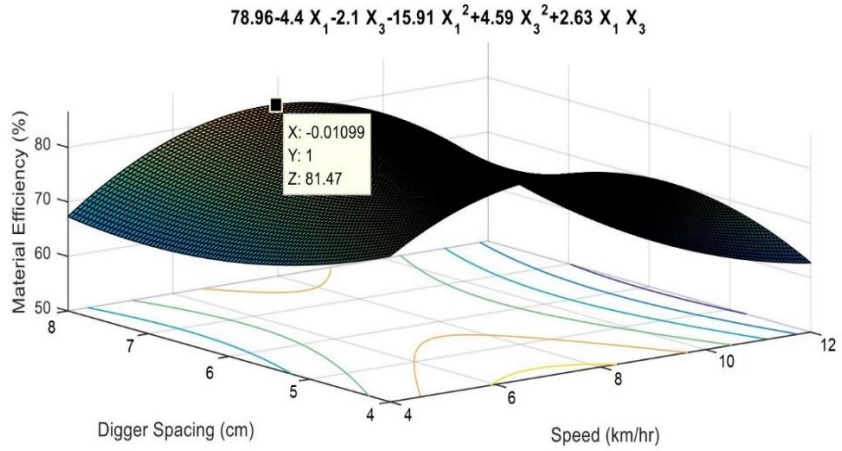

Figure 5. Response Surface Curve of the Effects Digger Spacing and Speed on the Material Efficiency of the Ginger Harvester

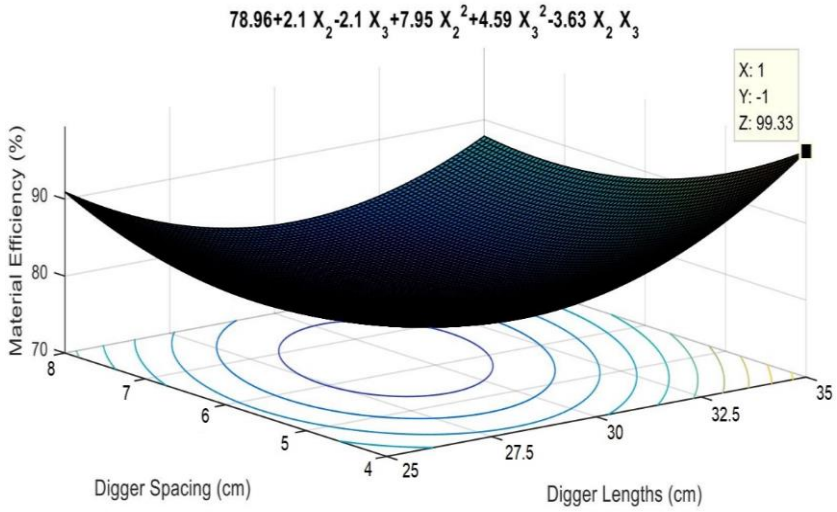

Figure 6: Response Surface Curve of the Effects Digger Length and Digger Spacing on the Material Efficiency of the Ginger Harvester

From the response surface curve in Fig. 4, the highest Material Efficiency of 89.07% was obtained when the digger length was 28cm and the speed was 12km/hr. In Fig.5, the highest Material Efficiency of 81.47% was obtained, when the digger spacing was 5.5cm and the speed was 12km/hr. From Fig.6, the highest overall Material Efficiency of 99.33% was obtained when the digger spacing was 8cm and the digger length was 25cm.

CONCLUSIONS

The following conclusions can be drawn from these experimental results and analysis, of the research: the linear effects of speed, the quadratic effects of speed, the quadratic effects of digger lengths and the interactions of speeds and digger lengths were significant to the Material Efficiency of the ginger harvester at 5% probability ($P \leq 0.05$) These effects alone accounted for about 94.14% of the variations in the Material Efficiency of the machine. The response surface curve showed that the material efficiency increased with speed and digger spacing, but decreased with digger lengths.

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EFEKTI BRZINE, DUŽINE I RAZMAKA ALATA NA MATERIJALNU EFIKASNOST KOMBAJNA ZA ĐUMBIR: PRISTUP PREMA POVRŠINI ODZIVA

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Apstrakt: Razvijeni kombajn za đumbir (*Zingiber officinale*) ispitan je zbog performansi tokom rada primenom metodologije odzivne (odgovora) površine. Neki od njegovih parametara, kao što su brzina rada, dužina i rastojanje alata za vađenje korena, varirali su da bi se odredio njihov uticaj na efikasnost konstrukcije mašine.
Istražena su tri nivoa brzina (4,8,12 km/h), tri nivoa dužine alata kopača (25, 30, 35 cm) i tri nivoa razmaka alata kopača (4, 6, 8 cm) jer su uticali na ekonomičnost i efikasnost ove mašine.
Rezultati su pokazali da su linearni efekti brzine, kvadrat efekta brzine, kvadrat efekta dužina alata kopača i interakcije brzina i dužina alata kopača, bili značajni za efikasnost primene materijala konstrukcije delova kombajna za đumbir sa verovatnoćom od 5% ($P \leq 0,05$).

Samo ovi efekti su činili oko 94,14% varijacija u materijalnoj efikasnosti mašine.
Kriva površine odziva (odgovora) je pokazala da se efikasnost primenjenog materijala povećava sa brzinom i razmakom kopača, ali se smanjuje sa dužinom kopača.
Najveća ukupna efikasnost materijala je postignuta kada su dužine alata-kopača bile 25 cm, a razmak alata-kopača 8 cm.

Ključne reči: *Đumbir, kombajn, odziv, površina, metodologija, materijal, efikasnost.*

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REVIEW OF BIODIESEL PRODUCTION FROM TRANSESTERIFICATION OF ESTERIFIED *Carica Papaya* OIL (CSO)

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Abstract: As a result of global urbanization and modernization, the use of petroleum (fossil fuel) is on the increase and there are growing concerns among stakeholders in the oil and gas industry over the depletion rate of petroleum reserves and its rising cost. The conversion of readily available sources of biomass to produce different types of biofuels to address the future energy crisis is one of the preferred attractive choices. Biodiesel is generally produced by the transesterification reaction of vegetable oils, waste vegetable oil or animal fats in the presence of a suitable catalyst. The choice of biodiesel as a preferred renewable source of energy was based on its biodegradability, non-toxic, lower emissions, sulphur free, low levels of polycyclic aromatic hydrocarbons (PAHs) and their nitrated compounds.
This alternative source of energy is environmentally friendly and could be used in the existing diesel engines with little or no modifications.
This will reduce the world's dependence on fossil fuels that are non-renewable with the attendant environmental benefits to mankind.

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However, the use of these edible vegetable oils will put pressure on the food uses of such oil which will result to fuel-food crisis in the future. This impending crisis can be readily averted by exploring non-edible crops/agricultural waste biomass that can be grown or harnessed domestically and capable of producing oils as valuable raw materials for the emerging industry. A free fatty acid (FFA) lower than 3% is necessary to carry out the base catalysed reaction to end.
For biodiesel production, the higher the acid value of the oil, the lesser the conversion efficiency hence the need for esterification process. Papaya seed contains 27.3% to 28.3% protein, 28.2% to 30.7% lipids, and 19.1% to 22.6% crude fibers, it is not economically used. The majority of seeds are produced as residues and discarded as agricultural waste during fruit processing, generating environmental issues. Oil is abundant in papaya seeds (13.9% to 40.0%), which is rich in monounsaturated fatty acids and beneficial phytochemicals as tocopherol, carotene, and phenolics. This provides information on how to reduce pollution and make waste seeds lucrative. As a result, the CPSO is receiving an increasing amount of attention.

***Key words**: Biodiesel, Esterified, Carica Papaya Oil (Cso).*

INTRODUCTION

As a result of global urbanization and modernization, the use of petroleum (fossil fuel) is on the increase and there are growing concerns among stakeholders in the oil and gas industry over the depletion rate of petroleum reserves and its rising cost. In addition to the increased energy demand, global energy security and the contributions of emission from the use of petroleum and its derived products resulting to global increase in greenhouse gases (GHGs), the mitigation of climate change would not be achieved if the search for alternative source of energy is not keenly considered [1-3]. To tackle the issue of environmental degradation and energy security, the use of cost effective, renewable and sustainable energy in the future is important. The conversion of readily available sources of biomass to produce different types of biofuels to address the future energy crisis is one of the preferred attractive choices [4, 5]. In the last few years, efforts were intensified by researchers across the globe to determine the applicability of vegetable oils which include oil from soybean, rapeseed, sunflower, safflower, palm oil, *chrysophyllumalbidium*, and canola; waste cooking oil, animal fats and their derivatives as sources of fuels [2, 5-8]. This will reduce the world's dependence on fossil fuels that are non-renewable with the attendant environmental benefits to mankind.
However, the use of these edible vegetable oils will put pressure on the food uses of such oil which will result to fuel-food crisis in the future [5-7, 9, 10]. This impending crisis can be readily averted by exploring non-edible crops/agricultural waste biomass that can be grown or harnessed domestically and capable of producing oils as valuable raw materials for the emerging industry.
There is a growing interest in biodiesel (fatty acid mono alkyl ester) because of the similarity in its properties to those of petroleum based diesel. The idea of using vegetable oils from seeds of plants for internal compression ignition engine is well known.

Rudolf Christian Karl Diesel championed the early development of diesel engine which he designed to run on vegetable peanut oil with a view desire to improve on the steam engines of the late 1800s [8,10]. However, its sustainability elements were considered challenging which were considered. Shortly after his death in 1913, crude oil became the primary source of energy particularly its refined product popularly called diesel. With the availability of cheaper crude oil, the diesel engine was redesigned to accommodate the properties of petroleum diesel [8]. Biodiesel is generally produced by the transesterification reaction of vegetable oils, waste vegetable oil or animal fats in the presence of a suitable catalyst. The choice of biodiesel as a preferred renewable source of energy was based on its biodegradability, non-toxic, lower emissions, sulphur free, low levels of polycyclic aromatic hydrocarbons (PAHs) and their nitrated compounds. This alternative source of energy is environmentally friendly and could be used in the existing diesel engines with little or no modifications [5, 11, and 12].

Currently, commercial biodiesel is produced from oil of first-generation vegetable plants (soybean, rape seed, sunflower, safflower, palm oil and canola which compete with food/pharmaceutical and cosmetic uses, resulting to the rising cost of such oils and high price of biodiesel and food [5-7,9,10]. The current research is focus on the use of second generation biomass whose oils are non-edible for the commercial production of biodiesel to avert the impending fuel-food crisis as most countries are net importer of edible vegetable oils [5, 6]. These non-edible oils are usually sourced from low-cost feedstock or freely available**.** The cost of biodiesel is reportedly 60-80% of the cost of feedstock [5, 7, and 9] and producing biodiesel from these non-edible oil feedstocks will ultimately reduce the challenges associated with food security. The most identified non-edible oils are rubber, *jatropha*, castor, linseed, cotton, *Karanja*, neem, waste used oil, waste used engine oil and tobacco. The main challenge of using non-edible vegetable oil is the presence of high free fatty acids (FFAs) that consume the homogeneous base catalyst during transesterification reaction hereby lead to soap formation (saponification). The use of esterified acid is therefore needed to reduce the FFAs of the oil.

In addition, homogeneous catalysts are difficult to separate from the reaction mixtures after reaction completion. Meanwhile, the conventional method uses homogeneous or heterogeneous catalysts depending on the FFAs and moisture content of the oil. The common conventional homogeneous catalysts for transesterification reaction are NaOH, KOH, carbonates and the alkoxides of Na and K. Acids such as H_2SO_4, HCl, H_3PO_4 and organic sulphonic acids are used for esterification (pre-treatment) process prior to transesterification (by alkalis) reaction for oils with high values of FFAs [5].

The homogeneous alkali-based transesterification is commercially used if the vegetable oil is substantially low in FFAs (<1% i.e. equivalent to 2 mg.KOH/g triglyceride) to prevent soap formation (saponification reaction) and allows easy separation of glycerol by-product. One of the sustainable non-edible oil whose waste is abundant on earth after consumption of the fruit is *Carica papaya* seed.

Literature on the fruit plant assessed total world production in 2020 was estimated at 13,894,705 metric tons, which is 1.9% higher than 2019 production. India is reported to be the leading producer of *Carica papaya*, accounting for over 43% of global production. Based on report by FAOSTAT in 2020, production of *Carica papaya* globally is estimated to *rise by 2.1 percent each year*, up to 16.6 million tons in 2029. Furthermore, the reports from literature indicted that a single seed of *Carica papaya* account for 26-40% oil content, but depend solely on the ranges of the fruits [29].

This seed is non-edible oil, non-environmentally friendly, and in fact it has posed disposal problems, causing more death to aquatic animals, plants and domestic animals when discharged in water or land [13-16].

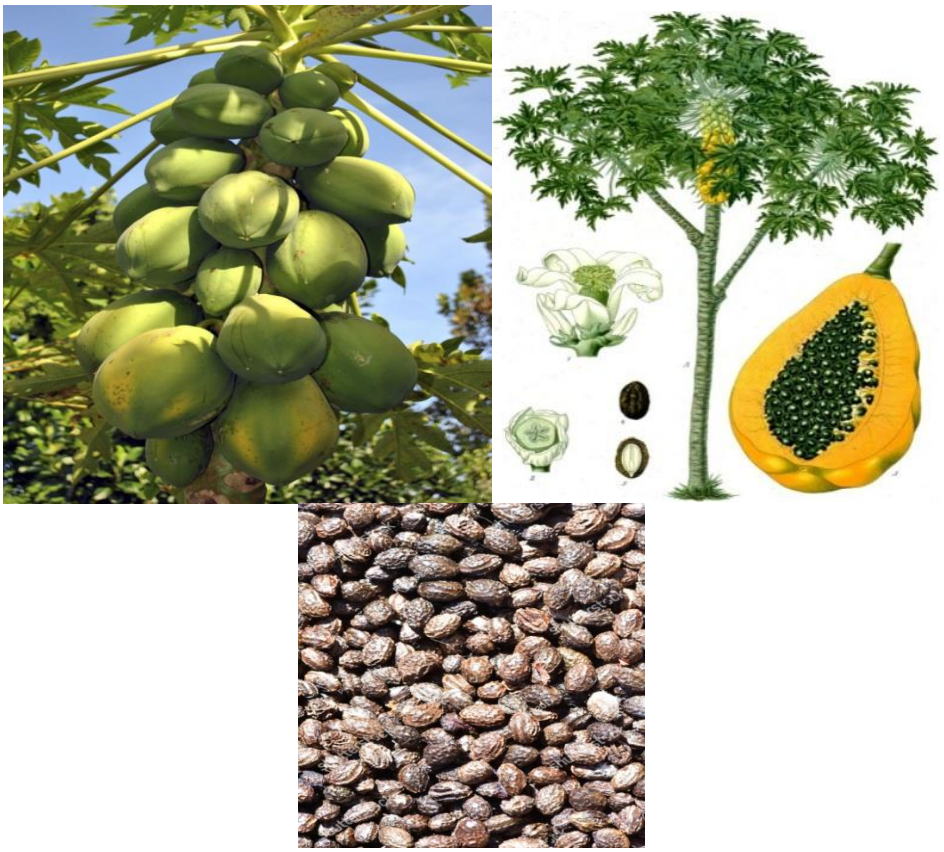

Figure 1. Utilization of the abundant *Carica papaya* seed

Utilization of the abundant *Carica papaya* seed in the world will reduce the dependence on fossil fuel as the main source of energy. This will reduce the prices of alternative sources of oil that is presently being used for commercial biodiesel production. Studies have shown that nano-catalysts such contain CaO, Al_2O_3, K_2O, SiO, and other compound derived from agricultural solid wastes are excellent heterogeneous base catalysts for the transesterification of oil to biodiesel [17-19].

Biodiesel

Researchers are searching for a viable replacement of petroleum-based fuels due to their high level of pollution to the ecosystem (land, air and sea) arising from their uses. Renewable energies (biomass, hydropower, solar, tidal waves, wind and geothermal) have been proposed as attractive preferences [20, 21]. However, biomass is considered as the cheapest source of renewable energy.

The earliest engine experimented by Rudolf Christian Karl Diesel were designed to run on vegetable peanut oils [8,10] which were later redesigned to accommodate the properties of petro-diesel when crude oil became abundant. The problem of atomization of high viscosity associated with vegetable oils did not allow the use of these oils in the newly redesigned diesel engines. The problem of high viscosity associated with oil from plant seeds can be alleviated by applying such methods as blending directly with petroleum diesel, micro-emulsification, pyrolysis and transesterification.

Transesterification is the most viable method employed today for the production of biodiesel from vegetable oil, waste used oil and animal fats [22]. The transesterification methods for biodiesel production available in literature are conventional base-catalyzed process, in-situ process, enzymatic process, supercritical process, co-solvent process, ultrasonic assisted and microwave-assisted process [23].

Feedstock's employed for Biodiesel Production

The feed stocks employed in biodiesel production are generally classified into vegetable oils, animal fats, and waste oils [24-27]. In recent times, several oils, including non-edible oils such as *Jatropha curcas* Linn, Oil palm (*Elaeisguineensis*), *Moringa oleifera*, Shea butter, Bitter melon, Kenaf, Kahalari Melon, palm kernel, animal fat, waste oils and Pumpkin (*Cucurbita maxima*) seeds have been used in the making of biodiesel [28-32]. Important consideration in selecting feedstock for biodiesel production includes: price, inconsistency in the quality and the chemical content feedstock, regular accessibility of the feedstock, elasticity to increases supply and cost of convey and pretreatment.

The current production of animal fat and vegetables oils is not sufficient to completely replace fossil diesel fuel. In order to lower the costs of production of biodiesel and to widen its feedstock base, waste cooking oil can be used. Certain quantities of used cooking oil are available all over the world. These are generated locally wherever food is cooked or fried in oil, for example, hotels, restaurants, KFC, etc. Nigeria does not have statistical data about the amounts of feedstock available. Nevertheless, an educated presumption can be made for waste cooking oil discarded annually in Nigeria. This amount is about 32 million metric tonnes of waste annually.

Better disposal of used waste oil creates a significant challenge because of problems associated with dumping and possible pollution of water and land resources.

Some of the used cooking oil is used for soap preparation and as an oil additive for fodder production. Nevertheless, major quantities of used waste oil are dumped illegally into landfills and rivers causing environmental pollution. [33-34] Used of waste used oil for biodiesel production to contribute to a reduction of greenhouse gases as well as eliminate the pollution of landfills and water.

Advantages and Disadvantages of using Biodiesel

The advantages of using biodiesel fall into three broad categories, environmental impact, energy security and economic impact.

Concerning environmental impact, biodiesel from vegetable oil causes a 57% reduction in greenhouse gases compared to fossil diesel. Indeed, biodiesel from cooking oil has an 86% reduction in greenhouse gases compared to fossil diesel.

Some of the harmful exhaust emissions are positively affected in that biodiesel reduces particulate matter by 47% compared to fossil diesel [9]. Ultimately, biodiesel is renewable, it is plant based, and so when is used can be re-grown.
With reference to energy security, it is important to consider that fossil oil is a limited resource. On the other hand, biomass is a renewable resource and locally available in many countries. National dependence on fossil oil is reduced by production of energy from locally available sources such as biomass.
Concerning economic impact, the bio-energy sector employed 2.8 million people globally in 2014. There is direct support for local agriculture: it is another way to support farmers. It has also been found that engine life is longer: biodiesel is a natural lubricant. Finally, biodiesel has a pleasant exhaust smell: When burned, the fuel emits a fried food or barbecue aroma.

Transesterification of Oils
Transesterification or alcoholises of different types of oils, triglycerides react with alcohol, generally methanol or ethanol, to produce esters and glycerine. To make it possible, a catalyst is added to the reaction [35]. The overall process is normally a sequence of three consecutive steps, which are reversible reactions. In the first step, from triglycerides, diglycerides are obtained, the second step produced monoglycerides from diglycerides and in the last step, and from monoglycerides glycerine is obtained. In all these reactions esters are produced. The stoichiometric relation between alcohol and the oil is 3:1. However, an excess of alcohol is usually more appropriate to improve the reaction towards the desired product. This process has been widely used to reduce the viscosity of triglycerides. Transesterification is one of the reversible reaction processes and proceeds essentially by mixing the reactants. However, the presence of a catalyst (a strong acid or base) accelerates the conversion.

Variables Affecting Transesterification Reaction
The process of transesterification is affected by various factors depending upon the condition used. Factors such as: FFA and moisture content, catalyst and concentration type, molar ratio of oil/methanol ratio, temperature and reaction time and effect of mixing. The effects of these factors are in this section.

Effect of free fatty acid and moisture
In transesterification process, free fatty acid and moisture content are input parameters for formative the feasibility of the vegetable oil. A free fatty acid (FFA) lower than 3% is necessary to carry out the base catalysed reaction to end. For biodiesel production, the higher the acid value of the oil, the lesser the conversion efficiency hence the need for esterification process. Both, in excess as well as low amount of catalyst may cause soap formation [36]. The initial materials used for base catalysed alcoholyses ought to convene certain specifications. The triglycerides should have lower acid value and all material should be substantially anhydrous.
The addition of sodium hydroxide catalyst compensates for higher acidity, but the resulting soap causes an increase in viscosity or formation of gels that interferes in the reaction as well as with separation of glycerol [37].

The ester yields may be drastically reduce when the reaction conditions is not met. The methoxide and hydroxide of sodium or potassium ought to be maintained in anhydrous status. Prolonged contact with air, interaction with moisture and carbon dioxide will diminish the effectiveness of these catalysts.

Effects catalysts and concentration type

Catalysts used for the transesterification are classified as alkalis, acid, enzyme or heterogeneous catalysts, among which alkali catalysts like sodium hydroxide, sodium methoxide, potassium hydroxide, potassium methoxide are more effective [38]. For the oil with high FFA content and more water, acid catalysed is suitable. The acids could be sulphuric acid, phosphoric acid, hydrochloric acid or organic sulfonic acid. Metanalysis of beef tallow was studied with catalysts NaOH and NaOMe. The NaOH used as a catalyst was significantly better than NaOMe when compared [24]. Sodium methoxide causes formation of several by-products mainly sodium salts, which are to be treated as a waste. It was observed that there is a need for high quality of oil with this catalyst [22].

As a catalyst in alkaline metanalysis, most sodium hydroxide or potassium hydroxide have been used, both in concentration from 0.4 to 2% w/w of oil. A successive conversion can be reach with when refined and crude oils with 1% either sodium hydroxide or potassium hydroxide. Metanalysis of soybean oil with the catalyst 1% potassium hydroxide has given the best yields and viscosities of esters [24]. Although chemical transesterification using an alkaline catalysis process gives high conversion levels of triglycerides to their corresponding methyl esters in short reaction times, several drawbacks can be seen in the reaction: glycerol recovery is difficult, it is energy intensive, alkaline waste water require treatment, the acidic or basic catalyst has to be removed from the product, free fatty acids and water interfere in the reaction. Enzymatic like lipases are able to effectively catalyse the transesterification reaction of triglycerides in either aqueous or non-aqueous systems, which can overcome the aforementioned problems [22]. In particular, the by – products, glycerol can be easily removed without any complex process, and also that FFA contained in waste oils and fats can be entirely converted to alkyl esters. On the other hand, the production cost of a lipase catalyst is significantly greater than of an alkaline one.

Effects of molar ratio of alcohol to oil and type of alcohol.

One of the most important variables affecting the yield of ester is the molar ratio of alcohol to triglyceride.

The stoichiometric ratio for transesterification requires three moles of alcohol and one mole of triglyceride to yield three moles of fatty acid alkyl esters and one mole of glycerol. However, transesterification is an equilibrium reaction in which a large excess of alcohol is required to drive the reaction to the right. For maximum conversion to the ester, molar ratios of 6:1 need to be used. The molar ratio has no effect on acid, peroxide, saponification and iodine value of methyl esters [39]. However, the high molar ratio of alcohol to vegetable oil interferes with the separation of glycerine because solubility increases. Equilibrium shift to the left when glycerine remains in solution, lowering the yield of the esters.

The base catalysed formation of ethyl ester is difficult compared to the formation of methyl esters.

Specifically, the formation of stable emulsion during ethanolysis is a problem. Methanol and ethanol are immiscible with triglycerides at ambient temperature, and the reaction mixtures are mechanically stirred to enhance mass transfer. During the course of reaction, emulsions usually form. In the case of metanalysis, these emulsions quickly and easily break down to form a lower glycerol rich layer and methyl ester rich layer. In ethanolysis, emulsions are easily stable and severally complicate the separation and purification of esters [37]. The formation of monoglyceride and triglycerides as intermediates products shows that both has polar hydroxyl group and non-polar hydrocarbon chains. These intermediate are strong surface active agents. In the process of alcoholises, the catalyst, NaOH/KOH is dissolved in polar alcohol phase, in which triglycerides must transfer in order to react. The reaction is initially mass – transfer controlled and does not conform to expected homogeneous kinetics. At critical level of higher concentration of the intermediates, emulsion form. The concentration of both intermediates will be very low when the emulsion becomes unstable. Hence, the reaction must be complete as much as possible in order to reduce the concentration of the mono and diglycerides.

Effects of reaction time and temperature

As the reaction time increases, the conversion rate increases. The transesterification of peanut, cotton-seed, sunflower and soybean oil under the condition of methanol/oil molar ratio 6:1, 0.5% sodium methoxide catalyst and 60 ^{o}C was carried out by [40]. The conversion was almost the same for the four oils after an hour 93 – 98% (w/w). [41] Studied the effect of reaction time on transesterification of beef tallow with methanol. The reaction was very slow during the first minute due to mixing and dispersion of methanol into beef tallow. The reaction proceeds faster from the first 5 min and the production were at maximum level as the reaction reach 15 min. It has been observed that the optimum reaction time reported by different authors was 7 h [42-45]. Transesterification takes place at any different temperatures depending on the type of oil used. [46] Studied the production of biodiesel from crude Neem oil feedstock and its emissions from internal combustion engines. The optimum reaction temperature for the oil yield was at 60 ^{o}C, [47] studied the application of response surface methodology for the optimizing transesterification of *Moringa oleifera* oil and recorded the optimum temperature to be 55^{o}C, while optimization of the transesterification reaction from cottonseed oil using a statistical approach was done by [45]. The maximum temperature for highest oil yield was 65^{o}C which mean the temperature clearly influenced the reaction rate and the yield of esters.

Effects of mixing/agitation

Since the oil is immiscible with NaOH - methanol solution, mixing is very important in the process of transesterification reaction. Once the two phases mixed, agitation is no longer needed [41] studied the effect of mixing on transesterification of beef tallow. No reaction was observed without mixing and when NaOH - MeOH was added to the melted beef tallow in the reactor while stirring, stirring speed was significant. Reaction time was the controlling factor in determining the yield of methyl esters. This suggested that the stirring speeds investigated exceed the threshold requirement of mixing.

Effect of FFA and Oil preheating

Because of nature and long chains present in the triglyceride, there is always a need to determine the FFA of the oil. The FFA ≤ 1.5 is only applicable to base catalyst transesterification process. Values higher ≥ 1.5 will need two steps approach (Acid first, then base catalysts). Apart from this factor that affects the biodiesel production, the pre-heating time of the oil is also important. Oil must be preheated for a particular time before being used for the biodiesel production

Catalysts

Many chemical reactions involved the use of one or more catalysts for reaction to reach completion. The type of catalyst used in a particular reaction depends solely on the reaction conditions and the nature of reactants involved. Although catalysts are not to be consumed in the reaction, its presence speeds up or limits reaction rate, and itself recover at the end of product formation. Nowadays, industries such as pharmaceuticals, polymers, petroleum, electronic, environmental treatment, chemical, and agrochemical industries employ the use of catalysts to achieve the end products. Also, the use of catalysts occupies an important place in academic research. A recent report revealed that the worldwide marketplace price of catalysts stood at USD 26.1 billion in 2019, and is anticipated to increase by 4% in 2020, and 4.5% progress
(https://www.grandviewresearch.com/industry-analysis/catalyst-market. Retrieved date: November 12th, 2022) rate in 2025 according to Compound Annual Growth Rate (CAGR). This makes it a value-added income for the financial sustainability of all nations if biomass waste can be employed. However, catalysts are primarily divided into four categories; homogeneous catalyst, heterogeneous catalyst, heterogenized-homogeneous catalysis, and biocatalysts.

Homogeneous catalysis involved the operation of the mixture in the same phase, the possible reactant and the catalyst exhibit a high uniform phase due to high reactivity and selectivity. Most oxidation, carbonylation, hydrogenation, esterification, and hydrocyanation are homogeneous catalysis in reaction. However, this nature of catalyst usage comes with its shortcoming, which includes among others recoverability problem, highly toxicity, and high cost, especially in esterification (bio-fuel production) case [22].

Heterogeneous Catalyst

Heterogeneous catalysis, on the other hand, involved the mixture that exists in different phases; the catalyst usually solid support or bulk form does not dissolve in the reactant, yet exhibit high reactivity. The advantages include ease of recoverability and reused, non-toxic, and of low cost [22].

These have made many industries such as hydrocarbon produced company (Fischer process), ammonia synthesis company (Haber-Bosch process), sulphury acid company (Contact process), soap making company (Saponification process), and petroleum company (transesterification process) to adhere to the use of this catalysts, apart from these advantages, heterogeneous catalysts produce in smaller particle size increase its activity due to surface phenomenon. The smaller the particles size the larger the surface area of catalysts during the reaction.

Heterogenized-homogeneous catalysis

Heterogenized-homogeneous catalysis is the mixture of the heterogeneous and homogeneous catalysts together. The homogeneous catalyst is embedded onto the solid supports to prepare the heterogenic analogy. However, these catalysts are difficult to produce due to complexity, less selectivity, reactivity, and covalent bonding between the polymer chain and the surface atoms (grafting) [20].

Biocatalysts

Biocatalysts are usually referred to as enzymes or ribozymes catalysts obtained from plants, microbes, or Goat tissue, which are used to catalyst reaction that takes place outside the living cells. This type of catalyst is on high industrial usage and has been considered an alternative to most industrial conventional catalysts due to the advantages such as mild reaction conditions, high selectivity, high efficiency, and non-toxic. Companies such as, dairy, baking, detergent, leather, textile, and biofuel utilized this catalyst for their production. Its major drawbacks are in-ability to convert a cellular catalyst into a bioprocess, difficulty in recoverability (brewing process) sustainability in harsh environmental conditions during culture (high temperature, extreme pH, high salt concentrations, organic solvent), instability in aqueous media (protein), cofactor dependability (non-protein chemical compound), possibility of an allergic reaction, and inactivation through inhibition [16].

***Carica papaya* oil (CSO)**

Carica papaya belongs to a family *Caricaceae* is a tropical plant that grows wild throughout the tropics. It has a lot of biologically active chemicals in it. Candy, jam, jelly, and pickles are all made from papaya, Because of the nutritional and functional elements found in papaya seeds, which account for about 20% of the total weight of the fruit [60], they could be potentially helpful. The tree's high concentration of natural self-defense chemicals makes it extremely resistant to insect and disease invasion.

CONCLUSIONS

In conclusion, papaya seed is edible and can be used as a substitute for black pepper because of its fiery flavor. Papaya seed, in fact, contains 27.3 percent to 28.3 percent protein, 28.2 percent to 30.7 percent lipids, and 19.1 percent to 22.6 percent crude fibers; nonetheless, it is not economically used.

The majority of seeds are produced as residues and discarded as agricultural waste during fruit processing, generating environmental issues. Oil is abundant in papaya seeds (13.9 percent–40.0 percent), which is rich in monounsaturated fatty acids and beneficial phytochemicals as tocopherol, carotene, and phenolics.

Furthermore, *Carica papaya* seed oil (CPSO) is discovered to be resistant to oxidation and can be produced into a new form of cooking oil with higher health benefits in the food business [36]. This provides information on how to reduce pollution and make waste seeds lucrative. As a result, the CPSO is receiving an increasing amount of attention.

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PREGLED PROIZVODNJE BIODIZELA TRANSESTERIFIKACIJOM ESTERIFIKOVANOG ULJA *Carica Papaia* (CSO)

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Apstrakt: Kao rezultat globalne urbanizacije i modernizacije, upotreba nafte (fosilnog goriva) je u porastu. Postoji sve veća zabrinutost između zainteresovanih strana u industriji nafte i gasa zbog stope iscrpljivanja rezervi nafte i njene sve veće cene. Konverzija lako dostupnih izvora biomase u proizvodnju različitih vrsta biogoriva za rešavanje buduće energetske krize je jedan od poželjnih atraktivnih izbora.

Biodizel se generalno proizvodi reakcijom transesterifikacije biljnih ulja, otpadnog biljnog ulja ili životinjskih masti u prisustvu odgovarajućih katalizatora. Izbor biodizela kao poželjnog obnovljivog izvora energije bio je zasnovan na njegovoj biorazgradivosti, netoksičnosti, nižim emisijama, bez sumpora, niskim nivoima policikličnih aromatičnih ugljovodonika (PAH) i njihovih nitratnih jedinjenja. Ovaj alternativni izvor energije je ekološki prihvatljiv i mogao bi se koristiti u postojećim tipovima dizel motora uz male ili nikakve modifikacije. Ovo bi smanjilo svetsku zavisnost od fosilnih goriva koja nisu obnovljiva sa pratećim ekološkim prednostima za čovečanstvo.

Međutim, upotreba ovih biljnih ulja izvršiće pritisak na upotrebu takvog ulja u ishrani, što će dovesti do krize sa hranom u budućnosti. Ova predstojeća kriza može se lako sprečiti istraživanjem nejestivih useva ili biomase poljoprivrednog otpada koji se mogu gajati ili iskoristiti za proizvodnju ulja kao vredne sirovine za industriju u nastajanju. Slobodna masna kiselina (FFA) niža od 3% je neophodna da bi reakcija katalizacijom (bazom) bila završena. Za proizvodnju biodizela, što je veća kiselinska vrednost ulja, to je manja efikasnost konverzije, stoga je potreban proces esterifikacije.

Semenka *Carica Papaia* (Papaja) sadrži 27,3% do 28,3% proteina, 28,2% do 30,7% lipida i 19,1% do 22,6% sirovih vlakana, ne koristi se ekonomično. Većina semenki u proizvodnji ulja su ostaci i odbacuju se kao poljoprivredni otpad tokom prerade, što dovodi i do evidentnih ekoloških problema. Ulje *Carica Papaia* (Papaja) (sadržaj 13,9% do 40,0%), je bogato mononezasićenim masnim kiselinama i korisnim fitohemikalijama kao što su tokoferol, karoten i fenoli. Ovo pruža informacije o tome kako smanjiti zagađenje i učiniti otpadno seme unosnim. Kao rezultat toga, seme *Carica Papaia* (CPSO) dobija sve veću pažnju.

Ključne reči: *biodizel, esterifikovano, Carica Papaia ulje (CSO).*

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MORPHOMETRIC ANALYSIS AND ITS IMPLICATION ON FLOOD AND EROSION MANAGEMENT IN LOWER KWA IBOE RIVER, SOUTH EASTERN NIGERIA

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Abstract: The study focused on morphometric analysis and its implication on flood and erosion management in Lower Kwa Iboe River, South Eastern Nigeria. The following objectives were taken into consideration: to map and characterize the Lower (downstream) Kwa Iboe River using Geographic Information System (GIS) and Remote Sensing technology, to examine the morphometric indicators in Lower Kwa Iboe River and its implications on flood and erosion control. Morphometric analysis was carried out at different sub-catchments in lower Kwa Iboe River. The lower Kwa Iboe River has four matured sub-catchments. These include: Anyang sub-catchment, Akpibe sub-catchment, Idim Ibedu/Ikot Ubo sub-catchment, as well as Idim Ntete sub-catchment. The result indicates that the calculated mean bifurcation ratio for the study area is 3.74, an indication that the study area is a lowland area. The length of overland flow of the lower Kwa Iboe basin is 1.25km, the drainage texture of the lower Kwa Iboe basin ranges from 0.77-1.23. This shows that the basin has a very coarse texture which is susceptible to flood disaster. The study area has an average elongation ratio of 0.19, circularity ratio (0.54) and form factor (0.42) which indicates that the shape of the basin tends towards elongation.
The result of the study implies that the basin is neither dissected nor prone to erosion but rather flood disaster which depends on a number of natural factors such as climate, rainfall, vegetation, rock and soil types. In conclusion, the watershed is only vulnerable to flood disaster especially the downstream.

Key words*: Morphometric analysis, flood, erosion management, Lower Kwa Iboe*

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River, Geographic Information System (GIS), mean bifurcation ratio

INTRODUCTION

Studies on drainage basin morphology and watershed management abound all over the world as a result of the relevance of water to the sustenance of life.

For many years, hydrologist have recognized that variations between drainage networks in their planimetric and topographic structure have profound effect upon their hydrology, particularly their flood response. Thus, a number of approaches have been employed to investigate these effects including statistical characterization of natural basin flow in relation to morphometric parameters, experiments on model basins, flow routing using specific channel network parameterization and various theoretical approaches [19, 34].

The form and structure of drainage basins and their associated drainage networks are described by their morphometric parameters. Morphometric properties of a drainage basin are quantitative attributes of the landscape that are derived from the terrain or elevation surface and drainage network within a drainage basin. Application of quantitative techniques in morphometric analysis of drainage basins was initially undertaken from topographic maps using manual methods. Drainage basin/watershed analysis based on morphometric parameters is very important for watershed planning and is the best method to identify the relationship of various aspects in the area. Prior to the invention of GIS technology, morphometric studies were basically done using the manual method, which involve paper tracing and manual calculations of parameter. This technique was very difficult, time consuming and less accurate [11]. Several studies [2] Also remarked that it is basically time consuming and inaccurate as compare to the GIS approach.

Today, Remote sensing and Geographical Information System (GIS) techniques are increasingly being used for morphometric analysis of drainage basins throughout the world [51], ASTER DEM and SRTM DEM remains the two major sources of digital elevation model for watershed studies. These sources provide a useful overview of the application of remotely sensed data to investigate river form. In the last decade, high-resolution satellite imagery has become available with the launch of Quick Bird and Ikonos satellites which offers a submeter resolution images that are less flexible than aerial photographs, which can be flown to order. For example, they can be used to capitalize on the immediacy of the aftermath of flood events. In addition, the measurement of planform changes over time provides useful information on system dynamics and magnitude and rates of channel change [1]. However, recent and historic planform change assessment provides an important context for river management.

Evident from studies on river basins especially in humid tropical are among the most extreme fluvial environments in the world due to a combination of unplanned urbanization, high variability in annual rainfall and infrequent occurrences of intense tropical storms which generate an energetic and powerful flow regime [51]. Regrettably, studies on channel morphology that is sculpted by fluvial processes is relatively understudied in Kwa Iboe River. There is therefore the need to fill in this space by conducting a similar study in the lower segment of the watershed. By implication, this would be useful in adopting best management practices that can be used in reducing rates of environmental degradation in the watershed.

Hence, it becomes necessary to conduct this research in Lower Kwa Iboe River, an area that is rapidly eroding and flooding due to extremely wet tropical conditions, anthropogenic activities, frequent intense storms and highly vulnerable to denudation processes.

Aim and Objectives of the Study

The general aim of the study is to examine the morphometric parameters in Lower Kwa Iboe River, South Eastern Nigeria with a view to examining its implication on flood and erosion control. To achieve the above aim, the following objectives were taken into consideration:

i. To map and characterize the Lower (downstream) Kwa Iboe River using Geographic Information System (GIS) and Remote Sensing technology;
ii. Examine the relationship among morphometric indicators in Lower Kwa Iboe River;
iii. Examines the implications of the study on flood and erosion control in the study area.

MATERIAL AND METHODS

Study Area

The Kwa Iboe river with its source traced to the rocky landscape of Amaise autonomous community in Isuikwuato LGA of Abia State located at latitude 5º 31' 44.744" N and longitude 7º 31' 2.104" E, traverses through 6 local government areas in Abia state and not less than 21 local government areas in Akwa Ibom State. The lower Kwa Iboe Watershed covers Ibeno, Eket, Esit Eket, ONNA, Etinan, Mkpat Enin, Okobo, Nsit Atai, Nsit Ubium, Nsit Ibom and parts of Ibesikpo Asutan local government area (Figure 1). The climate of the area is typical of humid tropical climate where the weather is almost wet all year round. It is mainly influenced by the movement of the Inter-Tropical Discontinuity (ITD) which is the boundary zone between the rain - bearing south westerly winds from the sea and dry north – east winds from Sahara, and it results in two seasons (wet and dry). Geologically, the basin is underlain by Coastal Sands Plains of tertiary and quaternary rocks of sedimentary origin which are not older than the quaternary age; the creeks have younger alluvial covers. Major landforms and relief common in the area comprise shallow depressions and numerous dry valleys. Such depressions are usually inundated during the rainy seasons and many a times create seasonal lakes which serve as major sources of water in the rural communities.

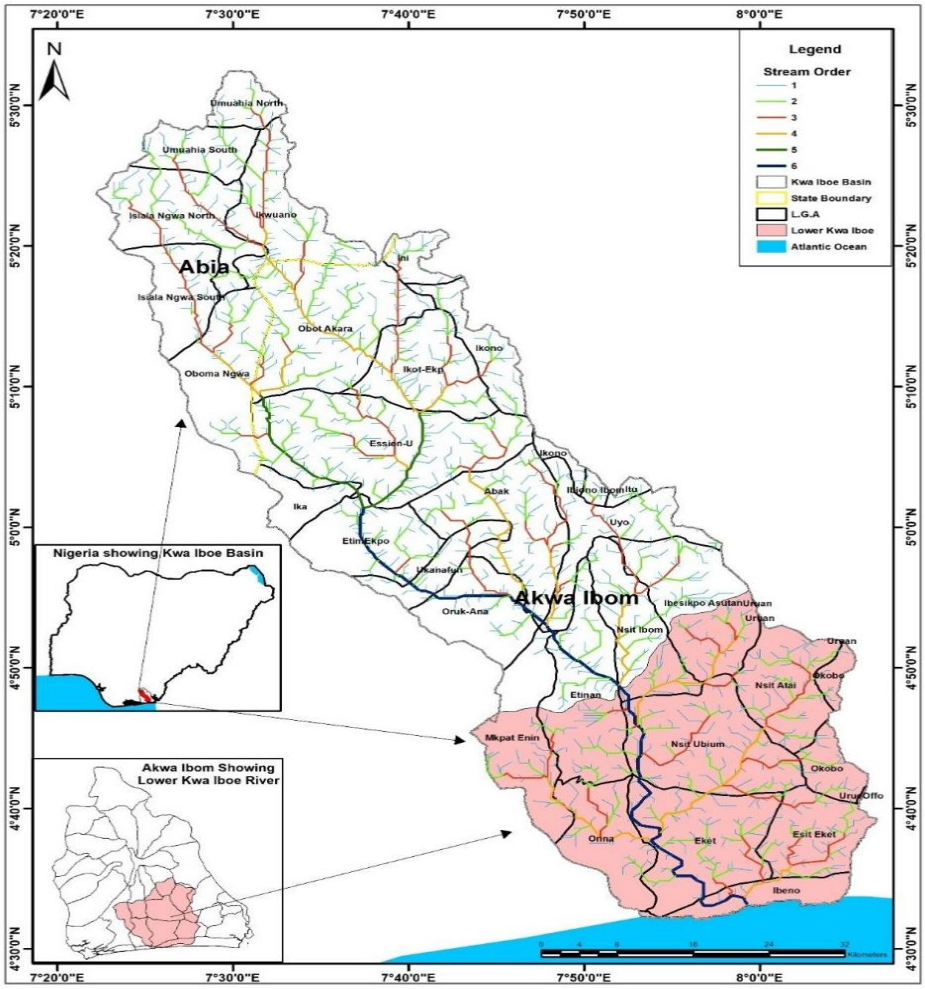

Figure 1. Location Map of Kwa Iboe Basin

Research Design

The study adopted a survey design approach. In this case, morphometric analysis was carried out at different sub-catchments in lower Kwa Iboe River.

Mapping and Characterizing the Lower (Downstream) Kwa Iboe River using Geographic Information System (GIS) and Remote Sensing Technology

In characterizing the basin, the 2023 ASTER DEM of the catchment area was downloaded from the USGS website and use for the stream network. The stream networks were extracted using ArcGIS 10.8 software via the spatial analyst tool box on ArcMap.

Using the clipped DEM of the catchment, hydrology was selected from the spatial analyst tool box, the DEM was first filled through the fill tool, flow direction and flow accumulation was determined still on the ArcMap menu. More so, using the flow accumulation data generated, a threshold value of 50 in relation to the elevation of the area was set using the raster calculator on the Map algebra command function. The Strahler stream ordering method was adopted in ordering the Kwa Iboe River system and was converted from raster to vector using the stream to feature function on the hydrology tool box. The topographic map of the study area was obtained from the office of the surveyor general of Akwa Ibom State. The projection type was UTM and spheroid of WGS 1984. The datum was the Minna datum, UTM zone 32N and the pixel size was 30meter.

RESULTS AND DISCUSSION

Examining the relationship among morphometric indicators in Lower Kwa Iboe River

Areal characteristics such as basin area, perimeter, stream length, etc. were extracted from the attribute tables of the watershed in ArcGIS (Table 1.) while linear and relief features were calculated using the respective equations as shown in Table 2.

Table 1. Parameters for Areal Drainage Classification in Lower Kwa Iboe River

S/N	Parameters	Formulae	References
1	Basin Area	Area from which water drains to a common stream and boundary determined by opposite ridges (GIS Analysis).	Strahler (1964)
2	Basin Perimeter	Outer boundary of drainage basin measured in kilometres (GIS Analysis).	Schumm (1956)
3	Basin Length	The straight line from the mouth of the basin to the farthest point on the basin perimeter (GIS Analysis).	Schumm (1956)
4	Form Factor	$F_r = A/L^2$. F_r = Form factor, A = Basin area, L = Basin length	Boyce and Clark, (1964), Horton (1945)
5	Elongation Ratio	Re= $\sqrt{A}$ /π / Lb Where, A= Area of the basin (km^2) Lb=(Maximum) Basin length (km) π =3.142	Schumm (1956)
6	Circulatory Ratio	Rc = 4πA/ P2 Where, A = Basin area (km^2) and P= Perimeter of the basin (km) π=3.142	Miller (1953)
7	Drainage Density	Dd = Lμ/A Where, Dd = Drainage density (km/km^2) Lμ = Total stream length of all orders and A = Area of the basin (km^2).	Horton (1945)

Contin. Table 1.			
8	Stream Frequency	Fs = Nμ/A Where, Fs = Drainage frequency (df). Nμ = Total no. of streams of all orders and A = Area of the basin (km^2).	Horton (1945)
9	Leminiscate Ratio	$K = L^2 / 4A$ Where L = Length of the basin A = Area of the basin	Schumm (1956)
10	Constant Channel Maintenance	$C = 1/Dd$ Where Dd = Drainage Density (Is the reciprocal of drainage density)	Horton (1945) Schumm (1956)
11	Drainage Texture	$R\ N_u/PR$ =Drainage texture, N =Number of streams, P= Drainage perimeter	Horton (1945), Smith(1950)
12	Infiltration Number (drainage intensity)	If = Dd × Fs Where, Dd = Drainage density (km/km^2) and Fs = Drainage frequency. (Also known as drainage intensity)	Zavoiance I (1985) Faniran (1968)

The lower Kwa Iboe River has four matured 4th order sub-catchments. These include: Anyang sub-catchment which drain Ibesikpo and Nsit Ibom area; Akpibe sub-catchment which drains Mkpat Enin and Onna; Idim Ibedu/Ikot Ubo sub-catchment which drain Nsit Atai and Nsit Ubium as well as Idim Ntete sub-catchment which drain Esit Eket and parts of Eket and Ibeno (Figure 2).

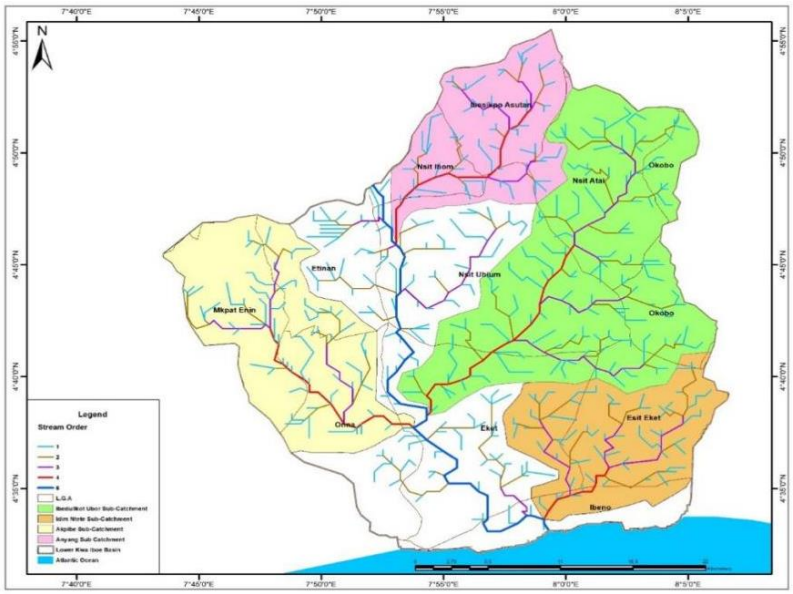

Figure 2. Stream Network of Sub-Catchments in Lower Kwa Iboe River, [7.]

Table 2. Parameters for Linear and Relief Classification of Lower Kwa Iboe River

S/N	Feature	Parameters	Formulae	References
13	Linear Feature	Stream Order	Hierarchical rank (GIS Analysis)	Strahler (1964)
14		Bifurcation Ratio	$Rb = N\mu / N\mu +1$ Where, Rb = Bifurcation ratio, Nμ = No. of stream segments of a given order and Nμ +1= No. of stream segments of next higher order.	Gregory and Walling, (1973), Schumm (1956)
15		Mean Bifurcation Ratio	Rbm = Average of bifurcation ratios of all orders	Strahler (1957)
16		Total Stream Length	GIS Analysis (Length of all the stream km)	Schumm (1963)
17		Mean Stream Length	$Lsm = L\mu/N\mu$ Where, Lμ = Total stream length of order 'μ' Nμ = Total no. of stream segments of order 'μ'	Schumm (1963), Strahler (1964)
18		Stream Length Ratio	$RL= Lsm / Lsm^{-1}$ Where, Lsm=Mean stream length of a given order and Lsm^{-1}= Mean stream length of next lower order	Horton RE (1945)
19		Length of Overland Flow	Lg=1/DD Where, DD=Drainage Density (km/km^2)	Horton (1945)
20	Relief Feature	Basin Relief or Local Relief	H = Z – z Where, Z = Maximum elevation of the basin (m) and z = Minimum elevation of the basin (m)	Hadley and Schumm (1961)
21		Relief Ratio	Rr = H / Lb Where, H = basin relief (m) and Lb = Basin length (m)	Schumm (1963)
22		Basin Slope	GIS Analysis	
23		Ruggedness Number	*R = Bh/Dd* Where, Bh=Basin relief, Dd=Drainage density	Schumm (1963)

Morphometric Characteristics of Lower Kwa Iboe River

The characterization of the basin was based on the linear, areal and relief aspect of the watersheds as represented in Table 3, 4 and 5 respectively.

The linear aspects include the stream order (U), stream length (Lu), mean stream length (Lsm), stream length ratio (RL), bifurcation ratio (Rb), among others which are determined and results have been presented in table 4.1.
The result indicates that the calculated mean bifurcation ratio for the study area is 3.74, (ranging from 3.14-4.07), an indication that the study area is a lowland area. According to [33] bifurcation ratios ranging from 3-5 indicate natural drainage system characterized by homogenous rock (which in this study area is sedimentary).

This low Rb value indicates less structural disturbance in lower Kwa Iboe basin and also identified it as a natural basin. The length of overland flow of the lower Kwa Iboe basin is 1.25km, which shows high surface runoff. Overland flow is significantly affected by infiltration (exfiltration) and percolation through the soil, both varying in time. Correspondingly, the stream frequency of the study area is 0.36 stream segments per square kilometer. This lower value indicates that the basin possesses low relief and a smaller number of streams. The existence of a smaller number of streams in a basin indicates matured topography, while the presence of large number of streams indicates that the stream is youthful and still undergoing erosion. The linear aspect of the basin can be also explained using the law of drainage composition.

Area, perimeter and length of a basin are the most significant parameters in quantitative morphology [28] and of all the morphometric parameters controlling drainage runoff pattern [4]. The basin area directly influences the size of the storm hydrograph, the magnitudes of peak and mean runoff. It is important to note that the maximum flood discharge per unit area is inversely related to size [17]. In Table 4, the average basin area, perimeter and length are 200.26km^2, 68.29km and 21.72km respectively. The small basin area and length of lower Kwa Iboe basin justifies the reasons why the area is at risk of flooding over the years. The area and length of a basin are directly related because the smaller the basin, the shorter the length. This factor affects the rate of discharge and chances of flood occurrence in the basin, as a result of lower concentration time (lag time) which will decrease infiltration rate and reduces water lost through evapotranspiration, hence Increase runoff volume. This is in agreement with the works of [29]. In the upper Kaduna catchment of Nigeria where drainage size is linked to the amount of runoff, and where the size of Ogbere and Ogunpa drainage basins in Ibadan, Nigeria were compared and the frequencies of flood occurrences linked to their sizes.

The drainage texture of the lower Kwa Iboe basin ranges from 0.77-1.23. This shows that the basin has a very coarse texture which implies that the basin is neither dissected nor prone to erosion but rather susceptible to flood disaster. Drainage texture depends on a number of natural factors such as climate, rainfall, vegetation, rock and soil types, infiltration capacity, relief and stage of development. The higher the drainage texture, the more the dissection and erosion in the basin. Weak rocks devoid of vegetative cover produce fine texture, while rocks which are hard and with vegetative cover produce coarse texture. There are five different drainage textures related to various drainage densities and these include: very coarse (below 2), coarse (2 - 4), moderate (4 - 6), fine (6 - 8) and very fine (8 and above). Parameters (elongation ratio, circulatory ratio, lemniscate k-factor and form factor) are used for characterizing drainage basin shape, which is an important parameter from hydrological point of view. The shape of the basin mainly governs the rate at which the water is supplied to the main channel.

Elongation ratio determines the shape of the basin and can be classified based on these values as circular (0.9 - 1), oval (0.8 – 0.9), less elongated (0.7 – 0.8), elongated (0.5 – 0.7), more elongated (< 0.5).

The study area has an average elongation ratio of 0.19, circularity ratio (0.54) and form factor (0.42) which indicates that the shape of the basin tends towards elongation. The elongation shape indicates that the basin will have a flatter peak of flow for longer duration.

In the same vein, the circularity ratio is a similar measure as elongation ratio. Here, the average circularity ratio value for the study area is 0.54 which indicate that the drainage basin is elongated and is characterized by medium relief.

This simply indicates that the basin has a dendritic pattern and is at a mature stage of the life cycle of the tributary basins. The form factor of the study area ranges from 0.36-0.52.

This shows that the basin is very elongated and thus has low peak flow of longer duration. Similarly, the mean constant of channel maintenance of the basin ranges from 1.39-1.64 with an average of 1.55. This implies that an average of 1. 55sq.ft surface is needed in the basin for the creation of one linear foot of the stream channel.

Table 3. Linear Aspects of Lower Kwa Iboe River

Indicator	Sub-catchment				Mean	Range
	Anyang	Idim Akpibe	Idim Ntete	Ibedu/Ikot Ubo		
Basin Order	4th order	4th order	4th order	4thorder		
Area (km)	135.56	194.41	143.27	327.79	200.26	135.56-327.79
Perimeter (km)	55.14	65.75	57.23	95.02	68.29	55.14-95.02
Form Factor	0.36	0.38	0.52	0.41	0.42	0.36-0.52
Elongation Ratio	0.21	0.19	0.19	0.17	0.19	0.17-0.21
Circulatory Ratio	0.56	0.57	0.55	0.46	0.54	0.46-0.57
Drainage Density	0.63	0.61	0.72	0.63	0.65	0.61-0.72
Stream Frequency	0.50	0.35	0.31	0.29	0.36	0.29-0.50
Drainage Intensity	0.32	0.21	0.22	0.18	0.23	0.18-0.32
Leminiscate Ratio	0.69	0.66	0.48	0.61	0.61	0.48-0.69
Constant Of Channel Mainten.	1.59	1.64	1.39	1.59	1.55	1.39-1.64
Drainage Texture	1.23	1.02	0.77	1.00	1.01	0.77-1.23

According to: Researchers Computation using GIS (2023).

Table 4. Areal Features of Lower Kwa Iboe River

Indicator	Sub-Catchment				Mean	Range
	Anyang	Idim Akpibe	Idim-Ntete	Ibedu/Ikot Ubo		
Basin Order	4thorder	4th order	4th order	4th order		
No. of order 1	53	54	31	66	51.00	31-66
No. of order 2	11	10	9	14	11.00	9-14
No. of order 3	4	3	3	4	3.50	3-4
No. of order 4	1	1	1	1	1.00	1
Total No. of Stream	68	67	44	95	68.50	44-95
length of order 1 (km)	39.6	61.89	52.49	104.54	64.63	39.6-104.54
length of order 2 (km)	16.09	22.63	24.82	49.35	28.22	16.09-49.35
length of order 3 (km)	13.31	17.73	18.83	33.12	20.75	13.31-33.12
length of order 4 (km)	16.9	16.73	7.40	19.75	15.20	7.40-19.75
Total Stream Length	85.9	118.98	103.54	206.76	128.80	85.9-206.76
Total mean stream length	21.48	29.75	25.89	51.70	32.21	21.48-51.70
Mean stream length 1(lu1)	0.75	1.15	1.69	1.58	1.29	0.75-1.58
Mean stream length 2(lu2)	1.46	2.51	2.76	3.53	2.57	1.46-3.53
Mean stream length 3(lu3)	3.33	5.91	6.28	8.28	5.95	3.33-8.28
Stream length ratio 1&2	0.51	0.46	0.61	0.45	0.51	0.46-0.61
Stream length ratio 2&3	0.44	0.43	0.44	0.43	0.44	0.43-0.44
Stream length ratio 3&4	0.20	0.35	0.85	0.42	0.46	0.20-0.85
Cumulative mean length of stream	22.44	26.3	18.13	33.14	25.0	18.13-33.14
Basin length (km)	19.30	22.74	16.60	28.24	21.72	16.60-28.24
Axial width (km)	9.44	8.65	7.96	10.87	9.23	7.96-10.87
Bifurcation Ratio 1&2	4.81	5.40	3.44	4.71	4.59	3.44-5.40
Bifurcation Ratio 2&3	2.75	3.33	3.00	3.50	3.15	2.75-3.50
Bifurcation Ratio 3&4	4	3	3	4	3.50	3-4
Mean Bifurcation Ratio	3.85	3.91	3.14	4.07	3.74	3.14-4.07
Length of Overland Flow	1.27	1.28	1.18	1.27	1.25	1.18-1.28

The constant channel maintenance which indicates the relative size of landform units in a drainage basin ranges between 1.39-1.64 with a mean of 1.55.

This indicate that a minimum of 1.55km^2 is required for the development and maintenance of the stream channels in lower Kwa Iboe basin, that is, 12.20km^2 of the basin area is required to maintain one linear unit of channel length. On the other hand, the lemniscate ratio which is an expression of the slope of a basin [17] ranges between 0.48-0.69 which indicate low runoff in the basin, all things been equal. The rate of surface runoff can be influenced by the characteristics of the falling rain and the prevailing environmental factors.

The relief ratio is the expression of the overall steepness of a basin, which indicates the intensity of erosion processes operating on slopes of the basin. The results in table 4.3 shows that the minimum basin relief is 7m found in areas around Ntete sub-catchment while the maximum relief is 18m found in Anyang and Ibedu/Ikot Ubor sub-catchments. The relief aspect includes the study of basin relief (Bh), relief ratio (Rh), and Ruggedness number (Rn), among others as shown in Table 5. The calculated basin relief of the watershed ranges from 10-19 with a mean of 16.25. The relief ratio of the study area which is the ratio of the total relief and the longest dimension of the basin parallel to the principal drainage line ranges from 0.52-1.49. The relief ratio therefore shows that the major portion of the basin is having gentle slope. This also confirmed that the runoff from the basin will be low as a result of gentle slope in major portion of the basin. Similarly, ruggedness number (Rn) reflects the slope and relief variation in the basin. It ranges between 0.0063-0.0296. The low value of Rn (mean= 0.01) implies that the basin area is less prone to soil erosion and having lack of intrinsic structural complexity in association with the basin relief and drainage density.

Implication on Flood and Erosion Management

The result of the study shows that lower Kwa Iboe River is a natural drainage system characterized by homogenous rock (which in this study area is sedimentary) with less structural disturbance. The low average bifurcation ratio of the basin also indicates that parts of its segment are liable to flooding. This finding agrees with the work of [16] which asserted that the lower the bifurcation ratio, the higher the risk of flooding. The drainage texture of the basin (very coarse texture) implies that the basin is neither dissected nor prone to erosion but rather flood disaster which depends on a number of natural factors such as climate, rainfall, vegetation, rock and soil types, infiltration capacity, relief and stage of development. The basin is elongated in shape indicating that it has a flatter peak of flow for longer duration and is characterized by medium relief. More so, the basin has a dendritic pattern and is at a mature stage of the life cycle of the tributary basins.

The study also revealed that the basin is very elongated and thus has low peak flow of longer duration. Consequently, the flood flow of this type of basin is easier to manage than the circular basin [39]. More so, in the present studied basin, the length of overland flow was low which indicates low permeability of subsoil and low surface run-off. The GIS analysis of the longitudinal profile also shows that all the sub-catchments exhibit convexity which is associated with drainage basins that generate low discharge which is an indication that the channel flow is restricted to a narrow valley characterized by very long valley sides.

The result of the hypsometric analysis of all the sub-watersheds of Lower Kwa Iboe River indicates that all the watersheds are in their mature stage (except Anyang) which implies that the watershed is quite matured and erosional processes have stabilized, meaning that the zone is only vulnerable to flood disaster especially the downstream.
In a nutshell, the study area is highly vulnerable to flood disaster especially in the lower sub-catchment. This is further indicated in the 3-D model of the study area (Figure 3).

Table 5. Relief Features of Lower Kwa Iboe River

	Sub-catchment				Mean	Range
Indicator	Anyang	Idim Akpibe	Idim Ntete	Ibedu/Ikot Ubo		
Basin Order	4th order	4th order	4th order	4th order		
Highest Elevation (m)	28	28	25	28	27.25	25-28
Lowest Elevation (m)	18	10	7	9	11.00	7-18
Basin Relief	10	18	18	19	16.25	10-19
Relative relief	0.18	0.27	0.31	0.20	0.24	0.18-0.27
Relief ratio	0.52	1.26	0.92	1.49	1.05	0.52-1.49
Ruggedness Number	0.0063	0.01098	0.01296	0.01197	0.01	0.0063-0.0296

According to: Researchers Computation using GIS (2023).

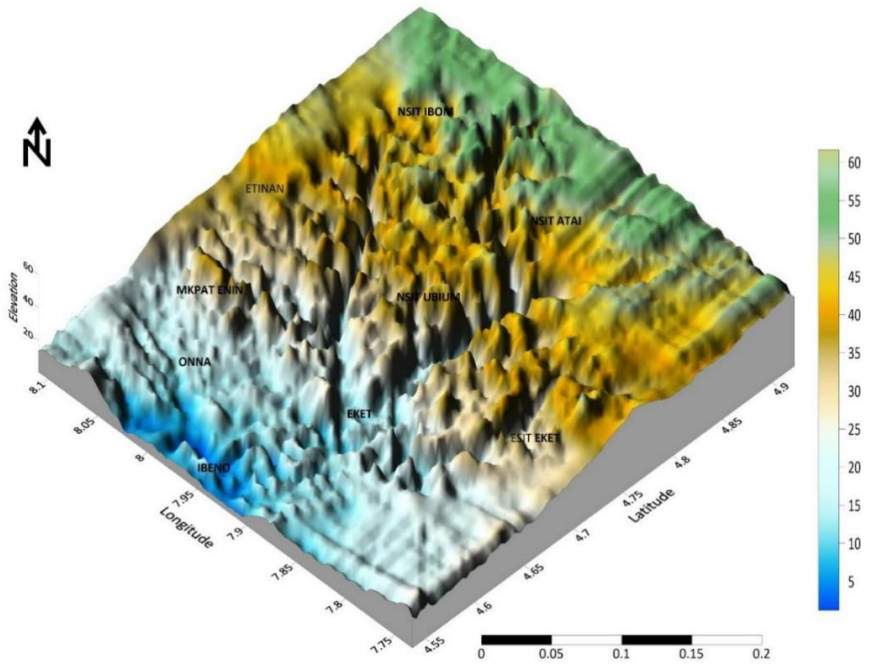

Figure 3. 3D Surface Model of Lower Kwa Iboe River
[Projection = Orthographic; Rotation = 45°; Tilt = 45°; Angle of View = 30°].

CONCLUSIONS

The lower Kwa Iboe River contain four 4th-order sub-catchments and it has a dendritic drainage pattern.

In assessing the hydraulic parameters, the result shows that Kwa Iboe River is highly entrenched river. More so, the bank full width versus discharge (exponent b) having the highest value of 0.36, indicates that more erosion occurred on the bank of the river due to the no cohesiveness of the bank materials and its ability to accommodate the flow. This can be attributed to the intense activities of sand mining practiced in the catchment area. Morphometrically, Kwa Iboe basin is well drained. The low values of bifurcation ratio reveal that there exists a very high risk of flooding. More so, as the basin is elongated in shape, it has a low discharge rate and highly permeable sub soil conditions. The low values of stream frequency and drainage intensity further confirm that the surface runoff is not quickly removed from the basin, thereby resulting in flooding.

Recommendation

In view of the findings reached and the implications discussed in the course of this research, the following recommendations are made:
Blue-Green Infrastructure (BGI) should be adopted by households and government in the area. These should include tree planting, road median, planting of grasses/vegetated surfaces, reserve areas, among others. These safeguard measures will prove to be worthwhile in the long run. Engineering construction such as stream channelization and construction of embankments along main river channels to reduce flooding is highly recommended.

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MORFOMETRIJSKA ANALIZA I NJENA IMPLIKACIJA KOD UPRAVLJANJA POPLAVAMA I EROZIJOM U DONJEM SLIVU REKE KWA IBOE, JUGOISTOČNA NIGERIJA

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Apstrakt: Studija se fokusirala na morfometrijsku analizu i njenu primenu kod upravljanja poplavama i erozijom za donje deo reke Kwa Iboe, jugoistočna Nigerija. Naredni ciljevi koji su uzeti u obzir: mapiranje i karakteristike donjeg dela (nizvodno) reke Kva Iboe koristeći Geografski informacioni sistem (GIS) i tehnologiju daljinskog detektovanja, ispitati morfometrijske indikatore u reci Lower Kwa Iboe i njihove implikacije na kontrolu poplava i pojavu erozije. Morfometrijska analiza je sprovedena na različitim podslivovima u donjem delu reke Kwa Iboe. Donji deo reke Kwa Iboe ima četiri podsliva: Anyang, Akpibe, Idim Ibedu/Ikot, Ubo Idim Ntete.

Rezultat studije pokazuje da je izračunati srednji koeficijent bifurkacije (račvanje rečnog toka) za područje istraživanja 3,74, što ukazuje da je područje istraživanja ravničarskog tipa. Dužina kopnenog toka donjeg basena reke Kwa Iboe je 1,25 km. Tekstura drenažog dela donjeg basena Kwa Iboe kreće se od 0,77 do 1,23. Ovi podaci pokazuju da sliv ima veoma grubu teksturu koja je podložna mogućim katastrofalnim posledicma od poplava. Proučavano područje ima prosečan koeficijent izduženja od 0,19; koeficijent kružnosti (0,54) i faktor forme (0,42) što ukazuje da oblik sliva teži izduženom obliku.
Rezultat studije implicira da basen nije ni raščlanjen ni podložan eroziji, već katastrofalne posledice od poplava zavise od niza prirodnih faktora kao što su klima, vrednosti padavina, vegetacija, stene i tipova zemljišta.
U zaključku, proučavani sliv reke (Kwa Iboe) je osetljiv samo na katastrofalne posledice od poplava, posebno u nizvodnom delu.

Ključne reči: Morfometrijska analiza, poplave, upravljanje erozijom, donji deo reke Kwa Iboe, Geografski informacioni sistem (GIS), srednji odnos bifurkacije.

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✧OVERVIEW OF THE POSSIBILITY APPLICATION OF SOME NANO DRONE TECHNOLOGIES IN MODERN AGRICULTURE

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Abstract. The use of different types of drones in almost all sectors of the global economy is growing rapidly, but the use of drones in agriculture has suddenly increased. According to some data from the literature, the market for different types of drones in agriculture alone is expected to grow from USD 1.2 billion in 2019 to USD 5.5 billion in 2024.

A particularly interesting phenomenon is the significant increase in the use of drones (especially various nano-types) in the world and the possibility of some of them being used in agriculture in the Republic of Serbia.

The world of drone technology has taken a huge leap forward with the introduction of nano drones. For example, some modern nano drone solutions have dimensions of less than 2 x 2 cm.

Nano drones are ultra-small remote-controlled aircraft that can perform a variety of tasks. They are equipped with advanced sensors and functions such as obstacle avoidance and high-speed maneuverability. Some models are even capable of taking aerial photographs, staying in the air for long periods of time and flying autonomously. Nano drones are now more affordable than ever before. Prices range from a few hundred dollars to several thousand, depending on the model and features. Nowadays, nano drones are affordable for everyday users in various fields.

This paper introduces nano drone technology (e.g. the type of nano drones and equipment) as a new application for greenhouses: There are some stages that greenhouse growers can consider for the use of nano drones;

Safe inspection of the structural components of greenhouses; Pollination processes (e.g. the role of RobotBee); Application of shading composite glasshouses; Crop monitoring/inventory of greenhouses.

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Key words: *Nano drones, possibilities of application in green/glasshouses, production of vegetable crops, control.*

✧

INTRODUCTION

The population of planet Earth is constantly increasing. The global demand for food is following the same trend. Agriculture must not only produce more to meet the increasing food consumption, but also do so in a more sustainable way than before [1]. In recent years, precision agriculture has made many technological advances (e.g. GPS, GIS or various drones), providing farmers with an increasingly modern set of tools to increase crop production.

Today, unmanned aerial vehicles (UAVs) occupy a prominent position in the technical and technological equipment of participants in modern agricultural production [1, 31, 33], [6, 26, 31], [32, 33], [36, 46]. Drones are used in many areas of agriculture, such as mapping, crop stress detection, estimation of biomass and nutrients in the field, chemical spraying, weed management, and finally geo-referencing in GIS [2].

Although the vast majority of agricultural applications take place outdoors, there are some attempts to use specialized drones in greenhouses. The authors [3] present a method for automatic detection and classification of pests using a Support Vector Machine using images captured by a drone and an IP camera. In addition, [4] proposed a ground and airborne robotic system to measure temperature, humidity, CO2 and brightness in the greenhouses of Almeria (Spain). A concept for plant pollination using nanocopter drones is presented by [6]; however, no technical details were given in the study.

In general, the lack of indoor applications (e.g. greenhouses) is mainly due to the limitations that exist in indoor environments such as greenhouses. To navigate a drone outdoors, for example, the exact position can easily be determined using GPS and GIS. For indoor applications, however, GPS is not an option

Therefore, different approaches for indoor localization have been proposed, in some cases involving more sophisticated sensors such as lidars and cameras. It is known that these sensors generate large amounts of data and the processing of the data is very computationally intensive. To reduce the onboard processing workload, these calculations are usually transferred to the ground controller or even to a remote computing cloud service. However, this requires a reliable connection (e.g. wireless or radio).

A stable connection (e.g. wireless or radio) between the drone and the control unit is an important aspect of indoor navigation. On the one hand, the drone should be able to receive navigation commands, and on the other hand, it should send its current status or position back to the control unit. The real-time data from the built-in sensors should therefore be transmitted reliably.

Since drones operate with high-frequency signals, indoor farms are complex systems in which phenomena such as reflection, absorption, diffraction, scattering and interference can lead to attenuation or signal loss. As a result, the connection may become unreliable.

The propagation of RF signals is also influenced by environmental conditions, material properties and angles of incidence. In addition, as the use of technology in agriculture becomes more popular, other wireless devices can transmit in the same spectrum, causing signal interference.

This is especially true for UAVs that use Wi-Fi for their communications. As different technologies can share the same Wi-Fi spectrum, interference is not unlikely. For example, [7] studied the effects of adjacent channel interference in IEEE 802.11 WLANs and [8] studied the interference between Wi-Fi and ZigBee networks.

In the past, some researchers have attempted to study RF signal propagation in different building materials. In [9], a list of materials was analysed over a wide frequency range. Similarly, in [10], propagation losses were investigated, but this time the specific frequency bands of 2.4 GHz and 5 GHz were chosen as part of the IEEE 802.11 standard for Wi-Fi applications. Although these studies show the behaviour of RF signals on different construction materials, these data cannot be directly translated into solid conclusions for entire constructions.

Another area that other studies have focused on is Wi-Fi assessment in different buildings. In [11], the relationship between the RSS and the throughput of an IEEE 802.11g network in an office building was analyzed, and the results showed that the throughput was not proportionally affected when the RSS was changed. The authors of [12] conducted an experimental propagation comparison between Wi-Fi and Super Wi-Fi networks indoors and proved that Super Wi-Fi can improve network performance due to better signal propagation indoors. In [13], the propagation topology of a house at 2.4 GHz was investigated by comparing experimental measurements with indoor propagation modeling. Finally, the authors of [14,15] proposed Wi-Fi heat mapping methods to evaluate Wi-Fi networks.

For example, the drones used in the paper Experimental connectivity analysis for drones in greenhouses [16] were the AR.Drone 2.0 and the Anafi, both developed by the French company Parrot [19, 20]. The AR.Drone 2.0 is a low-cost, Linux-based drone, while the Parrot Anafi is a professional platform with advanced features. Both drones are equipped with various sensors, including an inertial measurement unit (IMU), a magnetometer, an ultrasonic altimeter and a pressure sensor, and each has two cameras. In addition, both comply with the 802.11n standard for sending and receiving commands and data to the control unit.

An ASUS X510UNR laptop equipped with a built-in Wi-Fi adapter based on the Intel 8265 chipset was used as the control unit.

As a control unit, an ASUS X510UNR laptop, which is equipped with a built-in Wi-Fi adapter based on the Intel 8265 chipset was used.

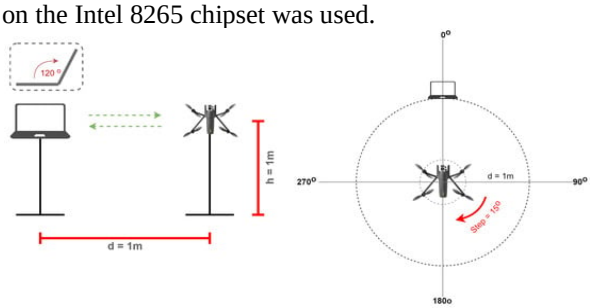

Fig. 1. Experimental radiation pattern configuration, [16].

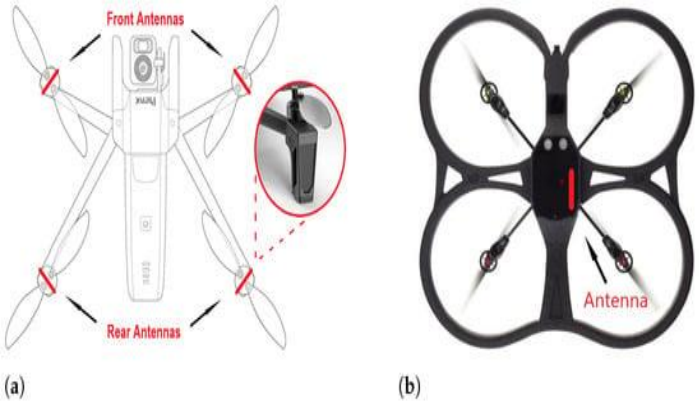

Fig. 2. Location of the antennas on two UAVs, [16].
(**a**) Parrot Anafi; (**b**) Parrot AR. Drone 2.0

The PC laptop (Fig. 1) in the experiment was configured to run Ubuntu 18.04 LTS. To ensure that the connection between a drone and a controller unit is reliable, the connection quality was evaluated. For this reason, three different experiments were conducted indoors and outdoors, measuring packet delay, throughput and signal strength. Data was collected using Python and the Linux integrated utilities ping and iwlist.

The outdoor experiments were conducted in an open field in Papendorp, (Netherlands), a location where there are few Wi-Fi networks. For the indoor test, the greenhouse facility on the campus of Wageningen College was used.

In real operation, the drones were able to navigate freely in space, and this is a dynamic process that can influence signal propagation. However, the greenhouse is a GPS-free environment, which means that significant errors occur during flights and it is difficult to maintain a constant position.

In this paper [16], we investigated the connectivity characteristics of two commercially available drones in the greenhouse specifically for video-based applications. Extensive measurements were performed under real-life conditions focusing on three main areas: the radiation pattern, the signal propagation within the greenhouse compartments and finally the maximum flight range that each drone can achieve without loss of video quality in the greenhouse corridor.

In this experiment [16], data was collected on signal strength, throughput and turnaround time for both drones in a greenhouse compartment. The drones were placed on the floor of the greenhouse at a distance of 2.5 m from each other and moved manually at each location. Measurements were taken at three different heights: 0.5 m, 1.5 m and 2.5 m. The data from each drone was collected in two different scenarios: first with the propellers switched on, with the throttle set to 100%, and then with the propellers switched off, with the throttle set to 0%.

During the measurements, not only were the position and orientation of the PC constant, but the drones also had a fixed orientation, as Fig. 3 shows. It is worth mentioning that no plants populated the greenhouse during the measurements .

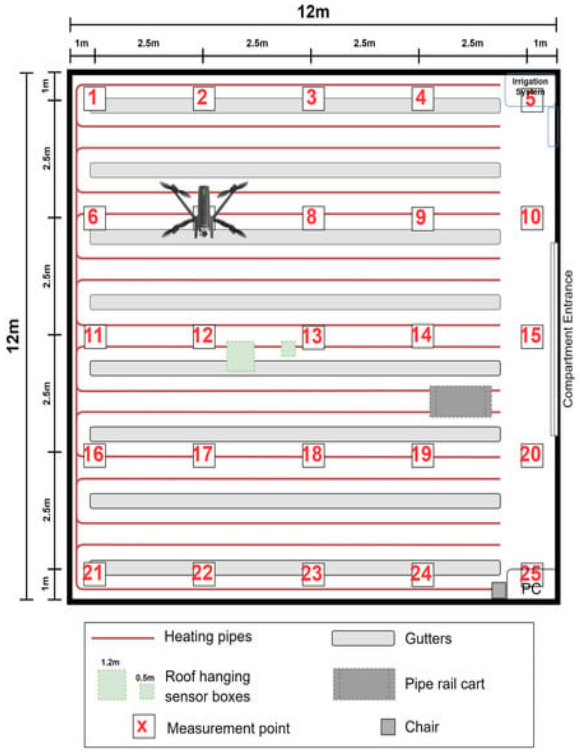

Fig. 3. Greenhouse compartment layout, [16].

The results of the radiation patterns show that both UAVs have anisotropic radiation patterns and that signal equalization on the receiver side may therefore be necessary for RSS applications. In addition, the UAVs are more susceptible to signal and packet loss in certain orientations, which can lead to a drastic increase in RTT. The results also show that the construction design of the greenhouse does not have a significant impact on the communication characteristics. However, the measurements taken closer to the roof were more prone to connection problems. Although the Parrot Anafi had a higher RTT than the AR.Drone 2.0 in all cases, it outperformed the AR.Drone 2.0 as it achieved a higher signal strength and throughput in all cases.

The measurements in the greenhouse corridor prove that the Parrot Anafi is capable of flying up to a distance of 110 m without compromising the video quality. The minimum RSS value required to achieve this range was −62 dBm. The AR.Drone 2.0 was only able to reach a distance of up to 30 m from the ground station, while the minimum RSS required was −70 dBm. Between the two drones used in this study [16], it can be concluded that the Parrot Anafi outperforms the AR.Drone 2.0 in almost all cases and can therefore be considered a more suitable platform for use inside greenhouses.

2. HOW NANO DRONES HAVE CHANGED THE WAY WE INTERACT WITH TECHNOLOGY

In recent years, nano-drones have revolutionized the way we interact with various technologies. These tiny, very or sometimes ultra-light robots have opened up a world of possibilities, from search and rescue missions to surveillance, and now offer a new way of interacting with different technologies in everyday life [22].

Nano drones are small, maneuverable and can be operated remotely or autonomously. They are equipped with sensors, cameras and communication systems that enable them to collect data and send it back to the user. This data can be used to monitor or control a variety of functions, such as surveillance, mapping and search and rescue operations.

Nano drones can even be used to detect changes in environmental conditions to better understand the environment for humans.

In addition to their practical applications, nano drones have allowed us to discover new ways of interacting with the world. They can be used to create unique art installations and document events in an unprecedented way. Due to their small size and maneuverability, nano drones are also perfect for virtual reality experiences, allowing users to explore virtual worlds in unprecedented ways.

The potential of nano drones is huge and their various applications and technologies are still being explored.

2.1. The Impact of NANO Robotics on the Future of Autonomous Flight

The advent of miniature robotics is revolutionizing the future of autonomous flight. Miniature robots — also known as micro-aerial vehicles (MAVs) - are small, lightweight robots that can fly in confined spaces and navigate complex terrain [22, 23]. They are the size and shape of insects and are able to navigate and maneuver more precisely and agilely than larger fixed-wing aircraft.

These miniature robots (MAVs) provide the necessary different solutions to the challenges associated with traditional autonomous flight.

MAVs are able to reach previously inaccessible places and fly autonomously for longer periods of time and with greater maneuverability. They are therefore becoming increasingly popular for applications such as search and rescue missions, surveillance and environmental monitoring.

The use of miniature robots for autonomous flight has a number of advantages. For example, MAVs can carry out complex missions without a human pilot, which enables faster reactions and more efficient operations. In addition, MAVs can fly over greater distances and at higher altitudes than conventional aircraft, which increases the range and accuracy of data collection. Therefore, MAVs can be used to collect more detailed and timely information from hard-to-reach areas.

Miniature robotics are expected to have a major impact on the future of autonomous flight. MAVs are already being used in various industries, such as agriculture, construction, energy and transportation. As technology advances, MAVs are likely to become even more common, opening up new opportunities for autonomous flight.

The future of autonomous flight is an exciting prospect, and miniature robotics is helping to make this a reality. MAVs have the potential to revolutionize the way we interact with our environment and improve the safety and efficiency of operations. Miniature robotics has the potential to revolutionize the way we interact with our environment and its impact on the future of autonomous flight should not be overlooked.

2.2.Future Developments in Nano Drone Technology

The use of nano drones, also known as micro aerial vehicles, is becoming increasingly popular in both the commercial and military sectors. Nano drones are small, lightweight and relatively inexpensive, making them ideal for a variety of applications. As technology advances and nano-drones evolve, new possibilities are emerging that could revolutionize the way we use these devices, [33], [22].

One of the most exciting developments in the field of nano drone technology is the use of artificial intelligence. AI-controlled nano-drones can be programmed to perform certain tasks autonomously, such as inspecting dangerous environments or delivering goods. This could drastically reduce the need for human intervention in many situations, making the technology even more attractive to companies and other organizations.

Another area of development for nano drones is the use of 3D printing. By creating components from scratch, nano drones can be designed and built faster, cheaper and more efficiently than ever before. This could open up a world of possibilities for the customization of drones and make them even more useful for a variety of applications.

The use of sensors is also becoming increasingly important in nano-drone technology. With the help of sensors, nano-drones can collect data in real time, giving them valuable insights into their environment and helping them to better navigate their surroundings.

This could be particularly useful for applications such as navigation, surveillance and search and rescue missions.

Finally, augmented reality in nano-drone technology is expected to become mainstream in the near future. Augmented reality will allow nano-drones to display information such as maps, directions and weather conditions in real time. This could be invaluable for a variety of applications, from navigation to search and rescue.

The future of nano drone technology is bright and the possibilities seem endless. As the technology continues to advance, the applications for these tiny devices are sure to expand.

3. SOME IMPORTANT TYPES OF NANO DRONES

3.1. PAV types of drones

In recent years, researchers have attempted to design and build unmanned aerial vehicles (Fig. 4) with the size and shape of insects [22-26], [31, 33, 36]. Therefore, a new class of drones called pico-aircraft or pico-air-vehicles (PAVs) has been defined [24]. Due to their small dimensions and low weight, there are currently only a few types of PAV aircraft. Quadrotor and mini aircraft are designs commonly used in the PAV class. Among the mentioned types, the single-rotor PAV has recently been performing with fewer advantages than the structures with rotating wings (quadrotor) because they mimic the movement of insects with wings that have incredible flight performances such as: hovering, sudden accelerations, and very fast turns [22]. Many researchers have worked on such constructions with micro-drones (Fig. 4). The Authors of [24] were pioneers in the field of controlled flights of microrobots. They proposed a concept for a microdrone with insect-like external parts and elastic joints (Fig. 4). The author [25] attempted to construct an insect-sized microdrone with a wingspan of about 25 mm and a weight of about 100 mg.

In order to research butterfly flight [22], a small and light butterfly-like drone was developed that weighs 40 mg, has a wingspan of 140 mm and a wing frequency of 10 Hz. The "RoboBee" project was initiated by the Author [23] to design and produce butterfly wings (Fig. 4.) as parts for PAV drones.

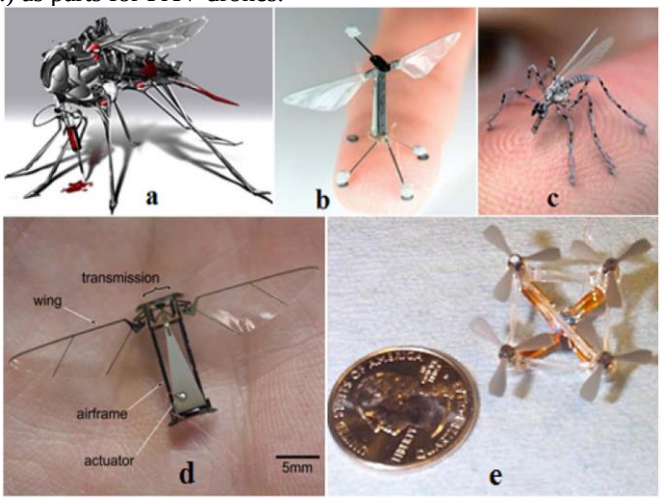

Fig. 4. Some important types PAV drones: (a, b, c, d) flapping wing, (e) quadrotor, [33].

3.2. Wasp III (UAV)

AeroVironment Wasp III developed the Nano Air Vehicle (NAV) under a DARPA (USA) funded research contract to develop a new class of air vehicle systems that can be used both indoors and outdoors.
This unconventional air vehicle, which mimics biological processes on an extremely small scale, could one day provide new reconnaissance and surveillance capabilities in urban environments.

The Wasp Micro Air Vehicle (MAV) is based on the technology of the former DARPA Black Widow MAV program. With a wingspan of 41 cm and a weight of 275 grams, the Wasp is AeroVironment's smallest UAS. Wasp can be manually controlled or programmed for GPS-based autonomous navigation.
To ensure system interoperability, Wasp uses the same advanced technology as AeroVironment's other UAS. The drone features: a high-resolution EO and IR camera in a compact, aerodynamic, modular payload; Range: 5 km line-of-sight; Endurance: 50 minutes; Speed: 20 knots in cruise flight; Operating altitude: 152 m (500 ft), Landing method: Low-level landing in a confined area.

3.3. PD-100 Black Hornet Nono Unmanned Air Vehicle

The Black Hornet Nano is a military unmanned aerial micro-vehicle (MUAV) that was developed in 2013 by the Norwegian company Prox Dynamics AS and is used by the armed forces of many countries [47]. Today, the PD-100 Black Hornet complete system consists of two UAVs and a base station. The drone has a length of around 100 mm and a rotor span of 120 mm. It weighs 16 g, including the surveillance camera. The entire system weighs less than 1 kg without the display. The small drone is easy to fly and takes less than a minute to take off. Black Hornet is equipped with a steerable electro-optical (EO) camera that captures both still images and live video and can be zoomed and displayed on a handheld device for a clearer picture.

The drone can either be controlled directly or programmed to fly a predefined path using the built-in GPS system. The digital data link allows the operator to control the drone within a visual range of 1,000 meters.

The Black Hornet micro drone is powered by a very small, rechargeable electrical battery. The battery allows a flight time of about 25 minutes (or a maximum distance of 2000 meters) before it needs to be recharged.

The Black Hornet nano is controlled by an operator from the ground using a joystick-like device. The Black Hornet base station provides planning, execution and analysis services to the system operator.

3.4. A biologically inspired, flapping-wing, hybrid aerial-aquatic microrobot

From millimeter-sized insects to meter-sized vertebrates, several animal species exhibit multimodal locomotion capabilities in air and water [35]. The development of robots that can move in both air and water requires versatile propulsion strategies that reconcile the different physical conditions in air and water. The transition between air and water environments is a major challenge at the scale of microrobots, as the surface tension at the surface can be significant in relation to the weight and forces generated by the animal/robot. Study [35] on the design and operation of an insect-sized robot that can fly, swim and switch between air and water. This 175 milligram robot uses a multimodal wing flapping strategy to move efficiently in both fluids.

This thesis in [35] analyzes the dynamics of flapping locomotion in an aquatic environment, identifies the challenges and benefits of surface tension effects in microrobots, and develops a series of new mesoscale devices culminating in a hybrid air- and water-bound microrobot.

Hybrid aerialand aquatic robots capable of traversing complex multiphase environments will have a wide range of applications, such as environmental exploration and search and rescue missions [35]. Due to their smaller size and lower weight, microrobots are advantageous for navigation in confined and cluttered environments. As the inertial forces decrease in the millimeter range, microrobots are more resistant to impact events such as a crash landing in water or a collision with obstacles.

Compared to conventional robots, microrobots can easily land on vertical surfaces or even perch on overhangs (by utilizing surface effects). Despite these functional advantages, hybrid air- and waterborne microrobots face unique manufacturing challenges and physical limitations [35].

According to [35], a hybrid air-water microrobot must solve two key problems: (i) multiphase actuation for air and water and (ii) overcoming surface tension for water ingress and egress. The large density difference between air and water leads to conflicting criteria for robot locomotion and design in these two environments. A number of robotic platforms such as fixed-wing, folding-wing and rotorcraft have been developed to explore multiphase locomotion. Although there are no fixed-wing or folding-wing designs that are fully operational in both air and water, a recent study adapted a rotorcraft for locomotion in water and demonstrated the transition from air to water and water to air. However, the design of a rotorcraft cannot easily be adopted by a microrobot, as it is difficult to manufacture and the surface tension can exceed the weight of the robot by more than ten times. In addition, the physics of scaling shows that conventional brushless motors are not feasible on the order of milligrams.

In this paper, the main challenges for hybrid locomotion in air and water in a subgram microrobot are identified and solved. In [35], the system dynamics of aquatic locomotion were investigated and it was found that an inherently unstable flapping-wing vehicle can be passively stabilized during swimming if it is operated at appropriate frequencies. He developed a 40-mg pulse device that uses electrolysis and combustion to achieve repeatable water-air transitions. This work [35] shows a bio-inspired hybrid air and water micro-robot with flapping wings. The robot has successfully demonstrated hovering in air, air-water transition, swimming, and take-off and landing on the water surface. This multifunctional microrobot is able to adapt to complex environments, and these locomotion capabilities will expand the functionalities and applications of future microrobots.

This robot could hover in the air, transition from air to water, swim, take off from the water surface and land (Fig. 5A). The robot hovered in the air and was inherently unstable without feedback. Using a motion tracking system with adaptive control, a stable hovering flight could be achieved (Fig. 5B). The control signals were calculated outside the airplane and sent to the robot via a cable band. When the robot touched down on the water surface, it broke the surface tension on impact and then sank into the water surface (Fig. 5C). To maintain its position or maneuver underwater, the robot flapped its wings at 9 Hz.

When the robot emerged from the water, it first swam to the surface (Fig. 5D). When it reached the water surface, two electrolyte plates in the robot body began to break down water into oxyhydrogen.

The gas was trapped in a chamber, and the increased buoyancy force gradually pushed the robot's wings out of the water (Fig. 5E). To completely detach from the water surface, we used an impulsive strategy:
An igniter ignited the oxyhydrogen mixture, and the robot jumped from the water surface (Fig. 5F). This combustion-based jump resulted in a typical jump velocity of 2.5 m/s and a typical jump height of 37 cm (Fig. 5F).
The robot took a ballistic trajectory in the air and landed on the ground about 0.55 s after take-off.

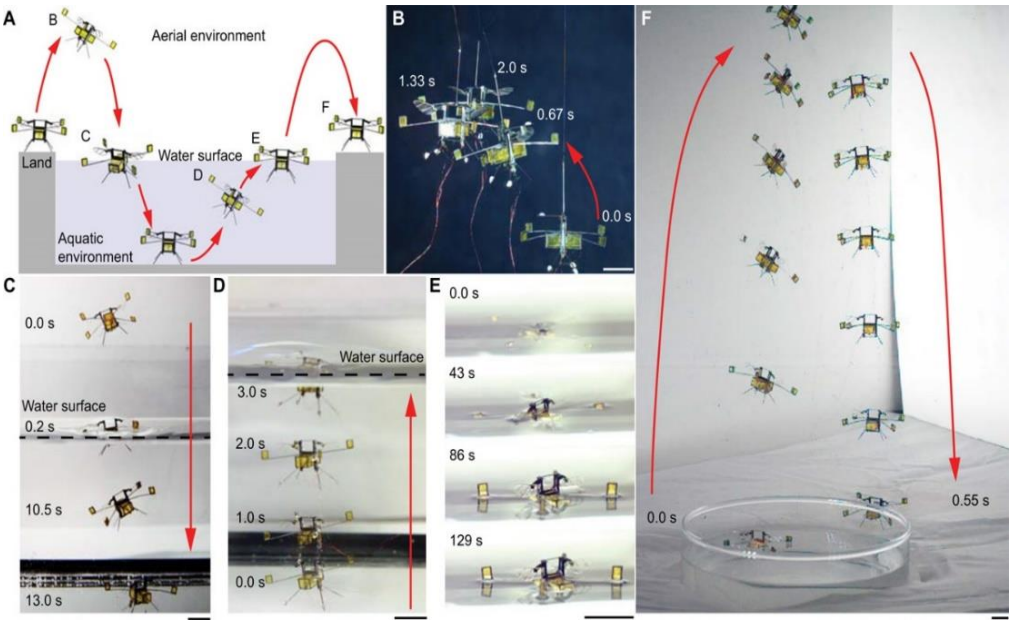

Fig. 5. Demonstration of aerial-aquatic locomotion and transition, [35].
(**A**) The robot is capable of aerial hovering, air-to-water transition, swimming, water-to-air transition, impulsive takeoff, and landing. (**B**) Composite image of a hovering robot. (**C**) Composite image of the robot transitioning from air to water. (**D**) Composite image of the robot swimming to the water surface. (**E**) Images of the robot gradually emerge from the water surface by capturing gas from electrolysis. (**F**) Composite image of robot take off and landing. Scale bars, 1 cm.

The presentation of a hybrid air-water microrobot with flapping wings [35] and Fig. 5 includes position (i) a detailed analysis of observations on the passive, upright swimming stability of the robot in water, (ii) the challenges and advantages that the surface tension of water brings to millimeter-scale robots, (iii) a discussion of meso-scale device design, and (iv) an impulsive method for water-to-air transition. The observation that a flapping-wing vehicle can be passively stabilized in water can be applied to larger, conventional robots. Flapping-wing locomotion in air and water is not subject to size and weight limitations. The flapping wing design has a number of advantages over conventional fixed-wing and rotorcraft.

3.5. Robobees from Harvard University

The idea behind the development of RoboBee (Fig. 6) was to develop autonomous micro aerial vehicles that are capable of flying independently and under their own control and achieving coordinated behavior in large groups. To this end, the development of RoboBee is roughly divided into three main components: Body, Brain and Colony. Body development is about constructing robotic insects that can fly autonomously using a compact and seamlessly integrated power source; brain development is about "smart" sensors and control electronics that mimic a bee's eyes and antennae and can dynamically sense and respond to the environment; colony development is about coordinating the behavior of many independent robots so that they act as an effective unit.
Robobees would displace wild and managed insect pollinators, many of which have highly specialized interactions with native flowering plants, further driving their decline and increasing human dependence on alternative pollination methods for food production.
Robobees would not pollinate wildflowers – from a grower's perspective, that would be a waste of resources, and from an engineer's perspective, that would mean they would need to be extremely diverse and subtle in their abilities to deal with flowers.

Fig 6. RoboBees, Wyss Institute at Harvard University, [36].

Inspired by the biology of bees, researchers at Harvard College's Wyss Institute [36] are developing RoboBees (Fig. 6, Fig. 7), man-made systems that could perform countless tasks in agriculture or disaster relief. A RoboBee is about half the size of a paper clip, weighs less than a tenth of a gram and flies with "artificial muscles" made of materials that contract when a voltage is applied. Additional modifications allow some RoboBee models to go from swimming underwater to flying and "settling" on surfaces using static electricity.

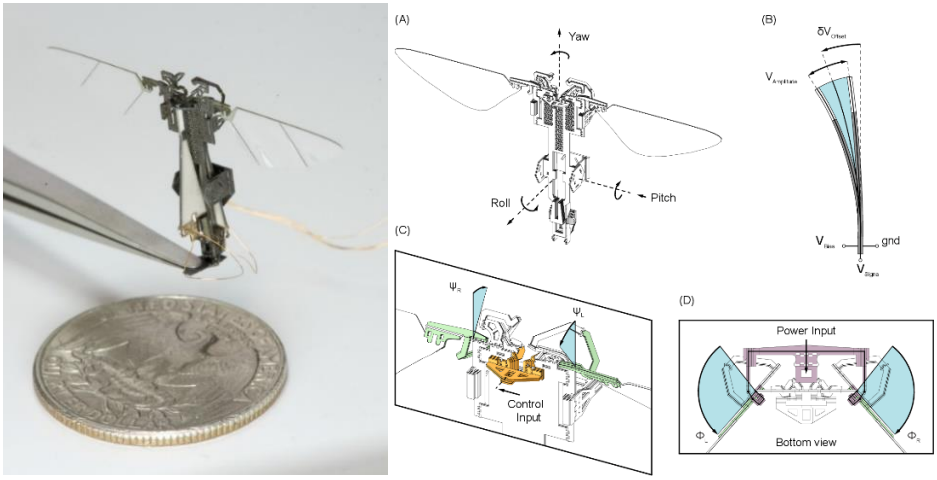

Fig.7. Flying 80-milligram, insect-scale, flapping-wing robot modeled on the morphology of flies, [36].

Robo-bees [34], or mechanical bees (Fig. 8) are machines that take over the work of real bees, e.g. pollinating plants and monitoring the health of beehives. They are used to increase productivity in agriculture, especially as bee populations are dwindling worldwide.

Robotic bees, also known as mechanical bees, are machines designed to imitate the work of real bees. They are mainly used for pollination, but can also be used to monitor hive health [34].

Bees play an important role in agriculture: according to the US Department of Agriculture, they pollinate around 35 percent of the world's food crops. And honey bees pollinate more than 90 commercially grown crops in the U.S. alone, including apples, broccoli and almonds. Most bees are kept like farm animals and transported from one place to another to pollinate the plants that ultimately provide the fruits and vegetables we all eat.

Fig.8. Robot bees or mechanical bees,

Although there is no threat of a global food shortage due to mass bee mortality, as is widely reported, honey bees still face major challenges [34].

Robotic bees represent a possible solution to this problem. Robotic bees, also known as mechanical bees, could be the future. How are robotic bees used?

Researchers and engineers from around the world have been experimenting with ways robots can do the work of real bees. Their creations come in a variety of shapes and sizes. Some fly around with propellers and use ionic liquid gel-coated horse hair bristles to collect and transfer pollen from one plant to another. Others have flexible wings powered by "artificial muscles" and use an electrostatic patch to perch on just about anything.

Following some major breakthroughs in the last several years, many of these projects are not far off from regular commercial use.

3.6. Pollinate Crops with Robot Bees

Some of the newer applications for drones in agriculture are still in the testing and development phase. One of the most publicized (and often invented) applications is the pollination drone. Researchers in the Netherlands and Japan are developing small drones that can pollinate plants without damaging them. The next step is to develop autonomous pollination drones that can work without constant instructions from operators and monitor the health of the plants.

Another drone technology under development also has to do with machine learning. Improving artificial intelligence (AI) in drones is important to make them more useful for smaller farmers in developing countries. Current drone technologies are more effective at monitoring known crops such as maize grown in large monoculture fields. Current drone monitoring programs struggle to detect areas with greater crop diversity, lesser known products and crops that look similar at all stages of growth and are therefore less effective at monitoring crop growth and health. More needs to be done to train AI systems to recognize less common crops and more diverse cropping patterns.

Drones have already transformed the agricultural industry and will continue to grow in the coming years. Although the use of drones is becoming increasingly useful for smallholder farmers, there is still a long way to go before they are part of every farmer's equipment, especially in developing countries. Regulations for the use of drones need to be enacted and revised in many countries, and more research needs to be done to investigate the effectiveness of drones in certain tasks such as pesticide application and spraying. There are many ways in which drones can be useful to farmers, but it is important to understand their limitations and functions before investing in expensive equipment.

3.7. Aerodynamically controlled pollination

The Polybee Company [36, 37] has developed a pollination method that works for strawberries, peppers, tomatoes and eggplants both indoors and in greenhouses (Fig. 8). Polybee Company [36, 37] has developed its own method, aerodynamically controlled pollination, in which self-fertile plants are pollinated without contact by using the downdraft of the drones to optimally vibrate the inflorescences (Fig. 8)

Fig 8. Polybee uses aerodynamically controlled pollination to dislodge the pollen, [36, 37].

These plants pollinate themselves and usually use bumblebees to transfer the pollen from the anthers to the stigma. While bumblebees pollinate the flowers by landing on the flower (recognizable by the small “blue spots" on the flowers), Polybee Co. use aerodynamically controlled pollination [17], [36, 37] to remove the pollen (Fig. 8)

“The idea is to transfer enough energy to the flower to detach the pollen grains from the anthers so that they fall onto the stigmas. Bees do this through vibration and contact, but can also take advantage of turbulent air currents.

The Polybee team investigated the fluid-structure interaction between the turbulent air and the flower and found that certain factors in the airflow are crucial for the release of pollen. According to Siddharth, these include turbulence, kinetic energy, air velocity, etc. With this knowledge, Polybee worked backwards to ensure that the drones create air conditions that trigger the release of pollen without ever touching the flower.

The company is promoting this autonomous pollination technology to both commercial farmers and seed breeders, the latter of which can benefit from precision pollination in pure breeding. Cross-pollination in the production of hybrid seeds is also on the company’s product roadmap, albeit at a later stage.

4. AGRICULTURE — NANO DRONES IN A GREENHOUSE?

Drone technology is finding new applications in the greenhouse [17]. There is no doubt that drones are an emerging technology, but do they have a place in greenhouses? The answer is clearly YES, but the applications we envision for outdoor agriculture may need to be adapted for greenhouses. “Like any other business, greenhouse operators are interested in the labor savings, operational efficiencies and business benefits that drones could offer.

4.1. Greenhouse Application

While it may seem like a crazy thought to consider flying small unmanned aircraft systems (sUAS) inside a greenhouse, there may be some useful applications that greenhouse growers should consider.

There are some applications that greenhouse growers might consider for UAS [17]: Safe inspection of components, sales and marketing, shading agent application, crop monitoring or crop inventory.

The first application is obvious - the safe inspection of components. How many greenhouses currently use one person to inspect gutters, covering materials, structural components and mechanical systems (e.g. cables, motors)?
The safe solution is to use a small drone equipped with live video to allow the operator to safely inspect these structural systems from the ground while a person acts as an observer. The observer helps the drone pilot to fly safely around the greenhouse.
One grower recounted how a worker fell out of a greenhouse with gutters during an inspection, and this event was the final motivation to purchase an $800 drone to accomplish the same task. This application alone should be a major reason to consider purchasing a UAS.

The next application is also an easy target. All agricultural and horticultural businesses should consider taking video or photos from the air to use at trade shows, on social media and on company websites for sales and marketing. How many TV commercials do you see today that use a short aerial video clip to promote a business? The perspective that images from these low altitudes offer is remarkable.
If you think your needs in this area are low, consider hiring an external drone company to collect your aerial images (photos or video) and then use their software to bring them into a final form.
When considering whether or not to do this in-house, you need to consider the cost of the aircraft, specialist insurance, camera/sensor, software and licensing. As with all other applications, it should be easy for you to find a local company that offers the imaging products you need.

The third application, the use of shading agents, may surprise you. Even in the U.S., there are many small (<55 pounds or <25 gr) UAS sprayers for sale that can be used to apply shading agents to greenhouse covers. While it is possible to find unmanned aerial sprayers that weigh more than 55 pounds (or 25 grams), from a regulatory standpoint, it is easier to fly aircraft that stay under that threshold. The 55-pound (or <25 gr) limit refers to the weight of the entire aircraft system (airframe, battery and payload) at takeoff.
One limitation with these sUAS is the density of water (i.e., 8.3 pounds/gallon or 3.75 kg/4.5lit). For this reason, most sUAS spray aircraft have tanks that hold less than 3 gallons, which limits the range in a single flight. This is a major advantage over manual and less safe application of shading agents.
The fourth application, scouting or crop monitoring, may be a little further in the future. The challenge with scouting/monitoring of ornamental plants is the diversity of crops produced. For monocultures such as corn, rice, turf and cotton, we are more likely to be able to link a specific plant problem (e.g. nutrient deficiency, insect infestation, water stress, disease) to the output of a sensor (e.g. thermal, multispectral) than for diverse greenhouse crops. In the near future, the mere fact that sUAS alert a farmer that something is wrong could be enough to justify the use of this technology in a greenhouse.

The last suggestion for sUAS use is inventorying. Many researchers, including us, have been working for years on automated ways to obtain inventory information using sUAS. As you can imagine, the most difficult scenario is when plant covers overlap. There are already companies (e.g. Drone Deploy and Agremo) whose products can help growers in row crops to count plants.
Whether the same software can count a variety of greenhouse plants at different stages of production is unclear. Inevitably, we will be able to use sUAS to perform automatic counts of greenhouse crops.
There are certainly other applications (e.g. pollination) and more you can think of, but this list should at least get you started in the right direction.

4.2. Robotic Bees Support Vertical Farms

In vertical farms [43], [52], plants (Fig. 9), are made to grow densely stacked on high shelves rather than in a field with the help of artificial light and artificial intelligence, without human intervention.
Under these conditions (vertical farms), robotic “bees",” such as the new technology, are a very good solution.

Fig 9. Vertical farms and future nano robotic [43], [52].

The modern concept of vertical farming was proposed in 1999 by Dickson Despommier, a professor at Columbia College [43]. It is the design of a kind of skyscraper farm (vertical farm) that could feed 50,000 people.

Vertical farming today faces technological and economic challenges with high start-up costs compared to traditional farms. Vertical farms also have high energy requirements because they use additional light such as LEDs. The world's first commercial vertical farm opened in Singapore in 2012. Robotic bees are not new to vertical farms.
Since the mid-20th century, researchers have been looking for ways to automate agriculture, such as tractors with automatic steering. In the 1980s and 1990s, engineers began tinkering with task-specific devices, such as a robotic melon harvester and tomato-picking robots.
Today, companies are developing autonomous bee robots for various tasks, and some devices can also perform additional tasks such as weeding, spraying pesticides and monitoring diseases.

CONCLUSIONS

Nano drone technology includes ultra-small remote-controlled aircraft that can perform a manz variety of tasks.
They are equipped with advanced sensors and functions such as obstacle avoidance and high-speed maneuverability. Various nano models are capable of taking precise aerial photographs, staying in the air for long periods of time and flying autonomously.
The world of drone technology has taken a huge leap forward with the introduction of nano drones, as some advanced technical solutions, such as nano drones, have a footprint of just 2 x 2 cm.
The technology of these drones is constantly improving, with new features such as face recognition, obstacle avoidance and flight stability being introduced.
These advances have been made possible by the miniaturization of components and the improved efficiency of special electric micromotors and batteries.
One of the safe applications of nano-drones today is the use of greenhouses for operations: safe inspection of greenhouse components; processes of pollination (e.g. the role of RobotBee); application of glass shading agents; crop monitoring/inventory of greenhouses.
Research on the application of nano-drones (especially the RobotBee like insect type) in some areas of agriculture should be continued.

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PREGLED MOGUĆNOSTI PRIMENE NEKIH TEHNOLOGIJA NANO DRONOVA U SAVREMENOJ POLJOPRIVREDI✧

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Abstract. Upotreba različitih tipova dronova u skoro svim sektorima svetske privrede brzo raste, ali upotreba dronova u poljoprivredi je naglo povećana. Prema nekim podacima iz literature, očekuje se porast tržište različitih poljoprivrednih dronova sa 1,2 milijarde dolara ($USD) u 2019. na 5,5 milijardi dolara ($USD) 2024. godine.

Posebno je interesantan fenomen značajno povećanje upotrebe različitih tipova i modela nano dronova u Svetu i mogućnost njihove upotrebe u poljoprivredi (objekti zaštićenog prostora).

Svet tehnologije dronova napravio je ogroman korak napred uvođenjem tenologije nano dronova, gde neka moderna rešenja imaju dimenzije manje od 2x2 cm.

Nano dronovi su ultra-male letelice sa daljinskim upravljanjem, koje su sposobne da obavljaju mnogo različitih zadataka. Opremljeni su ultra naprednim senzorima sa karakteristikama kao što su izbegavanje prepreka i manevrisanja pri velikim brzinama. Cene se kreću od nekoliko stotina do više hiljada US dolara u zavisnosti od modela, karakteristika opreme i specifičnosti namene.

Ovaj rad predstavlja pregled tehnologije primene nekih tipova nano dronova i njihove neophodne opreme i nove primene u staklenicima ili plastenicima (ili slični zatvoreni objekti) kao neke faze koje korisnici staklenika mogu razmotriti za upotrebu, kao što je:

Bezbedna inspekcija nekih strukturnih komponenti staklenika/plastenika; Procesi oprašivanja (npr. uloga RobotBee); Primena smeše za osenčenje stakla na svim stranicama staklenika; Monitoring stanja useva/inventar plastenika ili staklenika.

Ključne reči: *Nano dronovi, mogućnosti primene u plastenicima/staklenicima, proizvodnja povrtarskih kultura, kontrola.*

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POVERTY STATUS OF THE RURAL WOMEN IN EJIGBO LOCAL GOVERNMENT AREA OF OSUN STATE, NIGERIA

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Abstract. The study assessed the poverty status of rural women in Ejigbo Local Government Area of Osun State, Nigeria. Specifically, it described the socio-economic characteristics and determined the poverty status of the rural women in the study area. A multistage sampling procedure was used to select 120 rural women for the study. Primary data were collected with the aid of a well-structured interview schedule and analyzed with the use of frequency counts, percentage, mean, standard deviation and Foster, Greer and Thsorbecke (FGT) index. The results reveal that the mean age of the respondents was 42.1 years. Majority (73.3%) were married, the mean household size was 5 persons and majority (60.8%) were members of cooperative societ(ies). The mean monthly income of the respondents was ₦52,283, poverty line was ₦34,855.33, poverty incidence was 0.5, poverty gap index was 0.192 and poverty severity was 0.098. The study concluded that half of the respondents was poor and recommended that governmental and non-governmental organizations should organize poverty alleviation programmed for the women in the study area.

Key words: *Poverty, status, rural, women, Ejigbo, local, government.*

INTRODUCTION

According to [10], poverty in its context refers to a situation and a process of severe deprivation or lack of resources and materials necessary to live in a minimum standard conducive to human dignity and well-being.

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They added that it implies deprivation of the means of subsistence. Social aspects of poverty can include lack of access to information, education, health care and political power. As related by [2], part of the quality of life could be quantified in monetary terms and expressed as income or expenditure of the consumer, but parts of it cannot be expressed in monetary terms. Whether quantifiable in monetary terms or not, quality of life implies a standard of living.

Considering the various elements that constitute a good standard of living, poverty can be defined as the inability of a person to achieve a specified minimum standard of living. This minimum standard of living is generally defined in terms of income per capita, or better still in terms of consumption or expenditure per capita. Anyone whose consumption is less than this specified minimum income is considered poor. The specified minimum income is called the 'poverty line'.

In any society, those who are likely to fall below the poverty line are mainly the unemployed, those in low-paid jobs, the self-employed, especially those in the informal sector, women especially women heads of household with children, the elderly, children, recent and destitute migrants [2]. The population of a country is generally almost equally divided between men and women, except in special circumstances such as war or highly selective immigration, which normally affect men more than women. However, through the ages, the sharing of power, wealth, influence, employment, etc. between men and women has never come close to equality. Even in the most advanced countries, gender inequality in the distribution of wealth has remained a pressing issue [9].

Over the years, many women have faced the formidable challenges of unemployment, lack of source of income, widowhood and single parenthood. Despite these challenges, the roles played by women in national development and in all facets of human activities have been quite remarkable. Although there has been considerable progress in the development of women's capacities, their participation in economic and political decision-making remains very limited [5]. The unpleasant experiences that women face affect their lives, their children and other household members.

Poverty prevents some women from enjoying their life privileges such as education, access to health facilities, participation in politics and the ability to control resources. Women have low incomes, low level of education, do not own land, have constraints in accessing health facilities, depend on subsistence agriculture but do not determine or control sales and do not make their lifestyle choices [5]. This study therefore examined the poverty status of the rural women of Ejigbo Local Government Area of Osun State, Nigeria.

Objectives of the study

The main objective of the study was to examine the poverty status of the rural women in Ejigbo Local Government Area of Osun State, Nigeria

The specific objectives of the study were to:

I. Describe the socio-economic characteristics of the rural women; and
II. Examine the poverty status of the rural women in the study area.

MATERIAL AND METHODS

The study area was Ejigbo Local Government in Osun State, Nigeria. Ejigbo is a prominent town in Yoruba Land and the headquarters of Ejigbo Local Government Area, one of the oldest Local Government Areas of Osun State in Nigeria. Ejigbo is situated in the middle of the region, as 35 km (22 miles) north-east of Iwo, 30 km (19 miles) from Ogbomoso in the north and 24 km (15 miles) from Ede in the south-east. It is about 40 km (25 miles) north-west of Osogbo, the capital of Osun State, and about 95 km (59 miles) north-east of Ibadan. It is part of the Ede North/Ede South/Egbedore/Ejigbo federal constituency.

The average elevation is 426 meters (1,398 ft), it has an area of 373 square kilometers (144 square miles). The average annual rainfall is 52.35 inches (1,330 mm), though there are great deviations from this mean value from year to year [8]. The sample selection was carried out using a multistage sampling procedure**.** At the first stage, simple random technique was used to select two (2) districts; Ejigbo and Olla from the four (4) districts (Ejigbo, Olla, Ilawo and Ife-Odan) in Ejigbo Local Government. At the second stage, purposive sampling technique was used to select three towns and three villages Ejigbo, Isundunrin and, Ayegbogbo from Ejigbo district and Olla, Masifa and Isoko from Olla district due to high livelihood activities and popularity of the towns and villages.

At the third stage, simple random technique was used to select twenty (20) rural women from each town and village to make a total of 120 respondents. Primary data was used in this study. The data were collected through the use of well-structured interview schedule and analyzed with the use of frequency counts, percentage, mean, standard deviation and Foster, Greer and Thsorbecke (FGT) index.

Measurement of variables

The FGT Index

The P-alpha measure proposed by [6] was used in analyzing poverty status of the women in the rural area. They include the head count index (P_o), poverty gap index (P_1), and poverty severity index (P_2).

Following [6], the formulae are given as;

$$P_\alpha = \frac{1}{N} \sum_{i=1}^{H} \left(\frac{z-y_i}{z}\right)^{\alpha} \quad \text{.....(1)}$$

$$P_0 = \frac{H}{N} \quad \text{.....(2)}$$

$$P_1 = \frac{1}{N} \sum_{i=1}^{H} \left(\frac{z-y_i}{z}\right) \quad \text{.....(3)}$$

$$P_2 = \frac{1}{N} \sum_{i=1}^{H} \left(\frac{z-y_1}{z}\right)^2 \quad \text{.....(4)}$$

Where ,
z is the poverty line, defined as the two thirds mean per capital of respondents' monthly income;
H is the number of poor respondents while
N is the total number of respondents;
y_1 is the per capital income of the nth respondent while
α is the poverty aversion parameter.
This takes the values 0 to 2 as shown above to mean poverty incidence, poverty depth/gap and poverty severity respectively.

Construction of poverty line

The poverty line was constructed to categorize the respondents into poor and non-poor groups using the two-third mean per-capita income as the benchmark as described by [11]. Respondents whose mean per-capita income fell below the poverty line were regarded as poor, while those whose per-capita income were above the benchmark were regarded as non-poor.
Per-capita income (PCI) = Income / respondents size
Total Per-capita Income (TPCI) =ΣPCI
Mean TPCI (MTPCI) = TPCI / Total number of respondents
Poverty line (PL) = 2/3 × MTPCI

RESULTS AND DISCUSSION

Socio economic characteristics
Results in Table 1 reveal that the mean age was 42.08±11.303 years. This implies that most of them can afford to engage in various livelihood activities that will contribute towards improved household wellbeing. This finding is similar to the finding of [1] which reported a mean age of 47.1 years among the sampled respondents. The results further reveal that majority (73.3%) of the respondents were married. This implies that the women had marital relationships and as such may have responsibilities. This is in line with the work of [7] which reported that majority of the sampled respondents were married.
The results further show that majority (75.0%) of the respondents had household size of between 4 to 6, the mean household size was approximately 5 persons. This could be because the respondents had learnt about family planning and so did not gave birth to too many children. Similarly, [3] reported an average of 5 members per household among the sampled respondents. The results further show that some (38.3%) of the respondents had tertiary education, some (35.8%) had secondary education, some (20.8%) had primary education while few (5.0%) had no formal education. This shows that majority of the respondents had at least secondary school education and that literacy in the area is at a higher level. The results contradict that of [4] which reported that a higher percentage of the sampled respondents had no formal education. The results further reveal that close to half (49.2%) of the respondents had trading as their primary occupation while some (24.2%) involved in farming. This implies that almost half of the respondents earn their living from trading.

The results further reveal that majority (60.8%) of the respondents were members of cooperative societ(ies). Membership of cooperative societ(ies) enhances access to credit, the implication of this result is that the rural women would be able to access credit that would enhance their means of livelihood and hence strategize better in mitigating poverty.

The results also reveal that monthly income earned by majority (73.3%) of the respondents was between ₦1-₦50,000. The monthly mean income of the respondents was ₦52283.33± ₦62381.475. These results show that income of the respondents was quite low and they might not be able to adequately afford consumption of good food, basic amenities such as clean water, health, education and energy. Hence, the respondents may not be able to easily utilize capital intensive poverty mitigation strategies.

Table 1. Distribution of the respondents according to their socio-economic characteristics (n=120)

Variables	Frequency	Percentage	Mean ± SD
Age			
≤ 30	21	17.5	
31-60	38	75.1	
> 60	9	7.4	42.08±11.303
Marital status			
Single	2	1.7	
Married	88	73.3	
Separated	10	8.3	
Divorced	6	5.0	
Widowed	14	11.7	
Household size (persons)			
1-3	9	7.5	
4-6	90	75.0	
7-9	21	17.5	5.18±1.408
Primary occupation			
Farming	29	24.2	
Civil service	11	9.2	
Artisan	13	10.8	
Trading	59	49.2	
Others	8	6.7	
Cooperative society membership status			
Member	73	60.8	
Not a member	47	39.2	
Monthly income (₦)			
1-50000	88	73.3	
50001-100000	22	18.3	
100001-150000	5	4.2	
150001-200000	2	1.7	
Above 200000	3	2.5	52283.33±62381.475

Source: Field survey, 2021.

Poverty profile of the respondents

Results in Table 2 show the distribution of the rural women according to their poverty status based on the poverty line (₦34,855.55). The Table reveal that half (50.0%) of the rural women were poor with monthly mean income of ₦21,500.00 which is below the poverty line (₦34,855.55) while 50.0% of the rural women were non-poor, having a monthly mean income of ₦83,066.67 which is above the poverty line (₦34,855.55). The total monthly mean income of the rural women was ₦52,283.33.

Poverty indices

The results of FGT indices of poverty (head count, poverty gap and poverty severity) are presented in this section.

Poverty incidence (Head count)

The index shows the proportion of the rural women that were poor. Results in Table 2 further reveal that the poverty incidence (Head count) was 0.50. This result implies that 50% of the sampled rural women were below the poverty line of (₦34,855.55).

Poverty Gap

Poverty gap measures the extent or depth of poverty. It measures how far the poor are below the poverty line. Results in Table 2 further reveal that the poverty gap index for this study was 0.192. This means that to bring an average poor rural woman in the study area to the poverty line, an income transfer of 0.192 of ₦34,855.55 which is ₦6,692.27 is required. Since the total number of the rural women in the study is 50 percent, then, the average monthly amount required to be transferred to all the poor rural women in the study area to bring them up to the poverty line was 50 multiplied by ₦6,692.27 which is ₦334,613.50.

Poverty Severity

The poverty severity index measures the severity of poverty among the poor. It shows the poorer of the poor. The poverty severity index for this study as shown in Table 2 was 0.098. This result implies that every poor rural woman is ₦0.098 poorer that the poor rural woman above her.

Table 2. FGT result showing the poverty status and poverty indices of respondents

Category	Frequency	Mean	Percentage
Non-poor	60	₦83,066.67	50
Poor	60	₦21,500.00	50
Total	120	₦52,283.33	100
Indices	Coefficient		
Poverty Incidence/ head count	0.50		
Poverty Gap	0.192		
Poverty Severity	0.098		

Source: Data analysis, 2021.

CONCLUSIONS

The study focused on poverty status of the rural women in Ejigbo Local Government Area of Osun State, Nigeria. Based on the empirical evidence from the study, it is concluded that poverty exists among the rural women in the study area. The poverty status revealed that 50% of the sampled rural women were poor (that is, on and below the poverty line of ₦34,855.55). The study therefore recommended that governmental and non-governmental organizations should organize poverty alleviation programmed for the women in the study area.

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STATUS SIROMAŠTVA RURALNIH ŽENA U PODRUČJU LOKALNE SAMOUPRAVE EJIGBO, DRŽAVA OSUN, NIGERIJA

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Apstrakt. Studija je procenila status siromaštva seoskih žena u oblasti lokalne uprave Ejigbo u državi Osun, Nigerija. Konkretno, opisala je socio-ekonomske karakteristike i odredila status siromaštva seoskih žena u oblasti istraživanja.
Višestepena procedura uzorkovanja je korišćena za odabir uzorka od 120 seoskih žena za istraživanje. Primarni podaci su prikupljeni uz pomoć dobro struktuiranog rasporeda intervjua i analizirani korišćenjem brojanja učestalosti, procenta, srednje vrednosti, standardne devijacije i Foster, Greer i Thsorbecke (FGT) indeksa.
Rezultati pokazuju da je srednja starost ispitanica 42,1 godina. Većina (73,3%) je bila u braku, prosečna veličina domaćinstva je bila sa 5 osoba, a većina (60,8%) su bili članovi zadruga. Srednji mesečni prihod ispitanica je 52.283 ₦, linija siromaštva 34.855,33 ₦, incidenca siromaštva 0,5. Indeks granice siromaštva 0,192, a težina siromaštva 0,098. Studija je zaključila da je polovina ispitanica bila siromašna i preporučila da vladine i nevladine organizacije države Nigerije, organizuju programe za smanjenje siromaštva za žene u oblasti istraživanja.

Ključne reči: *Siromaštvo, status, seosko(ruralno), žene, Ejigbo, lokalna, vlada.*

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SELECTED ENGINEERING AND SENSORY PROPERTIES OF BAKED PRODUCTS PREPARED FROM COMPOSITE WHEAT-SOLOGOLD SWEET POTATO FLOUR

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Abstract: Flours from other sources have been incorporated into wheat flour to improve on the nutritional and sensory properties of baked products. However, the quality of production and sustainability of such baked product is still a challenge faced by bakery industries. The aim of this study is to evaluate selected engineering and sensory properties of baked products prepared from composite wheat sologold sweet potato flour; so as to guide the bakers to achieve improved product quality, development and sustainability. In this study, biscuit samples were prepared according to Onabanjo and Dickson method, the bread samples were prepared according to the Straight dough method, the cake samples were prepared according to Egg foaming method while the selected engineering and sensory properties were determined in accordance with standard procedures. The results obtained showed that the optimum blend (70% wheat: 30% sologold sweet potato) flour has specific volume of the baked products range from 4.12 to 0.50 ml/g, crumb moisture from 18.54 to 12.04%, oven spring from 2.38 to 1.12mm, sample height from 4.05 to 1.01mm, sample mass from 146.30 to 8.52g, appearance from 9.40 to 8.70, texture from 8.50 to 7.50, aroma 9.20 to 8.0, flavor from 9.0 to 8.10, crust color from 8.80 to 7.0, overall acceptability from 9.30 to 8.10, intension of consumption from 9.20 to 8.0 and browning index from 1.0 to 4.6.

These evaluated engineering and sensory properties of the optimum blend flour attest high quality baked products (bread, biscuit and cake).

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Hence could be utilized to enhance and facilitate product development, quality control and product sustainability of composite baked products. The optimum blend ratio is therefore recommended to bakers.

Keywords: *Wheat flour, sologold flour, baked products, engineering qualities, sensory properties.*

INTRODUCTION

Composite flour refers to a mixture of two or more types of flours derived from different sources, blended together to create a new flour product with enhanced nutritional, functional, and economic properties [1] . The type and quality of flour vary based on the source of material and processing methods employed [2, 3]. Composite flour can be derived from different grains, cereals, legumes, tubers and root crops.

The combination of different flours in composite flour is to enhance the overall quality of the final product which is based on the desired characteristics [4]. Each flour component contributes distinct characteristics, such as flavor, texture, color and nutritional profile which can be leveraged to achieve desired outcomes such as maintaining acceptable sensory qualities and consumer acceptance. Generally, wheat flour is the main flour for baking and it provides structure, texture and flavor to baked product [5]. It forms the foundation of bread, cakes, cookies, pastries, and other baked products. However, the incorporation of another flour to wheat flour which is the main flour for baking materials tend to reduce the gluten effect on the baked products, which may lead to changes in taste, texture, color, and appearance compared to complete wheat flour-based products [6].

Usually, when wheat flour is hydrated and mixed with yeast, the gluten protein in it will cause the formation of an elastic network that traps gases produced by yeast or leavening agents; leading to the rising of dough and a light, airy and sponge like texture in baked products [4, 7].

However, selected engineering properties of baked products include specific volume, crumb moisture, oven spring, sample volume, sample mass, sample color, appearance, texture, aroma, flavor, crust color, crumb color, browning index, overall acceptability and intention for consumption [8, 9]. They play crucial roles in determining the quality, desirability and marketability of baked products [5, 10]. A comprehensive understanding of these properties aids in the development of nutritious, functional, and cost-effective composite products [7]. It will also enhance bakers to produce consistent, high-quality baked products with desirable qualities and shelf life [11, 12]. More so, the bakery industry can optimize their production processes and meet consumer expectations in terms of sensory experience, product attributes, product development and product sustainability [13].

Reported [1], that bread was made from blend of orange sweet potato and wheat flour at various ratios (0:100, 5:95, 10:90, 15:85, 20:80 and 25:75). It was observed that the qualities of breads such as loaf size (volume, specific volume and height) significantly decreased while loaf weight increased as blending ratio of orange sweet potato flour increases.

[5] had reported also that the produced bread loaf weights ranged from 450 to 500 g; loaf volume, 1171.73-1239.84 cm3 and specific loaf volume, 2.48-2.62 cm3/g. There was no significant difference in the samples crust color, crumb holes, stability, elasticity, firmness, shape regularity, appearance; and no panelist showed a total dislike for the taste of any of the samples. [11] evaluated the quality of bread fortified with sesame seed. The average values of color, texture, flavor, overall acceptability, loaf volume, specific volume and shelf life of the bread samples increased with increasing sesame seed addition.
[10] worked on tiger nut and sesame flour partially substituted into wheat flour at six blend ratios of 100:0:0 (sample A), 90:10:0 (sample B), 85:10:5 (sample C), 80:10:10 (sample D), 75:10:15 (sample E) and 70:10:20 (sample F) respectively. It was reported that the physical properties of the bread loaves showed a significant decrease in quality with the addition of tiger nut and defatted sesame flour with the wheat flour. The bread weight ranged from 158.23 to 210.07 g, loaf volume varied from 360 to 672 cm3, bread specific volume was in the range of 1.71-4.14 cm3/g and oven spring lied between 0.43-2.80 cm. In this study, wheat flour and sologold sweet potato flour are combined so as to harness the beneficial attributes of each component and create a nutritious, versatile and balanced flour blend for the production of bakery products. Some of the engineering properties of baked products from composite wheat-sologold sweet potato flour, developed are essential to be determined. This will help in the assessment of the desirability, quality and marketability of these selected baked products.

MATERIALS AND METHODS

Material Sourcing and Equipment

Wheat flour and fresh sologold sweet potatoes used for the study were collected from National Root Crops Research Institute (NRCRI) Umudike, Abia State, Nigeria. The following equipment were employed: steel ruler, minolta spectrophotometer, sulphuric acid solution, microcrystalline cellulose, sharp knife, venier caliper, electronic dough mixer, electronic weighing balance, tape rule, hammer mill, mechanical sieves, stop watch, desiccators, bowls, crucibles and conventional oven.

Determination of optimum blend ratio based on engineering properties of the wheat-sologold potato composite flour

The wheat-sologold sweet potato composite flour engineering properties such as proximate composition, particle size, flowability, rheological, functional and thermal properties obtained for the best blend ratio per property assessed were further evaluated to obtain the blend ratio that would possess each of the assessed property at its optimum value with respect to their interactions in the composite flour.

The best blend ratio of the composite flour was chosen and used to produce baked products. Some of the engineering properties considered for baked products such as biscuit, cake and bread were evaluated to assist in product sustenance, development and quality control.

Production of some baked products from composite wheat-sologold sweet potato flour

(a) Production of Biscuit

The biscuit samples were prepared according to the method described by [14], as shown in Figure 1.

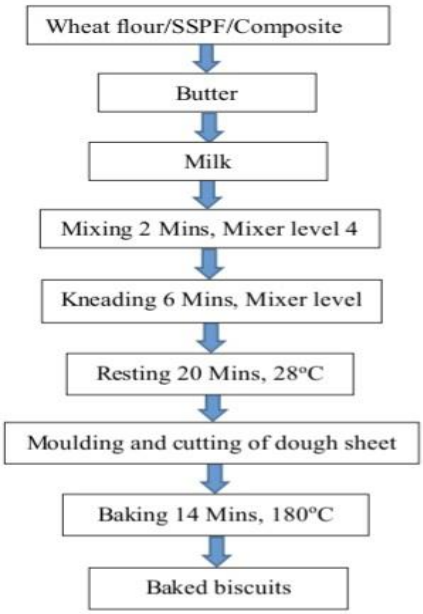

Figure 1. Flow chart for the production of biscuit

The samples were formulated using high gluten baking flour (Dangote flour) according to recipes in Table 1.

Table 1. Wheat-sologold sweet potato flour formulation

Samples	Flour Blend Ratio	SSPF (g)	WF (g)
A1	100% WF, 0% SSPF	0	300
B1	90% WF, 10% SSPF	30	270
B2	80% WF, 20% SSPF	60	240
B3	70% WF, 30% SSPF	90	210
B4	60% WF, 40% SSPF	120	180
B5	50% WF, 50% SSPF	150	150
B6	40% WF, 60% SSPF	180	120
B7	30% WF, 70% SSPF	210	90
B8	20% WF, 80% SSPF	240	60
B9	10% WF, 90% SSPF	270	30
A2	0% WF, 100% SSPF	300	0

SSPF=Orange fleshed sweet potato flour , WF= Wheat flour

Dough of the samples were made with 100% wheat, 100% SSPF (controls) and the optimum blend ratio of 70% wheat, 30% SSPF.
Ingredients were mixed thoroughly thereafter each of the flour samples was added to form dough which was obtained by mixing and kneading in an electronic mixer (Kenwood chef-KM201) for 1 minute using speed 4. Water was then added and mixed further for 2 minutes. The dough was left to rest for 15 minutes at room temperature and thereafter followed by sheeting to a thickness of 2mm using a guide board by manual rolling.

The biscuits were shaped with a cutter and baked in a conventional oven (Bistro AR6E, Sweden) on an aluminium tray at 180^{o}C for 14 minutes. Biscuits were cooled for 30 minutes to room temperature of 28.5^{o}C. The appropriate engineering properties were then analyzed.

Production of Bread

The bread samples were prepared according to the straight dough method described by [15]. The ingredients which include the flour, shortening, salt, yeast, emulsifier, milk and sugar were prepared and weighed accurately into a mixing bowl. The optimum blend (70% wheat and 30% sologold sweet potato flour) and the two controls (100% wheat and 100% sologold sweet potato flour) were also prepared. The ingredients such as flour, instant yeast and sugar were measured and mixed in a mixer. The other ingredients such non-fat milk, improver, salt, shortening and water were then added to the mixture. The mixture was kneaded into dough and then assembled, thereafter folded to allow gas expulsion as well as completion of distribution of yeast activity for further growth. The dough was then cut into the required sizes and rounded to shape into a smooth layer. The dough was then left to rest for about 10-20 minutes before molding. The molded dough was placed in a baking tin and transferred into the proofer for the final proofing which takes between 45-55 minutes at 37^{o}C. The dough was baked in baking oven at 220^{o}C for 20 minutes. The bread produced was then brought out of the oven, de-panned and allowed to cool for about 30 minutes at room temperature.

Production of Cake

Cake samples were prepared according to egg foaming method [16]. The cakes were made from 100% wheat, 100% SSPF (controls) and blend of 70% wheat and 30% SSPF. The ingredients used for the cake making includes wheat flour and SSP flour, egg, butter, milk and sugar. The egg and sugar were whipped to a thick foam butter using a mixer. The milk was added then the sifted flour was added gradually into the butter and stirred well for uniform mixing to take place. The mixture was then poured to the baking pans (4x8 inches) and baked in oven at 180^{o}C for 30 minutes. The cake was cooled at room temperature for an hour prior analysis.

Determination of selected engineering and sensory properties of the produced composite baked products

(a) Determination of selected engineering properties of composite wheat-SSP baked products

The composite baked products engineering properties such as sample volume, sample mass, specific volume, oven spring, sample height and crumb moisture were determined in accordance to the method described by [17].

I. Seed displacement method was used to determine the sample volume. In this method, sesames seeds were used to cover the composite baked product sample inside a container of known volume, until the seeds fill the entire container.

A steel ruler was used to cut off the excess seed that have overfilled the container. The volume of the sesame seeds used was determined by pouring it into a graduated volume measuring cylinder.

The same sesame seeds were also used to fill the same container of known volume in the absence of the baked product. The sample volume was calculated as the difference of the two values.

Sample volume = V_1-V_2 .... (1)

Where,
V_1 = the volume of the seed displaced without the baked product sample, and
V_2 = the volume of the seed displaced with the baked product sample

II. Specific volume was calculated by dividing the volume of a composite baked product sample by the mass of the same composite baked product sample. It is expressed in (cm^3/g)

Specific volume = $\frac{volume\ of\ a\ composite\ bread}{mass\ of\ the\ same\ composite\ bread}$..... ..... (2)

III. The crumb moisture were determined using the methods prescribed by [18] for the determination of crumb moisture content. It involves the use of standard sorption isotherm curve for microcrystalline cellulose, established using standard sulphuric acid solution (H_2So_4). 50 grams weight of the baked product sample was measured into a desiccator along with a weighing bottles and dry microcrystalline cellulose for 24 hours. The baked product crumb moisture was determined by measuring the weight gained by the microcrystalline cellulose that naturally absorbs moisture from the sample, and referring to the standard isotherm curve for the read the corresponding crumb moisture value [19, 20].

IV. The oven spring of the baked products were determined by measuring the crust height of the baked samples with the use of venire caliper and the readings were taken in millimeter (mm).

V. The sample height of the baked products was determined by measuring from the base to the top of the sample with the use of the measuring ruler and readings were taken in millimeter (mm).

VI. The sample mass of the baked products were determined by weighing the samples on an electronic weighing balance and readings were taken in grams (g).

(b) Determination of the sensory attributes of wheat-sologold composite baked product

I. The sensory attributes were determined by human interpretation of those attributes as perceived by senses of smell, taste, touch and sight, [1].

The sensory evaluations were carried out immediately after production and cooling of the composite baked product.

The evaluation was useful in determining and assessing how people feel about the product by allowing them to practically test the baked products and comment based on personal assessment and feelings about the product.

The sensory qualities evaluated are appearance, aroma, taste, texture and overall acceptability. The sensory evaluation was designed based on 5-point hedonic scale which enabled panelists to express exactly the regiment of choice between acceptance and rejection. Sensory attributes such as flavor, texture and taste were evaluated using a nine-point hedonic scale [21]. Panelists featured were students and staff whom are organoleptically familiar with the baked products. The hedonic scale was ranked as follows: 10-8 scores: like extremely to very much, 7-5 scores: moderately to slightly like, 4-2 scores: neither like nor dislike to dislike slightly to dislike moderately and 1-0 scores: dislike very much to dislike extremely. A total of 20 respondents were used to evaluate the sensory attributes of the composite baked product.

II. The color of the composite baked product was determined using Minolta spectrophotometer (CM-3630 MINOLTA, JAPAN). The various color components were determined using the following procedure: The spectrophotometer was set up, and connected to a computer. The spectrophotometer was turned on with the computer for booting. After the computer the booting process, the computer was logged on to the Minolta color spectrophotometer software. In a few second the computer asked for a zero calibration which was subsequently done using input buttons. The equipment also asked for a white calibration which was done using a white board placed in the specimen medium 0 (Absolute black) to 100 (pure white). In a few seconds the equipment demanded for loading of the specimen which was done. Selection of color component to be measured was also demanded and was selected. The measurement was performed in few minutes and the result was read and recorded via the output medium which is the computer monitor. It was used as the measure the product lightness (L*), redness (a*) and chroma levels (b*) which were recorded respectively. Browning index assessment was carried out by measuring the visual brown area on each sample with the scale of 1 (no browning, excellent quality), 2 (slight browning), 3 (<25% browning), 4 (25-50% browning) and 5 (>50% browning), [8].

RESULTS AND DISCUSSION

I. Selected engineering properties of wheat-sologold sweet potato composite baked products

The results of the selected engineering properties of composite baked products evaluated include specific volume, crumb moisture, oven spring, sample height, sample volume and sample mass as presented in Figure 2; with Figure 3 showing the baked breads, biscuits and cakes produced from the composite flour sample while Figure 4 shows the selected engineering properties of baked samples from composite wheat-sologold sweet potato flour blends.

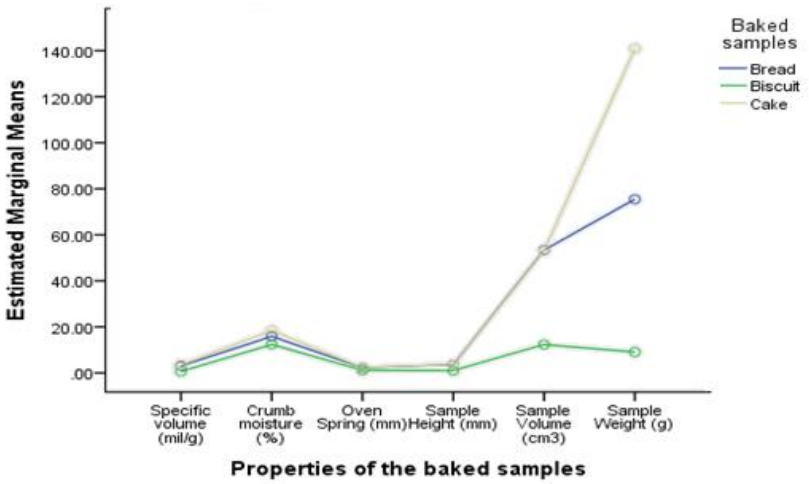

Figure 2. Selected engineering properties of composite wheat-sologold sweet potato baked products

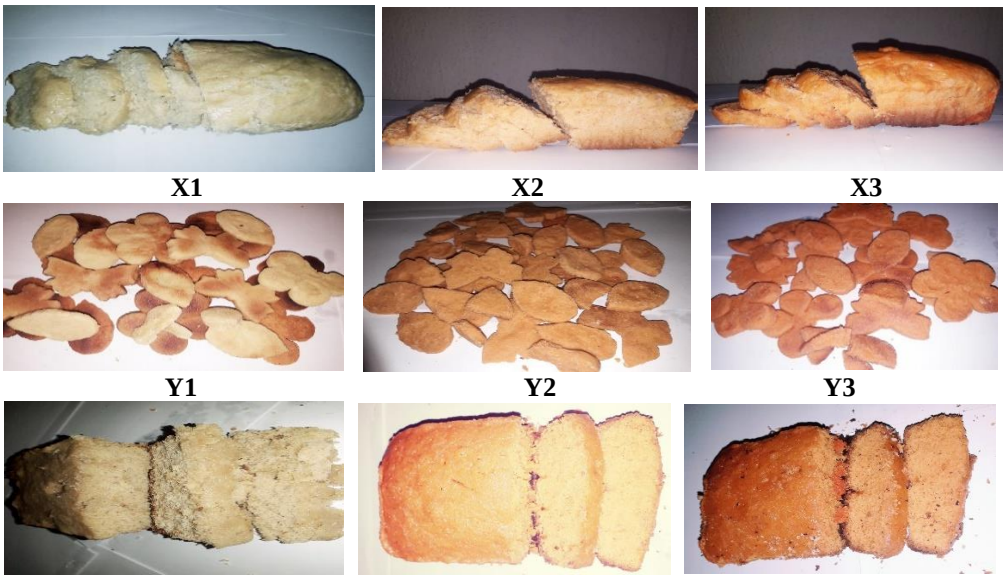

Figure 3. The composite baked breads, biscuits and cakes

X1: Bread (100% wheat flour, 0% sologold flour) X2: Bread (70% wheat flour, 30% sologold flour)
X3: Bread (0% wheat flour,100% sologold flour)
Y1: Biscuit (100% wheat flour, 0% sologold flour) Y2: Biscuit (70% wheat flour, 30% sologold flour)
Y3: Biscuit (0% wheat flour, 100% sologold flour)
Z1: Cake (100% wheat flour, 0% sologold flour) Z2: Cake (70% wheat flour, 30% sologold flour)
Z3: Cake (0% wheat flour, 100% sologold flour)

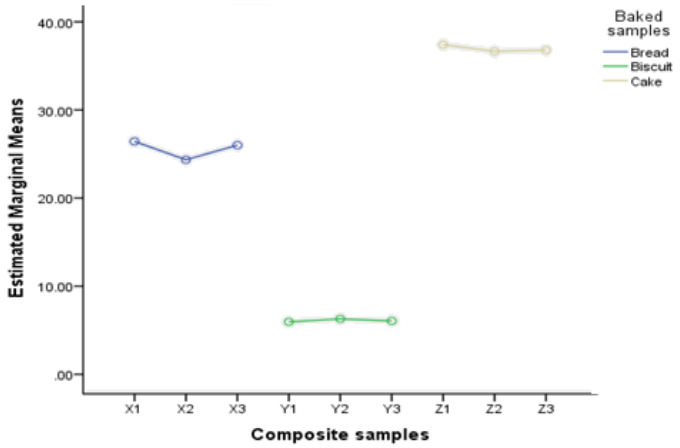

Figure 4. Selected engineering properties of baked samples from composite wheat-sologold sweet potato flour blends

(a) Specific volume of wheat-sologold flour composite baked products

Specific volume is an important parameter of baked products that indicate the texture and density of the product [22, 23]. A higher specific volume generally corresponds to a lighter and more airy texture, which is mostly desired for products like bread and cakes [24, 3]. The result obtained showed that the specific volume of the composite baked products and controls range from 0.50-4.12 ml/g as presented in Figure 2. It also shows that specific volume for the control experiments X1, Y1 and Z1 recorded the highest values of 3.64 ml/g, 0.58 ml/g and 4.12 ml/g which is due to the 100% wheat flour inclusion and X3, Y3 and Z3 had lower values of 3.28 ml/g, 0.50 ml/g and 4.04 ml/g while X2, Y2 and Z2 had the lowest values of 2.20 ml/g, 0.42 ml/g, 2.50 ml/g respectively. Considering the percentage inclusion of sologold sweet potato flour (SSPF) which accounted for the low values of specific volume, this inferred that specific volume depend on percentage inclusion of SSPF. The result is in agreement with [24] who reported significant decrease in specific volume with increase in white sweet potato flour substitution when most process parameters were kept constant. According to [25], the specific volume indicates the amount of air that can remain in the final product, where higher gas retention of the product leads to a higher specific volume. This indicates that samples containing SSPF had lower gas retention than that of 100% wheat flour. The baked products from the optimum blend all have modest specific volume due to the high ratio of wheat (70%) in the blend.

(b) Crumb moisture of wheat-sologold flour composite baked products

An optimal crumb moisture level ensures a moist and tender crumb while preventing excessive dryness or sogginess [26, 27]. This is crucial because moisture content affects the shelf life, softness, and overall quality of baked products.

The results showed that the crumb moisture range from 12.04% to 18.54% for the wheat-sologold composite baked products and controls.

However, the crumb moisture values for the baked products and the control experiments had slight variation; with higher percentages recorded in the control samples (Figure 4). Crumb moisture enables bakers to assess the quality processes and storage conditions accordingly. Hence, it is essential to control crumb moisture to prevent staling or excessive moisture loss during storage, which can lead to low product quality and decreased consumer satisfaction [2, 28]. The crumb moisture content of the baked products from the optimum blend of wheat-sologold sweet potato induced that the quality of the baked products are good and appealing to consumers.

(c) Oven spring of wheat-sologold flour composite baked product

Oven spring is the rapid rise in volume that occurs during the first few minutes of baking [25, 29]. It is primarily attributed to the expansion of trapped gases within the dough due to the heat of the oven [25]. The result shows that the highest values of the oven spring were recorded in X1, Y1 and Z1 as 2.30mm, 1.14 and 2.38 while X2, Y2 and Z2 recorded the lowest values of 2.20mm, 1.12mm and 2.30mm respectively (Figure 2). The result of this study is in agreement with [30] which reported that oven spring of bread made from 100% wheat and 100% sweet potato flour were 2.32 and 2.18mm. Oven spring occurs due to the expansion of gases, such as carbon dioxide, trapped within the dough [31]. It contributes to the formation of desirable, well-risen structure and an open crumb texture [6, 32]. The oven spring values of the baked products from the optimum blend of wheat and sologold sweet potato showed their desirable and well-risen structures.

(d) Sample height of wheat-sologold flour composite baked product

Sample height provides an objective assessment of the height of the final product. By monitoring and controlling baked product height, bakers can ensure consistent quality, portion control, and optimize ingredient usage [32, 33]. The sample height for the control samples X1, Y1 and Z1 were 4.05mm, 1.03mm and 4.04mm while X2, Y2 and Z2 had 3.10mm, 1.01mm and 3.09mm respectively which recorded the lowest sample height.

This may be due to the absence of gluten which is responsible for elasticity and rising in wheat flour. It is in agreement with the report of [23, 29] where lower values were reported for 100% wheat baked product. Baked products with heights are generally preferred as they indicate a well-risen, light, and fluffy texture [13, 32]. Hence, the respective heights recorded for the baked products from the optimum blend of wheat and sologold sweet potato indicated well-risen baked products.

(e) Sample volume of wheat-sologold flour composite baked product

Sample volume is an essential parameter for assessing the quality and consumer acceptability of baked products [27, 34]. The volumes of baked samples: X3, Y3 and Z3 were 53.12 cm^3, 12.32 cm^3 and 52.12cm^3 which are lower than those of X1, Y1 and Z1 but higher than values of X2, Y2 and Z2. The result implication is that sample volume is dependent on percentage inclusion of SSPF.

The result is in agreement with [7, 23, 25] which all reported increase in sample volume with decrease in the level of substitution. The incorporation of SSPF into samples preparation significantly decrease the volume of the baked samples. Gluten is vital to enhance the structural framework and rising volume of the baked products.

According to [17] low amount of gluten can cause reduction in the gas retention capacity during baking, thereby reducing the volume of the baked product.

The results obtained are in agreement with the observations of [27] which reported that baked products incorporated with sweet potato flour decreases the volume. Sample volume directly influences consumer perception of product value, as larger loaves are often associated with higher quality [34]. Hence, the volume of the baked products from the optimum blend of wheat and sologold sweet potato showed their well risen volumes.

(f) Sample mass of wheat-sologold flour composite baked product

Sample mass is an essential parameter for assessing the yield and portioning of bakery products [23, 35]. By accurately measuring sample mass, bakers can ensure consistency in product size and control costs by controlling the amount of dough used for each loaf [7]. The highest sample mass values were recorded in X2, Y2 and Z2 of 75.41g, 9.46g and 146.30g respectively while X1, Y1 and Z1 had the lowest sample mass of 72.26g, 8.52g and 135.62g. However, there were significant increase in sample mass of X3, Y3 and Z3 with 73.69g, 9.20g and 140.80g. This is as a result of 30% wheat flour been replaced with SSPF. Sample mass provides valuable information for ensuring consistency in portion sizes and meeting specific mass requirements for different product types. Sample mass is the actual mass of a baked product [8]. The mass of the respective baked products from the optimum blend of wheat and sologold sweet potato are appropriate and acceptable.

II. Statistical analysis on baked products engineering properties

Table 2 shows the ANOVA values of the selected engineering properties of the baked products.

Table 2: ANOVA of the selected engineering properties of baked products

Properties		Sum of Squares	Df.	Mean Square	F	Sig.
Specific volume	Between Groups	352.24	1	1536.577	0.425069	0.035
	Within Groups	6	10	.02		
	Total	358.24	11			
Crumb moisture	Between Groups	181.83	1	1714.127	0.009969	0.927
	Within Groups	6	10	.06		
	Total	187.83	11			
Oven spring	Between Groups	232.49	1	289.5919	0.105963	0.040
	Within Groups	6	10	.01		
	Total	238.49	11			
Sample height	Between Groups	173.54	1	2734.946	0.401251	0.021
	Within Groups	6	10	.03		
	Total	179.54	11			
Sample volume	Between Groups	289.919	1	6332.49	0.145337	0.019
	Within Groups	6	10	.04		
	Total	295.919	11			
Sample weight	Between Groups	350.365	1	40254.82	0.215752	0.043
	Within Groups	6	10	.02		
	Total	356.365	11			

Based on the statistical analysis of variance for specific volume of the baked samples presented in Table 2, there was significant difference in the specific volume of the samples ($p \leq 0.05$). Specific volume of samples increases significantly with increase in wheat flour added to the sample. Crumb moisture of the baked products show that there was no significant difference ($p > 0.05$) in the samples crumb moisture content. It plays a crucial role in determining the texture, shelf life, and overall quality of bakery goods. The result of the ANOVA for oven spring of the baked products show that it is significant ($p > 0.05$). Oven spring is critical in baked products, as it contributes to a desirable light and airy texture. Result for sample height, sample volume and sample mass of the baked products show that they are significant ($p \leq 0.05$). Consistency in sample height and volume is crucial for batch-to-batch reproducibility and ensuring the desired product characteristics. Samples containing SSPF showed significant increase in mass compared to samples with 100% wheat flour. Therefore, the engineering properties of the baked products from the optimum blend of wheat and sologold sweet potato is appropriate and recommendable.

III. Sensory properties of wheat- sologold flour composite baked products

The results of the sensory evaluation of the composite baked product are presented in Figures 5 and 6. The sensory attributes evaluated include appearance, texture, aroma, flavour, crust colour, overall acceptability and intension for consumption.

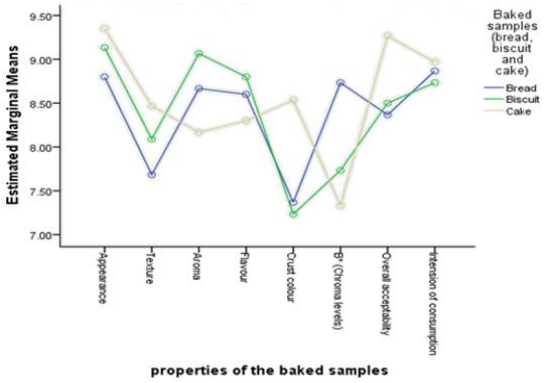

Figure 5. Sensory properties analysis of composite wheat-sologold sweet potato baked products

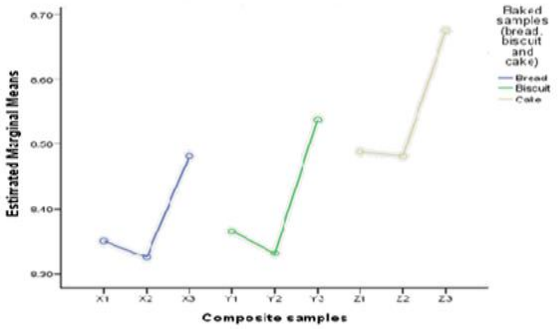

Figure 6. Sensory analysis of composite samples of wheat-sologold sweet potato

(a) Appearance of wheat-sologold flour composite baked product.

The appearance (visual appeal) of a baked product influences consumers' perception and purchase decision. The colour, shape, and overall presentation can create a sense of freshness and quality [1, 3]. The appearance of the composite baked products X3, Y3 and Z3 (8.90, 9.20 and 9.40) differs slightly from the control samples X1, Y1 and Z1 (8.70, 9.10 and 9.30) and X2, Y2 and Z2 (8.80, 9.10 and 9.35) respectively. The addition of wheat flour appear to make the samples more attractive and well accepted by the panelists than the one with 100% sologold flour. This is in agreement with [25] where similar result was reported. The result as also confirmed, what other researchers have reported regarding the reduction in quality appearance of composite baked products with increasing level of substitution [2, 16]. A well-shaped and evenly browned pastries with attractive toppings are more likely to be preferred by customers [13]. The attractive appearance of the baked products from the optimum blend of wheat and sologold sweet potato enhances their perceived quality, freshness and desirability.

(b) Texture of wheat-sologold flour composite baked product.

Texture refers to the tactile qualities of baked products such as its softness, crispiness, chewiness, or creaminess. The texture significantly impacts the sensory experience and consumer satisfaction [3, 34]. The texture of the composite baked products (X3, Y3 and Z3) showed texture values of 7.75, 8.10 and 8.50 (Figure 5). The control experiments X1, Y1 and Z1 had 7.80, 8.12 and 8.50 while the values recorded for X2, Y2 and Z2 was 7.50, 8.05 and 8.40. According to Wanjuu *et al*., (2018), texture contributes to the overall sensory experience and consumer satisfaction. The desired texture of baked products should be soft and fluffy on the inside with a crispy crust on the outside [16]. The right balance of tenderness of the baked products from the optimum blend created a pleasurable eating experience.

(c) Aroma of wheat-sologold flour composite baked product

Aromatic compounds in baked products contribute to the perception of freshness and quality [25]. The result of aroma of the composite baked products X3, Y3 and Z3 had 8.70, 9.20 and 8.20 as presented in Figure 5. The values obtained from X1, Y1, Z1 were 8.80, 9.20, 8.30 and X2, Y2, Z2 had 8.50, 8.80 and 8.00 respectively.

This implies that higher percentage of wheat flour does guarantee better aroma of the wheat-sologold composite baked product [1]. This result agrees with [2] which reported 100% wheat flour product had higher aroma score when compared with composite baked product. The aroma of the baked products from the optimum blend plays a crucial role in creating a pleasant environment that stimulates appetite.

(d) Flavour of wheat-sologold flour composite baked product.

Flavour is a combination of taste and aroma. It is a crucial factor in determining food preference and consumer acceptance [25]. The result of flavour for composite baked products X3, Y3 and Z3 showed high values of 8.70, 9.00 and 8.50; the control experiments X1, Y1 and Z1 recorded 8.60, 8.80 and 8.30 while X2, Y2 and Z2 had 8.50, 8.60 and 8.10.

A desirable flavour profile is crucial for consumer acceptance and repeat purchase. The flavour profile of a baked product determines its uniqueness and consumer preference [2]. The flavour of baked products from the optimum blend was appealing; which is essential for customer satisfaction.

(e) Crust colour of wheat-sologold flour composite baked product.

A consistent and appealing crust colour suggests proper baking, caramelization, and flavour development [23]. Control samples X1, Y1 and Z1 had 7.10, 7.00 and 8.10 for crust colour while X2, Y2 and Z2 recorded 7.60, 7.40 and 8.80 which implies that the crust colour as a factor is dependent on the level of SSPF substitution. The result is in agreement with the report of [29]. The desired colour can vary depending on the type of product, such as golden-brown crusts in bread or a deep golden colour in pastries [17]. The proper crust colour of the baked products from the optimum blend indicated appropriate baking time, temperature and ingredient quality.

(f) Overall acceptability of wheat-sologold flour composite baked product.

Overall acceptability refers to the consumers' overall perception and satisfaction with a baked product. It takes into account various sensory attributes including appearance, texture, aroma, and flavor [10]. Overall acceptability for samples X1, Y1 and Z1 recorded 8.40, 8.50 and 9.30 while samples X2, Y2 and Z2 recorded 8.10, 8.20 and 9.00. There was decline in the overall acceptability with increase in substitution of wheat with SSPF. The results of this study are in agreement with [13], who reported decrease in overall acceptability with increase in SSPF substitution. It takes into account multiple sensory attributes such as appearance, texture, aroma, and flavor.

Understanding what attributes contribute to overall acceptability can help bakers improve their products and meet consumer expectations. The high overall acceptability value by panelist on the baked products from the optimum blend showed their satisfaction and acceptance of the products.

(g) Intension of consumption of wheat-sologold flour composite baked products

Factors such as taste, visual appeal, aroma, and overall experience influence consumers' intention to consume a baked product [6]. The results of the intension of consumption of the composite baked products (X3, Y3 and Z3) showed highest values of 9.00, 8.90 and 9.20 while control samples X1, Y1 and Z1 recorded 9.00, 8.80 and 9.00 and X2, Y2 and Z2 recorded 8.60, 8.50 and 8.70.

Understanding consumer preferences and aligning product attributes with their expectations is crucial for success in the bakery industry [30]. The high intension of consumption rating by panellist of the baked products from optimum blend of wheat and sologold sweet potato showed their willingness to consume more of the baked products.

IV. Browning index of wheat-sologold flour composite baked product.

The color characteristics/browning index of the composite baked products and control samples were presented in Figures 7 and 8. These include the lightness (L*), measure of redness (a*) and chroma levels (b*). L* represents the degree of lightness (-value = black, +value = white), chroma a* indicates the red/green value (+value = redness, -value = greenness) and chroma b* denotes yellow/blue (+value = yellowness, -value = blueness).

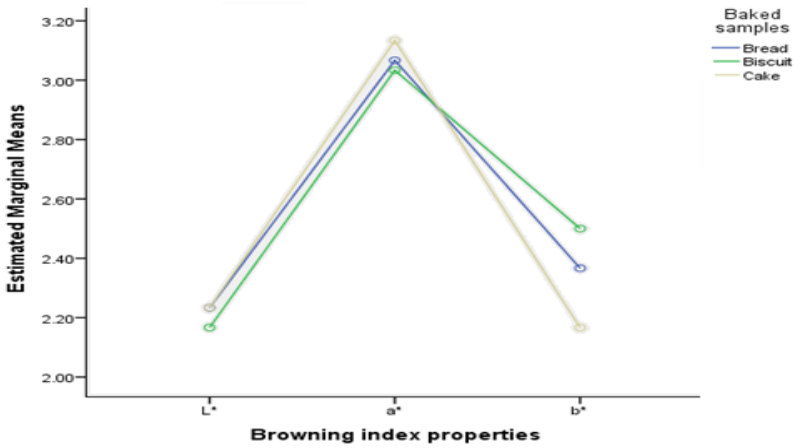

Figure 7. Browning index properties of composite wheat-sologold sweet potato baked products

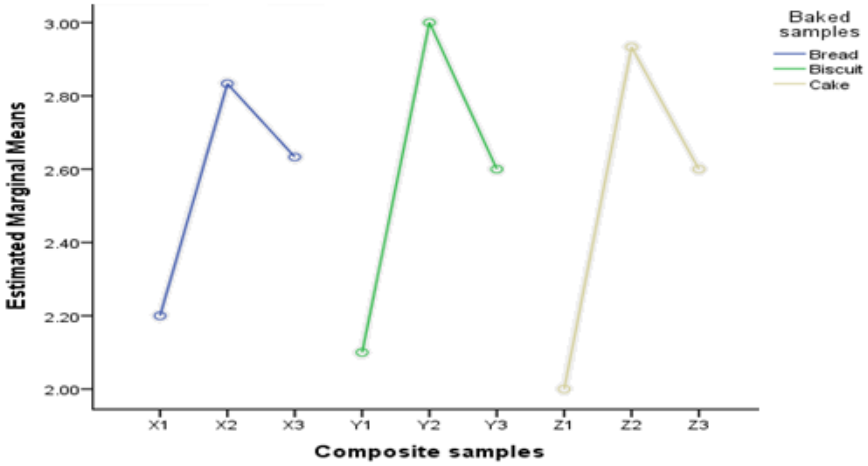

Figure 8. Browning index of composite wheat-sologold sweet potato baked products

Browning index refers to the degree of browning or Maillard reaction that occurs during baking. It affects the taste, aroma, and appearance of food products. The result of lightness (L*) of the composite baked products X3, Y3, Z3 showed 2.5, 2.0, 2.0 and values for the control experiments X1, Y1, Z1 recorded 3.2, 3.0, 3.5 for lightness (L*) while X2, Y2, Z2 recorded 1.0, 1.5, 1.2 (Figure 7).

Composite samples X3, Y3 and Z3 recorded for L* (2.5, 2.0, 2.0), a* (3.2, 3.0, 3.3) and b* (2.2, 2.8, 2.5) respectively which showed excellent and slight browning of the composite baked products. The browning index of baked products from the optimum blends showed the desirable browning, flavor development and consistent quality of the baked products.

V. Statistical analysis on baked product sensory properties

Statistical analysis on the sensory composition of the baked products is presented in Table 3.

Table 3. ANOVA of the sensory analysis of wheat-sologold composite baked products.

Composition		Sum of Squares	Df.	Mean Square	F	Sig.
Appearance	Between Groups	45.7	1	0.105625	0.28499	0.605
	Within Groups	8	14	.02		
	Total	53.7	15			
Texture	Between Groups	44.4	1	0.370625	0.10562	0.028
	Within Groups	8	14	.01		
	Total	52.4	15			
Flavor	Between Groups	60.5	1	0.653624	0.235273	1.034
	Within Groups	8	14	.01		
	Total	68.5	15			
Crust color	Between Groups	232.12	1	0.900584	0.55136	0.037
	Within Groups	8	14	.04		
	Total	240.13	15			
Aroma	Between Groups	174.96	1	7.952273	0.730237	0.690
	Within Groups	8	14	.03		
	Total	182.95	15			
Overall Acceptability	Between Groups	1645.68	1	0.748036	2.343567	0.027
	Within Groups	8	14	.05		
	Total	1653.68	15			
Intension of consumption	Between Groups	7269.38	1	0.330426 4	4.424616	0.016
	Within Groups	8	14	.06		
	Total	7277.38	15			

The statistical analysis of variance (ANOVA) in Table 3 shows the level of significance of texture, crust color, overall acceptability and intension of consumption to be significant ($p \leq 0.05$) which shows the texture, crust color, overall acceptability and intension of consumption between the samples differs significantly while the level of significance of appearance, flavor and aroma of the samples were greater than 0.05 ($p > 0.05$).

The difference in the sensory properties between the optimum blend of the baked products and the other controls is significant in texture, crust color, overall acceptability and intension of consumption. The statistical analysis on the browning index of the baked products is shown in Table 4.

Table 4: ANOVA of the browning index of wheat-sologold composite baked product

Composition		Sum of Squares	Df.	Mean Square	F	Sig.
L*	Between Groups	539.944	16	59.99378	3.854499	0.026
	Within Groups	.021	2	.002		
	Total	5384.231	18			
a*	Between Groups	28.77422	23	14.38711	2.933013	0.048
	Within Groups	.076	2	.006		
	Total	2450.332	25			
b*	Between Groups	192.5039	17	24.06299	1.486901	1.010
	Within Groups	.001	2	.000		
	Total	1850.247	19			

The statistical analysis of variance (ANOVA) for chroma levels (L*, a*and b*) of the composite baked products are presented in Table 4 shows L* and a* to be significant ($p \leq 0.05$) which showed that lightness and redness between the baked products from the optimum blend and the control samples differs while the level of significance of b* were greater than 0.05 ($p > 0.05$). Hence, there are no differences in the yellowness of the samples.

CONCLUSION

Evaluation of the selected engineering and sensory properties of composite baked products (bread, biscuit and cake) showed that composite baked products produced from 70% wheat and 30% sologold sweet potato flour exhibits high qualities and are recommended for bakers and consumers.

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IZABRANE INŽENJERSKE I OSNOVNE OSOBINE PEČENIH PROIZVODA PRIPREMLJENIH OD KOMPOZITNOG PŠENIČNO-SOLOGOLD BRAŠNA SLATKOG KROMPIRA

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Apstrakt: Brašno od drugih kultura je mešano sa pšeničnim brašnom, kako bi se poboljšale nutritivne i senzorne osobine pečenih proizvoda.
Međutim, kvalitet proizvodnje i održivost ovako pečenih proizvoda i dalje je izazov za pekarsku industriju. Cilj ovog rada je procena odabranih inžinjerijskih i senzornih osobina pečenih proizvoda pripremljenih od kompozitnog pšeničnog sologold brašna slatkog krompira, kako bi se pekari usmeravali za postizanje boljeg kvaliteta proizvoda, razvoj i održivost.

U ovoj studiji uzorci keksa su pripremljeni po Onabanjo o Dickson metodi, uzorci hleba su pripremljeni po metodi ravnog testa, uzorci kolača su pripremljeni po metodi dodavanja jaja u smesu, dok su odabrane inženjerske i senzorne osobine određene u skladu sa standardnim procedurama.

Dobijeni rezultati su pokazali da optimalna mešavina (70% od pšeničnog i 30% slatkog krompira) ima specifičnu zapreminu pečenih proizvoda u rasponu od 4,12 do 0,50 ml/g, vlažnost mrvice proizvoda od 18,54 do 12,04%, otvore kalupa u pećnici od 2,38 do 1,12 mm, visina uzorka od 4,05 do 1,01 mm, masa uzorka od 146,30 do 8,52 g, izgled od 9,40 do 8,70, tekstura od 8,50 do 7,50, aroma 9,20 do 8,0, ukus od 9,0 do 8,10, ukupna boja kore od 7. od 9.30 do 8.10, intenzitet potrošnje od 9.20 do 8.0 i ukupni braon indeks kora proizvoda (smeđa boja) od 1.0 do 4.6.

Ova procenjena inženjerska i senzorna svojstva optimalne mešavine brašna potvrđuju visokokvalitetne pečene proizvode (hleb, keks, kolači). Zato se mogu koristiti za poboljšanje i olakšavanje razvoja proizvoda, kontrole kvaliteta i održivosti proizvoda od kompozitnih pečenih proizvoda.

Zbog toga se pekarima preporučuje ptikazan optimalan odnos mešanja brašna.

Ključne reči: *Pšenično brašno, Sologold brašno, pekarski proizvodi, inženjerski kvaliteti, senzorna osobine.*

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