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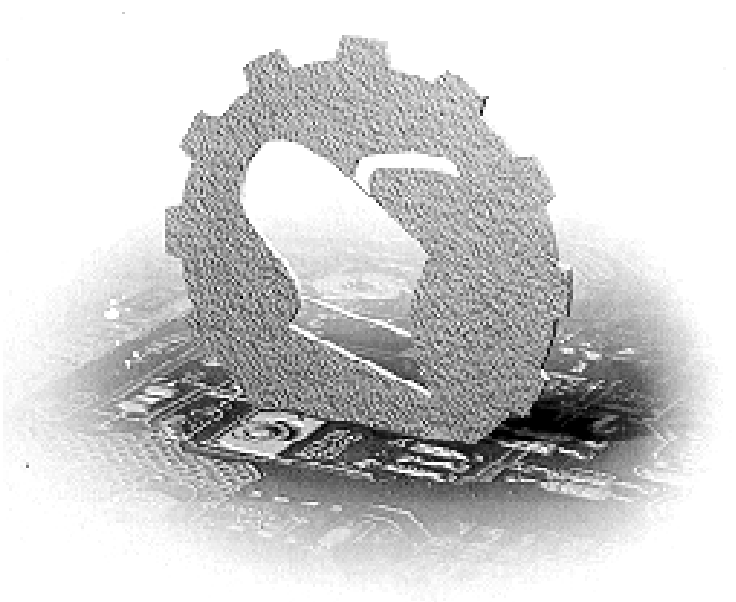

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CONSTRAINTS TO UTILIZATION OF COPING STRATEGIES AMONG ARABLE CROP FARMERS IN HERDSMEN-FARMERS CONFLICTS IN OSUN STATE, NIGERIA

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Abstract The study identified the constraints to the utilization of coping strategies by arable crop farmers in herders-farmers conflicts in Osun State, Nigeria. It specifically described the socio-economic characteristics of arable crop farmers, identified the coping strategies used by the arable crop farmers and identified the constraints to utilizing the coping strategies. A multi-stage sampling procedure was used to select 270 arable crop farmers for the study. A well-structured interview schedule was used to collect data from the arable crop farmers. Data collected were analyzed using frequency counts, percentages, mean and standard deviation. The results revealed that the mean age of the arable crop farmers was 51±8.2 years, the majority (80.7%) of the arable crop farmers were males, a majority (88.5%) were married, the mean household was 8 and almost all (99.3%) had no insurance for their farm crops. Coping strategies utilized were praying for peace ($\bar{x}$=2.75) and early harvesting ($\bar{x}$=2.48). Constraints experienced were farm destruction in absence of the farmers ($\bar{x}$=4.75) and difficulty in borrowing money ($\bar{x}$=4.62). The study recommended that the farmers should ensure their crops, and that government and stakeholders should lessen the constraints to the utilization of the coping strategies in the study area.

Keywords: *Constraints, utilization, coping strategies, arable crop farmers, herdsmen-farmers, conflicts.*

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INTRODUCTION

Economic demand for cattle in the country is attributed to the increase in the number of herders and their herds, resulting in more demand for greener pastures beyond the existing capacity.

Fulani pastoralists or Fulani herdsmen are nomadic or semi-nomadic herders whose primary occupation is livestock rearing [1]. Worsened by unfavorable climate change, this has contributed to competition for the available land for grazing and cultivation and thus provoking conflicts between herders and farmers [2]. Livestock keeping is known to all cultures and groups, and an increase in the production of crops and animals has often resulted in cultivating uncultivated lands to meet the ever-growing demand as well as raw materials for industry and export to supply its expanding population [3].

The necessity to provide food crops and animals has led to struggles over the control of economically viable lands. This has led to competition between the two agricultural land user groups [4]. The socio-economic lives of both the farmers and the herdsmen revolve around land and land dispute easily degenerate into conflicts between the herdsmen and farmers of the host communities. However, the conflicts have demonstrated a high potential to exacerbate the insecurity and food crisis, particularly in rural communities where most of the conflicts are localized, with reverberating consequences nationwide [5]. [6] posited that several studies have shown that to meet the projected demands for a rising population, diet shifts, and increasing biofuels consumption, global crop production needs to be doubled by 2050 by boosting crop yields from four tracked key global arable crops such as maize, rice, wheat, and soybean with a capacity of producing nearly two-thirds of global agricultural calories to meet these rising demands.

The herdsmen activities had been one of the securities and developmental challenges on the agricultural sector most especially arable crop farmers as Nigerians were emphasizing the need for the promotion of agriculture as an alternative to oil as a major source of national revenue [7]. Therefore, farmers and herdsmen conflicts bring about disaster and subsequent hazards that lead to the destruction of lives and properties which threaten the unity of the country at large and also precipitate national disintegration as a result of the immense values the Fulani herdsmen attach to their cows [8]. The primary occupation of the people in Osun State is farming but most farmers live on a subsistence pattern of agriculture mostly arable crop production such as maize, soya beans, rice, yams, cassava, vegetable and cocoyam thereby contributing to food security in the State and the country in general. The people of the State accommodate other tribes such as Igbo, Hausa, Tivi, and Fulani to live together in peaceful coexistence with them and they have been experiencing peace for several years.

The importance of rearing cattle by Fulani herdsmen within the State cannot be overemphasized as it creates employment opportunities for the youths in the area of rearing, meat vending, use of cow dung as organic fertilizers as well as the use of cow bones as raw materials for production of livestock feeds.

An increase in the population growth and socio-economic dynamism of the arable crop farmers and herdsmen in Nigeria has led to competition over agricultural resources such as land and water; this in turn has led to herdsmen-farmers conflicts.

In recent times, herdsmen-farmers conflicts have cost the Nigerian state a lot in terms of man and materials, yet the situation worsened every day in the country. [9] observed that the lingering herders-farmers' conflicts have not only turned out to be one of the major security challenges but also a threat to national food security in Nigeria.

In a similar view, [10] opined that the conflicts between farmers and herdsmen have been on a daily increase in recent years, threatening the nation's security, stability and peace. Herdsmen-farmers' conflicts in Nigeria started in the middle-belt region, consisting of Benue, Taraba and Plateau before spreading to southwest States [11].

The issue of herdsmen-farmers conflicts has become a major challenge and matter of concern in Osun State as it has made many parts of the State inhabitable for some of the agrarian communities and thereby disengaged them from farming activities [12]. There has been hue and cry by many people in various communities across Osun State on the lingering herdsmen-farmers conflicts in the recent past; the conflicts have taken a new dangerous dimension and become so frequent culminating in killings, maiming, and in some cases burning of houses and invasion of communities. Various government strategies such as the establishment of grazing reserves have been implemented to address the conflicts, but many of these strategies put in place by the government appear not to have yielded positive results as killings and destruction of properties were on the rise. If these conflicts are not nipped in the bud, they may affect the achievement of Sustainable Development Goal 2 which aims at ending hunger, achieving food security and improving nutrition and promoting sustainable agriculture by 2030 and may result in food insecurity of the State and Nigeria in general. Hence this study identified constraints to the utilization of coping strategies among arable crop farmers in herdsmen-farmers conflicts in Osun State, Nigeria. It specifically describes the socio-economic characteristics of the arable crop; identify the coping strategies used by the arable crop farmers during and after the herdsmen-farmers conflicts; and identify constraints to utilizing the coping strategies by the arable crop farmers in the study area.

MATERIALS AND METHODS

The study area was carried out in Osun State, Nigeria. Osun State was created on Tuesday, 27th August 1991, from the old Oyo State. It is bounded in the north by Kwara State and partly by Ekiti State and Ondo State in the east, in the south by Ogun State and in the west by Oyo State. It has an area of approximately 9,026 square kilometer's and a population of 3,416,959 (1,734,149 males and 1,682,810 females) [13].

The population of the study included the arable crop farmers in Osun State, Nigeria whose farms were destroyed by herdsmen in recent times. A multistage sampling procedure was used to select respondents for the study. There are three agricultural zones in the State namely: Osogbo, Iwo, and Ife-Ijesa zones. The first stage involved a purposive selection of three (3) Local Government Areas (LGAs) where herdsmen and arable crop farmers' conflicts were prevalent from each of the three agricultural zones. The second stage involved the purposive selection of two (2) communities from each selected LGA where herdsmen and arable crop farmers' conflicts were prevalent. The third stage involved the use of the snowball technique to select fifteen (15) arable crop farmers whose farms were destroyed by herdsmen in recent times from each of the farming communities making a total number of two hundred and seventy (270) arable crop farmers. Data were collected with the use of a well-structured interview schedule.

Simple descriptive statistical techniques such as frequency counts, percentages, mean, standard deviation and weighted mean scores were used to analyze the data collected.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of arable crop farmers.

Results in Table 1 reveal that the mean age of the arable crop farmers was 51 with a standard deviation of 8.2. This further reveal that few of the arable crop farmers were youths with greater physical strength, greater knowledge acquisition propensity and faster rate of learning, this could be dangerous for the future of sustainability of arable crops in the study area. However, this finding disagrees with [14] that the respondents were in their advanced age. The results further reveal that majority (80.7%) of the arable crop farmers were males while few (19.3%) were females. The result of having a larger percentage of men than women indicated that planting arable crops such as maize compared to cultivating vegetables in the study area requires physical strength engagement of males most especially in land preparation, planting weeding, harvesting and processing. This finding agrees with [15] that the majority of the arable crop farmers sampled were male. The results further reveal that majority (88.5%) of the arable crop farmers were married. The large percentage (88.5%) of married male and female arable crop farmers indicates that most of the farmers in the study areas had families of their own, who can supply them cheap labor force on their farms, thereby reducing the cost of the production. This result supports the finding of [16] that most arable crop farmers in Osun State were married.

The results further show that the mean household was 8 persons with a standard deviation of 3 persons. The finding indicates that the arable crop farmers in the study areas had large household sizes, which could assist in farming activities to reduce the cost of production. The results further show that the majority (71.1%) of the arable crop farmers had farm sizes between 1 and 15 acres. This finding indicates that a larger proportion of the arable crop farmers were small and medium scale farmers, and very few cultivated a little above medium scale.

This result supports [17] that rural communities engaged in arable crop production as a means of livelihood and economic sustenance in the provision of essential nutritional needs for their families and support of the nation's food security. The results further reveal that almost all (99.3%) of the arable crop farmers in the study area had no insurance for their farm crops. While very few (0.7%) of the arable crop farmers insured their farm crops. The results further reveal that only very few (0.4%) of the arable crop farmers had business property insurance for their farms and very few (0.4%) had liability insurance for their farms. This result is in tandem with [18] findings that very insignificant arable crop farmers engaged in an insurance policy. Lack of farm crop insurance may lead to total loss of investment as a result of herdsmen crop destruction.

Table 1. Distribution of arable crop farmers according to their socio-economic characteristics (n = 270)

Variables	Frequency	Percentage	Mean	Standard deviation
Age in years				
30-45 years	73	27.0		
46-60 years	164	60.7		
61-75 years	33	12.2	51.	8.2
Sex				
Male	218	80.7		
Female	52	19.3		
Marital status				
Married	239	88.5		
Separated	7	2.6		
Divorced	1	.4		
Widowed	13	4.8		
Widower	10	3.7		
Household size				
1-5 members	50	18.5		
6-10 members	184	68.1		
11 and above members	36	13.3	8	3
Farm size				
1 – 15	192	71.1		
16-30	62	23.0		
31-45	9	3.3		
46-60	4	1.5		
61-75	3	1.1	13.5	11.9
Possession of farm crops insurance				
Have insurance	2	0.7		
Have no insurance	268	99.3		
Type of Insurance				
Business property insurance	1	0.4		
Liability insurance	1	0.4		

Source: Field survey, 2021

Coping strategies utilized by arable crop farmers against herdsmen's attack.

Results in Table 2 reveal that praying for peace ($\bar{x}$=2.75) was ranked first, followed by early harvesting ($\bar{x}$=2.48). The third-ranked coping strategy was the early planting of crops ($\bar{x}$=2.32), which was followed by appeasing the other parties ($\bar{x}$=2.23) and others in that order. This finding was supported by [19] who reported that the sampled respondents most often used prayer for peace as the first emotion-oriented coping strategies.

In addition, planting and harvesting crops early may assist the farmers to avoid extreme weather conditions that lead to the state of cattle grazing on any available plant.

This finding agrees with that of [20]) who also found out that the selected respondents employed early planting of crops as a coping strategy.

From the scales of measurement of 1, 2, and 3 for "not at all", "to a lesser extent" and "to a large extent", respectively coping strategies whose means measure up to 2 (that is 1+2+3/3) were used as a benchmark or the utilized coping strategies. This means that 7 of the coping strategies could be regarded as being utilized. This result shows that praying for peace, early harvesting of crops, early planting of crops, appeasing the other parties, avoiding planting crops along river banks to avoid destruction, having farms in different locations and avoiding planting of arable crops in the dry season were the utilized coping strategies. This result further infers that any intervention that would be applied to mitigate herders-farmers' conflicts in the study area should be applied to enhance the utilization of all the coping strategies in ascending order, except drinking alcohol/drugs and smoking Indian hemp to suppress the trauma.

Table 2. Distribution of arable crop farmers based on the use of coping strategies (n=270)

Coping strategies	Mean	Standard deviation	Rank
Praying for peace	2.75	0.513	1st
Early harvesting	2.48	0.655	2nd
Early planting of crops	2.32	0.728	3rd
Appeased the other parties	2.23	0.786	4th
Avoiding planting crop along river banks to avoid destruction	2.20	0.796	5th
Having farms in different locations	2.12	0.797	6th
Avoiding planting of arable crops in dry season	2.09	0.843	7th
Educating farmers and herdsmen on their interdependence	1.86	0.792	8th
Informed the Police / Nigeria Sec. and Civil Defense Corps.	1.83	0.830	9th
Cultivating large farm to mitigate against destruction	1.83	0.841	10th

Source: Field survey, 2021.

Constraints to the utilization of coping strategies

Results in Table 3 reveal that farm destruction carried out in farmers' absence that makes herders' identification difficult (($\bar{x}$=4.75) ranked first, staying late on the farm may further endanger farmer's life ($\bar{x}$=4.69) ranked second, the process of borrowing money takes longer time and makes the loan useless ($\bar{x}$=4.62) ranked third, planting of toxic trees like *Jatropha curcas* will take years before maturity ($\bar{x}$=4.54) ranked fourth, making fence round the farm land requires huge amount of money ($\bar{x}$=4.44) ranked fifth, planting minor crops or leasing the farm area to minimize losses may affect food security ($\bar{x}$=4.43) ranked sixth, formation of farmers' association and use of vigilante for farm protection proved ineffective ($\bar{x}$=4.42) ranked seventh, lack of extension workers or personnel to facilitate and educate farmers on the need of their interdependence with the herdsmen ($\bar{x}$=4.41) ranked eighth, avoiding planting in dry season along river banks will complicate food insecurity ($\bar{x}$=4.37) ranked ninth and others in that order.

From the scales of measurement of 1, 2, 3, 4, and 5 of "strongly disagree", "disagree", "undecided", "agree" and "strongly agree" respectively, indicators of constraints to the utilization of coping strategies whose means measure up to approximately 3 (that is 1+2+3+4+5/5) were used as a benchmark for the constraints. This means that out of the seventeen constraints to the utilization of coping strategies, all were identified as major constraints, these were; farm destruction carried out in farmers' absence which makes herders' identification difficult, staying late on the farm may further endanger farmer's life,

the process of borrowing money takes longer time and makes the loan useless, planting of toxic trees like *Jatropha curcas* will take years before maturity, making fence round the farmland requires a huge amount of money, planting minor crops or leasing the farm area to minimize losses may affect food security, formation of farmers' association and use of vigilante for farm protection proved ineffective, lack of extension workers or personnel to facilitate and educate farmers on the need of their interdependence with the herdsmen, and avoiding planting in the dry season and along river banks will complicate food insecurity and others in that order.

This result further infers that any intervention that would be applied to prevent/mitigate herders-farmers' conflicts in the study area should be applied to enhance the lessening of all the constraints to the utilization of coping strategies in ascending order.

Table 3. Distribution of arable crop farmers based on constraints to the use of coping strategies (n=270)

Constraints to the utilization of coping strategies	Mean	SD	Rank
Farm destruction carried out in farmers' absence makes herders' identification difficult	4.75	0.482	1st
Staying late on the farm may further endanger the farmers' life	4.69	3.148	2nd
The process of borrowing money takes a longer time and makes the loan useless.	4.62	0.558	3rd
Planting toxic trees like *Jatropha curcas* will take years before maturity.	4.54	3.207	4th
Making a fence around the farmland requires a huge amount of money.	4.44	0.680	5th
Planting minor crops or leasing the farm area to minimize losses may affect food security.	4.43	0.722	6th
The formation of farmers' associations and the use of vigilantes for farm protection proved ineffective.	4.42	0.875	7th
Lack of extension workers or personnel	4.41	3.185	8th
Avoiding planting in the dry season and along river banks will complicate food insecurity.	4.37	0.734	9th
The nomadic nature of the herdsmen makes it difficult for law enforcement agents to arrest and prosecute the culprits	4.36	0.900	10th
The land tenure system prevents farmers from cultivating large areas of a farm.	4.36	0.814	11th
Punishment of offenders is difficult due to corruption, ethnicity and lack of political will.	4.35	0.844	12th
Diversification will lead to a scarcity of arable crop products and produce.	4.31	0.822	13th
Seeking litigation is tantamount to wasting time and money.	4.26	0.899	14th
Compensating the affected farmers has no effect as the damages paid are not up to the destruction done.	4.26	0.810	15th
Stealing and diversion of government relief materials meant to mitigate the herdsmen's attack.	4.21	0.905	16th
Drinking alcohol/drugs and smoking Indian hemp will expose the youths to criminal acts.	4.14	1.135	17th

Source: Field survey, 2021.

CONCLUSION AND RECOMMENDATIONS

Arable crops farmers were middle-aged, married, male, with no insurance for their crops. Coping The study recommended that the farmers should ensure their crops, and that government and stakeholders should lessen the constraints to the utilization of the coping strategies in the study area.

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OGRANIČENJA U KORIŠĆENJU STRATEGIJE SUOČAVANJA KOD KONFLIKTA FARMERA I STOČARA U POLJOPRIVREDI DRŽAVE OSUN, NIGERIJA

Oluwagbenga T. Alao[1], Ibidun O. Ibitunde[2], Oluyinka S. Isola[3]

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Apstrakt. Studija je indentifikovala ograničenja upotrebe strategija suočavanja od strane farmera (ratarske kulture) u sukobima između stočara i farmera u državi Osun, Nigerija. U strategiji su posebno opisane socio-ekonomske karakteristike farmera ratarskih kultura, i indentifikovane strategije suočavanja koje koriste farmeri ratarskih kultura i određenih ograničenja za primenu strategija suočavanja.
Višestepena procedura uzorkovanja je korišćena za odabir 270 poljoprivrednika koji gaje ratarske kulture. Dobro struktuiran raspored intervjua je korišćen za prikupljanje podataka od farmera za oblasti ratarskih kultura. Prikupljeni podaci su analizirani korišćenjem registrovanja učestalosti, procenata, srednje vrednosti i standardne devijacije.
Rezultati istraživanja su pokazali da je srednja vrednost starosti farmera-ratara bila 51±8,2 godina, većina (80,7%) ratara su bili muškarci, većina (88,5%) su bili oženjeni, a prosečno domaćinstvo je imalo 8 godina i skoro svi (99,3%) nisu imali osiguranje za svoje poljoprivredne useve.
Korišćene su strategije suočavanja sa: molitvama za mir ($\overline{x}$=2,75) i primena rane žetve gajenih kultura ($\overline{x}$=2,48). Ograničenja su bila: uništenje farme u odsustvu farmera ($\overline{x}$=4,75) i teškoće/problemi kod pozajmljivanja novca ($\overline{x}$=4,62).

Studija preporučuje da farmeri treba da osiguraju svoje useve, a da vlada aktuelne države i zainteresovane strane u konfliktu, treba da smanje/promene ograničenja u korišćenju strategija suočavanja u oblasti istraživanja sukoba farmera.

Ključne reči: *Ograničenja, korišćenje, strategije suočavanja, ratari, stočari-poljoprivrednici, sukobi.*

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ASSESSMENT OF CLIMATE CHANGE ADAPTATION PRACTICES OF ARABLE CROP FARMERS IN KWARA STATE, NIGERIA

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Abstract: This study examined the climate change adaptation practices of farmers cultivating arable crops in Kwara State. One hundred and twenty (120) farmers were drawn for this study using multi stage sampling method. An interview schedule was designed to gather relevant data and analyzed with descriptive and inferential statistical tools. Results reveal that the average years of farming experience was 7 years with majority having no formation education. The topmost effects of climate change were crop loss (mean=4.82), food insecurity (mean=480) and the inability to plan ahead (mean=4.79). The leading mitigation practices employed by farmers were organic farming practices (mean=3.59), crop rotation methods (mean=3.53) and afforestation (mean=3.52). Foremost challenges to effective mitigation were insufficient extension contact (mean=4.85), poor support by the government (mean=4.71) and inadequate required production inputs (mean=4.69). Correlation analysis showed that educational status of the farmers indicated positive significant relationship with mitigation practices employed by farmers.

The study concluded that organic farming practices, crop rotation methods and afforestation were the leading mitigation practices employed by farmers in Kwara State. There is need for extension organizations in the study area should recruit more extension agents to enable practical field demonstration of climate change adaptation practices.

Key words*: Crop rotation, extension contact, farm loss, food insecurity, organic farming*

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INTRODUCTION

Similar to other developing countries, agriculture in Nigeria is dominated by small scale farmers who constitute 80% farming population cultivating less than 10 hectares [1]. These farmers mainly cultivate arable crops (rice, cowpea, maize, sorghum, millet etc.) and reside in the rural areas. These farmers faced several challenges ranging from inadequate access to inputs, inadequate access to farm credit, inadequate extension service providers, unstable agricultural policies and programmed, inadequate allocation of fund for agricultural research as well as the negative consequences of climate change. It is no longer news that greenhouse gas emitted into the atmosphere has caused notable shift in regular rainfall pattern, intensity of sunshine and temperature needed for food crops to survive.

Climate change can be described as the change in climate patterns. The change is solely caused by the emission of greenhouse gas that produces heat trapped by the atmosphere resulting to global warming. The leading sources of greenhouse gas being escaped to the atmosphere are human activities and natural systems. The natural occurrences are wetlands, earthquakes, forest oceans, and permafrost while activities of man causing greenhouse gas emission include industrial activities, change in land use and process of energy production [2]. The negative influence of climate change has direct impact on agricultural growth. This is because climate change cause significant shift in average rainfall pattern and intensity of sunshine and temperature needed for food crops to survive. It has further caused changes in ground-level ozone concentrations, atmospheric carbon dioxide and the nutritional quality of some foods [3].

To tackle the advert outcomes of climate change in most human endeavor, people across the world have applied mitigation and adaptation measures against greenhouse emission. Mitigation can be described as measures to minimize and curtail the emission of greenhouse gas while adaptation measures are actions to reduce vulnerability of threats that may arise from change in climatic condition. In the agricultural sector, Nigerian farmers in recent times have applied many practices to lessen the implications of climate change. In Southern and Western parts of Nigeria, several authors have listed many indigenous and climate smart adaptive strategies used by farmers cultivating arable crops. Some of the practices include practice of irrigation system (Fadama), planting of drought tolerant seeds, planting of trees (afforestation), and the application of organic practices which include the adjustment in planting date, use of manure, fallowing, mulching and timely harvest of crops [4,5]. Unfortunately, utilization of climate mitigation practices has been threatened by inadequate finance, high level of farmers' illiteracy, low knowledge of technical-know how, poor knowledge of weather forecast and low status of awareness on climate change effects among farmers [6].

Climate change has been talked about for so long and it is no doubt that it is gradually affecting agricultural development efforts in Kwara State especially in the crops production sector.

Most farmers in Nigeria are small-scale holders that operate with small finance and little capability to adopt expensive farming strategies very high weather incidents (climate change) such as heavy rainfall, heavy wind, thunder storm and flood are hazardous to crop farming, animals and humans. These usually result to loss of arable crops, prevalence of diseases and pests [7].

There are some mitigation practices that are less stressful with minimal cost. Such practices should be used by small scale arable crops farmers. Although some of these mitigation practices have already been put to use by the farmers, thus empirical study is needed to understand prominent climate mitigation practices used by farmers growing arable crops to avert the effects of change in climate in Kwara State.

The broad purpose of this study was to examine climate change adaptation practices among farmers cultivating arable crops in Kwara State. Specifically, the study (i) examined perceived effects of climate change on arable crops, (ii) investigated mitigation practices used to lessen the effects of climate change in growing arable crops, and (iii) identified the challenges faced by farmers growing arable crops on the use of climate change mitigation practices in Kwara State. Hypothesis (H0) states thus: socio-economic characteristics do not significantly affect the mitigation practices used to minimize the effects of climate change among farmers growing arable crops

MATERIAL AND METHODS

Study area

The study was carried out in Kwara State, located in North Central geopolitical zone of Nigeria. Kwara State is positioned between parallels 8Â° and 10Â° north latitudes and 3Â° and 6Â° east longitudes. Kwara State consists of sixteen Local Government Areas namely Ilorin East, Asa, Ifelodun, Ilorin South, Kaiama, Ilorin West, Irepodun, Moro, Isin, Baruten, Offa, Edu, OkeEro, Pategi, Oyun, and Ekiti.

Sampling size and sampling produce

All farmers growing arable crops in Moro Local Government were considered in the study. Three-stage selection procedure was applied to arrive at sample size. Two districts (Malete and Gaa Alaanu) in Moro local government were selected randomly in the first stage. Second stage entailed random selection of 15 farming communities in each of the districts selected. In the third stage, 4 arable crop farmers were randomly selected in each village which gives a gross sampling size of 120 respondents.

Data collection and analysis

Primary data was collected with interview schedule. Data gathered were analyzed and presented using frequency count, percentage, mean score. Stated hypothesis was analyzed using Pearson Moment Correlation (PPMC) statistical tool.

Perceived effects: Strongly agree=5, agree=4, undecided=3, disagree=2, strongly disagree=1. Usefulness of mitigation practices: highly useful=4, useful=3, undecided=2, not useful=1. Challenges to use of mitigation practices: Highly severe=5, severe=4, undecided=3, not severe=2, not a constraints=1.

RESULTS AND DISCUSSION

Socio economic characteristics of respondents

Based on results of data analysis displayed in Table 1, arable crops farming was dominated (78.3%) by male. The mean age was 42.5 years. Many of the respondents were married (75.0%) with mean score of 5 persons in each household. The percentages of respondents that have primary, secondary and tertiary education were 13.3 percent, 15.0 percent and 9.2 percent respectively. Results show that respondents had 14 years of experience in arable crop cultivation.

Table 1. Socio economic characteristics of respondents (n, 120)

Variables	Classes	Frequency	Percent	Mean
Age				42.5
Household size				5.0
Farming experience (years)				7.0
Sex:	Male	94	78.3	
	Female	26	21.7	
Marital status:	Single	2	1.7	
	Married	90	75.0	
	Widow	2	1.7	
	Widower	17	14.2	
Education:	No formal	3	2.5	
	Primary	16	13.3	
	Secondary	18	15.0	
	Tertiary	11	9.2	
	Arabic	72	60.0	

Source: Field survey, 2021.

Perceived effects of climate change on arable crop farmers

According to results of analysis presented in Table 2, the topmost effect of change in climate on arable crop farming was that it brings about crop loss to the farmers (mean=4.82). Secondly, climate change cause food insecurity (MS=4.80) is a key effect on arable crops. The third effect of climate change on arable crops is that climate change hinders the farmers to plan ahead (MS=4.79). The least effect of climate change is that it brings about livelihood diversification (MS=4.00).

Table 2. Effect of climate change on arable crop farming

Statements on effects	Mean	Standard Deviation	Rank
It brings about loss to the farmers	4.82	0.389	1st
It causes food insecurity	4.80	0.402	2nd
It hinders the farmers to plan ahead	4.79	0.517	3rd
It reduces profit	4.69	0.562	4th
It reduces efficiency	4.68	0.521	5th
It discourages the farmers from planting	4.62	0.568	6th
It reduces crop yield	4.25	1.343	7th
Increases rural-urban migration	4.17	1.056	8th
It brings about livelihood diversification	4.00	1.177	9th

Source: Field Survey, 2021.

Adaptation practices use by farmers

Results of data analysis in Table 3 showed the adaptation practices used by crop farmers to reduce vulnerability to the effects of change in climatic condition. The foremost adaptation practice used was the use of organic farming (mean=3.59). The next practice was the use of crop rotation (mean=3.53). Afforestation/reforestation and weed management were other mitigation practices employed by farmers with the mean scores of 3.52 and 3.45 respectively. The least used mitigation practices are shifting cultivation and use of improved seed varieties with mean score of 2.97 and 3.09 respectively.

Table 3. Use of climate change adaptation practices

Climate change adaptation practices	Mean	Standard Dev.	Rank
Organic farming	3.59	0.571	1st
Crop rotation	3.53	0.774	2nd
Afforestation and reforestation	3.52	0.797	3rd
Weed management	3.45	0.873	4th
Planting of cover crops	3.40	0.887	5th
Cultivation of improved crops	3.34	0.792	6th
Altering of planting date	3.31	0.893	7th
Alley cropping	3.29	0.739	8th
Water management	3.27	1.016	9th
Nutrient management	3.13	1.092	10th
Use of improved seed varieties	3.09	0.923	11th
Shifting cultivation	2.97	1.000	12th

Source: Field survey, 2021.

Challenges to use of climate change adaptation practices

As shown in Table 4, the most severe problem hindering farmers to employ mitigation practices is the insufficient extension contact (mean=4.85). The second constraint according to their severity is poor support by the government with a mean score of 4.71. Inadequate production inputs and poor access to credits were also key constraints with mean scores of 4.69 and 4.62 respectively. The least constraint affecting arable crop farmers according to their level of severity are inadequate access to information on climate change and time consuming exercise with MS of 3.71 and 3.69 respectively.

Table 4. Challenges to use of climate change adaptation practices

Challenges	Mean	Standard Dev.	Rank
Insufficient extension contacts	4.85	0.633	1st
Poor support by the government	4.71	0.640	2nd
Inadequate required production inputs (e.g., land, seeds, fertilizer etc.)	4.69	0.562	3rd
Poor access to formal credits	4.62	0.611	4th
Insufficient land	4.54	0.815	5th
Inadequate awareness of farmers on climate change adaptation practices	4.54	1.090	5th
Irregular visit of extension agents	4.25	1.063	7th
Inadequate awareness of farmers on climate change variability	3.89	1.067	8th
Poor access to information on climate change	3.71	1.402	9th
Time consuming practices	3.69	0.814	10th

Source: Field survey, 2021.

Hypothesis of the study

Null: socio-economic characteristics do not have significant effect on mitigation practices used to minimize the effects of climate change among farmers growing arable crops.

The results PPMC analysis in Table 5 showed a positive and significant correlation coefficient (r= 0.01<0.05) between education attainment and mitigation practices used to minimize the effects of climate change among farmers growing arable crops. This finding indicates that the increase in education status will bring about increase use of climate change adaptation practices among farmers in the study area.

Table 5. Results of correlation analysis between educational status and climate change adaptation practices used by farmers

		Educational status	Adaptation practices
Educational status	Correlation (Pearson)	1	0.316**
	Probability		0.001
	N	120	106
Adaptation practices	Correlation (Pearson)	0.316**	1
	Probability	0.001	
	N	106	106

Decision: reject null hypothesis (p<0.01)

The mean age implies that arable crop farmers were still young and within the active age. The finding confirms the report of Authors [8] who found that farmers growing arable crops in Kwara State are relatively young and capable to engage in stressful activities in crop farming. This study also shows that farmers growing arable crops in the study area were educated. Literacy level of the farmers could positively influence their acceptance and application of climate smart innovation practices introduced by extension agents. This observation conforms with report by Authors [9] that individual farmers with educational attainments are usually fast adopters of innovations. Finding indicates that many farmers cultivating arable crops in Kwara state are highly experienced.

The topmost effect of change in climate on arable crop farming was that it brings about crop loss to the farmers. This is because, climate change affects yield of crops in a farm and also damage and reduce the growth rate of some group. Consequently, this will lead to the loss to the farmers. Secondly, climate change cause food insecurity is a key effect on arable crops. This is because arable crop farming is paramount in keeping the availability of food all year round, therefore, a slight change in climate causes reduction in arable crop productions which ultimately causes food insecurity in Nigeria. The third effect of climate change on arable crops is that climate change hinders the farmers to plan ahead. This is so because the farmers are scared of sudden change in climatic condition which could have serious effects on their crops and thus are skeptical to plan ahead. The least effect of climate change is that it brings about diversification.

The mean score of 4.00 is also high based on the 5-point Likert scale used but this effect is the least among the ways change in climate can affect arable crops. Other effects are reduced profit and efficiency. It also discourages farmers from planting crops, reduced crop yield as well as increased rural-urban migration.

This finding agrees with previous study which found that climate change brings about loss to farmers, food insecurity and ultimately discourages them in farming [7].

The foremost mitigation practice used was the use of organic farming, implies that the non-use of synthetic agro-chemicals was the main method used by farmers to minimize the effects of climate change. The least used mitigation practices are shifting cultivation and use of improved seed varieties. This implies that extension agents need to educate the arable cop farmers more about the use of improved seed varieties because, improved seed varieties can serve as a very reliable method of reducing the effect of climate change. Other mitigation practices used are planting of cover crops, cultivation of improved crop, altering of plant date, alley cropping, water management and nutrient management. This agrees with previous study which found that organic farming and planting of cover crops are ways of mitigation practices of climate change [10].

The most severe problem hindering farmers to employ mitigation practices is the insufficient extension contact. This shows that extension agents need to work more in educating farmers cultivating arable crops on the use of adaptation practices. This is evident in table 4 where most of the farmers do not use improved seed varieties. The second constraint according to their severity is poor support by the government. This implies that the government needs to provide more support to arable crop farmers especially since the area the one mainly involved in providing food for the country. Furthermore, inadequate production inputs and poor access to credits were also key constraints. The least constraint affecting arable crop farmers according to their level of severity are inadequate access to information on climate change and time consuming exercise. Other challenges to adaptation practices against the menace of climate change conditions in crop farming were insufficient land, irregularity of extension services and inadequate awareness on climate change. This corroborates the report of study which stated that insufficient extension contacts and lack of attention by the government are the main challenges facing farmers growing arable crops on the adoption to utilize climate change mitigation practices [11].

A positive and significant correlation between education attainment and adaptation practices used to minimize the effects of climate change among farmers growing arable crops indicates that the increase in education status will bring about increase use of climate change adaptation practices among farmers in the study area.

CONCLUSIONS

The research showed that climate change affects arable crops by causing loss of crops to farmers in Kwara State, Nigeria. To manage the effects, farmers mainly get climate change information through neighbor and radio. Furthermore, the research work also indicated that insufficient extension contact was the most severe challenge hindering farmers growing arable crops to use required adaptation practices against changes in climate condition.

Therefore, extension organizations in Kwara State should recruit more extension agents to enable practical field demonstration of climate change adaptation practices.
Also, government intervention programmed is needed to enable increase access of farm inputs such as improved seed varieties to help avert the effects of variation in climatic condition. More awareness of adaptation practices against the menace of change in climate should also be delivered to the farmers in Kwara State.

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PROCENA PRAKSE PRILAGOĐAVANJA POLJOPRIVREDNIKA KLIMATSKIM PROMENAMA ZA RATARSKE USEVE U DRŽAVI KWARA, NIGERIJA

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Apstrakt: Ova studija je ispitala praksu prilagođavanja na klimatske promene poljoprivrednika koji uzgajaju ratarske useve u državi Kwara.

Studija obuhvata sto dvadeset (120) farmera, upotrebom višestepene metode uzorkovanja. Raspored intervjua je dizajniran da prikupi relevantne podatke i analizira ih pomoću deskriptivnih i inteferencijalnih statističkih alata.
Rezultati otkrivaju da je prosečno radno iskustvo u poljoprivredi bilo 7 godina, pri čemu većina nema formacijsko obrazovanje. Najveći efekti klimatskih promena bili su gubitak useva (srednja vrednost=4,82), nesigurnost hrane (srednja vrednost=480) i nemogućnost planiranja unapred (srednja vrednost=4,79). Vodeće prakse ublažavanja uticaja koje su poljoprivrednici koristili bilo je: organizovanje prakse organske poljoprivrede (srednja vrednost=3,59), metode plodoreda (srednja vrednost=3,53) i pošumljavanje (srednja vrednost=3,52).
Najveći izazovi (nedostatci) za efikasno ublažavanje uticaja klimatskih promena bili su: nedovoljan kontakt sa stručnim savetnicima (srednja vrednost=4,85), slaba podrška vlade Nigerije (srednja vrednost=4,71) i neadekvatni potrebni proizvodni inputi (srednja vrednost=4,69).
Korelaciona analiza pokazuje da obrazovni status farmera ima pozitivnu vezu značajnu zbog prakse ublažavanja uticaja koje koriste farmeri.
Studija ima zaključak da organizovanje organske poljoprivrede, metode plodoreda i pošumljavanje, predstavljaju vodeće metode kao praksa ublažavanja koje koriste farmeri u državi Kwara u Nigeriji.
Postoji potreba da savetodavne organizacije u oblasti istraživanja treba da angažuju više savetodavnih agenata (stručnih službi) kako bi omogućile praktičnu terensku demonstraciju primene u praksi prilagođavanja klimatskim promenama.

Ključne reči: *Plodored, produžni kontakt, gubitak farme, nesigurnost hrane, organska poljoprivreda*

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ARABLE FARMER'S ENTERPRENEURIAL COMPETENCIES AND POVERTY STATUS IN BOLUWADURO LOCAL GOVERNMENT AREA OF OSUN STATE, NIGERIA

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Abstract: Poverty affects all sectors of society and believed to be higher in rural areas. However, entrepreneurial competencies have proved to be a weapon to reduce poverty among the populace. This study sought to investigate the effects of entrepreneurial competencies on household poverty in Boluwaduro Local Government Area of Osun State, Nigeria. Primary data were collected with the aid of well-structured questionnaire using a multi-stage sampling procedure to randomly select 120 household heads from the study area. Descriptive and inferential statistics such as FGT poverty index, budgetary analysis and probit regression were used for data analysis. The results showed that the mean age of the farmers was 50.94 years and were majorly males with a mean farm size of 7.43 acres cultivated mainly by family labour. Total household expenditure per month was N49730.5. The result of the budgetary analysis reveals a BCR of 1.8. Entrepreneurial competencies level was found to be moderate in the study area and 31.7% of the farmers were poor. Probit analysis showed that the Pseudo R-squared is 0.434, commitment and social competencies were significant at 1% and 5% level indicating positive influences on poverty reduction.

It was recommended that farmers in the study area should show high commitment to agri-entrepreneurship and government should initiate policies that would enhance commitment of people and social activities to further reduce poverty level.

Keywords*: Poverty, entrepreneurial, capacities, farming households*

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INTRODUCTION

Poverty is defined as situation of severe deprivation or lack of resources and materials necessary to live in a minimum standard conducive to human dignity and well-being [1]. Manifestations of poverty include inadequate distribution of resources, lack of access to basic social services such as education and health, food shortage, low life expectancy and lack of participation in decision-making processes. According to [2], millions around the globe, particularly individuals living in informal communal groups, are constantly in short of resources, which leads to environmental degradation, pushing the poor further into extreme, hardcore poverty.

In Nigeria, the proportion of Nigerians living below the poverty line of less than one dollar a day has increased dramatically during the last two decades [3]. In 2016, over 99 million Nigerians lived on below $1.90 a day [4] and a recent release shows that poverty rate in the country stands at 40.1% in 2019 using $1.05 (₦376.52) per capita per day [5]. Major causes for the destabilization of the economic growth and the increase in poverty situation in Nigeria are corruption and inconsistency in government policies and programs ([6]; [7]). High level of poverty in the rural regions was attributed to lack of infrastructural facilities and inadequate access to public services ([8]; [5]). To reduce poverty among Nigerians, successive governments introduced various poverty reduction programmes which are yet to achieve the desired objectives because of poor design and implementation.

Entrepreneurship has assumed a more significant role in the economic development of Nigeria as it has extended beyond increasing per capita output and income. However, despite the potential of agriculture in the Nigerian economy, poverty and hunger have remain threats and obstacles to the development of the country [9]. Thus, with the exceptions of few cases, the role of entrepreneurship and innovation has been given little emphasis in agriculture in spite of the fact that it is a critical aspect of value-added agriculture [10]. Competency is a combination of knowledge, skills, abilities and other characteristics which are required for successful task execution. It helps a person to perform better in practical form. It is the transformation of knowledge, skills and attitudes to performance for a particular task successfully. Competency is helpful in distinguishing the superior performers from other performers.

Agricultural entrepreneurs do have entrepreneurial competencies, mostly those associated with diversification of undertakings, which defines their entrepreneurial deeds [11] and it is expected that agricultural production in the country should expand through innovation and diversification and to be able to cope with this development, farmers need entrepreneurial competence to be able to recognize and pursue enterprise opportunities that will lead to job creation, improvement in their income and the country's economic growth [12].

It is therefore important to study impact of entrepreneurial competencies on farm households' poverty, and this study was carried out to investigate the impacts of farmers' entrepreneurial competencies on household poverty in Boluwaduro Local Government Area of Osun State, Nigeria while the specific objectives are to examine the levels of entrepreneurial competencies, determine the poverty status of the farmers in the study area, and evaluate the effects of entrepreneurial competencies on the poverty status of the farmers in the study area.

MATERIAL AND METHODS

Study Area

Osun is an inland State in South-Western Nigeria. Its capital is Osogbo. It is bounded in the north by Kwara State, in the east partly by Ekiti and Ondo States, in the south by Ogun State and in the west by Oyo State. The State of Osun was created on August 27, 1991, from the old Oyo State. Boluwaduro is one of the thirty Local Government Areas in Osun State, Nigeria at Latitude 7°57'00" N and Longtitude 4°45'00"E. Its headquarters are in the town of Otan Aiyegbaju. It has an area of 144 km^2 and a population of 70,775 at the 2006 census. People living in the Local Government Area are Yoruba, Igbo, Hausa, and Ebira with their primary occupation as farming and their secondary occupation as trading, driving and civil service.

The average annual rainfall is 52.35 inches (1,330 mm), though there are great deviations from this mean value from year to year. Usually, the rainy season lasts from April to October. The topography of the Local Government Area is hilly, so crops grown there are tree crops, Cocoa, Kolanut, Coconut, Oil palm and arable crops such as yam, cassava and pepper.

Sampling Technique and Sample Size

The study was carried out using a multi-stage sampling procedure. The first stage involves the purposive selection of Boluwaduro LGA. The second stage is the purposive selection of four major towns from Boluwaduro LGA they include; Otan Aiyegbaju, Eripa, Iresi and Igbajo. Lastly, random selection of thirty-five (35) farmers from Otan Ayegbaju, thirty (30) farmers each from Eripa and Iresi and twenty-five (25) farmers from Igbajo proportional to the size of the communities to make a total of 120.

Method of Data Analysis

The tools that were used in analyzing collected data include; descriptive statistics and inferential statistics. Simple descriptive statistics such as means, percentages and frequency distribution was used to describe the socio and demographic characteristics of the respondents, Foster Greer and Thorbecke (FGT) was used to measure poverty of the farmers and Probit regression was used to know the effects of entrepreneurial competencies on poverty status of the farmers.

Foster Greer and Thorbecke measure of poverty indices: The FGT poverty indices developed by [13] was used to measure and decompose respondents' poverty indices based on their entrepreneurial competencies. The FGT model is specified as:

Z = the poverty line
y = the daily per capita expenditure which comprises expenditure on both food and non-food commodities
i = individual household 1, 2, …….., 120
q = the number of poor farming households in the population of size n,
α = the degree of poverty aversion;
α =0; is the headcount index () measuring the rate/incidence of poverty;

α =1 is the poverty gap index() measuring the depth of poverty that is on average, how far the poor is from the poverty line;

α =2 is the squared poverty gap() measuring the severity of poverty among households, that is, the depth of poverty among the poor.

Probit regression: Probit regression model following ([14]; [15]) was adopted in analyzing the effects of farmers' entrepreneurial competencies on their poverty status. Probit regression, also called probit model, is used to model dichotomous or binary dependent variable (Y) which takes on the value (0/1). In this study, the binary probit model takes the value of 0 for poor households, and 1 for the non-poor households. The probability of belonging to one group and not to the other can be stated as:

$$\rho_i = prob[Y_i = 1/X] = \int_{-\infty}^{x_i'\beta} (2\pi)^{-½}\, exp\left(-\frac{t^2}{2}\right) dt \quad \ldots\ldots\ldots\ldots\ldots (1)$$
$$= \Phi(x_i'\beta)$$

where φ denotes the cumulative distribution of a standard normal random variable [16].

It should be noted that association between a given variable and the result of probability is determined by means of marginal effect (ME). The ME measures the change in probability which is related to continuous explanatory variables on the probability P(Yi = 1 | X). As opined by [17], the model is specified as:

$$\frac{\partial \rho_i}{\partial x_{ik}} = \phi(x_i'\beta)\beta_{k'} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Hence, marginal effects was calculated and reported in this study, and none of the five entrepreneurial constructs will have significant effect on household poverty as postulated.

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Farmers

Table 1 presents the socio-economic characteristics of farmers. The results in Table 1 show that the mean age of the farmers was approximately 50.94 years. This implies that the farmers are not younger and this old age might affect their productivity. Gender analysis of the farmers showed that (84.2%) were male while the rest 15.8% were female. This can be attributed to the traditional right of dominance the males have over females on issues like land acquisition and other production factors which conforms with [18] that observed that male farmers have superiority and dominance in land acquisition among arable crop farmers in Southwest Nigeria. The farmers' marital status revealed that married persons accounted for (92.5%) while the single were (7.5%).

This implied that majority of the farmers were married which may be attributed to the prevalence of early marriages or the ideals of the customs and traditions that are held in high esteem.

The mean household size is 7±3 persons. This implied that the farmers who were engaged in farming enterprises in the area have a relatively large household size that formed bulk of the farm labour demand of the households which conform with [9] result that the average household in their study is 6 persons.

The results in Table 1show the educational level of the respondents in the study area which revealed that about 55.0% had completed their Secondary education, (25.8%) of the rural household had completed their primary education while 19.2% had no formal education. This implies that approximately 55.0% of the farmers had formal education which no doubt increases their literacy levels and invariable had impacted their productivity.

More than half (60.8%) of the farmers had between 1 and 2.5 acres, 16.7% of had between 2.5 and 5 acres, (23.3%) of them had above 10, (8.3%) of them had between 2.6 and 5.0 while 7.5% had between 7.6 and 10 acres of land. The mean farm size is 7.43 acres. This is an indication that majority of the farmers in the study area were peasant farmers practicing subsistence agriculture. The findings imply that farmers in the area are mainly smallholders operating on less than or equal to 2.0 hectares of farmland. This could be as a result of land tenure system or due to the increasing population leading to acquisition of farm lands for industrial and residential purposes.

The type of labour employed by the rural household as revealed by the results in Table 1 show that few (42.5%) of the respondents used family and exchange in their work force, 28.3% of the respondent hired, 15.0% used their family, 10.0% used exchange method while 4.2% were exchange and hired. The implication of the findings is that farmers make use of family more than other sources in the study area.

Table 1. Socio-economic Characteristics of the Farmers

Characteristics	Frequency	Percentage (%)
Age		
≤ 29	5	4.2
30-39	4	3.3
40-49	18	15.0
≥ 50	93	77.5.
Mean = 50.94	S.D = 8.14	
Sex		
Male	101	84.2
Female	19	15.8
Marital Status		
Single	9	7.5
Married	111	92.5
Household Size		
< 3	13	10.8
4 – 6	76	63.3
7-9	9	7.5
> 9	22	18.4
Mean = 7.0	S.D = 3.0	
Level of Education		
No formal education	23	19.2
Primary Education	31	25.8
Secondary Education	66	55.0
Farm size		

Contin. Table 1.		
1-2.5	73	60.8
2.6-5.0	10	8.3
5.1-7.5	0	0
7.6 -10	9	7.5
Above 10	28	23.3
Mean = 7.43	S.D = 9.26	
Labour type		
Family	18	15
Exchange	12	10
Hired	34	28.3
Family and Exchange	51	42.5
Exchange and Hired	5	4.2

Source: Field Survey Data, 2021.

Level of entrepreneurial competencies

Table 2 presents farmer's level of entrepreneurial intent/drive in agribusiness in the study area. The levels of entrepreneurial drive in agribusiness for this study were based on asking farmers about their perceptions on their various rate of adoption of entrepreneurship behavior in agribusiness. The assessments were rated in a three-point likert scale of highly (3), moderately (2) and low (1). Majority (84.1%) of the farmers in the area perceived their extent of perseverance drive as been moderate, 9.2% reported of been high in perseverance of entrepreneurial competencies in agriculture, while 6.7% of the farmers identified low in perseverance of entrepreneurial competencies in agriculture in the area. Quite a substantial number (76.6%) of the farmers in the area perceived their extent of commitment drive as been moderate, 11.7% reported of been high in commitment of entrepreneurial competencies in agriculture, while 11.7% of the farmers identified been low in commitment of entrepreneurial competencies in agriculture in the area.

Larger proportion (75.8%) of the farmers in the area perceived their extent of motivation drive as been moderate, 14.2% reported of been low in motivation of entrepreneurial competencies in agriculture, while 10.0% of the farmers identified being high in motivation of entrepreneurial competencies in agriculture in the area. Majority (80.0%) of the farmers in the area perceived their extent of opportunity recognition drive as been moderate, 15.0% reported of been high in opportunity recognition of entrepreneurial competencies in agriculture, while 5.0% of the farmers identified been fair in opportunity recognition of entrepreneurial competencies in agriculture in the area. About two-third (69.2%) of the farmers in the area perceived their extent of social drive as been moderate 22.5% reported of been high in social of entrepreneurial competencies in agriculture, while 8.3% of the farmers identified been low in social drive of entrepreneurial competencies in agriculture in the area.

The results in Table 2 show that in spite of the poor enabling environment for entrepreneurial activities in the area, farmers still adopt entrepreneurial activities.

The finding shows a greater hope for entrepreneurship development in the area. The implication of the findings is that when there is adequate enabling environment, good government and private sector support to these farmers, entrepreneurship spirit will sprout out in the area while problem of food security and rural poverty would be minimized.

Table 2. Farmers' level of entrepreneurial competencies

Category	Perseverance	Commitment	Motivational	Opportunity recognition	Social Drive
Low	8 (6.7)	14 (11.7)	17 (14.2)	6 (5.0)	10 (8.3)
Moderate	101 (84.1)	92 (76.6)	91 (75.8)	96 (80.0)	83 (69.2)
High	11 (9.2)	14 (11.7)	12 (10.0)	18 (15.0)	27 (22.5)

Source: Data analysis, 2021
Note: Figures in parenthesis are the percentages of respondents in each category.

Poverty status and Foster-Greer-Thorbecke (FGT) poverty indices of the Farmers

Households were classified into either non-poor or poor based on the established poverty line following [19]. Table 3 shows the incidence, depth and severity of poverty in the area. Poverty incidence (Po) or head count is the proportion of households whose per capita monthly consumption expenditure falls below the established poverty line. The result of the analysis indicated that, about three-quarters (68.3%) of the households were non poor, while 31.7% were poor. This implies that most of the farmers in the study area are not poor. This is contrary to the findings of [20]. (NBS, 2013) who reported high incidence of poverty in the State. Poverty depth (P1) measures the mean distance between the expenditure (or income) of the average poor and the poverty line. Table 16 displayed the [13] indices. The result reveals that the poverty incidence 0.316 of the respondent are poor, implying that in the study area, 31.7% were poor among the farming households. The poverty depth of 0.071 indicated that the average income of the poor in the state was 7.1% less than the poverty line, while the severity of the poverty (P2) of 0.037 showed that the incomes of the poor were not close to the poverty line. This indicates a lower poverty level in the study area. Therefore, to successfully alleviate poverty in the area, appropriate policy instruments and approaches should be fashioned to lift farming household out of poverty totally.

Table 3. FGT results showing poverty status of respondents

Status	Frequency	Poverty incidence	Poverty gap/depth	Poverty severity
Poor	38	0.316 (31%)	0.071 (7.1%)	0.037 (3.7%)
Non poor	82	68.3		

Source: Data analysis, 2021

Effects of entrepreneurial competencies on farmers' poverty status

Table 4 presents probit regression results of the effects of entrepreneurial competences on household poverty status. The result revealed a Wald chi2 value of 15.027**, with a Pseudo R -squared of 0.434.

This was statistically significant at the $P<0.01$ level, thus indicating that the model had a good fit to the data and a significant explanatory power. 2 out of the 5 explanatory variables related to household poverty status included in the model were statistically significant at different levels ($P <$ 0.01, $P < 0.05$ and $P < 0.1$).

The results in Table 4 shows that commitment of the household heads was found to be negative and significant at 1% level which implies that commitment has a great importance in the determinant of poverty in the study area. Probability level with a coefficient of -0.231which indicates that a unit increase in entrepreneurial competencies of commitment will cause a decrease in the household heads intensity of being poor by a factor of -0.231. This may be attributed to the fact that being committed to their enterprises helped their involvement in other profitable ventures. The result concurs with findings of ([21]; [22]).

Socials variable which includes social capital, social group (cooperative society, ethnic and religious association) of the household heads was found as shown in Table 4 to be negative and significant at 5% probability level with a coefficient of -0.252which indicates that a unit increase in entrepreneurial competencies of social activities will cause a decrease in the household heads intensity of being poor by a factor of -0.252.Associations would enhance the means of livelihood of the farmers. This corroborates to that of [21] and [22] that of the three significant explanatory variables, social competence had the greatest effect on the poverty status of the respondents in their study area. To accentuate, perseverance had a negative but not significant influence on household poverty, having an inverse relationship means that a household continues to stay in its, poverty state because of their perseverance competency, in other words they flow with the little they have to munch.

Commitment was significantly negative to poverty status, implying that as commitment increases there will be decrease in their poverty status. Literally, it means they have determination to move up their status and become a better household. Being motivated does not necessarily connote doing, the result showed that motivational competencies of the respondents was positively not significant to the household poverty status, implying that being motivated those not mean you will be ready to take actions that will lift the household poverty status. In same vein, opportunity recognition assumes the same assumption.

Table 4. Probit regression showing results on the effect of entrepreneurial competences on household poverty status

Variable	Coefficient	Robust Std. Error	P>|z|
Perseverance	-0.191	0.119	0.110
Commitment	-0.231	0.086	0.007**
Motivational	0.107	0.088	0.226
Opportunity recognition	0.086	0.105	0.413
Social	-0.252	0.111	0.023*
Observations	120		
Pseudo R –squared	0.434		
Wald chi2	15.027**		

Source: Data analysis, 2021

*** Significant at 1%, ** Significant at 5%, * Significant at 10%

CONCLUSIONS

It was concluded based on the findings of this research that poverty is low among farming households in the study area and that farmer's entrepreneurial competencies level (moderate) had explained their household poverty status.

This has led to reduction of poverty among the farming household in the area. However, the extent of poverty reduction is still very in significant, which is an indication that the farmers have not fully taken advantage of some of the entrepreneurial activities or have participated to a less extent. Therefore, it is recommended that policies towards infrastructural facilities development in the rural areas should be initiated to further reduce poverty among farmers in the study area. Farmers in the study area should be motivated and show commitment to agri-entrepreneurship and they should be engaged in social capital such as social cohesion, cooperative societies and ethno religious activities. Government should also intensify efforts on entrepreneurial training in form of adult education, workshops and seminars for the farmers in order to reduce the level of poverty among the farmers.

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PREDUZETNIČKE KOMPETENCIJE POLJOPRIVREDNIKA I STATUS SIROMAŠTVA U PODRUČJU LOKALNE SAMOUPRAVE BOLUWADURO U DRŽAVI OSUN, NIGERIJA

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Apstrakt: Siromaštvo pogađa sve sektore društva i veruje se da je znatno veće u ruralnim područjima Nigerije . Međutim, preduzetničke kompetencije su se pokazale kao oružje za smanjenje siromaštva među stanovništvom. Ova studija je imala za cilj da istraži efekte preduzetničkih kompetencija na siromaštvo domaćinstava u oblasti lokalne uprave Boluwaduro u državi Osun, Nigerija.

Primarni podaci su prikupljeni uz pomoć dobro struktuiranog upitnika korišćenjem višestepene procedure uzorkovanja kako bi se nasumično odabralo 120 predstavnika Boluwaduro domaćinstava kao područja istraživanja.

Za analizu podataka korišćene su deskriptivne i inteferencijalne statističke metode kao što su FGT indeks siromaštva, budžetska analiza i probit regresija.

Rezultati su pokazali da je srednja vrednost starosti farmera bila 50,94 godine i da su uglavnom to bili muškarci sa prosečnom veličinom farme od 7,43 acr (približno 3,00 ha) koja se obrađuju uglavnom zajedničkim porodičnim radom.
Ukupni mesečni troškovi domaćinstva iznosili su N49730,5 (približno 99,45 EUR).
Rezultat analize budžeta pokazuje BCR od 1,8. Utvrđeno je da je nivo preduzetničke kompetencije umeren u oblasti istraživanja i 31,7% poljoprivrednika je bilo siromašno. Probit analiza je pokazala da je Pseudo R-kvadrat 0,434; posvećenost i socijalne kompetencije su bile značajne na nivou od 1% i 5%, što ukazuje na pozitivne uticaje/trendove na smanjenje siromaštva.
Preporučeno je da poljoprivrednici u oblasti istraživanja treba da pokažu visoku posvećenost poljoprivrednom preduzetništvu i da vlada Nigerije treba da pokrene politike koje bi poboljšale posvećenost ljudi i društvenih aktivnosti za dalje smanjenje nivoa siromaštva.

***Ključne reči**: siromaštvo, preduzetništvo, kapaciteti, poljoprivredna domaćinstva*

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EVALUATION OF THE MECHANICAL AND THERMAL CHARACTERISTICS OF MAIZE HUSK BRIQUETTE AS AN ALTERNATIVE ENERGY SOURCE

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Abstract. This paper presents the mechanical and thermal characteristics evaluation of maize husk briquette as an alternative energy source to enhance sustainability and efficiency. The experimental test conducted for a 0.6kg weight of briquette showed the volatility and moisture content to have a mean value of 62.52 and 0.27%; while the compressive strength was revealed to be 3.06k N/m^2. The thermal evaluation showed that the mean burn temperature of the maize husk briquette rose from 70.70^{o}C to 83.34^{o}C in 8 minutes, 98.72^{o}C in 10 minutes and finally 100^{o}C in 12 minutes; when compared to fire wood which burns slowly from 46^{o}C in 5 minutes, to 53^{o}C in 9 minutes, 68^{o}C in 10 minutes, 82^{o}C in 12 minutes, 94^{o}C in 18 minutes and finally to 100^{o}C in 21 minutes. Further, the comparative analysis result revealed that the maize husk briquette has more oxygen and nitrogen at 44.64 and 4.22%, compared to charcoal. It also has more ash content of 11.47% due to its volatility to burn effectively. On the other hand, the maize husk briquette has a low carbon and sulfur contents after burning at 43.55 and 0.051%. These findings will help address the disposal challenges of accumulated maize husk at and crop residues as an alternative sustainable source to meet green environmental and technological demands.

Key words: *Briquette, energy source, husk, thermal conductivity.*

INTRODUCTION

The use of wood is on the increase, and on a daily basis especially in the less technologically developed countries of the world.

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With deforestation becoming a major problem in many parts of the developing world, the increased scarcity of fuelwood for household cooking, leaving kerosene and gas as the major cooking fuels. An estimated 3 billion people in our current estimated 7.63 billion people in the world rely on wood, kerosene, biomass, and coal for cooking in general, which has led to rapid deforestation and loss of more than 3% of the world's forests on a yearly basis, [24]. The use of fuel wood in the large scale by especially the rural communities without same force of replenishing the depletion, poses serious environmental consequences in many countries and the world in general. Biomass fuels are long term potential sources of renewable energy, because of its abundant availability and CO_2 neutral. Depending on the technology selection, biomass can be used as fuel in various forms; liquid, gas and solid. Also, biomass is an indispensable renewable resource, and having it in the form of wood and agricultural wastes constitute one of the third largest alternative source of primary energy in the world aside from coal and oil [3]. The common practice is to burn these residues as waste by recycling to ameliorate the accumulation of greenhouse gases.

Consequently, there is an increasing need to source for alternative as it pertains to fuels, especially as it concerns cooking so as to reduce deforestation leading to the cutting of trees for the purpose of fuel wood. One of such energy sources is the use of biomass for briquette production through carbonized or un-carbonized densification and manufacture processes. The process of compressing this waste into a product of higher density than the original raw material state is known as densification, [17] Using agricultural residues as energy is an attractive option. Briquetting is a compacting or densification process to increase the low bulk density of biomass to high density, from 150–200 kg/m^3 to 900–1300 kg/m^3 [2]. Biomasses, especially from wood and energy crops, are important energy carriers that contribute to the energy demand.

For these waste residues to become a more attractive alternative fuel, they have to be upgraded to improve their burning performance. However, there is need to subject them to conversion processes in order to mitigate these problems. One of the promising solutions to these problems was the application of briquetting technology.

It is a kind of technology to obtain clean energy from the use of bio-waste to create usable and effective briquettes to replace traditional firewood and charcoal in various domestic activities.

These products with uniform shape and sizes can be more easily handled using existing handling and storage equipment and thereby reduce cost associated with transportation, handling, and storage [8].

Burning briquettes as a fuel completes a natural cycle; on combustion they only release as much carbon dioxide back in the atmosphere as was originally absorbed by the growing tree during photosynthesis. Briquettes can be used for power generation or for thermal application but mostly they are used for thermal application in industries replacing conventional fuel. [1] investigated the impact of particles on mechanical durability of wheat straw briquettes, and observed that the increase of the rotational speed of the working chamber caused a slight decrease in the value of the mechanical durability of briquettes for all investigated fractions. [21] focused on briquettes produced from wheat, oat, canola, as well barley straw, and proved best particle size between 25–32 mm. [15] investigated the optimal feedstock particle size and its influence on final briquette quality, and conclusion, results values did not support prevailing opinion that smaller particle sizes are more suitable for briquette production.

Subsequently, [27] investigated The Effects of Some Processing Parameters on Physical and Densification Characteristics of Corncob Briquettes, and concluded that the processing parameters such as particle size, % binder ratio and compaction pressure significantly affected the physical and densification characteristics of briquettes produced from corn-cob. Good quality and highly storable briquettes can be produced from the blend of corncob and cassava starch gel [12]. This was because the briquettes produced have sufficient density and relaxed density. Furthermore, the shelf-life of the stored briquettes showed reasonable stability even after six months of storage. Also, the bulk density of the relaxed briquettes, which is 315 kg /m^3, was higher than the residue materials was 50.32 kg/m^3. This translated into 626% volume reduction. It also provides technological benefits and a desirable situation for material storage, packaging and transportation, and lastly; hence, the finer the particle size, the more positive attributes of good quality briquette such particle has. In the similar manner, the lower the binder ratio, the better the briquettes, while higher compaction pressure will result in more quality briquettes [26].

Further, [19] investigated the production of charcoal briquettes from biomass for community use, stating that the three biomass types were tested for their suitability for making charcoal briquettes, sugarcane bagasse (SB), cassava rhizomes (CR), and water hyacinth (WH). As fresh biomass samples were sun dried and then burnt in a 200 liter incinerator with a controlled amount of air. The resulting char particles were mechanically pressed into a hollow-cylindrical shape. It was found that the CR charcoal briquettes had the best properties in terms of heating value, compressive strength, and extinguishing time. Additionally, [29] looked into the various production methods, procedures and processes that are deployed to process loose biomass into biomass briquettes, they established the cactus binders is insensitive to working pressure on compaction due to binder's composition, concluded that the optimum briquetting parameters are pressure of 19MPa and loose biomass to binder ratio of 35:36.

Other studies such as [25] explored and compared the effects of three different binders, including starch, enhanced treated bio-solids and microalgae, on density, durability, energy content and combustion characteristics of fuel briquettes produced from blends of maize husks, corn cobs and bagasse, in a multilevel factorial design experiment. [10] Investigated Characterization of Briquettes from Maize Bran and Palm Kernel Shell, concluding that Fuel characterization of briquette produced from maize bran and palm kernel shell was done and the ultimate analysis for the briquette resulted into 45.67%, 5.80%, 0.05%, 1.78% and 46.70% for Carbon, Hydrogen, Sulphur, Nitrogen and Oxygen respectively. Proximate analysis gave 18.97%, 64.54%, 14.16%, and 21.30% for moisture content, volatile matter, ash content and fixed carbon respectively. The values of volatile matter and ash content are good and acceptable compared to the results from the previous work. The briquette performance was evaluated compared to firewood through water boiling test which showed that 1 kg of the briquette took 15 minutes to boil 2litres of water where as it took 1.2 kg of firewood 21 minutes to boil the same quantity of water.

Maize Factories could be done on the cottage, small, medium and large-scale, depending on availability of capital and the raw materials [26]. The husks are used for the production of potassium Hydroxide solution or as fuel for milling plants. It can be seen that virtually all parts of maize are useful. The disposal challenges of accumulated maize mills and crop residues on the field will be resolved through briquetting and its attendant energy utilization.

Hence, harnessing maize bran for energy will promote maize cultivation and guarantee national food security and heat will be generated for domestic an industrial cottage applications, since lots of potential energy abounds in these residues, therefore reducing the current pressure on forest products for rural energy supply. However, there is the need to subject the strength and durability of this biomass product to tests; hence, this paper presents the mechanical and thermal evaluation of maize husk briquettes to perform a comparative analysis, as an alternative energy source to wood charcoal.

MATERIALS AND METHODS

The material used for the experimental analysis was Maize husk, with the unwanted materials were removed and sorted to ensure a fine pure particles of the husks.

Afterwards the husks were molded into briquettes using a molder and extruder that transform it into a briquette without the use of any binder. The briquettes were further developed by using a compressing machine operating with an efficiency of 94% to produce two variable samples A and B.

The physical properties of the developed briquette samples were determined by conducting some experimental tests.

First, the size and weight were measured for each sample then the density was determined afterwards using the ratio of the mass to the volume. The mass was obtained by using a digital weighing scale, while the volume was calculated by taking the linear dimensions (length, breadth and thickness) of the briquette by means of a vernier caliper.

Subsequently, the percentage volatile of the briquette was established when a 2g of pulverized sample in a crucible was placed in the oven that was set to burn at a temperature of 550ºC for 12mins until a constant weight was obtained. Then, the briquette was removed and weighed after cooling; where the values of these parameters were used to determine the percentage volatile matter using eq. (1); where P_{VM}, Rh_{Bb} and Rh_{Ba} are the Percentage of Volatile Matter of the Maize husk briquette, Weight of oven dried sample of maize husk briquette; and Weight of sample of maize husk briquette after burning for 12mins in the furnace at 550ºC.

$$P_{VM} = \frac{Rh_{Bb} - Rh_{Ba}}{Rh_{Bb}} \times 100 \quad \text{..... (1)}$$

The moisture content of the maize husk material before and after briquetting was determined using experiment standard for Moisture Content [30], where the initial weight (W_1) of the sample was first recorded before being placed in an oven set at 103ºC for 24 hours. The samples were then removed and cooled in a desiccator, and reweighed for the final weight (W_2); where; *MC*, W_1, and W_2 are the Moisture Content, the weight of briquette before going into Oven, and the weight of briquette after oven experiment as expressed in eq. (2),

$$MC = \frac{W_1 - W_2}{W_2} \times 100 \quad \text{.....(2)}$$

Further, the compressive strength was determined by using a universal strength-testing machine of 100 kN capacity with standard method [30]. The test was carried out 21 days after briquetting when the briquettes had attained their maximum strength. The peak stress displayed at the end of each test was recorded.

The percentage ash content and percentage fixed carbon were determined using eq. (3) and (4) respectively, according to [31] by placing it in a crucible; where the weight of the crucible plus specimen was determined. This content was then burnt in a furnace at 550^{o}C until all the carbon was eliminated. It was heated slowly at the start to avoid flaming and the crucible was protected from strong drafts at all times to avoid mechanical loss of test specimen. The weight of the samples after burning were recorded as the weight of the oven-dry test specimen given in eq. (3); where P_A, W_A and Rh_{Bb} are the ash Percentage, weight of ash and weight of oven dried sample of maize husk briquette.

$$P_A = \frac{W_A}{Rh_{Bb}} \times 100 \quad \text{.....} \quad (3)$$

Further, the fixed carbon percentage (P_{FC}) was calculated by subtracting the sum of percentage volatile matter (P_{VM}) and percentage ash content (P_A) from 100 in eq. (4); while, the Gallen Kamp Ballistic Bomb Calorimeter apparatus was used, to determine the heating value of the biomass briquettes.

$$P_{FC} = 100 - (P_{VM} + P_A) \quad \text{.....} \quad (4)$$

Additionally, a comparative analysis of the physical and thermal characteristics for the maize husk briquette and charcoal were done to determine the material that emits the least greenhouse gases to produce the required heat as source energy to the society.

RESULTS AND DISCUSSION

The results of the experimental test conducted for the physical Characteristics of the developed maize husk briquette showed the size, weight, and compressive strength of the material. The value for the mean density and volatility for the variable briquette samples A and B were 524kg/m^3 and 62.52%, for an average weight measured of 0.6kg. Subsequently, the compressive strength and moisture content were evaluated at 3.06 kN/m^2 and 0.27%.

Table 1. Physical and Fuel Characteristics of Briquette from Maize

Parameters	Unit	Maize Husk Briquette Samples		Mean Value
		A	B	
Length of the Briquette	mm	60	62	61
External diameter of the Briquette	mm	39	39	39
Weight of the Briquette	kg	0.06	0.06	0.06
Volatility	%	62.51	62.53	62.52
Moisture Content, MC	%	0.27	0.27	0.27
Compressive Strength	kN/m^2	3.05	3.07	3.06

The proximate analysis gave the percentage volatile matter, percentage ash and percentage fixed carbon of the briquette; while the ultimate analysis was performed on finely ground and oven dried samples to find the amount of Carbon, Hydrogen, Nitrogen and Sulphur (C, H, N, and S) by using the CHNS Elemental Analyzer. The experiments were performed two times and the mean readings were taken for all the characterization. The briquette from the mixture has an ash content and fixed carbon of 11.47%, and 21.00%. Further, results of the heating value of the briquette was 24.21 for all samples, with a composition values of 43.55%, 4.20%, 0.05 %, 1.35% and 44.64% for carbon, hydrogen, sulfur, nitrogen and oxygen respectively. Consequently, the mean value for the chemical composition of the briquette in Fig.1., showed that the maize briquette contains carbon and oxygen at 43 and 44%; and sulfur and hydrogen as the lowest values a t 0.5 and 4.2% were the highest and lowest elements respectively.

Table 2. Thermal Characteristics of Briquette from Maize

Parameters	Unit	Maize Husk Briquette Samples		Mean
		A	B	Value
Heating Value	MJ/kg	24.21	24.21	24.21
Carbon Content	%	43.57	43.54	43.55
Hydrogen Content	%	4.20	4.21	4.20
Sulfur Content	%	0.05	0.06	0.05
Nitrogen Content	%	1.36	1.34	1.35
Oxygen Content	%	44.65	44.63	44.64
Ash Content	%	11.48	11.46	11.47
Fixed Car Moisture	%	21.00	21.01	21.00

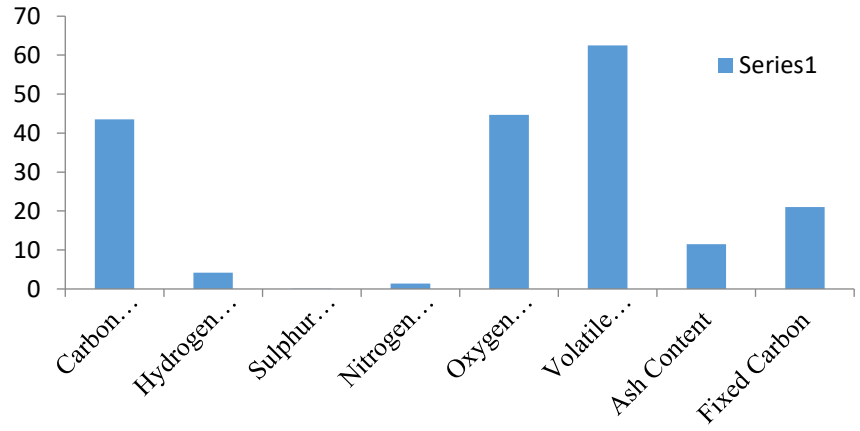

Fig. 1. Percentage composition of Maize Husk Briquette

The results of the physical and thermal characteristics of Maize husk briquette and two sources of charcoal according to [31] were presented in Table 3.
The comparative analysis results revealed that the carbon and sulfur contents of 43.55% and 0.051% for the maize husk is less than that of the charcoal from oak and pine at 87.01% and 0.150% and 86.10% 0.250% respectively.

However, the needed hydrogen and oxygen content for the maize husk at 4.220 and 44.64% are higher than the charcoal. Also, the ash content after burning was evaluated to be 11.47, with a high nitrogen content value of 1.350 as compared to charcoal at 0.5% and 0.2%.

Table 3. Combustion Characteristics of Maize Husk Briquette and Charcoal

Parameters	Unit	Maize Husk Briquette 550°C	Charcoal (Made from oak) 550°C	Charcoal (Made frompine) 550°C
Length of the sample	mm	61.01	58.71	59.05
External diameter of the sample	mm	39.10	42.32	38.26
Weight of the sample	kg	0.06	0.08	0.08
Carbon Content	%	43.55	87.01	86.10
Hydrogen Content	%	4.20	2.40	2.50
Sulphur Content	%	0.051	0.150	0.250
Nitrogen Content	%	1.350	0.50	0.20
Oxygen Content	%	44.64	6.90	9.60
Volatile Matter	%	62.52	14.70	18.10
Ash Content	%	11.47	3.10	1.70
Fixed Carbon	%	21.10	82.20	80.20

CONCLUSION

The mean burn temperature of the maize husk briquette rose from 70.70 °C to 83.34 °C in 8 minutes, 98.72 °C in 10minutes and finally 100 °C in 12minutes. Compared to fire wood which burns slowly from 46°C in 5mins, to 53°C in 9minutes, 68°C in 10minutes, 82°C in 12minutes, 94°C in 18minutes and finally to 100°C in 21minutes. The rapid combustion observed could be due to porous nature of the maize bran briquettes compared to the relatively dense firewood. The porosity in the maize husk briquettes to leave more readily and be consumed rapidly in the flame. The comparative analysis result revealed that the maize husk briquette has more oxygen and nitrogen compared to charcoal. It also has more ash content and volatility to burn effectively. On the other hand, the carbon, nitrogen and sulfur contents of the maize husk briquette after burning was low when compared to charcoal. These findings will help address the disposal challenges of accumulated maize husk at mills and crop residues on the field will be resolved through briquette making and its attendant energy utilization as an alternative sustainable source.

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PROCENA MEHANIČKIH I TERMIČKIH KARAKTERISTIKA BRIKETA OD KUKURUZNE LJUSKE KAO ALTERNATIVNOG IZVORA ENERGIJE

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Sadržaj. Ovaj rad predstavlja procenu mehaničkih i termičkih karakteristika briketa od kukuruzne ljuske kao alternativnog izvora energije za poboljšanje održivosti i efikasnosti.

Eksperimentalni test sproveden za briket težine 0,6 kg pokazao je da isparljivost i sadržaj vlage imaju srednju vrednost od 62,52 i 0,27%; dok je utvrđena čvrstoća na pritisak 3,06kN/m^2. Termička procena je pokazala da je srednja temperatura sagorevanja briketa od kukuruzne ljuske porasla sa 70,70^{o}C na 83,34^{o}C za 8 minuta, 98,72^{o}C za 10 minuta i konačno 100^{o}C za 12 minuta; u poređenju sa ogrevnim drvetom koje gori sporo od 46^{o}C za 5 minuta, do 53^{o}C za 9 minuta, 68^{o}C za 10 minuta, 82^{o}C za 12 minuta, 94^{o}C za 18 minuta i konačno do 100^{o}C za 21 minut.

Rezultati uporedne analize pokazuju da briket od kukuruzne ljuske ima više kiseonika za 44,64 i azota za 4,22% u poređenju sa drvenim ugljem.

Takođe ima više pepela za 11,47%, zbog svoje isparljivosti, zbog osobine da efikasno sagoreva.

Istovremeno, briket od kukuruzne ljuske, ima nizak sadržaj ugljenika i sumpora nakon sagorevanja od 43,55 i 0,051%.

Ovi rezultati će pomoći u rešavanju izazova odlaganja i sačuvane kukuruzne ljuske i ostataka useva kao alternativnog održivog izvora energije, zbog ispunjavanja ekoloških i tehnoloških zahteva i normi.

Ključne reči: *Briket, izvor energije, ljuska, toplotna provodljivost.*

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COMPRESSIVE STRENGTH AND LEACHABILITY EFFECTS OF TREATED DRILL CUTTINGS AS A PARTIAL REPLACEMENT OF CEMENT IN CONCRETE PRODUCTION

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Abstract:This study examines the compressive strengths and leachability effects of treated drill cuttings as a partial replacement of cement in concrete production. Workability tests on various water-binder ratios (w/b) on the fresh concrete showed that an optimum w/b of 0.5 was adequate for the concrete to be workable. Replacement levels of 0, 5, 10, 15, 20, and 25% were used to produce cement-drill cuttings concrete at a 1:1.5:3 mix ratio.

The blended concrete gave a compressive strength in the range of 26.20N/mm^2 for 5% to 22.46N/mm^2 for 20% replacement levels at 28 days curing time, more than the minimum compressive strength of 20N/mm^2 and 25N/mm^2 specified for concrete strength class C/20 and C/25, respectively. The strength activity index of 90.56, 98.76, 89.05, 98.05, and 77.64% for 5, 10, 15, and 20% replacement levels at 28 days of curing time was obtained surpassing the minimum 75% specified for normal concrete by the code.

The wet/dry durability effects of the blended concrete at any replacement level passed the structural integrity with less than 5% of the structural integrity of the material lost. The chloride and total polycyclic aromatic hydrocarbons (TPAHs) leachability effects both met the DPRs target values for reusable materials.

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The study has shown that drill cuttings have a good pozzolanic effect on concrete, especially when activated at the temperature of 500ºC for 180 minutes.
It also shows that treated drill cuttings could replace cement up to 20% by weight to produce concrete of adequate strength using a w/b ratio of 0.5 and mix ratios of 1:1.5:3. The study has also shown that treated drill cuttings replaced with cement to produce concrete which is durable to both wet/dry and leaching effects of chlorides and TPAHs to the environment.

***Keywords**: Waste, leaching, particle size, curing, fineness modulus.*

INTRODUCTION

The process of drilling oil and gas wells generates two types of waste – drilling fluids and drill cuttings. Drilling wastes are the second largest volume of waste, behind produced water, generated by the exploration and production industry [1]. American production industry (API) estimated that in 1995 about 150 million barrels of drilling waste was generated from Onshore wells in the United States alone [2]. A certain quantity of drilled cuttings cannot be avoided during drilling operations due to several factors such as insufficient setting time, inefficient mechanical separation equipment, the type of formation being drilled and the type of drilling fluid being used. The inability to remove all the drilled solids (cutting) from the fluid system makes them be considered as a continual contaminant of the fluid system.

The quantity of cuttings or drilled solids removes from the hole during operation is tremendous, and often as much as 100,000b/day of cuttings must be carried by mud [3]. Also, Al-Ansary and Al-tabbies [4] reported that about 50,000 - 80,000 tonnes of the wet-weight of oily drill cuttings are produced annually on the UK continental shelf. These drilled cuttings that consist of rock and low-yielding clays incorporated into the mud during drilling are one of the sources of solids in the mud, apart from commercial solids added to the mud and chemically precipitated solids.

Drill cuttings carried by mud (drilling fluid) are usually retrieved at the surface of the platform where they go through some separations from the drilling fluid, this process allows the circulating fluid to re-enter the drilling process. In this case, it would be worth finding ways and means of processing the drill cuttings (a waste) into a useful product and in that case, providing a solution to an environmental problem at the same time.

The oil-based drill cuttings being used as a partial substitute for cement in concrete production were treated by a thermal desorption unit at a temperature of 500ºC in 3 hours [5] which is one of the methods of removing oil from the cuttings to reduce the leachability of other contaminants.

These thermally desorbed oil-based drill cuttings can be recycled for use as a major constituent of mixes for making substantially monolithic specialized civil engineering concrete structures of large sites such as roads and drilling pads [1].

This study investigated the compressive strengths and leachability effects of treated drill cuttings as a partial replacement of cement in concrete production. The results showed that the blended concrete can be used to produce concrete class C/20 and C/25, respectively without any adverse environmental effects.

MATERIAL AND METHODS

The following materials were used in the production of blended concretes:

i. Portland limestone cement 42.5R grade.
ii. Fine aggregate of natural sand obtained from Choba River of maximum nominal size of 3.18mm.
iii. Coarse aggregate gravel obtained from a quarry site at Okigwe, Imo State of a maximum nominal size of 19mm.
iv. Thermally treated oil-based drill cuttings of the nominal size of < 63µm.
v. Potable tap water available in the civil engineering laboratory was used for mixing and curing the concrete.

Preparation of drill cuttings

The oil-based drill cuttings were collected from a waste treatment facility at Onne, Rivers State at a pre-treated temperature and time of 400^{o}C and 90 minutes. To prepare the oil-based drill cuttings as a pozzolanic material, it was treated at an optimum temperature and time of 500oC and 3 hours and ground for 1 hour and then allowed to pass through a 63µm sieve [5]. These treated oil-based drill cuttings were used as a partial substitute for cement at percentage replacement levels 5, 10, 15, 20, and 25% in the production of concrete.

Aggregate characterization

To determine the suitability of the fine and coarse aggregates (sand and gravel) for concrete production, sieve analysis was conducted on the aggregates. The particle size distribution curves for the aggregates were plotted and their corresponding grading properties: nominal size, fineness modulus, coefficient of curvature (C_c), and coefficient of uniformity (C_u) were determined. The characterization of the aggregates was conducted by the standard procedure (BS 1377 parts 1 and 2).

Particles size distribution of aggregates

A set of sieves was arranged beginning (top) with one which was the largest aperture and ending with the pan. The stacked sieves were shaken for about 5 to 10 minutes with a mechanical shaker, and then each set of sieves was weighed. Mass retained, percentage retained and percentage passing was calculated. The percentage passing versus sieve diameter was plotted and relevant parameters such as effective size, uniformity coefficient C_u and coefficient of curvature C_c were calculated.

Uniformity coefficient $C_u = \frac{D_{60}}{D_{10}}$ ……(1)

Coefficient of curvature $C_c = \frac{D_{30}^2}{D_{10}D_{60}}$ …..……. (2)

D_{30} is the diameter of 30% passing,
D_{10} is the diameter at 10% passing,
D_{60} is the diameter at 60% passing.

Fineness modulus of samples

The fineness modulus is a single figure which expressed the grading of an aggregate or material. When the sieve analysis is carried out, the fineness modulus is then obtained by adding up all percentages of samples retained on the BS test sieves and dividing the sum by 100.

$$\text{Fineness Modulus (FM)} = \frac{Cumulative\ Percentage\ Retained}{100} \quad \text{.....(3)}$$

Concrete mix proportioning

The mix ratio of 1:1.5:3 was used for the study and the water-cement ratio of 0.5. BS 8110 specifies the following relationships to develop the mix proportions for the concrete constituents and conditions since the batching was carried out by weight.

Weight of cement = Unit weight of concrete x volume of cement.
Weight of sand = Unit weight of concrete x volume of sand.
Weight of gravel = Unit weight of concrete x volume of gravel.
Weight of water = Water – Cement ratio x weight of cement.

Table 1. Mix design for mix ratio of 1:1.5:3.

Constituent Material	0% DC	5% DC	10% DC	15% DC	20% DC	25% DC
Cement, kg	1.5	1.45	1.35	1.275	1.2	1.125
Drill cutting, kg	0.0	0.075	0.15	0.225	0.3	0.375
Sand, kg	2.25	2.25	2.25	2.25	2.25	2.25
Gravel, kg	4.5	4.5	4.5	4.5	4.5	4.5
W/C ratio	0.5	0.5	0.5	0.5	0.5	0.5
Total water, kg	0.75	0.75	0.75	0.75	0.75	0.75

Workability of cement – drill cuttings concrete

The concrete investigated was of mix ratio 1:1.5:3 (binder: sand: gravel) with varied water-binder ratios of 0.40:1, 0.45:1, 0.5:1, 0.55:1, 0.60:1, 0.65:1, and 0.70:1. To determine the optimum water-binder ratio that could produce workable blended concrete, slump test was conducted in accordance with BS 1881(102).

Compressive strengths of the cement – drill cuttings concrete

The test was carried out according to BS 1881:116 method. The concrete cubes of sizes 150 x 150x 150mm were prepared using the predetermined optimum water-binder ratio (w/b), with different percentages of drill cutting as a substitute for cement. Three cubes for each concrete mix were cast and cured for 7,28,56,90 and 120 days before crushing. The compression testing machine plunger was set under a CBR ring capacity of 50kN and the were samples crushed at a uniform rate of 1mm/min. The readings of the maximum force required to shear the samples were recorded.

Strength activity index (SAI)

The strength activity index (SAI) is a measure of the pozzolanic of supplementary cementation material (SCM) and is measured as the strength relative to the control in percentage. For an SCM to be classified as pozzolan the strength of the blended cement at 7 days and/or 28 days must not be less than 75% of the strength of normal concrete [6].

Wet/Dry durability test of the cement-drill cuttings concrete

This test was to evaluate the resistance of the cement drill cuttings concrete material to the natural weathering stresses of repeated wetting and drying cycles. The test was performed in accordance with ASTM D - 4843 methods. The cured (28 days) test samples were subjected to ten test cycles. Each cycle consisted of a period of five hours submerged under water and 42 hours in an oven under low drying conditions (71^{o}C). The change in volume, moisture content and weight loss were determined after each cycle. After the ten cycles, the total sample weight loss was determined.

Toxicity characteristics/leaching procedure test (TCLP) of the cement-drill cuttings concrete

The solidified matrix of the concrete was crushed to a particle size of proximately 1mm in diameter, and 5g of the crushed/ground samples were homogenized in reagent water. The pH of the medium was determined using a digital pH meter (HANNA Model pH- 211) and the obtained value was used to select the extraction fluid for the leachate extraction. The crushed samples (100g) were then extracted for 18 hours at 30rpm at 22^{o}C with the extraction fluid. After the agitation period, the mixtures were filtered and the filtrate was taken as the TCLP extract which was used to determine the chlorides and total polycyclic aromatic hydrocarbons (TPAHs) leachates from all the replacement levels of the cement-drill cuttings concrete produced. The chlorides and the TPAHs TCLP extracts were tested according to APHA 2520B and APHA 6440C, respectively.

Plate 1. Moulds for casting cubes.

Plate 2. Demolded cubes ready for curing

Plate 3. Blended concrete in curing tank

Plate 4. Blended concretes at different replacement levels after curing ready for crushing

Plate 5. Weighing of the concrete before crushing

Plate 6. Crushing the concrete for compressive strength measurement

RESULTS AND DISCUSSION

Aggregates characterization

For the gradation characteristics of the aggregates, the results of the sieve analysis are presented as the particle–size distribution curves as shown in Table 2 and Figure 1. It was observed that both the sand and gravel distribution curves were within the region classified as sand (fine aggregate) and gravel (coarse aggregate), respectively.

Table 2. Particle size distribution analysis of the fine and coarse aggregates.

Sieve size (mm)	% Passing	% Retained	Sieve size (mm)	% Passing	% Retained
2.00	99.4	0.6	22.4	85.64	14.36
1.40	98.8	1.2	16	48.60	51.4
0.710	91.5	8.5	13.2	34.81	65.19
0.500	74.8	25.2	9.5	10.09	89.91
0.355	43.5	56.5	4.75	0.58	99.42
0.250	13.1	86.9			
0.180	5.2	94.8			
0.125	2.9	97.1			
0.075	1.1	98.9			

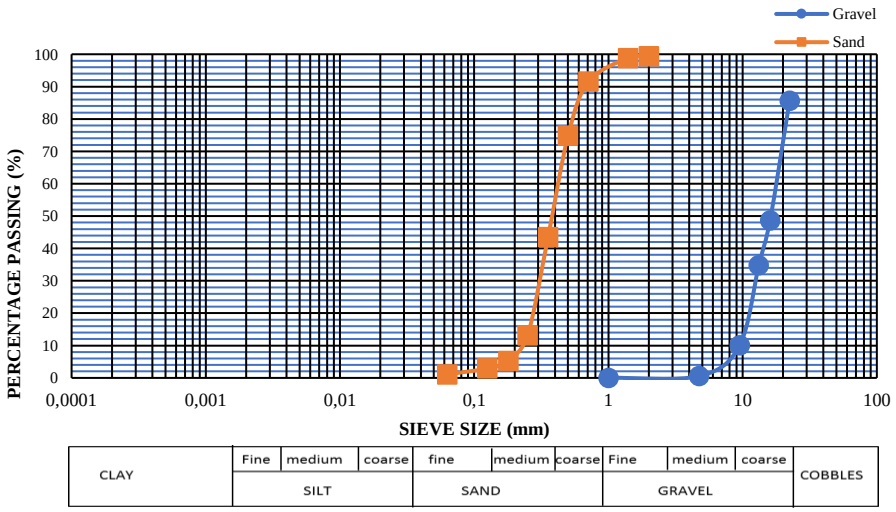

Figure 1. Particle size distribution curves of the sand and gravel.

Also, more than 90 per cent of the gravel was retained above the 4.75mm sieve size, the upper bound for aggregate to be categorized as fine aggregate, while more than 95% of the sand passes 2.00mm and more than 98% retained on 0.075mm sieve size. Hence, both the sand and the gravel are within the specified requirements for fine and coarse aggregates in concrete production (BS 1377). The uniformity coefficient C_u and coefficient of curvature C_c for the sand and gravel are 0.16, 0.9 and 2.00, 1.13 respectively, which showed that the aggregates are well sorted, while their fineness moduli are 4.69 and 3.20 which are within the acceptable values (ASTM C125).

Workability of cement-drill cuttings concrete

The results of the slump test conducted on the fresh concrete containing different proportions of drill cuttings as a replacement for cement at different water-binder ratios are presented in Table 3.

Table 3. Effect of water-binder ratio (w:b) on the slump of the blended cement-drill cuttings concrete.

Drill Cuttings Content (%)	Slump Value (mm)						
	Water-binder ratio (w/b)						
	0.40	0.45	0.50	0.55	0.60	0.65	0.70
0	0	73	100	118	135	170	210[a]
5	0	40	60	90	110	150	220[a]
10	20	75	100	125	190	220[a]	
15	30	60	160	200	220[a]		
20	5	10	30	180	200	210	220[a]
25	15	40	50	90	180	210	220[a]

The results show that for all mixes apart from w:b of 0.70:1, for normal, 5,20 and 25% drill cutting, w:b of 0.65:1 for 10% drill cuttings and also w:b of 0.60:1 for 15% drill cuttings concretes that have collapse slump all other mixes were of a true slump. However, concrete mixes containing 0% and 5% drill cuttings at 0.4:1 water-binder (w:b) ratio were viscous and stiff due to inadequacy of water, and so could not have slump value. As the w:b ratio increases from 0.40:1 to 0.70:1 at an interval of 0.05, the slump increases accordingly for an equal percentage of drill cuttings replacement in the mix. For example, at 10% drill cuttings, the slump increases from 20mm to 190mm. However, at 5, 10, and 15% drill cuttings replacements, the slump increased with an increase in the number of drill cuttings for the same water-binder ratio. This trend indicates that less water is required to maintain the same consistency as the drill cuttings content increases up to 15%, but more water is required to maintain the same consistency as the drill cuttings content increases from 20 to 25% replacement.

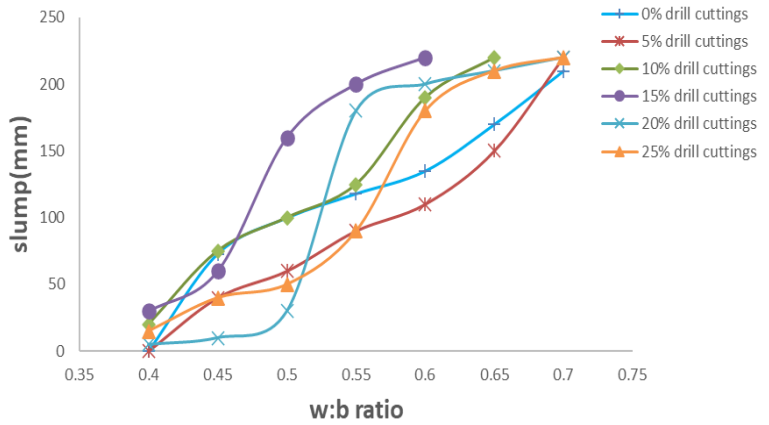

Figure 2. Effect of w/b ratio on the slump of blended cement-drill cuttings concrete

Also, at a water-binder ratio of 0.4:1 with 10%, 15%, 20% and 25% drill cuttings content, the slump values were 20, 30, 5 and 15mm respectively and the slumps were of true slumps. But at 0% and 5%, the mix becomes harsh with zero slumps at 0.40:1 of w: b. The results show that drill cuttings at 5%, 20% and 25% replacements appear to absorb more water than Portland limestone cement in the mix while 10% and 15% drill cuttings absorb less water than the Portland limestone cement. Water-binder ratios from 0.45:1 to 0.55:1 were adequate to produce a workable mix with a true slump for all the replacement levels of drill cuttings used for the mixes, while at w:b of 0.60:1 at 15% drill cuttings, 10% drill cuttings at 0.65:1 w:b and 0, 20, and 25% drill cuttings at 0.7:1 w:b the slump values were more than 200mm with collapse slumps.

Slump test is sensitive to change in consistency corresponding to slumps between 10 and 200mm and the test is not considered suitable beyond these extremes. Also, a mix having a slump between 60-130mm is considered to be plastic and required either mechanical or hand compaction [7]. This behavior suggests that 0.45:1, 0.55:1 water-binder ratio (w:b) could be considered. To avoid being on the lower extreme of 10mm (slump value for 20% drill cutting at 0.45:1 water-binder ratio) and on the higher extreme of 200mm (slump value for 15% drill cuttings at 0.50:1 water-binder ratio), the water-binder ratio of 0.50:1 should be considered appropriate, water binder ratio above 0.55:1 could lead to segregation and excessive bleeding of concrete in which water or water-rich cement rises to the surface of the concrete to produce a weak surface layer or be trapped under the aggregate particles [8].

Compressive strengths of drill cuttings-cement blended concrete

To evaluate the effects of drill cuttings on the compressive strength of blended concrete samples, various percentages of drill cuttings were used to replace Portland limestone cement. Figure 3, shows the compressive strengths of blended drill cutting samples containing different percentages of drill cuttings after 7, 28, 56, 90, and 120 days of curing.

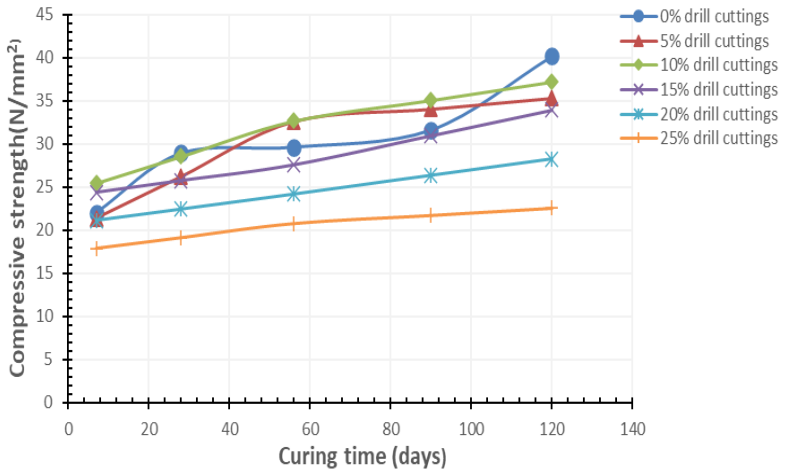

Figure 3. Compressive strength of concrete samples containing different percentages of drill cuttings after 7, 28, 56, 90, and 120 days of curing.

When compared to the control sample (0%) replacement, the compressive strength of cement –drill cutting concrete increased as the curing age increased irrespective of the content of the drill cuttings replaced in the samples. At the early age of 28 days of the concretes the compressive strength decreased as drill cuttings content increased. For normal concrete 0% drill cuttings, the compressive strength at 28 days is 28.93N/mm^2 while that of 5,10,15,20 and 25% are 26.20, 28.57, 25.77, 22.46 and 19.15N/mm^2 respectively, representing a decrease of 9.44, 11.24, 10.92, 22.36 and 33.81% respectively. But at a later curing age of 56, 90 and 120 days, the strength development increased with concrete containing different levels of drill cuttings compared to the normal concrete at 7 and 28 days, but all the blended concrete strengths are below that of normal concrete at 120 days. At 120 days, normal concrete has a strength of 40.23N/mm^2 about 28.09% higher than 28 days strength. Similar findings were reported by [9, 10] for cement-drill cuttings concrete at replacement levels of 5, 20 and 35%.

The increase in strength was also observed in blended concretes at 120 days of curing with 5,10,15,20 and 25% replacement levels, with compressive strengths of 35.33, 37.23, 33.96, 28.27 and 22.58N/mm^2 at increases of 25.84, 23.26, 24.12, 20.55 and 15.19% respectively. This strength increases of cement-drill cuttings blended concrete indicates that the treated drill cuttings have the potential to contribute to late strength gain. This characteristic suggests that the treated drill cuttings possess pozzolanic properties. The results are comparable to the works of [11] and [14].

Strength activity index (SAI)

The strength activity indices (SAIs) of the cement drill cuttings blended concrete are presented in Table 4. At 7 days, all the drill cuttings replacement levels (contents) blended-cement concrete met the minimum SAI permissible limit (75%), but at 28 days of curing age, the SAIs for 5,10,15 and 20% are 90.56, 98.76, 89.08 and 77.64% respectively, which is greater than the minimum recommended by (ASTM, 1999) thus suggesting pozzolanic activity occurring during this period. As the level of calcium silicate hydrate (C-S-H) gel is a phase responsible for strength gaining, it is likely that with suitable substitution of cement with drill cuttings, formation of this phase is initially inhibited and then allowed to develop at a later age, resulting in strength increase with age.

Table 4. Compressive strength (CS) (N/mm^2) and strength activity index (SAI) of the blended cement-drill cuttings concrete.

	7		28		56		90		120	
Drill cuttings contents (%)	CS	SAI	CS	SAI	CS	SAI	CS	SAI	CS	SAI
0	22.00	100	28.93	100	29.41	100	31.64	100	40.23	100
5	21.38	97.18	26.20	90.56	32.62	110.05	34.06	107.65	35.33	87.82
10	25.47	115.77	28.57	98.76	32.69	110.29	35.10	110.94	37.23	92.54
15	24.40	110.91	25.77	89.08	27.60	93.12	30.98	97.91	33.96	84.41
20	21.16	96.18	22.46	77.64	24.20	81.65	26.37	83.34	28.27	70.27
25	17.91	81.41	19.15	66.19	20.8	70.18	21.75	68.74	22.58	56.13

Concrete grades or strength classes denote the compressive strength of concrete, which is taken as the 28-day crushing strength of concrete cubes (BS EN, 2004).

The compressive of the blended cement concrete at 28 days of curing at replacement levels of 0, 5, 10, 15, 20 and 25% as shown in Table 3 were produced at a mix ratio of 1:1.5:3 (binder: sand: gravel) at a water-binder ratio of 0.5:1.

The compressive strength results shows that all the blended concretes met the minimum compressive strength of C/20 concrete grade which can be used for plain concrete construction works [15]. Also, the compressive strength results from Table 3 at the same mix ratio and the water-binder ratio at cement drill cutting concrete replacement levels of 5, 10 and 15% only, met the minimum compressive strength C/25 concrete grade which can be used for construction of reinforced load-bearing building structural members such as columns, beams and slabs in mild exposure condition [15].

Wet/dry durability effects on the blended cement-drill cuttings concrete

The wet/dry durability was used to evaluate the ability of both plain concrete (0% drill cuttings), with blended cement-drill cuttings concrete at replacement levels of 5, 10, 15, 20, and 25% at 1:1.5:3 mix design and 0.5:1 water-binder ratio to resist weathering by the natural environment after 28 days curing, it entails simulation of the harsh environment and subject the concretes to those conditions. The results in Table 4 show that the wet and dry durability effect of all the concrete ranged between 99.79 – 99.83%.

Table 4. Wet and dry durability test of blended concrete for different replacement levels at 28 days curing time after ten cycles

S/No.	Replacement levels (%)	Mean moisture content (%)	Wet and Dry durability effect (%)	Standard $\leq 5\%$ DPR, 2002
1	0	0.17	99.83	0.17
2	5	0.17	99.83	0.17
3	10	0.17	99.83	0.17
4	15	0.17	99.83	0.17
5	20	0.18	99.82	0.18
6	25	0.21	99.79	0.21

The least wet and dry durability effect was observed for the blended concrete at a 25% replacement level. It is worthy of note that all the concrete samples favorably satisfied the stipulated 10 dipping cycle criteria, with less than 5% of material lost, thus passing the stipulated standard (DPR, 2002). This also agreed with the works of [16], [17] which showed a concrete durability factor of 98.3% (1.7%) after 10 cycles of wet and dry conditions.

Leachability effects on the blended cement-drill cuttings concrete

The toxicity characteristics leaching procedures test was used to access the leaching effects of the blended cement-drill cuttings concretes at different replacement levels of 5,10,15,20 and 25% at 1:1.5:3 mix design and 0.5:1 water-binder ratio after 28 days of curing. This is necessary since high concentrations of chlorides and total polycyclic aromatic hydrocarbons if released into the environment as a result of leaching from any material can pose a great danger to human and animal lives and an early deterioration of

structures and monuments, so the leachability test results of chlorides from Table 5 shows that all the replacement levels met the DPR's intervention value of 5000mg/l for reusable materials.

Table 5. Toxicity characteristics leaching procedure test for blended concrete for different replacement levels at 28 days curing time.

S/N.	Replacement levels (%)	Chloride (mg/l)	TPAHs (mg/l)
1	5	60	0.033
2	10	30	0.125
3	15	120	0.077
4	20	140	0.064
5	25	90	0.015

Also, the leachability test results of total polycyclic aromatic hydrocarbons (TPAHs) from Table 5 show that all the replacement levels met the DPR's target value of 1mg/l and intervention value of 40mg/l for reusable materials. Also, previous works of [1], [16], [18] – [22] have shown that blended-cement concretes with pozzolanic materials (treated drill cuttings) are particularly effective for stabilization.

CONCLUSIONS

Drill cuttings when treated at a heating temperature and time of 500^{o}C and 3 hours at a concrete mix ratio of 1:1.5: at 0.5:1 water-binder ratio can be used in plain concrete construction i.e., concrete class C/20 at replacement levels of 5, 10, 15, 20 and 25%. Also, the drill cuttings at the same treatment levels at the same concrete mix ratio and water-binder ratio can be used in constructing reinforced load-bearing building structural members (beams, slabs and columns). i.e., concrete class C/25 at replacement levels of 5, 10 and 15%.

Both the drill cuttings-cement concrete class C/20 and C/25 produced from the heated temperature and time have a strength activity index greater than 75% as stipulated by (ASTM, 1999). The wet and dry durability effects of the drill cuttings-cement concrete class C/20 and C/25 produced for all the replacement levels (5-25%) passed the wet and dry durability effects with less than 5 per cent of the blended concrete matrix lost, after exposure to harsh environmental condition. Also, these blended concrete classes at different replacement levels (5-25%) at 28 days of curing, passed the toxicity characteristics leaching effects of both the chloride and total polycyclic aromatic hydrocarbons (TPAHs) target values for reusable materials, thus the treated drill cuttings can be said in compliance with environmental guidelines on chlorides and TPAHs for sustainable reuse as construction materials.

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IZDRŽLJIVOST NA PRITISAK I UTICAJ NA PROPUSTLJIVOST TRETIRANIH OTVORA BUŠOTINA KOD DELIMIČNE ZAMENE CEMENTA U PROIZVODNJI BETONA

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Sadržaj: U ovoj studiji ispitane su vrednosti sila na pritisak i efekat curenja (propustljivosti) tretiranih otvora (bušotina) kod delimične zamene cementa u proizvodnji betona. Test ispitivanja obradivosti na različitim odnosima vezivanja vode (w/b) na svežem betonu su pokazala da je optimalna vrednost w/b=0,5 bila adekvatna da beton bude obradiv.

Nivoi zamene od 0, 5, 10, 15, 20 i 25% su korišćeni za proizvodnju betona u mešavini 1:1 i 5:3. Mešani beton je dao vrednosti otpora na pritisak u opsegu od 26,20 N/mm^2 za 5% do 22,46 N/mm^2 za 20% nivoa zamene cementa tokom vremena očvršćavanja od 28 dana, više od minimalne vrednosti otpora na pritisak vrednosti od 20N/mm^2 i 25N/mm^2 specificirane za klase čvrstoće betona C/20 i C/25, respektivno.

Indeks aktivnosti čvrstoće od 90,56; 98,76; 89,05; 98,05 i 77,64% za nivoe zamene od 5, 10, 15 i 20% na 28 dana vremena očvršćavanja dobijen je premašujući minimalnih 75% propisanih standardom za normalan beton.

Efekti izdržljivosti mešanog betona na mokro/suvo na bilo kom nivou zamene prevazišli su strukturalni integritet sa manje od 5% izgubljenog strukturalnog integriteta materijala.

Efekti uticaja hlorida i ukupnih policikličnih aromatičnih ugljovodonika (TPAHs) su ispunili ciljne vrednosti DPR za materijale za višekratnu upotrebu.

Studija je pokazala da bušotine imaju dobar pucolanski efekat na beton, posebno kada se aktiviraju na temperaturi od 500^{o}C u trajanju od 180 minuta.

Takođe ispitivanje pokazuje da se u obrađenoj bušotini može zameniti cement do 20% po težini da bi se proizveo beton adekvatne čvrstoće koristeći odnos veziva vode (w/b) od 0,5 i odnos mešanja od 1:1 i 5:3.

Istraživanje/studija takođe pokazuje da su obradjeni otvori bušotina kod zameni sa cementom, stvorili beton otporan na suve i vlažne efekte propuštanja hlorida i TPAH jedinjenja u životnu sredinu.

Ključne reči: *Otpad, ispiranje, veličina čestica, očvršćavanje, modul finoće.*

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EFFECT OF SIZE DISTRIBUTION AND RIPENESS ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF *Spondias mombin* FRUITS

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Abstract: The effect of size distribution and ripeness on some properties of *Spondias mombin* fruits was investigated in this study. The mean length of a ripe small, medium, and large *Spondias mombin* fruit is 27.3, 35.2, and 38.5 mm, respectively. Also, the width and thickness varied from 19.9 to 29.9 mm and 19.2 to 30.0 mm, respectively. In half-ripe fruits, the length, width, and thickness for small, medium, and large size distribution also varied from 28.2 to 38.7 mm; 20.9 to 28.9 mm and 19.6 to 28.7 mm, respectively. The length of the unripe small, medium, and large sized fruits was 28.1, 35.1, and 38.9 mm, respectively. The width and thickness increased from 21.8 to 29.2 mm and 20.6 to 29.2 mm, respectively. As the size increased from small to large, the moisture content increased in each case for the three conditions of ripeness. The sphericity and bulk density of the fruit increased with the sizes and ripeness of the fruits. The effect of size and degree of ripeness on physical properties was significant. An increase in size and change in orientation increased compressive strain, with the highest being 0.169 at the large size and longitudinal position.

The highest compressive stress of the fruit was observed as 9.00 N/mm^2 when in a transverse position. The energy required for breaking the fruit was highest (2.5 J) in a longitudinal orientation. The effect of size, degree of ripeness, and orientation of the fruit on the compressive properties were significant.

Key words*: Size, shape, fracture resistance, ripeness*

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INTRODUCTION

The *Anacardiaceae* family includes the hog plum (*Spondias mombin*). It is native to the tropical Americas (West Indies) and has been naturalized as an orchard tree in other places, including Africa, India, and Indonesia. It grows well in both desert and humid environments [1, 2]. In the Caribbean, it is known by numerous names, including "jobo" or hog plum. It is generally known as the "Ashanti" plum in Ghana, and "iyeye" among the Yorubas in Nigeria. The fruit has a leathery outer peel and a thin layer of pulp that can be consumed fresh or processed into juice, concentrate, jellies, and sherbets. The taste from the apple is astringent [3]. It has a significant quantity of phenolics, vitamin C, and tannins [4]. The seed has an oil content of 31.5% [1].

The physical and mechanical properties of most agricultural materials are affected by variety and some processing conditions such as heat-treatment and moisture conditioning on *Spondias mombin* fruits, palm fruit, jatropha kernels, jatropha seed, jatropha fruit, Niger seed, caper fruit, hemp seed, and lentil seeds, respectively, among others [2, 5-9]. Also, the knowledge of these properties is required in the design, fabrication, and installation of process machines for agricultural materials. Some physical properties of the Spondias mombin fruit have been investigated [6], the relationship between this and sizes of the fruit and degree of ripeness as they affect the design of processing machines for the fruit has not been reported.

The ripeness of a fruit has been reported to affect certain properties. Autor [10] investigated the effect of ripening on the physical properties of raspberry and highlighted the strong influence of the ripening stage on anthocyanins. Similarly, investigating the effect of the ripening of peaches on its properties [11] reported a significant increase in colour intensity and a reduction in acidity, firmness, and crispness as maturity increases. Within the first 10 days of ripening, the solid-like characteristics of mango puree has been reported to reduce alongside the energy of cohesion [12], while for Saba banana, there was a reduction in the starch content and an increase in the acid concentration [13]. It is, therefore, important that studies on fruit properties should not be limited to only one ripening stage.

There have been only few studies on the effect of ripening stage on the properties of *Spondias mombin.* Bora et al. [14] reported that the weight of the pulp of *Spondias mombin* increased during ripening from the green-mature to the ripe stage, but the weight of the seeds and skin had no significant difference for the green mature and half-ripe Spondias mombin fruits. As a result of its climacteric nature, other properties like catenoid content, chlorophyll, ascorbic acid, total soluble solids, and total number of acids of *Spondias mombin* have been reported to be affected by the ripening stage [15].

Studies on the effect of ripeness on the engineering properties of *Spondias mombin* are not available. This study, therefore, aims at determining some physical and mechanical properties of Spondias mombin with reference to fruit size and degree of ripeness.

MATERIAL AND METHODS

Fresh graded *Spondias mombin* samples (Figure 1) of different ripeness stages were the primary material in this category. Samples were collected from the Obafemi Awolowo University premises Ile-Ife, Nigeria. The samples were graded by physical observation according to ripeness (ripe, half-ripe, and unripe) and size (small, medium, and large).

Figure 1. *Spondias mombin* fruits

Determination of Physical Properties

The size, shape indices, and mass of *Spondias mombin* fruit was experimentally determined. Twenty (20) were randomly selected and graded based on ripeness (ripe, half-ripe and unripe) and size (large, medium, and small). Each of the sample in each of the category was measured five times. The measured parameters comprise; the length (major diameter) (l), the width (minor diameter) (w) and the thickness (intermediate) (t) using Vernier calliper (0.01 mm accuracy) [16].

The sphericity index of the *Spondias mombin* fruit was estimated to determine the shape. The sphericity index, S_p, is a dimensions quantity obtained for the measurements of hundred (100) randomly selected *Spondias mombin* fruits. It was estimated from (1).

$$S_p = \frac{(lwt)^{1/3} \times 100}{l}\% \quad \text{.....(1)}$$

Where,
l = major diameter,
w = minor diameter,
t = intermediate diameter

The bulk density (ρ_b) of the *Spondias mombin* fruits was determined using a standard procedure. According to this procedure, a cylindrical container of known mass and volume was filled with *Spondias mombin* fruits and weighed.
The mass of the *Spondias mombin* was estimated by subtracting the weight of the empty cylinder from that of the same container filled with *Spondias mombin* fruits. This procedure was done in ten (10) replicates. The bulk density (ρ_b) was, therefore, estimated from the ratio of the mass of the *Spondias mombin* fruits to the container volume [9].

Determination of Mechanical Properties

Twenty-four *Spondias mombin* fruits were randomly selected from the ripe, half-ripe and unripe categories and the small, medium, and large categories. The fruit was placed between two parallel plates of a Universal Compressive Testing Machine (UCTM) controlled by a microcomputer (Figure 2) and loaded laterally and longitudinally.

The compression for each load orientation was set at a rate of 5mm/min. The compression load on each sample was sustained till failure was initiated. After the failure was observed, the compressive load, compressive stress, compressive strain, stress, energy, and modulus of elasticity were obtained [17].

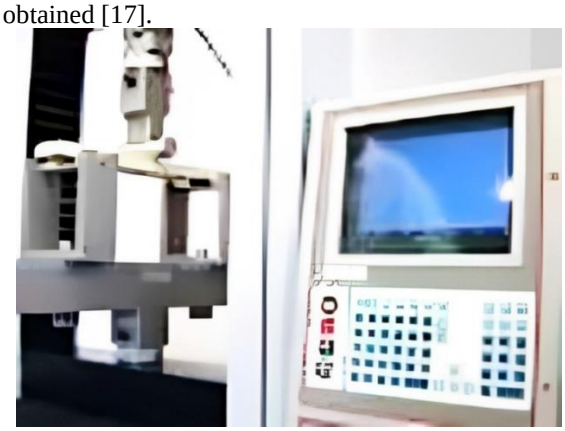

Figure 2. Universal Compressive Test Machine

Moisture Content Determination

The moisture content of the *Spondias mombin* fruits was determined by using the standard method by ASAE. Approximately 100 g of *Spondias mombin* fruits for each size category was weighed to the nearest 0.001 g in a moisture dish. The dish with *Spondias mombin* sample was placed in an oven at 80 °C for 48 hours. At the end of oven-drying, the dish was quickly removed, and placed in a desiccator covered with the lid, until room temperature is reached. It is thereafter taken out of the desiccator and weighed. The moisture content (wet basis) for the sample was estimated as a ratio of the weight loss in the sample to the initial weight of the fresh sample, as in (2). This procedure was replicated five times for each degree of ripeness of the fruit.

$$m_w = \frac{W_a}{W_b} \times 100 \qquad \text{..... (2)}$$

Where,

m_w = moisture content wet basis (%),
W_a = moisture loss,
W_b = initial test sample weight.

RESULTS AND DISCUSSION

Physical Properties of *Spondias mombin* fruits

The result of the study on size, sphericity, and bulk density are presented in Tables 1 and 2. The size distribution of *Spondias mombin* is presented in Table 1. The result showed that the ripe fruit length is 27.3, 35.2, and 38.5 mm for small, medium, and large, respectively.

Also, the width and thickness varied from 19.9 to 29.9 mm and 19.2 to 30.0 mm, respectively, within the same size distribution. In half-ripe fruits, the length, width, and thickness for small, medium, and large size distribution also varied from 28.2 to 38.7 mm; 20.9 to 28.9 mm and 19.6 to 28.7 mm, respectively.

Unripe fruits' length was 28.1, 35.1, and 38.9 mm for small, medium, and large sizes, respectively. Also, the width and thickness increased from 21.8 to 29.2 mm and 20.6 to 29.2 mm, respectively, within the same size distribution. The results also showed that as the size increased from small to large, the moisture content increased in each case for the three conditions of ripeness. For example, the moisture content of the unripe fruit for the length of 28.1, 35.1, and 38.9 mm were 76.0, 78.4, and 80.8%, respectively. This could be expected since an increase in size also increases the pore space within the fruits, and more moisture would have been stored. This trend is similar to the observation of Murthy and Bhattacharya [18] on the study of the physical properties of black pepper. Also, similar findings were reported Authors [6] and [7] on Jatropha fruit. The data obtained in the physical dimensions will help appropriately specify some parts of processing machines for the fruit. Bearing in mind that different sizes at the different conditions of ripeness are gathered during harvesting.

The sphericity of the fruits was observed to increase with a change in size from small to large for ripe, half-ripe and unripe fruits, respectively (Table 2). The respective sphericity for small, medium, and large fruits was 73, 87, 96, for ripe; 73, 87, 94, for half-ripe; and 77, 87, 95, for unripe fruits. The increase in *Spondias mombin* fruit's sphericity with the increase in size can be attributed to the relationship between moisture content and linear dimensions discussed above. An increase in sphericity with an increase in moisture content has also been reported by many authors [6-8] on different fruits. Sphericity is an indication of the shape and flowability of the material.

The bulk density increased as size increased at each level of ripeness of the fruits (Table 2). The bulk density was also observed to increase with the size of the fruit from small to large. The bulk density of the fruit at different sizes (small, medium, and large) were 5.9, 7.5, and 9.4; 5.8, 7.5, and 8.7; and 5.8, 7.1, and 7.8 x 10^3 kg/m^3 for ripe, half-ripe and unripe condition, respectively. The result agrees with the findings of other researchers [6, 7]. The data are fundamental in the handling of the material. The average bulk density alongside other properties is used in estimating the porosity [19-24].

Table 1. Size distribution and moisture content of *Spondias mombin* fruits based on ripeness

Size	Ripe fruits				Half-ripe fruits				Unripe fruits			
	l	w	t	MC	l	w	t	MC	l	w	t	MC
S	27.3 ± 1.60	19.9 ± 0.67	19.2 ± 1.07	86.0	28.2 ± 1.89	20.90 ± 1.80	19.6 ± 1.22	78.0	28.1 ± 2.01	21.8 ± 1.33	20.6 ± 2.00	76.0
M	35.2 ± 2.19	26.3 ± 1.36	25.4 ± 3.45	88.0	35.3 ± 2.06	25.9 ± 1.35	25.7 ± 1.20	80.0	35.1 ± 0.61	25.8 ± 0.84	25.5 ± 0.91	78.4
L	38.5 ± 1.22	29.9 ± 2.04	30.0 ± 1.31	89.0	38.70 ± 1.61	28.9 ± 0.82	28.7 ± 0.74	87.3	38.9 ± 1.14	29.2 ± 0.93	29.2 ± 0.80	80.8

Key: S: Small; M: Medium; L: Large; l: Major diameter (mm); w: Minor diameter (mm); t: Intermediate diameter (mm); MC: Moisture content (%)

The moisture content of the fruit increased with the size of the fruit from small to large.

The moisture content at different sizes (small, medium, and large) were 86.0, 88.0, and 89.0; 78.0, 80.0, 87.3 and 76.0, 78.4, and 80.8 for ripe, half-ripe and unripe conditions, respectively.

This result will help in determining the quantity and quality of juice extracted under different conditions. The moisture content changed from 86.0 to 89.0% for ripe fruits.

This observation could result from more moisture being stored in the pore space [18]. The trend also conforms to the findings of [25] on the moisture content of hard-shell clam.

Table 2. Physical properties of *Spondias mombin* fruits based on ripeness

Size	Ripe fruits				Half-ripe fruits				Unripe fruits			
	S_p	Ma	V	ρ_b	S_p	Ma	V	ρ_b	S_p	Ma	V	ρ_b
S	73.00 ± 2.08	7.70 ± 1.07	1.17 ± 0.21	5.81 ± 0.11	74.00 ± 2.57	7.00 ± 1.10	1.25 ± 0.20	5.78 ± 0.10	77.00 ± 3.91	6.90 ± 1.07	1.17 ± 0.21	5.81 ± 0.11
M	87.00 ± 3.45	12.70 ± 1.63	1.67 ± 0.16	7.50 ± 0.31	87.00 ± 2.81	12.00 ± 1.15	1.60 ± 0.11	7.57 ± 0.31	87.00 ± 1.86	11.30 ± 1.04	1.53 ± 0.10	7.31 ± 0.26
L	96.00 ± 3.59	17.60 ± 1.67	1.93 ± 0.16	9.13 ± 0.14	94.00 ± 1.28	15.70 ± 1.51	1.75 ± 0.15	8.96 ± 0.19	95.00 ± 1.71	14.00 ± 1.73	1.79 ± 1.50	7.83 ± 0.12

Key: S: Small; M: Medium; L: Large; S_p: Sphericity (%); Ma: Mass (kg); V: Volume (10^{-5} m³); ρ_b: Bulk density (10^5 kgm³)

Mechanical Properties of Spondias mombin

The compressive strain, compressive stress, energy required to break fruit, size distribution, and ripeness are discussed below.

Compressive strain

The result of compressive strain is discussed in terms of size distribution, ripeness, and orientation. In Table 3, it could be observed that increased size gave rise to increased compressive strain. The longitudinal position's compressive strain for small, medium, and large are 0.111, 0.140, and 0.169, respectively. While on the transverse position, the compressive strain for small, medium, and large were 0.114, 0.111and 0.102, respectively (Table 3). This result follows the trend reported by [26].

The compressive strain of unripe fruit (i.e., 0.151) was higher than that of ripe fruit (i.e., 0.135) when the fruit was in a longitudinal position, as shown in Table 4. The compressive strain of unripe fruit was 0.133, higher than ripe (i.e., 0.123) when the fruit was in the transverse position. The result shows that the degree of ripeness affected the compressive strain, indicating a physiological change in the mesocarp of the fruits as ripeness progresses. This trend conforms with [27] observation in their study of fracture resistance to compressive loading of selected Bambara groundnut.

Compressive stress

The compressive stress on the fruit is also discussed in size distribution, degree of ripeness, and orientation. Table 5. shows the effect of size on the compressive stress of the fruit. The compressive stress of *Spondias mombin* of sizes (small, medium, and large) are 2.13, 3.84, and 3.32 N/mm^2, respectively, when the fruit was in longitudinal position.

When the fruit was transverse, the compressive stress for small, medium, and large were 3.32, 3.86, and 5.18 N/mm^2, respectively.
This shows that as the size increased, the compressive stress increased. This trend follows [28] observation on the compressive properties of safflower seed.

The result showed decreased compressive stress as the degree of ripeness decreased (Table 6). The compressive stress of ripe, about- to- ripe, and unripe were 6.0, 1.8, and 2.17 N/mm^2 when the fruit was in longitudinal position and 6.26, 3.40, and 2.02 N/mm^2, respectively, when the fruit was in a transverse position. Compressive stress increased from 1.8 N/m^2 to 7.7 N/m^2 and decreased to 1.8 N/m^2 as the size increased while in the transverse position, compressive stress increased from 2.3 N/m^2 to 4.6 N/m^2 and then reduced to 3.4 N/m^2. Lastly, for the unripe and longitudinal position, the compressive stress decreased from 1.9N/m^2 to 1.4N/m^2 and increased to 2.2 N/m^{2}as the size increased. At the transverse position, the compressive stress ranged from 1.4 to 3.3 N/m^2 as the size distribution increased. The result implied that *Spondias mombin* withstands heavy load at the transverse position than the longitudinal position, which [29], also reported similarly for sunflower and kernel, respectively.

Table 3. Compressive strain as affected by size distribution

Size Distribution	Longitudinal (mm/mm)				Transverse (mm/mm)		
	Ripe	Half-ripe	Unripe		Ripe	Half-ripe	Unripe
Small	0.146	0.059	0.127		0.115	0.068	0.159
Medium	0.133	0.125	0.163		0.144	0.058	0.132
Large	0.127	0.215	0.164		0.088	0.110	0.107

Table 4. Compressive strain affected by fruit size and ripeness

Ripeness	Longitudinal (mm/mm)			Transverse (mm/mm)		
	Small	Medium	Large	Small	Medium	Large
Ripe	0.146	0.133	0.127	0.115	0.144	0.117
Half-ripe	0.059	0.125	0.215	0.068	0.058	0.111
Unripe	0.127	0.215	0.164	0.088	0.110	0.107

Table 5. Compressive stress as affected by size distribution

Size Distribution	Longitudinal (N/mm^2)			Transverse (N/mm^2)		
	Ripe	Half-ripe	Unripe	Ripe	Half-ripe	Unripe
Small	2.70	1.77	1.93	4.27	2.27	1.40
Medium	2.50	7.65	1.38	5.50	4.57	1.50
Large	6.00	1.80	2.17	9.00	3.37	3.17

Table 6. Compressive stress as affected by ripeness

Ripeness	Longitudinal (N/mm^2)			Transverse (N/mm^2)		
	Small	Medium	Large	Small	Medium	Large
Ripe	2.70	2.50	6.00	4.27	5.50	10.73
Half-ripe	1.77	7.65	1.80	2.27	45.70	3.37
Unripe	1.93	1.30	2.17	1.40	1.50	3.17

Energy to break the fruit.

The energy required to break the fruit is also discussed based on size distribution, degree of ripeness, and orientation. Table 7 shows the energy required to break the fruits of the various sizes. It could be observed that the energy required to break the fruit increase with the energy value embedded in the yellow *mombin* (65.42 kcal/100 g).
The value is similar to that obtained from other tropical fruits such as guava and mango [4]. From the result observed, the highest energy was observed at medium-size ripe when the fruit was in longitudinal position. When the fruit was in a transverse position, the energy required was less. A further result showed that the energy required to break the fruit decreased with the degree of ripeness from unripe to half-ripe in a longitudinal position. In contrast, the energy required to break the fruit increased as the degree of ripeness increased from unripe to about ripe (Table 7).

Table 7. Energy to break the fruit as affected by ripeness

Ripeness	Longitudinal (nm)			Transverse (nm)		
	Small	Medium	Large	Small	Medium	Large
Ripe	0.025	0.026	0.090	0.042	0.048	0.109
Half-ripe	0.009	0.050	0.008	0.007	0.538	0.028
Unripe	0.015	0.005	0.015	0.007	0.008	0.025

CONCLUSIONS

A study of the physical and mechanical properties of *Spondias mombin* fruit as affected by size distribution and ripeness was carried out in this study. The size of *Spondias mombin* fruits was observed to range from 27.3 to 38.9 mm in length, width from 19.9 to 29.9 mm, while the thickness from 19.2 to 30.0 mm with various sizes and degrees of ripeness. As the size increased from small to large, the moisture content increased for the three conditions of ripeness (i.e., ripe, half-ripe, and ripe). The sphericity of the fruit increased with the change in the sizes of the fruit from small to large for different conditions of ripeness.
Also, sphericity increased as the moisture content of the fruit increased from 80% to 85%. The bulk density increased as the size increased at each level of ripeness of the fruits.
The bulk density ranged from 5.8 x 10^3 kg/m^3 to 9.4 x 10^3 kg/m^3 and increased with an increase with size at each level of ripeness. The increase in size also gave rise to an increase in compressive strain. The compressive strain ranged from 0.111 to 0.169 for different orientations of the fruits. The compressive stress of the fruit varied from 1.77 - 7.65 N/mm^2 in the longitudinal position and 1.45 - 9.00 N/mm^2 in the transverse position. The energy required for breaking the fruit at the longitudinal position varied from 0.007 to 2.5 Nm and 0.007 Nm to 0.109 Nm for the transverse position.

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UTICAJ DISTRIBUCIJE VELIČINE I ZRELOSTI NA NEKE FIZIČKE I MEHANIČKE OSOBINE PLODOVA VOĆA *Spondias mombin*

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Apstrakt: U ovom radu istražen je uticaj distribucije veličine i zrelosti na neka svojstva plodova voća *Spondias mombin*. Srednja dužina zrelog malog, srednjeg i velikog ploda *Spondias mombin* (Mobinska žuta šljiva) je 27,3, 35,2 i 38,5 mm, respektivno.
Takođe, širina i debljina su varirale od 19,9 do 29,9 mm i 19,2 do 30,0 mm, respektivno. Kod poluzrelih plodova, dužina, širina i debljina za male, srednje i velike distribucije takođe su varirale od 28,2 do 38,7 mm; 20,9 do 28,9 mm i 19,6 do 28,7 mm, respektivno. Dužina nezrelih malih, srednjih i velikih plodova bila je 28,1, 35,1 i 38,9 mm, respektivno. Širina i debljina su povećane sa 21,8 na 29,2 mm i 20,6 na 29,2 mm, respektivno. Kako se veličina povećavala od male do velike, sadržaj vlage se povećavao u svakom slučaju za tri uslova zrelosti.

Sferičnost i nasipna gustina ploda su povećane sa veličinom i zrelošću plodova. Uticaj veličine i stepena zrelosti na fizička svojstva bio je značajan. Povećanje veličine i promena u orijentaciji sile povećali su naprezanje pri pritisku, pri čemu je najveća bila 0,169 pri velikom prečniku (veličina ploda) i uzdužnom položaju. Najveći pritisak na plod je 9,00 N/mm2 u poprečnom položaju. Energija potrebna za lomljenje ploda je najveća (2,5 J), kod uzdužne orijentacije ploda.
Uticaj veličine, stepena zrelosti i orijentacije ploda na kompresivne osobine bio je značajan.

***Ključne reči**: Veličina, oblik, otpornost na lomljenje, zrelost*.

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HEAVY METALS ACCUMULATION BY MAIZE *(Zea Mays L.)* GROWN ON SOILS AMENDED WITH MUNICIPAL SOLID WASTE COMPOSTS

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Abstract. An experiment was conducted to investigate the accumulation of some heavy metals by maize *(Zea mays L.*) grown on soils amended with different levels of municipal solid waste compost (MSWC) in Dakadda experimental farm, Uyo. Eighteen plants samples were collected from three different plots and analyzed for heavy metals (Cd, Fe, Mn, Cu, and Pb) contents using atomic absorption spectrophotometry. Results obtained revealed the following ranges for the metals in grain: Cd:0.041-0.059mgkg^{-1}, Fe:42.62-62.23mgkg^{-1}, Mn:7.92-12.20mgkg^{-1}; Cu:6.26-19.40mgkg^{-1} and Pb:0.25-0.36mgkg^{-1}, while the ranges in stover: Cd:0.029-0.120mgkg^{-1}, Fe:41.62-54.30mgkg^{-1}, Mn:14.21 -20.43mgkg^{-1}; Cu:10.46-24.30mgkg^{-1} and Pb:0.21-0.31mgkg^{-1}. The results obtained from this study have shown considerable and unacceptable levels of heavy metals in maize grain and stover for the amended soils. It was observed that compost application increased the status or level of micro-nutrients when compared with the control plots (treatments), except for Mn and Cd in grain and Mn and Pb in the stover. On a general note, the concentrations of micronutrients were found to be higher in grain than in stover, except for Cu and Mn. The study also reveals that concentrations of most of the heavy metals analysed for in maize grains varied positively with their corresponding levels in stover. However, worthy of note is that although the levels of heavy metal contents obtained were within the permissible WHO and FAO standards, except for Lead, Pb, which was slightly higher than normal. It is believed that the results could be more favourable in this study than elsewhere because of the low content of industrial or hazardous wastes.

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Also, the waste could have been more degraded than might result from use of less than two years old dumpsite wastes elsewhere where there could be less highly degradable matter, less exposure to air before application to soil, drier waste, or where decomposition has been otherwise inhibited. Thus, on a general note, cultivating edible plants on dumpsite soils or soils reclaimed from a municipal solid waste disposal site, may not be safely used as a soil conditioner due to the fact that they have the potential of posing risk to crops or public health.

***Keywords**: Heavy metals, Municipal Solid Waste Compost, Maize Grain, Maize Stover, Concentration*

INTRODUCTION

With rising interest in organic agriculture, the production of organic-grade MSW compost for agriculture is also gaining popularity because of its positive effect on biological, physical, and chemical soil properties [1]. [2] reported that waste materials, and materials derived from wastes, possess many characteristics that can improve soil fertility and enhance crop performance. These materials can be particularly useful as amendments to severely degraded soils associated with mining activities. A variety of materials have been investigated for their suitability as soil amendments. For example, applications of composted municipal solid waste and composted crop residues were shown to increase soil fertility and improve structural stability in agricultural soils [3].

The use of composted municipal solid waste contains high organic matter which can be absorbed by plants [4] and improves soil quality [5]. Soil organic matter consists of a variety of simple and complex carbon compounds and thus provides food for a variety of organisms. It provides much of the cation exchange and water-holding capacities of surface soils [6].

Municipal solid waste exerts a positive influence on physical and chemical soil properties such as porosity, aggregate stability, water holding capacity, cation exchange capacity, and releases nutrient generally [7].

However, there are concerns about potential public health hazards from the presence of pathogens and pollutants such as trace metals and organic contaminants [8].
Furthermore, the bioavailability of these non-essential heavy/trace metals could pose serious health and environmental problems to the inhabitants of the vicinity of the dumpsites. The effects of these metals depend on the concentrations and pH level in the system for example, its excesses in plants decreased growth.

Oblivious of the potential ecological and health risks which may arise due to heavy metal contaminants transport in the soil profile and then into the food chain through the plant, the researcher seeks to optimize waste use in crop production while also mitigating contaminant transport as well as recommend guidelines regulating the safe use of waste in agriculture. Thus, this research work was carried out to evaluate the quality of plants grown on dumpsite soils and extrapolate the results obtained on the suitability or otherwise of such plants for human consumption.

The information provided herein is expected to contribute in the optimization of adopted application rates of MSW for optimum crop productivity, and elimination of ecological and public health risks.

MATERIALS AND METHODS

Study Area

The study area is the Uyo metropolis. Uyo is located between Latitude $5^{o}1'^{1}N$ and $5^{o}3^{1}N$ and Longitudes $7^{O}55^{1}E$ and $8^{o}05^{1}E$ above sea level within the tropical rainforest belt with evergreen vegetation (see more detail on Figures 3.1 and 3.2). Uyo covers a total land area of $8{,}412km^{2}$. It has a mean annual temperature between $26^{o} – 27^{o}$ and has two distinct seasons: the wet season (April to October) and the dry season (November to March). The rainy season usually lasts for about 7 or 8 months.

The rains are of high intensity and of bimodal pattern with two weeks' peaks in July and September, and a period of 2 – 3 weeks of little or no rain (called August Break) in between. The dry season gives rise to the post-season characteristic of a maximum rainfall regime in which the months with the heaviest rainfall are usually June and July for the first rainfall maximum and September for the second Maximum. The annual rainfall ranges from 2,000mm to 3000mm. The location of Akwa Ibom is just North of the equator and within the humid tropics and its proximity to the sea makes the state generally humid. Naturally, maximum humidity is recorded in July while the minimum humidity occurs in January [9].

Experimental Design

MSW compost samples were collected from four different dumpsites in Uyo. The MSW compost consists of organic waste, inorganic waste including food waste, plant cuttings, sawdust, plastics, paper, glass, metals, fabrics, bricks and dusts etc.

The municipal solid waste used for the study was obtained from waste sites found around market places within the Uyo metropolis. The biodegradable materials were properly sorted before the materials which were composted aerobically. The composted materials consist of food waste, plant leaves, vegetable scrap, plant cuttings, paper, etc. the composted products used in the study was free of odour and dark in colour – but with small amount of foreign materials. The wastes at these locations were filled about 2-5 years ago.

The composition of composite and topsoil samples was analysed in the laboratory using selected soil physical and chemical properties which were determined after soil samples were collected with the use of soil auger at depth of 1 – 20cm. for this study, these landfill wastes were excavated from the sites using a backhoe and spade. The landfill waste (compost) was screened with a sieved (local basket) of about 6mm screen for removal of the oversize materials, and the end-product, named compost in this paper, was used for experiments.

Municipal Solid waste composts (MSWC) were applied two weeks before sowing of the maize crop. The soil was excavated from each plot and combined and mixed with compost. The experiment consisted of nine treatments laid out in Randomized Complete Block Design (RCBD) consisting of three organic manure sources, namely composted Greenyard manure, Sawdust-riched compost, and mixed municipal solid waste, each at three levels (0tha^{-1}, 3tha^{-1}, and 6tha^{-1}) and replicated three times, to produce a total of 27 treatments. Field experiment at two locations, the Dakadda Estate Farm, and the Idoro road Farmland, were conducted in 2022 growing season. Each plot size was 6m X 6m (36m^2) consisting of five rows of maize, 75cm between row and 25cm within row distances. This planting distance was chosen because it is the recommended planting distance for maize according several literatures reviewed.

Each plot in the same block had a width of 1m (that is, separated by a buffer zone of 1m), but between blocks a width of 2m. In order to discharge runoff from each plot if flooded, drainage was allowed between blocks. Maize seeds were collected from Itam market and sown into plots at a depth of 3-4cm, containing four seeds per hole, after which it was thinned to two plants per stand after maize had emerged from the grown. Maize was rainfed; weeds were controlled by hand weeding using a hoe and all other agronomic practices were observed except the application of fertilizers, outside the compost applied.

Municipal solid waste composts were obtained from the points illustrated in the GIS map. The composite composts were weighed with a weighing balance after being uploaded from a Tipper and Pick up van, transferred into the plots and applied to the various experimental plots.

There are several varieties of Maize. In this study, the traditional white maize variety was selected on the basis of its adaptability to the climatic zone (agro-ecology) and its resistance to disease. It was obtained from the local Itam Market in Uyo. Maize *(Zea mays L.*) was planted two weeks after incorporation of treatments.

The seed rate was two seeds per hole. The seedlings were thinned down to two per hole at two weeks of germination and weeding was done weekly.

On maturity, maize grain and stover were harvested from each plot, excepting the outside (border) rows. Harvested maize plants were weighed on a fresh basis in the field. All maize plants from each plot were kept separate, peeled and cut into grain and stover, labelled and taken to the laboratory for analysis.

Laboratory Analysis

Samples of maize (*Zea mays L.*) were collected from the experimental Farm amended with different concentrations of Municipal Solid Waste compost while the unamended soil served as the control sample. The plant samples collected were properly labelled accordingly for Atomic Absorption Spectrophotometer (AAS) Analysis using Buck Scientific Model 210VGP in order to determine heavy metal concentrations contents in Maize grain and stover. At maturity, maize was harvested from each plot. A total of 18 plants samples were collected from the three different plots (six samples per plot) into some pre-cleaned polyethylene bags. Each sampled maize plant was cut into two parts (Grain and stover) using a stainless steel cutter.

All maize grains and stovers were dried in the oven at 70^0C for 96 hours. The dried maize grains and stovers were ground in an agate mortar. Thereafter, 0.5g of the sieved portion of each sample of maize grain and stover was placed into a conical flask and 5.0ml of sulphuric acid was added and covered. Each of the flasks were then placed on a hot plate and heated to 80-90^0C in a fume cupboard for about an hour. The samples were then removed on appearance of a light-coloured fume and cool for 10 minutes after which 2.0ml of distilled water and 3.0 ml of 30% hydrogen peroxide were added to the sample.

It was then filtered into 50ml volumetric flask using Whatman No. 42 filter paper as described by [10,11]. The filtrates were analysed concentrations of Cadmium (Cd), lead (Pb), Zinc (Zn), Nickel (Ni), and Iron (Fe) in the MSWC and control samples were determined using Atomic Absorption Spectrophotometer, model Sp-9 (Pye Unicam). The mean values per sample were recorded.

Statistical Analysis

The mean as well as standard deviation were used to determine the spatial relationships in the study area as well as the concentrations at 95% confidence level ($p<0.05$).

RESULTS AND DISCUSSION

The results of this research are as presented in Tables 1 and Tables 2 below.

Table 1. Effect of MWSC application on the micro nutrients in maize grain and stover

Treatment	Grain					Stover				
	Cd	Fe	Mn	Cu	Pb	Cd	Fe	Mn	Cu	Pb
G0	$0.051^{e}\pm 0.000$	$42.62^{i}\pm 0.000$	$8.02^{h}\pm 0.000$	$6.26^{i}\pm 0.000$	$0.250^{g}\pm 0.000$	$0.049^{c}\pm 0.000$	$41.62^{i}\pm 0.000$	$19.45^{b}\pm 0.000$	$12.21^{g}\pm 0.014$	$0.280^{d}\pm 0.000$
G3	$0.055^{b}\pm 0.000$	$55.21^{d}\pm 0.001$	$9.19^{d}\pm 0.000$	$7.20^{g}\pm 0.000$	$0.350^{b}\pm 0.000$	$0.052^{b}\pm 0.000$	$47.00^{e}\pm 0.001$	$18.80^{d}\pm 0.000$	$15.28^{d}\pm 0.000$	$0.290^{c}\pm 0.001$
G6	$0.052^{d}\pm 0.000$	$48.31^{h}\pm 0.010$	$7.92^{i}\pm 0.000$	$6.80^{h}\pm 0.000$	$0.300^{e}\pm 0.003$	$0.049^{c}\pm 0.000$	$46.92^{f}\pm 0.000$	$14.21^{i}\pm 0.000$	$10.46^{i}\pm 0.000$	$0.240^{g}\pm 0.000$
S0	$0.041^{g}\pm 0.000$	$54.28^{e}\pm 0.000$	$10.02^{b}\pm 0.001$	$8.11^{f}\pm 0.000$	$0.280^{f}\pm 0.000$	$0.033^{e}\pm 0.000$	$52.82^{b}\pm 0.000$	$18.50^{e}\pm 0.000$	$11.11^{h}\pm 0.000$	$0.270^{e}\pm 0.000$
S3	$0.059^{a}\pm 0.000$	$61.08^{b}\pm 0.000$	$9.90^{c}\pm 0.000$	$14.24^{c}\pm 0.000$	$0.360^{a}\pm 0.000$	$0.120^{a}\pm 0.000$	$51.42^{c}\pm 0.000$	$20.43^{a}\pm 0.000$	$17.33^{c}\pm 0.000$	$0.260^{f}\pm 0.007$
S6	$0.044^{f}\pm 0.000$	$62.23^{a}\pm 0.000$	$8.90^{e}\pm 0.000$	$11.48^{e}\pm 0.000$	$0.310^{d}\pm 0.001$	$0.008^{h}\pm 0.000$	$54.30^{a}\pm 0.000$	$14.92^{g}\pm 0.000$	$14.23^{e}\pm 0.000$	$0.210^{i}\pm 0.000$
M0	$0.044^{f}\pm 0.000$	$58.41^{c}\pm 0.000$	$8.82^{f}\pm 0.000$	$12.40^{d}\pm 0.000$	$0.250^{g}\pm 0.000$	$0.043^{d}\pm 0.000$	$42.41^{h}\pm 0.002$	$14.51^{h}\pm 0.014$	$14.00^{f}\pm 0.002$	$0.220^{h}\pm 0.000$
M3	$0.041^{g}\pm 0.000$	$53.54^{f}\pm 0.002$	$8.42^{g}\pm 0.000$	$18.30^{b}\pm 0.003$	$0.320^{c}\pm 0.000$	$0.029^{g}\pm 0.000$	$43.54^{g}\pm 0.000$	$19.30^{c}\pm 0.003$	$20.00^{b}\pm 0.007$	$0.310^{a}\pm 0.000$
M6	$0.054^{c}\pm 0.001$	$51.74^{g}\pm 0.000$	$12.20^{a}\pm 0.001$	$19.40^{a}\pm 0.014$	$0.320^{c}\pm 0.000$	$0.031^{f}\pm 0.001$	$48.70^{d}\pm 0.003$	$18.40^{f}\pm 0.000$	$24.30^{a}\pm 0.000$	$0.300^{b}\pm 0.000$

Source: The Researcher (2023).

Table 2. FAO/WHO maximum permissible values of heavy metals in edible crops

Element	Permissible values (mg/kg)
Cd	0.2
Pb	0.3
Ni	67.9
Fe	425.5
Cu	73.3
Zn	99.4
Mn	N.A
Cr	N.A
As	NA
Sc	N.A

Source: [13].

Values are mean ± standard deviation of duplicate determination. Means in the same column bearing different superscripts are significantly ($p<0.05$) different (Table 1).

The results related to average concentration of Cd, Fe, Mn, Cu AND Pb in maize as influenced by one-time application of MSWC at harvest are presented in Table 1. Significantly higher concentrations of Cd, Fe, and Pb were observed with the treatment receiving 3 tha^{-1} MSWC with the values of 0.059 ppm, 62.32 ppm, and 0.360 ppm, respectively. The lowest concentration of Cd, Fe, an Pb (0.041, 42.62 and 0.250 ppm, respectively) was recorded in treatment receiving no grain waste (GO).

Again, the values of micronutrients in stover are lesser than the values in grain. The result of this study is in agreement with the findings of [12] where the effect of application of the distillery spent wash R. O. reject on micronutrient content of maize showed higher values in grain than in stover.

Levels of heavy metals recorded in maize grain and stover obtained from treated soils were relatively higher than the levels in the control sample except for Fe, Mn, and Cd in the maize grain and Mn and Pb in the maize stover. It was observed that the heavy metal concentrations in maize grain obtained at two different levels (3 tha^{-1} and 6tha^{-1}) of the various MSW were within the FAO/WHO permissible limit (table 2) except for lead. The lead, Pb, concentration in maize grain were found to be higher than the FAO/WHO threshold limit except for the control samples. The lead, Pb concentrations in maize stover were lower than the FAO/WHO threshold limit except for M3 sample with very high concentration (0.310$mgkg^{-1}$). However, the concentration of Cd, Fe, Mn, and Cu in all the samples falls within the FAO/WHO permissible limits for heavy metals accumulation in edible crops. The presence of high Pb concentrations in M3 and M6 maize grain samples may be attributed to the dumping of waste batteries, cosmetics, metal products and pipes at the refuse dumpsites that has leached into the soil and then into the food chain through plant uptake from the contaminated soil. The increase in Pb concentrations is similar to the results of [13].

The accumulation of trace elements on crops depends on numerous factors, namely soil properties, plant species, compost application rate, and compost content in metals. From various literatures reviewed, including the study by [14,15], particular concern has been given on the availability of Zinc and copper and their accumulation in plant tissues.

Municipal Solid waste compost increased both Zinc and copper in the tissues of crops, but their contents were maintained within the optimum range for growth, except for lettuce treated with the highest concentration, suggesting that compost could be safely used as a soil conditioner.

Also, no accumulation of Arsenic, Lead, Nickel, and Chromium in the leaves and fruits was observed, in agreement with their low metal availability in the soil as it was assessed by SPLP extraction.

The results obtained from this study have shown considerable and acceptable levels of heavy metals in maize grain/ stover for both amended and unamended soils. The results of the study have also revealed that concentrations of most of the heavy metals analyzed for in maize grains varied positively with their corresponding levels in stover. However, worthy of note is that although the levels of heavy metal contents obtained were within the acceptable WHO and FAO standards except for the slightly high concentration of lead found in maize grown on the Municipal solid waste compost amended soil. It is believed that the results could be more favourable in this study than elsewhere because of the low content of industrial or harzardous wastes.

Also, the waste could have been more degraded than might result from use ofshort term landfill waste elsewhere where there could be less highly degradable matter, less exposure to air before application to soil, drier waste or where decomposition has been otherwise inhibited. Thus, on a general note, cultivating edible plants on dumpsite soils or soils reclaimed from a municipal solid waste disposal site may not be safely use as a soil conditioner due to the fact that they have the potential of posing risk to crop or public health.

CONCLUSION

It was observed that compost application increased the status or level of micro-nutrients when compared with the control plots (treatments), except for Mn and Cd in grain and Mn and Pb in the stover. On a general note, the concentrations of micronutrients were found to be higher in grain than in stover, except for Cu and. Considering the WHO and FAO standards or permissible safe limits for edible plants, it was observed that the concentrations or values of heavy metals (micronutrients) in the plant grown in the MSWC amended soils fell within the FAO/WHO permissible or safe limit except for Pb, in the maize grain which was slightly higher than the limit and were found to be present in the mixed municipal solid waste samples of dosage 3 tonnes and 6 tonnes per hectare. The green manure and the sawdust compost at all levels of waste application were not affected.

It was believed that the presence of high Pb concentrations in the m3 and m6 maize grain samples were attributed to the dumping of waste batteries, cosmetics, metal products, and a host of other synthetic substances which are harzardous wastes at the dumpsites. It can therefore be inferred that cultivating edible plants on dumpsite soils or soils reclaimed from a MSW disposal site may or may not pose a significant risk for public health, depending on the composition of the waste.

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AKUMULACIJA TEŠKIH METALA U KUKURUZU (*Zea Mais L.*) GAJENOMNA ZEMLJIŠTU IZMENJENOM DODAVANJEM KOMPOSTA OD ČVRSTOG GRADSKOG OTPADA

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Apstrakt. Eksperiment je obavljen zbog ispitivanja akumulacija nekih teških metala u delovima kukuruza (*Zea mais L.*) gajenom na zemljištu kojem su dodavani različiti nivoi komposta formiranog od čvrstog komunalnog otpada (MSWC) na eksperimentalnoj farmi Dakadda, Uio, Nigerija.

Ukupno (18) biljnih uzoraka je sakupljeno sa tri različite parcele i analiziran je sadržaj teških metala (Cd, Fe, Mn, Cu i Pb) primenom metode atomske apsorpcione spektrofotometrije.

Dobijeni rezultati su pokazuju različite opsege teških metala u zrnu:
Cd: 0,041- 0,059mgkg^{-1}, Fe:42,62 - 62,23mgkg^{-1}, Mn:7,92 - 12,20mgkg^{-1};
Cu: 6,26 - 9,40mgkg^{-1} i Pb:0,25 - 0,36mgkg^{-1}.
Sadržaj teških metala u zelenom delu biljke kukuruza bili su: Cd:0,029-0,120mgkg^{-1},
Fe: 41,62 - 54,30mgkg^{-1}, Mn:14,21 - 20,43mgkg^{-1}; Cu:10,46 - 24,30mgkg^{-1} i
Pb: 0,21 - 0,31mgkg^{-1}.

Rezultati dobijeni ovim istraživanjem su pokazali značajne i neprihvatljive nivoe teških metala u zrnu kukuruza i delu stabljike kukuruza za izmenjena zemljišta kojim je dodavan kompost. Uočeno je da primena komposta povećava status ili nivo mikronutrijenata u poređenju sa kontrolnim parcelama (tretmanima), osim za sadržaj Mn i Cd u zrnu i Mn, Pb u stablu kukuruza.

Uopšteno govoreći, utvrđeno je da su koncentracije mikronutrijenata veće u zrnu nego u ostalim delovima biljke, osim Cu i Mn. Studija takođe otkriva da su koncentracije većine analiziranih teških metala u zrnu kukuruza pozitivno varirale sa njihovim odgovarajućim nivoima u ostalim delovima kukuruza .

Kako tako, vredi napomenuti, da su dobijeni nivoi sadržaja teških metala bili u okviru dozvoljenih standarda SZO i FAO, osim Pb, koji je bio nešto viši od normalnog sadržaja. Veruje se da bi rezultati istraživanja u ovoj studiji (eksperimentalna farma Dakadda), mogli biti povoljniji nego na drugim mestima, zbog niskog sadržaja industrijskog ili opasnog otpada u ovom ispitivanom materijalu (kompostu).

Takođe, ovaj kompost je mogao biti više degradiran nego što bi mogao biti rezultat korišćenja otpada manje od dve godine starog odlagališta na drugim mestima, gde bi moglo biti manje visoko razgradivih materija, manje izlaganja vazduhu pre unošenja u zemljište, otpada sa manjim sadržajm vlage, ili gde je raspadanje bilo drugačije inicijalizovano.

Dakle, generalno posmatrano, prinos gajenih biljaka za ishranu na prikazanom zemljištu odlagališta ili zemljištu obnovljenom materijalom sa deponije čvrstog komunalnog otpada, ne može se bezbedno koristiti, kao oplemenjivač zemljišta, zbog činjenice da može predstavljati rizik za useve ili javno zdravlje.

Ključne reči: *Teški metali, kompost od čvrstog komunalnog otpada, zrno kukuruza, stabljika kukuruza, koncentracija.*

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MATHEMATICAL RESULTS OF THE PARAMETERS AFFECTING THE UNIFORM SPREADING PRODUCTIVITY OF COMBINED PLOUGH FERTILIZERS USING THE GRAPHO-ANALYTICAL METHOD

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Abstract: The correct application of mineral fertilizer norms and the study of effective energy saving methods, the use of fertilizers in soil and climate conditions for the cultivation of agricultural plants are the urgent tasks of modern agriculture.The main problem in the world is the uneven sowing and disturbance of the ecological situation during the application of fertilizers.So, in many developed countries, the mechanization of this field has been given a lot of attention. Many fertilizer spreading machines and equipment have been produced in this direction. However, in this field, accurate spreading of fertilizers and equal distribution in the soil remains a problem. Uneven fertilization significantly affects the characteristics of the crop and causes environmental pollution.The inhomogeneity of the field in terms of nutrients resulting from fertilization is often the main cause of uneven cropping. It causes yield loss in cereal crops, which can reach 25-60% in some years. Our research has determined that, depending on the design features of the spreaders and the quality of the fertilizers applied, the uneven distribution of the applied fertilizers can vary between 40-60% of the norm, which ultimately leads to nutrient deficiencies. It was observed that the productivity of cereal crops decreased by 11-15 centner/ha with the increase of uneven distribution of fertilizers in the field to 70-80%.In order to partially eliminate the scientific and technical deficiencies in grain growing, a combined plough was developed in our laboratory. Factors affecting productivity were analyzed by the grapho-analytical method of the combined plough, graphs were obtained by theoretical methods.

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Fertilizer rate, optimal selection of the speed of the aggregate creates conditions for obtaining the maximum productivity of mineral fertilizers in the field.Grapho-analytical methods are convenient for selecting the closest targets.

Key words: *Mineral fertilizer, combined plough, productivity, equal amount.*

INTRODUCTION

In order to prevent excessive soil compaction and reduce fuel consumption, it is considered effective to perform several operations in one trip of the tractor with a combined unit [1;2;3;4].At the same time, the combination of plowing operations with equal amounts of fertilizers gives more economic results.

At the "Agromechanics" Scientific Research Institute, a new combined plough was developed in the " Mechanization of crop production " laboratory.

This combined plough cultivates the soil at the same time as well as precise spreading of mineral fertilizers.It was effectively used to give mineral fertilizers to the subsoil.Fertilizer prevents environmental pollution by preventing energy losses at the same time.Here, the fertilizer is not dispersed into the air.Simply ATP-2 fertilizer is applied to the soil through the pipes of the spreader. A smooth spreader is attached to the outlet of the pipes to ensure uniform spreading of fertilizers.The overturned soil rising from the slope of the plough is poured onto the scattered ground.

Figure 1. Combined plough, [5].

The use of the combined plough completely reduces the operation of spreading fertilizer with fertilizer spreaders before the plowing operation, the costs and labor spent on it, at the same time, high efficiency of the use of fertilizers is ensured, i.e., putting the fertilizer under the soil prevents its loss, ensures its uniform spreading, etc. In addition, time is significantly saved and operations can be performed in a short time.

MATERIAL AND METHODS

Theoretical and experimental methods were used in the performance of the work [7]. Experiment planning plays a key role in the efficiency and acceleration of research work [8;9].

The planning of the experiment is to conduct an experiment on the factors that have a serious effect by reducing the number of factors without taking into account the low values of the factors that affect the function by determining the multifactor dependencies with the grapho-analytical method.For this purpose, the regression equation of the multi-factor function is drawn up.

The general expression of the regression all equation 1-2 present:

$$f(y) = a_0 + a_1x_1 + a_2x_2 + \cdots + a_nx_n + a_1a_2x_1x_2 + a_2a_3x_2x_3 + \cdots + \cdots \quad \text{..... (1)}$$

$$a_{n-1}a_nx_{n-1}x_n + a_1x_2^2 + \cdots + a_nx_n^2 + \cdots \text{.....} \quad \text{.....} \quad \text{.....} \quad (2)$$

is written as here:

$a_1 ... a_n$ are regression coefficients;

$x_1 ... x_2 ... x_n$ are studied parameters.

One of the main issues is the determination of the regression coefficient.

Determining these coefficients by different methods (least squares, etc.) creates difficulties by requiring a lot of time. The importance of determining the coefficients is that if those coefficients have a relatively small and negative value, then the parameters representing those coefficients are shortened and the number of experiments is reduced.Taking these into account, we have developed a methodology for determining those coefficients using a simple method and suggested its application. The essence of that method is that the minimum and maximum values of the sought parameter are determined, the value of the function on the ordinate axis, and the value of the argument on the abscissa axis are indicated by the scale, and the tangent (tgα) of that dependence is determined.

The coefficients indicated in the regression equation are replaced by a_1, a_2,...,an $tg\alpha_2$, ..., $tg\alpha_n$.

$$f(y) = tga_0 + tga_1x_1 + tga_2x_2 + \cdots + tga_nx_n + tga_1tga_2x_1x_2 +$$

$$+tga_2tga_3x_2x_3 + tga_{n-1}tga_nx_{n-1}x_1 + (tga_1x_2)^2 + \cdots + (tga_nx_n)^2 \quad \text{.....} \quad (3)$$

should be written in the form.

This dependence can be shown on the coordinate axis as follows.

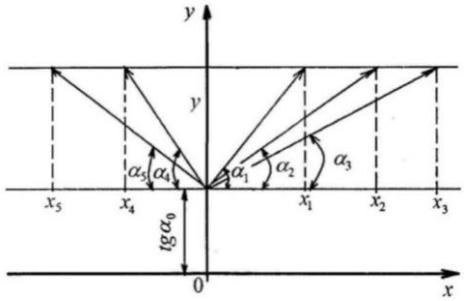


Figure.2. Determination of the tangent of the vertical axis on the abscissa axis of the ordinate axis

As you can see from this graph

$$a_0 = tga_0;\ tga_1 = \frac{y}{x_1};\ tga_2 = \frac{y}{x_2};\ tga_3 = \frac{y}{x_3};$$
$$tga_4 = \frac{y}{x_4};\ tga_5 = \frac{y}{x_5} \text{ ... ...} \quad \text{... ... ...} (4)$$

If we solve and sum these expressions with respect to y:

$$\Sigma y = tga_0 + tga_1x_1 + tga_2x_2 - tga_3x_3 - tga_4x_4 - tga_5x_5 + tga_1tga_2x_1x_2 +$$
$$+tga_2tga_3x_2x_3 + tga_3tga_4x_3x_4 + tga_4tga_5x_4x_5 + tg^2a_1x_1^2 + tg^2a_2x_2^2 +$$
$$tg^2a_3x_3^2 + tg^2a_4x_4^2 + tg^2a_5x_4^2 \text{.....} \quad \text{.....}(5)$$

we receive their statements.

Here, any coefficient that is small or negative is excluded from the regression equation.

So, suppose that tg α_3 is small, tg α_4 and tg α_5 are negative, then the regression equation

$$\Sigma y = tga_0 + tga_1x_1 + tga_2x_2 + tga_1tga_2x_1x_2 + tg^2a_1x_1^2 + tg^2a_2x_2^2\ ; \text{ .....}(6)$$

takes the form and thus it is appropriate to carry out the transformation of the function based on the arguments x_1 and x_2.

RESULTS AND DISCUSSION

In laboratory conditions, the working body of the combined plough, the scattering productivity of the smooth spreader was determined.We can write a mathematical formula based on the diameter d of the support wheel of the combined plough, the spreading working width of the machine B, the fertilizer rate Q and the working speed.

$$W_s = \frac{4 \cdot Q \cdot v}{\pi \cdot d \cdot B};\ \text{g/m}^2 \text{ .....} \quad \text{..... (7)}$$

here:

W_s – fertilizer spreading efficiency, g/m^2

Q – the amount of fertilizer poured from the fertilizer tube in 1 cycle of the support wheel, g

d – the diameter of the support wheel, d=0.35 m

B- is the overall working width of the smooth spreader, B=1.4 m

v – unit speed, v = 1.67 m/sec

π = 3.14

Dependence of dispersion productivity on aggregate speed (v).

W_s= f (v)

$$W_s = \frac{4 \cdot 7{,}84 \cdot V}{3{,}14 \cdot 0{,}35 \cdot 1{,}4} = 20.38\ v$$

If we write the value v = 1.67 m/sec instead

W_s = 34.04 g/m^2 ; tg $\alpha_1 = \frac{w_s}{v} = \frac{34.04}{1.67}$ = 20.38º

2) Dependence of scattering productivity on the fertilizer rate (Q)

W_s= f (Q) ; $W_s = \frac{4 \cdot Q \cdot 1.67}{3.14 \cdot 0.35 \cdot 1.4}$ = 4.34· Q

If we take Q = 7.84 g

W_s = 34.04 g/m^2

tg $\alpha_2 = \frac{w_s}{Q} = \frac{34.04}{7.84}$ = 4.34º

3) Dependence of spreading productivity on the working width (B) of the smooth spreader

W_s= f (B)

$W_s = \frac{4 \cdot 7.84 \cdot 1.67}{3.14 \cdot 0.35 \cdot B}$ = 47.65 $\frac{1}{B}$

If B = 1.4 m

W_s= 47.65 $\frac{1}{1.4}$ = 34.04 g/m^2

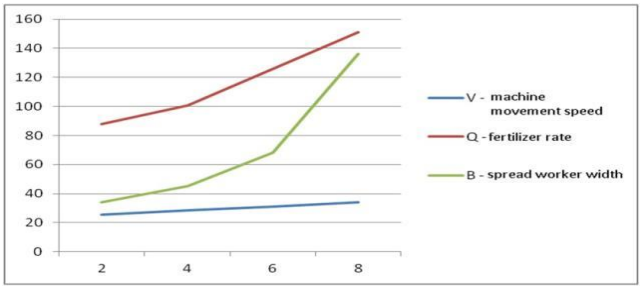
tg $\alpha_3 = \frac{w_s}{B} = \frac{34.04}{1.4}$ = 24.31º

according to the obtained results, the regression equation is as follows

$\sum W_s$ =20.38·v + 4.34· Q + 47.65· $\frac{1}{B}$ + ...+...;

$\sum W_s$ =20.38· v + 4.34· Q + 47.65· $\frac{1}{B}$ +20.38 ·4.34·v· Q + 20.38·v^2 + 4.34· Q

W_s,g/m^2



8 partitions

8 partition channels are written on the x-axis, and fertilizer sowing productivity is written on the y-axis

Figure. 3 Factors affecting sowing performance

From the graph in Fig.3, it is clear that W_s - the 1st factor that most affects the sowing productivity Q - fertilizer rate, 2nd factor B- spread worker width,3- the less influential factor V is the speed of movement of the machine [5;6].

Table. 1 Price table of factors affecting productivity

$V_{işçi,}$ m/s	1.25	1.39	1.53	1.67
W_s g/m^2	25.48	28.33	31.18	34.04
$B_{işçi}$, m	0.35	0.70	1.05	1.40
W_s g/m^2	34.05	45.39	68.07	136
Q, g	20.27	23.18	29	34.8
W_s g/m^2	87.97	100.6	125.86	151.03

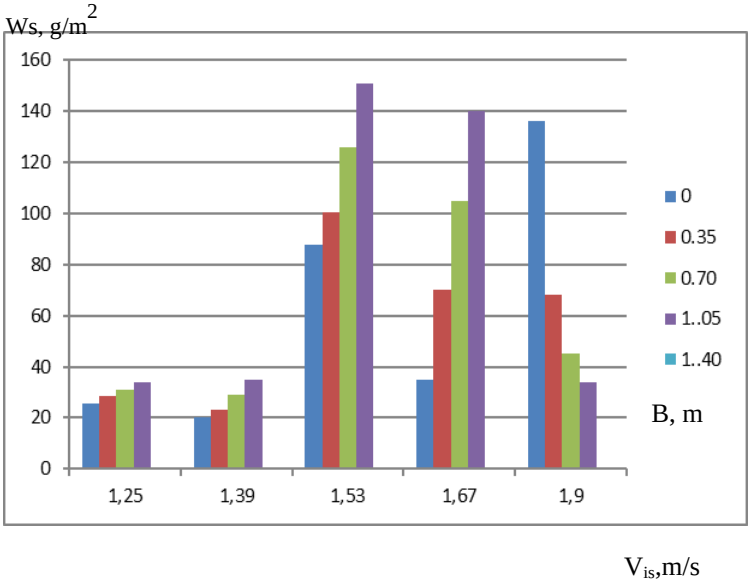


Figure. 4. Fertilizer sowing productivity depending on the working width and speed of the machine

Table 2. Economic comparison

s/s	The name of indicators	Unit of measurement	Mechanization options			
			SP -12 plough	Amazone ZA M -1500	Single time operations Total	Experimental Combined plough
1.	Productivity	ha/h	0.72	5.12	0.72	0.72
2.	Duration of technological operation	h	450	450	450	450

Cont.Table 2.

3.	Capital investment	dollars	8.17	20.05	28.22	14.88
4.	Depreciation expense	dollars	398.22	3.4	401.62	399.18
5.	Current repair and maintenance costs	dollars/ha	16.40	6.48	22.88	17.89
6.	Fuel and lubricant cost	dollars/ha	12.23	1.72	13.95	12.23
7.	Operating costs	dollars	1346.9	931.91	2278.80	1348.74
8.	Costs incurred	dollars	1348.94	936.92	2285.86	1352.45
9	Economic efficiency	dollars	-	-	-	933.40
10.	Economic efficiency in grain growing	ha/dollars	-	-	-	123.53
		kg/ha	-	-	-	600
11.	Economic efficiency during the growing season in grain growing	dollars	-	-	-	40023.53
		t	-	-	-	194.4
12.	Overall economic benefit	dollars	-	-	-	40956.93

Table 2 shows a comparative analysis of technological operations. Thus, the smooth and even distribution of mineral fertilizers in the field with the use of combined plough increases the productivity in grain growing from a minimum of 26 centner/ha to 32 centner/ha.

If we calculate that a kilogram of wheat costs about 21 cents, 600 kg per hectare allows us to get an economic economic income of 123.5 dollars / ha, and during the season - 3200 ha of land with an economic benefit of 40 003 dollars.

CONCLUSION

1. Plowing and fertilizing work on the slopes was performed in one go by using the combined plough. Fertilizing evenly under the soil prevents environmental pollution and increases the efficiency of fertilizer use.
2. As a result of economic testing of the combined plough, the working speed was 4 ... 6 km/h, the working width was 1.51 m, the cultivation depth was 20 ... 25 cm, the fertilizer application rate was 65 ... 328 kg/ha.
3. Uniform distribution of urea fertilizer under the soil was 92.0%, double superphosphate - 94.0%, potassium chloride - 93.0%.
4. Field and farm experiments have shown that with the reduction of uneven dispersion of mineral fertilizers with experimentally combined plough provides 20% of minimum green mass productivity and grain growth of 600 kg/ha.
5. As a result of the application of the combined plough, labor costs are reduced by 14.65% and operating costs by 18.3% compared to the usual method.
6. The annual economic benefit of one device is US $933.4 due to the difference in costs incurred.
7. Fertilizer rate and unit speed are the main factors affecting the productivity of fertilizer spreading in the technological operation carried out by the combined plough.

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MATEMATIČKI REZULTATI ISTRAŽIVANJA PARAMETARA KOJI UTIČU NA UJEDNAČENU PRODUKTIVNOST RASIPANJA MINERALNIH ĐUBRIVA SA KOMBINOVANIM PLUGOM, PRIMENOM GRAFO-ANALITIČKE METODE

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Apstrakt: Proučavanje efikasnih metoda uštede energije kod primene određenih normi primene mineralnih đubriva, korišćenje đubriva u zemljišnim i klimatskim uslovima za uzgoj poljoprivrednih kultura je urgentan zadatak savremene poljoprivrede.

Glavni problem u Svetu je neujednačenost. setve i narušavanja ekološke situacije pri primeni mineralnih đubriva.

Dakle, u mnogim razvijenim zemljama se mehanizaciji ove oblasti poklanja velika pažnja. U tom pravcu proizvedeno je mnogo različitih mašina i oprema za rasipanje mineralnih đubriva.

Međutim, praktično u polju, tačno rasipanje đubriva i ravnomerna raspodela u zemljištu ostaje problem.
Neravnomerno đubrenje značajno utiče na karakteristike useva i izaziva zagađenje životne sredine. Nehomogenost zemljišta u pogledu hranljivih materija koja nastaje đubrenjem je često glavni uzrok neujednačenih razvoja useva i prouzrokuje gubitak prinosa kod žitarica, koji može dostići 25-60%

Istraživanjem je utvrđeno da, u zavisnosti od konstrukcijskih karakteristika rasipača i kvaliteta primenjenog mineralnog đubriva, neravnomerna raspodela primenjenog đubriva može da varira između 40-60% od norme, što na kraju dovodi do nedostataka hranljivih materija. Uočeno je da je produktivnost žitarica opala za 11-15 centi/ha uz povećanje neravnomerne raspodele đubriva u polju za 70-80%.

Da bi se delimično otklonili naučno-tehnički nedostaci u gajenju žitarica, u tu svrhu je razvijen kombinovani plug u našoj laboratoriji i Institutu Ganja, Azerbejdžan.

Faktori koji utiču na produktivnost analizirani su grafo-analitičkom metodom za kombinovani plug, a grafikoni su dobijeni primenom teorijskih metoda.

Ujednačenost rasipanja đubriva, optimalani izbor brzine agregata stvara uslove za dobijanje najveće produktivnosti korišćenja mineralnih đubriva na polju.

Primenjene grafo-analitičke metode su pogodne za prikazivanje najbližih ciljeva istraživanja.

Ključne reči: *Mineralno đubrivo, kombinovani plug, produktivnost, jednaka količina*

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UZDUŽNA I POPREČNA EKSPLOATACIONA STABILNOST TRAKTORA SA ASPEKTA BEZBEDNOSTI PRI AGROTEHNIČKIM OPERACIJAMA

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Sažetak: U Republici Srbiji je, i pored izvesnog smanjenja broja nesreća sa traktorima u periodu 2010-2020., još uvek ima veliki povređenih i poginulih lica.

Pri dosadašnjim analizama uzroka nesreća sa traktorima, izveštaji su se formalno svodili na sledeće: rukovaoc bio pod dejstvom alkohola; nebezbedna i neprilagođena vožnja po terenima sa usponima i padovima kao i seoskim i šumskim putevima; neispravnosti komandi za: kočenje, upravljanje, transmisiju (uključenje i isključenje radi uštede goriva), neispravnost pneumatika i dr.; neispravnosti i neposedovanja svetlosne signalizacije; neuspostavljanja potrebnog balasta u odnosu na potrebnu stabilnost traktora, naročito pri kretanju uz uspone i niz padine; eksploatacija traktora bez kabine ili bezbedonosnog rama; slaba distrakcija, nepoštovanja saobraćajnih propisa, vožnja traktora od strane maloletnih lica i sl.

U ovom radu, razmatrana je stabilnost, pri kretanju traktora uz nagib, kao i pri kretanju na bočnom nagibu kroz bilans sila i faktora koji utiču na stabilnost, odnosno ugla nagiba pri kojem potencijalno može doći do prevrtanja traktora. Ti podaci dobijeni analizom sila koje deluju na traktor, su veoma bitni, sa aspekta bezbednosti pri eksploataciji u agrotehničkim i transportno-specifičnim uslovima.

Ključne reči: *Traktor, uzroci nesreća, stabilnost, bezbednost, eksploatacija*

UVOD

Naučni radovi i saopštenja o bezbednosti u eksploataciji traktora pri poljoprivrednim i transportnim operacijama, u suštini se baziraju, na statističkim podacima kojima se prikazuje broj nesreća sa smrtnim posledicama ili povredama učesnika u eksploataciji i analiza uzroka i posledica tih nesreća.

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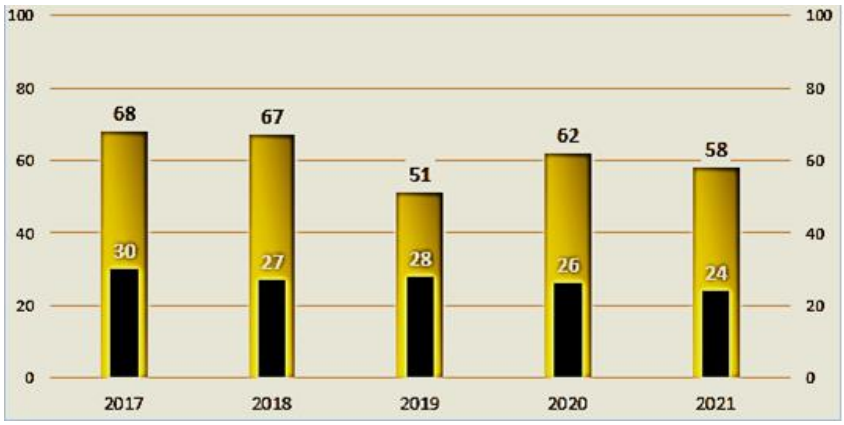
Uviđajući potrebu da se daju određena objašnjenja koja će u opštim crtama objasniti neke uzroke pojava raznih nesreća pri radu sa traktorom, a biti od koristi za praksu, u radu su obuhvaćena osnovna pravila kojih vozač traktora mora da se pridržava radi sigurne i bezbedne eksploatacije. U prilog tome, data je teorijska analiza stabilnosti traktora pri kretanju na usponima i padovima, na kojima se obično dešavaju nesreće, [7].

Prema podacima Agencije za bezbednost saobraćaja Republike Srbije, [10] u poslednje tri godine poginulo je 160 traktorista u saobraćajnim nesrećama, od toga 50 % na putu, u saobraćaju.

U saobraćajnim nezgodama od 1997. do 2021. godine u R.Srbiji je 1.657 osoba poginulo u saobraćajnim nezgodama sa učešćem traktora, od kojih 1.198 lica kao rukovaoci ili putnici, ali što posebno zabrinjava da je od ukupnog broja poginulih 67 maloletnika, kao i daje svaka deseta osoba starija od 65 godina, [10].

U Srbiji je u periodu 1997-2021. registrovano 1.230.000 saobraćajnih nezgoda u kojima je život izgubilo 20.344 osoba. A od ukupnog broja saobraćajnih nesreća, oko 27.000 je sa učešćem traktora u kojima je poginulo 1.657 osoba,[6] .

Na slici 1 prikazani su podaci [10], broja teško telesno povređeni i poginulih u udesima sa traktorom u periodu 2017-2021.



Grafik 1: Broj povređenih i poginulih osoba u udesima sa traktorom u periodu 2017-2021, [10].
Chart 1: Number of injured and killed persons in tractor accidents in the period 2017-2021, [10].

MATERIJAL I METOD RADA

Aspekt bezbednosti i uzroci nesreća pri eksploataciji traktora

Kao što je pomenuto i dalje smo svedoci nesreća u kojima učestvuje traktor,sa velikim brojem poginulih i znatnim brojem lakše i teže povređenih u udesima u kojima je učestvovao traktor, kako je ilustrativno prikazano [8], [10], na slici 2.

Slika 2. Nezgode u kojima je učestvovao tractor, [8], [10].
Fig. 2. Accidents involving the tractor, [8], [10].

Razlozi i uzroci koji direktno utiču na izazivanje nesreće su raznovrsni, a kada se navode uzroci, obično se svode na konstatacije i pitanja: Do nesreće je došlo zbog: prevrtanja traktora pod teretom na nagibu; gubitka kontrole upravljanja; sletanja sa seoskog puta; sletanja sa prikolicom sa seoskog puta; zanošenja pri kretanju; preko mosta; debalansa opterećenja; neadekvatnog agregatiranja; nebezbednog korišćenja prevoza pratećih osoba; upotrebe alkohola; neadekvatne svetlosne i znakovne signalizacije; nepropisnog zaustavljanja na putevima; nanešenog blata na putevima; kvara na traktoru-kod sistema za upravljanje, kočenje i dr.; otkaza motora: defekta pneumatika; nepoštovanja saobraćajnih propisa i dr.

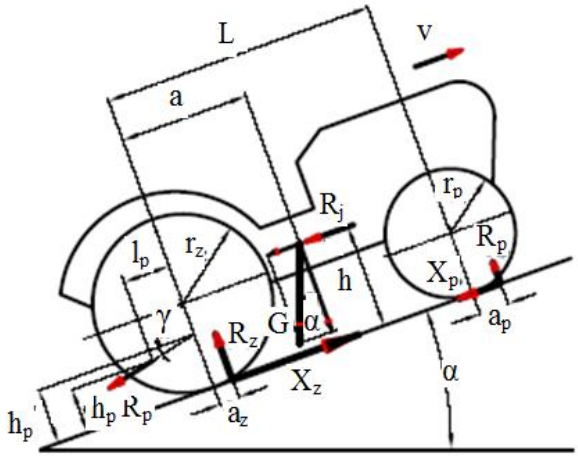
Uzmajući u obzir navedene uzroke nesreća, u daljoj analizi u ovom radu, data je opšta analiza kretanja traktora na usponu, na bočnom nagibu, kada može doći do bočnog prevrtanja oko podužne ose traktora i proklizavanja pogonskih točkova na terenu, pri čemu postoji mogućnost okretanja traktora oko ose zadnjeg pogonskog mosta.

MATERIJAL I METOD RAD

Analiza bilansa snage i sila koje deluju na traktor

Teorijska analizu stabilnosti pri kretanju na usponu i bočnom nagibu u ovom radu izvršena je analizom pojava vučnih sila i statičkih reakcija pri eksploataciji traktora na pomenutim terenima. Normalne reakcije podloge mogu imati različite vrednosti, kao i značaj u zavisnosti od uzajamnih sila i momenata koji deluju za vreme kretanja. Veličina tih reakcija ukazuje na uticaj vučnih i kočionih sila, dinamičke karakteristike, uzdužnu i poprečnu stabilnost, opterećenje pneumatika i komponenata transmisije i njihova tribološka svojstva i dr.

Ako bi se posmatrao opšti slučaj kretanja traktora 4x2, koji se kreće na usponu pod uglom (α), u odnosu na horizontalu, kao što je prikazano na slici 3, sa zadnjim vodećim i prednjim vođenim točkovima i teorijskim poluprečnicima pneumatika, zadnjih (r_z) i prednjih (r_p), može se konstatovati na osnovu [4], [5], [7], činjenice:



Slika 3. Šematski prikaz dejstva sila i reakcija podloge pri kretanju na usponu, [4], [5], [7].
Fig. 3. Schematic of action force and the reaction medium in motion on an incline,[4], [5], [7].

1. Težina traktora (G), deluje u centru težišta mase, koje je definisano dvema koordinatama, uzdužnom (a) i vertikalnom (h). Prva koordinata (a), definiše rastojanje od centra težišta do ose vodećeg točka, a druga (h) rastojanje od centra težišta do kontaktne površine.

2. Normalna reakcije podloge, (R_z), na vodećem točku, deluje na ekscentričnom rastojanju (a_z), a reakcija na vođenom točku (R_p), na rastojanju (a_p), u odnosu na osu točka normalnu na površinu podloge.

3. Tangencijalne sile deluju paralelno sa površinom podloge, i to pogonska sila, koja izaziva kretanje (X_Z), deluje na rastojanju (r_z), od ose vodećeg točka, a sila otpora kretanju (X_p), dejstvuje u suprotnom smeru od pogonska sile, na rastojanju (r_p), od ose vođenog točka.

4. Vučni otpor (Rpot), deluje na vučnoj poteznici traktora na visini (hp), pod uglom (α), u odnosu na površinu podloge.

5. Ukupna sila inercije (Ri), javlja se pri kretanju traktora, (predpostavka da deluje u visini težišta mase traktora), ali za ovu analizu je zanemarljiva i smatra se da je Ri=0, [7],

Inercijalne sile obrtnih masa, i otpora vazduha, zavise od broja obrtaja rotirajućih elemenata, odnosno brzine kretanja, koje imaju znatno veći uticaj kod motornih vozila, u odnosu na traktor zbog manjih brzina kretanja, pa ti faktori nemaju značajan uticaj na opšta vučno-dinamička svojstva, pa se pri ovakvim analizama mogu zanemariti.

Pri kretanju, vučnoj sili traktora, suprostavlja se sila otpora na poteznici, koja dejstvuje u približno istom pravcu, ali suprotnog smera. Tačka na poteznici na kojoj se agregatira priključna mašina ili oruđe, pojednostavljuje se radi lakše analize i smatra tačkom spajanja oruđa. Njena visina iznad površine tla je (h'_p), pod uglom (γ), definisana je odnosom (slika 3):

$$h_p^{'} = h_p + l_p \cdot tg\gamma \qquad .....(1)$$

l_p-je uzdužno rastojanje od tačke spajanja oruđa, na primer, prikolice na poteznici ili nekog drugog oruđa agregatiranog sa traktorom, do ose vodećeg točka.

Ugao poteznice (γ), ima pozitivnu vrednost, u uslovima kada je linija vučnog otpora okrenuta nadole u odnosu na kontaktnu površinu. Otpor kotrljanja pogonskih točkova u uslovima kretanja traktora, deluje u suprotnom smeru od pogonskog momenta i usvaja se u oznaci kao (M_f). [2],[3].

Iz prikazane šeme se vidi da normalna reakcija podloge (R_P), dejstvuje na prednje točkove, a postavljanjem jednačine momenta svih sila koje deluju na traktor, u odnosu na tačku (O_2), u kojoj pogonska tangencijalna sila (X_z), preseca osu pogonskog točka normalnu na površinu podloge, pa jednačina ravnoteže dobija oblik prikazan matematičkom relacijom:

$$R_P\left(L + a_p\right) + R_Z \cdot a_z + G \cdot \sin\alpha \cdot h + P_i \cdot h + R_p \cos\gamma_p \cdot h_p^{'} - G \cdot \cos\alpha \cdot a_t = 0 \qquad .....(2)$$

gde je: L- osno rastojanje između točkova, prednjeg i zadnjeg mosta.

Zamenom u jednačini proizvoda $R_z.a_z$ i $R_p.a_p$, odgovarajućim momentima otpora kotrljanja prednjih i zadnjih točkova (M_{fz} i M_{fp}), koji predstavljaju zbirni odgovarajući moment otpora kotrljanja traktora, koji se u uslovima kretanja može usvojiti kao (M_f), pa se dobija formula koja određuje reakciju R_P:

$$R_P = \frac{G \cdot \cos\alpha \cdot a_t - \left(G \cdot \sin\alpha + R_f\right) \cdot h - R_p \cdot h_p^{'} - M_f}{L} \quad \text{..... (3)}$$

U ovim i daljim analizama, može se usvojiti da je ugao $\gamma \approx 0^0$, odnosno $\cos\gamma = 1$.

Normalna reakcija podloge pogonskih točkova (R_z), može se odrediti iz projekcije dejstvujućih sila na ravan, normalnu na površinu podloge:

$$R_P + R_Z = G \cdot \cos\alpha + R_p \cdot \sin\gamma_p \quad \text{..... (4)}$$

Ako se umesto reakcije (R_P), zameni njeno značenje iz jed.(3), sledi:

$$R_z = \frac{G \cdot \cos\alpha \cdot \left(L - a_t\right) + \left(G \cdot \sin\alpha + R_i\right) \cdot h - R_P \cdot h_p^{'} + M_f}{L} + R_p \sin\gamma_p \quad \text{..... ..(5)}$$

Ako se posmatra kretanje na nagibu, (α), član G.sinα, u jednačini (3), ima negativan predznak (-). Sila inercije (R_i), takođe može imati različite znakove. Pri blokiranom kretanju (npr. u slučaju kočenja), imaće negativan znak. Pri ustaljenom kretanju sa agregatom na horizontalnoj podlozi, reakcije (R_P i R_z), imaju vrednosti (jed, 6 i 7):

$$R_P = \frac{G \cdot a_t - R_p \cdot h_p^{'} - M_f}{L} \qquad R_z = \frac{G \cdot (L - a_t) + R_p \cdot h_P^{'} + M_f}{L} + R_{p\cdot} \cdot \sin\gamma_p \quad \text{(6), (7)}$$

Reakcije (R_P i R_z), koje dejstvuju na točkove traktora u stacionarnom stanju, bez agregata, na horizontalnoj podlozi, nazivaju se statičkim reakcijama i označavaju se sa R_{Pst} i R_{Zst}. Izjednačavanjem predhodnih jednačina sa nulom, svih sila i momenata, anuliraju se članovi koji su korelativni sa kretanjem traktora, pa sledi:

$$R_{Pst} = G \cdot \frac{a_t}{L} \qquad R_{Zst} = G \cdot \frac{L - a_t}{L} \quad \text{.....(8)}$$

$$R_P + R_Z = G \cdot \cos\alpha + R_p \cdot \sin\gamma_p \quad \text{.....(9)}$$

Nagib linije otpora kretanju, pokazuje takođe uticaj na intenzivnosti preraspodele normalnih opterećenja na točkovima, kao i pri veličini nagiba pri postojanju dodatne visine uslovne tačke poteznice agregata ($h_p^{'} \neq h_p$).

Pri utvrđivanju normalnih reakcija (R_P i R_z), vozila neophodno je uzeti u obzir dejstvo spoljašnjih sila, kao silu otpora vazduha (R_a), koja deluje u centru čeone površine na visini (≈h), od površine podloge, koja je u slučaju kretanja traktora, zanemarljivo mala i uzima se da je jednaka nuli. Primenom formule (3), proizilazi da reakcije (R_P i R_z), kod vozila treba dopuniti formulom za vrednost momenta ($R_a \cdot h$). U formuli za (R_p), ona mora biti sa znakom minus, a u formuli za (R_z), sa znakom plus, tako da se tim momentom prednji točkovi rasterećuju, a zadnji opterećuju.

Za bolje sagledavanje o tome kako se raspodeljuju normalne reakcije između prednjih i zadnjih točkova, pri različitim uslovima kretanja sa mogućnošću upoređenja uticaja izmerenih veličina (R_P i R_z), pogodna je sledeća analiza.

Ako se odnos (R_P/G), nazove, koeficijentom opterećenja prednjih točkova, a odnos (R_z/G), koeficijentom opterećenja zadnjih točkova i označe sa (λ_p i λ_z)., njihove vrednosti se mogu odrediti po različitim metodama proračuna reakcija (R_P i R_z), pa pri razmatranju kretanja traktora sa agregatom na horizontalnoj podlozi koeficijenti (λ_p i λ_z), imaće značenje:prema formulama:

$$\lambda_p = \frac{a_t}{L} - \frac{R_P \cdot h_p^{'} + M_f}{G \cdot L} = \lambda_{pst} - \frac{R_P \cdot h_p^{'} + M_f}{G \cdot L} \quad \text{.....10)}$$

$$\lambda_z = \frac{L - a_t}{L} + \frac{R_P \cdot \left(h_p^{'} + L \cdot \sin\gamma_p\right) + M_f}{G \cdot L} = \lambda_{zst} + \frac{R_P\left(h_p^{'} + L \cdot \sin\gamma_p\right) + M_f}{G \cdot L} \quad \text{.....(11)}$$

U tim formulama $\lambda_{p_{st}} = \frac{a_t}{L}$; $\lambda_{z_{st}} = \frac{L - a_t}{L}$, definišu koeficijente opterećenja prednjih i zadnjih točkova, pri stacionarnom-statičkom položaju.

Ako je pravac vučnog otpora na poteznici paralelan površini puta (γ=0), to je: $\lambda_p + \lambda_z = 1$.

Ako je $\gamma \neq 0$, to će pri kretanju na nagibu biti $\lambda_p+\lambda_z>1$, a pri usponu $\lambda_p+\lambda_z<1$.

Pri kretanju vozila ravnomerno po horizontalnoj podlozi bez agregata je:

$$\lambda_p = \frac{a_t}{L} - \frac{M_f + R_a \cdot h_a}{G \cdot L} = \lambda_{pst} - \frac{M_f + R_a \cdot h_a}{G \cdot L} \quad \text{..... (12)}$$

$$\lambda_z = \frac{L - a_t}{L} + \frac{M_f + R_a \cdot h_a}{G \cdot L} = \lambda_{zst} + \frac{M_f + R_a \cdot h_a}{G \cdot L} \quad \text{.....(13)}$$

Veličina (λ_p), ima značaj u zaključku upravljivosti mašine, a veličina (λ_z), karakteriše na zadnjim vodećim točkovima, prijanjanje. Na raspodeli normalnih opterećenja između prednjih i zadnjih točkova značajan je uticaj položaja centra težišta agregata. Kod traktora točkaša centar težišta je bliže zadnjim točkovima i u proračunu se obično uzima $R_{Zst}\approx(0{,}65\text{-}0{,}7).G$.

Smanjenjem težine, na zadnjim točkovima, pogoršavaju se sposobnosti vučnog dejstva traktora, a umanjenjem težine koja se prenosi na prednje točkove, pogoršavaju se karakteristike uzdužne i bočne stabilnosti, kao i njegova prohodnost. Kod samohodnh vozila na prednje točkove se prenosi značajno manji deo težine ($R_{Pst}\approx0{,}2G$), međutim mora se imati u vidu da se pri agregatiranju izvesnih uređaja i mašina, centar težišta takvog agregata menja, ugradnjom balasta.

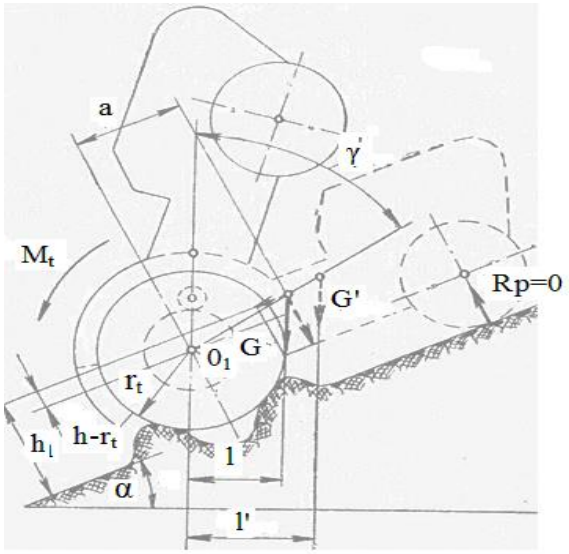
Proklizavanje pogonskih točkova pri kretanju traktora (4x2) na usponu

U eksploataciji, prevrtanje traktora može biti prouzrokovano proklizavanjem pogonskih točkova, kao što je šematski prikazano na slici 4. Proklizavanjem, prestaje njihovo translatorno kretanje, a nastaje rotaciono u mestu, odnosno proklizavanje oko ose (0_1), tj. ose zadnjeg pogonskog mosta. Razmatranje procesa prevrtanja [4], [5], [7], koji se može dogoditi do trenutka mogućeg delovanja/vrednosti (M_t), ograničenog momentom nošenja kvačila/spojnice u prvom stepenu prenosa je prikazano:

$$M_t = \beta \cdot M_M \cdot i_l \cdot \eta_{tr}, \qquad \text{.....(14)}$$

gde je:
β-koeficijent nošenja spojnice,
M_M- nominalni obrtni moment motora.

Jednačina ravnoteže konstrukcije traktora u odnosu na osu zadnjih točkova i pojavu zakretanja oko tačke (0_1), dešava se od trenutka odvajanja prednjih točkova od podloge, pa sledi: $M_t = G' \cdot l'$, gde je: G' –težina dela konstrukcije, jednaka težini traktora uz odbitak težine pogonskih točkova, l'-krak sile (G'), u odnosu na osu pogonskih točkova.



Slika 4. Šema zakretanja traktora pri proklizavanju pogonskih točkova, [4], [5], [7].
Fig. 4. Schematic of rotation of the tractor at skidding wheel-drive, [4], [5], [7].

Ukoliko se centar težine pogonskih točkova nalazi na geometrijskoj osi, onda je moment težine tih točkova u odnosu na osu jednak nuli, pa je: $G' \cdot l' = G \cdot l$, gde je:
G-težina traktora, l-krak težine (G), u odnosu na osu pogonskih točkova.

Kako je relacija:

$$G \cdot l = G \cdot a \cdot \cos\alpha - G(h - r_t)\sin\alpha,$$

to je novi izraz:

$$G' \cdot l' = G[a \cdot \cos\alpha - (h - r_t)\sin\alpha] \qquad \text{.....(15)}$$

Uslovi nemogućnosti kretanja traktora oko ose zakretanja točkova mogu biti definisati matematičkom relacijom:

$G[a \cdot \cos\alpha - (h - r_t)\sin\alpha] > \beta \cdot M_M \cdot i_I \cdot \eta_{tr}$, odakle sledi relacija:

$$a \cdot \cos\alpha - (h - r_t)\sin\alpha > \frac{A \cdot \beta \cdot P_M \cdot i_I \cdot \eta_{tr}}{G \cdot n_M}, \quad \text{..... (16)}$$

Odnos, $\frac{P_M}{G} = P_{sp}$, predstavlja specifičnu snagu traktora, u odnosu $\frac{i_I}{n_M} = \frac{0{,}377 \cdot r_t}{v_{M1}}$

,

gde je:

V_{M1}-nominalna brzina traktora u I_{-OM} stepenu prenosa,

P_M-nominalna snaga motora,

n_M- nominalni broj obrtaja motora,

A-faktor snage,

η_{tr}-koeficijent korisnog dejstva transmisije, pa iz toga sledi relacija:

$$a \cdot \cos\alpha - (h - r_t)\sin\alpha > r_t \frac{260 \cdot \beta \cdot P_{sp} \cdot \eta_{tr}}{v_{M1}} \quad \text{..... (17)}$$

Uslovi izraženi predhodnom jednačinom nisu održivi, jer ona samo definiše faktore koji utiču na mogućnost „zakretanja“ i proklizavanja pogonskih točkova u takvim uslovima. Povećanjem snage motora, sa nižom vrednošću prvog stepena prenosa i brzina kretanja je manja, smanjuje se i koordinata težišta mase (a), a povećeva koordinata (h). Sa povećanjem koeficijenta nosivosti spojnice (β), verovatnoća zakretanja traktora se povećava. Uslovi održavanja stabilnosti traktora se pogoršavaju ako se zakreću pogonski točkovi pri kretanju uz nagib.[1], [2].

Treba reći, da zakretanje konstrukcije traktora oko ose pogonskih točkova, koje prouzrokuje odvajanje prednjih točkova od tla, još uvek ne znači neminovno zakretanje traktora. Potpuno zakretanje nastaje u slučaju ako je motor traktora (sa učešćem kinetičke energije njegovih rotirajućih masa) u stanju da ostvari interval rada takav da dovede traktor pod ugao (γ), kada je prevrtanje traktora neminovno. Tada se težište mase traktora pomera u vertikalnom pravcu ose koja prolazi kroz osu pogonskih točkova (pod uglom **γ** i dalje pomera pod dejstvom težine (povećava se ugao **γ**). [14]

Poprečna-bočna stabilnost traktora točkaša

Poprečna stabilnost traktora sa točkovima karakterizuje se veličinim bočnog ugla (β), pri kojem traktor i dalje može da bude stabilan bez prevrtanja. Na slici 5, prikazana je šema traktora na bočnom nagibu

Postavljanjem jednačine momenata u odnosu na tačku (0_1), dobija se:

$$G \cdot \cos\beta_{kr} \cdot \frac{B}{2} = G \cdot \sin\beta_{kr} \cdot h \quad \text{.....(18)}$$

Iz jednačine (18), proizilazi da je vrednost kritičnog ugla bočnog nagiba pri kojem traktor može da stoji : $tg\beta_{kr} = \frac{B}{2h}$. .....(19)

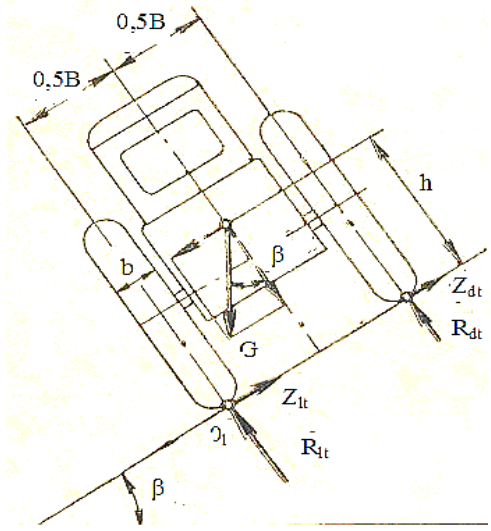
Kritični ugao bočnog nagiba (β_{kr}), na kojem se nalazi traktor zavisi od: širine tragova zadnjih točkova (B) i visine težišta (h).

Specifičnost kretanja traktora na nagibu je takođe veoma važna (u ovom slučaju puzenje), sa aspekta projekcije sila koje karakterišu kretanje u odnosu na osu paralelnu površini puta/nagiba je prikazana relacijom:

$$G \cdot \sin \beta = Z_{lt} + Z_{dt}$$

Najpogodnije značenje veličina reakcije ($Z_{lt} + Z_{dt}$), je zavisnost:

$$Z_{lt} + Z_{dt} = \varphi_z \cdot G \cdot \cos \beta_{kr}\,, \qquad \text{.....(20)}$$



Slika 5. Šematski prikaz sila koje deluju pri bočnom položaju traktora, [4].
Fig. 5. Schematic of forces acting at the lateral position of the tractor, [4].

gde je φ_z-koeficijent bočnog prijanjanja točkova traktora sa podlogom. Uzimajući u obzir nemogućnost kretanja traktora na bočnom nagibu, jed. (19), dobija oblik:

$G \cdot \sin \beta_{kr} \le \varphi_z \cdot G \cdot \cos \beta_{kr}$, sledi izraz:

$tg\beta_{kr} \le \varphi_z$ ..... (21)

Koeficijent prijanjanja (φ_z) zavisi od: sile trenja, mehaničkih svojstava površine zemljišta/podloge po kojoj se traktor kreće, konstrukcije traktora, vrste i tipa pneumatika, pritiska u pneumaticima, raspodele težine traktora i dr.

Na osnovu sprovedene analize kretanja traktora na usponu i bočnom nagibu definisane su vrednosti ugla (α_{kr}) pri kretanju na usponu i ugla (β_{kr}) pri kretanju na bočnom nagibu. Na osnovu toga, kritičan ugao prevrtanja(α_{kr}) traktora 4x2 pri kretanju na usponu je u granicama α_k=40-50^{0,} a pri kretanju traktora na bočnom nagibu kritični ugao do kojeg bi moglo da dođe do prevrtanja je β_k=30-35^0.

Kada je u pitanju bočna stabilnost, ona je direktno zavisna od širine osa pogonskih točkova (B), koja kod traktora sa točkovima ima mogućnost povećanja, pa time i povećanja vrednosti kritičnog ugla (β_{kr}) i vertikalne visine težišta mase traktora (h).

U oba slučaja bitan faktor stabilnosti traktora pri kretanju u navedenim uslovima je koeficijent prijanjanja pneumatika i podloge, koji je za suvi zemljani put (ϕ=0,65-0,7), ili za vlažan/mokar (ϕ=0,5-0,55). [5], [9].

ZAKLJUČAK

Obzirom da je reljef Republike Srbije brdsko-planinski (osim Vojvodine), gde se često sa agregatiranim traktorom obavljaju pojedine agrotehničke operacije koje pri kretanju mogu izazvati smanjenje reakcije na prednjim točkovima, pa i odvajanja točkova od podloge, pa time i do mogućnosti prevrtanja traktora. Slična je konstatacija i pri kretanju na bočnim kosinama kada identično zbog povećanja horizontalne, a smanjenja vertikalne sile, dolazi do odvajanja točkova leve ili desne strane i time takođe do mogućnosti prevrtanja oko uzdužne ose traktora. U oba slučaja značajan faktor je koeficijent prijanjanja koji sa nižim vrednostima više utiče na mogućnost navedenih prevrtanja traktora, a time i smanjenja bezbednosti pri eksploataciji.

Značajno je istaći da je na osnovu izvedene analize pri kretanju traktora (4x2), na usponu kritični ugao (α_k=40-50^0), koji prouzrokuje smanjenje normalne komponente mase, a povećanje horizontalne koja pod tim uslovima može prouzrokovati mogućnost prevrtanja traktora. Slična konstatacija je analizom utvrđena, da je kritičan ugao pri kretanju na bočnom nagibu (β_k=30-35^0), pri kojem iz istih razloga može doći do potencijalnog prevrtanja traktora.

U poslednjih nekoliko decenija u Republici Srbiji, veća pažnja se posvećuje bezbednosti, obaveznom ugradnjom kabina i bezbedonosnih ramova, ali i ispunjavanju ergonomskih uslova i komfornosti rukovaoca traktora.

Iz navedenih razloga Autori ovog rada i njemu sličnih u ovoj oblasti, dali su značajan doprinos u tom kontekstu.

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LONGITUDINAL AND TRANSVERSE OPERATIONAL STABILITY OF THE TRACTOR FROM THE ASPECT OF SAFETY IN AGROTECHNICAL OPERATIONS

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Abstract: In the Republic of Serbia, despite a certain decrease in the number of accidents with tractors in the period 2010-2020., the number of injured and killed people is still high.

In previous analyzes of the causes of accidents with tractors, the reports were formally reduced to the following: the operator was under the influence of alcohol; unsafe and unsuitable driving on terrains with ups and downs as well as rural and forest roads; malfunctions of controls for: braking, steering, transmission (switching on and off to save fuel), malfunction of tires, etc.; malfunctions and lack of light signaling; failure to establish the necessary ballast in relation to the required stability of the tractor, especially when moving uphill and down slopes; exploitation of a tractor without a cab or a safety frame; weak distraction, non-observance of traffic regulations, tractor driving by minors etc.

In this paper, stability was considered when the tractor was moving up a slope, as well as when moving on a side slope through the balance of forces and factors that affect stability, i.e. the angle of inclination at which the tractor could potentially overturn.

Those data obtained by analyzing the forces acting on the tractor are very important from the aspect of safety during exploitation in agrotechnical and transport-specific conditions.

***Key words**: Tractor, causes of accidents, stability, safety, exploitation*

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PRIMENA MAŠINSKOG UČENJA ZA IDENTIFIKACIJU STANJA KOTRLJAJNIH LEŽAJEVA KOD POLJOPRIVREDNE MEHANIZACIJE NA OSNOVU VIBRACIJA

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Sažetak: Održavanje mehanizacije predstavlja preventivne aktivnosti kroz stalno praćenje pokretnih radnih delova poljoprivredne mehanizacije i pravovremeno intervenisanje samo ako određena mera odstupa od utvrđenih vrednosti. Kotrljajni ležajevi predstavljaju jednu od glavnih komponenti rotirajućih delova mašina i njihova svojstva direktno utiču na pouzdanost poljoprivredne mehanizacije. Kraći vek trajanja kotrljajnih ležajeva dovode to niže pouzdanosti poljoprivredne mehanizacije što su posledice neadekvatnog tehničkog održavanja i upotrebe. Praćenje stanja ležajeva na mašinama može se postići veoma zastupljenim metodama koje vrše analizu signala vibracija. Cilj ovog rada je primena modela dobijenog mašinskim učenjem za prepoznavanje stanja kotrljajnih ležajeva sa dovoljnom tačnošću koristeći podatke o vibracijama. Uzeta su u obzir normalna stanja i stanja sa greškom kod ležajeva kako bi se realizovani model mogao koristiti za ranu detekciju nepovoljnog rada poljoprivredne mehanizacije i sprečavanje većih oštećenja. Otkrivanje nepovoljnih stanja kotrljajnih ležajeva na osnovu vibracija u ranoj fazi doprinelo bi pravovremenoj reakciji korisnika, sprečavanju većih kvarova i ekonomskih gubitaka. Ideja je da se dobijeni model prenese na uređaje u okviru koncepta Fog računarstava i primenjuje u neposrednoj blizini radne mašine i operatera.

Ključne reči: *Mašinsko učenje, vibracije,* poljoprivredne mehanizacije, *ležajevi, detekcija greške.*

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UVOD

U konstrukciji traktora, pogonskih i radnih poljoprivrednih mašina ugrađeni su kotrljajni ležajevi za prenos snage, obrtnog momenta i pokretanje vratila, osovina, osovinica, spojnica i dr. Kotrljajni ležajevi predstavljaju jednu od glavnih komponenti delova rotirajućih mašina i njihov kvalitet i svojstva direktno utiču na pouzdanost mašina. Otkazivanje ili neipsravan rad kotrljajnih ležajeva mogu dovesti do nepovoljnog režima rada cele mašine, njene potpune disfunkcionalnosti pa čak i do katastrofalnih posledica po opremu i okruženje sa ogronim ekonomskim gubicima.

Kraći vek trajanja kotrljajnih ležajeva u toku eksploatacije i niža pouzdanost poljoprivredne mehanizacije su posledice neadekvatnog tehničkog održavanja i upotrebe, kao i ekstremnih uslova koji vladaju u poljoprivrednoj proizvodnji. Mašine se ne kvare iznenada, bez upozorenja već sa unapred utvrđenom granicom upozorenja i granicom kvara. Česti pokazatelji nestabilnog rada pogonskih i priključnih mašina su povećana vibracija, prekomerna buka, visoka temperatura i udari. Farmeri koji poseduju poljoprivrednu mehanizaciju sami rukuju sa njom i održavaju je na osnovu iskustva, subjektivne procene o stanju i ponašanju u toku rada. Danas, za nadzor i detekciju stanja kotrljajnih ležajeva postoje metode i savremena oprema, ali malo se u praksi koristi, jer je skupa. Zato rukovaoci u toku rada mašine prepoznaju oštećeni deo na osnovu svojih čula i to posmatranjem, osluškivanjem neobičnih šumova i pojačane buke, ili dodirivanjem zagrejanih ležajeva.

Ležajevi koje karakteriše visoka pouzdanost umanjuju rizike da dođe do nezgoda u radu i redukuju troškove održavanja mašina. Nadgledanje rotirajućih delova, pravoremena dijagnostka kvarova i preventivno održavanja su veoma važni zadaci u cilju smanjenja opasnosti da dodje do oštećenja mašina. Pri tome analiza vibracionih podataka koji su u relaciji sa greškom ili defektom jeste jedna od često korišćenih metoda za utvrđivaje stanja pojedinih delova mašine [1].

U radu [2], Autori su dali pregled istraživanja na temu detektovanja i prepoznavanja greški u radu mašina na osnovu podataka o vibracijama. Doktorska disertacija [3] predstavlja detekciju otkaza kotrljajnih ležajeva analizom signala vibracija primenom odgovarajućih naprednih metoda.

Ukoliko postoje podaci o vibracijama i stanjima kotrljajnih ležajeva može se iskoristit mašinsko učenje kako bi se izvršilo pravovremeno prepoznavanje stanja i greške u budućem radu mašine. Detekcija greške kod ležajeva preko signala vibracija i akustičnih signala, kao i poređenje različitih metoda mašinskog učenja prikazani su u radu [4]. Analiza vibracija u svrhu detekcije greške kod ležajeva i klasifikacija uz pomoć inteligentnog filtera predstavljeni su u radu [5]. Još jedan od primera klasifikacije stanja kod ležajeva rada Autori [6], predstavili su koristeći statistička svojstva signala vibracija u vremenskom i frekventnom domenu. Dok su u radu [7], prikazana najnovija dostignuća metoda dubokog učenja u prepoznavanju grešaka kod rotirajućih delova mašina na osnovu vibracionih signala.

Cilj ovog rada je predstavljanje modela dobijenog mašinskim učenjem za prepoznavanje stanja kotrljajnih ležajeva sa dovoljnom tačnošću, a na osnovu prikupljenih podataka o vibracijama. Realizacija i mogućnosti jednog takvog modela prikazani su nad skupom postojećih podataka o vibracijama ležajeva. Uzeta su u obzir normalna stanja i stanja sa greškom kod ležajeva kako bi se realizovani model magao koristiti za ranu detekciju nepovoljnog rada mašine i sprečavanje većih oštećenja.

ZNAČAJ NADGLEDANJA STANJA KOTRALJAJNIH LEŽAJEVA

Savremeni traktori, radne i priključne poljoprivredne mašine se koriste u vrlo teškim klimatskim, zemljišnim i radnim uslovima okoline. Poljoprivredna mehanizacija se upotrebljava kratko, samo u toku sezone, dok se u dužem periodu ne koriste, i tada treba da se utvrdi stanje i preduzmu preventivne mere na zaštiti svih delova mašina, pa i kotrljajnih ležajeva. Utvrđivanje stanja treba da ukaže na mesta moguće pojave kvara na konstrukcijama poljoprivredne mehanizacije. Na osnovu dijagnostike sprovode se odgovarajuće procedure održavanja, koje se baziraju na otklanjanju kvarova ili zameni delova traktora i priključnih mašina.

Rana dijagnostika je vrlo bitna zbog brzog i sigurnog otkrivanja stanja i početka nastanka kvara delova i kasnijeg preventivnog održavanja mašina u granicama funkcionalne ispravnosti, a sve do vrednosti granice upozorenja. Pomoću odgovarajuće metode praćenja i kontrole stanja graničnih vrednosti, kao i rane detekcije, potencijalni kvar se može rano otkriti (pre granice upozorenja). Na taj način se mogu na vreme preduzeti konkretne mere radi sprečavanja nastanka većih oštećenja delova ili sklopova na motorima, pogonskim i priključnim poljoprivrednim mašinama. Najčešći kvarovi tj.greške su na elementima za prenos kružnog kretanja, snage i obrtnog momenta, kao što su ležajevi, vratila,osovine, osovinice, spojnice i dr. Pre prekoračenja vrednosti prelaska granica kvara i nastanka neispravnosti je granica upozorenja. Prelazak ove granice podrazumeva da pojedine tačke elemenata za prenošenje obrtnog momenta odstupaju u malim amplitudama od putanje nekog središnjeg položaja u toku pravilnog kružnog okretanja i dolazi do pojave vibracija.

Praćenjem i analizom mašina, odnosno praćenjem vibracija na ležaju može se otkriti čitav niz problema. Svetski eksperti iz oblasti tehničke dijagnostike, na osnovu bogatog iskustva, navode da se preko vibracija može identifikovati čak 95% problema na rotacionim sklopovima. Problemi na ležišnim sklopovima koji se otkrivaju preko vibracija su: neuravnoteženost (debalans), labavost sklopa, elektro problemi, neodgovarajuće centriranje, ležajevi lošeg kvaliteta, kriva vratila, oštećeni zupčanici, i dr. Na mobilnim poljoprivrednim mašinama kao glavni uzroci pojave oštećenja kotrljajnih ležajeva mogu se navesti: loša konstrukciona rešenja, oštri režimi rada, nepravilna montaža, upotreba neodgovarajućih maziva i fizičko-hemijskih svojstava materijala od kojeg su izrađeni ležajevi [8].

Istraživanja sprovedena na analizi pouzdanosti mašina za ubiranje šećerne repe pokazuju da je najveća frekvencija otkaza bila kod: zavrtnja 43 %, ležaja 18 %, gumenih lopatica 14,9 %, osovinica diska 16,1 % i ostalih delova 8 %. Slična je situacija sa otkazima i kod traktora i drugih poljoprivrednih mašina [9].

Pri dejstvu spoljašnjih sila, usled obrtanja elementa ležaja dolazi do periodične promene elastičnih deformacija staza kotrljanja, što dovodi do pojave vibracija elemenata ležaja. U praksi se, međutim, najveće vibracije javljaju usled netačnosti unutrašnje geometrije ležaja, kao i usled odstupanja od hrapavosti i talasastih staza kotrljanja. Za opisivanje dinamičkog ponašanja mašinskih elementa se koriste termini buka i vibracije, koji su međusobno povezani i služe za praćenje i dijagnostiku elemenata mašina.

Vibracije nastale u ležaju mogu se svrstati u četiri kategorije:

- vibracije usled konstrukcije i funkcionisanja ležaja;
- vibracije usled geometrijske nesavršenosti nastalih pri proizvodnji i montaži ležajeva; vibracije usled oštećenja elemenata ležaja prouzrokovane eksploatacijom, habanjem i oštećenjem staza kotrljanja,
- vibracije usled negativnog delovanja okoline ležaja [10,11].

Prema [11,12] stvaranje neuravnoteženih masa (debalansa) i pojavu vibracija izazivaju labavost sklopa, neodgovarajuće centriranjei ishabanost-pohabanost delova ležajeva. Merenjem veličina vibracija, dobijaju se podaci o trenutnim nedostacima mašina i to:

- radijalne vibracije merene u vertikalnom pravcu daju podatke o strukturalnoj slabosti,
- aksijalne vibracije merene duž linija osovina su obično rezultat pogrešnog centriranja, loše montiranih spojnica i savijenih osovina i
- horizontalne vibracije predstavljaju rezultat stanja ravnoteže.

MATERIJAL I METODE RADA

Pri oštećenju ležaja dolazi do njegovog zagrevanja, pojave šumova, buke i vibracija koje se mogu izmeriti, ili na određen način izračunati i uporediti sa preporukama proizvođača mašine i ležaja. U slučaju kada su pređene vrednosti granice upozorenja dolazi do oštećenja ležaja i povećanja vibracija preko dozvoljenih granica, pa ležaj treba zameniti novim. Danas postoje savremeni, precizni instrumenti za merenje vibracija, buke i temperature ležaja (vibromeri), koji mogu da se koriste pri praćenju i održavanju ležaja. Podaci korišćeni kao primer preuzeti su iz baze podataka koja sadrži niz senzorskih podataka prikupljenih sa simulatora za kvarove mašina, [11].

U radu je primer prepoznavanja stanja kotrljajućih ležajeva sproveden uz pomoć algoritama mašinskog učenja za klasifikaciju. Pri tome je korišćen Scikit-learn paket otvorenog koda namenjen za pružanje sveobuhvatne podrške metodama mašinskog učenja u programskom jeziku Pyhton, a koji je široko prihvaćen i koristi se u oblasti nauke o podacima. Python pored svojih osnovnih funkcionalnosti oslanja se takođe na eksterne pakete što omogućava gotovo sva numerička izračunavanja. Scikit-learn sadrži kolekciju efikasno implementiranih metoda mašinskog učenja koje su dobro dokumentovane i održavane od strane naučne zajednice, [12].

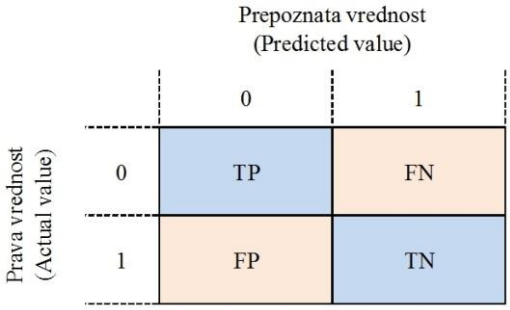
Predstavljeni model dubokog učenja namenjen za prepoznavanje nepovoljnog stanja kod rotirajućih delova sproveden je uz pomoć Keras biblioteke za veštačke neuronske mreže. Keras ima visok nivo apstrakcije, koji je relativno lak za korišćenje pošto je napisan u programskom jeziku Python. Keras je izgrađen nad baznom platformom koju čini TensorFlow biblioteka za neuronske mreže i lako može da koristi da pokrije svaki aspekt tokom realizacije dubokog učenja, [13].

Primenom metode mašinskog učenja preko signala vibracije, izvršena je dijagnostika pri čemu je prepoznat normalan rad ispravnih kotrljajnih ležajeva i rad ležajeva sa greškom u radu. Takođe, u slučaju stanja koje ukazuje na grešku primenom mašinskog učenja preko signala vibracije prepoznaje se kategorija problema (neuravnoteženost , horizontalna i vertikalna pomeranja ili oštećenje kotrljajnih staza).

Testiranje prikupljenih podataka na osnovu pokazatelja tačnosti i preciznosti izvršeno je primenom više metoda mašinskog učenja za klasifikaciju kao:

Support Vector Machine (SVM), K-Nearest Neighbors (KNN), Multi-layer Perceptron (MPP), Naive Bayes, Decision Tree, Gradient boosting, Bagging, XGBoost, AdaBoost, kao i Artifical Neural Network (ANN).

Dobijeni model nakon faze treniranja analiziran je pomoću konfuzione matrice (Confusion matrix) odnosno preko pokazatelja tačnosti (*Accurancy*) i preciznosti (*Precision*).



Slika 1. Konfuziona matrica
Figure 1. Confusion matrix

Na Slici 1. predstavljena je forma konfuzione matrice u slučaju binarne klasifikacije koja se može koristiti za utvrđivanje pozdanosti i primenjivnosti treniranog modela u predikciji novih vrednosti nad testnim podacima. Prema datoj postavci binarnih vrednosti (0 i 1), pozitivne vrednosti su označene sa 0, dok su negativne vrednosti označene sa 1. Redovi u matrici sa leve strane obeleženi su sa pozitivnim i negativnim vrednostima pravih vrednosti. Dok su kolone iznad matrice obelezeni sa pozitivnim i negativnim vrednostima predviđenih vrednosti. Unutar matrice nalaze se brojevi koji odgovaraju njihovim presecima odnosno koliko je pogođeno pravih vrednosti. Za prikazanu formu konfuzione matrice oznake su prestavljene na sledeći način:

TP – True Positive – broj tačnih pozitivnih vrednosti
FP – False Positive – broj pogrešnih pozitivnih vrednosti
FN – False Negative – broj pogrešnih negativnih vrednosti
TN – True Negative – broj tačnih negativnih vrednosti

Na osnovu predstavljenih vrednosti u matrici računaju se parametri tačnost i preciznost. Tačnost se izračunava prema obrascu 1.

$$Tacnost\,(Accuracy) = \frac{TP + TN}{TP + FN + FP + TN} \quad \text{.....(1)}$$

Preciznost se može izračunati isto iz predstavljenih podataka u matrici prema obrascu 2.

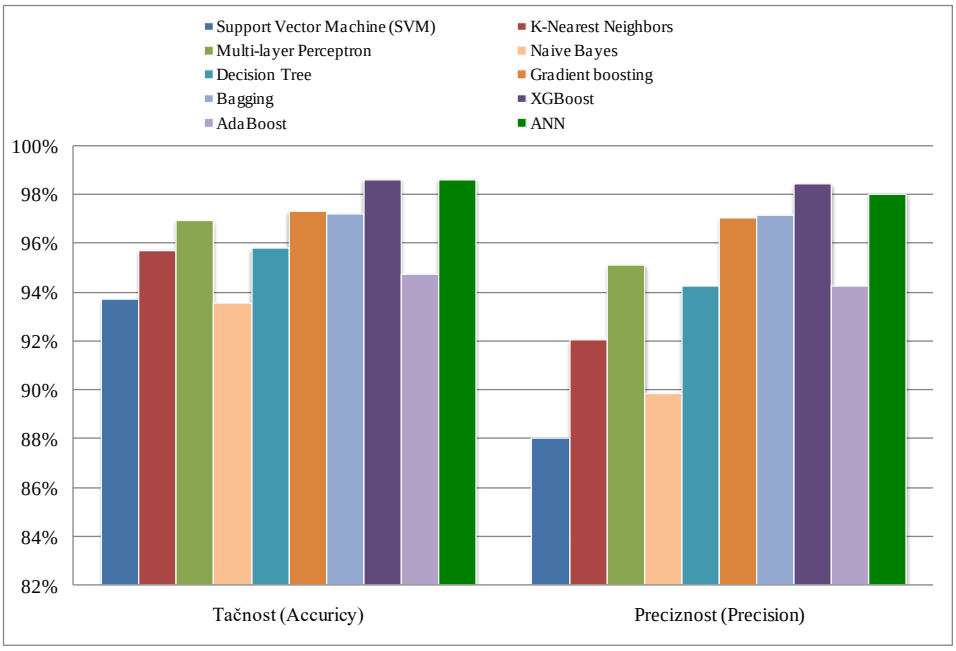
$$Preciznost\,(Precision) = \frac{TP}{TP + FP} \quad \text{.....(2)}$$

Za sve navedene algoritme mašinskog učenja vrši se proces treniranja i validacije modela a nakon toga vrši se testiranje nad novim podacima koji su unaped odvojeni za tu namenu. Proverava se sa kojim uspehom svaki od modela vrši klasifikaciju novog skupa podataka koristeći navedenu metriku, pre svega tačnost i preciznost.

REZULTATI ISTRAŽIVANJA I DISKUSIJA

Usled oštećenja ležajeva, neuravnoteženog (debalansa) i ekcentričnog kretanja, dolazi do pojave vibracija elemenata u malim amplitudama, za koje rukovaoc ne može da proceni da li su u dozvoljenim granicama ili nisu. Tek kasnije, prelaskom dozvoljenih granicai pojavom većih amplituda vibracija, nastaju veća oštećenja i kvarovi, pri čemu ležaji stvaraju buku koje čovek može da detektuje osluškivanjem. Kasno otkrivanje početka neispravnog stanja mašine dovodi do većih kvarova i otkaza. Na početku male i zanemarljive vibracije mogu se pojačati i izazvati značajno veće vibracije, neuravnoteženost i jaku buku ležajeva.

Merenje i analiza mehaničkih vibracija je zbog svoje pouzdanosti, najčešće upotrebljavana tehnika detekcije i lokalizacije oštećenja kotrljajnih ležajevana pogonskim i priključnim poljoprivrednim mašinama sa rotirajućim delovima. Kontinuirani monitoring vibracija pruža dovoljno informacija o stanju delova sistema traktora i mašina, čime se sprečava brzo širenje oštećenja i pojava otkaza.

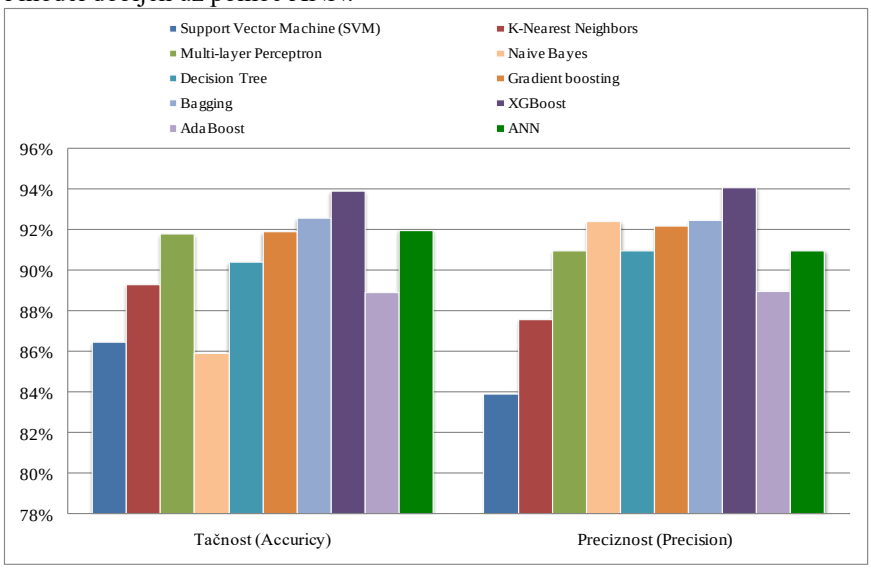


Grafik 1. Tačnost i preciznost kod modela sa dve kategorije podataka: normalno stanje i neuravnoteženo stanje (debalans)
Chart 1. Accuracy and Precision in models with two data categories for bearing: normal and inbalance state

U navedenoj postavci sistem za prikupljanje podataka čine dva akcelorometra, analognog tahometra i mikrofona. Na taj način su i organizovani podaci u tabelama, pri čemu prva kolona sadrži podatke sa tahometra za procenu učestalosti rotacije, zatim u sledećih šest kolona nalaze se po tri podatka sa akcelerometara na dve pozicije i sedma kolona predstavlja podatke sa mikrofona. Podaci su prikupljani u slučaju 5 stanja koji se mogu definisati kao normalno funkcionisanje, greška usled neravnoteže, greška usled horizontalne i vertikalne neusklađenosti i greška usled defekata na unutrašnjoj i spoljašnjoj traci ležajeva, [12].

Koncept formiranja i primene modela za prepoznavanje stanja ležajeva kod mašina prikazan je nad definisanim skupom podataka i primenom metoda mašinskog učenja kao što je opisano u drugom poglavlju - Metodici rada. Iz navedenog skupa podataka uzeti su podaci o vibracijama koje su prikupljene sa senzora u dve tačke i cilj je bio predvideti na osnovu njih kada su kotrljajnih ležajevi u normalnom rada, a kada imaju neku grešku. Zbog postojeće strukture podataka i ograničenih resursa na kojima je vršeno testiranje ideja je bila da se sprovede binarna klasifikacija. Izdvojeni su prvo podaci koji spadaju u dve kategorije, a to su podaci u normalanom radu i podaci sa greškom usled neuravnoteženosti ležajeva. Primenom algoritama mašinskog učenja treniran je model sa 75% postojećih podataka i nakon toga je testiran nad preostalih 25%. Metrika sa kojom je pokazana uspešnost prepoznavanja navedena dva stanja prikazana je na grafiku 1.

Na grafiku 1. mogu se uočiti visoke vrednosti za parametre tačnosti i preciznosti koji ukazuju da binarna klasifikacija može uspešno koristiti u prepoznavanju navedene dva slučaja, normalan rad ležajeva i u suprotnom rad ležajeva usled greške zbog neuravnoteženosti. Može se uočiti da se po najvišim procentulanim vrednostima detekcije stanja izdvajaju algoritimi XGBoost, Bagging, Gradient boosting, Multy-layer Perceptron, kao i model dobijen uz pomoć ANN.



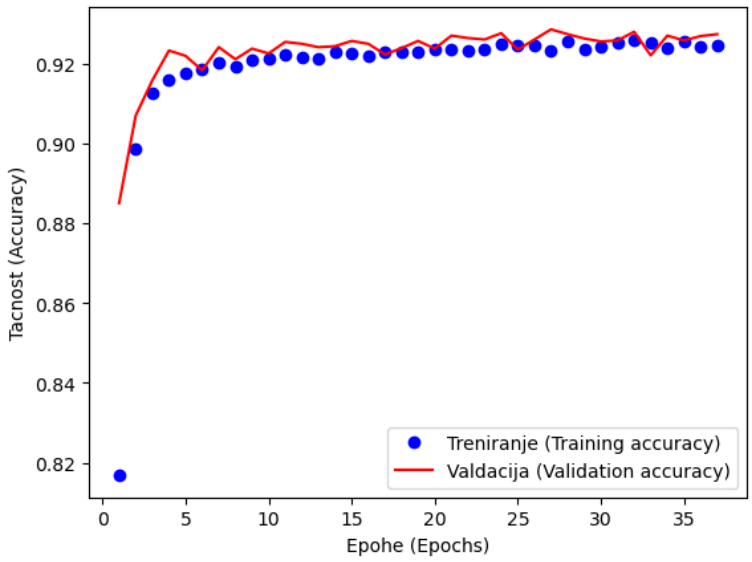
Grafik 2. Tačnost i preciznost kod modela sa dve kategorije podataka: normalno stanje i ležajevi sa problemom u radu

Chart 2. Accuracy and Precision in models with two data categories: normal state and bearing operation problems

Međutim pored navedenog slučaja kada se kod kotrljajnih ležajeva pojavi rad u neravnotežnom stanju mogu se javiti i drugi problemi. Kao što je navedeno u korišćenom primeru skupa podataka, uzeti su u obzir horizontalni i vertikalni pomeraji osovine, kao i oštećenja na unutrašnjoj i spoljašnjoj kotrljajnoj stazi ležajeva. Shodno tome potrebno je izvršiti klasifikaciju uzimajući u obzir i ostale navedene mogućnosti tako da je izvršena isto binarna klasifikacija između normalnog rada ispravnog ležaja, što predstavlja prvu kategoriju i svih ostalih navedenih defektnih stanja, što bi predstavljalo drugu kategoriju. Nakon testiranja modela dobijene vrednosti za tačnost i preciznost prikazane su prikazane na grafiku 2.

Na grafiku 2., može se uočiti da najbolje rezultate daje ista grupa algoritma kao u prethodnom slučaju pri čemu se još više izdvaja XGBoost algoritam. U ovom slučaju njegove vrednosti za tačnost i preciznost dostižu 94%.

Iako korišćeni algoritmi za klasifikaciju koji su učitani iz biblioteke scikit-learn daju iste prihvatljive vrednosti za tačnost realizovana je i jedna veštačka neuronska mreža (ANN). Tačnost u procesa treniranja i validacije modela tokom 40 epoha prikazan je na grafiku 3.



Grafik 3. Tačnost tokom treniranja i validacije modela
Chart 3. Accuracy during model training and validation

Ideja je bila da se model dobijen preko ANN može kasnije dodatno podešavati, odnosno da se iskoristi i u drugim sličnim slučajevima koji se odnose na vibracije kod ležajeva. Krerani model potencijalno može dalje biti upotrebljen u konceptu poznatom kao prenos učenja (Transfer learning) [16].

U slučaju detekcije nepovoljnog stanja preko binarne klasifikacije dalje se može izvršiti prepoznavanje kojoj kategoriji pripada problem koji je izazvao nepovoljan rad. Na kraju je izvršena klasifikacija koristeći algoritme mašinskog učenja kako bi se naknadno utvrdio uzrok koji je doveo do greške (Grafik 4).

Grafik 4. Tačnost i preciznost modela sa višestrukom klasifikacijom uzroka greške
Chart 4. Accuracy and precision in models with classification of fault causes

Može se uočiti da najbolje pokazatelje ima isto algoritam XGBoost i njegov model se može odabrati za prepoznavanje stanja rotirajućih ležajeva na osnovu vibracija. Za potrebe treniranja i validacije modela bili su potrebni računarski resursi visokih performansi, ali cilj je bio da se model prenese na uređaje koji su blizu mesta merenja i koje obično karakterišu ograničeni računarski resursi.

Treniranje modela i analiza bi bili izvršeni na Cloud platformi dok bi dobijeni model primenu mogao imati u okviru Fog računarstva [17]. Prema ovom konceptu model bi mogao biti upotrebljen za prepoznavanje stanja neposredno kod mesta merenja na računarski podržanim uređajima. Uređaji koji bi pripadali nivou Fog računarstva mogu se formirati uz pomoć Raspberry Pi [18] ili PYNQ Z2 [19] podrške. Ovakvi uređaji se mogu uključiti u mrežu direktno na lokaciji gde se preuzimaju podaci o vibracijama sa senzora i izvršiti klasifikaciju podataka bez potrebe za njihovim slanjem na Cloud.

ZAKLJUČAK

Dijagnostika i održavanje mehanizacije je oblik preventivnih aktivnosti stalnim praćenjem mašina dok su još u radu, pri čemu se interveniše samo ako određena mera odstupa od utvrđenih vrednosti. Za praćenje stanja ležajeva na mašinama koriste se napredne tehnike dijagnostike među kojima je veoma zastupljena analiza signala vibracija, a upravo je klasifikacija podataka o vibracijama primenjena u ovom radu.

Predstavljen je pristup kojim bi se vršila identifikacija stanja kotrljajnih ležajeva posredstvom modela mašinskog učenja. Navedeni model bi imao svoju ulogu u nadgledanju budućeg rada mašine i prepoznavanju neželjenih stanja ležajeva.

Otkrivanje greške u radu na osnovu vibracija u ranoj fazi doprinelo bi pravovremenoj reakciji korisnika, sprečavanju većih kvarova i ekonomskih gubitaka. Ideja je da se dobijeni model prenese na uređaje u okviru koncepta Fog računarstava i primenjuje u neposrednoj blizini radne mašine i operatera.

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APPLICATION OF MACHINE LEARNING FOR THE IDENTIFICATION OF THE ROLLING BEARINGS STATE IN AGRICULTURAL MECHANIZATION BASED ON VIBRATION

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Abstract: Mechanization maintenance represents preventive activities through constant monitoring of working parts of agricultural mechanization and timely intervention only if a certain measure deviates from the established values. Rolling bearings are one of the main components of rotating machines, and their properties directly affect the reliability of agricultural mechanization. The shorter service life of rolling bearings leads to lower reliability of agricultural mechanization, which is the consequence of inadequate technical maintenance and use. Bearing's condition monitoring on machines can be achieved by widely used methods that analyze vibration signals. This paper aims to apply a model obtained by machine learning to recognize the condition of rolling bearings with sufficient accuracy using vibration data. Normal states and states with bearing errors were taken into account so that the realized model could be used for early detection of unfavorable mechanic operation and prevention of major damages. Detecting the faulty conditions of rolling bearings based on vibrations at an early stage would contribute to the timely reaction of users, preventing major breakdowns and economic losses. The idea is to transfer the resulting model to devices within the concept of Fog computing and apply it close to the working machine and the operator.

Key words: *Machine learning, vibration, agricultural mechanization, bearings, error detection.*

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