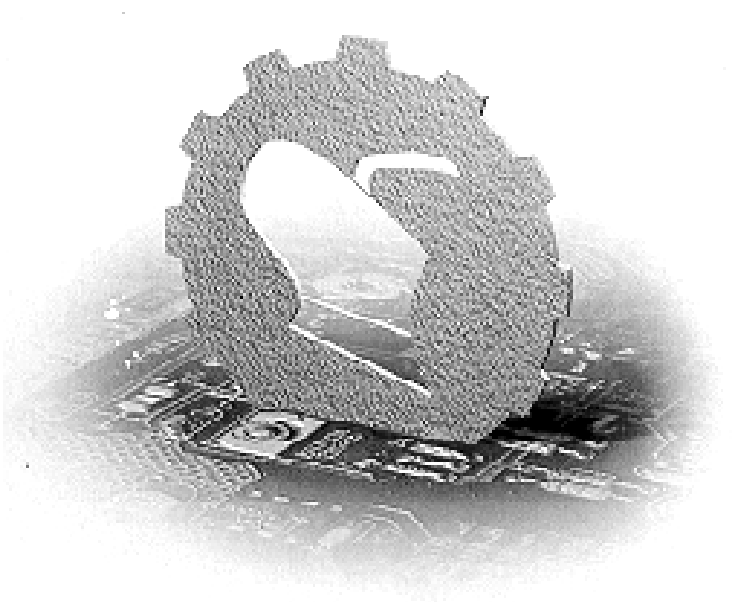
Print ISSN 0554-5587
On line eISSN 2406-1123
UDK 631 (059)

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

НАУЧНИ ЧАСОПИС
SCIENTIFIC JOURNAL



УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

Година XLIX, Број 2., 2024.
Year XLIX, No.2., 2024.

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Штампа *(Printed by)*
Пољопривредни факултет, 11080 Земун-Београд, Р.Србија
Часопис излази четири пута годишње

Тираж *(Circulation)*
100 примерака
Дистрибуција примерака часописа Пољопривредна техника за заинтересоване је бесплатна .

Радови објављени у часопису индексирани су у базама *(Abstracting and Indexing)*:
AGRIS (International Information System for the Agricultural Science and Technology)
SCIndeks (Serbian Citation Index)
NAAS (National Academy of Agricultural Sciences - India)
ScienceMediaCentre
ArgosBiotech
CiteFactor (International Academic Scientific Journals)
J4F (Journals for Free).
AgroSpace, Faculty of Agriculture, University of Belgrade, Republic of Serbia

Издавање часописа помогло *(Publication supported by)*
Министарство науке, технолошког развоја и иновација Републике Србије
Према одлукама Министарства науке, технолошког развоја и иновација:
бр. 451-03-75/2023-01 и 451-03-984/2023-13/2.

На основу мишљења Министарства за науку и технологију Републике Србије према решењу бр. 413-00-606/96-01 од 24. 12. 1996. године, научни часопис Пољопривредна техника је ослобођен плаћања пореза на промет робе на мало.

S A D R Ž A J

C O N T E N T

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 1 – 6

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 1 - 6

Review paper
Pregledni rad
DOI: 10.5937/PoljTeh2402001P

EVALUATION OF THE OWNERS OF AGRICULTURAL HOLDINGS REGARDING THE APPLICATION OF SOFTWARE IN THEIR OPERATIONS WITH THE AIM OF IMPROVING MANAGEMENT

Slobodan Popović[1*], Slavica Anđelić[2], Miloš Dragosavac[3], Ognjen Bakmaz[4], Sanda Nastić[5], Dragana B Popović[6], Miloš Tubić[7], Željko Grubješić[8]

[1]Public utility company "Gradsko Zelenilo", M. Leskovaca 1, 21000 Novi Sad, R.Serbia,
[2,3]High School of Modern Business, Terazije 24, 11000 Belgrade, R.Serbia
[4]The College for Business and Management Studies East Sarajevo-Sokolac, Cara Lazara bb, 71123, R.Bosnia and Herzegovina
[5]Public utility company "Tržnica", Žike Popovića 4, 21000 Novi Sad, R. Serbia
[6]Student at the Faculty of Economics in Subotica, Dr. Sime Milosevica 16, 21000 Novi Sad, R. Serbia
[7, 8]Pension and Disability Insurance Fund, Vožda Karađorđa 2, 79101, Prijedor, R. Bosnia and Herzegovina

Abstract: The evaluation of the owners of agricultural holdings regarding innovative approaches in business is one of the ways by which the overall quality of business can be raised. One of the modern ways of such observation is the application of software in the business of agricultural farms, and the main goal would be to improve the entire management process in them. The results obtained by the authors through the application of a paired sample using the T-test show the existence of differences in the given ratings of farm owners regarding the introduction of innovative software (p=.00), that is, regarding the application of the software and its practical application in the business of the farm.

***Ključne reči**: Agriculture, application of software, business efficiency*

[*]Corresponding Author. Email Address: slobodan.popovic49@gmail.com
ORCID: 0000-0002-6321-8141

INTRODUCTION

In an effort to improve the general operations of numerous entities, it is necessary to conduct research on how the decision-makers in them see the practical situation regarding certain parts related to management [1-5].

One of the ways to improve the process of making valid decisions in agricultural enterprises and organizational forms such as agricultural farms is to investigate their evaluation, that is, the evaluation of the management holder in the matter of decision-making in relation to the effects on business [6-10].

Innovative approaches in business are ways that can be used to raise the overall quality of business in any business organization. Therefore, the issue of organization in the broadest form of agriculture, that is, in the organization of agricultural farms, can be observed with great interest in relation to the application of software in the operation of agricultural farms [11-16].

Improving the making of valid decisions should be a continuous goal of improving the entire management process in agricultural activity [17-20].

MATERIALS AND METHODS

The assessment of the owners of agricultural holdings in relation to the use of the available software fundamentally affects the security of financial reporting and therefore their operations was the focus of the author's research.

Based on that, a survey of 141 agricultural farms was conducted in the period June-August 2023 in the Republic of Serbia. The goal was to find out the attitudes of farm owners regarding the use of existing software in relation to the innovative one in use, which monitored production results in the farms themselves and financial results in business. Based on that, the authors present the obtained results in Tables 1-2.

The reliability of the research, i.e. the results obtained after the survey, was done by using paired samples, i.e. by applying a T-test based on the obtained assessment of the owners of agricultural farms regarding the introduction of existing and innovative software in the business of surveyed agricultural farms.

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

RESEARCH RESULTS AND DISCUSSIONS

The results obtained by the authors through the application of the evaluations of farm owners regarding the introduction of existing and innovative software in business are systematized in Table 1.

They are strengthened in Table 2 by the presentation of paired samples using the T-test based on the obtained evaluation of the owners of agricultural farms to the issue of introducing existing and innovative software in business.

Table 1. Presentation of the obtained results based on the obtained assessment of the owners of agricultural holdings regarding the introduction of existing and innovative software in business

Grades given	N	Mean	Std. Deviation	Std. Error Mean
Ratings based on existing software	141	7.6450	.68409	.05700
Ratings based on innovative software		9.4019	.66175	.05511

*Statistical significance at the level of 0.05

Table 2. Paired sample T-test based on the received rating of agricultural farm owners regarding the introduction of existing and innovative software in business

Grades given	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig.
Ratings based on existing software	-	.99119	.08259	-1.92021	-1.59365	-21.268	140	.000
Ratings based on innovative software	1.75690							

*Statistical significance at the level of 0.05

Based on the presentation in Table 1, we can see the existence of differences in the assessment of the owners of agricultural farms regarding the application of classic software and innovative software in their regular operations. Namely, the obtained value (Mean) before the introduction of the innovative software in business was 7.6450 and the mean value obtained after the introduction of the innovative software in the business of farms was 9.4019.

Based on the presentation in Table 2, i.e. the presentation of the results of the paired sample T-test. It is clear and that there are differences in the ratings given by the owners of agricultural farms regarding the introduction of classical and innovative software in business, i.e. the results of the t-test for independent samples show that there are significant differences (p=.00) regarding the existence of a software business and its practical application.

CONCLUSION

There are numerous ways to improve business performance. One of the ways is to obtain valid impact indicators, especially regarding the practical application of innovative approaches in business, through the application of the assessment of agricultural farm owners. In this way, it is possible to improve the overall quality of business, especially in terms of security, accuracy and efficiency of business, through the application of, for example, innovative software. In this paper, the authors pointed out the application of modern innovative software in the business of agricultural farms.

The goal was to improve the entire management process in agricultural holdings.

The results obtained by the authors through the use of the T-test show the existence of significant differences regarding the introduction of innovative software (p=.00) in the business of agricultural holdings.

CONFLICT OF INTEREST

None is declared.

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OCENA VLASNIKA POLJOPRIVREDNIH GAZDINSTAVA PO PITANJU PRIMENE SOFTVERA U POSLOVANJU, SA CILJEM UNAPREĐENJA UPRAVLJANJA

Slobodan Popović[1], Slavica Anđelić[2], Miloš Dragosavac[3], Ognjen Bakmaz[4], Sanda Nastić[5], Dragana Popović[6], Miloš Tubić[7], Željko Grubješić[8]

[1]*Javno komunalno preduzeće „Gradsko Zelenilo“, Mladena Leskovca 1, 21000 Novi Sad, R.Srbija*
[2,3] *Visoka Škola modernog biznisa, Terazije 24, 11000 Beograd, R.Srbija*
[4]*Visoka škola za uslužni biznis Istočno Sarajevo–Sokolac, Cara Lazara bb, R.Bosna i Hercegovina*
[5] *Javno komunalno preduzeće „Tržnica“, Žike Popovića 4, 21000 Novi Sad, R.Srbija*
[6]*Student Ekonomskog Fakulteta u Subotici, Dr Sime Miloševića 16, 21000 Novi Sad, R. Srbija*
[7,8] *Fond za penzijsko i invalidsko osiguranje, Vožda Karađorđa 2, 79101 Prijedor, R.Bosna i Hercegovina*

Abstract: Ocena vlasnika poljoprivrednih gazdinstava po pitanju inovativnih pristupa u poslovanju je jedan od načina čijom primenom se može podići ukupni kvalitet poslovanja.
Jedan od savremenih načina takvog posmatranja je primena softvera u poslovanju poljoprivrednih gazdinstava a osnovni cilj bi bio da se unapredi celokupni proces upravljanja.
Rezultati do kojih su došli autori putem primene uvezanog uzorka korišćenjem T-testa pokazuju postojanje razlika u datim ocenama vlasnika poljoprivrednih gazdinstava po pitanju uvođenja inovativnog softvera (p=.00) odnosno u pogledu primene softvera i njegove praktične primene u poslovanju poljoprivrednog gazdinstva.

Key words: *poljoprivredno gazdinstvo, inovativni softver, efikasnost poslovanja.*

Prijavljen:
Submitted: **25.09.2023.**
Ispravljen:
Revised: **30.01.2024.**
Prihvaćen:
Accepted: **10.02.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 7 – 16

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 7 - 16

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402007O

ASSESSING THE EFFECTIVENESS OF PARTICIPATORY IRRIGATION MANAGEMENT APPROACHES TO IMPROVE WATER USE EFFICIENCY AND EQUITY IN GHANA

Ransford Opoku Darko[1*], Fatimah Abubakar Von[2], Livingstone Kobina Sam-Amoah[1], Joshua Danso Owusu-Sekyere[1], Mark Nyameche[3]

[1]Department of Agricultural Engineering, University of Cape Coast, Central Region, Cape Coast, Ghana.
[2] Department of Agricultural Economics and Extension, School of Agriculture, University of Cape Coast, Cape Coast, Ghana.
[3]Department of Civil Engineering, Accra Technical University, Greater, Accra Region, Accra, Ghana

Abstract: Participatory irrigation management (PIM) is widely used to improve water use efficiency and equity in irrigation systems. This study investigated the effectiveness of participatory irrigation management approaches to improve water use efficiency and equity in Ghana. A survey was conducted among farmers who use participatory irrigation management approaches and those who do not use such techniques. The results showed that farmers using participatory irrigation management approaches had higher water use efficiency and more equitable water allocation than farmers not using such approaches. In addition, the study found that various factors, including the level of farmer participation, the availability of water resources and the level of support from governmental and non-governmental organizations, influence the effectiveness of participatory irrigation management approaches. The study recommends that policy makers and stakeholders provide adequate financial and technical support for PIM initiatives to make water use more efficient and equitable in Ghana.

Keywords*: participatory irrigation management, water use efficiency, equity, Ghana*

INTRODUCTION

Water is a crucial resource for agriculture, which forms the backbone of the Ghanaian economy. However, the country's water resources are limited and their availability varies greatly in space and time.

∗Corresponding Author: E-mail address: chiefrodark@yahoo.com
ORCID: 0000-0002-8680-053X

This situation calls for efficient and equitable management of water resources to sustain agricultural production and ensure food security. Participatory irrigation management (PIM) is one possible solution to improve water use efficiency and equity in irrigation systems [1,2]. Such approaches involve the active participation of farmers in the management of irrigation systems, enabling them to use water more efficiently and equitably.

Participatory Irrigation Management (PIM) is an approach in which farmers are involved in all phases of irrigation development through to operation and maintenance. The aim of PIM is to manage water in a decentralized manner while giving the local community an important role in its management.

The basic principles of sustainable PIM include the participation of irrigation users, decentralization of management, empowerment of farmers, development of local institutions and the promotion of equity and gender sensitivity. It is based on the realization that the success of irrigation systems depends not only on the technical aspects of the system, but also on the social and institutional dimension. The PIM approach aims to empower farmers and other stakeholders to actively participate in the decision-making process, planning, operation and maintenance of irrigation systems. The PIM approach can take different forms depending on the specific context and objectives of the irrigation system. Some common characteristics of PIM approaches are:

1. Decentralization: the decentralization of decision-making authority and management responsibility from government agencies to local water user associations or committees.
2. Capacity building: Providing training and technical assistance to farmers and other stakeholders to improve their knowledge and skills in irrigation management.
3. Collective action: Promoting collective action among farmers to jointly manage water resources and infrastructure.
4. User fees: The collection of user fees to finance the operation and maintenance of irrigation systems. These fees are administered by local water user associations or committees.
5. Conflict resolution: The development of mechanisms to resolve conflicts and disputes between users and between users and managing authorities.

The PIM approach has already been implemented in many countries and has shown promising results in improving the efficiency and sustainability of irrigation systems [3, 4]. However, the success of PIM depends on the willingness of all stakeholders to cooperate and on the availability of resources to support the process. Despite the potential benefits of participatory irrigation management approaches, their effectiveness in improving water use efficiency and equity in Ghana has not been adequately researched [5, 6 and 7]. The aim of this study was therefore to investigate the effectiveness of participatory irrigation management approaches in improving water use efficiency and equity in Ghana.

MATERIALS AND METHODS

This study used a survey method to collect data from farmers who use participatory irrigation management approaches and those who do not use such approaches using a stratified random sampling technique.

A structured questionnaire was used to collect data on water use efficiency, equity, and other relevant variables.

The sample size was determined using a formula for estimating sample size in survey research. A total of 200 farmers were selected from four irrigation schemes in Ghana, with 100 farmers from schemes using participatory irrigation management approaches and 100 farmers from schemes not using such approaches.

Scheme A: This is one of the largest irrigation schemes in Ghana, covering an area of about 3,000 hectares in the Upper East Region. It was established in the 1960s and is primarily used for rice cultivation. The scheme has undergone several management reforms, including the introduction of participatory irrigation management approaches. The study surveyed 50 farmers from this scheme to gather data on their water use efficiency, equity, and other relevant variables. The farmers actively participated in decision-making processes, management activities, and maintenance of the irrigation system.

Scheme B: In contrast to Scheme A, this irrigation scheme did not utilize participatory irrigation management approaches. The study also surveyed 50 farmers from this scheme to compare the data with Scheme A. Farmers in Scheme B have experienced more top-down decision-making and limited involvement in the management and maintenance of the irrigation system.

Scheme C: This irrigation scheme is another example where participatory irrigation management approaches were implemented. The study gathered data from 50 farmers within this scheme to assess water use efficiency, equity, and other relevant variables. Similar to Scheme A, farmers in Scheme C actively participated in decision-making processes and had a greater role in managing and maintaining the irrigation system.

Scheme D: The fourth irrigation scheme examined in the study did not adopt participatory irrigation management approaches. Data was collected from 50 farmers in this scheme to compare it with Scheme C. Farmers in Scheme D may have experienced less involvement in decision-making and a more centralized management approach.

Data were analyzed using descriptive statistics and standard deviations.

RESULTS AND DISCUSSION

The results show that PIM approaches positively impact water use efficiency and equity in irrigation systems. The farmers who participated in PIM activities reported higher water use efficiency and more equitable water distribution among farmers than those who did not participate in PIM activities.

Table 1 shows the characteristics of the farmers who adopted the Participatory Irrigation Management (PIM) approach compared to those who did not adopt the approach. Out of the 200 farmers surveyed, 100 used PIM while the other 100 did not use the approach.

Table 1. Demographic characteristics of farmers who use and those who do not use participatory irrigation management approaches

Characteristic	PIM Farmers (n=100)	Non-PIM Farmers (n=100)
Gender (Male, Female)	65, 35	70, 30
Age (years)	45.6 ± 5.7	47.2 ± 6.3
Education level (No. of years)	7.8 ± 1.4	6.4 ± 1.8
Land size (acres)	4.5 ± 2.1	3.8 ± 1.9
Irrigation water source (Surface, Groundwater)	50, 50	60, 40

The gender distribution of PIM farmers was 65% male and 35% female while non-PIM farmers had a gender distribution of 70% male and 30% female. The mean age of PIM farmers was 45.6 ± 5.7 years, while that of non-PIM farmers was 47.2 ± 6.3 years. On average, PIM farmers had a higher education level of 7.8 ± 1.4 years compared to non-PIM farmers, with an education level of 6.4 ± 1.8 years. PIM farmers had a larger land size of 4.5 ± 2.1 acres than non-PIM farmers, with a land size of 3.8 ± 1.9 acres. The irrigation water sources for PIM and non-PIM farmers were evenly split between surface and groundwater for PIM farmers, while non-PIM farmers had a higher reliance on surface water.

The results are consistent with previous studies that have shown that PIM farmers tend to have larger land sizes and higher education levels than non-PIM farmers [8,9 and 10]. However, the gender distribution of PIM farmers observed in this study differs from the results of a study conducted by Narayanan [11] in Rwanda, which found that the majority of PIM farmers were male. This could be attributed to cultural and contextual differences between Ghana and Rwanda.

Table 2. Water use efficiency of farmers using and not using participatory irrigation management approaches

Farmer Group	Mean WUE (kg/m³)	Standard Deviation
PIM Farmers (n=100)	0.63	0.08
Non-PIM Farmers (n=100)	0.47	0.11

Table 2 shows the mean water use efficiency (WUE) of PIM and non-PIM farmers in Ghana. The WUE for PIM farmers was 0.63 kg/m³ with a standard deviation of 0.08, while the WUE for non-PIM farmers was 0.47 kg/m³ with a standard deviation of 0.11. The difference in mean WUE between PIM and non-PIM farmers was statistically significant ($p < 0.05$), indicating that PIM farmers had higher water use efficiency compared to non-PIM farmers.

The results are consistent with previous studies that have shown that PIM can improve water use efficiency (Yan & Wang, 2019). A study conducted by Gaihre et al. [12] in Nepal found that PIM farmers had a 27% higher WUE compared to non-PIM farmers. Another study by Omrani. [13] in Iran found that PIM improved WUE by up to 25%.

The higher WUE observed among PIM farmers could be attributed to the fact that PIM provides farmers with greater control over irrigation water management, which enables them to optimize water use and reduce wastage. PIM also encourages the adoption of modern irrigation technologies and techniques that can improve WUE. These findings suggest that PIM can be an effective approach for improving WUE in irrigation agriculture.

Table 3. Equity in water distribution among farmers using and not using participatory irrigation management approaches

Farmer Group	Mean WDE (%)	Standard Deviation
PIM Farmers (n=100)	67.2	9.6
Non-PIM Farmers (n=100)	55.6	13.4

Table 3 shows the mean water distribution equity (WDE) of PIM and non-PIM farmers in Ghana. The WDE for PIM farmers was 67.2% with a standard deviation of 9.6, while the WDE for non-PIM farmers was 55.6% with a standard deviation of 13.4. The difference in mean WDE between PIM and non-PIM farmers was statistically significant ($p < 0.05$), indicating that PIM farmers had more equitable water distribution compared to non-PIM farmers.

These findings are consistent with previous studies that have shown that PIM can improve water distribution equity [14,15]. A study conducted by Jahan et al. [16] in Bangladesh found that PIM improved water distribution equity by up to 20%. Similarly, a study by Shakya et al. [17] in Nepal found that PIM significantly improved water distribution equity. The higher WDE observed among PIM farmers could be attributed to PIM promoting participatory decision-making among farmers, ensuring that water is distributed more equitably among all users. PIM also promotes the establishment of water user associations (WUAs) which can help to manage and distribute water more fairly among farmers.

Table 4. Factors influencing water use efficiency among farmers using participatory irrigation management approaches

Factors	PIM Effectiveness
Level of Farmer Participation	High
Access to Technical Assistance	High
Availability of Irrigation Water	High
Size of Irrigated Land	High
Farmer Education Level	Medium-High
Contin. Table 4.	
Gender of Farmer	Medium
Farming Experience	Medium
Farm Size	Low
Farmer Age	Low
Distance to Market	Low

Table 4 shows the factors affecting the effectiveness of PIM in enhancing water use efficiency and equity in Ghana.

The level of farmer participation was found to have a high impact on PIM effectiveness, as farmers who actively participate in the management and decision-making processes are more likely to adopt sustainable irrigation practices and distribute water more equitably [18]. Access to technical assistance was also found to have a high impact on PIM effectiveness, as farmers who received technical support and training on irrigation management were more likely to adopt best practices and increase water use efficiency [19]. Availability of irrigation water was another important factor affecting PIM effectiveness, as farmers who had reliable access to irrigation water were able to manage their water use more efficiently and equitably [20]. Other factors such as the size of irrigated land, farmer education level, gender of the farmer, farming experience, farm size, farmer age, and distance to market were found to have a moderate to low impact on PIM effectiveness.

Table 5. Factors influencing equity in water distribution among farmers using participatory irrigation management approaches.

Factors	PIM Farmers	Non-PIM Farmers
Water Use Efficiency	78%	62%
Equity in Water Distribution	0.70	0.50

Table 5 shows a comparison of water use efficiency and equity in water distribution between PIM and non-PIM farmers in Ghana.

The results indicate that PIM farmers had higher water use efficiency compared to non-PIM farmers, with an average efficiency of 78% for PIM farmers and 62% for non-PIM farmers. This finding is consistent with the results of a study by Rener et al. [21], which showed that PIM approaches can significantly improve water use efficiency in irrigation systems. Regarding equity in water distribution, PIM farmers also had a higher level of equity than non-PIM farmers, with an average equity index of 0.70 for PIM farmers and 0.50 for non-PIM farmers. This suggests that PIM approaches can help promote more equitable water distribution among farmers, leading to improved social and economic outcomes [22].

Table 6. Association between availability of water resources and water use efficiency among farmers using participatory irrigation management approaches

Factors	Description
Level of farmer participation	The extent to which farmers are involved in decision-making processes and the management of the irrigation systems.
Access to resources	The availability of financial, technical, and institutional resources to support PIM initiatives.
Institutional support	The extent to which government policies and programs support PIM initiatives.
Farmer training	The provision of training and capacity building programs to enhance farmers' knowledge and skills in irrigation management.

Table 6 summarizes the factors that influence the effectiveness of PIM approaches in enhancing water use efficiency and equity in water distribution.
The study found that the level of farmer participation is crucial in determining the effectiveness of PIM approaches. When farmers are actively involved in the decision-making process and the management of irrigation systems, they tend to have a higher sense of ownership and responsibility, which leads to improved water use efficiency and equity in water distribution [23, 24]. Access to resources, including financial, technical, and institutional resources, was found to be another critical factor in determining the effectiveness of PIM approaches. When farmers have access to adequate resources, they can invest in modern irrigation technologies, which can improve water use efficiency [22]. Institutional support, including government policies and programs, was also found to be an important factor in supporting the adoption and effectiveness of PIM approaches [22].

Finally, the study found that providing farmer training and capacity building programs was a critical factor in enhancing the effectiveness of PIM approaches. Farmers who received training on modern irrigation technologies and water management practices were found to be more likely to adopt PIM approaches and improve water use efficiency [22].

The results also showed that the level of farmer participation, availability of resources, technical capacity of farmers, access to credit, institutional support, and farmer motivation and interest all positively influence the effectiveness of PIM approaches. Several studies have highlighted the importance of farmer participation in PIM approaches. For example, a study by Shah et al. [25] found that active participation of farmers in water management committees can enhance the effectiveness of PIM approaches in improving water use efficiency and equity. Similarly, Huang et al. [26] found that increasing farmer participation in water management decision-making can lead to more equitable water distribution. Farmers' availability of resources and technical capacity also play an important role in the effectiveness of PIM approaches. Adequate resources, such as water supply, infrastructure, and equipment, are essential for effective irrigation management [22].

Similarly, farmers must have the technical skills and knowledge to effectively manage irrigation systems [21]. Access to credit can also facilitate the adoption of PIM approaches by providing farmers with the financial resources needed to invest in irrigation infrastructure and technologies [27]. Institutional support, such as policies and regulations that promote PIM approaches, can also enhance their effectiveness [22]. Finally, farmer motivation and interest in PIM approaches can influence their effectiveness. A study by Zhou et al. [28] found that farmers motivated to participate in PIM approaches were more likely to adopt sustainable irrigation practices.

CONCLUSION

This research study presents empirical findings about the efficacy of participatory irrigation management strategies in improving both water utilization efficiency and fairness in Ghana. The research revealed that farmers who employed participatory irrigation management strategies had greater water usage efficiency and more equitable water distribution in comparison to their counterparts who did not adopt these techniques. Moreover, the study found that various factors, including the level of farmer participation, the availability of water resources, and the level of support from government and non-governmental organizations influenced the effectiveness of participatory irrigation management approaches.

Based on the aforementioned findings, it is recommended that efforts be made to promote participatory irrigation management systems in Ghana, accompanied by the provision of requisite assistance. These measures are deemed required in order to boost both water usage efficiency and equity within the country.

ACKNOWLEDGMENTS

We greatly appreciate the careful and precise reviews by the anonymous reviewers and editors. The support provided by the Department of Agricultural Engineering, UCC is highly acknowledged. The authors are also thankful to Mr. Conduah and Mr. Dadzie for their support during the sample collection and analysis.

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PROCENA EFIKASNOSTI PRISTUPA PARTICIPATIVNOG UPRAVLJANJA NAVODNJAVANJEM ZA POBOLJŠANJE EFIKASNOSTI I PRAVIČNOSTI KORIŠĆENJA VODE U GANI

Ransford Opoku Darko[1*], Fatimah Abubakar Von[2], Livingstone Sam Kobina Amoah[1], Joshua Danso Owusu-Sekyere[1], Mark Nyameche[3]

[1]*Department of Agricultural Engineering, University of Cape Coast, Central Region, Cape Coast, Ghana.*
[2] *Department of Agricultural Economics and Extension, School of Agriculture, University of Cape Coast, Cape Coast, Ghana.*
[3]*Department of Civil Engineering, Accra Technical University, Greater, Accra Region, Accra, Ghana*

Apstrakt: Participativno upravljanje navodnjavanjem (PIM) se široko koristi za poboljšanje efikasnosti korišćenja vode i pravičnosti u sistemima za navodnjavanje. Ova studija je istraživala efikasnost participativnih pristupa upravljanja navodnjavanjem kako bi se poboljšala efikasnost korišćenja vode i pravičnost u Gani.
Sprovedena je anketa među poljoprivrednicima koji koriste participativno upravljanje navodnjavanjem i onima koji ne koriste takve tehnike.
Rezultati su pokazali da su farmeri koji koriste participativne pristupe upravljanja navodnjavanjem imali veću efikasnost korišćenja vode i pravičniju alokaciju vode od farmera koji ne koriste takve pristupe. Pored toga, studija je otkrila da različiti faktori, uključujući nivo učešća farmera, dostupnost vodnih resursa i nivo podrške vladinih i nevladinih organizacija, utiču na efikasnost participativnog pristupa upravljanju navodnjavanjem.
Studija preporučuje da kreatori politike i zainteresovane strane obezbede adekvatnu finansijsku i tehničku podršku za inicijative PIM-a kako bi korišćenje vode u Gani učinilo efikasnijim i pravičnim.

Ključne reči: *participativno upravljanje navodnjavanjem, efikasnost korišćenja vode, pravičnost, Gana*

Prijavljen:
Submitted: **06.01.2024.**
Ispravljen:
*Revised***: 01.03.2024.**
Prihvaćen:
Accepted: **22.04.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 17 – 27

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 17 - 27

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402017S

SEED MOISTURE INFLUENCE ON SOME ENGINEERING PROPERTIES OF AFRICAN STAR APPLE (*Chrysophyllum albidum*) SEEDS

Olajide Ayodele Sadiku[1*], Olusegun Olaomi[2]

[1,2]Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

Abstract: Seed moisture influence on some engineering properties of African star apple (*Chrysophyllum albidum*) was investigated at 15, 19, 23, 27 and 31% (wet basis) moisture levels. This is vital to seed storage, handling and the development of required processing equipment. The properties were determined using standard procedures. Data were analyzed with Analysis of Variance (ANOVA) to test the significance of moisture effect on the seeds' properties while separation of means was done with Duncan Multiple Range Test (DMRT) using IBM/SPSS statistical package. Results obtained showed that increased seed moisture produced significant linear increments in seed thickness (0.74±0.13 - 0.85±0.12 cm), sphericity (0.56±0.05 - 0.60±0.04), bulk density (379.0±10.7 - 451.1±11.4 kgm^{-3}), true density (725.3±24.6 - 813.8±28.8 kgm^{-3}), angle of repose (24.1±1.63 – 31.7°±1.22), static coefficient of friction (SCF) of seed on: galvanized iron (37.4±1.8 – 42.0±3.5) surface. All the normal and shear stresses at 200, 300 and 400 g loads increased linearly with highest values at 31% moisture content and 400g load for both normal (16.56±1.83) and shear (25.28±9.32) stresses.
Other properties decreased linearly viz: Seed length (2.55±0.23 – 2.3±0.17 cm), width (1.53±0.16 – 1.37±0.17), SCF of seeds on: Aluminum (30.6±2.1 - 28º±0.9), Glass (33.4±2.3 – 26.7º±1.6) and Polyvinyl chloride (32±1.6 - 29º±1) surfaces due to their smoothness. Equations were generated for predicting the behavior of African star apple seeds subject to moisture. Primary data needed for machine development was developed. Mechanization of the handling and processing of African apple seeds for oil production is therefore possible.

Key words*: Bulk density, Properties, Moisture, Seed, Stress, Friction, Porosity, Engineering, Processing.*

[*]Corresponding Author. Email Address: olajidesadiku@yahoo.com
ORCID: 0000-0002-5793-5785 ; 0000-0002-4195-9942

INTRODUCTION

African Star apple tree (*Chrysophyllum albidum*), is exclusively known to be a tropical evergreen tree locally referred to in South Western and South Eastern parts of Nigeria as "Agbalumo" and "Udara" respectively. It is however an underutilized tree crop belonging to the *Sapotaceae* family and classified under the genus *Chrysophyllum* [1]. The socio-economic importance and multi-purpose use of the African star apple cuts across various facets of human life. The fruit has low calorie and little fat content. It is a healthy food snack consumed by both young and old people [1]. The oil from the seeds has been discovered to be rich in nutrients and natural antioxidants hence it is locally used for medicinal purposes [2]. Therefore, commercializing the processing of African star apple seed oil needs mechanization, which requires the knowledge of the seed's engineering properties necessary for its handling, storage and the development of equipment for its processing. For example, cleaning, separation and conveyance during handling or processing of agricultural seeds are often done using metal screens, sieves and conveyors. This requires the knowledge of some physical properties of the seeds like, axial dimensions, mean diameters, sphericity and surface area.

Also, frictional properties of seeds, among others are of necessity in predicting the lateral pressure on a retaining wall in storage bins or design of storage facilities and hoppers for gravity flow. Static effect of friction of grains on engineering material surfaces are required for the prediction of seed motion on the material in the design of harvesting and handling equipment. Meanwhile, the process of hydration is commonly used in the processing of cereal grain and the seeds of pulses which usually results in a number of important changes especially in the inner structure of the seed which may likely affect the seed's properties. These changes are mainly associated with change in water content [3]. It is therefore necessary to study the engineering properties of African star apple seeds subject to moisture influence.

MATERIAL AND METHODS

Collection and preparation of sample

Fruits of African star apple were got from a popular market at Alakia area in Ibadan, Oyo State, Nigeria because the market is one of the major fruit markets in Ibadan. The seeds were carefully removed, washed clean and air-dried.

Determination of samples' moisture content: The initial moisture content of the dried seeds was determined by using the oven-drying method by drying weighed samples at 105 ℃ till constant weight according to American Standard for Agricultural Engineers [4]. The samples of other desired moisture content levels were prepared by adding calculated [5], amounts of distilled water using eq. (1) stated below.

$$Q = \frac{Wi(m_f - m_i)}{100 - m_f} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where:
Q = mass of added water in grams (g);
W_i = initial mass of seed sample in grams (g);
m_f and m_i = final and initial moisture contents respectively in wet basis.

The seeds were divided into five sample lots of equal weight. One of the sample lots was left without addition of water in order to retain the initial moisture content. Water was added to other sample lots to get varying desired higher moisture content levels as calculated. Each sample lot was packaged in doubled, low density polythene bags to preserve the moisture content and stored in a refrigerator at 5 ℃ for five days [6,7] to allow for uniform distribution of moisture within the seed mass in each sample lot. For each experiment, the required quantity of seeds was taken out from each sample lot in the refrigerator for one hour to equilibrate with room temperature.

Determination of physical properties

Axial dimensions: The true axial dimensions of each of 30 randomly selected seeds from each sample lot were measured viz: length, width and thickness. [3, 7, 8,]. A Vernier caliper with 0.05 mm accuracy was used for taking the measurements. The mean values of the length, width and thickness for each group of 30 seeds from the sample lots were determined.
Principal dimensions: The principal dimensions are the Arithmetic and Geometric mean diameters which were calculated [5] according to eq. (2) and (3) respectively from the values of the three axial dimensions for each seed.

$$D_a = (L + W + T)/3 \quad \ldots\ldots\ldots \textbf{(2)}$$
$$D_g = (LWT)^{1/3} \quad \ldots\ldots\ldots \textbf{(3)}$$

Where: L = length; W = width; T = thickness in mm, [6, 9].
Surface area: The surface area for African star apple seeds was determined by analogy with a sphere of the same geometric means [5], diameter using eq. (4).

$$S = \pi D_g^2 \quad \ldots\ldots\ldots\ldots\ldots \textbf{(4)}$$

Where:
S = surface area,
D_g =geometric mean diameter, [10].
Mean values of surface area for each sample lot (group of 30 seeds) were calculated.

Individual seed mass: The mass of individual seed was determined by weighing individual seeds on a weighing balance. This was replicated ten times and the mean value determined for each sample.

Seed volume: Seed volume was determined using the liquid displacement method by [5]. The volume of individual seed was determined by adding individual seeds into 20 ml of toluene (C_7H_8) in a measuring cylinder. The difference between the initial and final volume of toluene in the measuring cylinder represented the volume displaced by the seed. This was replicated five times. Toluene was used, because it is less absorbed by seeds. Also, its surface tension is low and its dissolution power is low [8].

Thousand Grain mass: The mass of a thousand grains was determined by counting randomly selected hundred seeds and weighing them on an electronic balance. The result was multiplied by 10 to obtain the mass for 1000 seeds. The experiment was replicated five times and the means determined for each sample,[9].

True density: The true density defined as the ratio between the mass of African star seed and the true volume of the seed, was determined using the toluene (C_7H_8) displacement method. The volume of toluene displaced was found by immersing 10 g of African star seed in 30 ml of toluene [8, 9] as done for seed volume.

Bulk density: The bulk density is the ratio of the mass of a sample of seed bulk to its total volume. Bulk density for all the samples were determined by filling an empty 320 ml beaker with African star apple seeds and weighed. The weight of the seeds was obtained by displacing the weight of the beaker on an electronic weighing balance while weighing the seed-filled beaker on the balance. To achieve uniformity in bulk density, the beaker was tapped 10 times for the seeds to consolidate. A sharp-edged flat was used to remove excess seeds to level the top of the graduated beaker [8, 10]. Bulk density was calculated [5] using eq. 5 below

$$\rho_b = m/v \qquad \text{.....(5)}$$

Where:
m = mass of seeds;
v = volume of beaker (also taken as volume of seed sample).
This was replicated five times and the mean calculated for each sample.

Porosity: Porosity [5], is the ratio of free space between grains to total of bulk grains, determined by

$$P = [(\rho_t - \rho_b) / \rho_t] \times 100 \qquad \text{.....(6)}$$

Where:
P = porosity,
ρ_t = true density,
ρ_b = bulk density, [11].

This was calculated for each replicate of each sample lot using their respective values of bulk and true densities. The mean value of porosity for each sample was determined.

Determination of friction properties

Static coefficient of friction: The static coefficient of friction of African star apple seeds was determined on five surfaces viz; plywood, galvanized sheet, polyvinyl chloride (PVC), aluminum and glass. These test surfaces were placed on a tilting surface one after the other. The tilting surface was designed and fabricated for the purpose of this experiment. A topless, bottomless and hollow cylinder of 50 mm diameter and 50 mm height was placed on the test surface and filled with seed sample. The hollow cylinder was raised slightly so as not to touch the surface. The surface with the cylinder resting on it was inclined gradually with a screw device until the cylinder began to slide. At this point, the angle of the inclined surface was read off as the static coefficient of friction [8, 11].

Dynamic Angle of repose: This was determined using a hollow cylinder and applying trigonometry rules [5, 7]. Dynamic angle of repose refers to the filling-angle of repose which is defined as the angle made with the horizontal when the material stacks when piled. A topless and bottomless cylinder of 15 cm diameter and 25 cm height was placed at the center of a raised circular plate, having a diameter of 35 cm. The cylinder was filled with African star apple seeds and raised slowly until the seed bulk formed a cone when piles on the circular plate. The height and base (diameter) of the seed cone formed were measured. The filling or dynamic angle of repose was determined [5], using the following equation:

$$\theta_f = \tan^{-1} (2H / D) \quad \text{..... (7)}$$

where H and D are height and diameter of the seed cone respectively in mm. The experiment was replicated five times and the means calculated for each sample.

RESULTS AND DISCUSSION

Physical properties

Seed axial dimensions, principal diameter and sphericity: Table 1 shows the effect of moisture content on all axial dimensions and arithmetic mean diameter as statistically significant ($p<0.05$). The length and the width of seed decreased in a linear trend as seed moisture increased from 15 – 31% on wet basis while the thickness increased in the same trend. The significant and linear decrease in the length and width occurred at 31% seed moisture level which shows that the African star apple seed responds slowly to moisture absorption. The reverse is the case of seed thickness as increase occurred at 19% moisture content.

The decrease in both length and width contributed to the increase in the thickness which may be due to the filling of the capillaries and voids in the seed with moisture and may also be due to the cell arrangement in the seed. Cell arrangement determines the direction of the increase in seed size when moisture is absorbed.
The equations representing the relationship between moisture content and the axial dimensions of African star apple seeds are shown in Table 1.

Table 1. Showing moisture influence on the axial dimensions of African star apple seeds

Moisture content %	Length (cm)	Width (cm)	Thickness (cm)	Arithmetic mean Diameter (AMD) cm	Sphericity %
15	2.55b±0.23	1.53b±0.16	0.74a±0.13	1.61b±0.11	0.56a±0.05
19	2.44b±0.24	1.48b±0.16	0.80b±0.16	1.57b±0.15	0.58ab±0.06
23	2.44b±0.4	1.46b±0.17	0.83b±0.08	1.58b±0.14	0.59b±0.07
27	2.43ab±0.18	1.45b±0.09	0.84b±0.05	1.57b±0.09	0.59b±0.03
31	2.30a±0.17	1.37a±0.17	0.85b±0.12	1.51a±0.11	0.60b±0.04

Note: Mean values along same column with same letter(s) are not significantly different ($p<0.05$)

The values of the average diameters actually depend on the values of the axial dimensions. The arithmetic mean diameter decreased in a second order polynomial trend (Table 1 and 5) as moisture increased from 15 to 31%. The decrease in arithmetic mean diameter also occurred at 31% moisture content similar to that of the width and length. Similar decrease in arithmetic mean diameter was reported by [10] for Cassia tora seeds, [9] for Nutmeg and also in geometric mean diameter for *Opeaburoo* and *Abontem* maize varieties by [6]. The arithmetic diameter is vital to aperture size in the engineering design of screens especially in separating and cleaning machines. The equation representing the relationship between seed moisture content and arithmetic mean diameter is given in Table 5. Sphericity increased significantly and linearly as seed moisture increased from 15 to 31%. The sphericity value for most agricultural seeds, as stated by [5] is in the range 0.32–1.00. [12] also reported that a seed is considered to be spherical when its value of sphericity falls between 0.3 and 1.0. Sphericity in African star apple seeds ranged from 0.56 to 0.60 within 15–31% moisture content which is still considered as spherical. Therefore African star apple seeds are considered spherical and will roll over surfaces more easily as their moisture content increases. The increase in sphericity of the seeds is as a result of the change pattern in the seed axial dimensions. Sphericity also contributes to the shape of the seed which determines the shape of the holes or apertures on the screens used in separating, and cleaning machines for seeds. The relationship between seed moisture content and sphericity of African star apple seeds is represented by the equation shown in Table 5. Increase in sphericity was also reported for Nutmeg seeds by [9], Baobab seeds by [7] and Cotton seeds by [11].

Thousand grain mass and seed mass: Thousand grain mass is the mass of 1000 seeds. For African star apple seeds, thousand grain mass increased linearly and significantly from 808.6 to 975.9 g (Table 3) with increasing seed moisture content (15–31% w.b.). It means that there is a commensurate increase in grain mass for every unit increase in moisture content.

The equation representing the relationship between grain mass and moisture content is shown in Table 8. Similar increase in thousand grain mass was reported by [11] for Cotton seeds, [15] for African yam bean and [10] for Cassia tora seeds. Seed mass is the mass of an individual seed and it increased from 0.84 to 1.12 g (Table 3) in a linear trend (Fig. 3) as moisture content increased from 15 to 31% w.b.

With no significant change recorded in the seed volume, it therefore holds that the same mass of seeds that will occupy a given volume container at 31% seed moisture content will likely occupy same volume at lower seed moisture content. These properties are vital to the engineering design of storage bins, conveyors and hoppers.

Table 2. Gravimetric properties of African star apple seed at different moisture content levels

Moisture content %	Thousand Grain mass (g)	Seed mass (g)	Bulk density kgm^{-3}	True density kgm^{-3}	Porosity %
15	808.6a±7.5	0.84a±0.2	379.0a±10.7	725.3a±24.6	47.7b±0.9
19	808.6a±7.5	0.87a±0.2	379.3a±14.8	758.2ab±24.6	50.0b±0.8
23	920.4b±27.8	0.94a±0.2	394.8b±6.2	769.3b±0.2	48.7ab±2.9
27	953.9c±12.6	0.99ab±0.2	427.7c±6.1	771.1b±42.2	44.5a±3.4
31	975.9d±15.8	1.12b±0.2	451.1d±11.4	813.8c±28.8	44.6a±2.6

Note: Mean values with same letter(s) along same column are not significantly different

Bulk density, true density and porosity: From ANOVA results (Table 3), it could be inferred that bulk and true densities increased significantly ($p<0.05$) with increasing moisture content (from 15 to 31%) and in a linear trend. Bulk density affects the structural loads, resistance to airflow of the stored mass and it is an important parameter in designing of drying and storage systems. Bulk density is the ratio of a bulk mass of a material to the volume it occupies while true density is the ratio of the mass of the seed to the true volume of the seed. The reason for increase in bulk and true densities was due to the rate of increase of the mass of seed which was more rapid than the rate of increase in the volume of seeds as moisture increased. Porosity is a function of both bulk and true densities and it decreased with increasing moisture content. The significant decrease in porosity in African star apple seeds means that the available pore spaces within the seed bulk decreased significantly as seeds acquire moisture. This is due to water molecules on the surface of the seeds filling the pores within the seed bulk adequately. Decrease in porosity also implies that there will be low or reduced aeration in the seed bulk, hence a low drying rate when the wet seed bulk is dried in a dryer. This is because heated drying air will not be able to circulate freely in the seed bulk. Similar result was reported by [6] for Baobab seeds. The models showing the relationship between seed moisture and bulk, true densities and porosity are stated in Table 8.

Dynamic angle of repose: The coefficient of internal friction refers to the friction of seed against seed in a seed bulk. As the seed moisture content increased in the range of 15 – 31% wet basis, there was a statistically significant ($p<0.05$) increase in coefficient of internal friction of the seeds as shown in Table 5 and it was linear in trend (Fig. 11). This means that the higher the seed moisture, the higher the friction among the seeds in the seed bulk therefore a commensurately high force will be required to initiate movement among the seeds in the seed bulk, that is, causing the seeds to slide or roll over one another especially when stacked.

The seeds tend to stick together at high moisture content because of the water film on the coats of the seeds which makes the coats soft and sticky. The coefficient of internal friction is important in the design of hoppers, flow channels and conveyors in processing and machines and transportation equipment for African star apple.

The dynamic angle of repose also increased linearly (Fig.11) with increasing seed moisture content. Table 5 shows a significant effect ($p<0.05$) of seed moisture content on dynamic angle of repose. The sticky nature of the coats at high moisture level hinders their free flow when poured therefore causing the angle of repose to increase. The dryer the seeds, the less sticky and more slippery they are and easily slide over one another, hence a low angle of repose. Dynamic angle of repose is important in designing the equipment for mass flow and structures for storage. Equations showing the relationship between moisture content and coefficient of internal friction and dynamic angle of repose are stated in Table 8. These results are similar to those reported for Fenugreek seeds grains by [14].

Table 3**.** Seed moisture content and static coefficient of friction of African star apple on different material surfaces

Moisture content %	Static coefficient of friction (SCF) on material surfaces(°)				Angle of repose (°)
	Aluminum	Galvanized iron	Glass	Polyvinyl chloride (PVC)	
15	30.6b±2.1	37.4ab±1.8	33.4c±2.3	32.0b±1.6	24.1a±1.63
19	29.6ab±0.5	37.6b±1.4	32.4c±1.5	31.6b±1.5	27.3b±2.39
23	29.4ab±1.3	40.6b±1.1	30.0b±1.2	29.4a±0.6	27.6b±1.64
27	28.2a±1.5	41.8a±4.1	28.4ab±0.6	29.3a±0.6	27.9b±2.84
31	28.0a±0.9	42.0a±3.5	26.7a±1.6	29.0a±1.0	31.7c±1.22

Mean values with same letter(s) along same column are not significantly different ($p<0.05$)

Static Coefficient of Friction: Static coefficient of friction applies to motionless objects. It is the ratio of the force that maintains contact between an object and a surface and the frictional force that resists the motion of the object. The static coefficient of friction was statistically significant ($p<0.05$) on all the tested surfaces except plywood (Table 6). Static coefficient of friction decreased linearly on Polyvinyl chloride (PVC), Glass and Aluminum surfaces while it increased linearly on Galvanized iron surface as seed moisture increased from 15% to 31% (Fig. 7). The highest and lowest values of coefficient of friction were found on galvanized iron (42º) at 31% moisture content and glass (26.7º) at 31% moisture content respectively (Table 6). [15] reported highest value of static coefficient of friction of African star apple seeds on galvanized sheet surface and the lowest value on aluminum surface. The reason for the increased friction coefficient at higher moisture content on galvanized iron is due to its rough surface despite the water film present on the seed coat. Similar results were given for *Garcinia kola* seeds by [12]. It therefore means that more force will be required to initiate motion in African star apple seeds on galvanized sheet surface as seed moisture content increases. Meanwhile, the linear decrease in the static coefficient of friction on aluminum, glass and PVC surfaces as moisture increases is due to their smoothness thereby making the seeds slippery on the surfaces hence contributing to the seeds' easy flow.

The static coefficient of friction is important in the design of conveyors because friction is necessary to hold the seed to the conveying surface without slipping or sliding backward. On the other hand, discharging requires less friction to enhance the discharging process.
Static coefficient of friction is also needed in the choice of structural material for the design of machine components involving the flow of bulk granular materials. The relationships between static coefficient of friction and the moisture content on all tested material surfaces can be represented with the equations in Table 5.

Table 5. Table of equations showing the relationship trend between the seed moisture content and the engineering properties of African star apple seed

S/N	Parameter	Model (Equation)	R^2
1	Length, cm	$y = -0.0128x + 2.7253$	0.8262
2	Width, cm	$y = -0.0088x + 1.6593$	0.9088
3	Thickness, cm	$y = 0.0065x + 0.6625$	0.8579
4	Arithmetic mean diameter, cm	$y = -0.0003x^2 + 0.0073x + 1.5499$	0.8063
5	Sphericity, %	$y = 0.25x + 52.75$	0.8333
6	Thousand grain mass	$y = 11.998x + 617.54$	0.9004
7	Seed mass, g	$y = 0.013x + 0.637$	0.9797
8	Bulk density, kgm^{-3}	$y = 4.8181x + 295.55$	0.9106
9	True density, kgm^{-3}	$y = 4.7491x + 658.31$	0.8949
10	Porosity, %	$y = -0.0324x^2 + 1.1963x + 37.776$	0.7302
12	Angle of repose (ᵘ) Static coefficient of friction (ᵘ) on:	$y = 0.395x + 18.635$	0.8559
13	Galvanized iron	$y = -0.27x + 46.09$	0.5818
14	Glass	$y = 0.435x + 20.175$	0.9892
15	Aluminum	$y = 0.165x + 25.365$	0.9486
16	Polyvinylchloride (PVC)	$y = 0.205x + 25.565$	0.8524

CONCLUSIONS

The following conclusions were drawn from this research:

1. The study revealed that increase in African star apple(*Chrysophyllum albidum*) seed moisture content had significant changes on most of its engineering properties considered.
2. Equations that can be used to predict the behavior of African star apple seeds during handling and processing were developed. The equations also show the relationship trend between moisture content and the engineering properties of the seeds.
3. With the baseline data developed, the design and fabrication of equipment necessary for handling and processing African star apple seeds is possible.

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UTICAJ VLAŽNOSTI SEMENA NA NEKE INŽENJERSKE OSOBINE JABUKE AFRIČKA ZVEZDA (*Chrisophillum albidum*)

Olajide Ayodele Sadiku[1], Olusegun Olaomi[2]

[1]Department of Agronomy, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria
[2]Department of Agronomy,Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria.

Apstrakt: Uticaj vlage na neke inženjerske osobine semena Afričke jabuke (*Chrisophillum albidum*) je ispitan pri 15, 19, 23, 27 i 31% osnovne vlažnosti. Ovo je od vitalnog značaja za skladištenje semena, rukovanje i razvoj potrebne opreme za preradu. Ove osobine su određene standardnim postupcima i metodama. Podaci su analizirani pomoću Analize varijanse (ANOVA) da bi se testirao značaj uticaja vlage na osobine semena, dok je analiza srednjih vrednosti izvršena Duncan Multiple Range Test (DMRT), korišćenjem statističkog paketa IBM/SPSS.

Dobijeni rezultati su pokazali da povećana vlažnost semena dovodi do značajnog linearnog povećanja: debljine semena (0,74±0,13 do 0,85±0,12 cm), sferičnosti (0,56±0,05 do 0,60±0,04), zapreminske gustine (379,0±10,7 do 4151 kgm^{-3}), stvarne gustine (725,3±24,6 do 813,8±28,8 kgm^{-3}), ugla mirovanja (24,1±1,63 do 31,7°±1,22), statičkog koeficijenta trenja (SCF) semena na površini podloge od galvaniziranog čelika (37.4±1.8 do 42.0±3.5) .

Normalna i naprezanja na smicanje pri opterećenjima od 200, 300 i 400 g su linearno rasla sa najvišim vrednostima kod 31% sadržaja vlage i opterećenja od 400 g, za normalno (16,56±1,83) i za naprezanje na smicanje (25,28±9,32).

Ostale osobine su se linearno smanjivale, odnosno: dužina semena (2,55±0,23 do 2,3±0,17 cm), širina semena (1,53±0,16 do 1,37±0,17), SCF na površinama podloga od: aluminijuma (30,6±2,1 do 28º±0,9), stakla (33.4±2.3 do 26.7º±1.6) i polivinil hlorida (32±1,6 do 29º±1), zbog glatke površine.

Generisane su jednačine za predviđanje ponašanja semena jabuke Afrička zvezda podložne uticaju vlage. Razvijeni su primarni podaci potrebni za razvoj mašina.

Stoga je moguća primena mehanizacije kod buduće prerade semena jabuke Afričke zvezda (*Chrisophillum albidum*), za proizvodnju ulja.

Ključne reči: *nasipna zapremina svojstva, vlaga, seme, napon, trenje, poroznost, inženjering, obrada.*

Prijavljen:
***Submitted*: 05.01.2024.**
Ispravljen:
***Revised*: 05.03.2024.**
Prihvaćen:
***Accepted*: 20.04.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 28 – 36

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 28 - 36

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402028C

YAM MINISETT PROCESSING MACHINERY, VIABILITY ANALYSIS

Igbo J. Chidiebere[*1], Kadurumba H. Chukwuma[2] , Abam I. Fidelis[2]

[1]*Engineering Research Unit, National Root Crops Research Institute, Umudike, Nigeria*
[2]*Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria*

Abstract: Developed Yam minisett processing machine was evaluated in this study and the economic viability was determined using benefit – cost methodology so as obtain the investment cost and to encourage its wide acceptance and adoption to control food security. Benefit –cost ratio, payback period, net present value nd account rate of return which constitute the economic parameters of the machine evaluated subject to prevailing economic indicators of materials in Abia State of Nigeria in 2021. The annual return rate of 64.90% outweighed banks maximum fixed deposits return of 16% and prime lending rate of 29% in Nigeria, its payback period of 1.85years is less than its 10 years useful life, the machine cost- benefit ratio of 1.75 and, net present value of ₦105,749,969.20 are more than one which was worthy for investment. These economic indicators setting showed positive credit recovering prospects of this innovation.

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Key words*: Yam minisett processing, Viability analysis, Food security, Benefit – cost methodology.*

INTRODUCTION

Economic viability points such as net present value, payback period, benefit cost ratio and accounting rates of returns are individually used to ascertain the economic efficiency of systems, the integrated methodology of these decision pointers are called benefit – cost analysis and are often used in new machinery assessment because of its high prediction accuracy, [1].

[*]Corresponding Author. E-mail: igbojoejoe@gmail.com
ORCID: 0000-0003-2906-4924; 0009-0009-0640-4659

All the potential cost and revenues that may be generated prior to actual implementation of investment decision in order to avoid the risk of going into an unprofitable investment and wasting valuable time and money using Cost- benefit analysis tool [2]. Using the cost–benefit analysis as a tool, it involves identification, categorization, projection, monetization, computing and comparison of present values of cost and benefits over the lifespan of an investment [3]. Using benefit-cost analysis, it indicates that an investment is worthy when its projected potential benefits outweigh its costs; when the rate of return exceeds the required minimum rate, its payback will be less than its salvage period and its net present value exceeds zero [1].

The costs and benefits of expenditure on engineering education from the viewpoints of students, the government and industry was researched by [4]. In a modern society the intellectual property generated by engineers is the drive of the economy. The intellectual property leads to production of the products required for a high standard of living. The trade of these products enables other occupations to flourish. Engineers may be obtained by training a nation's youth or by importing those trained elsewhere. The findings are that all parties benefit significantly from expenditure on engineering education, and that engineering education provides benefits to the government and the nation exceeding those derived from expenditure on education in other disciplines. The factors considered in the analysis were students, government, and industry, with society in general being linked to the gains to the government.

The objective of the research work done by [5], was to evaluate, on the basis of theoretical aspects of the project cost-benefit analysis (CBA) method, the efficiency of methods applied in the construction and infrastructure development projects currently taking place in Latvia. At the end of the research, it was found that application of project management principles to improve efficiency of the administration of allocated financing and to perform compliant project initialization, securing efficient realization of construction and infrastructure development projects that is compliant with the project management principles and fosters sustainable business.

A resilient and dynamic cost benefit analysis (CBA) framework for road construction projects was developed by [6]. The research systematically reviewed academic quality ensured, selected Norwegian construction projects and rigorous peer-reviewed articles. The research identified some key attributes (e.g. resiliency, dynamics, system thinking) that the traditional CBA lacks and the framework developed integrates these attributes to fill the gap. The research has theoretical implication from the methodological improvement perspective. The practical implication was to avoid inefficiencies and obtain better regulation in government policies.

It was stated by [7], on his research that a cost-benefit analysis (CBA) methodology is presented to enable contractors to assess the true cost of accidents prevention and the associated benefits of accident prevention as part of pre- and post-contract project evaluation. The research investigated the cost and benefit of accident prevention, with a view to drawing attention to the economic consequences of effective/ineffective management of health and safety by contractors. A quantitative research methodology was employed in investigating these costs and benefits within the UK construction industry. The results of ratio analyses indicate that the benefits of accident prevention far outweigh the costs of accident prevention by a ratio of approximately 3:1. Further, the results demonstrated that for every £1 spent on accident prevention, contractors gained £3 as benefits.

The results also show that small contractors spend relatively higher proportions of their turnover on accident prevention than medium- and large-sized contractors and that small- and medium-sized contractors gain relatively higher proportions of their turnover, in total, as benefits of accident prevention than large contractors. It is concluded that the CBA method can provide a guide to contractor's decision making in regard to accident prevention. When acted upon, the method has the potential to contribute to a reduction in costs.

Safety issues in the construction site with the base of Cost Benefit Analysis was researched by [8] . Their work reviewed the rate of accidents in the construction industry and presents a model predicting CBA of accident prevention on construction projects. A quantitative method approach was used to collect data from health and safety managers in the construction industry for the survey. A total of 29 companies were selected for questionnaire survey. A Ratio Analysis was adopted to calculate the relationship between the turnover and cost/benefit of the companies and Correlation Analysis was used to find the correlation coefficient for developing CBA model. A simple linear regression model was adopted to identify the effect of total costs of accident prevention on benefits of accident prevention. The result revealed that costs of accident prevention are significantly associated with benefits of accident prevention.

Profitability of a gari processing machine in Ondo state was revealed by [9], while [10], confirmed viability of small – scale palm oil processing in River State with this procedure. [11], showed that the novel palm nut-pulp machine is profitable when compared to the existing manual method of processing by the use of cost benefit analysis. [12] showed a cost benefit ratio of more than one garri produced when cost and returns of cassava production in Ekiti state were analyzed. Since is advisable for investors to be convinced of the profitability and wide acceptance of novel yam minisett processing machine before investing. From the review, the established minisett technology was not adopted by famers because of drudgery and risk of inflicting injuries thus mechanized yam minisett technology by the design and fabrication of yam minisett production machine, cost-benefit to determine its potential profitability in investing

MATERIAL AND METHODS

The yam minisett processing machine was assessed for economic viability in this study with multi – criteria cost – benefit analysis measure. This involved computation and comparison of its payback period, accounting rate of return, net present value and benefit cost ratio using the prevailing economic indicators which is the market prices of materials in Abia state of Nigeria between January and December, 2021. The decision criteria applied include that the payback period of this machine must be less than its assumed useful life of five years, thus five years business plan was used. Its net present value and benefit cost ratio must be greater than zero and one respectively. In addition, the investment’s rate of return must be greater than the upper limits of Nigerian banks lending and fixed deposit interest rates in order to justify its possible funding from personal savings and bank credits [11].

Records showed the benchmark business registration cost, interest rate, corporate income tax rate for Nigeria companies (with more than one million Naira turnover) as N25,000, 14% and 30% respectively within this study period. ([13], [14]).

The fixed deposit interest rate of Nigeria bank as at December 31, 2021 fall between 7.09 to 16% while their prime lending rates for agriculture or manufacturing range from 7 to 29% [13]. The maximum annual rent of required space for this business is N150,000 while N30,000 constitute Nigeria minimum wage per month during this investigation. Five (5) working days per week of 8 hours per day with one hour break per day was also applied. The average unit cost of seed yam and electric energy bulb used during this period were N254.3/kg and 36.150 per kwh respectively while the mini sett andyam peels sale for N367/kg and N 65/kg respectively. The payback period (Pb), accounting rate of return (ARR), net present value (NPV) and benefit - cost ratio (BCR) of the yam minisett processing machine were computed from its financial data collected. The optimal performance parameters are also determined in this study using the following relations in equation (1), (2), (5) and (6) given by [3];

$$P_b = \frac{C_i}{Bn} \quad (1)$$

$$\frac{33{,}739{,}426.24}{18{,}280{,}661.89} = 1.85$$

The cash inflow at year t is given by the total revenue at year t less the total expenses for that year.

$$ARR = \frac{Bn}{C_i} \quad (2)$$

ie $\frac{18{,}280{,}661.89}{33{,}739{,}426.24} = 0.54181$

$$NPV = \sum_{t=1}^{n} \frac{B_{nt}}{(1+r_i)^t} - C_i \quad (3)$$

Also,

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

ie $\frac{399{,}383{,}204.19}{228{,}480{,}098.93} = 1.75$

similarly,

$$PVC = \sum_{0}^{t} \frac{C_i}{(1+r_i)^t} \quad (5)3.41)$$

and

$$PVB = \sum_{0}^{t} \frac{B_n}{(1+r_i)^t} \quad (6)3.42)$$

Where:

Ci = initial investment cost
Bn = average annual net benefit (cash inflow)
Bnt = net cash inflow at time, t
PVC = present values of costs
PVB = present value benefits
Pb = Payback period
ARR = Account rate of return
NPV = Net present value
BCR = Benefit cost ratio
ri = Rate of Return

RESULTS AND DISCUSSION

The unit cost of fabrication and installation of the yam minisett cutting machine was determined as two hundred and forty-three thousand, five hundred naira (₦243,500) only, while thirty-three million, seven hundred and thirty-nine thousand, four hundred and twenty-six naira, twenty-four kobo (N33,739,426.24) only constitutes its associated the initial investment cost (Table 1). This table also showed that this investment goes with a net annual profit (cash inflow) of eighteen million, six hundred and ten thousand, ninety-two naira, fourteen kobo (N18,610,092.14) only and a payback period of 1 years Eight months (1.85 years). Thus, cutting yam mini sett with this machine is worthy since its payback period is less than its salvage period of ten years. In addition, its benefit-cost ratio shown in Table 2 is 1.75 which implies a benefit of ₦1.75 for every ₦1 spent is also encouraging. Positive investment potential of this yam minisett cutting machine is also very obvious from Table 3 which showed that its annual rate of return as 64.90% and its net present value as one hundred and five million, seven hundred and forty-nine thousand, nine hundred and sixty-nine naira, twenty kobo (₦105,749,969.20) only. Positive net present value (> 0) is desirable of any worthy investment while 64.90% annual return of this machine is encouraging because it outweighed banks maximum fixed deposits return of 16% and prime lending rate of 29% in Nigeria. These indicated positive prospect of recovering credit used for funding this investment. Hence, advancing the yam minisett processing sector with this machine is encouraged.

Table 1. Analysis of Initial Investment cost and payback period of yam minisett processing machine

Description	Expenditure (₦)	Revenues (₦)
FIXED COSTS		
Machine Fabrication/Installation Cost	218,500.00	
Business Registration Cost	25,000.00	
SALVAGE VALUE OF MACHINE		
SUB-T0TAL	*243,500.00*	
ANNUAL RECURRENT EXPENDITURE		
Yam cost	28,860,000.00	
Electric energy cost	539,776.24	
Water cost	1,620,000.00	
Maintenance cost	584,150.00	
transportation cost	1,040,000.00	
Wage	632,000.00	
Rent	2200,000.00	
SUB-TOTAL	*33,495,926.24*	
INITIAL INVESTMENT COST	33,739,426.24	

Contin. Table 1.		
ANNUAL RECURRENT REVENUE		
Sales from Yam minisett		56,523,210.96
Yam Peels		3,244,105.55
SUB-T0TAL		59,767,316.*51*
GROSS ANNUAL INCOME		26,271,390.27
LESS FIXED COST RECOVERY	156,160.00	
NET INCOME		26,115,230.27
LESS 30% TAX	7,834,569.081	
PROFIT		18,280,661.89
PAYBACK PERIOD	1.85	

Table 2: Analysis of benefit-cost ratio of yam minisett cutting machine

Period (Years)	PVC (₦)	PVB (₦)
0	33,739,426.24	58,976,517.07
1	30,264,265.34	52,901,935.81
2	27,147,046.01	47,453,036.43
3	24,350,900.27	42,565,373.67
4	21,842,757.54	38,181,140.18
5	19,592,953.49	34,248,482.70
6	17,574,879.28	30,720,888.98
7	15,764,666.71	27,556,637.41
8	14,140,906.04	24,718,303.76
9	12,684,392.72	22,172,318.47
10	11,377,900.29	19,888,569.71
Total	228,480,093.93	399,383,204.19
	BENEFIT-COST RATIO	1.75

Table 3. Analysis of annual rate of return and net present value of yam minisetting cutting machine

Period (Years)	1	2	3	4	5	6	7	8	9	10	Average
Annual Income (₦)	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.91	26,742,005.9	26,742,005.91	26,742,005.91
Discount Factor at 14%	0.877192982	0.769467528	0.674971516	0.592080277	0.519368664	0.455586548	0.399637323	0.350559055	0.307507943	0.26974381	
Present Value of Income (₦)	23,457,899.92	20,577,105.19	18,050,092.28	15,833,414.28	13,888,959.89	12,183,298.15	10,687,103.64	9,374,652.32	8,223,379.23	7,213,490.55	13,948,939.54
Depreciation (₦)	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00	156,160.00
Net Income After Depreciation (₦)	23,301,739.92	20,420,945.19	17,893,932.28	15,677,254.28	13,732,799.89	12,027,138.15	10,530,943.64	9,218,492.32	8,067,219.23	7,057,330.55	13,792,779.54
Taxes at 30%	6,990,521.98	6,126,283.56	5,368,179.68	4,703,176.28	4,119,839.97	3,608,141.45	3,159,283.09	2,765,547.70	2,420,165.77	2,117,199.17	4,137,833.86
Net Income After Taxes (₦)	16,311,217.94	14,294,661.64	12,525,752.59	10,974,077.99	9,612,959.92	8,418,996.71	7,371,660.55	6,452,944.62	5,647,053.46	4,940,131.38	9,654,945.68
Initial Value of Investment (₦)	33,739,426.24	33,583,266.24	33,427,106.24	33,270,946.24	33,114,786.24	32,958,626.24	32,802,466.24	32,646,306.24	32,490,146.2	32,333,986.24	
Final Value of Investment (₦)	33,114,786.24	32,958,626.24	32,802,466.24	32,646,306.24	32,490,146.24	32,333,986.24	32,177,826.24	32,021,666.24	31,865,506.2	31,709,346.24	
Average (₦)	18,201,528.78	17,206,561.64	16,329,521.77	15,555,926.87	14,873,073.18	14,269,817.03	13,736,383.30	13,264,197.30	12,845,737.3	12,474,405.59	14,875,715.28
ARR (%)			64.90								
NPV (₦)			105,749,969.20								

CONCLUSIONS

The developed yam minisett processing machine is economically viable because its annual return rate of 64.90% outweighed banks maximum fixed deposits return of 16% and prime lending rate of 29% in Nigeria. Also its payback of 1.85years is far less than its 10 years useful life while its respective benefit-cost ratio and net present value of 1.75 and ₦105,749,969.20 are more than one expected of worthy investment. These economic indicators setting imply positive credit recovering prospect of this innovation. Hence, general adoption of this novel yam minisett processing machine is recommended because it reduced drudgery and food losses and improves food security

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MINISET MAŠINE ZA PRERADU ZRNA YAM, ANALIZA ODRŽIVOSTI

Igbo J. Chidiebere[1], Kadurumba H. Chukwuma[2], Abam I. Fidelis[2]

[1]*Engineering Research Unit, National Root Crops Research Institute, Umudike, Nigeria*
[2]*Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Nigeria*

Apstrakt: Razvijena miniset procesna mašina za preradu zrna kulture Yam procenjena je u ovoj studiji. Ekonomska isplativost je određena korišćenjem metodologije koristi – troškovi, kako bi se dobio trošak investicije i podstaklo široko prihvatanje i usvajanje mašine u kontroli bezbednosti proizvodnje hrane.

Odnos koristi i troškova, period vraćanja, netto sadašnja vrednost i stopa prinosa koji čine ekonomske parametre mašine procenjene su u zavisnosti od preovlađujućih ekonomskih pokazatelja materijala u državi Abija u Nigeriji u 2021. Godišnja stopa povrata sredstava od 64,90% nadmašila je određeni maksimum banaka.
Povraćaj fiksnih depozita od 16% i primarna kreditna stopa od 29% u Nigeriji, njen period otplate od 1,85 godina je kraći od korisnog veka mašine, od 10 godina.
Odnos troškova i koristi mašine od 1,75 i netto sadašnja vrednost od 105.749.969,20 ₦ su više od onog koji je bio vrednost ulaganja.
Ovo predstavljanje ekonomskih pokazatelja pokazalo je pozitivne izglede za kreditni oporavak ove inovacije.

Ključne reči: *Yam miniset prerada, analiza održivosti, bezbednost hrane, metodologija koristi – trošak.*

Prijavljen:
Submitted**: 15.01.2024.**
Ispravljen:
Revised**: 15.03.2024.**
Prihvaćen:
Accepted**: 25.04.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 37 – 51

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 37 - 51

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402037A

ANALYSIS OF COSTS AND RETURN OF DATE PALM FRUITS (*Phoenix Dactylifera* Linn) MARKETING AMONG RETAILER TRADERS IN KADUNA METROPOLIS, KADUNA STATE, NIGERIA

Oluyinka Christopher Ariyo*

Department of Entrepreneurship and Innovative Agriculture,
Federal College of Forestry Mechanization, Afaka, Kaduna, Nigeria
Forestry Research Institute of Nigeria, Ibadan, Nigeria

Abstract: Date palm trees (*Phoenix Dactylifera* Linn) are an economic crop which fruits are used for food, medicine and income in the arid and semi arid zone of Nigeria. The study was undertaken to analyse the costs and return of date palm fruits marketing among retailer traders in Kaduna metropolis, Kaduna. Two-stage sampling technique was employed which led to random selection of 80 respondents. Structure questionnaires were administered to the respondents and data collected were analysed with descriptive statistics, cost and return, and regression analysis. The results showed that all the respondents are male, 21-30 years of age, married with household size of 6-10 family members and had Qur'anic education. The result further showed that marketing of date fruits was profitable with net marketing income of ₦ 8,400 per respondent per month and return on investment of ₦ 0.11. Variables such as years of marketing experience, quantity of date palm purchased and revenue were significant at (P< 0.01) percent probability level. Also purchase cost and quantity of date palm sold were significant at (P< 0.05) percent while transportation cost and household size were significant at (P < 0.10) percent. The major constraints of date fruits marketing are inadequate capital, pest infestation, inadequate storage facilities and insecurity.

The study recommends that unemployed teeming population especially youths should be encouraged to go into the business of date palm fruits marketing to earn a living.

*Corresponding Author. E-mail: ask4ariyo@yahoo.com
ORCID: 0000-0001-8512-9433

Key words**:** *Date fruits, retailer, marketing, net marketing income, youth*

INTRODUCTION

Date palm (*Phoenix Dactylifera* Linn) is one of the oldest cultivated crop in the desert and semi-desert areas of the world. It is grown principally within longitude 15^{o}N and 30^{o}N which extends from North-West Africa and Asia. In many countries, its growth is highly valued and regarded as a national heritage and a multi-purpose tree crop. It is a crop that is tolerant to harsh environmental desert conditions and poor soil and is seen as an important subsistence crop in many of the desert areas of the world. The Arabia Gulf and North Africa are the main producers of dates in the world. In 2006, the total date palm production in the world was about 7 million tons and was produced by top 10 countries such as Egypt, Saudi Arabia, Iran, United Arab Emirates, Pakistan, Algeria, Sudan, Oman, Libya, and Tunisia [1].

Nigeria is not listed among the date producers at the global scene which may be due to lack of facts and figures on the Nigeria date palm production sector. However, date palm production can be included in the Agricultural Transformation Agenda (ATA) programme of the Federal Government of Nigeria to ensure food availability, food security and to combat desertification [2]. In Nigeria, dates are largely cultivated in the northern regions of the country specifically over latitude 10^{0}N of the equator [3]. This part includes Jigawa, Kano, and Katsina states. According to [4], dates can also be grown in Nasarawa, Niger, Plateau and Benue states which forms the lesser parts of derived savannah areas. [5] opined that in the early 17th century, date palm was introduced into Nigeria by Arab traders from North Africa through trans- Sahara trade. He further stated that its (date palm) cultivation and marketing is still at subsistence level. There are thousands of different types of date palm cultivars that are grown, depending on their water and sugar contents at full maturity, these includes those with soft, semi-dry, and dry fruits [1].

The choice of cultivating Date palm by the farmers could be due to its high profit, nutritional composition, environmental advantages and its tolerance to poor soil conditions [6]. Its cultivation improves the economic status of the famers and a good alternative to improve the food security and nutrition of the people [7]. Also, it was reported by [8] that the tree of Date palm has several uses and economic benefits in improving the ecology of the deserts. The tree is highly valued and has significance in the traditional of the Islamic world. The consumption of date palm is more in the northern part of Nigeria and with increase in population of this area, the demand for it is expected to rise in the nearest future. The tree apart from provision of date fruits for food also supply other products which have been used extensively by the inhabitants of the rural and urban areas

The Date palm tree is usually tall at maturity and produces a sweet fruit called dates. The fruits are small in size, around 1½ inches (3.87 cm) in length and normally oval in shaped. The colour of the fruit may be medium to dark brown and possibly with reddish hue. The skin has a bright appearance and is very thick and wrinkled. Date palm tree is multipurpose in nature; it gives nutrients for energy, protection and refuge by providing construction materials such as leaves and timber products for shelter.

According to [9], the fruits serve as prominent staple, nutritious food and source of energy and economic value for many years.
The fruit contains 77% carbohydrate (mostly invert sugar e.g. glucose and fructose) that can readily be absorbed into the body without passing through digestion which the ordinary sugar undergoes. Date fruits contain fat (0.4%), protein (4%), pectin (2%), and fibre (9%). According to [10], date fruits are rich in vitamin A, B1 (thiamine), B2 (riboflavin) and B7 (niacin). It also contains aluminium, cadmium, chloride, sulphur and oleic acid in different amount [11]. Date may be thought to be an ideal food that provides required nutrient for the body and has a lot of potential health benefits. [6] reported that date fruits can be eaten as food and as well as delicacy. The diets of many people may be improved where dates are eaten as food rather than when eaten as delicacy. Date palm has a lots of nutritional value, highly yielding and longer life span therefore is been called a tree of life [12].

The variation in the number of date palm tree, production and consumption of date palm from one region to another and from nation to nation is due to the existing conditions in the environment of the region and nation. For instance, the Nigerian date palm production is at subsistence level with famers having few trees stands on their farms and two or more stands in their homestead. Date palm production is projected at about 21,700 metric tonnes in Nigeria [5]. The total area put into date palm production in Nigeria is not more than 1,446.8 ha [13]. The estimated consumption of date is put at 89,850 metric tonnes [14], this shows that Nigeria can produce only 24% of its consumed date palm, the remaining 76% of date consumed in Nigeria are imported from the neighbouring countries like Chad and Niger, [15].

Dates is a highly value confectionery which are traditionally marketed all over the world either fresh or dried and as dates products such as date drinks, they remain a subsistence crop that are very important in most of the desert areas [16]. The sales of date fruits is more pronounced in the northern part of Nigeria especially in Kaduna State. It is often seen in the study area being displayed by itinerant and sedentary hawkers who engage in the business and offer all manner of services to attract their customers. Though despite the fact that dates is marketed in the study area many years ago, information on its retail trade for income generation is scanty thus necessitated the need to conduct research on cost and return of date palm fruits marketing among retailer traders in Kaduna metropolis, Kaduna state. The objectives of the study are: (i) describe the socio-economic characteristics of date marketers (ii) evaluate costs, return and profitability of the business (iii) determine factors affecting the net profit of the marketers and (iv) describe constraints faced by the marketers in date palm marketing.

The study hypothesized that there is no significant difference between the net marketing profit of the respondents and factors that are affecting it.

MATERIAL AND METHODS

Study Area

The study was conducted in Kaduna metropolis, in the north central geopolitical zone of Nigeria. Kaduna state lies between latitude 10^0 37^1 N and longitude 7^0 $17^,$ E and its coordinates is 10^0 $20^,$ N and 70^0 $45^,$ E (Wikipedia).

According to 2006 census figure, Kaduna state has a population of about 6,066,512 people. After Lagos and Kano, Kaduna state constitutes the third largest in the federation of Nigeria [17].
It has a total land area of about 46,053 square kilometre and the density is about 131.7 square Kilometre (341.2 square metre) (Wikipedia). The metropolis of Kaduna is made up of two Local Government Areas: Kaduna North and Kaduna South, and parts of Chikun and Igabi LGA. It is located about 100km north of the country's Federal Capital, Abuja. The capital of Kaduna State is Kaduna; it is the commercial and industrial centre of Nigeria. Many factories such as textile, beverages, furniture, etc are found within the metropolis. It serves as trade midpoint for cotton, livestock, durra sorghum, corn, shea nuts, ginger and the surrounding agricultural areas because of the rail and road facilities. The climate is characterized with wet and dry seasons and resembles that of Northern Guinea Savanna. The annual rainfall is between 700mm-1000mm and last between April to October while dry season last for 5 to 7 months and it start from October to March. The major ethnic groups and inhabitant of the city are the Hausas, Gwaris, Katafs, Gbagijs, Bajju, Nimzom, Koro and Jaba. Others include the Fulanis, Tiv, Idoma, Yoruba and Ibos.

Data Collection Method

Primary data were collected from the date palm retail traders using structure questionnaire.

Techniques of Sampling

The sampling unit for the inquiry were the date palm retail traders. Two-stage sampling techniques were used in selecting respondents for this research. In stage one (1), four markets in each Local Government that made up of Kaduna Metropolis were purposive selected. The selection was focused on the presence of high concentration of marketers and high volume of date palm fruits traded. The markets are: Kasuwan Barci market Kaduna south LGA, Abubakar Gumi market in Kaduna north LGA, Rigassa market in Igabi LGA and Sabo market in Chikun LGA. Equal number of 20 marketers was selected at random in each market to make sample size of 80 marketers used. Copies of well designed questionnaire were administered to gather data on the objectives of the study.

Data Analysis

The data gathered were analysed using descriptive statistics such as tables, frequency distributions and percentages. Cost and return assessment was used to estimate the cost acquired and revenue generated by the traders. Multiple regression analysis was used to establish the factors affecting the net marketing profit of the marketers and also to postulate the hypothesis. The cost and return model is given below:

TMC=AVC+AFC..... **(1)**

Where:
TMC = Total Marketing Cost (₦),
AVC = Average Variable Cost of Marketing (₦),
AFC = Average Fixed Cost of Marketing (₦)
The fixed inputs (assets) of marketing such as tables, mudu (measure), tray and wheelbarrow where depreciated with straight line method.

$D = Oc - Sv/N$ ..... …….. **(2)**

Where:
D= Annual depreciation,
Oc= Original cost of fixed assets (₦),
Sv= Salvage or Scrap value (₦)

The annual depreciation of fixed assets was brought down to month for each fixed asset to have the actual cost of the asset per month

The Gross Income (G. I) of marketing was obtained with the below model

$$G.I = \sum_{n=i}^{F} Q_{DPF} * P_{DPF} \text{.....} \quad \text{(3)}$$

Where $\sum_{n=i}^{D}$ = Summation sign,
Q_{DPF} = Quantity of date palm fruits sold per month in ‘‘Mudu’’
P_{DPF} = Average price of date palm fruits per ‘‘mudu’’ (₦), F = Fresh date palm fruits,
D = Dried date palm fruits. The total gross income of fresh and dried date palm fruits

was obtained with: $TGI = G.I_{FDP} + G.I_{DDP}$..... ……. **(4)**

Where:
$G.I_{FDP}$= Gross income from fresh date palm fruits sold (₦),
$G.I_{DDp}$= Gross income from dried date palm fruits sold (₦)

The Net Marketing Income (NMI) was calculated with:

TGI - TMC..... **(5)**

Return per Capital Invested (RPCI)

This is defined as net marketing income (NMI) divided by total marketing cost

(TMC). RPCI=NMI/ TMC..... **(6)**

This reveals the sum of cash returns to the marketer for each naira devoted in the sales of Date palm business.

Regression Analysis

The factors affecting the net profit of the marketers were determined by regression analysis. Three functional forms namely; Linear, Semi log and Double log functions were used.

The functional form better than all others was carefully chosen based on coefficient of multiple determinations R^2- value, F- statistics, t- values, a-priori expectation and the total number of significant variables.

The general form of the model is presented as follows:

$$Y=f(X_1, X_2, X_3, X_4, X_5, X_6 ..... X_{13} + \mu_i)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \textbf{(7)}$$

Explicit functions of the general model are:

$$\text{Linear Function: } Y=\beta_o+\beta_1X_1 +\beta_2X_2 +\beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6....+ \beta_{13}X_{13} + \mu_i\ldots.. \textbf{..(8)}$$

Semi-Log Function:

$$Y=\beta_o + \beta_1\log X1+\beta_2\log X_2+\beta_3\log X_3+\beta_4\log X_4+\beta_5\log X_5+\beta_6\log X_6...+\beta_{13}\log X_{13}+\mu_i\ldots\ldots \quad \textbf{(9)}$$

Double Log Function:

$$\text{Log}Y=\beta_o+\beta_1\log X1+\beta_2\log X_2+\beta_3\log X_3+\beta_4\log X_4+\beta_5\log X_5+\beta_6\log X_6...+\beta_{13}\log X_{13}+\mu_i\ldots \quad \textbf{(10)}$$

Where,
X_1 = Age (years); X_2 = Marital status; X_3 = Household size (Actual number);
X_4 = Educational level (Actual years); X_5 = Marketing experience (years), (years);
X_6 = Quantity of date palm purchase (''*Mudu*'');
X_7 = Quantity of date palm sold (''*Mudu*''); X_8 = Revenue (₦); X_9 = Purchase cost (₦);
X_{10} = Storage cost (₦); X_{11} = Transportation cost (₦); X_{12} = Packaging cost (₦) and
X_{13} = Marketing charges (₦), β_o = Constant term,
β_1 to β_{13}= Regression coefficient or parameters,
X_1 to X_{13} = Independent or explanatory variables,
μ_i = Error term or Random error,
Y = Net marketing profit from the sales of date palm (₦)

RESULTS AND DISCUSSION

Socio- Economic Characteristics of the Marketers

The marketer's socio- economic characteristics on Table 1 revealed that 100% of the marketers of date palm are males. This implies that the business required physical efforts and agility to run. This agreed with the findings of [18] that the marketing of date palm is male dominated.

The age of the respondents varied from 10-40 years, 50% of the marketers are within age range of 21-30 years while 36.25% falls within 31-40 years.

Only 13.75% are within 10-20 years. This means that the larger percentages (86.25%) of the marketers are between the active age range of 21-40 years. This showed that most of the respondents are within the active and economically productive age range (15-64) stipulated by [19].

The marital status of the marketers showed that 81.25% are married and 18.75% single. This corroborates the findings of [18], [20] which stated that the majority (93.65% and 96.30%) of date palm traders are married. The family size of a household is an important variable; it may provide support and serves as source of labour in marketing.

The household size revealed that the majority (51.25%) had 6-10 family members. This agreed with [21] which stated that an average family size in Nigeria is about 6-7 persons per household. But, [22] opined that the average household size in the savannah zone of Nigeria was 10. Other respondents such as 37.50% and 11.25% had 11-15 and 1-5 family members respectively.

In terms of educational levels, 42.50% had Qur'anic education, 26.25% and 18.75% had secondary and primary education while only 12.50% did not have formal education. This showed that formal education is important for the marketers of date palm fruits to succeed.

The years of experience of the marketers has a great influence in marketing agricultural products. It plays great role in managerial ability and decision making process. The years of experience in date palm marketing in this study indicated that 56.25% had between 6-10 years of experience, 32.50% and 11.05% had 1-5 and 11-15 years of experience respectively. This showed that greater than half of the marketers had 6-10 years of experience.

The access to credit showed that 97.50% of the marketers do not have opportunity of credit facilities; only 2.50% had right to credit. Non-accessibility to credit facilities will affect the capital base of the business, the level and volume of business activities.

Table 1. Socio- economic characteristics of the respondents

Variable	Frequency	Percentage
Gender		
Male	80	100
Female	-	-
Age		
10-20	11	13.75
21-30	40	50.00
31-40	29	36.2
Marital status		
Single	15	18.75
Married	65	81.25
Household size		
1-5	9	11.25
6-10	41	51.25
11-15	30	37.50
Educational level		
Qur'anic	34	42.50
Primary	15	18.75
Secondary	21	26.25
Non-Formal education	10	12.50
Years of experience		
1-5	26	32.50
6-10	45	56.25
11-15	9	11.05
Access to credit facilities		
No	78	97.50
Yes	2	2.50

Source: Computed from Field Survey Data, 2022.

Cost and return analysis of date palm fruits marketing

Table 2 showed the costs incurred and return generated from the sales of date palm. The total cost of marketing was ₦ 73,382.75, this comprises of total variable cost (₦72, 625.67) and total fixed cost (₦ 757.08). Total purchase cost constituted the highest percentage of the variable cost, accounting for 95.49%. This is followed by rent cost (1.72%), transportation cost (1.52%) packaging cost (0.71%) and storage cost (0.41%), while market charges (0.13%) formed the least percentage of the variable cost. In terms of the fixed cost, wheel barrow accounted for the highest percentage of fixed cost (35.22%). Others fixed cost such as cost of tables, mudu and tray were represented by different percentages 27.52%, 24.22% and 13.04% respectively. Looking at the total cost, total variable cost gave the highest percentage of the total cost, forming 98.97% while total fixed cost contributed only 1.03%.

The average quantity of fresh and dried date palm purchased and sold by the respondents was 50 and 33.13 mudu. The average cost price (fresh and dried) was ₦ 725 and ₦ 906.67 while the average selling prices were ₦ 925.80 and ₦ 1,022.22 respectively. The gross incomes obtained from sales of fresh and dried date palm were ₦ 30,671.75 and ₦ 51,111.00, thus giving a total income of ₦ 81,782.75 per month per respondent. This showed that the marketing of date palm is highly profitable in the study area judging by the gross income. But the gross income is not a sustainable index of profitability because it does not take into account the variable cost and other fixed assets cost. Hence, the net marketing income of ₦ 8,400 per respondent per month was obtained by removing the total marketing cost from the total gross income. Also return on investment of ₦ 0.11was realised, indicating that for every one naira invested in the business ₦ 0.11 is obtained as profit. This showed that the marketing of date palm was profitable in the study area. However, the net marketing profit obtained in this study was higher than the value obtained by [20] **f**or retailer (₦ 336.57/kg) and wholesaler (₦ 329.58/kg) during the peak period of marketing date palm, but lower than the value (₦ 217797.57) per annum which translate to ₦ 18,149.80 per month) obtained by [18]. This could be due to differences in the units of sales, inflation, location, marketing strategies, inefficient in marketing, technical know- how and period of the business which is characterized by peak and off- peak period.

Table 2. Cost and Return of Date Palm Fruits Marketing

Variables	Quantity (*Mudu*)	Unit price (₦)	Gross income (₦)	Cost (₦)	% VC	% TMC
Dried date palm	50	1,022.22	51,111.00			
Fresh date palm	33.13	925.80	30,671.75			
A. Total Gross Income			81,782.75			
B. Variable cost						
Dried date palm	50	906.67		45,333.50		
Fresh date palm	33.13	725		24,019.25		
Total purchase cost				69,352.75	95.49	94.51
Rent cost				1,250	1.72	1.71
Transportation cost				1,106.25	1.52	1.51
Packaging cost				516.67	0.71	0.70

Contin. Table 2.

Market charges				100	0.13	0.14
Storage cost				300	0.41	0.41
C. Total Variable cost(TVC)				72,625.67		98.97
D. Fixed cost					% FC	
Wheel barrow				266.67	35.22	0.36
Tray				98.75	13.04	0.13
Mudu				183.33	24.22	0.25
Table				208.33	27.52	0.28
E. Total Fixed Cost				757.08	100	1.03
F. Total Marketing Cost (TMC)= C +E				73,382.75		100
Net Marketing Income (NMI)			8,400			
Return per Capital Invested (RPCI)			0.114			

Source: Computed from Field Survey Data, 2022.

Factors affecting the net profit of the marketers

The result of regression analysis which postulates the relationship between the Net Marketing Income (NMI) and set of explanatory variables affecting the NMI is presented on Table 3. The functional form that was selected to discuss the relationships was linear function. The table revealed that age, marital status, household size, educational level, years of marketing experience, quantity purchased, quantity sold and revenue were positively related to the net marketing profit. This means that increase in the value of coefficient of respective variables will bring about one unit increase in the profit. On the other hand, variables such as purchased cost, storage cost, transportation cost and packaging cost, and marketing charges were negatively connected to the net marketing profit, indicating that as the coefficient value of any these variable increases, it will result to a unit decrease in the net marketing profit of the respondent. This agree with [18] which found transportation cost, storage cost and packaging cost to be negatively related to net income obtained from the sales of date palm.

Years of marketing experience, quantity of date palm purchased and revenue were significant at ($P< 0.01$) percent probability level. Also quantity of date palm sold and purchase cost were significant at ($P< 0.05$) percent while household size of the marketers and transportation cost were significant at ($P < 0.10$) percent. [18] found transportation cost, storage cost and packaging cost to significantly affect the net income of date palm at ($P < 0.01$) percent level of probability.

The R^2 value of 0.7635 indicated that 76.35% of the difference in the net income is explicated by the variables contained within the model while the remaining 23.65% was ascribed to random error. The F- value of 2.71 reveals the entire model is statistically significant at ($P< 0.01$) meaning that all the variables considered in the model has influence on the net income of the marketers. With this result the null hypothesis which stated that there is no significant difference between the net marketing profit of the respondents and factors that are affecting it is rejected and the alternative hypothesis accepted.

Table 3. Result of Regression Analysis

Variable	Coefficient	t-values	P>/t/
Constant	3.658871	12.98	0.000
X1 = Age of respondents	0.0342326	0.43	0.669
X2 = Marital status	0.0003999	0.44	0.660
X3 = Household size	0.00294253	1.73*	0.090
X4 = Educational level	0.0044935	0.52	0.603
X5 = Years of marketing experience	0.0034793	1.80***	0.006
X6 = Quantity purchase	0.092071	2.70***	0.004
X7 = Quantity sold	0.00240723	2.50**	0.016
X8 = Revenue	0.0176334	2.73***	0.009
X9 = Purchase cost	-0.0000218	-2.29**	0.027
X10 = Storage cost	- 0.0001052	-0.10	0.920
X11 = Transportation cost	-0.0001337	-1.79*	0.086
X12 = Packaging cost	-0.0022363	-0.08	0.940
X13 = Marketing charges	-0.0090068	-0.71	0.483
X14 = Rent cost	-0.0007755	-0.65	0.519
F- Statistic	2.71		
R^2	0.7635		
Adjusted R	0.6322		

Source: Computed from Field Survey Data, 2022.
*** Significant at 0.01 ** Significant at 0.05 *Significant at 0.10

Constraints faced by the respondents in date palm marketing

The problems faced by the marketers in date palm marketing are presented on Table 4. Inadequate capital had the highest percentage of 100% and was ranked first in the list of the constraints. Inadequate capital will limit the ability of the respondents to expand the business. This perhaps may be the reason most of the respondents bought small quantity of date palm for sale. [23] opined that marketers of date palm has low tendency to save and had little or nothing to trade for profit. Generally, marketers are faced with inadequate capital as a major constraint to expand their business and are usually ranked first among the constraints [24].

Another constraint which influences the quality and quantity of date palm during storage is pest invasion; this accounted for 85% of the constraint and was ranked second. This concurs with the statement of [25] which said that pest and disease are major problem confronting marketers of cocoa in Oyo state, Nigeria.

Problem of inadequate storage facilities was ranked 3rd and had 63.75%. Insecurity, price fluctuation and seasonality of date palm were other constraints that formed 58.75%, 33%, 32.50% and were ranked 4th, 5th and 6th respectively. Insecurity keeps marketers in perpetual fear and does not allow them to go to farms and rural places to buy date palm for sale. Price fluctuation occurs when there is a variation in demand and supply of date palm. Prices of date palm normally rises during the Moslem fasting (*Ramadan***)** and festive period, most especially December time when wedding ceremonies are more [26]. According to [27], the major problem confronting marketers is price fluctuation followed by inadequate market information, spoilage and low quality product.

Problem of high transportation cost and bad road network formed 27.50% and 20%, and ranked 7th and 8th respectively, [28] opined that delay in transportation is detrimental to date palm marketing because it causes date palm fruits to be contaminated with disease spots, shallow crinkling, loose taste, and aroma. High cost of transportation is the major problem faced by the marketers as propounded by [29], [30]. On the other hand, [31] opined that high taxes during transportation lead to high cost of transportation. According to [32], the agricultural outputs and productivity is impacted by road infrastructure. [33] stated that improving road networks is a step towards enhancing production and marketing generally; this will generate more income and increase the standard of living of farmers and marketers. They further stated that transportation of agricultural inputs and outputs from one place to the other is very important and a key factor in agricultural development and the only means by which farm produce can be moved from the farm to the different consumers.

Table 4. Result of Regression Analysis

Constraints	*Frequency	Percentage	Rank
Inadequate capital	80	100.00	1st
Seasonality	26	32.50	6th
Inadequate storage facilities	51	63.75	3rd
Pest infestation	68	85.00	2nd
Insecurity	47	58.75	4th
High transportation cost	22	27.50	7th
Price fluctuation	33	33.00	5th
Bad road network	16	20	8th

Source: Computed from Field Survey Data, 2022.
*Multiple responses

CONCLUSIONS

The results of the findings concluded that male (100%) dominated the marketing of date palm fruits; they were married with highest age range of 21-30 years and household size of 6-10. They had qur'anic education, meaning that western education has little or no effect on the business, and experience of 6-10 years but do not have access to credit facilities. The cost and return analysis of date palm fruits marketing was profitable with net marketing income of ₦ 8,400 and return on investment of ₦ 0.11 per respondent per month. The major factors affecting the net marketing profit of the marketers are purchase cost, transportation cost, years of marketing experience, quantity of date palm purchased, revenue, quantity of date palm sold and household size of the marketers. It can also be concluded that the major constrains to date palm fruits marketing are inadequate capital, pest infestation, inadequate storage facilities, insecurity and price fluctuation.

RECOMMENDATIONS

The study recommends that:

1. The unemployed teeming population especially youths should be encouraged to go into the business of date palm fruits marketing to earn a living.
2. The marketers should come and pool their resources together to form cooperative society where they will be able to obtain loan at low interest rate to expand their business
3. Credit facilities should be provided to the markets through commercial banks and other lending institutions at lower interest rate, this will help the marketers to improve their capital and expand their business
4. Research institute should research and come up with storage facilities that will eliminate pest infestation of date palm fruits in the store. This will help minimises losses in the storage and improve the quantity and quality of date palm fruits available for marketing

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ANALIZA TROŠKOVA I DOBITI OD PLODOVA URME (*Phoenik Dactilifera* Linn) KOD TRGOVINE NA MALO U METROPOLI KADUNA, DRŽAVA KADUNA, NIGERIJA

Oluyinka Christopher Ariyo

Department of Entrepreneurship and Innovative Agriculture,
Federal College of Forestry Mechanization, Afaka, Kaduna, Nigeria
Forestry Research Institute of Nigeria, Ibadan, Nigeria

Apstrakt: Stabla palme (*Phoenix dactylifera* Linn) i plod urma, su ekonomska kultura voća koje se koriste za hranu, lekove i prihod u sušnoj i polusušnoj zoni Nigerije. Studija je urađena da se analiziraju troškovi i marketing plodova voća-palme (urme) između trgovaca na malo u glavnom gradu Kaduna, država Kaduna, Nigerija. Primenjena je dvostepena tehnika uzorkovanja koja je dovela do slučajnog odabira 80 ispitanika. Ispitanicima su dostavljeni strukturni upitnici, a prikupljeni podaci analizirani su deskriptivnom statistikom troškova i dobiti i regresionom analizom.
Rezultati su pokazali da su svi ispitanici muškog pola, starosti 21-30 godina, oženjeni sa domaćinstvom od 6 do10 članova porodice, koji imaju obrazovanje zasnovano na Kuranu.
Rezultat je dalje pokazao da je marketing voća (urme) bio profitabilan sa netto marketinškim prihodom od ₦8.400 po uzorku mesečno i povratom ulaganja od ₦ 0,11. Varijable kao što su godine marketinškog iskustva, količina kupljenih plodova palme (urme) i prihod, bile su značajne na nivou verovatnoće ($P<0,01$).
Takođe, nabavna cena i količina prodate urme bili su značajni u % na nivou ($P<0,05$), dok su troškovi transporta i veličina domaćinstva bili značajni u % na nivou ($P<0,10$). Glavna ograničenja marketinga ovog voća (urme) su neadekvatan kapital, najezda štetočina, neadekvatni prostori za skladištenje i nesigurnost prodaje.

Studija preporučuje da ne zaposlenu populaciju koja nema mnogo raspoloživih poslova, posebno omladinu, treba ohrabriti da se bavi marketingom plodova palmi (urme), kako bi zaradili sredstva za život.

Ključne reči: *Urme, prodavac, marketing, neto marketinški prihod, mladi*

Prijavljen:
***Submitted*: 12.03.2024.**
Ispravljen:
***Revised*: 25.04.2024.**
Prihvaćen:
***Accepted*: 05.05.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 52 – 63

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 52 - 63

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402052N

RESEARCH RESULTS OF THE COMBINED MACHINE THAT FERTILIZES THE SOIL ON THE SLOPES

Qurbanov Huseyn Nuraddin*

Agromechanika, Scientific Research Institute
Laboratory Mechanization of Crop production
Ganja City, Azerbaijan

Abstract: One of the important agrotechnical measures that ensure abundant and high-quality harvest is the equal distribution of mineral fertilizers in the field. Equal distribution of nutrients (nitrogen, phosphorus, potassium) in equal quantities, equality of nutrient points in the soil layer is ensured. An environment of continuous nutrition of the seed is created. Even distribution of mineral fertilizers in the soil layer in grain cultivation, as well as plant resistance during wintering, has a positive effect on plant height and quality grain maturity. In our research work, by evenly distributing mineral fertilizers in the soil layer, more than 6 centners of yield per hectare was obtained. A combined machine was developed in our laboratory, experimental field and laboratory tests were conducted. According to the main results of the research, 3 types of mineral fertilizers were taken. Urea, double superphosphate, potassium fertilizers were determined in the distribution percentage and amount of fertilizers on slopes up to 15 degrees. Depending on the slopes, the amount of distribution of mineral fertilizers per 1 m^2 and the amount of fertilizers per plant were determined. Based on the obtained results, graphs and tables were drawn up and analyzed.

Key words: *Combined plough; slopes; mineral fertilizers; equal distribution; degree*

*Corresponding Author. E-mail: genclik79@mail.ru
ORCİD: 0000-0002-3907-3384

INTRODUCTION

The Republic of Azerbaijan is a typical mountainous country, high mountains have created its own relief, which creates conditions for the formation of a well-formed soil-vegetation cover. Here, the diversity and complexity of the relief conditions, the unique characteristics of the climate, the plowing and cultivation works in the direction of the width of the slope in highly inclined areas and the application of soil protection measures have led to the development and wide spread of mountain farming.The territory of the republic consisted of 8.6 million hectares, 60% of which is covered by mountainous and foothill regions.

As a result of non-application of the rotation system in mountain farming, insufficient application of mineral fertilizers, especially organic fertilizers, and failure to carry out agrotechnical measures, the upper fertile layer of the soil is washed away and poured into streams and rivers, as a result of which a large amount of humus, nitrogen and other nutrients are lost.In such soils, the energy reserve of the upper humus layer is also sharply reduced, [3].

In order to prevent water erosion in the mountain regions of Azerbaijan, they currently plow the soil across the slope or in the horizontal direction of the field (along the contour).In most cases, the sowing of agricultural crops is carried out in the direction of the width of the slope. However, in narrow areas where it is not possible to move plows and seeding units in the direction of the width of the slope, all operations are carried out in the direction of the length of the slope, as a result of which the farmlands are exposed to the destructive effect of water erosion and become completely unsuitable for agriculture.Observations show that on slopes with a slope of more than 6°, the destructive effect of water is manifested even when plowing and sowing work is carried out in the direction of the width of the field.

The experience of many years shows that in the mountain and foothill regions of the republic, due to the application of the rotation system of grass fields and mineral fertilizers, autumn crops (wheat, barley, etc.) produce more than spring crops. In general, up to 60% of mountain farmland is devoted to winter grain.Therefore, it is of particular importance to develop and apply the progressive technology of soil cultivation and appropriate mechanization tools to prevent water erosion in the winter crops located on the mountain slopes, [7].

For the main application of solid mineral fertilizers in our country, almost all farmers and more than 60% of European countries have disc centrifugal fertilizer spreaders. Machines of this type have proved to be reliable, high productivity, structurally simple, low energy consumption and maneuverability during their operation for many years. The technological process of distributing fertilizers through these machines is very simple.Under the influence of centrifugal force, fertilizers are accelerated along the blades and spread around the machine on the surface of the soil, flying in a fan-shaped flow, [13].

In the last two decades, the productivity of machines for supplying mineral fertilizers has increased by 2-3 times, spreading width by 1.5-2.5 times, load-carrying capacity by 10 times, and special metal consumption has decreased by 10-20%.

The working width of the spreader always exceeds the design dimensions of machines with centrifugal working bodies, which is one of their main advantages.

In this case, the dispersion equation usually works with the previously unknown overlap of adjacent transitions, [4].The impossibility of strictly fixing the optimal working width is one of the main disadvantages of centrifugal working bodies of fertilizer machines.The optimal working width determined experimentally for a certain type of fertilizer with changes in working conditions limits it to be so.In addition, the actual working width of the machine does not always correspond to the optimal spreading, which causes speed variations and uneven application.It follows from this that the agrotechnical indicators of the centrifugal working bodies of the machines depend on each other and do not remain stable during operation due to the influence of many factors, [5;12].

Machines with a centrifugal working body are not able to apply powder and granular fertilizers over a large working width.But the main drawback of these machines is the uneven distribution of fertilizers, especially when working on slopes. In farm conditions, it reaches 80% and often exceeds the allowed agricultural requirements by 2 - 8 times [11].

MATERIAL AND METODS

The combined plough was developed in our laboratory to ensure an equal amount of mineral fertilizer under the plow. A new smooth spreading working part has been developed to ensure even spreading of fertilizers.It is installed on the rear part of the smooth distributing bucket [6;8]. The main factor affecting the productivity and technological process of the distributed bucket is the fertilizer rate.The fertilizer rate is divided into 19 levels. Norms are determined based on field monitoring and analysis. NDVI taken by drone or GIS system can be determined based on maps. Our main goal is to determine the fertilizer norms and the amount of mineral fertilizer applied to each tissue in order to achieve an even distribution of mineral fertilizers on the slopes. Our main goals are to provide the root system of grain with nutrients in the soil, [9].

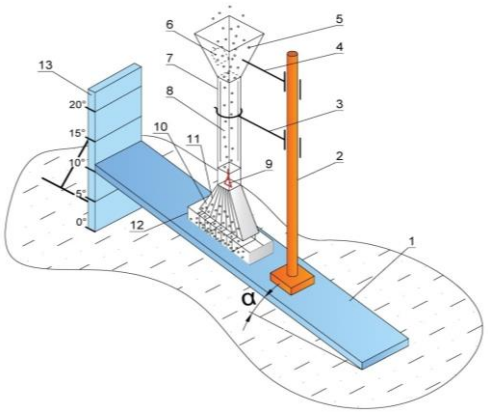


Figure 1. Device for determining the dispersion equation of a smooth scatterer
1-main support; 2- tripod; 3; 4–holder; 5–fertilizer box; 6–valve regulating the fertilizer rate; 7–fertilizer tube cover; –fertilizer pipe; 9–pendulum cone; 10-fertilizer distributor; 11 – partition; 12 - partitioned container for pouring fertilizer; 13 – regulating the slope along the vertical support

Experimental studies of the newly created smooth scattering part were carried out in the laboratory at 4 main degrees of inclination by means of a suitable device.Inclination degree 0; 5; 10; 15 was,experimental studies were conducted on 3 different mineral fertilizers (Figure 1).

The amount of even distribution of fertilizers on different slopes of the combined plough can be calculated by the following formula, [10].

$$G_b = \frac{G_N}{100} D_x \; ; \quad \text{.....} \quad \text{.....} \quad \textbf{(1)}$$

Here:

G_b – amount of equal distribution of mineral fertilizers in one hectare area, kg

G_N – mineral fertilizer application rate per 1 ha, kg

D_x – is the percentage of equal distribution of mineral fertilizers at different slopes,%

The amount of equal distribution of mineral fertilizers in 1 m^2 of the combined quota can be calculated by the following formula.

$$G_v = \frac{G_n}{100} D_x \; ; \quad \text{.....} \quad \text{.....} \quad \textbf{(2)}$$

Here: G_v – equal distribution amount of mineral fertilizers in 1 m^2 area, gr

G_n – mineral fertilizer fall rate per 1 m^2 area, gr

D_x – is the percentage of equal distribution of mineral fertilizers at different slopes, %

The amount of mineral fertilizers evenly distributed under the plow of the combined plough can be calculated by the following formula.

$$G_p = \frac{G_v}{N} \; ; \quad \text{.....} \quad \text{.....} \quad \textbf{(3)}$$

Here: G_p – amount of mineral fertilizer per plant, gr

G_v – equal distribution amount of mineral fertilizers in 1 m^2 area, gr

N – we have accepted the number of plants in 1 m^2, number N=220.

Figure 2. Experimental study of the combined plough

RESULTS AND DISCUSSION

According to the conducted research, the speed of the combined plough is 4...6 km/h, the width of the fertilizing tool is 1.51 m, the depth of soil cultivation is 18-22 cm, the amount of fertilizer is changed according to the slope of the fertilizer sowing rate, equal distribution in the soil layer (figure 2) [1, 2].The amount of equal distribution of urea, double superphosphate and potassium chloride fertilizers is studied in table 1, table 2, table 3.

The fertilizer of the combined plough was based on the rate of sowing and according to the density of the grain in the field as a result of our experiment.It was studied in table 4, table 5, table 6, taking into account the equal distribution of mineral fertilizers, with an average of 220 plants per 1 m^2 of soil.

The mentioned results allow us to create accurate algorithmic programs for the application of various mineral fertilizers on the slopes, to perform the exact application of fertilizer norms.If we take into account that there are difficult working conditions on the slopes, technological operations and the fact of water and wind erosion of the slopes, it is positive for the assessment of the work of the combined plough.

The combined plough mineral fertilizers, with their uniform distribution, carry out plowing and fertilizing in a single step in various difficult conditions related to the enrichment of soil nutrients.

Table 1. Determination of the quantity of urea fertilizer in the field

No	The amount of fertilizer applied to 1 ha, kg	Even distribution amount of fertilizer given to 1 ha area, kg				Even distribution amount of fertilizer on 1 m^2 of soil, gr			
		Slopes				Slopes			
		0^0	5^0	10^0	15^0	0^0	5^0	10^0	15^0
1.	65	62,4	61,5	59,9	57,7	6,2	6,1	5,9	5,7
2.	76,8	73,7	72,6	70,7	68,2	7,3	7,2	7,0	6,8
3.	88	84,5	83,2	81,1	78,1	8,4	8,3	8,1	7,8
4.	99	95,1	93,7	91,2	87,9	9,5	9,3	9,1	8,7
5.	109,6	105,3	103,7	101,0	97,3	10,5	10,3	10,1	9,7
6.	120	115,2	113,5	110,6	106,5	11,5	11,3	11,0	10,6
7.	132	126,8	124,9	121,6	117,2	12,6	12,4	12,1	11,7
8.	142,3	136,7	134,6	131,1	126,3	13,6	13,4	13,0	12,6
9.	154,2	148,1	145,9	142,1	136,9	14,7	14,5	14,1	13,6
10.	164,4	157,9	155,6	151,5	146,0	15,7	15,5	15,1	14,5
11.	176,2	169,2	166,7	162,4	156,4	16,9	16,6	16,2	15,6
12.	182,7	175,5	172,9	168,3	162,2	17,5	17,3	16,8	16,2
13.	202,7	194,7	191,8	186,8	180,0	19,5	19,2	18,7	18,0
14.	231,8	222,7	219,3	213,6	205,8	22,2	21,9	21,3	20,6
15.	290	278,6	274,4	267,2	257,5	27,8	27,4	26,7	25,7

Contin.Table 1.

16.	348	334,3	329,3	320,7	309,0	33,4	32,9	32,0	30,9
17.	406,6	390,6	384,8	374,7	361,1	39,1	38,5	37,5	36,1
18.	465,4	447,1	440,5	428,9	413,3	44,6	44,0	42,8	41,2
19.	520	499,6	492,1	479,2	461,8	49,9	49,2	47,9	46,1

Table 2. Determination of the quantity of doublesuperphosphate fertilizer in the field

No	The amount of fertilizer applied to 1 ha, kg	Even distribution amount of fertilizer given to 1 ha area,kg				Even distribution amount of fertilizer on 1 m^2 of soil,gr			
		Slopes				Slopes			
		0^0	5^0	10^0	15^0	0^0	5^0	10^0	15^0
1.	103,8	101,3	100,5	97,9	96,3	10,2	10,1	9,8	9,7
2.	122,7	119,7	118,8	115,8	113,9	11,9	11,9	11,6	11,5
3.	140,5	137,2	136,1	132,5	130,4	13,7	13,6	13,3	13,2
4.	158,1	154,4	153,1	149,2	146,7	15,4	15,3	14,9	14,8
5.	175,1	170,9	169,5	165,1	162,4	17,1	16,9	16,5	16,4
6.	191,6	187,1	185,6	180,8	177,8	18,7	18,6	18,1	18,1
7.	210,8	205,8	204,2	198,9	195,7	20,6	20,4	19,9	19,8
8.	227,3	221,9	220,1	214,4	210,9	22,2	22,1	21,4	21,3
9.	246,2	240,4	238,4	232,3	228,5	24,1	23,9	23,2	23,2
10.	262,5	256,3	254,2	247,6	243,6	25,6	25,4	24,7	24,6
11.	281,4	274,7	272,5	265,5	261,2	27,5	27,3	26,5	26,4
12.	291,8	284,9	282,6	275,3	270,8	28,5	28,3	27,5	27,4
13.	323,7	316	313,5	305,4	300,5	31,6	31,4	30,5	30,4
14.	370,2	361,4	358,5	349,3	343,6	6,1	35,9	34,9	34,8
15.	463,1	452,1	448,5	436,9	429,8	45,2	44,9	43,7	43,5
16.	555,7	542,5	538,2	524,2	515,8	54,3	53,8	52,4	52,2
17.	649,3	633,9	628,8	612,5	602,7	63,4	62,9	61,3	61,1
18.	743,2	725,6	719,8	701,1	689,8	72,6	71,9	70,1	69,8
19.	830,4	810,7	804,2	783,4	770,8	81,1	80,4	78,1	77,1

Table 3. Determination of the quantity of potassiumchloride fertilizer in the field

No	The amount of fertilizer applied to 1 ha, kg	Even distribution amount of fertilizer given to 1 ha area,kg				Even distribution amount of fertilizer on 1 m^2 of soil,gr			
		Slopes				Slopes			
		0^0	5^0	10^0	15^0	0^0	5^0	10^0	15^0
1.	92,3	89,4	89,1	87,4	86,5	8,9	8,9	8,7	8,6
2.	109,05	105,7	105,3	103,2	102,2	10,5	10,4	10,3	10,2
3.	124,96	121,1	120,7	118,3	117,1	12,1	12,0	11,8	11,7
4.	140,58	136,2	135,8	133,1	131,7	13,6	13,5	13,3	13,1
5.	155,63	150,8	150,3	147,4	145,8	15,1	15,0	14,7	14,6
6.	170,4	165,2	164,6	161,4	159,6	16,5	16,4	16,1	15,9
7.	187,44	181,7	181,1	177,5	175,6	18,2	18,1	17,7	17,5
8.	202,06	195,8	195,2	191,3	189,3	19,5	19,5	19,1	18,9
9.	218,68	212,1	211,2	207,1	204,9	21,2	21,1	20,7	20,4
10.	233,45	226,3	225,5	221,1	218,7	22,6	22,5	22,1	21,8
11.	250,2	242,5	241,7	236,9	234,4	24,2	24,1	23,6	23,4
12.	259,43	251,5	250,6	245,7	243,1	25,1	25,0	24,5	24,3
13.	287,83	279,1	278,1	272,6	269,7	27,9	27,8	27,2	26,9
14.	329,16	319,1	318,1	311,7	308,4	31,9	31,8	31,1	30,8
15.	411,8	399,2	397,8	390,1	85,9	39,9	39,7	39,0	38,5
16.	494,16	479,1	477,4	468,1	463,1	47,9	47,7	46,8	46,3
17.	577,37	559,7	557,8	546,8	541,1	55,9	55,7	54,6	54,1
18.	660,87	640,7	638,5	625,9	619,3	64,1	63,8	62,6	61,9
19.	738,4	715,8	713,4	699,4	692,1	71,5	71,3	69,9	69,2

Table 4. Determination of the amount of urea fertilizer per plant in the field

No	The amount of fertilizer given to 1 m^2 area, gr	Number of plants per 1 m^2 area, PS	Amount of fertilizer per plant, gr			
			Slopes			
			0^0	5^0	10^0	15^0
1.	6,5	220	0,028	0,027	0,026	0,025
2.	7,7	220	0,033	0,032	0,031	0,030
3.	8,8	220	0,038	0,037	0,036	0,035
4.	9,9	220	0,043	0,042	0,041	0,039
5.	10,96	220	0,047	0,046	0,045	0,044
6.	12	220	0,052	0,051	0,05	0,048
7.	13,2	220	0,057	0,056	0,055	0,053

Contin. Table 4.

8.	14,2	220	0,061	0,060	0,059	0,057
9.	15,4	220	0,066	0,065	0,064	0,061
10.	16,4	220	0,071	0,070	0,068	0,065
11.	17,6	220	0,076	0,075	0,073	0,070
12.	18,3	220	0,079	0,078	0,076	0,073
13.	20,3	220	0,088	0,087	0,085	0,081
14.	23,2	220	0,100	0,099	0,096	0,093
15.	29	220	0,126	0,124	0,121	0,116
16.	34,8	220	0,151	0,149	0,145	0,140
17.	40,7	220	0,177	0,175	0,170	0,164
18.	46,5	220	0,202	0,2	0,194	0,187
19.	52	220	0,226	0,223	0,217	0,209

Table 5. Determination of the amount of doublesuperphosphate fertilizer per plant in the field

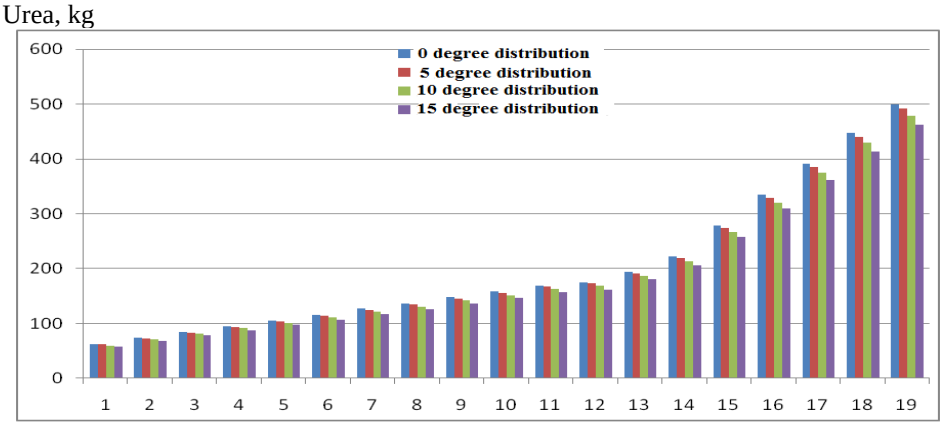
No	The amount of fertilizer given to 1 m^2 area, gr	Number of plants per 1 m^2 area,PS	Amount of fertilizer per plant, gr			
			Slopes			
			0^0	5^0	10^0	15^0
1.	10,40	220	0,046	0,045	0,044	0,044
2.	12,26	220	0,054	0,054	0,052	0,052
3.	14,05	220	0,062	0,061	0,060	0,06
4.	15,81	220	0,07	0,069	0,067	0,067
5.	17,5	220	0,077	0,076	0,075	0,074
6.	19,2	220	0,085	0,084	0,082	0,082
7.	21,08	220	0,093	0,092	0,090	0,09
8.	22,73	220	0,100	0,100	0,097	0,096
9.	24,63	220	0,109	0,108	0,105	0,105
10.	26,25	220	0,116	0,115	0,112	0,111
11.	28,14	220	0,125	0,124	0,120	0,12
12.	29,18	220	0,129	0,128	0,125	0,124
13.	32,37	220	0,143	0,142	0,138	0,138
14.	37,02	220	0,164	0,163	0,158	0,158
15.	46,31	220	0,205	0,204	0,198	0,197
16.	55,58	220	0,246	0,244	0,238	0,237
17.	64,93	220	0,288	0,285	0,278	0,277
18.	74,32	220	0,33	0,326	0,318	0,317
19.	83,04	220	0,368	0,365	0,355	0,350

Table 6. Determination of the amount of potassiumchloride fertilizer per plant in the field

No	The amount of fertilizer given to 1 m^2 area, gr	Number of plants per 1 m^2 area, PS	Amount of fertilizer per plant, gr			
			Slopes			
			0^0	5^0	10^0	15^0
1.	9,23	220	0,041	0,040	0,039	0,039
2.	10,9	220	0,047	0,047	0,046	0,046
3.	12,5	220	0,055	0,054	0,053	0,053
4.	14,06	220	0,061	0,061	0,060	0,059
5.	15,6	220	0,068	0,068	0,066	0,066
6.	17,04	220	0,075	0,074	0,073	0,072
7.	18,74	220	0,082	0,082	0,080	0,079
8.	20,20	220	0,088	0,088	0,086	0,085
9.	21,87	220	0,096	0,095	0,094	0,092
10.	23,34	220	0,102	0,102	0,100	0,099
11.	25,02	220	0,11	0,109	0,107	0,106
12.	25,94	220	0,114	0,113	0,111	0,110
13.	28,78	220	0,126	0,126	0,123	0,122
14.	32,92	220	0,145	0,144	0,141	0,14
15.	41,18	220	0,181	0,180	0,177	0,175
16.	49,42	220	0,217	0,216	0,212	0,210
17.	57,74	220	0,254	0,253	0,248	0,245
18.	66,09	220	0,291	0,29	0,284	0,281
19.	73,84	220	0,325	0,324	0,317	0,314

Uniform distribution of urea fertilizer on 1 ha

Urea, kg



Fertilizer rates

Figure 3. Uniform distribution of urea fertilizer in 1 ha of combined plough

Even distribution of double superphosphate fertilizer on 1 ha

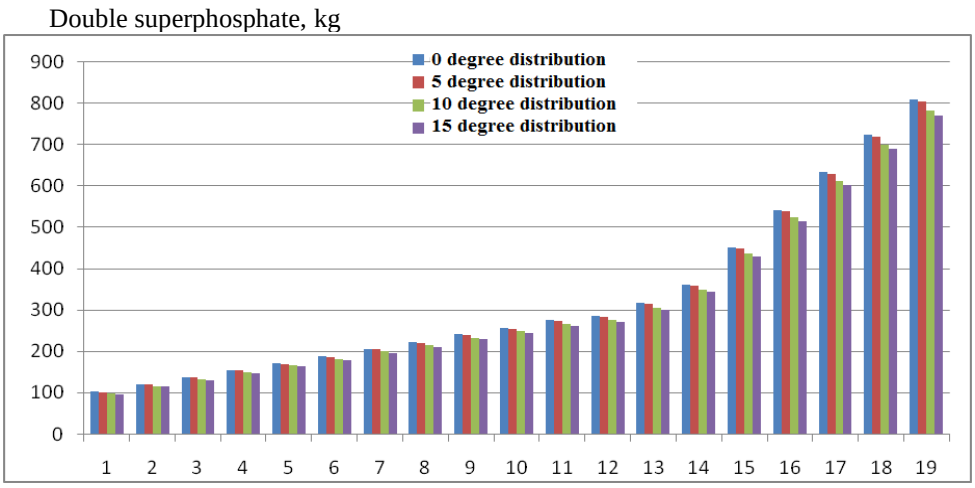


Figure 4. Uniform distribution of double superphosphate fertilizer on 1 ha of the combined plough

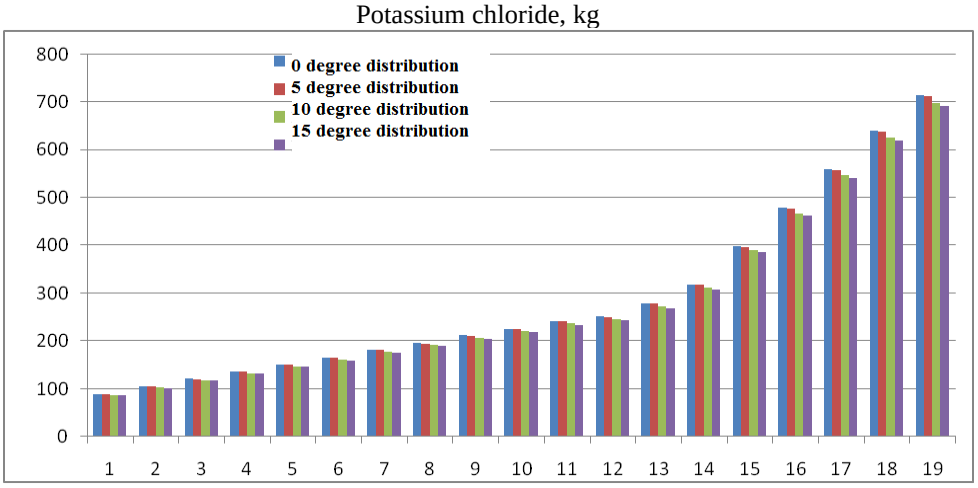


Figure 5. Uniform distribution of potassium chloride fertilizer in 1 ha of the combined plough

From the diagrams shown above (Figure 3, Figure 4, Figure 5) it is clear that the amount of mineral fertilizer scattering increases depending on the slope, and the amount of uneven distribution increases.That is, one of the main factors affecting the distribution is the fertilizer rate.Fertilizer rate is regulated on 19 levels. The combined fertilizer is successful in applying mineral fertilizers in the required rate.

It is known from the diagrams that the density and granularity of mineral fertilizers affect the even distribution. With the equal distribution of mineral fertilizers per hectare, the feeding area of 1 plant is 45 cm^2.These indicators characterize the normal food area.

The newly created combined plough has made it possible to obtain 6 centners more than the productivity of grain crops by distributing mineral fertilizers evenly under the soil under special difficult conditions.At the same time, quality grain was obtained.

As a result of combined plough laboratory and field tests in grain growing, 5.7...49.9 g of urea, 9.7...80.4 g of double superphosphate, 8.6...71.5 g of potassium chloride mineral fertilizers, per 1 m^2 area performs equal distribution on slopes forming angles of 0...15 degrees. Equal distribution of mineral fertilizers was on average 92% in urea, 94% in double superphosphate, and 93% in potassium chloride.

CONSLUSION

1. The use of the combined plough completely reduces the operation of spreading fertilizer with fertilizer spreading machines before the plowing operation, the costs and labor spent on it, and it ensures that the operations are performed in a short time by saving time. Distribute fertilizer under the ground is environmentally friendly and prevents fertilizer loss.

2. As a result of the farm test 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, and the fertilizer sowing rate was 65-830 kg/ha.

3. The average indicator of the experimental combined plough for spreading solid mineral fertilizers with the given construction and kinematic parameters was the equal application of granulated urea fertilizer - 92%, double superphosphate 94%, potassium chloride - 93%, the working width of the unit was 1.51 m.

4. Combined plough 5.7-49.9 g of urea, 9.7-80.4g of double superphosphate, 8.6-71.5 g of potassium chloride mineral fertilizers, evenly distributed on 1 m^2 area, 0-15 on slopes forming angles of degrees.

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REZULTATI ISTRAŽIVANJA KOMBINOVANE MAŠINE ZA ĐUBRENJE ZEMLJIŠTA NA NAGIBU

Qurbanov Huseyn Nuraddin

Agromechanika, Scientific Research Institute
Laboratory Mechanization of Crop production
Ganja City, Azerbaijan

Apstrakt: Jedna od važnih agrotehničkih mera koja obezbeđuje predpostavku visokog kvalitetnog prinosa, je ravnomerna raspodela mineralnih đubriva u polju. Distribucija hranljivih materija (azot, fosfor, kalijum) u jednakim količinama, obezbeđena je po dubini u sloju zemljišta. Na ovaj način, stvara se okruženje stalne i pravovremene ishrane semena. Ravnomerna raspodela mineralnih đubriva u zemljišnom sloju u gajenju žitarica, kao i otpornost biljaka tokom zimskog perioda, kasnije, pozitivno utiču na visinu biljaka i kvalitetno zrenje zrna kulture koja se gaji.
U našem istraživačkom radu, ravnomernom raspodelom mineralnih đubriva u zemljišnom sloju, dobijeno je više od 6 centi kod prinosa po hektaru.
U našoj laboratoriji razvijena je kombinovana mašina, obavljeni su ogledi na polju i laboratorijska ispitivanja.
Prema glavnim rezultatima istraživanja uzete su 3 vrste mineralnih đubriva. Urea, dvostruki superfosfat, kalijumova đubriva su određena u procentu raspodele i količini đubriva na nagibima do 15 stepeni. U zavisnosti od nagiba određivana je količina raspodele mineralnih đubriva po 1 m^2 i količina đubriva po pojedinačnoj biljci.
Na osnovu dobijenih rezultata istraživanja, urađeni su i analizirani grafikoni i tabele.

Ključne reči: *Kombinovani plug, nagib, mineralna đubriva, jednaka raspodela, stepen*

Prijavljen:
Submitted: **22.02.2024.**
Ispravljen:
*Revised***: 20.04.2024.**
Prihvaćen:
Accepted: **16.05.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 64 – 74

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 64 - 74

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402064A

FARMERS' KNOWLEDGE AND ATTITUDE TOWARDS AGRICULTURAL MOBILE PHONE APPLICATIONS IN NIGERIA

Joy Yetunde Adelowo[1], Gbolagade Benjamin Adesiji[1], Temidire Adesiji[2], Sola Emmanuel Komolafe[*1]

[1]*Department of Agricultural Extension and Rural Development, University of Ilorin, Ilorin, Nigeria*
[2] *Department of Computer Engineering, University of Ilorin, Ilorin, Nigeria*

Abstract: In order to enhance the dissemination of agricultural information to farmers, numerous Agricultural Mobile Phone Applications (AMPAs) have been developed to bridge the knowledge gap between experts and agricultural practitioners. However, the extent to which farmers are aware of these Applications remains uncertain. The study therefore aimed at examining the knowledge of and attitude towards AMPAs among cassava farmers in South-west, Nigeria. A three-stage sampling procedure was employed to select 410 respondents for the study. Data were analyzed using both descriptive and inferential statistics, including frequency counts, percentages, means, and regression analysis. The findings of the study were that farmers exhibited a high level of knowledge for IITA herbicides calculator (80.4%), Airtel 4-2-1 call App (88.6%), and Akilimo App (75.3%). Farmers had a positive attitude towards the use of the IITA herbicides calculator (75.0%), Airtel 4-2-1 call App (84.5%), and Akilimo App (80.4%). Regression analysis showed that level of education ($\beta = 0.260$, $p=0.044$), and smart phone ($\beta= 0.278$, $p=0.022$) owned were also positively significant to the knowledge level while age ($\beta= -0.278$, $p=0.021$) have negative significance.
The study concluded that farmers in the study area had good knowledge and favourable attitude about AMPAs. The study therefore recommended that designing user interfaces that cater to the preferences and usability needs of different age groups is important noting that younger users may navigate complex interfaces, while older users may prefer simpler and more intuitive designs.

[*]Corresponding Author. E-mail: kemmas04@yahoo.com
ORCİD: 0000-0002-2293-1506

***Key words**: Agricultural apps, knowledge, attitude, education and ownership of phone*

INTRODUCTION

To attain a higher productivity increase in cassava production, mobile applications related to agriculture have been developed as a result of the advancement of technology [1,2], to bridge the knowledge and information gap covering a wide range of operations specifically for cassava production and its value chain. The International Institute of Tropical Agriculture (IITA) and several other organizations developed numerous digital solutions to address some of the agronomic issues threatening cassava productivity in Africa to bring about the transformation needed to achieve food security. The selected Apps in this study were Akilimo App, Airtel 4-21 call App and IITA herbicide calculator App. Akilimo app is an advisory tool that provides site-specific recommendations to cassava farmer in order to increase their Cassava-based cropping systems [3]. Airtel 4-2-1 call App is a component of Akilimo that provide a voice-based tutorial on Cassava production, weather, education, rice amongst others by simply dialing 4-2-1 on any mobile phone with an Airtel sim card. IITA herbicides is a mobile application developed to prevent herbicide abuse, such as over-dosing and/or under-dosing herbicides.

Agriculture is location-specific thus, it is imperative that farmers receive specialized guidance on best practices, appropriate usage of inputs, precise weather forecasts, and up-to-date market and price information, hence harnessing the evolution of internet use and related digital technology like smartphones and apps, farmers can get the information they need as well as overcome limitations faced by the traditional agricultural extension service delivery [4]. In addition, each user of agricultural applications has a unique knowledge and comprehension of the app, and how well the app is used can also be influenced by the user's environment, friends, and personal traits like age, gender, and educational background.

In South-west Nigeria, Cassava farming plays a vital role in the agricultural sector, contributing significantly to the region's economy. With the increasing prevalence of mobile phone applications designed for agricultural purposes, there exists a gap in understanding the knowledge of cassava farmers on these technologies. The effectiveness of these applications in enhancing farming practices and increasing agricultural productivity is uncertain due to the limited insights into farmers' knowledge, and usage of the Apps. Studies on mobile applications by farmers is an aspect of technological innovation that has received much attention, but most of these studies tend to focus on usage, diffusion, and adoption without taking into consideration the knowledge and attitude of users using a mobile phone application like agricultural Apps [1,5]. To address these gaps, knowledge and usage of agricultural apps is a major concern, since the users of an application, and their judgment, determines its success or failure.

Therefore, the extent to which farmers know agricultural mobile phone applications among cassava farmers in the study are is not well-documented, leading to a limited understanding of the applications. It is against this background that the study intends to provide answers to the following research questions:

(i) What is the level of knowledge of cassava farmers on agricultural mobile phone applications in the study area?
(ii) (ii) What is the attitude of cassava farmers in the study area towards the use of agricultural mobile phone applications?
(iii) (iii) Do socio-economic characteristics of cassava farmers have significant relationship with their knowledge on agricultural mobile phone applications in the study area.

MATERIAL AND METHODS

Study area

This study was carried out in Southwestern part of Nigeria. South-west Nigeria comprises of six states namely Oyo, Ogun, Osun, Ekiti, Ondo and Lagos states as shown in Figure 3**.** The six states lie between longitude $2^{o}31^{1}$ and $6^{o}00^{1}$ East and latitude $6^{o}21^{1}$ and $8^{o}37^{1}$ North with a total land area of 77,818 km2. The coordinates Latitude and Longitude in the three selected states for this study are as follows Oyo (8^{o} 00' 00'' N: 4^{o} 00' 00''E), Ogun (7^{o} 00' 00'' N: 3^{o} 35' 00''E), and Ekiti (7^{o}40' 00'' N:5^{o} 15'00''E).

Population, sampling procedure and sample size

The population of the study comprised all the cassava farmers trained on agricultural mobile phone app in the selected South-West States in Nigeria. A three-stage sampling procedure was employed to select respondents for the study. The first stage involved the purposive selection of two states in South-West, Nigeria. Oyo and Ogun States were purposively selected for the study because Akilimo, Airtel 4-2-1, and IITA herbicide calculator have been launched and disseminated to some selected cassava farmers on the use of these apps by African Cassava Agronomy Initiative (ACAI) programme of IITA, Justice, Development and Peace Movement (a Non-Governmental Organization) in Oyo State and Ogun State Agricultural Development Programme, among other promoters of agricultural apps. In addition to the aforementioned, cassava cultivation is one of the major crops grown in these areas. The second stage involved the purposive selection of two and three Local Government Areas in Ogun and Oyo State respectively. The third stage involved the proportionate random selection of 20% in each Local Government Areas of 2050-trained farmers, resulting in a sample size of 410 respondents. Data were analyzed using both descriptive and inferential statistics, including frequency counts, percentages, means, and regression analysis. Summary of the sampling procedure is presented in Table 1.

Table 1. Summary of sampling procedure and sample size

Stage 1	Stage 2	Stage 3	
Purposive selection of two States	Purposive selection of LGAs	Proportionate random selection of cassava farmers	20% of trained cassava farmers
Oyo State	Afijo	330	66
	Akinyele	425	85
	Iseyin	505	101
Ogun State	Ijebu ode	375	75
	Odeda	415	83
Total		2050	410

Data collection and analysis

Primary data was collected with interview schedule. Data gathered were analysed and presented using frequency count, percentage, mean score. Stated hypotheseis was analysed using Regression statistical tool. Knowledge statements were placed on a 5-point Likert type scale. The scales are very high, high, moderate, low and very low while scores of 5,4,3,2 and 1 were assigned respectively. Respondent knowledge was then categorized as low and high knowledge. Attitudinal statements were placed on a 5-point Likert type scale. This was measured as strongly agree, agree, undecided, disagree and strongly disagree while scores of 5,4,3,2 and 1 were assigned respectively for positively worded statement but reverse was the case for negatively worded statements. A minimum score of 30 and maximum of 150 was expected from each respondent. Respondent attitudes were then categorized as between 30 -90 favorable attitudes and between 91- 150 as unfavorable attitude.

RESULTS AND DISCUSSION

Farmers' Knowledge on Agricultural Mobile Phone Application

Mobile phones have played vital role in enhancing farmers' knowledge about agriculture, and supporting rural development in developing countries [6]. The knowledge of cassava farmers regarding agricultural mobile phone applications can vary depending on factors such as their access to technology, education, exposure to information, and their engagement with agricultural extension services. Also, agricultural mobile apps provide valuable information and knowledge related to farming practices, market prices, weather forecasts, and more. The results on knowledge of farmers on IITA herbicides calculator app in South-West Nigeria as presented in Table 2 showed that farmers agreed to the following knowledge statements such as I can download the app on the play store applicable to my device with a mean score of (5.00), it does not require data after the first download (4.87), also respondents can operate the app offline as much as they want with a mean score of (4.82) respectively.

The findings suggest that farmers are knowledgeable with IITA herbicides calculator app operations. This might be because of the simplicity of downloading the app and clicking on the parameters for calculating herbicides. This is in line with these findings, report that knowledge of farmers on herbicide calculator app helped to reduce underdosing and overdosing the farm with herbicides and prevents environmental pollutions [7]. Hence, respondents have high knowledge (80.4%) on herbicides calculator app in the study areas. Result reveals that farmers exhibited varying degrees of knowledge statements on Akilimo app such as Akilimo app does not have options for detection of cassava disease with a mean score of (4.51) and can determine the land area of their farm through the app with a mean score of (4.28). This implies that cassava farmers can determine their farm area, farm size and are unable to upload picture of diseased plant.

On knowledge categorization of Akilimo App in Table 3, respondents have high knowledge (75.3%) of Akilimo App.

The results reveals that farmers agreed to the following knowledge statements on airtel 4-2-1 call app such as airtel 4-2-1 call app language option is available in English and the three major Nigerian languages with a mean score of (5.00), it is very easy and convenient to use (4.71), and the airtel service does not require airtime or data before I can access the service (5.00).

This implies that due to the portability, ease of dialing calls and available language options on mobile app, farmer of have high knowledge on the app. Furthermore, the reason for the dominance of voice call app was best explained by the similar findings [8] of which also reported that majority (97.1%) of the farmers affirmed that information via voice call app is timely, as 94% affirmed to the reliability of the information received through the app. On knowledge categorization of airtel 4-2-1 call app, respondents have high knowledge (88.6%) of airtel 4-2-1 call app.

Table 2: Distribution of the respondents on knowledge of agricultural mobile phone application

Knowledge on Agricultural Mobile Phone Application	Mean score
IITA Herbicide calculator App	
I can calibrate accurately the required herbicides to be use on the farm	4.70
I can operate the app offline as much as I want	4.82
Calculating the volume of water to use is difficult	4.57
It requires a lot of data that is why I do not use it	4.36
It does not require data after the first download	4.87
Herbicide calculator apps is easy and convenient to use	3.00
It does not require update	4.20
I can update app when the need arises	4.35
The app is error free	4.02
The parameters for calculating herbicides are difficult	4.21
I can download the app on the play store applicable to my device.	5.00
Description on how to use the app is available when you click on it.	4.27
I can reset the parameters for calculation on the app	4.85
AKILIMO App	
I can determine the land area of my farm through Akilimo apps	4.28
It provides the option of choosing my farm location	3.64
When I click on the unit price options, it does not connect and it say invalid unit price	4.28
It does not provide information on weed management practices	3.64
The fertilizer blending on the app does not load while using the app	3.31
The schedule planting date and harvesting dates options does not provide the expected yield.	3.31
It is too complex for me to understand	3.22
It does not have options for detection of cassava disease	4.51
The inter-cropping pattern is not flexible to use on the app	3.98
Recommendations is not available on the app	3.36
Is the apps user friendly	3.73
I do not use the app often because it consumes data when in use.	2.85
Do you get recommendations while using Akilimo App	3.65
Are Update available on the app	3.07
Unable to complete a task on the app	3.69
Error pop up while using the app	4.03
It takes times to learn and understand it	1.63

Contin. Table 2.

Airtel 4-2-1 Interactive Voice Recording (IVR) service App	
4-2-1 call app language option is available in English and the three major Nigerian languages	5.00
It is very easy and convenient to use	4.71
I can listen to drama programs related to cassava farming	3.80
It provides information on News, current affairs, education and governance	4.04
I understand fertilizer recommendation for cassava and maize intercropping	4.48
I can monitor weather conditions with 4-2-1	3.95
Health News such as family planning, Lassa fever, covid-19, yellow fever are timely and informative	4.72
Tailored fertilizer recommendations is available according to ecological zones and state applicable to the users	4.62
It provides voice base tutorial on cassava and other arable crops	4.50
It provides good agronomic practices on six steps to weed management	4.33
The airtel service does not require airtime or data before I can access the service	5.00
It provides best planting practice	4.60
I can operate it easily on both basic and smart phone	4.93
I can update my profile on 4-2-1	4.20

Source: Field survey, 2023

Table 3. Distribution of the respondents by the categorization of their knowledge level on IITA Herbicide Calculator, Akilimo and Airtel 4-2-1 call App.

Apps	Category	Frequency	Percentage (%)
IITA Herbicide Calculator	High	119	80.4
	Low	29	19.6
	Total	148	100
Akilimo	High	292	75.0
	Low	96	25.0
	Total	388	100
Airtel 4-2-1 call App	High	195	88.6
	Low	25	11.4
	Total	220	100

Source: Field survey, 2023.

Farmers' Attitude towards Agricultural Mobile Phone Applications

Some cassava farmers may have a positive and enthusiastic attitude towards using agricultural mobile phone apps. They may recognize the potential benefits of these apps in terms of accessing valuable information, improving farming practices, connecting with markets, and enhancing productivity and profitability. These farmers are likely to actively seek out and embrace the use of such apps in their cassava farming operations. Other cassava farmers may have a neutral or open-minded attitude towards agricultural mobile phone apps. They may be willing to explore and learn about these apps, but their level of enthusiasm may depend on their understanding of the apps' benefits and their experiences with using agricultural apps.

From the result in Table 4, respondents embraced the use of IITA Herbicide calculator apps, I use the app because it enables me to calculate right and prevent environmental pollution with a mean score of (4.47) respectively.

This implies that the farmers were generally in support of mobile phone technologies.

This suggests that most of the farmers were convinced of the efficacy of the mobile phone technologies at enhancing their farming activities through effective information disseminating potential of mobile apps [9].

It also implies that the farmers in the study area are ready to take part extensively in the deployment of apps, particularly agricultural mobile phone apps. Furthermore, favorable attitude of farmers towards mobile phone was also established by a study in Niger state of Nigeria where they also revealed that 7 out of the 10 parameters used in assessing the perception of the farmers on relevance of mobile phone technologies got mean score above 3 [10]. Also, the findings revealed that the farmers across the study area predominantly express a favourable disposition towards mobile phone apps. Table 10 also revealed that respondents with a mean score of 3.57 disagreed that Akilimo App has no impact on cassava productivity. 50% of respondents disagreed that they do not use the app because of several interface with a mean score of 3.37. Majority of the farmers with a mean score of 82.2% acknowledged that the use of 4-2-1 Interactive Voice Recording (IVR) service on airtel network to access information is available in three major Nigerian languages. Also, 99.5% of the respondents with a mean score of 4.80 disagreed to the statement that the 4-2-1 call app is not effective.

The overall attitude toward mobile apps in the study area was favorable with 75.0% for herbicides calculator which implies that the purpose and benefits of developing the app has been achieved by the users while that of Akilimo is 80.4%, and 84.5% for Airtel 4-2-1 are also being favorable which means that respondents have a favorable attitude toward the apps as a means of obtaining information to improve farm decision-making on cassava production. The knowledge of cassava farmers on agricultural mobile phone application determined their attitude towards it. This is because farmers need a tool that will facilitate access to agriculture information as well as provide information which is applicable or specific in their local environment context [4].

Several literatures on mobile phones technologies have reported positive attitude, high level of knowledge and minimal constraints as effective factors promoting adoption of technologies [11]. It is important to note that attitudes towards agricultural mobile phone apps can evolve over time as farmers gain more experience, receive training and support, and witness the benefits of using these apps. Engaging farmers in participatory processes, involving them in app development and tailoring the apps to their specific needs can contribute to more positive attitudes among cassava farmer.

Table 4. Distribution of the respondents by their attitude towards agricultural mobile phone applications

Attitudinal Statements	SA %	A %	UD %	D %	SD %
IITA Herbicide calculator					
I embrace the use of IITA Herbicide calculator apps	46.6	53.4			
I don't need IITA Herbicide calculator app before applying herbicides on my farm	-	-	18.9	50.0	31.1
Contin. Table 4.					
I will use IITA Herbicide Calculator app to help forestall incidents of under-dosing or overdosing of herbicides.	47.1	32.3	-	8.8	14.5
I use the app because it enables me to calculate right and prevent environmental pollution	69.5	20.5	-	6.8	4.1

Contin. Table 4.

I use Herbicide calculator *app because it* works offline and can be use as much as I want	54.1	45.9			
I use IITA Herbicide calculator app because of its accuracy	27.0	35.1	20.3	14.9	2.7
Akilimo App					
Akilimo App has no impact on cassava productivity	6.9	8.2	19.1	35.6	30.2
Akilimo App does not detect production problem for prompt response	16.8	22.9	11.6	24.7	24.0
The advice from the app on land preparation methods, weed management, planting densities and fertilizer application for intercropped Cassava fields as well as planting and harvest dates for high cassava root starch quality is easy to use.	17.0	26.3	14.4	20.6	21.7
I do not use the app because I can't inter-crop and blend fertilizer of my choice	26.3	22.7	14.7	22.7	13.6
It drained my battery a lot when in use	17.2	17.0	14.2	25.8	25.8
I become confuse when using the app	11.3	19.3	26.8	18.1	24.5
I do not use the app because of several interface	14.2	15.7	21.1	7.3	31.7
The best planting practices are not available on the app	8.0	10.3	39.4	19.6	22.7
It predicts the yield of cassava root and compare with the net income for the farmer from the sale of the roots to provide recommendations that help the farmer optimize his/her income	10.6	17.2	22.2	26.0	24.0
Fertilizer recommendations are expensive	20.6	20.9	18.3	17.5	22.7
Intercropping Cassava with Maize recommendations is not available on the app	31.7	22.7	14.4	11.6	19.6
I can use the app to calculate tailored fertilizer recommendation	26.3	22.7	11.1	19.1	20.8
The schedule planting helps me to calculate the investment	14.9	24.0	13.4	18.0	29.7
I use the app because it provides decision support on high cassava starch production.	22.9	22.7	18.3	21.7	14.4
I do not use the app because of poor internet connectivity on my farm location	22.6	17.2	25.0	26.0	9.0
Airtel 4-2-1 call App					
I use the 4-2-1 Interactive Voice Recording (IVR) service on AIRTEL network to access information because it is available in three major Nigeria languages.	82.3	17.7			
It is easier to for me to use IITA Interactive Voice Recording (IVR) service when i have any challenge in Cassava farming.	20.5	30.9	10.5	14.5	23.6
I use the call app often because it is free	55.0	25.5	10.0	8.6	0.9
Health information available on the call app do not met my health needs	21.8	14.5	25.5	22.3	14.9
I use the app because I can listen to drama programs related to cassava farming.	40.0	25.5	20.0	6.8	7.7
It is a good app because it provides information on other crops	25.5	28.2	20.4	14.5	11.4
I do not use the app because I do not get advice/ recommendations	10.5	14.5	9.1	35.5	30.4
I can dial the 4-2-1 number for weather information	22.7	19.1	13.2	19.1	25.9
The app is not effective		0.5	19.5	80.0	

Table 5. Distribution of the respondents by the categorization of their attitude towards IITA Herbicide Calculator, Akilimo and Airtel 4-2-1 call App.

Apps	Category	Frequency	Percentage (%)
IITAHerbicide Calculator	Favorable	111	75.0
	Unfavorable	37	25.0
	Total	148	100
Akilimo	Favorable	312	80.4
	Unfavorable	76	19.6
	Total	388	100
Airtel 4-2-1 call App	Favorable	186	84.5
	Unfavorable	34	15.5
	Total	220	100

Source: Field survey, 2023.

Factors Influencing farmers' Knowledge on Agricultural Mobile Phone Applications

Results from table 5 shows the relationship between socioeconomic characteristics of the respondents and their knowledge level on agricultural mobile application in the study area, it was observed that age (β= -0.278, p=0.021) have negative significance on their knowledge. This implies that the older the age of the farmers, the lesser their knowledge to agricultural apps. The negative value of the coefficient indicates a decrease in use of agricultural mobile apps with the increase in age of the farmer. Also, young farmers will be vaster and more knowledgeable about agricultural mobile application mobile. Level of education (β = 0.260, p=0.044), and smart phone (β= 0.278, p=0.022) owned were also positively significant to the knowledge level, i.e the higher the level of education of the cassava farmer the more knowledgeable the cassava farmer. Also, cassava farmer using internet and social media as source of information will be more knowledgeable, farmers using smart phone will be more knowledgeable than respondents using basic phone. This is in line with the study of [12] who asserted that farmers with more education are more likely to embrace new technologies like Agricultural apps and increase their productivity. Education also helps to boosts the capacity to obtain, decode, and assess helpful information for agricultural production. From this study, it appeared that the higher a person's level of education of farmers, the higher the likelihood they owned and used agricultural mobile apps for their farm activities.

Table 6. Regression analysis showing the relationship between the socio-economic characteristics of the respondents and the cassava farmers' knowledge level of agricultural mobile application

Predictors	Unstandardized coefficient		Standardized coefficient	T	Sig.
	B	Std error	Beta		
Constant	5.297	0.900		2.321	0.026
Age	0.157	-0.154	-0.278	-1.020	0.021
Sex	2.468	1.273	0.397	1.939	0.060
Marital status	0.563	2.125	0.118	0.265	0.793
Level of education	1.315	0.977	0.269	1.247	0.044
Religion	0.033	0.136	0.213	0.067	0.923
Average land cultivated	0.201	0.125	0.090	1.616	0.104
Income	-5.751E-08	0.018	0.231	0.322	0.332
Membership of association	-0.581	1.003	0.095	0.579	0.566
Farming experience	0.977	-2.136	0.061	- 0.401	0.103
Smart phone owned	0.123	0.113	0.451	0.101	0.022

Source: Field survey, 2023. $R^2 = 0.764$ Adjusted $R^2 = 0.723$

CONCLUSIONS

Based on the findings of this study, it can be inferred that Cassava farmers have good knowledge about agricultural apps. The attitude of the cassava farmers was favourable to the usage of agricultural mobile app. The study suggests that designing user interfaces that cater to the preferences and usability needs of different age groups is important. Younger users may navigate complex interfaces, while older users may prefer simpler and more intuitive designs. Considering age-related factors during the application's design process can enhance usability and user experience. Policy makers can design incentive programs that encourage cassava farmers to use mobile apps. This can include subsidies for app subscriptions or access to affordable smartphones which may help reduce the observed gap between the basic phone and smartphone ownership. Efforts to inform the farmers in general about the benefits of smartphone ownership should target young people in particular.

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ZNANJE I STAV FARMERA KOD UPOTREBE MOBILNIH TELEFONA I APLIKACIJA ZA POLJOPRIVREDU U NIGERIJI

Joy Yetunde Adelowo[1], Gbolagade Benjamin Adesiji[1], Temidire Adesiji[2], Sola Emmanuel Komolafe[1]

[1]Department of Agricultural Extension and Rural Development, University of Ilorin, Ilorin, Nigeria
[2] Department of Computer Engineering, University of Ilorin, Ilorin, Nigeria

Apstrakt: Da bi se poboljšalo širenje agronomskih informacija za farmere su razvijene brojne aplikacije za mobilne telefone u poljoprivredi (AMPA) kako bi se premostile prepreke u znanju između stručnjaka i poljoprivrednika. Međutim, u kojoj meri su farmeri svesni upotrebe ovih aplikacija je neizvesno.
Studija je zato imala za cilj da ispita znanje i stav prema aplikacija AMPAs među farmerima oblasti gajenja korena Cassava (*Manihot esculenta*), na jugozapadu Nigerije.
Primenjena je trostepena procedura uzorkovanja i odabir 410 ispitanika za istraživanje. Podaci su analizirani korišćenjem deskriptivnih i inferencijalnih statistika, uključujući brojanje učestalosti, procente, srednje vrednosti i regresionu analizu.
Nalazi studije su bili: farmeri su pokazali visok nivo znanja za IITA kalkulator za herbicide (80,4%), Airtel 4-2-1 call App. (88,6%) i Akilimo aplikaciju (75,3%).
Farmeri su imali pozitivan stav prema upotrebi IITA kalkulatora herbicida (75,0%), Airtel 4-2-1 call App (84,5%) i Akilimo aplikacije (80,4%).
Regresiona analiza je pokazala da su nivo obrazovanja (β = 0.260, p=0.044) i posedovanje pametnog telefona (β= 0.278, p=0.022) takođe pozitivno značajni za nivo znanja, dok je starost učesnika (β= -0.278, p=0.021) ima negativan značaj.
Studija je zaključila da farmeri u oblasti ovog istraživanja imaju dobro znanje i povoljan stav o AMPA aplikacijama.
Studija je zato preporučila da je važno dizajniranje korisničkih interfejsa (pristupa) koji zadovoljavaju preferencije i potrebe o upotrebljivosti različitih starosnih grupa, imajući u vidu da mlađi korisnici mogu da koriste složene interfejse, dok stariji korisnici mogu da preferiraju za jednostavnim i intuitivnim dizajnima (rešenjima) aplikacija za mobilne telefone.

Ključne reči: *Poljoprivredne aplikacije, znanje, stav, obrazovanje i vlasništvo nad telefonom*

Prijavljen:
***Submitted*: 28.02.2024.**
Ispravljen:
***Revised*: 05.03.2024.**
Prihvaćen:
***Accepted*: 21.05.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 75 – 81

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 75 - 81

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402075C

GROWTH AND YIELD EFFECTS OF CUCUMBER IN A SOILLESS GREENHOUSE USING COCOPEAT AND RICE HUSK AS GROWING MEDIA

Maxwell I. Chikwue[1], Rachael I. Ezem[1], Nnaemeka R. Nwakuba[1*], Achinike Okogbule-Wonodi[2]

[1]Federal University of Technology, Owerri, Nigeria,
School of Engineering and Engineering Technology
Department of Agricultural and Biosystems Engineering
[2]Rivers State University, Nigeria, Faculty of Engineering
Department of Agricultural & Environmental Engineering

Abstract: This study was conducted to determine the growth and yield performance of cucumbers planted using agricultural wastes that served as a planting media (soilless farming) against traditional soil planting. The research was carried out in a greenhouse of 10.64 m^2 area. The experiment was randomized in a complete block design which comprised two treatments and three replications with a control experiment (soil farming). The treatments were: T_1 and T_2 irrigated manually at intervals of once per day. The physicochemical parameters of the culture media were determined, also the agronomic parameters (growth indices) of the plants were determined and the results were subjected to statistical analysis.

The result showed that T_2 (100% rice husk) had the highest plant height of 151.0 cm on average, and a pedicel length of 12. 8cm.T_2 (100% rice husk) produced the highest cucumber fruit yield of 0.53 kg/m^2 with an average length and size of 23.77cm and 542.73 cm, respectively while T_1 (100% cocopeat) produced the lowest yield of cucumber for harvest. The control experiment (soil), with the highest average stem diameter of 2.57 cm had an average fruit length and size of 23.77 cm and 429.5 cm, respectively. The difference between the culture media was significant ($P < 0.01$) as yield and some other growth indices were higher in rice husk growing media.

*Corresponding Author. E-mail: nrnwakuba@gmail.com
ORCİD: 0000-0003-4356-8184

Results showed that crop growing indices for cucumber plants were sufficient when cultured in rice husk substrate, showing the capacity of this agricultural waste to anchor plant growth while providing alternative waste disposal and utilization methods for this waste. Prospects for further work are suggested.

***Key words**: Greenhouse, soil, crop waste, porosity, hydroponic, milling industry.*

INTRODUCTION

The misuse of resources (soil), unplanned industrialization and the release of domestic and industrial wastes into the water sources pollute the soil and water resources which are most important for food production. The increasing need for food and raw materials for food industries in an increasingly rising population region like Nigeria necessitates the effective use of water resources. This increasing challenge has led to the adoption of alternative food-crop production techniques, for immediate consumption and as raw material for industries. [1]. For many millennia, farming has been dependent on soil because it is seen as the most available growing medium for plants. It harbours air, and water, among others for plant growth. However, soil degradation, climate change; and population increase have been identified as major global challenges facing land use for food production [2]. These challenges have led to the adoption of many organic and inorganic materials as a growing medium for crops across the world. Soilless culture as one of the adopted methods can be defined as any method of growing plants without the use of soil as a rooting medium, in which the nutrients absorbed by the roots are supplied via irrigation water. The nutrients to be supplied to the crop are dissolved in appropriate concentration in the irrigation water and such solution is referred to as a "nutrient solution" [2]. When choosing a growing media, the media must be subjected to meet some criteria fit for use as a growing media. The most important functions of the growing media are to serve as a reservoir for plant nutrients, hold water for the plants, gas exchange, and provide anchorage for the plant [3]. Rice husk and coco peat are organic substrates that have been used by some researchers to amend the soil for planting while some have used them in combination with other organic substrates to culture and cultivate to provide anchorage for crops.

According to [4], investigations reviewed how [5] addition of rice husk to the soil in the rice farm caused the rice farm to increase in yield for a long time. He also stressed that the results of the use of zeolite, vermiculite and some organic materials as media for hydroponic tomato production showed that the lowest yield was obtained from the rice husk and a mixture of rice husk with other materials.

The highest yield, shoot dry weight and several clusters per pot were obtained from coco peat and perlite + mica media [6]. Authors [7], investigated the effect of some media including date palm peat, perlite, cocopeat and a mix of these materials on growing indices of tomatoes. Their results showed that fruit yield, fruit number, stem length, titratable acidity and ascorbic acid (in fruit) in different media had no significant differences. The effect of some culture media such as date-palm peat, cocopeat and perlite on some tomato growing indexes was studied in [8]. The treatments were perlite, date-palm peat and different ratios of coco peat and perlite and date-palm peat and perlite.

Results showed a higher amount of total soluble solids (TSS) was related to coco peat and perlite treatment that had no significant difference with date palm peat and perlite, perlite and date palm peat treatments. These researches were all centred on locating alternative materials for planting crops inside and outside the greenhouse. Most of the materials were used for soil amendment purposes due to the unavailability of these materials and cost-related challenges too.

However, in a clime like Nigeria where there is an abundance of rice husk lying waste at rice mills, another agro-waste also is cocopeat, a by-product of the coconut dehusking process which could serve as a substrate on its own (that is, providing an anchorage for plants). Coconut fibre is also known as palm peat, cocopeat, cocos, kokos and coir. Coir is coconut pith, the fibrous part just under the heavy husk. Coir is biodegradable and a good medium, for plant propagation through the flowering and fruit growth stages. Rice husk on the other hand is a by-product of the rice milling industry. It accounts for about 20% of whole rice grains. The annual yield of rice husks in Egypt is about 960,000 tons (one ton of rice paddy produces 200 kg of the husk), [9].

Currently, appropriate disposal methods have not been put in place to efficiently dispose of or utilize this waste. Inhabitants of the environments where this waste is produced tend to dispose of it only by burning the waste material and this has also posed health-challenging issues therefore this present study aimed to compare the effects of rice husk, cocopeat, and soil (control) as a growing media, on the growth and performance of cucumber crop (*Cucumis sativus L.*) in the greenhouse. The objective of this research also was to carry out some physicochemical characteristics of these culture media used in the cultivation of cucumber. It also covered the assessment of some selected growth indices of the cucumber crop during the growing and harvesting period. Analysis of variance (ANOVA) using SPSS statistical software was used to verify the effects and significance of the different treatment levels in cucumber production done in the greenhouse.

MATERIAL AND METHODS

This research was carried out in a greenhouse located in the Department of Agricultural and Bioresources Engineering of the Federal University of Technology, Owerri. The experiment was designed using the randomized complete block design (RCBD) technique with two complete treatments and three replications. The treatments were: 100% coconut coir, or cocopeat, 100% rice husk, and pure loamy sand soil. *Cucumis Sativus L*. cultivar was used as the seed under study.

Cucumber seeds were sown one seed per square hole in a cocopeat medium inside a seedling tray and young plants at three true leaf stages were transplanted into the plastic grow bags filled with the different growing media.

One cucumber plant per bag was planted in grow bags of dimensions 63.5cm wide and 40.6cm high from ground level and the distance between bags was 27cm row-wise and 22cm column-wise. Plants were grown between June and August. The cucumber plants were fertigated with a nutrient solution (A formulation of BIC Farms Concept, Abeokuta), mixed at 10 g per 100 L of water for mix B and 12 g per 100 L of water for only mix A, a week after transplanting till before fruiting.

The pH of the nutrient solution was kept between 5.5-6. Irrigation was performed by hand twice daily based on the water-holding capacity of the media (which varied from 8.33 to 186.23%). The average temperature day and night were kept at 30°C and 18˚C, respectively.

Some of the physicochemical characteristics of the culture media including; Bulk density, organic carbon, total porosity, water holding capacity, cation exchange capacity, and moisture content were measured. Electrical conductivity (EC) and pH of the culture media were also measured using the Microorganism population in the culture media and were determined using the five-fold serial dilution method. The plants were grown for three months and the selected growing indices included; Plant height (cm), stem diameter (cm), fruit weight (kg), fruit length (cm), fruit size (cm^2), the total number of fruits harvested throughout the growing period, and pedicel length (cm), were measured during and after the growing period. Experimental data normality was verified, and then the data were submitted for analysis of variance, using SPSS Statistical software. Means were compared using Duncan multiple tests ($P < 0.05$).

RESULTS AND DISCUSSION

Physicochemical properties of media

The results of some selected physicochemical characteristics of the culture media are listed in Table 1. The lowest bulk density (0.90) and highest porosity (30.45) were related to 100% rice husk. This is an indication that the media portrayed sufficient root aeration than the other media. By implication, root media sufficiency indicates a better supply of oxygen, water and nutrients to the cultivated plants. The EC value (0.15µs/cm) was higher in 100% rice husks and lowest in the soil medium (0.02µs/cm).

Table 1. Some physicochemical characteristics of the culture media

Substrate	Bulk density, g/cm^3	WHC, ml	OC, g	MC, %	Porosity, %	MP	pH	EC, (µs/cm)	CEC, (meq/100g)
100% cocopeat	0.99	26.00	2.00	186.3	0.45	$1.23x\ 10^7$	6.62	0.15	3.29
100% rice husk	0.90	2.00	2.34	73.5	0.53	$33.8x10^6$	5.82	0.39	2.62
Loamy sand soil	1.58	4.00	0.91	8.33	0.59	$2.45x10^7$	6.22	0.02	2.36

The 100% cocopeat CEC (3.29meq/100g) and MP (1.23×10^7) showed an ability to conduct and supply more nutrient compounds to the crop, however, this was limited by the capacity of this media to hold water longer than the other media WHC (26%) and this is followed by 100% rice husk, CEC (2.62meq/100g) and MP (33.8×10^6).

The 100% rice husk had the lowest pH (5.82), this is a similar result when compared to Mohammadi's (2013) research. However, 100% rice husks had the lowest water holding capacity, WHC (2%) which resulted in the media requiring higher irrigation water quantity or demand.

Growing indices

The results of the selected growing indices of the cucumber crop are presented in Table 2. Plants in 100%rice husk medium recorded the highest fruit yield compared to the other media at a 5% level significant difference. The rice husk medium also recorded the highest pedicel length. The level of porosity, cation exchange capacity, bulk density and water-holding capacity of rice husk media was sufficient enough to support plant root health, this, in turn, supported water and nutrient elements availability for plant growth and better fruit yield. The medium's higher porosity and lower bulk density provided less resistance to root motion in this medium.

Table 2. Effect of the culture media on the growth and yield of cucumber

Culture media	Stem diameter, cm	Plant height, cm	Fruit number	Fruit weight, kg	Fruit length, cm	Pedicel length, cm	Fruit diameter cm	Fruit size, cm^2
100% cocopeat	2.10	106.00	12	0.30	3.73	11.5	0.25	0.93
100% rice husk	2.37	151.00	21	0.43	28.10	12.8	9.66	271.31
Loamy sand soil	2.57	123.30	15	0.36	23.77	8.00	9.04	214.88

A good growing media would provide sufficient anchorage to the plant, serve as a reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate [4]. The fruit length and diameter in 100%cocopeat were the lowest and it had a significant difference from the other culture media at a 5% level. This was a result of its high-water holding capacity and higher bulk density even with a lower porosity value than the rice husk medium. These medium plant roots suffered suffocation and salinity issues due to their ability to retain fluid (both water and nutrient mix) longer than the other media. This led to a delay in its maturity and fruiting duration extending effects to the fruit size.

Most researchers incorporate these organic wastes into the soil as soil amendments to improve its productivity or growth yield [4]. However, for this research, these organic (agricultural) wastes were used by themselves as an anchorage for plant growth and development and this was carried out in comparison to traditional soil growing medium. Mohammadi [4] recorded an improvement in the physicochemical properties of soil when mixed with organic wastes, however, he noted that there was an increase in the microorganism population due to the decomposition process which battled with the crop for nutrients and as a result led to the lower yield he had.

CONCLUSIONS

This research, however, focused on using these organic wastes on their own (soilless farming) as a medium for plant growth and development in greenhouse agriculture. The organic matter or waste used for this research was 100% fresh and had not passed through fermentation or an earlier use period.

The result obtained from this study clearly showed that rice husk waste with a bulk density of 0.90g/cm3, water holding capacity of 2 ml porosity of 53% and cation exchange capacity of 3.29 meq/100g can be comfortably adopted as a medium for plant growth and development. It gave the best physical and chemical conditions required of a plant growth media and produced the highest yield (21 fruits) within the required fruiting period. Therefore, there is no need for composting, charring or using the material as a soil amendment to achieve the desired output. Adopting organic waste as a culture media in itself alone will not only improve crop yield but will reduce its mass deposit and illegal disposal techniques adopted by the producers of these agricultural waste materials. This is one of the objectives of this research, to not only create an alternative waste disposal technique for rice husk and cocopeat wastes but to also achieve a zero-waste goal of SDG 2030 by providing an alternative waste utilization method which is in this research as a culture media.

Waste-to-wealth conversion is a keenly pursued subject in Nigeria by policymakers and industry stakeholders, driven by international and domestic needs concerning the mission statement in the Nigeria agenda. It has been observed, therefore, that using this method for recycling agricultural waste, not only utilized the agricultural wastes but provided food and employment to the populace. However, improvements on the work by the installation of solar-powered, sensor-timed drip irrigation that could irrigate the crop under study or any other crop based on their crop water needs are recommended for further studies.

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EFEKTI NA RAST I PRINOS KRASTAVCA UPOTREBOM KOKOS VLAKANA I LJUSKI PIRIČA KAO PODLOGE ZA GAJENJE U STAKLENIKU

Maxwell I. Chikwue[1], Rachael I. Ezem[1], Nnaemeka R. Nwakuba[1], Achinike Okogbule-Wonodi[2]

[1]Federal University of Technology, Owerri, Nigeria, School of Engineering and Engineering Technology Department of Agricultural and Biosystems Engineering
[2]Rivers State University, Nigeria, Faculty of Engineering Department of Agricultural & Environmental Engineering

Apstrakt: Ovo istraživanje je sprovedeno da bi se utvrdio rast i prinos krastavaca zasađenih na podlozi od poljoprivrednog otpada koji je služio kao sredina za sadnju (uzgajanje bez zemljišta) u odnosu na tradicionalnu sadnju ove kulture. Istraživanje je obavljeno u stakleniku površine 10,64 m2. Eksperiment je randomizovan u kompletnom blok sistemu koji se sastojao od dva tretmana i tri ponavljanja sa kontrolom (klasična obrada zemljišta). Tretmani su bili: T_1 i T_2 navodnjavanje ručno sa intervalom jednom dnevno. Utvrđeni su fizičko-hemijski parametri podloge, agronomski parametri (indeksi rasta) biljaka krastavca i rezultati su podvrgnuti statističkoj analizi.
Rezultat je pokazao da varijanta T_2 (100% podloga je od ljuske pirinča) ima najveću visinu biljke u proseku od 151,0 cm i dužinu peteljke od 12,8 cm. Varijanta T_2 (100% podloga od ljuske pirinča) daje najveći prinos ploda krastavca od 0,53 kg/m^2 za prosečne dužine i veličine od 23,77 cm i 542,73 cm, respektivno. Uzorak T_1 (100% podloga kokos vlakno) dao je najmanji prinos krastavca za berbu.
Kontrolni ogled (podloga zemljište), sa najvećim prosečnim prečnikom stabljike od 2,57 cm, ima prosečnu dužinu krastavca 23,77 cm i veličinu 429,5 cm, respektivno. Razlika između podloga za uzgoj krastavaca je bila značajna ($P < 0,01$) jer su prinos i neki drugi indeksi rasta bili viši kod varijante T_1 sa podlogom od ljuske pirinča.
Rezultati su pokazali da su indeksi porasta za biljke krastavca bili dovoljni kada se gaje na podlozi od ljuske pirinča, pokazujući kapacitet ovog poljoprivrednog otpada za obezbeđenje rasta i prinosa gajenih biljaka, istovremeno obezbeđujući potrebu kao alternativnu metodu odlaganja i korišćenja ovog otpada. Predlažu se dalji ogledi i nastavak istraživanja.

Ključne reči: *Staklenik, zemljište, biljni otpad, poroznost, hidroponika, mlinska industrija.*

Prijavljen:
***Submitted*: 17.03.2023.**
Ispravljen:
***Revised*: 02.05.2024.**
Prihvaćen:
***Accepted*: 15.05.2024.**

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XLIX
Broj 2, 2024.
Strane: 82 – 104

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XLIX
No. 2, 2024.
pp. 82 - 104

Original Scientific paper
Originalni naučni rad
DOI: 10.5937/PoljTeh2402082U

ENHANCING COOKING BANANA PRESERVATION: A MATHEMATICAL MODEL APPROACH

Muofunanya F. Umunna[*1]; S. A. Adzor[2]; D. F. Ikikiru[1]; O. Nyorere[1]; S. K. Chigbo[3]; E. T. Erokare[1]; A. B. Eke[3]

[1] *Department of Agricultural Engineering, Faculty of Engineering, Delta State University of Science and Technology, Ozoro, Nigeria*
[2] *Department of Materials and Metallurgical Engineering, Faculty of Engineering, Delta State University of Science and Technology, Ozoro, Nigeria*
[3] *Department of Agricultural and Bioresources Engineering, College of Engineering and Engineering Technology, Micheal Okpara University of Agriculture, Umudike, Nigeria*

Abstract: This study systematically investigated the solar drying kinetics of cooking banana slices with thicknesses of 5mm, 10mm, and 15mm at temperatures of 50°C, 60°C, and 70°C. Employing the solar drying method, the drying process exhibited a diffusion-controlled mechanism, transitioning from a brief constant rate period to a predominant falling rate period until reaching equilibrium moisture content. The drying rate constant (k) displayed an increasing trend with elevated temperature, while an inverse correlation was observed with slice thickness, establishing direct and inverse relationships with drying time and temperature, respectively.

Fifteen thin-layer drying models were applied to fit the moisture ratio (MR) data, and the Midilli-Kucuk model demonstrated superior performance, attributed to its high R^2 value (0.997) and lowest values of RMSE (0.00228) and X^2 (0.0000132).

Proven to be a robust tool, the Midilli-Kucuk model effectively predicted the single-layer drying kinetics of cooking banana slices, providing valuable insights for dryer design and processing.

Empirical equations derived from the obtained data enable the prediction of drying kinetics specifically for cooking banana slices in the solar drying method.

[*]Corresponding Author. Email address: umunnamuofunanya25@gmail.com
ORCID: 0000-0001-8737-2795

This study contributes significantly to the comprehension and optimization of the drying process for unripe cooking banana, offering practical implications for dryer design and processing enhancements.

***Key words**: Solar, drying, kinetics, cooking, banana, slices, Midilli-Kucuk, model*

INTRODUCTION

According to [1] and [2], cooking banana (*Musa* spp., ABB genome) originated from the hybridization of *Musa acumulata* and *Musa balbisiana*. Cooking banana fruits resemble unripe desert bananas, albeit larger in size than other banana cultivars. These cooking bananas are commonly consumed either raw, ripe, or cooked, while a portion is processed into stable products [2].

The introduction of cooking banana to southeastern Nigeria in the late 1990s by the International Institute of Tropical Agriculture (IITA) aimed to combat the black sigatoka disease. These bananas are nutritionally rich and have medicinal properties, particularly the flowers, which can be used to treat ulcer, dysentery, and bronchitis [3]. However, their high moisture content, ranging from 70-80% (wb) in ripe form, makes them vulnerable to post-harvest losses and weight loss during transportation [4].

Drying is a globally practiced food preservation method, reducing water content to prevent deterioration and microbial spoilage. Understanding the drying behaviour of agricultural products is crucial for equipment development and improvement. Mathematical modeling, based on the drying of thin layers of the product, plays a key role in simulating drying processes [5].

Mathematical modeling is essential for controlling the drying process and improving product quality. It helps study variables, predict drying kinetics, and optimize operational parameters. Various mathematical equations are used to describe agricultural product drying, with thin layer models being widely employed due to their simplicity [6]. Fick's second law is typically used to explain liquid diffusion, forming the basis for describing drying phenomena when employing thin-layer drying equations [7].

Numerous mathematical models have been applied to various agricultural products. These models are crucial for predicting effective drying times and temperatures, minimizing nutrient degradation [8]. However, there is limited research on the drying behaviour of cooking bananas, particularly during the water removal stage.

High moisture content in bananas, if not properly dried, leads to susceptibility to microbial attacks and substantial post-harvest losses. For example, India and Brazil have reported significant losses in banana production [9]. Cooking bananas are highly perishable, particularly when harvested unripe and green. Losses primarily result from poor handling, inadequate storage, and transportation options.

Drying is an effective alternative to extend the shelf life of cooking bananas. Modern drying methods aim to reduce energy consumption while maintaining product quality. Mathematical modeling of drying kinetics plays a pivotal role in this process. Drying kinetics vary for different agricultural products, and selecting the appropriate drying model is crucial.

Numerous models have been put forth to elucidate the moisture loss rate during the thin-layer drying of agricultural products, as demonstrated by [10].

The behavior of thin layers in this context hinges on how quickly moisture is transported from the material. This internal movement of moisture is governed by various physical mechanisms that act in different combinations. The choice of physical mechanisms for moisture movement is ultimately contingent on the nature of the product to be dried. Consequently, it is possible that the established models may not entirely suit the drying process for mangoes.

The study conducted by [11] proposed a straightforward model for moisture transfer in multi-dimensional products. In their research, they formulated the drying time for infinite slab products by establishing an analogy between heat diffusion and moisture transfer. This approach was further extended to multidimensional products by introducing geometric shape factors.

Understanding drying kinetics is pivotal in process modeling and design. However, the available data in the literature are often insufficient for comprehensive process design, making product-oriented experiments a common necessity. In the existing body of literature [12] introduced a widely recognized drying curve that encompasses two main phases: the constant drying rate period and the falling rate period. Nonetheless, it's worth noting that not all materials adhere to this specific pattern. In some cases, only the falling rate regions are observed.

The constant drying rate phase occurs when a film of water is readily available at the drying surface for evaporation into the surrounding medium. During this phase, the drying rate is akin to what occurs when a pool of water evaporates into the air. The rate is heavily influenced by factors such as air temperature, air humidity, and the efficiency of heat transfer to the water.

Conversely, the falling rate regions signify an increased resistance to both heat and mass transfer. This occurs when the surface water is depleted, and the moisture to be evaporated comes from within the material's structure, necessitating transport to the surface. Multiple falling rate regions suggest the potential for drying rates to be influenced by structural changes, such as case hardening and shrinkage.

Numerous studies have explored the thin layer drying method across a variety of agricultural products. Noteworthy examples include investigations into the drying of olive fruit [8], date palm [13], cocoa [14], potato mash [15], rapeseed [16], litchi [17], sorghum [18], hazelnuts [19], and finger millet [20]. Employing drying kinetics, coupled with chemical analysis, proves invaluable in forecasting optimal drying time and temperature combinations. This approach minimizes the degradation of nutritional parameters within the crop, enhancing overall efficiency.

The study's general objective is to identify a suitable thin layer drying model for cooking bananas. Specific objectives include investigating the effects of slice thickness, temperature, microwave power, and solar drying methods on cooking banana drying kinetics. Additionally, the study aims to determine effective moisture diffusivity and activation energy, as well as develop empirical prediction equations for oven, microwave, and solar drying methods.

The research is justified by the need to reduce post-harvest losses of cooking bananas and extend their shelf life. By understanding the drying kinetics, this study aims to improve food productivity, decrease losses, and enhance farmers' income. Proper drying techniques and mathematical modeling are essential for efficient post-harvest processing and preservation of agricultural products.

MATERIAL AND METHODS

2.1 Sample Collection and Preparation

A bunch of unripe cooking bananas (*Musa bluggoe*) as presented in Figure 1 was purchased from Ndoro Market in Umuahia, Abia State. The selection of these bananas was based on their availability, as well as their medicinal and nutritional properties. Banana fingers were chosen based on their appearance and size, ensuring there was no evidence of mechanical damage. Afterward, they were detached, peeled, washed, and sliced into various thicknesses (5 mm, 10 mm, and 15 mm), using a sharp stainless steel knife. The slice thickness was determined with a digital vernier caliper with a sensitivity of 0.01mm.

Figure 1. Cooking banana

Experimental Procedure for Solar Drying

An active solar drying apparatus, situated within the Department of Agricultural and Bio-resources Engineering, as depicted in Figure 2, was utilized. The solar drying system incorporated key components, including a solar collector, an 180W capacity solar panel, a DC blower fan, a drying chamber, heat storage unit, drying trays, and a 200Ah rated solar battery. The solar dryer, featuring a transparent cover made of perplex material, demonstrated efficient utilization of solar energy. The 180W solar panel charged the DC battery, powering the intelligently programmed control box. This control box regulated the DC blower at intervals, responding to moisture levels within the drying chamber. Within the drying chamber, products undergoing drying were positioned on perforated metal trays, facilitated by a convenient door for easy tray insertion and removal. A heat storage unit, containing black pebbles, effectively harnessed and stored solar energy for sustained use. Positioned atop the dryer, a blower directed air from the inlet opening through a solar collector chamber, passing through the product bed. Solar radiation, captured by the system, heated the air flowing through the drying product.

The heated air traversed the drying chamber, and at its zenith, vents facilitated the removal of moisture.

Figure 2. Active solar drying device

Design of Experiment

The experiments were carried out following a factorial design, comprising two factors, each with three levels. This resulted in a 2x3 factorial design (2 factors, 3 levels each). The independent parameters for the research study were temperature and thickness. Temperature was classified into three levels, denoted as T1, T2, and T3, whereas thickness was delineated by three levels: t1, t2, and t3. To ensure robustness and reliability, these experiments were replicated thrice, and the average values were employed for subsequent calculations.

Factorial design for solar drying

Table 1 presents the combinations of thickness (5 mm, 10 mm, and 15 mm) with corresponding experiments for solar drying. It also provides a clear overview of the combinations of thickness and drying method used. Thus serving as a valuable reference for understanding the factorial design implemented in the study.

Table 1. Factorial Design Experiments for Solar Drying at Various Thickness Levels.

Thickness (mm)	Solar
5	Experiment 1
10	Experiment 2
15	Experiment 3

Moisture Content Determination

The initial moisture content of the cooking banana slices was assessed using a Mermet oven set at 105ºC for 24 hours until a constant weight was achieved, following the method outlined by [21]. The experiment was meticulously replicated to ensure precision. Moisture content on a wet basis was calculated using Equation 1.

$$Mc\ (w.b)\ \% = \frac{\boldsymbol{Ww - Wd}}{\boldsymbol{Ww}} \boldsymbol{x} \frac{\mathbf{100}}{\mathbf{1}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where:
Mc = (W.b) moisture content at wet basis,
Ww = weight of wet sample (g),
Wd = weight of dried sample (g)

Determination of Moisture Ratio (MR)

The moisture ratio (MR) for the cooking banana was determined using Equation 2, as proposed by [22].

$$MR = \frac{Mt - Me}{Mo - Me} \quad \text{…… (2)}$$

Subsequently, the moisture ratio was further simplified in accordance with the methodology outlined by [23] as expressed in Equation 3.

$$MR = \frac{Mt}{Mo} \quad \text{…… (3)}$$

Where:
Mt= Moisture content at any time (t),
Mo = Initial moisture content,
Me = Equilibrium moisture content

All values are expressed as grams of water per gram of dry matter. The values of Me were determined as the moisture content at the conclusion of the drying process when the sample ceased to lose mass.

Drying Rate Calculation (DR)

The drying rate was determined following the formulation provided by [24], [25], and [26] in Equation 4.

$$D_r = \frac{M_{t+dt} - M_t}{dt} \quad \textbf{……..(4)}$$

Where:
M_t = moisture content at a specific time (g water g dry base-1),
M_{t+dt} = moisture content t+dt (g water g dry base-1),
t = drying time (hr)

Determination of Effective Moisture Diffusivity

The effective moisture diffusivity (D_{eff}) was calculated using a lumped parameter approach, considering all potential resistances to moisture transport. For an infinite slab in one dimension, assuming negligible temperature gradient within the product, constant temperature and diffusivity, and no significant external resistance, moisture transfer during the falling-rate drying period was determined using Fick's Second law, as expressed in Equation 5, [27].

$$MR = \frac{8}{\pi^2} \sum_{n=0}^{\infty} \left(\frac{1}{2n+1}\right) \exp\left(-\frac{(2n+1)^2 \pi^2 D_{eff} t}{4L^2}\right) \quad \text{…… (5)}$$

Where:
MR is the moisture ratio,
D_{eff} = effective diffusivity (m^2/s)
Mt = the moisture content at any time (Kg water /kg dry matter),
n = 1, 2, 3 -------- the number of term taken into consideration,
t = the time of drying in seconds, *l* =the thickness of slice (m)

Equation 5 is further simplified as shown in Equation 6, 7, and 7 respectively in line with [28].

$$MR = \frac{8}{\pi^2} \exp\left[\frac{\pi^2 D_{eff} t}{4L^2}\right] \quad \text{……(6)}$$

$$MR = \frac{8}{\pi^2} \exp(-kt) \quad \text{…… (7)}$$

The slope k is calculated by plotting *In(MR)* versus time

$$K = \frac{\pi^2 D_{eff}}{4l^2} \quad \text{… … … … … … … … … (8)}$$

Determination of the Activation Energy
Temperature has a significant impact on diffusivity, and to quantify this effect, the Arrhenius Equation 9 was utilized. Higher activation energy indicates greater sensitivity to temperature [29]. Taking the natural logarithm of Equation 9 reveals a linear relationship between the natural log of diffusivity and temperature. In cases where a robust correlation cannot be established, it suggests that external factors strongly influence effective diffusivity [30]. To account for these effects, a mathematical relationship must be proposed and tested using non-linear regression.

$$D_{eff} = Do \exp\left(\frac{-Ea}{R(T+273.15)}\right) \quad \text{….. (9)}$$

Where:
Ea = energy of activation ($kJmol^{-1}$),
R = the universal gas constant ($8.3143Jmol^{-1}KJmol^{-1}KJmol^{-1}$),
T = absolute temperature of the drying medium (K),
Do = line intercept, which is always constant .

The linear form equation, derived through the application of logarithmic operations, is presented in Equation 10.

$$InD_{eff} = InDo \exp\left(\frac{-Ea}{R(T+273.15)}\right) \quad \text{…… (10)}$$

Mathematical Modelling of Drying Kinetics

To comprehensively investigate the drying kinetics of agricultural commodities, effective modeling of drying behaviour becomes indispensable. Data acquired from the experimental drying of cooking banana at various temperatures and thicknesses were subjected to fitting with fifteen thin-layer drying mathematical models proposed by various authors, as detailed in Table 2. The curve fitting process utilized [31] the Microsoft Excel (2016) Solver add-ins.

Statistical Evaluation of Drying Models

Relevant statistical parameters were employed to discern the most suitable drying equation/model that accurately represents the drying curves of the samples, and to assess the validity of the fits. The least square method of parameter estimation, as outlined by [32], was applied to ascertain the missing parameters of the drying models.

The coefficient of determination (R^2), the reduced chi-square value, an (x^2)d root mean square error (RMSE), as expressed in Equations 11, 12, and 13, were employed for the selection of the optimal equation that captures the drying curves of the sample.

The determination of the best fit relied on identifying the highest values of R^2 and the lowest values of X^2, in accordance with the criteria established by [33] and [34].

After determining the unknown parameters, the model underwent validation through a comprehensive comparison of experimental data and predicted data to ensure consistency.

$$R^2 = \frac{\sum_{i=1}^{N} MR_{Pre,i} MR_{exp,i} - \sum_{i=1}^{N} MR_{pre,i} \sum_{i=1}^{N} MR_{exp,i}}{\sqrt{(\sum_{i=1}^{N} (MR_{pre,i})^2 - (\sum_{i=1}^{N} MR_{pre,i})^2)(N\sum_{i=1}^{N} MR_{exp,i} - (\sum_{i=1}^{N} MR_{exp,i})^2)}} \quad \textbf{.....(11)}$$

Where:

$MR_{exp,i}$ (experimental moisture ratio),

$MR_{pre,i}$ (predicted moisture ratio),

n is the number of constants, and

N is the number of observations.

$$X^2 = \frac{\sum_{i=1}^{n} (MR_{exp,i} - MR_{pre,i})^2}{N-n} \quad \textbf{.....(12)}$$

$$\textbf{RMSE} = \left[\sum_{i=1}^{N} \frac{1}{N} (MR_{exp,i} - MR_{pre,i})^2\right]^{\frac{1}{2}} \quad \textbf{... (13)}$$

Table 2. Thin layer mathematical models used

No	Model name	Model Equation	Reference
1	Newton	MR = exp (-kt)	Mujumdar (2006)
2	Page	MR = exp ($-kt^n$)	Flores et al. (2012)
3	Modified Page	MR = exp[$-(kt)^n$]	Demir et al. (2007)
4	Henderson and Pabis	MR = a exp ($-kt^n$)	Radhika et al.(2011)
5	Modified Henderson and Pabis	MR = a exp(−kt) + b exp(−gt) + c exp(−ht)	Zenoozian et al. (2008)
6	Midilli and Kucuk	MR = a exp($-kt^n$) + bt	Midilli and kucuk (2002)
7	Modified Midilli	MR = a exp(−kt) + b	Gan and Poh (2014)
8	Logarithmic	MR = a exp (-kt)+c	Yagcioglu et al. [1999]
9	Two-term	MR = a exp($-K_1t$) + b exp ($-K_2t$)	Sacilik (2007)
10	Two-term exponential	MR = a exp($-k_0t$) + (1 – a)exp ($-k_1at$)	Dash et al. (2007)
11	Demir et al.	MR = a exp ($-K\ t)^n$ + b	Demir et al. (2007)
12	Verma et al.	MR = a exp(−kt) + (1 − a)exp (−gt)	Akpinar (2006)
13	Approximation of diffusion	MR = a exp(−kt) + (1 − a) exp (−kbt)	Yaldyz and Ertekyn (2007)
14	Hii et al.	MR = a exp($-K_{\ 1}t^n$) + b exp($-K_{\ 2}t^n$)	Kumar et al. (2014)
15	Wang and Singh	MR = $1+at+bt^2$	Radhika et al. (2011)

Where: MR = (M – Me)/(Mo – Me),
Moisture ratio (dimensionless); a, b, c, g, h, k, k_0, k_1, k_2,
n = drying constants,
t = drying time (min).

RESULTS AND DISCUSSION

Influence of Temperature on Moisture Content Removal

In Figures 3-5, a discernible trend emerges as an escalation in drying temperature correlates with an augmented drying rate, consequently leading to a reduction in overall drying time. This phenomenon is attributed to the inherent relationship between drying temperature and the associated driving force for heat transfer. As elucidated by [35], higher drying temperatures engender a more substantial water vapour pressure deficit, defined as the variance between saturated water vapour pressure and the partial pressure of water vapour in air at a given temperature.

This differential pressure represents a pivotal driving force influencing the efficiency of the drying process. The findings presented herein align with prior research, notably the work of [35], and are congruent with observations reported by [36]. The study establishes that elevated drying temperatures contribute to an intensified water vapour pressure deficit, thereby expediting the overall drying kinetics. Moreover, the investigation discerns that the duration required to reduce the initial moisture content to a predetermined level is contingent upon various drying conditions.

Specifically, the drying time exhibits an inversely proportional relationship with temperature, with the longest duration observed at 50°C and the shortest at 70°C.

Furthermore, the thickness of the material plays a crucial role, with the drying period extending for the maximum duration at a thickness of 15mm and contracting to the minimum at 5mm. These nuanced findings underscore the interplay of temperature and thickness in shaping the dynamics of the drying process.

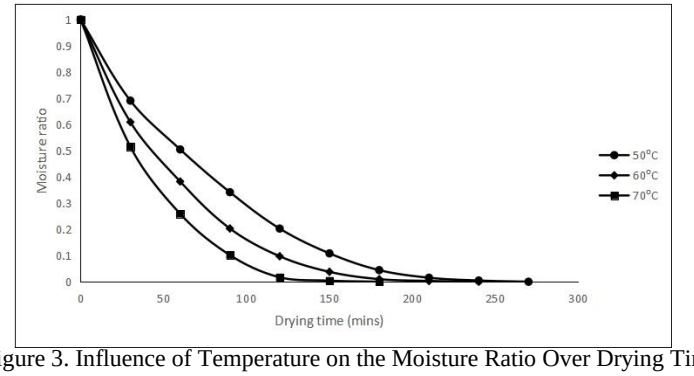

Figure 3. Influence of Temperature on the Moisture Ratio Over Drying Time at a Slice Thickness of 5 mm

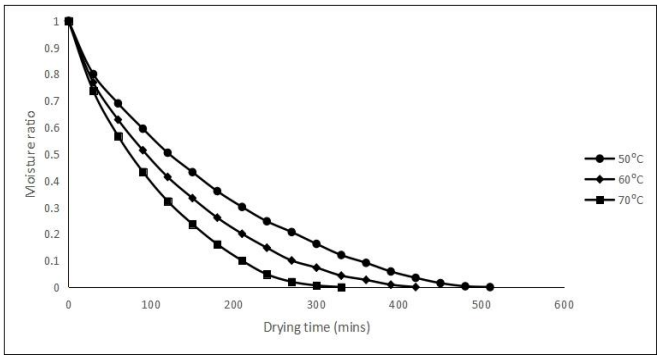

Figure 4. Influence of Temperature on the Moisture Ratio Over Drying Time at a Slice Thickness of 10 mm

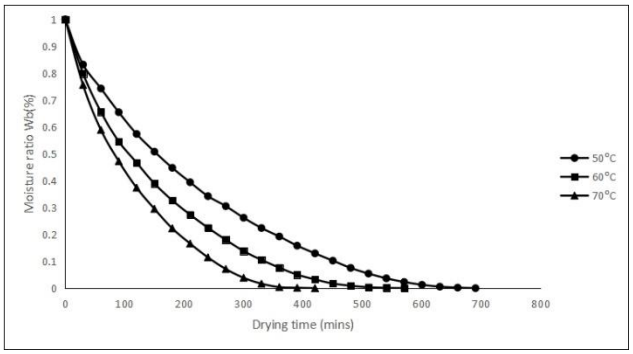

Figure 5. Influence of Temperature on the Moisture Ratio Over Drying Time at a Slice Thickness of 15 mm

Influence of Slice Thickness on the Moisture Ratio Variation over Drying Time

The graphical representation in Figures 6-8 underscores a discernible correlation between slice thickness and drying time. Notably, there is a conspicuous increase in drying time as the slice thickness augments. Conversely, a continuous decrease in drying time is evident as moisture content diminishes.

This observation signifies that the drying process experiences a substantial reduction in time as it nears the initial moisture content. The inverse relationship between drying time and moisture content is particularly noteworthy, implying that the duration required for the material to reach a certain moisture level diminishes significantly as it approaches the initial moisture content.

Furthermore, the data elucidates that sample thickness is a pivotal factor influencing drying time, with higher thicknesses correlating with prolonged drying periods.

In essence, these findings emphasize the critical impact of both slice thickness and moisture content on the kinetics of the drying process. As slice thickness increases, so does the drying time, while a decrease in moisture content is associated with a notable reduction in the time required for the material to attain its specified moisture level. This nuanced understanding contributes valuable insights into the intricate dynamics governing the drying behaviour under different thickness and moisture content condition.

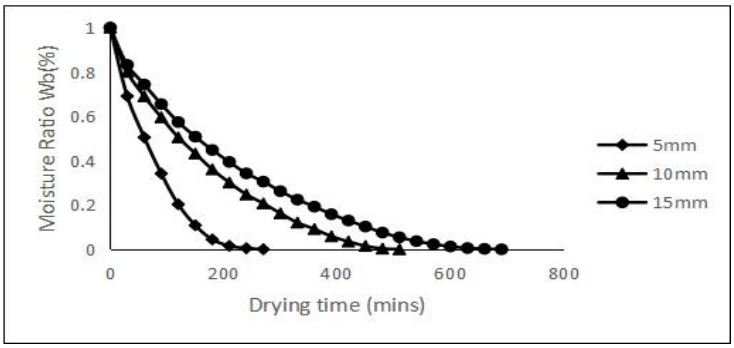

Figure 6. Influence of Slice Thickness on the Moisture Ratio Variation Over Drying Time at 50°C

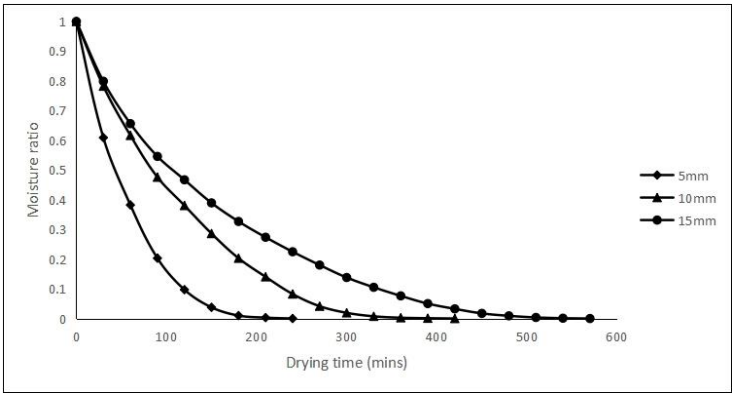

Figure 7. Influence of Slice Thickness on the Moisture Ratio Variation Over Drying Time 60ºC

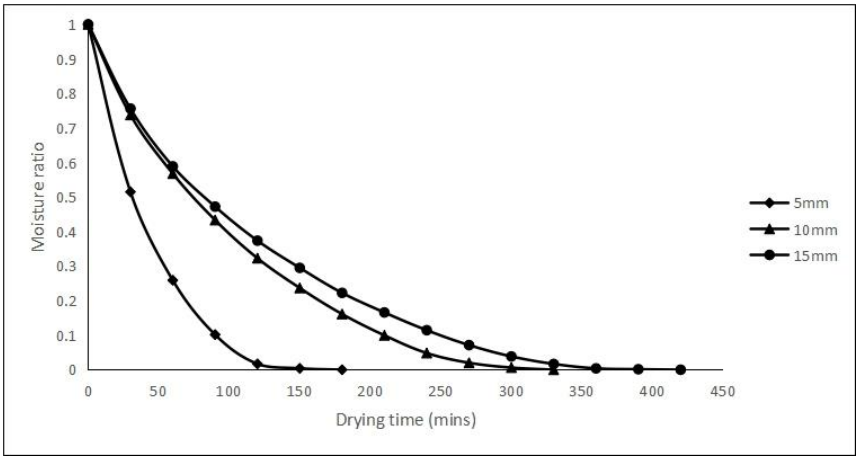

Figure 8: Influence of Slice Thickness on the Moisture Ratio Variation Over Drying Time 70ºC

Impact of Drying Rate on Drying Time at Various Temperatures

In Figures 9-11 the drying rate profiles are illustrated with respect to time, encompassing various thicknesses and temperatures. The determination of drying rate involved the computation of the time required to eliminate a specified quantity of moisture from the drying samples. Notably, the drying rate exhibited a diminishing trend concomitant with an increase in both drying time and temperature. This decline in drying rate during the process is indicative of a reduction in moisture migration from the interior to the surface of the product. The observed behavior of the drying rate manifests in both constant and falling rate periods. Initially, the drying rate was notably high, corresponding to the elevated moisture content in the samples. As the drying process advanced towards the falling rate period, the drying rate gradually decreased until reaching a state of constancy, marking the attainment of the equilibrium moisture content stage. This dynamic aligns with prior studies, as evidenced by [37] in the context of onion slices [38] for parboiled wheat, and [39] in the case of green beans. The parallel trends observed in the current investigation substantiate the broader applicability of these findings across diverse drying scenarios.

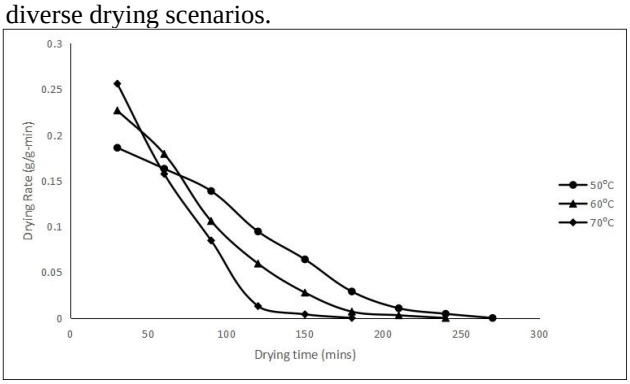

Figure 9. Impact of Drying Rate on Drying Time at Various Temperatures for slice thickness of 5mm

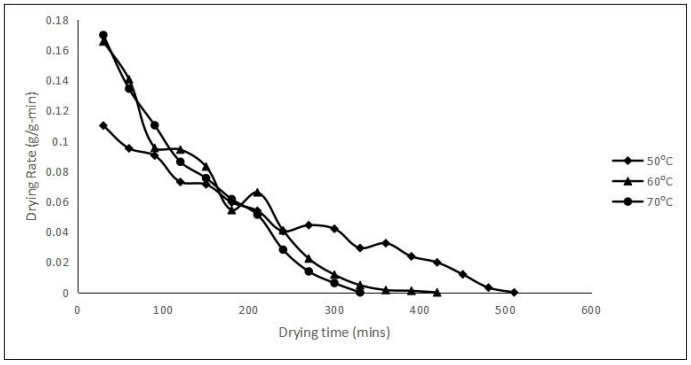

Figure 10. Impact of Drying Rate on Drying Time at Various Temperatures for slice thickness of 10mm.

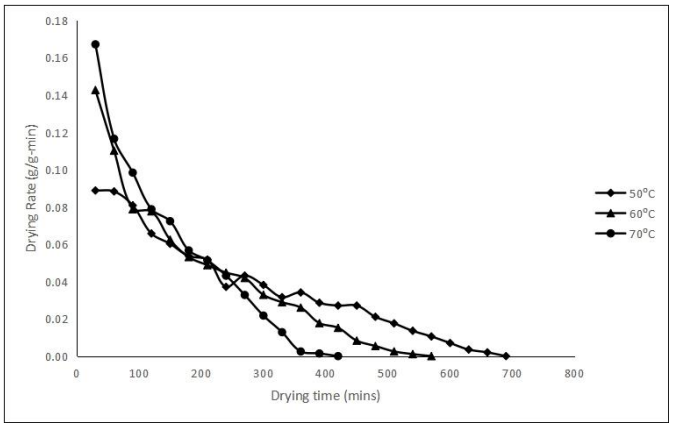

Figure 11. Impact of Drying Rate on Drying Time at Various Temperatures for slice thickness of 15mm

Impact of Temperature and Slice Thickness on Drying Time

The graphical representation of drying temperatures against drying duration is depicted in Figure 12. Notably, the observed trends indicate a substantial influence of slice thickness and drying temperature on the drying time of the product. Examining specific combinations, it becomes evident that the product characterized by the lowest thickness (5mm) and the highest temperature (70°C) manifests the briefest drying duration, recording a mere 180 minutes. Conversely, the product featuring the highest thickness (15mm) coupled with the lowest temperature (50°C) results in the lengthiest drying period, totaling 690 minutes.

These findings elucidate a direct correlation between drying time and temperature, wherein higher temperatures correspond to shorter drying durations. Conversely, a distinct inverse relationship is observed between drying time and slice thickness, where thinner slices correlate with briefer drying periods.

This nuanced understanding enhances our comprehension of the interplay between temperature, slice thickness, and drying time, providing valuable insights for optimizing the drying process in various scenarios.

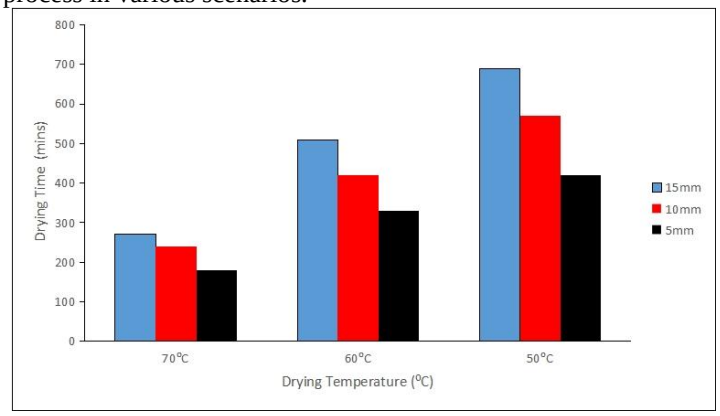

Figure 12. Impact of Drying Temperature on Drying Time

3.5 Drying rate constant (K)

The determination of the drying rate constant involves a methodical approach, achieved by plotting the natural logarithm of the moisture ratio (ln MR) against time (t). This analytical process is elucidated through the graphical representations in Figures 13-15. The rationale behind employing the natural logarithm lies in its ability to transform the moisture ratio data into a linear format when plotted against time. The resulting plots exhibit a linear relationship, and through this transformation, the drying rate constant (K) can be precisely determined. The logarithmic transformation facilitates the generation of a straight-line graph, and the slope of this line corresponds to the drying rate constant under the specific conditions prevailing during the drying process.

In essence, Figures 13-15 capture the crucial step of estimating the drying rate constant by leveraging logarithmic transformation, providing a visual depiction of the relationship between ln MR and time. This approach not only enhances the precision of the determination but also allows for a comprehensive understanding of the drying kinetics at the given set of conditions.

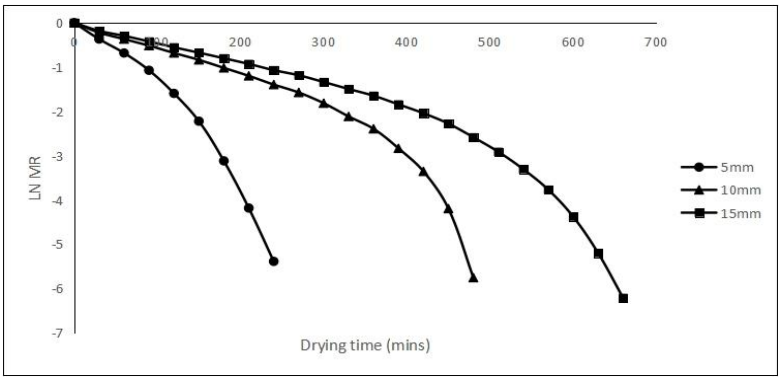

Figure 13. Logarithm of Moisture Ratio for Slice Thicknesses of 5mm, 10mm, and 15mm in Relation to Drying Temperature at 50°C

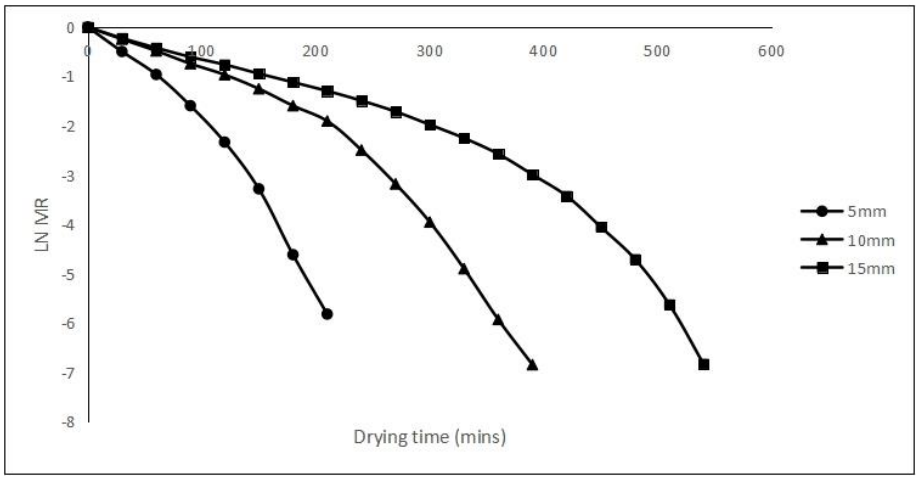

Figure 14. Logarithm of Moisture Ratio for Slice Thicknesses of 5mm, 10mm, and 15mm in Relation to Drying Temperature at 60°C

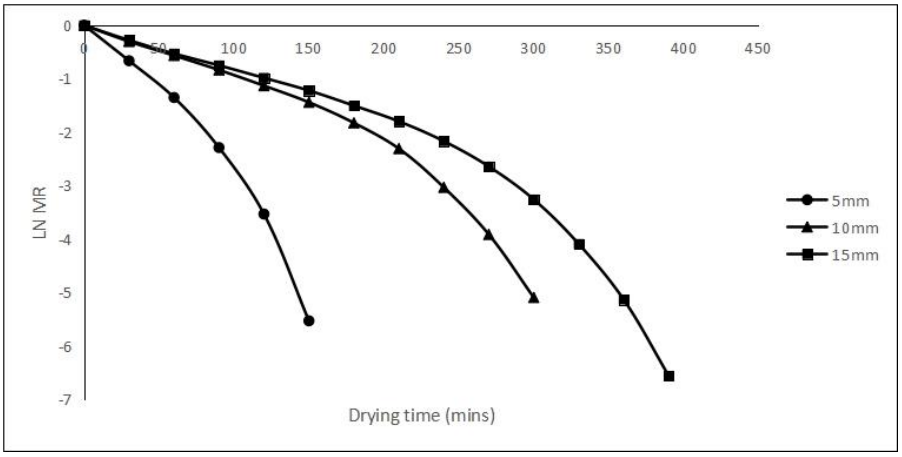

Figure 15. Logarithm of Moisture Ratio for Slice Thicknesses of 5mm, 10mm, and 15mm in Relation to Drying Temperature at70°C

Kinetics of Solar Drying

Figures 16-19 present the drying curves for cooking banana slices with thicknesses of 5mm, 10mm, and 15mm during solar drying. The drying process revealed distinct phases, characterized by short constant and extended falling rate periods. In Figure 16 the drying rate curves depict a notable decrease in drying rate with increasing sample thickness.

This observation aligns with the trend of increased drying time at higher sample thickness, a phenomenon attributed to the diminished drying rate. Similar findings have been reported in previous studies [40] and [41].

Figures 18-19 provide a comprehensive overview of the drying measurements and parameters recorded during the course of the drying durations for 5mm, 10mm, and 15mm sample thicknesses.

An examination of the drying chamber temperature reveals a peak around midday (12:00 pm), consistently surpassing ambient temperature levels. Solar intensity is shown to peak between 11:30 am and 2:00 pm, followed by a gradual decline. Relative humidity exhibits an inverse relationship with drying chamber and ambient temperatures, decreasing sharply during the noon period due to the heating of air. Wind speed demonstrates higher levels during the afternoon and evening compared to the early morning.

The increase in drying rate is observed to coincide with the rise in solar intensity, with the maximum drying rate occurring between 12:00 pm and 2:00 pm. This peak aligns with the drying chamber reaching its maximum temperature, as illustrated in Figures 18-19. These detailed observations offer valuable insights into the intricate interplay of environmental factors and their impact on the solar drying kinetics of cooking banana slices.

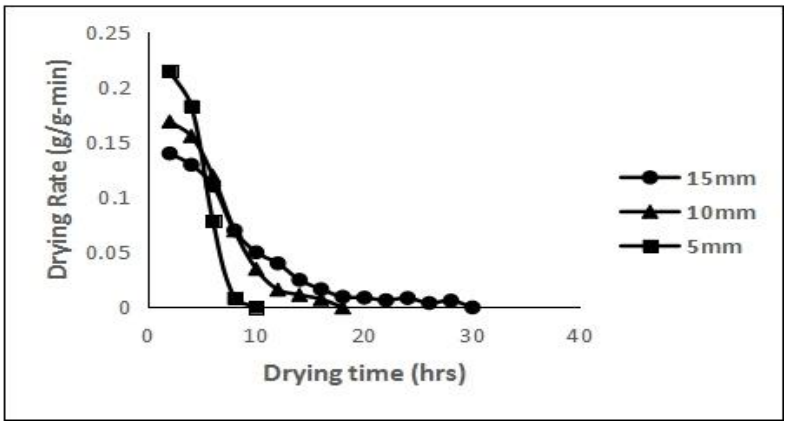

Figure 16. Solar drying rate for cooking banana

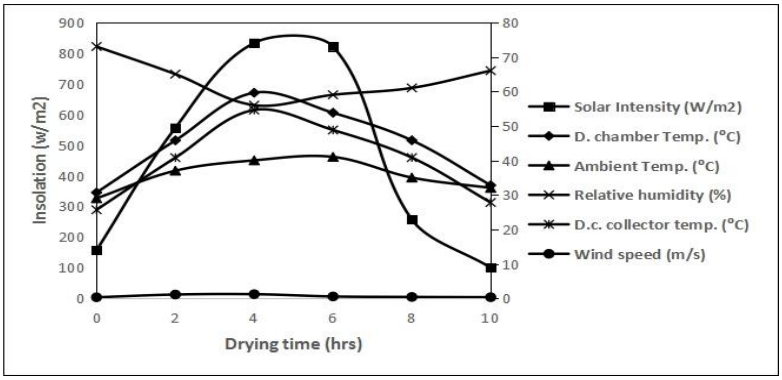

Figure 17. Solar drying parameter values for thickness of 5mm

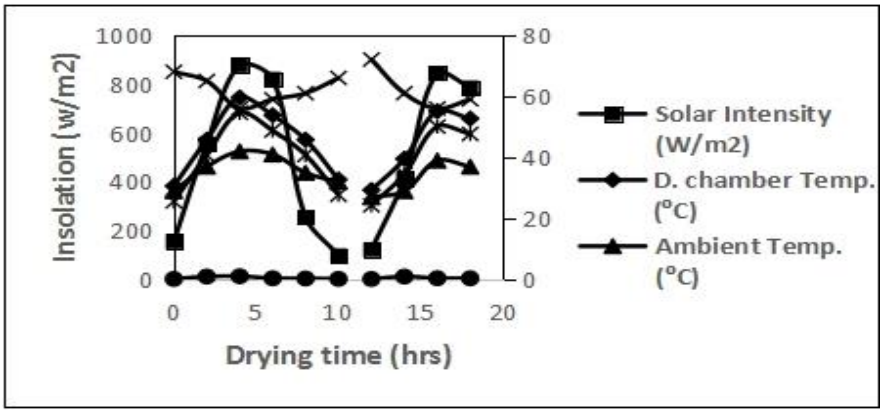

Figure 18. Solar drying parameter values for thickness of 10mm

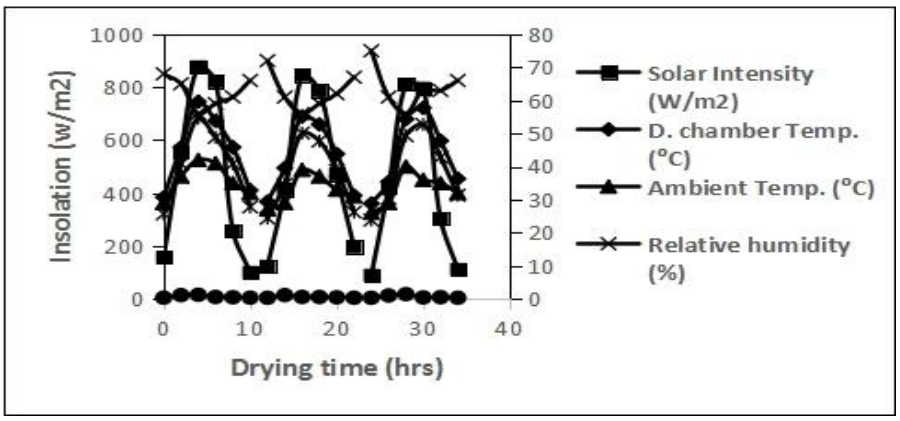

Figure 19. Solar drying parameter values for thickness of 15mm

Modeling Solar Drying Kinetics for Cooking Banana Slices

Table 3 provides a comprehensive overview of the statistical outcomes derived from the non-linear regression analysis conducted on the experimental data of solar drying, employing the moisture ratio as a key parameter. The validation of the best-fitted model was meticulously undertaken through both statistical and graphical assessments.

In tandem, Table 4 presents the outcomes of the non-linear regression analysis for the best-fitting model, elucidating the chosen model's conformity to the experimental data. Various criteria were employed to evaluate the goodness of fit, including the highest R^2 value, the lowest RMSE, and the reduced chi-square (X^2).

Following a rigorous assessment based on these criteria, the model proposed by Midilli and Kucuk emerged as the most appropriate representation for the single-layer drying behaviour of cooking banana slices in solar drying processes. This selection was made due to its superior alignment with the experimental data and its notable performance in terms of statistical metrics.

Table 3. Statistical Analysis of Selected Drying Models for Solar

		Solar		
No	Model Name	R^2	X^2	RMSE
1	Newton	0.969	0.000276	0.0126
2	Page	0.968	0.00405	0.0513
3	Modified Page	0.968	0.00405	0.0513
4	Henderson and Pabis	0.960	0.00147	0.0305
5	Modified Henderson and Pabis	0.985	0.00624	0.05517
6	Midilli and Kucuk	0.997	0.0000132	0.00228
7	Modified Midilli	0.991	0.0000236	0.004
8	Logarithmic	0.987	0.0000406	0.00493
9	Two-term	0.944	0.00544	0.0537
10	Two-term exponential	0.944	0.00483	0.0537
11	Demir *et al.*	0.987	0.0000523	0.00493
12	Verma *et al.*	0.989	0.00213	0.0375
13	Approximation of diffusion	0.944	0.005	0.054
14	Hii *et al.*	0.961	0.002	0.029
15	Wang and Singh	0.917	0.0663	0.22249

Table 4. Statistical Analysis of the Midilli and Kucuk Model for Solar Drying

	t(mm)	N	A	$K(min)^{-1}$	B	R^2	X^2	RMSE
	5	1.175	1.0023	0.00373	0.0006168	1.000	1.89E-07	0.00034
Solar	10	1.258	1.0091	0.003044	0.0007628	0.999	2.61E-06	0.00125
	15	0.993	1.0401	0.007397	0.0004546	0.993	3.69E-05	0.00526
	Mean	1.142	1.0172	0.00472	0.000611	0.997	1.32E-05	0.0023

Validation of the Selected Model

The validation of the statistical results for the Midilli and Kucuk model was conducted through a meticulous comparison of experimental moisture ratio (MR) and predicted moisture ratio (MR) data.

The validation process involved plotting the predicted MR values against the corresponding experimental MR values, as illustrated in Figures 20-22. The graphical representation clearly indicates the proximity of the predicted MR values to the linear trend of the graph, affirming the reliability of the selected model.

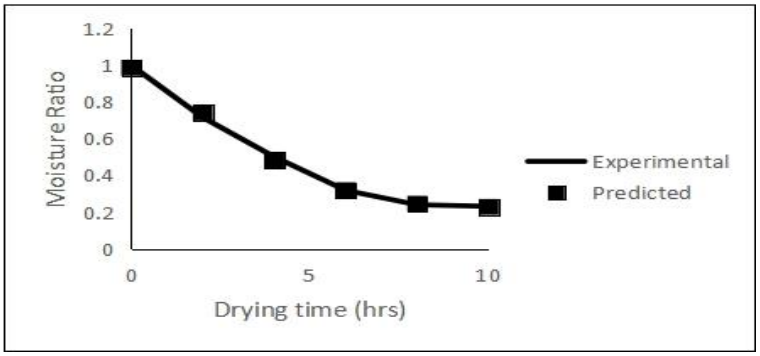

Figure 20. Comparison of experimental and predicted moisture ratio values by Midilli and Kucuk model for 5mm thickness for solar drying

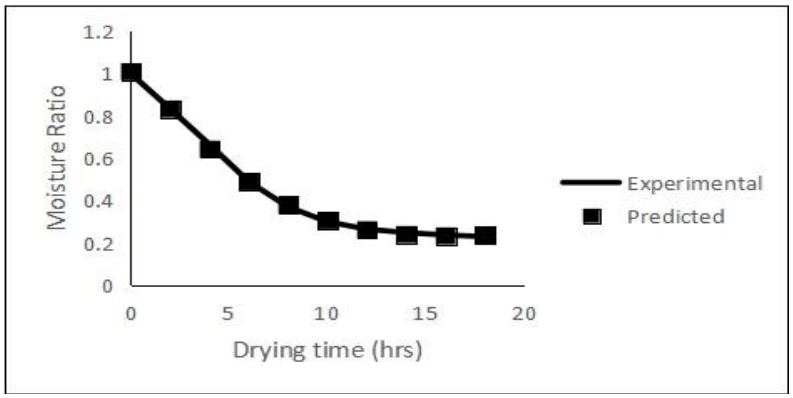

Figure 21. Comparison of experimental and predicted moisture ratio values by Midilli and Kucuk model for 10mm thickness for solar drying

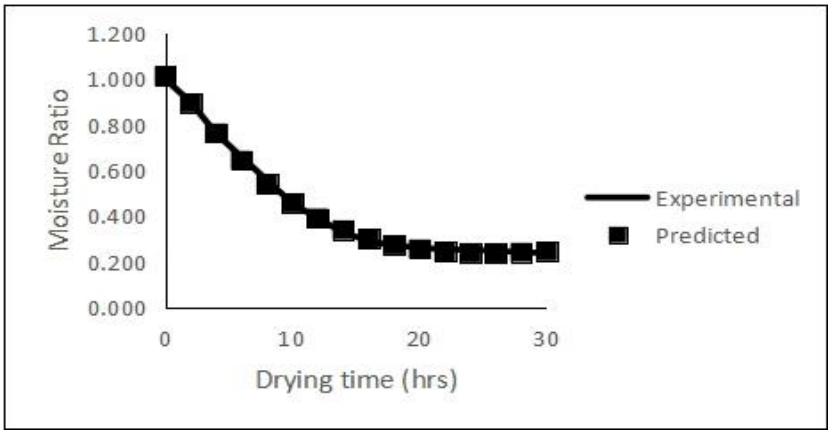

Figure 22. Comparison of experimental and predicted moisture ratio values by Midilli and Kucuk model for 15mm thickness for solar drying

Considering the constants, coefficients, and factors of the Midilli and Kucuk drying model for solar drying, successful prediction of the moisture ratio for cooking banana slices with thicknesses of 5mm, 10mm, and 15mm at different drying stages (t) within the temperature range of (50-70 ^{o}C) can be achieved using the following equations.

$$5mm;\ MR = 1.002\ Exp\ (-3.73E^{-3}xt^{1.175}) + 6.168E^{-4}t \quad \ldots\ldots\ldots (14)$$

$$10mm;\ MR = 1.009\ Exp\ (-3.04E^{-3}xt^{1.258}) + 7.628E^{-4}t \quad \ldots\ldots\ldots (15)$$

$$15mm;\ MR = 1.040\ Exp\ (-7.40E^{-3}xt^{0.993}) + 4.546E^{-4}t \quad \ldots\ldots\ldots (16)$$

CONCLUSIONS

In light of the findings from the research study, the ensuing conclusion emerges:

1. The findings underscored that the drying mechanism for cooking banana follows a diffusion-controlled process. Commencing with a brief constant rate period, the predominant drying occurred during the falling rate period, culminating with the attainment of the equilibrium moisture content threshold (EMC).
2. Drying rate constant (k) exhibited an upward trend with increasing drying temperature, while it decreased in tandem with an increase in slice thickness. Succinctly, this implies a direct relationship between drying time and slice thickness, coupled with an inverse correlation with drying temperature.
3. Fifteen thin-layer drying models were employed to fit the drying data (MR), and their validity was assessed through coefficients of determination (R^2), root mean square error (RMSE), and reduced chi-square (X^2) parameters. The Midilli-Kucuk model emerged as the most adept in elucidating the single-layer drying kinetics across diverse experimental conditions, outperforming alternative model for solar drying scenario due its high R^2 value, and lowest values of RMSE and X^2.
4. These results establish the efficacy of the Midilli-Kucuk model as a robust tool for predicting the single-layer drying kinetics of cooking banana slices, serving as a valuable asset in the design of dryers and processing of unripe cooking banana. Empirical equations were formulated based on the obtained data to facilitate the prediction of drying kinetics for cooking banana slices in solar drying method.

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POBOLJŠANJE KVALITETA BANANA POSTUPKOM SUŠENJA: -PRISTUP MATEMATIČKIM MODELOM

Muofunanya F. Umunna[1]; S. A. Adzor[2]; D. F. Ikikiru[1]; O. Nyorere[1]; S. K. Chigbo[3]; E. T. Erokare[1]; A. B. Eke[3]

[1]Department of Agricultural Engineering, Faculty of Engineering, Delta State University of Science and Technology, Ozoro, Nigeria
[2]Department of Materials and Metallurgical Engineering, Faculty of Engineering, Delta State University of Science and Technology, Ozoro, Nigeria
[3]Department of Agricultural and Bioresources Engineering, College of Engineering and Engineering Technology, Micheal Okpara University of Agriculture, Umudike, Nigeria

Apstrakt: Ova studija sistematski je istražila kinetiku solarnog sušenja kriški banana debljine 5 mm, 10 mm i 15 mm na temperaturi od 50°C, 60°C i 70°C.

Koristeći solarnu metodu, proces sušenja je pokazao mehanizam kontrolisan difuzijom, prelazeći sa kratkog perioda konstantne brzine na period preovlađujućeg pada brzine, sve dok se ne postigne ravnotežni sadržaj vlage. Konstanta brzine sušenja (k) pokazuje rastući trend sa povišenom temperaturom, dok je uočena inverzna korelacija sa debljinom preseka kriški, uspostavljajući direktnu i inverznu vezu sa vremenom sušenja i temperaturom, respektivno.

Petnaest tankoslojnih modela sušenja primenjeno je kako bi odgovarali podacima o odnosu vlage (MR).

Model Midilli-Kucuk je pokazao superiorne performanse, pripisane visokoj vrednosti R^2(0,997) i najnižim vrednostima RMSE (0,00228) i X^2 (0,0000132).

Dokazan kao robustan alat, Midilli-Kucuk model je efikasno predvideo kinetiku jednoslojnog sušenja kriški banana, pružajući vredne podatke za dizajn i konstrukcije sušara.

Empirijske jednačine izvedene iz dobijenih podataka omogućavaju ostvarenje predviđanje kinetike sušenja posebno za sušenje kriški banana solarnom metodom.

Ova studija značajno doprinosi razumevanju i optimizaciji procesa sušenja nezrele banane za sušenje, nudeći praktične implikacije za dizajn sušara i poboljšanja obrade.

Ključne reči: *Solarno, sušenje, kinetika, kuvanje, banana, kriške, Midilli-Kucuk, model*

Prijavljen:
***Submitted*:27.03.2024.**
Ispravljen:
***Revised*: 19.05.2024.**
Prihvaćen:
***Accepted*: 29.05.2024.**

CIP Каталогизација у публикацији
Народна библиотека Србије, Београд
631(059)
ПОЉОПРИВРЕДНА техника : научни часопис =
Agricultural Engineering : Scientific Journal /
одговорни уредник Мићо В. Ољача – Год. 1, бр. 1
(1963)- . Београд; Земун : Институт за пољопривредну
технику, 1963 - Београд. (Штампарија: DUGA MOTIV ,
11030 Београд). - 25 цм
Тромесечно. – Прекид у излажењу од 1987-1997. године
ISSN 0554-5587 = Пољопривредна техника
COBISS.SR-ID 16398594