International Journal of Scientific Research in Multidisciplinary Studies
Vol.9, Issue.8, pp.01-05, August 2023
E-ISSN: 2454-9312 P-ISSN: 2454-6143
Available online at: www.isroset.org

Research Paper

Design, Fabrication and Performance Evaluation of a Hammer Cum Burr Mill

Obolo A.A.[1], Ale M.O.*[2], Kareem K.M.[3]

[1,2,3]Department of Agricultural & Bio-Environmental Engineering Technology, Nigeria

Corresponding Author: alebosunenator@gmail.com

Received: 28/Jun/2023; **Accepted**: 26/Jul/2023; **Published**: 31/Aug/2023. | **DOI**: https://doi.org/10.26438/ijsrms/v9i8.15

Abstract—A hammer cum burr mill developed, and its performance was evaluated using yam and cassava flakes. The machine consists of a hopper, hammer mill unit, a conveyor, attrition mill unit, the frame and 2 horsepower prime mover. To evaluate the performance of the machine, two experiments were conducted. In the first experiment, varying speeds of 750, 1270 and 1800 rpm at a constant machine load of 0.5 kg were used. In the second experiment, varying machine loads of 0.5, 1.0, 1.5 and 2.0 kg at a constant speed of 1270 rpm. The moisture content of yam and cassava flakes were kept constant at 12.5% dry basis. The results of the research showed a polynomial relationship between speed and milling efficiency in the cassava experiment as well as the capacity in both the yam and cassava experiments. While a linear relationship was observed between speed and milling efficiency in the yam experiment and same observation was made between the machine load and milling efficiency as well as machine capacity in both the yam and cassava experiments. The optimum milling efficiencies of 93 and 85% were recorded at respective speeds of 1270 and 750 rpm for cassava and yam. The optimum efficiencies were achieved at a machine load of 0.5 kg. The hammer cum burr mill was tested and found suitable for milling of cassava and yam flakes into flour ("elubo"). It can also be used for plantain flour and other related food materials. Therefore, it is recommended for the use of farmers and agricultural processors.

Keywords— Cassava, design, fabrication, flour, performance indices, size reduction

1. Introduction

Size reduction is an important phase in food production technology. The form of reduction depends on the type of produce or the requirement from the consumers of such produce. At times, size reduction may require more than one size reduction machine, that is more than one machine or principle is used before the desired fineness is achieved. If the size reduction process is carried out to the fullest extent (reducing the harvested crop to desired finest particle) then the process is known generally as milling [1].

Processing of agricultural produce frequently requires size reduction of solid materials for different purposes. Size reduction may help other processes like expression, extrusion and extraction. It may also reduce the period for heat treatment in blanching and cooking [2]. The generic term used for size reduction is comminution and it includes different operations like crushing, grinding/milling, mincing and dicing. Breaking of hard material along cracks or defects in their structure is achieved using diverse forces. The types of forces commonly used in the process of food reduction are compressive, impact, attrition/shear and cutting forces [3].

A burr mill is a mill used to reduce the size of small food products between two revolving abrasive surfaces in a clockwise direction and separated by a distance usually set by the operator. It is also called attrition mill. The machine usually includes a revolving screw that pushes the food through. The main principle of the burr mill is the crushing of the crop between two plates that are rubbed together. The plates have grooves cut on one or both faces of the plates. The use of burr mills and hammer mill are widespread and they have greatly eased the tedious task of pounding grains and food flakes manually. Dry products of root crops are usually milled separately using the hammer mill and the burr mill to achieve the optimum particle size.

To improve the effectiveness of milling operation in food processing with optimum reduction of the cost and time, some of the milling machines or principles can be combined to a single-unit operation in which the works of the hammer and the burr mills can be performed simultaneously in a single operation. This study is therefore on the design, fabrication and performance evaluation of hammer cum burr mill.

1.1 Research Objectives

The objectives of this study are:
1. to design hammer cum burr mill.
2. to fabricate and assemble the components of the machine.
3. to evaluate the performance of the machine.

© 2023, IJSRMS All Rights Reserved

2. Related Work

Reduction of particle size like milling is a necessity for agricultural produce for further processing or utilization [4]. The physical and mechanical properties of materials often determine the degree and rate of reducing agricultural materials to an appropriate texture. Features of materials like fibrousness, friability, heat-sensitivity, wetness, fatty or sticky nature and density are some of the most common challenges in milling operation [3]. Size reduction is also used to transform solid nature of materials to slurry to vary its rheological characteristics. Particle size of agricultural produce can be controlled by using different screens and clearances. The type of mill used for size reduction also has a major impact on the quality and yield of produce.

The major machines involved in milling are roller mill, disc mill, burr mill and the hammer mill [5]. The roller mill consists of two or more steel roller revolving towards each other in opposite direction to pull particles of food through the space between the rollers. There are various types of disc mills ranging from single disc mills, double disc mills to pin-disc mill.

Hammer mill is an essential machine in the pharmaceutical and food processing industries [6]. It can be used to crush, pulverize, shred, grind and reduce material to suitable sizes.
A conventional hammer mill machine with a semi-circular screen was reported by [7]. The efficiency of the mill was influenced by the moisture content of the materials and the operating speed of the mill. Relationship between drum speed and machine efficiency under different grain moisture content, hammer thickness and concave clearance was reported by [8] [9].

3. Experimental Method

3.1 Machine Description and Operation

The hammer cum burr mill (Figure 1 and 2) comprises of the hopper, the hammer unit, the conveyor, the burr unit and the frame. The hammer unit consists of twenty hammers of 100mm in height and 16 mm thickness and a shaft of 30mm diameter. While the burr unit consists of two plates, the burr control shaft and the burr chamber. The dry materials are fed into the mill through the hopper and simultaneously milled to the desired particle size of flour ("elubo") by crushing the materials in the hammer unit while the crushed materials are further milled into the desired fine particle size of "elubo" by the bur unit. The mill is powered by 2 horsepower electric prime mover via belt and pulley transmission system.

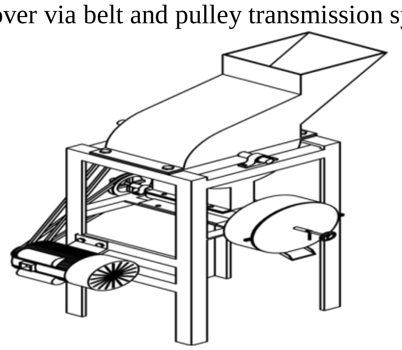


Figure 1: Isometric View of the Hammer Cum Burr Mill

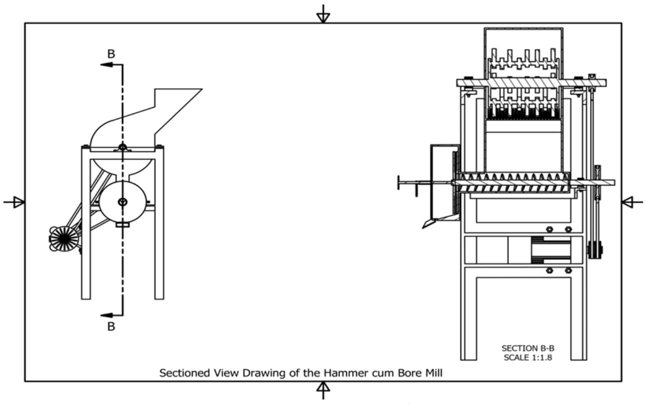


Figure 2: Section View of the Mill

3.2 Design Methodology

The design of component-units of the hammer cum burr mill was carried out using the specific functions of each component units as factors for design considerations.

3.2.1 Capacity of the Hopper

Volume of the Hopper, V (m^3)

$$V = \frac{1}{2} \times AB \times BC \times BE \quad (1)$$

$V = 0.0086m^3$

For dry cassava tuber, the density ranges from 810 to 870 kg/m^3 at 12% moisture content [10].
Therefore, the capacity of the hopper for cassava flake in mass (kg)

$$Mass = Density \times Volume \quad (2)$$

$Mass = 7.482\ kg$

For dry yam tuber, the density ranges between 700 to 910 kg/m^3 [11].
Therefore, the capacity of the hopper for yam flake in mass (kg)

$Mass = 7.835\ kg$

3.2.2 Shaft Selection

The diameter of the shaft was determined using equation 3 as expressed by [12]. The shaft was therefore selected based on the available standard that is closed to the determined diameter.

$$d^3 = \frac{16}{\pi s_s}\sqrt{(k_b M_b)^2 + (K_t M_t)^2} \quad (3)$$

Where; d is the shaft diameter in meter, M_b is the maximum bending moment in Nm, M_t is the maximum torsional moment in Nm, K_b is the combined shock and fatigue factor applied to bending moment = 1.5, K_t is the combine shock and fatigue factor applied to torsional moment = 1.0, S_s is the ultimate stress of mild steel without key way = $55MN/m^2$.
Calculated shaft diameter = 27.45mm.
Therefore, shaft of 30mm was selected.

© 2023, IJSRMS All Rights Reserved

3.2.3 Determination of Power Requirement

The power required for operation by the machine was determined using equation 4 as expressed by [13].

$$P = 2\pi nT/60 \quad (4)$$

Where P is the power in Watt, n is the shaft speed in rpm and T is the torque required to turn the shaft at the circumference of the driven pulley in Nm.

Power required to drive the shaft = 1.31kW
Assuming 10% power loss due to friction, total power required = 1.441 kW
Therefore, a prime mover of 2 horsepower (1.50 kW) was selected.

3.2.4 Power Transmission System

The mechanisms and systems in the machine are driven via the v-belt and pulley arrangement from 2 horsepower prime mover of 1420 rpm.
With the power rating, a belt of type A cross-sectional symbol was selected [14].

3.3 Performance Test Procedure

To evaluate the machine performance, two experiments were carried out for both yam and cassava flakes. In the first experiment, varying operating speeds of 750, 1270 and 1800 revolution per minute at a constant machine load of 0.5 kg were used. In the second experiment, varying machine loads of 0.5, 1.0, 1.5 and 2.0 kg at a constant operating speed of 1270 revolution per minute. Each experiment was repeated in three replicates and the varying speeds were achieved using a variable pulley arrangement. The moisture content of yam and cassava flakes used was 12.5% dry basis. The moisture content was determined using a grain moisturemeter; the weight of the samples of the yam and cassava flakes was measured with the use of an electronic weighing balance and the milling time was taken by using a stop-watch. The milling efficiency and the machine capacity were respectively determined using equations 5 and 6. The particle size of the milled cassava and yam products were analyzed using sieve particle size analysis.

Throughput capacity, C_t is expressed by [15] as

$$C_t = W_s/T_a \quad (5)$$

Where; W_s is total weight of sample input (kg). T_a is average milling time (hr).

Milling Efficiency, S_m is expressed by [15] as

$$S_m = \frac{W_s}{W_m} \times 100 \quad (6)$$

Where W_s is weight of sample collected after milling (kg), W_m is weight of input sample.

4. Results and Discussion

4.1 Effect of Machine Speed on Milling Efficiency

The results of the evaluation tests as presented in Figure 3, showed that the performance of the hammer cum burr mill was greatly influenced by the operating speed and the moisture content of the cassava and yam flakes as previously reported by [9] in a burr mill study. The milling efficiency decreased from 85% to 77% when the operating speed increased from 746 rpm to 1812 rpm at a moisture content of 12.5%. This is in conformity with [8] in a study on the effect of some operational factors of a hammer mill. But it is contrary to [9] that reported that milling efficiency in a burr mill increased with an increase in operating speed. The results obtained portrayed a linear dependence of the milling efficiency with the operating speed with coefficient of determination, r^2 of 0.9864 for yam flakes while the relationships between the two parameters that can be described as polynomial with coefficient of determination, r^2 of 1 was recorded for cassava flakes.

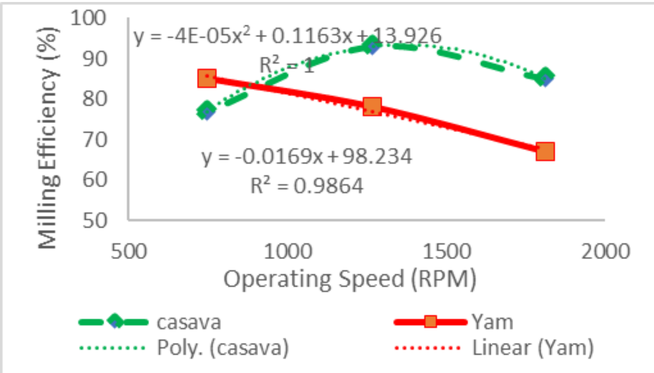


Figure 3: Effect of Machine Speed on the Milling Efficiency

4.2 Effect of Machine Speed on Machine Capacity

As observed from the result in Figure 4, machine capacity increased from 7.5 kg/h to 10 kg/h at a constant feed input of 0.5 kg and average moisture content of 12% for cassava experiment when the operating speed increased from 746 rpm to 1812 rpm. This is also similar to the study by [8]. While the machine capacity decreased with an increase in operating speed and later increased with an increase with further increase operating speed. The result obtained showed a linear dependence of the machine capacity with the operating speed for cassava flakes while a polynomial relationship between the two parameters was recorded for yam flakes.

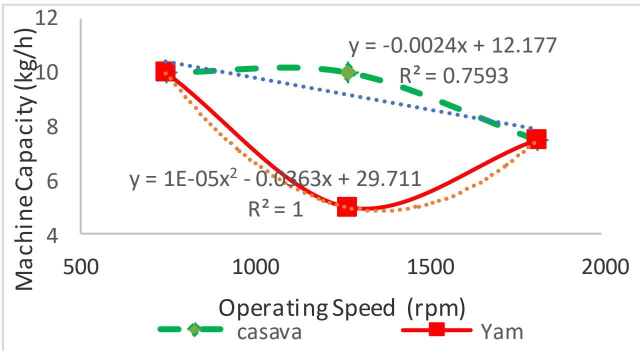


Figure 4: Effect of Machine Speed on the Machine Capacity

© 2023, IJSRMS All Rights Reserved

4.3 Effect of Feed Input on Machine Capacity and Milling Efficiency

The evaluation results as presented in Figure 5 showed that the milling efficiency decreased from 98% to 37% when the feed input increased from 0.5 kg to 2 kg in the cassava experiment at optimum operating speed of 1269 rpm. and from 60 % to 18 % in the yam experiment at optimum operating speed of 746 rpm. This is in conformity with a study by [16] that reported a similar trend on the effects of pool volume on wet milling efficiency. This inverse but linear relationship is with coefficient of determination, r^2 of 0.9575 for cassava experiment and 0.9854 for yam experiment. A linear relationship was also observed in Figure 6, where machine capacity increased with an increase in feed input at respective optimum operating speeds of 1269 and 746 rpm at respective coefficient of determination, r^2 of 0.9394 and 0.9 for both cassava and yam experiments.

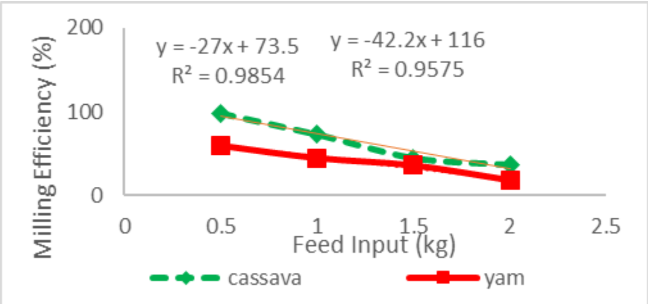


Figure 5: Effect of Feed Input on the Milling Efficiency

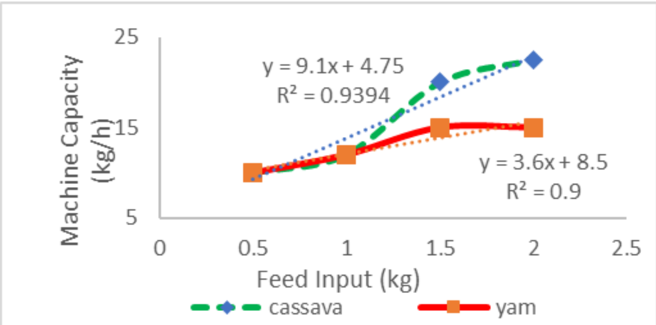


Figure 6: Effect of Feed Input on the Machine Capacity

4.4 Effect of Machine Speed on Particle Size of Yam and Cassava flour

As presented in Figure 7, the particle size of the cassava flour decreased with an increase in operating speed. This is contrary to [8] that is similar to the result of the yam experiment in which the particle size of the yam flour increased with an increase in the operating speed of the machine. Both experiments were carried out at constant feed input of 0.5 kg. This result also showed that the trend of the relationship differs from one product to the other. The relationship between the operating speed and the particle size in the cassava experiment can be described as linear with coefficient of determination, r^2 of 0.9602. While the relationship in the yam experiment was also linear, but inverse with coefficient of determination, r^2 of 0.9949.

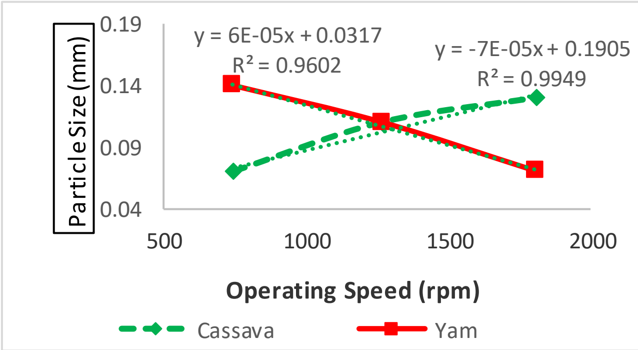


Figure 7: Effect of Machine Speed on the Particle Size of the Flour

5. Conclusions

A hammer cum burr mill was designed, fabricated, tested and found suitable for milling of dry solid agricultural crops like cassava and yam flakes to the desired fine particle size in a single operation. From the result of the evaluation test, it can be concluded that, the performance of the hammer cum burr mill is highly influenced by the operating speed and the moisture content of the cassava and yam flakes; a good correlation exists between the operating speed and the milling efficiency in both cassava and yam experiments at optimum feed input of 0.5 kg. There is also a good correlation between the feed input and the milling efficiency at the optimum speed of 1269 rpm in the cassava experiment and 746 rpm in the yam experiment as well as between the speed of operation and the particle size (fineness) of the milled product (flour) in both cassava and yam experiments at optimum feed input of 0.5 kg

Conflict of Interest

There is no conflict of Interest.

Authors' Contributions

Obolo A. A. conceived the study and involved in the design, development and performance evaluation of the machine.

Ale, M. O. researched literature, involved in the design and development of the machine, analysed the data and wrote the first draft of the manuscript

Kareem K. M. participated in development of the machine as well as manuscript proof reading

All authors reviewed and edited the manuscript and approved the final version of the manuscript.

References

[1] F. Lyu, M. Thomas, W.H. Hendriks, P. Vander, Size reduction in feed technology and methods for determining, expressing and predicting particle size: A review. Animal Feed Science and Technology, **2020.**

[2] P.J. Fellows, Blanching- An overview of Food Processing Technology, Principles and Practice. Woodhead Publishing Series in Food Science and Technology, **2017.**

[3] Y. O. Bankole, O.A Tanimola, B. S Adesina, D. O. Samuel, Quality of Pepper Paste using different Milling Methods. Journal of Interdisciplinary Studies. Vol.**2**, Issue.**10**, pp.**187- 193, 2013.**

© 2023, IJSRMS All Rights Reserved

[4] A. Oyelami, A. Oluwole, incorporating grain detection and speed control mechanisms in hammer mill operations. Nigerian Journal of Technology (NIJOTECH) Vol.**42**, Issue.**2**, pp.**222 – 229, 2023.**
[5] S. Sushant, K. Archana, Method of Size Reduction and Factors affecting Size Reduction in Pharmaceutics. International Journal of Pharmacy. Vol.**4**, Issue.**8**, pp.**57-64, 2013.**
[6] M. Sujay, Working of Hammer Mill, Solution Parmacy, **2021.**
[7] N. Yancey, T.W. Christopher, Tyler, "Optimizing Hammer Mill Performance Through Screen Selection and Hammer Design." Biofuel 4(1): 85-94. Vol:10.4155/bfs. 12.77, **2013.**
[8] M. S. El Shal, M. A Tawfik, A. M. El Shal, K. A. Metwally. Study Effect of Some Operational Factors on Hammer Mill. Misr J. Ag. Eng. Vol.**27**, Issue.**1**, pp.**54 – 74, 2010.**
[9] M. O. Ale, O. G. Olajide, W. A. Akinfiresoye, Effects of Moisture Content and Operating Speed on the Milling Efficiency of a Burr Mill. Journal of Multidisciplinary Engineering Science Studies. Vol.**3**, Issue.**5**, pp.**1717– 1721, 2017.**
[10] N. H. Baharuddin, M. Mohamed, N. Mohammad, M.M.A. Abdullah, Potential of Cassava Root as a Raw Material for Bio-Composite Development, **2016.**
[11] B. A.Wahab, A. A Adebowale, S. A. Sanni, O.P. Sobukola, A. O. Obadina, Effect of Species Pretreatment and Dry Methods on the Functional and Pasting Properties of High- Quality Yam Flow. Food Science and Nutrition. Vol.**4**, Issue.**1**, pp.**50-58, 2015.**
[12] A. S. Hall, A. R. Holowenko, H. G Laughlin, Theory and Problems of Machine Design. Schaum's Outline Series. McGraw Hill. New York, **1982.**
[13] R. S. Khurmi, J. K. Gupta,.Design of machine elements."Eurasia Publishing House(pvt.) Ltd, 5th edition, **2013**
[14] PSG., Design data compiled by Faculty of Mechanical Engineering P. S. G. College of Technology. Coimbatore 641004 India, **1982.**
[15] O. G. Olajide, M. O. Ale, T. A. Abisuwa. Performance evaluation of a burr mill for processing of maize grits. International Journal of Engineering Sciences andTechnology. Vol.**5**, Issue.**4**, pp.**55-71, 2016.**
[16] F. M. Katubilwa, Effects of pool volume on wet milling efficiency, Ph.D. thesis submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, **2012.**

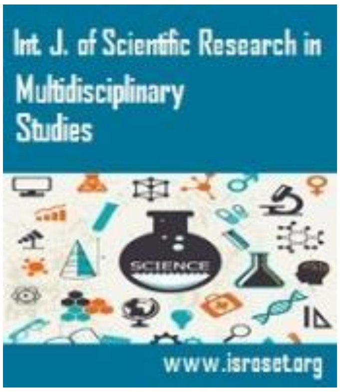
AUTHORS PROFILE

Obolo A. A. earned her B. Eng. in Agricultural Engineering from Federal University of Technology, Akure in 2010, and M.Eng. in Processing and Storage Engineering in 2017 from the same University. She is currently working as a Lecturer in the Department of Agricultural and Bio- Environmental Engineering Technology, Rufus Giwa Polytechnic, Owo, Nigeria. She is a member of The Nigerian Society of Engineers (NSE), Nigerian Institution of Agricultural Engineers (NIAE), International Research and Development Institute (IRDI), Women in Technical Education Development (WITED) and Association of Professional Women Engineers of Nigeria (APWEN) and she registered with the Council for the Regulation of Engineering in Nigeria in 2017. She has published more than 15 research papers in reputed international journals. Her main research work focuses on agricultural material handling, environmental engineering, agribusiness, renewable energy and transitioning to net-zero carbon energy technologies. She has over 10 years of teaching and research experience.

Ale, M. O. earned his M. Eng. and Ph.D. in Agricultural & Environmental Engineering from the Federal University of Technology Akure, Nigeria in 2014 and 2021, respectively. He is an alumnus of PTC+ (now, Aeres Training Centre International), Ede, the Netherland where he received a certificate in practical course on Agricultural Equipment. He is currently working as a Principal Lecturer in the Department of Agricultural & Bio-Environmental Engineering Technology, Rufus Giwa Polytechnic Owo, Nigeria. He is a member of Nigerian Institution of Agricultural Engineers (NIAE), American Society of Agricultural and Biological Engineers (ASABE); International Soil Tillage Research Organization (ISTRO) and Nigerian Society of Engineers (NSE) and he registered with the Council for the Regulation of Engineering in Nigeria (COREN) in 2009. His research interests are in the development of indigenous farm machinery for mechanization of agriculture; soil dynamics and soil-crop machine interactions and policy review on food security and rural development. He has over forty (40) publications in reputable international academic journals, conference proceedings as well as text books. He has over 20 years of teaching and research experience.

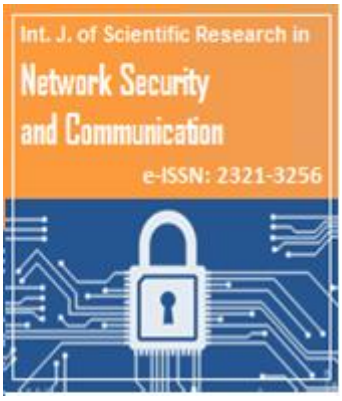
Kareem K. M. earned his B.Tech. in Agricultural Engineering from Ladoke Akintola University of Technology, Ogbomoso Oyo state He is currently working as an Assistant Lecturer in Department of Agricultural and Bio-Environmental Engineering Technology where he is being mentored in agricultural machine system design and management.

© 2023, IJSRMS All Rights Reserved



Submit your manuscripts at
www.isroset.org
email: support@isroset.org

Make a Submission



Call for Papers:
Authors are cordially invited to submit their original research papers, based on theoretical or experimental works for publication in the journal.

Make a Submission

All submissions:
- must be **original**
- must be **previously unpublished research results**
- must be **experimental or theoretical**
- must be in **the journal's prescribed Word template**
- and will be **peer-reviewed**
- may not be **considered for publication elsewhere at any time during the review period**