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Development of a low-cost motorized cassava mesh-sieving machine for small-scale food processing industries in Nigeria

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Abstract: *Sieving operation is a significant process during the transformation of dewatered cassava mesh into garri. The traditional sieving method practiced in Nigeria is a time and energy consuming process that requires human interaction with a minimal output than the mechanized method. The traditional sieving method is a manual process, which is usually associated with drudgery and fatigue. Thus, this study focused on the design, construction and performance evaluation of a low-cost motorized cassava mesh-sieving machine for small-scale food processing industries in Nigeria. Galvanized steel was employed in the fabrication of the parts that will be in contact with the cassava mesh such as the sieve, sieving chamber, collector, top concave cover and hopper, to avoid food contamination that could result from the use of mild steel. The sieving machine is powered through a belt and pulley system by an electric motor of 2-horsepower with 1400 revolutions per minute. The novelty of this machine is that it is easy-to-operate, and was implemented using locally available materials that are cheap, and hence it is cost-effective. The results of the performance evaluation unveiled that the developed cassava mesh-sieving machine can sieve 5.2kg of cassava mesh in 14 seconds with an output of 5.4725kg of sieved cassava mesh, which shows that the developed cassava mesh-sieving machine has a sieving capacity of 1337.14kg/hr and a sieving efficiency of 99.5%. The results also unveiled that the developed system is efficient, economical, eco-friendly, reduces drudgery and fatigue than the traditional cassava mesh-sieving methods commonly used in Nigeria by the rural farmers and small-scale food processing industries.*

Keywords - Cassava mesh-sieving machine, mechanized sieving method, small-scale food processing

1. INTRODUCTION

The cassava mesh-sieving machine is an essential component in the post-harvesting processes of cassava, a staple root crop that plays a crucial role in the diet of many people in the tropical regions like Nigeria, particularly in the production of *garri*, a popular West African food product [1]. Cassava is the third-largest source of food carbohydrates in the tropics, after rice and maize. Cassava production in Nigeria reached a peak of 45 million metric tonnes by the year 2015 to become the largest producer in the world [2]. In 2020, global production of cassava root was 303 million tons, with Nigeria as the world's largest producer, contributing about 20% of the world total cassava production [3]. Thus, cassava is one of the most important crops in Nigeria. It is the most widely cultivated crop in the southern part of the country in terms of area devoted to it and number of farmers growing it. Other major growers were Democratic Republic of the Congo and Thailand [4]. However, it pertinent to note that the traditional method of mesh sieving is commonly practiced in Nigeria in spite of the large volume of production of this important crop. Thus, the development of a low-cost cassava mesh-sieving machine is necessary in Nigeria owing to the need to reduce the labor-intensive nature of the traditional cassava mesh-sieving method, which is time- and energy-consuming, and physically demanding operation, and often results in low productivity and inconsistent product quality, as manual sieving can be unhygienic, exposing the cassava products to contamination [5]. The traditional sieving method also poses ergonomic challenges as it can cause physical strain and potential injuries such as back-pain for the workers involved [6]. With the invention of mechanized sieving machines, the cassava mesh-sieving process has become much faster and less laborious, allowing for increased production and better quality of the final product. The design and fabrication of these machines have evolved over the time such that recent developments incorporate advanced principles such as the slider-crank mechanism, which converts rotary motion into the reciprocating movement of the sieving tray, automatic feeding systems and variable speed controls, thus optimizing the sieving process [7]. These improvements are aimed at enhancing the quality of the final product, reducing waste, and minimizing the physical labour required thereby significantly contributing to the efficiency of the sieving machine, making it possible to handle larger volumes of cassava mesh and produce a more consistent product quality [8]. Despite these advancements, there is still a need for further research to enhance the energy efficiency of these machines and to make them more accessible to small-scale processors [7]. However, in most of the Africa countries like Nigeria, rural farmers and small-scale food processing industries still practice the traditional method of sieving cassava mesh with a hand-woven raffia sieve with human as a source of power during the post-harvesting processes of this vital agricultural produce [9]. Thus, the development of a mechanized cassava mesh-sieving machine aims to overcome these problems by improving efficiency, reducing labour, ensuring consistent product quality and enhancing the hygienic conditions of the sieving process, increasing the production capacity and improving the livelihoods of those involved in small-scale cassava processing industries.

Several studies have reported the development of cassava mesh-sieving machines in the literature. For example, Ovat and Nyong [10] developed a motorized vibratory sieving machine with an efficiency of 94.5%, with the aim of improving garri production process. The machine consists of two parts: the granulating and sieving units; and the average time taken to sieve 5.48kg of garri was 51.2 seconds. However, due to the complexity and bulkiness of the machine, maintenance will be hard to carry out diligently. Sulaiman and Adigun [11] fabricated a cassava lump breaker with locally available materials such as mild steel. However, they recommended that the machine should be constructed with stainless steel materials due to corrosion and the need for hygienic final product. Moreover, they failed to carry out a comprehensive performance evaluation of the machine in terms of efficiency and throughput capacity. Tambari et al [12] designed a reciprocating cassava mesh-sieving machine that uses the principle of slider crank mechanism to convert the rotary motion of the pulleys to the reciprocating movement of the sieving tray. The machine has an output of 100.59kg/hr and an efficiency of 75.7%. Oladebeye et al [13] designed, fabricated and conducted the performance evaluation of a cassava mesh-sieving machine with lump breaking device using rotary sweepers. The machine consists of a rotary sweeper with the sieve to sift the dewatered cassava mesh poured into it through the hopper, and it can sieve 16.7kg of dewatered cassava mesh in a batch and it is capable of producing 1.2tonnes of sifted cassava mesh in 60 minutes. The machine is driven by a synchronous electric motor of 3.75kW with 1450 rpm, and has a sieving efficiency of 98%. However, the design and mechanism of the operation of the machine is complex, and hence the operation of the machine by rural farmers, maintenance or replacement of any part will be difficult. Ajewole et al [14] modified and conducted a performance evaluation of an existing cassava mesh-sieving machine at three moisture content levels: 24.6%, 22.3% and 20.2%, at varying speeds of 1200rpm, 970rpm, 730rpm and feed rates of 5kg, 10kg, 15kg, and 20kg. The machine achieved its highest efficiency of 99.4% at 20.2% moisture content and 1200rpm, with an output capacity of 569.03kg/hr. There is therefore the need for the development of an efficient cost-effective cassava mesh-sieving machine with a high output capacity for small-scale cassava processing industries in Nigeria to reduce the high initial cost associated with the existing cassava mesh-machines in Nigeria, further enhance the efficiency of the machine, and eliminate/drastically reduce the drudgery associated with the traditional sieving method. Therefore, this study focused on the design, construction and performance evaluation of an efficient low-cost motorized cassava mesh-sieving machine for rural farmers and small-scale food processing industries in Nigeria.

2. MATERIALS AND METHODS

2.1 Components of the sieving machine

The main components of the system include the frame, the sieving mechanism, an electric motor with belt and pulley system, and a collecting chamber. The frame is one of the main units of the machine on which all other components of the machine were supported. The sieving mechanism consists of the sieve and sieving chamber with sieving brushes mounted on a cylindrical chamber of length 600mm and diameter 220mm and a rotating shaft. The electric motor of 2-hp with 1400 rpm powers the machine through the belt and pulley system, and the collecting chamber with a pan serves as an outlet for collecting the sieved cassava mesh.

2.2 System design

2.2.1 Determination of angle of inclination of the machine

The machine was designed to be inclined at an angle of 14.36º to aid dispatch of the sieved cassava mesh from the machine (Figure 4). This angle of inclination of the machine was determined using the tangent function as expressed by equation (1).

$$\tan\theta = \frac{(A-B)}{C} \tag{1}$$

Where; A = Height of point A, B = Height of point B, C = Horizontal distance between points A and B

$$\tan\theta = \frac{(A-B)}{C} = \frac{820-610}{820} = \frac{210}{820} = 0.2561, \theta = \tan^{-1}(0.2561) \Rightarrow \theta = 14.36°$$

2.2.2 Shaft design

The design of the shaft was subjected to both twisting and bending moments. The shaft that passes through the center of the sieving chamber is supported by pillar 206 bearings at both ends. The power delivered by the shaft was determined as $18.66Nms^{-1}$according to Shigley and Mischke [15] using equation (2).

$$P = F \times V \tag{2}$$

where; P = Power (Nms^{-1}), F = Force of sieving, $m \times a = 5 \times 0.25 = 1.25N$, V = velocity (m/s) = $\frac{2\pi\times 0.095}{0.04} = 14.93m/s$

$$P = F \times V = 1.25 \times 14.93 = 18.66Nms^{-1}$$

Likewise, the total weight of the sieving system acting on the shaft, W, was estimated as follows:

W = Weight of the sieving brush (W_{sb}) + Weight of the pan carrying the sieving brush (W_p)

$$W = W_{sb} + W_p = 0.15 + 8.85 = 9kg$$

2.2.3 Determination of maximum torque and maximum bending moment

The maximum torque was determined as 10.18Nm using equation (3).

$$M_t = \frac{60\,P}{2\pi N} \tag{3}$$

where M_t = Torque Nm, N = speed rev/min and P = power (the electric motor power) KW

$$M_t = \frac{60P}{2\pi N} = \frac{60 \times 1492}{2\pi \times 1400} = 10.18Nm$$

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Thus, the required tangential driving force was calculated using equation (4)

$$F_t = 2T \times d \quad (4)$$

where, F_t = Tangential force (N-m), T = Applied Torque (N-m) and d = diameter of gear(m)

$F_t = 2T \times d = 2(10.18) \times 0.06 = 1.2$Nm

The maximum bending moment was determined as 20.75Nm from the force diagram (Figure 2).

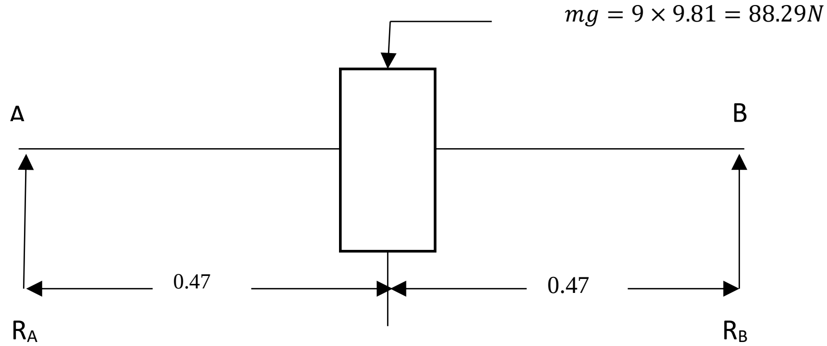

Figure 2: Force diagram showing the forces acting the machine

Calculating the reaction:

$R_A + R_B = 88.29$

$\sum M_B = 0$

At point B, $R_A - 88.29 + R_B = 0$

Bending moment calculation:

At point A, $B.M_A = 0$

$R_A \times 0.94 = 88.29 \times 0.47 = \dfrac{41.4963}{0.94} = 44.145N$

$\therefore R_B = R_A = 44.145N$

Shear force calculation:

At point A, $R_A = +44.145N$

At point C, $R_A - 88.29 = 44.145 - 88.29$

At point A, $B.M_C = R_A \times 0.47 = 44.145 \times 0.47$
$= 20.75Nm$

At point A, $B.M_B = 44.145 \times 0.94 - 88.29 \times 0.47 = 0$

Maximum bending moment, M_{BM} = 20.75Nm

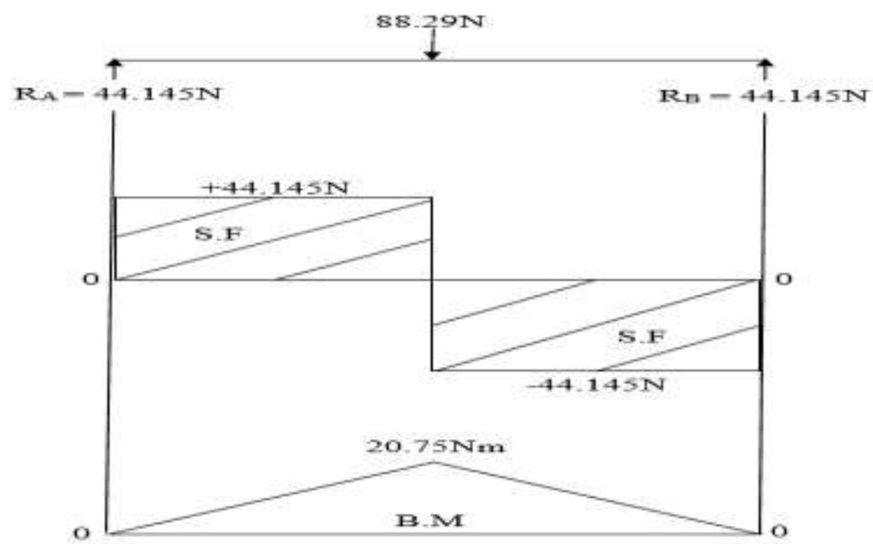

Figure 3: The shear force and bending moment diagram

2.2.4 Pulley design

The ratio between the velocities of the electric motor pulley/driven pulley and the driven was determined as 1:3 according to Adetunji et al [17] using equation (6).

$$D_e N_e = D_d N_d \quad (6)$$

Where, D_e = Diameter of the driver pulley, m; D_d = Diameter of the driven pulley, m; N_e = Speed of the driver in rpm and N_d = speed of the driven in rpm. Since the length of belt that passes over the driver in one minute is equal to the length of belt that passes over the follower in one minute [17], therefore;

$N_d = N_d = \frac{D_e N_e}{D_d} = \frac{60 \times 1400}{190} = \frac{84000}{190} = 442\ rpm$

Thus, the speed ratio = $\frac{N_e}{N_d} = \frac{1400}{442} = 3.17 = 1:3$

2.2.5 Belt design

The length of the belt required was determined as 1452mm according to Ananth et al [18] using equation (7).

$$L = \pi (R + r) + \frac{R-r}{C} + 2C \quad (7)$$

Where; R = radius of the pulley on the drive shaft (95mm), r = radius of the pulley on the motor shaft (30mm), C = Center distance between the two pulley (530mm), and L = Length of belt required, mm.

$$L = \pi(95 + 30) + \frac{95 - 30}{530} + 2(530)$$
$$= 392 + 0.122 + 1060 = 1452mm$$

Likewise, using an electric motor of 2hp and 1400rpm, the belt tensions on both the tight and slack sides, T_1 and T_2, were determined as 509N and 169N, respectively, according to Oladebeye et al [13] using equation (8).

$$T = (T_1 - T_2)r \quad (8)$$

Where; T = Torque transmitted by electric motor (10.18Nm), r = radius of electric motor pulley

Calculating for T_1;

$$T_1 = T \sin r \times 100 = 10.18 \sin 30 \times 100 = 509N$$

Assuming belt tension ratio ≤ 3;

$$T_2 = \frac{T_1}{3} = \frac{509}{3} = 169N$$

$$\therefore Total\ belt\ tension, T = 509 + 169 = 678N$$

Likewise, the pulley-belt contact angle, θ, was evaluated according to Alabi et al [19] using the expression:

$$\theta = 180 + \left(D_1 - \frac{D_2}{2}\right) \quad (9)$$

Where; D_1 and D_2 are motor and machine pulley diameter.

$$\theta = 180 + 60 - \frac{30}{2} = 180 + (60 - 15) = 180 + 45 = 225°$$

2.2.6 Design of the hopper

The volume of the hopper was calculated as $6.129m^3$ according to Khurmi and Gupta [16] using equation (5).

$$V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{(A_1 \times A_2)}\right) \quad (5)$$

Where; V = Volume of the hopper, m^3, A_1 = area of the top = 250mm^2 = 62.5m, A_2 = area of the base = 100mm^2 = 10m, h =height of the hopper = 0.185m

$$V = \frac{0.185}{3}\left(62.5 + 10 + \sqrt{(62.5 \times 10)}\right) = 0..616(99.5)$$
$$= 6.129m^3$$

3. RESULTS AND DISCUSSION

3.1. The developed machine

The developed sieving machine is an efficient low-cost motorized cassava mesh-sieving machine for small-scale food processing industries in Nigeria (Figure 4). The main components of the sieving machine include the frame, a collecting chamber, an electric motor of 2hp. and 1400 rpm that powers the machine via a belt and pulley system, and the sieving mechanism. The sieving mechanism consists of the sieve and sieving chamber with sieving brushes, mounted on a cylindrical chamber of length 600mm and diameter 220mm and a rotating shaft. Galvanized steel was employed in the fabrication of the parts that will be in contact with the cassava mesh such as the sieve, sieving chamber, collector, top concave cover and hopper, to avoid food contamination that could result from the use of mild steel. Figure 5 presents the system engineering designs. The novelty of this sieving machine is that it is easy-to-operate, and was implemented using locally available materials that are cheap, and hence it is cost-effective.

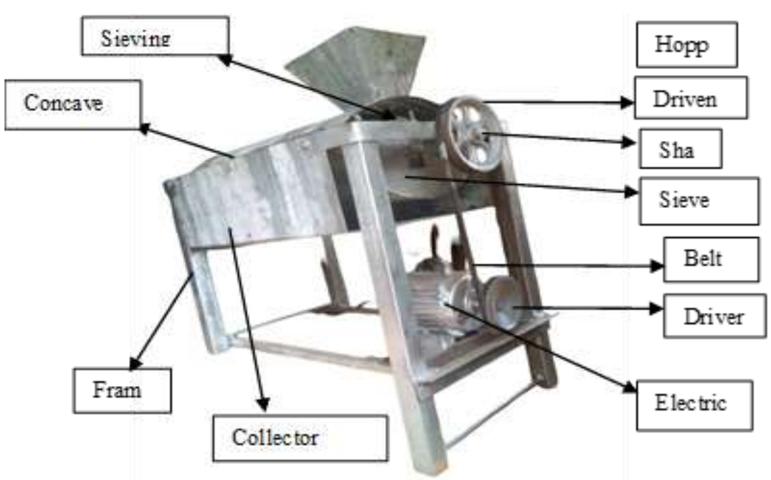

Figure 4: Picture of the developed cassava mesh-sieving machine

3.2. Performance evaluation of the developed sieving machine

A performance evaluation of the developed sieving machine was carried out to determine the sieving capacity and sieving efficiency. The quantity of cassava mesh (kg) to be sieved was weighed on a balance and the weight was recorded. The time taken for the sieving operation to be completed was also noted and recorded. Likewise, the sieved samples collected (output) from the sieve and the sieved residues were weighed and recorded. Thus, the developed sieving machine was tested at a speed of 1400rpm. The performance test of the developed machine was repeated for several times using the same quantity of the un-sieved cassava mesh and at the same speed of 1400rpm. The average values of the sieved cassava mesh samples and the time taken for the sieving operations to be completed were noted. The sieving capacity of the machine is the rate at which the machine sieves cassava mesh in kilogram Per hour and this was calculated as 1,389kg/hr according to Ovat et al [10] using the expression:

$$SC = \frac{M}{t} \quad (10)$$

Where SC is the sieving capacity of the machine (kg/hr), M represents the mass of the cassava mesh loaded into the sieve (kg), t is the time taken to complete the sieving operation (hr), The results of the performance evaluation unveiled that the developed cassava mesh-sieving machine can sieve 5.2kg of cassava mesh in 14 seconds with an output of 5.4725kg of sieved cassava mesh, which shows that the developed cassava mesh-sieving machine has a sieving capacity of 1337.14kg/hr and a sieving efficiency of 99.5%. Table 1 presents a Comparative analysis of performance of the existing cassava mesh-sieving machines and the new sieving machine. The results of the comparative analysis conducted based on certain key parameters such as machine sieving capacity, sieving efficiency, weight of cassava mesh before sieving, weight of sieved cassava mesh and time taken to sieve a particular amount of cassava mesh revealed that the new sieving machine is within the range and it is very efficient. Thus, the developed sieving machine is designed for low-income farmers and small-scale food processing industries, and so it is made from cheap available resources/materials to lower the cost, however little modifications and upgrade can transform the machine to industrial large-scale standard

Table 1: Comparative analysis of the performance of existing cassava mesh-sieving machines and the new sieving machine

S/N	Title of study	Performance Indicators					Ref.
		Weight of cassava mesh before sieving (kg)	Weight of sieved cassava mesh(kg)	Time taken for sieving (s)	Sieving capacity (kg/hr)	Sieving efficiency (%)	
1.	Development of a low-cost motorized cassava mesh sieving machine	5.2	5.4725	14	1337.14	99.5	This present study

2.	Motorized vibratory sieving machine for improved garri production	5.48	5.18	51	385.2	94.5	[10]
3.	Design, fabrication and performance evaluation of improved cassava mash sifter	10	9.2	286	135	93.3	[20]
4.	Fabrication of cassava lump breaker	5	4.6	153	132.78	90	[11]
5.	Innovation: Rural women cassava processing and food production	15	13.1	324	200	86.5	[21]
6.	Performance evaluation of a dewatered cassava mash sifter	12.5	11.9	130	386	95	[14]
7.	Design analysis of a reciprocating cassava sieving machine	3.86	2.92	104	100.59	75.7	[12]

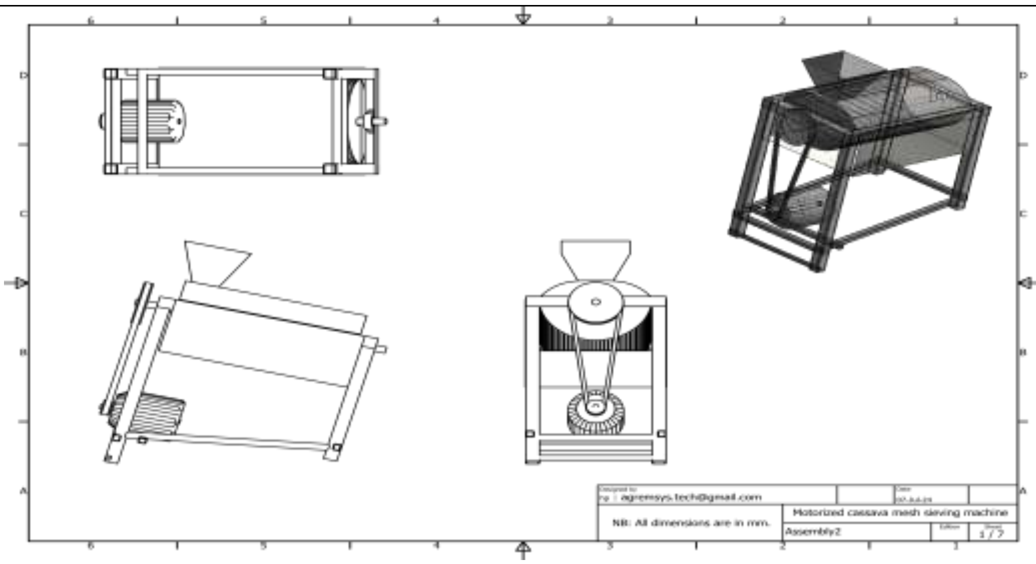

Figure 5: The system engineering drawings

4. CONCLUSION

This study has demonstrated the design, construction and performance evaluation of an efficient low-cost motorized cassava mesh-sieving machine for rural farmers and small-scale food processing industries in Nigeria. The main components of the sieving machine include the frame, the sieving mechanism, a collecting chamber and an electric motor of 2hp. and 1400 rpm that powers the machine via a belt and pulley system. Galvanized steel was employed in the fabrication of the parts that will be in contact with the cassava mesh such as the sieve, sieving chamber, collector, top concave cover and hopper, to avoid food contamination that could result from the use of mild steel. The novelty of this machine is that it is easy-to-operate, and was implemented using locally available materials that are cheap, and hence it is cost-effective. The results of the performance evaluation unveiled that the developed cassava mesh-sieving machine can sieve 5.2kg of cassava mesh in 14 seconds with an output of 5.4725kg of sieved cassava mesh, which shows that the developed cassava mesh-sieving machine has a sieving capacity of 1337.14kg/hr and a sieving efficiency of 99.5%. The results also unveiled that the developed system is efficient, economical, eco-friendly, reduces drudgery and fatigue than the traditional cassava mesh-sieving methods commonly used in Nigeria by the rural farmers and small-scale food processing industries.

REFERENCES

[1] C. Ozoh, C. Imoisi, and J. U. Iyasele, "Effect of pH and duration of fermentation on the sensory, physicochemical and proximate characteristics of garri," *Trends Appl. Sci. Res,* vol. 19, pp. 156-169, 2024.

[2] W. G. Adebayo, "Cassava production in africa: A panel analysis of the drivers and trends," *Heliyon*, vol. 9, no. 9, 2023.

[3] R. Sengar, "Cassava processing and its food application: A review," *Pharma Innov. J,* vol. 2, pp. 415-422, 2022.

[4] D. McKey and M. Delêtre, *The emergence of cassava as a global crop*. Burleigh Dodds Science Publishing, 2017.

[5] D. Lasisi, B. Adewumi, O. Dairo, and O. Awonorin, "Review On Cassava Mash, Methods And Mechanisms," *LAUTECH Journal of Engineering and Technology,* vol. 12, no. 2, pp. 56-66, 2018.

[6] C. Anyanwu, C. Ibelegbu, C. Ugwu, V. Okonkwo, and C. Mgbemene, "Comparative evaluation of mesh sieve performance of a wet cereal slurry sieving machine," *Agricultural Engineering International: CIGR Journal,* vol. 23, no. 1, pp. 115-127, 2021.

[7] A. Ahiakwo, K. Simonyan, and A. Eke, "Effects of sieve aperture modification on dewatered cassava mash sieving process," *Nigerian Journal of Technology*, vol. 38, no. 2, pp. 512-519, 2019.

[8] C. O. A. Agbo, "Development of fermented cassava wet sieving equipment for rural settings," *Indian Journal of Engineering,* vol. 18, no. 49, pp. 109-115, 2021.

[9] S. Musa, E. Samuel, M. Sani, and E. Mari, "Cassava production, processing and utilization in Nigeria: A review," *African Scholar Journal of Biotechnology and Agricultural Research (JBAR-1),* vol. 6, no. 1, pp. 43-64, 2022.

[10] F. A. Ovat, O. Nyong, and J. Adie, "Development of a Motorized Vibratory Sieving Machine for Improved Garri Production."

[11] M. Sulaiman and R. Adigun, "Fabrication of cassava lump breaker," *Unpublished project report submitted to the Department of Mechanical Engineering, Kwara State Polytechnic, Ilorin,* 2008.

[12] S. Tambari, G. Dan-Orawari, D. Aziaka, and V. Ayejah, "Design analysis of a reciprocating cassava sieving machine," *OSR Journal of Mechanical and Civil Engineering,* vol. 12, pp. 07-15, 2015.

[13] D. H. Oladebeye, E. R. Adefidipe, and O. Awogbemi, "Performance Evaluation of Dewatered Cassava Mash Sieving Machine using Rotary Sweepers."

[14] P. Ajewole, I. Oni, and T. Osadare, "Performance Evaluation of a Dewatered Cassava Mash Sifter."

[15] J. E. Shigley and C. Mischke, "Limits and fits," *Standard Handbook of Machine Design,* pp. 1-19, 1986.

[16] R. Khurmi and J. Gupta, *A textbook of machine design*. S. Chand publishing, 2005.

[17] O. Adetunji, O. Dairo, T. Aina, and A. Osunlana, "Development of an Improved Garri Sifting Machine," *Pacific Journal of Science and Technology,* vol. 14, no. 2, pp. 67-75, 2013.

[18] K. N. S. Ananth, V. Rakesh, and P. K. Visweswarao, "Design and selecting the proper conveyor-belt," *International Journal of Advanced Engineering Technology,* vol. 4, no. 2, pp. 43-49, 2013.

[19] I. Alabi, "Design, Fabrication and Performance Evaluation of Motorized Cassava Lumps Breaker," HND Thesis, *Agricultural Engineering Department, Kwara State Polytechnic, Ilorin,* 2009.

[20] E. Kudabo, E. Onipede, and O. Adegbenro, "Design, fabrication and performance evaluation of an improved cassava mash sifter," *J. Agr. Vet. Sci,* vol. 4, pp. 53-64, 2012.

[21] T. Adekanye, "Innovation and Rural Women: Cassava Processing and Food Production," *Technology and Rural Women; Conceptual and Empirical Issues,* 1983.