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Research Article

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Design and Development of Motorized Cassava Mash Sieving Machine for Garri Production

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AbstractA motorized cassava mash sieving machine comprising of a 3HP electric motor, pulverization unit, sieving unit, collection unit and fiber outlet was designed and developed. This machine breaks and sieves dewatered cassava mash and also make way for the fiber to leave the system through the fiber outlet thereby reducing drudgery and eliminating time wastage during the process. This machine also eliminated human contact with the cassava during the process unlike the existing semi-mechanized and traditional sieving method. Performance test analysis revealed that the developed machine after four experimental runs with different feed rate was 93.37% and sieves an average of 4.75kg of cassava at 99 seconds with an average throughput of 174.46kg/hr. at 25% moisture content, compared with a manual/traditional process, were an individual breaks and sieves same at 469.5 seconds at an average efficiency of 85.95% having a throughput of 38.42kg/hr. Thus, this innovation saves energy and time and also improves hygiene in cassava mash sieving for garri production.

Keywordscassava, dewatered *cassava mash, drudgery,* sieving, garri production

1. Introduction

In the past, maize was Africa's most important food crop, however, maize production in Africa is risky due to unpredictable rainfall, and it is not financially feasible to depend on irrigation. For this reason and perceived others, cassava (ManihotEsculeta, Crantz) became the most important food crop in Africa [1]. Cassava as a food crop could play a vital role in the food security of the world because of its capacity to yield under marginal soil conditions and its tolerance to drought. It can be processed into garri, lafun, tapioca kokote, fufu and ackhe.

Processing operations involves: harvesting of the tubers, peeling of outer chamber, washing, grating, fermentation (depending on the purpose of the cassava), dewatering, sieving (sifting), garifying, cooling and storage. When all these process has been achieved, the complete garri is now ready for consumption. Though these processes are difficult and consumes lots of time before the final or end product is achieved, starting from the peeling process which is done manually and exposes one to the risk of the knife coming in contact with the hand, then dewatering of cassava mash is a difficult operation which is also carried out manually which involves tying and twisting the neck of a Hessian sack over which heavy stone are placed for one or two days, pressing out the moisture content with manually operated hydraulic jack and this occurs after the grating operation, The duration of this fermentation affect the color, taste and texture of the garri. After fermentation is complete, the mash is pressed to reduce the water content and the cyanide acids, then down to the sifting process which also consumes time when done manually and also exposes the individual involve to dangers of waist pain, back pain and loss of finger nails and also drudgery.

Dewatered cassava mash consists of particles bonded into a lump during dewatering. The processing of cassava mash into garri requires that this lump of cassava mash be broken and crushed over before a sieving or screening. This process is necessary to separate fine particles of cassava mash required for the garification process from the unwanted coarse particles resulting from inefficient grating operation.

According to Peter, et al [2] sifting of cassava mash is one of the major problems of garri processing over the years, demanding urgent solution. In 1980, cassava production was relatively steady with highest production of 33million tons till early 90's when the production rose to about 87million tons. Sifting involves the separation of the coarse particles i.e. ungrated portion of cassava lumps from the fine and smoother ones [3]. After the moisture content of the mash or pulp has been reduced to about 35 to 40% in the process of dewatering, it is then sieved. To determine the moisture content, a small lump of the pulp is taken and squeezed between the palm, if it is sufficiently dewatered, it will disintegrate i.e. break into smaller particles easily. Put the dry pulp into a sieve and sift it to remove the unwanted thrash. Sieving operation in Nigeria is done mainly with the traditional method by peasant farmers [1]. An improve process of making garri is describe by Nessrs Levis and in Research Report No. 2, Federal Institute of Industrial Research, 1985. However it was felt that a number of technical and mechanical improvements could be adopted which would make garri processing more efficient and save considerably factory space requirement. The processes include peeling, grating, pressing/fermenting, granulating/separating and frying. Pulverization of pressed mash and sieving of dewatered mash or lumps is necessary to achieve efficient heat transfer during frying process [4]. Ife Research Group (1998) reported that in Osun and Ondo state, manual sieving method still dominate (84.5%) and (15.4%) processors used the machine and of these, 66.7% utilize the grater, while the remaining 33.3% used the mechanical shaker. They also reported that the mechanical shaker is unreliable while some processors sieve after using the grater, this is because the grater does not remove the fiber but only achieves further size reduction [4].

Different tools and machines has been designed to improve its yield and reduce more stress from human. Yet in most rural areas we still find some act of drudgery because of non-availability of these machines. In any of the processes of garri production especially the manual sifting, the risks are numerous such that the person is prone to losing its finger nails which can actually lead to injury on palm when rubbed on the metallic sift thereby contaminating the garri with blood, which also can be infectious. The individual involved is also prone to back pain, waist pain and sometimes headache, he/she is also at risks of inhaling the poisonous gas (cyanide) that evolve during the process. Time loss during this process is the most important factor to check. Therefore it very necessary to design and fabricate this machine using our locally sourced materials so as to reduce cost and make it available to an average farmer living in the rural area and also improve the quality and quantity of its product, especially now that agriculture and mechanization for food security and economy stability is important.

This project is therefore aimed at Development of a motorized cassava mash sieving machine that will brake dewatered cassava mash lumps, sieve or separate the mash of cassava from the fibers.

2. Materials and Method

The materials used for the fabrication of the cassava mash sieving machine include: mild steel angle iron, mild steel plate, mild steel shaft, stainless steel plates for resistance for corrosion and strength, bolts and nuts, bearings, V-belts, single phase electric motor, cast iron pulleys. While, the materials and equipment used for the performance evaluation of the developed garri sifting machine are dewatered cassava mesh, weighing balance and a stop watch.

2.1. Description of the machine

The developed cassava mash sieving machine having a dimensions of 1300cm by 900cm by 500cm consisting of three chambers, the cake breaking chamber (pulverization), the sieving chamber, the collecting chamber

The frame is the main supporting structure upon which every other component of this cassava mash sieving machine is mounted. It is a welded section constructed from 50mm×50mm×3mm mild steel angle Iron. At the top of the frame sits the feed hopper which is a conical frustum constructed from 2mm thick mild steel sheet with dimensions 470mm and height of 470mm and tapers to form a square aperture of 200mm for easy flow into the pulverization chamber. The pulverization chamber sits on the frame also, but below the hopper unit.

The pulverization chamber consists of a 25mm diameter mild steel shaft of length 640mm, with a 135mm cast iron diameter pulley, pulverization chamber membrane of 500mm in length made of 240mm diameter stainless steel cylinder perforated at about 15 to 20mm and twenty pieces of 30 mm width mild steel rods (beaters) with a length of 100mm each. The beaters were welded vertically to the membrane in a random spacing from one another.

The rotary motion of beaters breaks the compacted lumps and forces it down to the sifting chamber through the perforated holes.

The pulverization unit, consist of a half cylindrical sift made of stainless steel material and a mild steel shaft of 25mm diameter and 990mm length and 280mm cast iron pulley diameter, the sifting membrane of 850mm in length, thirty pieces of 30mm width mild steel rod with length of 130mm each welded vertically on the shaft in a random spacing from one another. The perforated size of the sift is less than 3mm to allow the fine particle of the cassava into the collection chamber as the shaft rotates. The fiber outlet is also located at this chamber.

The collection unit, is positioned below the sieving chamber/tray, this is where the finest cassava ready for frying falls. This chamber is made of aluminum sheet material. This chamber can alsostore sieved cassava until it is ready for usage.

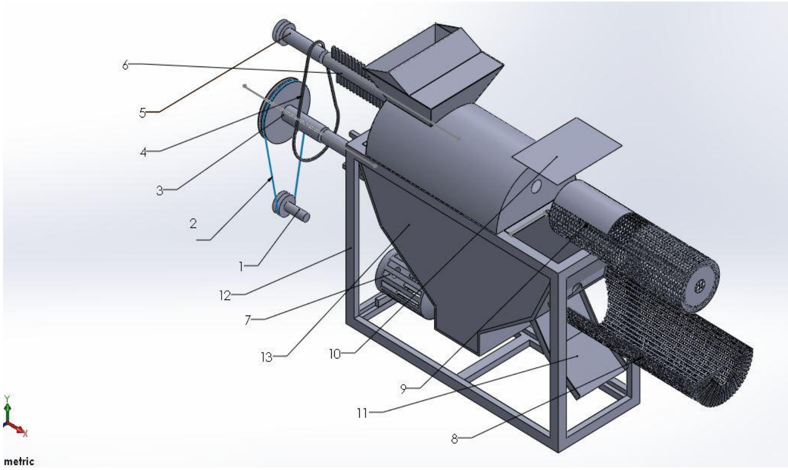
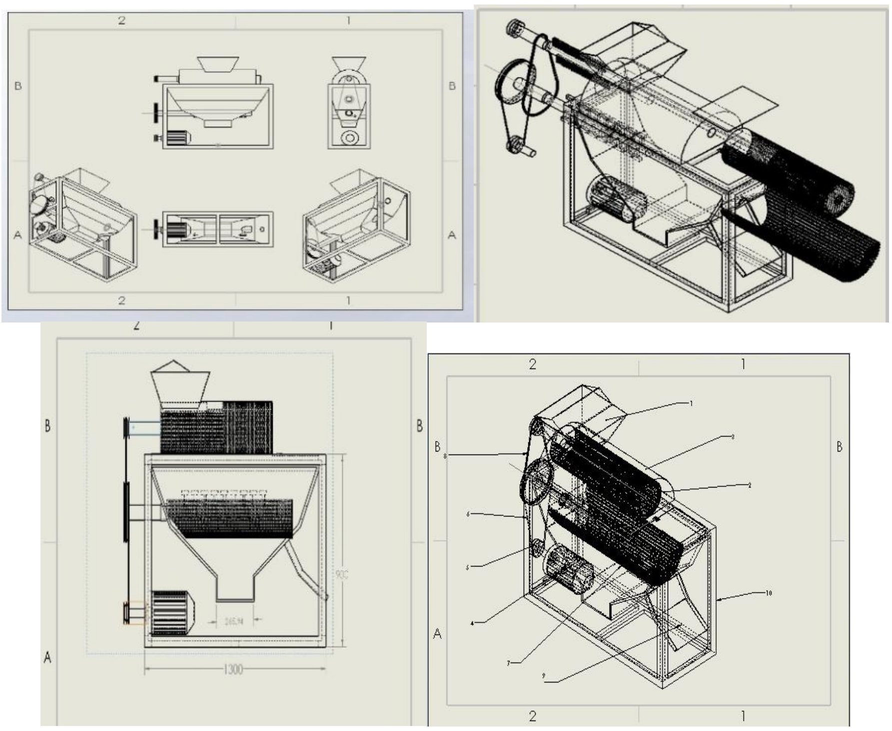


Figure 1: Exploded view of cassava mash sieving

1. electric motor shaft, 2. v-belt, 3. sifting shaft, 4.v belt, 5. pulverization shaft, 6. Beaters, 7. electric motor, 8. sieve(sifting chamber), 9.sieve(pulverization chamber), 10. top cover, 11. Outlet, 12. Frame, 13. body



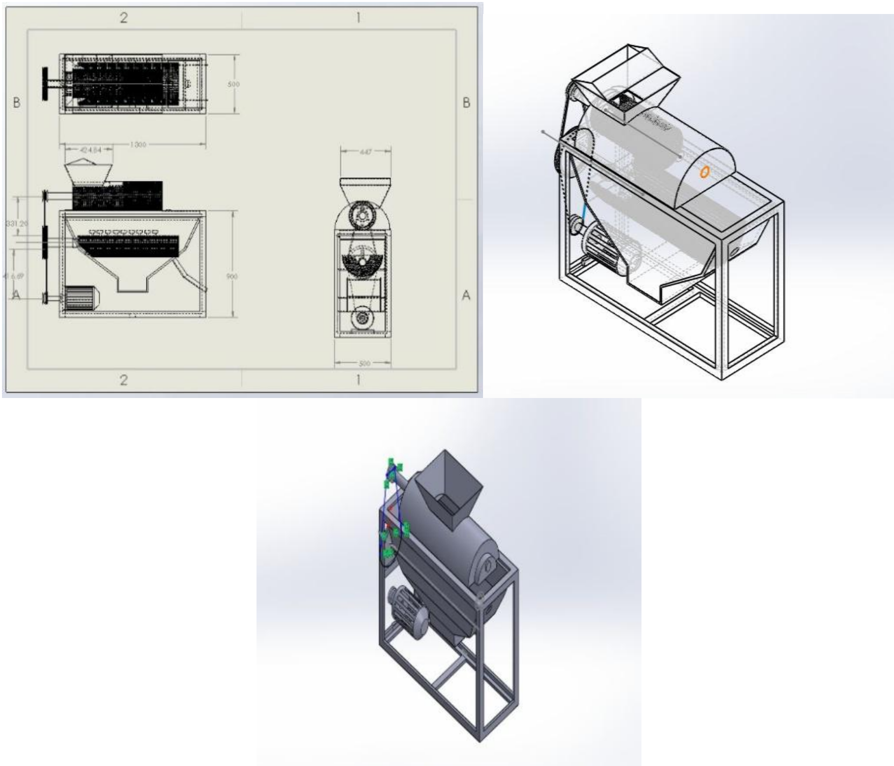


Figure 2: Isometric views of cassava mash sieving machine

3. Design Analysis

3.1 Weight capacity of the pulverization unit

The effective weight capacity of this system at the pulverization chamber depends on the volume of the cylinder and that of the shaft with the beaters attached on it. Length and diameter of the cylinder are 0.5m and 0.24m respectively.

Therefore the effective weight capacity of chamber was determined using this equation.

$W = g \times \rho_{dw} \times V_{PC}$ (1)

Where ρ_{dw} = density of the dewatered cassava which is given as $563kg/m^3$ (Stephen tambara 2015)

$V_{PC} = 0.75[(\pi r^2 l - \pi {r_s}^2 l_s + n_b w_b t_b l_b)]$ (2)

Where n_b = total number of beaters.

w_b = Width of beaters.

t_b =Thickness of the beaters while l_b = length of the beaters.

Therefore the effective weight capacity of chamber was determined as 369.4N using this equation.

$W = g \times \rho_{dw} \times V_{PC}$ (3)

g = acceleration due to gravity. = $9.81m/s^2$

3.11 Weight capacity of the sifting barrel.

The effective weight capacity of this system at the sifting chamber depends on the volume of the cylinder, considering the fact that it is a half cylinder and that of the shaft with the beaters attached on it alongside with the paddles.

Therefore the effective weight capacity of chamber was determined using this equation

$W = g \times \rho_{dw} \times V_{SC}$ (4)

Where ρ_{dw} = density of the dewatered cassava mash which is given as $563kg/m^3$ (Stephen tambara 2015)

Therefore considering 20% headspace, the maximum allowable fill volume V_{SC} was determined as $0.0598m^3$ using the equation

Therefore the effective weight capacity of chamber was determined as 330.6N using this equation. g = acceleration due to gravity. = $9.81m/s^2$

3.12 Selection ofThe Feed Hopper

Due to the properties of dewatered cassava mash a mass-flow pattern hopper of pyramidal shape that has an angle of inclination of 30^o (about 10^ohigher than the angle of repose of cassava on steel) was selected as the feed hopper through which the dewatered cassava goes into the system.

3.13 Selection ofThe Pulley And Belt For This Machine

The speed selected for the design of the sieving unit was assumed to be 650rpm, Since the rated speed of the electric motor is 1440 rpm and a 125 mm diameter pulley is fixed to the electric motor shaft, equation 6 [5-7]$VR = \frac{N_1}{N_2} = \frac{D_2}{D_1}$ (4)

Where;

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4c} \quad (5)$$

3.14 Determination of shafts diameter

The shafts were designed for appropriate load and torque, which is being transmitted, and therefore have ample strength and rigidity. Considering availability, a mild steel shaft was used for the fabrication, the shaft diameters, d of the pulverization shaft and sifting shaft of this machine were determined using the equation (6) below

$$d = \left[\frac{16}{\pi\tau}\sqrt{(k_b m_b)^2 + (k_t m_t)^2}\right]^{1/3} \quad (6)$$

Where τ = 42 N/mm^2. The maximum twisting moment acting on the shaft.

M_t = Maximum Twisting Moment on the shafts, N-mm.

M_b = Maximum Bending Moment on the shafts, N-mm.

K_b = Combined shock and fatigue factor for bending.

The allowable shear stress for steel shaft with provision for keyway, τ is given as 42N/mm^2[6] while the respective maximum twisting moment on the sieving shaft, m_t can be determined using this equation

$$M_t = (T_1 - T_2)\frac{D_2}{2} \quad (7)$$

$$T_1 = T_{max} - T_c \quad (8a)$$

T_{max} = Maximum tension and is given as$T_{max} = \sigma a$ (8b)

Where σ = maximum safe stress

Where a, m are Cross sectional area of the belt and mass of belt material per unit length can be obtain from the table (IS 2494:1974) [8]

T_c = Centrifugal tension of the belt and as $T_c = mv^2$

v =Linear velocity of the belt in m/s and is given by the equation below.

$$V = \frac{\pi ND}{60 \times 1000} \quad (9)$$

N= speed of the shaft in rpm

D= Diameter of the pulley.

T_2 = Tension on the slack side of the belt. And can be determined using the equation

$$2.3 log\frac{T_1}{T_2} = \mu\theta \operatorname{cosec}\beta [8] \quad (10)$$

μ = Coefficient of friction between the belt and pulley and is obtained from the table.

$$\theta = 180 - [2\sin^{-1}(\frac{D_2 - D_1}{2C})] \quad (11)$$

The bending moment on the pulverization shaft was determined using fig 3.1

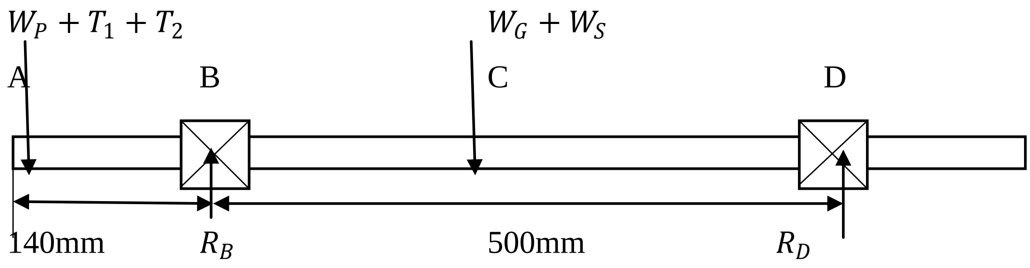


Figure 3.1: bending moment on the pulverization shaft

Thus the maximum bending moment on the pulverization chamber shaft is 32435Nmn. The maximum twisting moment of the shaft is 16147.6Nmm from equation (7). Since the feeding of the dewatered cassava is gradual and steady, K_b = 1.5, K_t = 1.0 [8] the shaft diameter was determined using equation (6) as 23.03mm. Therefore a standard 25mm diameter solid mild steel shaft was selected for the pulverization chamber.

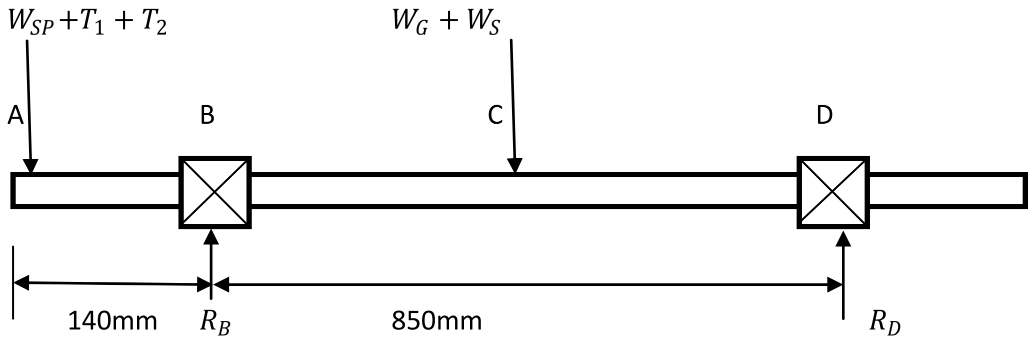


Figure 3.2: Bending moment on shifting shaft

Thus the maximum bending moment on the pulverization chamber shaft is 66491.25Nmn. The maximum twisting moment of the shaft is 8271.45Nmm from equation (7). Since the feeding of the dewatered cassava is gradual and steady, K_b = 1.5, K_t = 1.0 (Khurmi and Gupta 2013) the shaft diameter was determined using equation (6) as 23.62mm thus 25mm diameter solid mild steel shaft was selected for the sifting chamber.

3.15 Selection of the Prime Mover

The power required for the operation of this machine is the total sum of the power required to drive its unit and the power to overcome the drive's friction. Therefore the power P_{pc} for the pulverization and P_{sc} the sifting chamber was calculated as 0.961kw and 0.905kw respectively using this equation below;

$P_{sc} = (T_1 - T_2)V$[8] (12a)

P_{sc} = Power transmitted by the electric motor to belt at the sieving chamber.

$P_{pc} = (T_3 - T_4)V$ (12b)

P_{pc} = Power transmitted to the belt at the pulverization chamber.

Therefore the total power was determined as 1.866kw from the equation below.

$P_T = P_{sc} + P_{Pc}$ (13)

Taking the load factor, η_m,of the motor as 0.80, the power rating of the electric motor required for the operation of the cassava sifting machine was determined as 2.33kW (3.12HP) from the relation in equation (14)[9].

$P_m = \frac{P_T}{\eta_m}$ (14)

Therefore a 3HP single phase electric motor was selected for the operation of the cassava mash sieving machine.

4. Results and Discussion

The results of the experimental investigation of the developed motorized cassava mash sieving machine with respect to each experimental procedure described in the previous section are presented table 4.0 and table 4.1 below.

Performance test analysis revealed that the efficiency of the developed machine after four experimental runs at different feed rate was 93.37% and sieves an average of 4.75kg of cassava at 99 seconds with an average throughput of 174.46kg/hr. at 25% moisture content, when compared with a manual/traditional process, were an individual breaks and sieves same at 469.5 seconds at an average efficiency of 85.95% having a throughput of 38.42kg/hr. Thus, this innovation saves energy and time and also improves hygiene in cassava mash sieving for garri production. The motorized cassava mash sieving machine will improved proper sieving as well as revenue generation in the sector. It also reduced drudgery and eliminates time wastage and excessive loss of cassava to chaffs. Adoption of this innovation will boost efficient production and recovery of quality sieved cassava mash for garri production in Nigeria and other part of the world where cassava are cultivated.

Table 4.0: Performance Analysis of the cassava mash sieving Machine for speed of 650rpm

For 25% moisture content.

Feed rate M_O (kg)	**Mass of the sieved cassava. M_S (kg)**	**Mass of sieved chaff. M_C (kg)**	**Throughput capacity TC (kg/hr)**	**Output capacity OC (kg/hr)**	**Time (s)**	**Efficiency η_s**
2	1.82	0.086	181.81	165.45	40	91%
4	3.78	0.12	173.91	164.34	85	94.5%
6	5.67	0.12	171.42	162.00	126	94.5%
7	6.55	0.16	170.73	159.57	148	93.5
4.75	4.45	0.121	174.46 kg/hr	162.88kg/hr	99.7 (s)	93.37%

Table 4.1: Performance Analysis of the cassava manually sieved

Feed rate M_O (kg)	**Mass of the sieved cassava. M_S (kg)**	**Mass of sieved chaff. M_C (kg)**	**Throughput capacity TC (kg/hr)**	**Output capacity OC (kg/hr)**	**Time (s)**	**Efficiency η_s**
2	1.66	0.20	42.55	35.31	170	83%
4	3.54	0.39	39.60	35.04	367	88.5%
6	5.24	0.55	38.21	33.37	567	87.3%
7	5.95	0.66	33.33	28.33	757	85%
4.75	4.09	0.45	38.42kg/hr	33.01kg/hr	469.5	85.95%

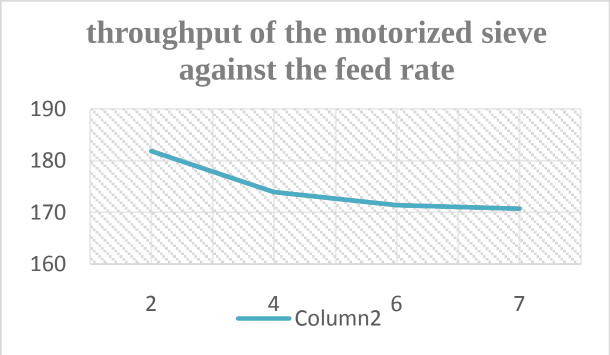


Figure 3: Graph of throughput of the motorized sieve against the feed rate

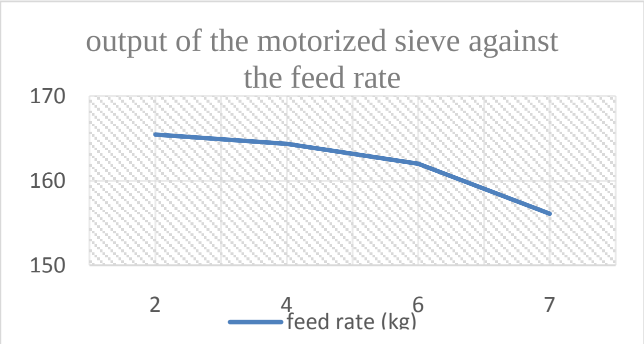


Figure 4: graph of output of the motorized sieve against the feed rate

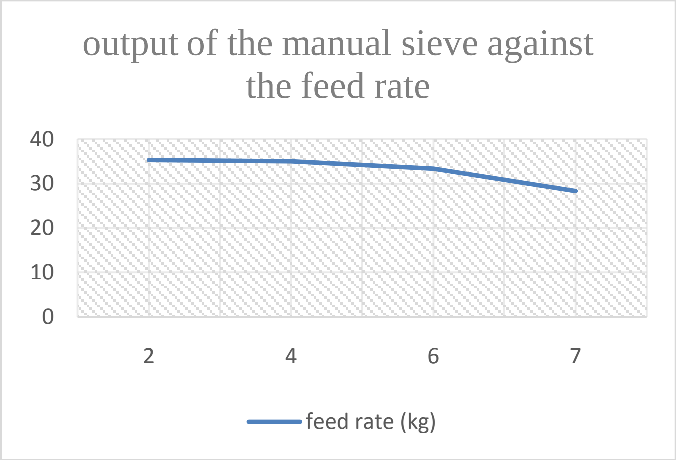


Figure 5: Graph of output of manual sieve against the feed rate

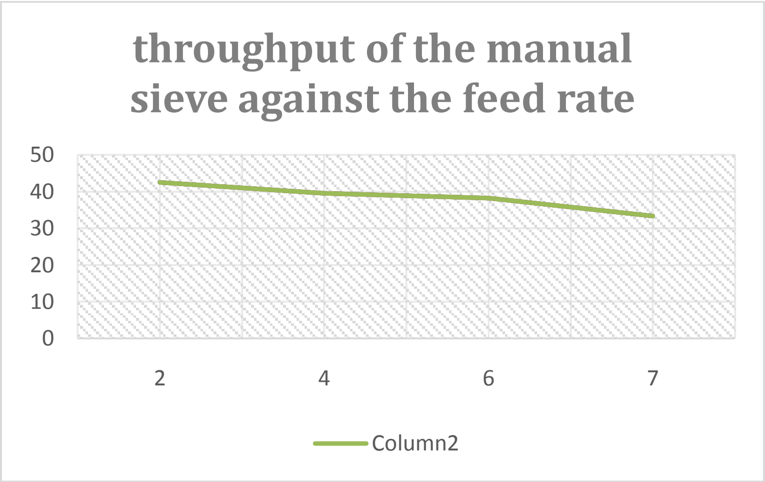


Figure 6: Graph of throughput of the manual sieve against the feed rate

5.1.Conclusion

A motorized cassava mash sieving machine used for the breaking and sieving operations for garri production was designed and developed using locally sourced standard materials at Michael Okpara University of Agriculture, Umudike. This machine performs with an average throughput capacity of 174.46kg/hr with an efficiency of 91.73% when tested randomly at different feed rate mass, and was compared with the manual sifting method which was performed randomly at different feed rate mass. The development of this machine improved the sieving quality and quantity of cassava mash flour for garri production and also eliminates drudgery, excessive loss of sieved cassava flour with the chaff and eliminates time wastage associated with the manual process. Thus, the innovation of the motorized cassava mash sieving machine is beneficial to the farmers especially now that the federal government is shifting from oil to agriculture and mechanization for food security and economy stability.

It is recommended that manufacturers should mass produce this machine to reduce cost of production through the benefit of bulk purchase of its production materials.

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