Performance Evaluation of Dewatered Cassava Mash Sieving Machine using Rotary Sweepers

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ABSTRACT

A dewatered cassava mash sieving machine with lump breaking device was designed using Computer Aided Design (CAD), and fabricated. The machine consists of a rotary sweeper with the sieve to sift the dewatered cassava mash poured into it through the hopper, and its powered by a 3.75 kW, 1450rpm electric motor. The machine was tested with ten samples of dewatered cassava mash of 5kg each and the result of the test analyzed statistically. The result shows that most dominant determinant of the efficiency of the machine is the moisture content of the cassava mash, which should be maintained at between 29.68% and 34.317%. For a cassava mash of average moisture content of 32%, the machine will have a sieving rate of about 0.21kg/s, sieving efficiency of 88.2% and attain a capacity of 0.7587ton/hr. The total cost of production of the machine is ₦250,000.00.

(Keywords: dewatered cassava mash, performance evaluation, sieving machine, sieving rate)

INTRODUCTION

Cassava, a woody shrub cultivated in Africa, particularly Nigeria, is scientifically called *Manihot esculenta*, and botanically called *Manihot utilissima* [1]. It is an edible starch tuberous root, hugely consumed in Nigeria because it is rich in carbohydrates, calcium, vitamins B and C, and essential minerals. Nigeria is the largest producer of cassava worldwide producing 54 Million tons in 2012 and the world's second largest consumer. Cassava tuber is the most perishable of roots and tubers and can deteriorate within two or three days after harvesting. It also contains cyanogenic glucocides which needs to be reduced to a level which is acceptable and safe for consumption [2].

Some cassava species can be eaten raw or cooked by human and some domestic ruminant animals. Cassava tubers can also be processed into alcoholic beverages, biofuel, animal feed, laundry starch, and used for medicinal purposes etc. It is locally processed to gari, fermented and unfermented flour, as well as a local delicacy called 'Fufu' for domestic consumption, lafun, abacha, etc., for human consumption. In 2004, the Nigerian government initiated a policy to produce bread with cassava: wheat flour ratio of 1:9 in Nigerian bakery industry [2, 3, 4].

Gari is the most popular staple food derived from cassava. It is a creamy-white granular flour with a slightly fermented flavor and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. It is widely known and consumed in Nigeria, either by being soaked in water with sugar, coconut, roasted groundnut, dry fish, cooked beans, moinmoin or as eba, a pasted/semi solid when poured into hot water and eaten with soup. Gari is rich in starch, has high fiber content, and contains protein and some essential minerals. When properly stored, gari has a shelf life of about six months. Processing of cassava to gari involves stages such as harvesting/sorting of cassava, peeling, washing, grating, fermentation, pressing or dewatering, sieving or sifting, frying, cooling (to room temperature), sieving, and packaging [5, 6, 7]. These processes are being mechanized ensure ease and speed of production, reduce stress during processing, eliminate contamination, and improve the hygienic condition of processing within short period of time [8].

Various researchers and machinery designers had, over the years come up with some mechanical devices or system for sieving cassava and its products, for example Adetunji et al. (2013) designed and fabricated an improved garri sifting machine using a single phase 1HP, 1400rpm electric motor. The machine though had sieving efficiency of 92.5% can only sieving garri and not cassava mash [4].

Odigboh, (1984) developed prototype of a machine, which can pulverize and sift garri mash. This machine is capable of handling 125 kg of garri mash per hour by producing more uniform garri mash than the one produced by manual method. However, the machine is only suitable for use in small and medium scale cassava processing industries and not for domestic use [9].

However, a sieving machine whose principle of operation is also slider – crank mechanism was designed and constructed by Ogunleye, (2003). The sieving efficiency of the machine was 78% while the sieving rate was 1 kg/ min. The peripheral speed of the v–belt of the machine was 1.178 m/s, which was too low for the v –belt drive. V–belts can only be used for peripheral speed between 5 m/s and 50 m/s [10].

Fayose (2008) developed a multipurpose wet sieving machine which extracts starch utilizing mechanism of shaking. The machine was developed to solve the problem associated with sieving of starch and other agricultural products in Nigeria. This machine is easy to operate and its maintenance is simple. The highest performance coefficient obtained was 98%. Therefore, it is recommended for use in small and medium scale industries [11].

Adegun, et al. (2011) also designed and fabricated a cassava processing units for producing stone-free gari with appreciable level of success [1]. A Pedal Driven Pulverizing and Sieving Machine for Dewatered Grated Cassava was designed by Olawale, et al. (2014), but without any record of fabrication and testing [3].

Olanipekun and Oluwadare (2016) carried out an improved Design, Construction and performance evaluation of 'Garri' Sieving Machine using the principle of slider-crank mechanism to set the sieve housing into motion. The machine which was powered by 1-horse power (0.745 kW) electric motor with angular speed of 900rpm and an average mesh size 2 mm by 4 mm resulted in a better sieving efficiency, and sieving rate when compared with the manual sieving method [12].

The resent work is to carry out the performance evaluation of a dewatered cassava mash sieving machine to determine the sieving rate, efficiency, and the capacity of the machine.

MATERIALS AND METHOD

A dewatered cassava mash sieving machine using rotary sweepers has been designed using Computer Aided Design (CAD), and fabricated. The machine consists of the hopper, the lump breaker unit mounted on a 6mm diameter and 886mm long stainless-steel shaft, frame, sieve, discharge outlet, driven by a v-belt powered by a 3.75 kW, 1450 rpm electric motor.

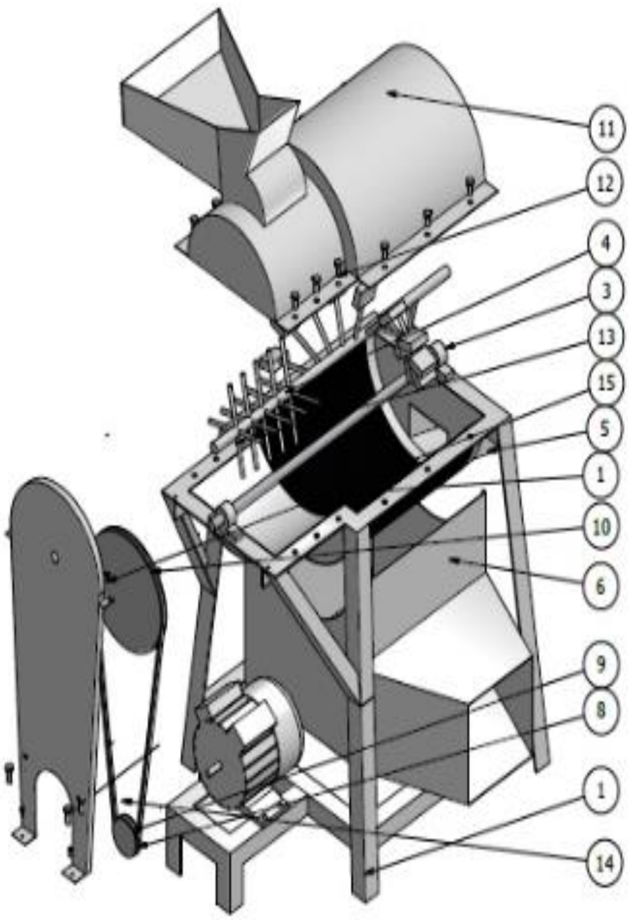
The frame is made of 50x50x2mm mild steel angle bar, while hopper is made of stainless steel of 3mm thickness. The sieve is made of stainless-steel square mesh, while the housing is made of stainless steel of 2.5mm thickness. The receiving tray or discharge outlet was made of stainless steel of 1.5mm thickness and aluminum 3mm thickness.

The machine was assembled as shown in Figures 1 and 2. A dewatered, unsieved, fermented cassava mash was sourced from a local gari processor within Ado Ekiti metropolis.

Performance Evaluation of the Machine

The machine was assembled as shown in Figure 1 and connected to source of electric supply, switched on and made to run at a speed of 1450rpm using a 3.75kW prime mover.

Fermented and dewatered cassava mash samples were introduced into the machine through the hopper. Ten samples of 5kg each with varied moisture content were used to aid the determination of the effects of moisture content on the sieving rate, sieving efficiency, and the capacity of the machine. The results are as tabulated in Table 1 while Figure 3 showed the plot of Sieving Efficiency (%) against Moisture content (%).



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	FRAME	
2	1	LUMP BREAKER BOTTOM	
3	1	BEARING	
4	1	SHAFT AND BREAKER	
5	1	SIEVE	
6	1	DISCHARGE OUTLET	
8	1	V-Belt	
9	1	Grooved Pulley1	
10	1	Grooved Pulley2	
11	1	UPPER CONCAVE	
12	16	ISO 4014 - M12 x 50	Hexagon head bolt - product grades A and B
13	13	ISO 4032 - M12	Hexagon nuts, style 1 - Product grades A and B
14	1	BELT GUARD	
15	4	ISO 4014 - M6 x 30	Hexagon head bolt - product grades A and B
16	1	Shaft	
17	1	ELECTRIC MOTOR	

Figure 1: Exploded Drawing of the Machine.

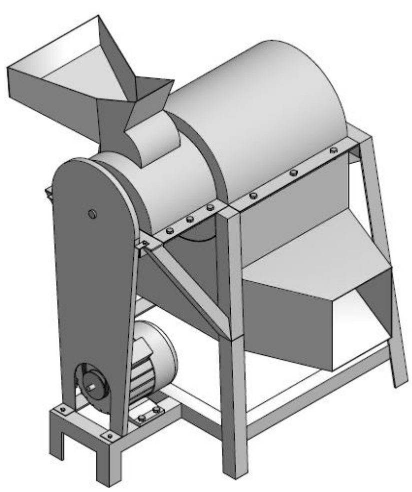


Figure 2: An Assembled Machine.

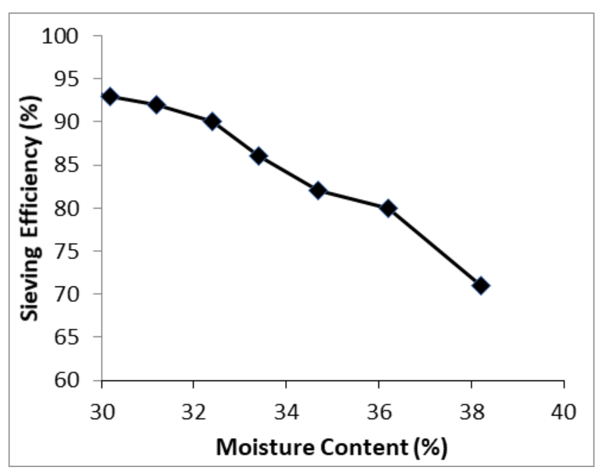


Figure 3: A Plot of Sieving Efficiency (%) against Mositure Content (%).

Table 1: Result of the Performance of the Machine on the Samples.

Samples	Mass of Sample before Sieving (Kg)	Moisture content of sample	Mass of Sample after Sieving (Kg)	Time taken to sieve (Secs)	Sieving Rate $(kg/secs)$	Sieving Efficiency (%)	Capacity of the Machine $(tonne/hr)$
1	5	38.2	3.55	30.0	0.1667	71	0.599
2	5	36.2	4.0	29.0	0.1724	80	0.620
3	5	34.7	4.1	28.59	0.1749	82	0.630
4	5	33.4	4.3	28.13	0.1777	86	0.640
5	5	32.4	4.5	27.66	0.1786	90	0.643
6	5	31.2	4.6	27.19	0.1839	92	0.662
7	5	30.2	4.65	24.15	0.2070	93	0.746
8	5	29.2	4.7	21.10	0.2370	94	0.850
9	5	27.8	4.8	18.05	0.2770	96	0.997
10	5	26.7	4.9	15.0	0.3333	98	1.200

$$Sieving\ rate = \frac{m_s}{t}\ \left({}^{kg}/_{secs}\right) \qquad \textbf{(1)}$$

$$\text{Sieving Efficiency} = \frac{m_s}{m_u} \times 100\% \qquad \textbf{(2)}$$

$$\text{Capacity of the machine} = \frac{1}{t_{hr}} \qquad \textbf{(3)}$$

$$t_{hr} = \frac{T_{1000kg}}{3600} = 0.83hr \qquad \textbf{(4)}$$

$$T_{1000kg} = \frac{1000}{Sieving\ rate} \qquad \textbf{(5)}$$

Where:

m_s = Mass of unsieved sample (kg) = 5kg
m_u = Mass of sieved sample (kg)
t = Time to sieve sample (secs)
t_{hr} = Time taken to sieve (hr)
T_{1000kg} = Time taken to sieve 1000kg of sample

The moisture content of the cassava mash greatly affected the time of sieving, the sieving rate, the efficiency, and hence the capacity of the machine. As shown in Figure 3, the sieving efficiency decreased with increase in the moisture content of the cassava mash samples.

Statistical Analysis of the Results

Statistical analysis involves the collection, and scrutinizing of a set of data in order to come to a conclusion on the implications and general overview of the data. Confidence Interval has been employed in the analysis of the data collected from the ten samples. The analyses are presented in Tables 2 to 5. In order to determine the confidence interval, the mean, $\bar{x}$, the standard deviation, σ, the standard error, and the margin of error are calculated through Eqs.6 - 9. The parameters of interest include the moisture content, sieving rate, sieving efficiency, and the capacity of the machine.

$$Mean, \bar{x} = \frac{\sum x_a}{n} \qquad \textbf{(6)}$$

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\sum(x_a - \bar{x})^2}{n}} \qquad \textbf{(7)}$$

$$Standard\ error = \frac{\sigma}{\sqrt{n}} \qquad \textbf{(8)}$$

$$\text{Confidence interval} = \bar{x} - t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}} \qquad \textbf{(9)}$$

Moisture Content

Table 2: Table showing Statistical Analysis of Moisture Content of Samples.

Samples	Moisture Content (%) x_a	$x_a - \bar{x}$	$(x_a - \bar{x})^2$
1	38.2	6.2	38.44
2	36.2	4.2	17.64
3	34.7	2.7	7.29
4	33.4	1.4	1.96
5	32.4	0.4	0.16
6	31.2	−0.8	0.64
7	30.2	−1.8	3.24
8	29.2	−2.8	7.84
9	27.8	−4.2	17.64
10	26.7	−5.3	28.09
	$\sum x_a = 320$		$\sum (x_a - \bar{x})^2 = 122.94$

$$\bar{x} = \frac{\sum x_a}{n} = \frac{320}{10} = 32\%$$

$$\sigma^2 = \frac{\sum (x_a - \bar{x})^2}{n} = \frac{122.94}{10} = 12.294$$

$$\sigma = \sqrt{12.294} = 3.506$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

The value of t is given as 2.09 from statistical table.

$$32 - 2.09 \frac{3.506}{\sqrt{10}} < \mu < 32 + 2.09 \frac{3.506}{\sqrt{10}}$$

$$32 - 2.3172 < \mu < 32 + 2.3172$$

$$29.683 < \mu < 34.317$$

Therefore the percentage moisture content of between 29.68% and 34.32% is recommended for the machine to achieve optimum performance of the machine.

Sieving Rate

Table 3: Table showing Statistical Analysis of Sieving Rate of the Machine.

Samples	Sieving rate (kg/s) x_r	$x_r - \bar{x}$	$(x_r - \bar{x})^2 10^{-3}$
1	0.1667	-0.04412	1.946
2	0.1724	-0.03842	1.47610
3	0.1749	-0.03592	1.29025
4	0.1777	-0.03312	1.09693
5	0.1786	-0.03222	1.03813
6	0.1839	-0.02692	0.7247
7	0.2070	-0.00382	0.0146
8	0.2370	0.02618	0.6854
9	0.2770	0.06618	4.380
10	0.333	0.12218	14.928
	$\sum x_r = 2.1082$		$\sum (x_r - \bar{x})^2 = 27.5807 \times 10^{-3}$

$$\bar{x} = \frac{\sum x_r}{n} = \frac{2.1082}{10} = 0.21082$$

$$\sigma^2 = \frac{\sum (x_a - \bar{x})^2}{n} = \frac{27.5807 \times 10^{-3}}{10} = 27.5807 \times 10^{-4}$$

$$\sigma = \sqrt{27.5807 \times 10^{-4}} = 0.05252$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

The value of t is given as 2.09 from statistical table.

$$0.21082 - 2.09 \frac{0.05252}{\sqrt{10}} < \mu < 0.21082 + 2.09 \frac{0.05252}{\sqrt{10}}$$

$$0.21082 - 0.034709 < \mu < 0.21082 + 0.034709$$

$$0.176 < \mu < 0.246$$

The recommended sieving rate for the machine is between 0.176$kg/secs$ and 0.246$kg/secs$. The machine should not be subjected to or made to work outside these limits.

Sieving Efficiency

Table 4: Table showing the Statistical Analysis of Sieving Efficiency of the Machine.

Samples	Sieving Efficiency (%) x_s	$x_s - \bar{x}$	$(x_s - \bar{x})^2$
1	71	-17.2	295.84
2	80	-8.2	67.24
3	82	-6.2	38.44
4	86	-2.2	4.84
5	90	1.8	3.24
6	92	3.8	14.44
7	93	4.8	23.04
8	94	5.8	33.64
9	96	7.8	60.84
10	98	9.8	96.04
	$\sum x_s = 882$		$\sum (x_s - \bar{x})^2 = 63.76$

$$\bar{x} = \frac{\sum x_s}{n} = \frac{882}{10} = 88.2$$

$$\sigma^2 = \frac{\sum (x_s - \bar{x})^2}{n} = \frac{637.6}{10} = 63.76$$

$$\sigma = \sqrt{63.76} = 7.985$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

The value of t is given as 2.09 from statistical table.

$$88.2 - 2.09 \frac{7.985}{\sqrt{10}} < \mu < 88.2 - 2.09 \frac{7.985}{\sqrt{10}}$$

$$88.2 - 5.277 < \mu < 88.2 - 5.277$$
$$82.92 < \mu < 93.48$$

If the recommended moisture content is adhered to, and the correct size of electric motor is used to run the machine, the expected efficiency of the machine is between 82.92% and 93.48%.

Capacity of the Machine

Table 5: Table showing the Statistical Analysis of the Capacity of the Machine.

Samples	Capacity of the machine $tonne/hr$ x_c	$x_c - \bar{x}$	$(x_c - \bar{x})^2 \times 10^{-3}$
1	0.599	-0.160	25.60
2	0.620	-0.139	19.32
3	0.630	-0.129	16.56
4	0.640	-0.119	14.20
5	0.643	-0.116	13.46
6	0.662	-0.097	9.41
7	0.746	-0.013	0.17
8	0.850	0.091	8.28
9	0.997	0.238	56.64
10	1.200	0.441	194.48
	$\sum x_c = 7.587$		$\sum (x_c - \bar{x})^2 = 358.12 \times 10^{-3}$

$$\bar{x} = \frac{\sum x_c}{n} = \frac{7.587}{10} = 0.7587$$

$$\sigma^2 = \frac{\sum (x_c - \bar{x})^2}{n} = \frac{358.12 \times 10^{-3}}{10} = 35.812 \times 10^{-3}$$

$$\sigma = \sqrt{35.812 \times 10^{-3}} = 0.1892$$

$$\bar{x} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}$$

The value of t is given as 2.09 from statistical table.

$$0.7587 - 2.09 \frac{0.1892}{\sqrt{10}} < \mu < 0.7587 - 2.09 \frac{0.1892}{\sqrt{10}}$$

$$0.7587 - 0.1250 < \mu < 0.7587 - 0.1250$$

$$0.6337 < \mu < 0.8837$$

The above value gives the range at which the machine is capable of producing per hour. From the value, it can be seen that the minimum amount of sieved cassava mash the machine can produced is 0.6337 ton/hr while the maximum amount of product is 0.8837 ton/hr.

CONCLUSION

This performance evaluation of a 3.75kW dewatered cassava mash sieving machine has been carried out. The machine was designed and fabricated using locally available material to reduce the cost of production. Stainless steel was used for the major parts of the machine in line with the globally accepted standard in the food processing industry.

The statistical analysis of the data from the performance evaluation was carried out to determine the confidence interval. The machine was found suitable for sieving fermented dewatered cassava mash of moisture content between 26.87% and 34.32% to achieve the sieving rate of between 0.176 kg/s and 0.246 kg/s, sieving efficiency of between 82.9% and 93.48%, and machine capacity of between 0.6337 ton/hr. and 0.8837 ton/hr.

Though the cost of production is relatively high at ₦250,000.00, the cost can be drastically reduced during mass production. The resuscitation of steel industry in Nigeria and the reduction in the exchange rate will no doubt cause a drastic reduction in cost of manufacturing in Nigeria. The machine is recommended for use by garri processors, small, medium scale enterprises in the rural areas. The noise level of the machine is within the acceptable limit and the operation of the machine poses no health or emotional hazards to the user.

ACKNOWLEDGEMENTS

The authors are grateful to Olarewaju Adebola Samuel, Olowookere Michael O., and Jenije Samson E.O. for their contributions in the testing of the machine, and to the authorities of the Olusegun Obasanjo Centre for Engineering Innovation, The Federal Polytechnic, Ado Ekiti, Nigeria for providing conducive environment for the work.

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SUGGESTED CITATION

Oladebeye, D.H., E.R. Adefidipe; and O. Awogbemi. 2020. "Performance Evaluation of Dewatered Cassava Mash Sieving Machine using Rotary Sweepers". *Pacific Journal of Science and Technology*. 21(2):95-102.

Pacific Journal of Science and Technology