International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 4 ǁ 2022 ǁ PP. 52-57

Development of an NCAM Motorized Reciprocating Dewatered Cassava Mash Sifter

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Abstract
A survey carried out on conventional or traditional method of sifting dewatered cassava mash showed that the method consumes time, energy, has low output and efficiency and is also hazardous to health due to low level of hygiene involved. A Motorized Reciprocating Dewatered Cassava Mash Sifter was developed at the National Centre for Agricultural Mechanization (NCAM), Ilorin Nigeria. The machine consists of three major chambers which are hopper, the sifting chambers and the collecting chambers. The machine's performance was evaluated at a dewatered cassava mash moisture content of 31.25%mc (WB) at three different operating speeds of 500, 700 and 900 rpm respectively using both pulverized and unpulverised dewatered cassava mash. The parameters considered where; sifting efficiency, mass recovery, output capacity and performance index, Results obtained during evaluation showed that the highest sifting efficiency obtained for the sifting machine was 90.00% at the speed of 2900rpm utilizing the pulverised Cassava mash, also having the highest output capacity and performance index were 98.37%, 286.66kg/hr and 87.10 respectively. The results from the evaluation indicated that the sifting operational speed and Dewatered Cassava Mash particle size played significant role on the sifting efficiency and output capacity, also concluded from the results was that the machine saved time and energy, reduced material wastage and hazards and therefore is more efficient than the conventional method. It is recommended that further evaluations should be carried out on the machine, using various moisture content of Dewatered Cassava Mash samples.

Keywords: *Development, Performance, sifting machine, conventional method, efficiency*

Date of Submission: 02-04-2022 Date of acceptance: 16-04-2022

I. INTRODUCTION

Cassava (Manihot esculenta) is a perennial woody shrub with an edible root, which grows in tropical and subtropical areas in the world. Cassava originated from tropical America and was first introduced into Africa in the Congo basin by the Portuguese around 1558. Today, it is a dietary staple in much of tropical Africa (IITA, 2009).

Garri is a cassava based product which is very popular in Nigeria and the west-African sub-region. Freshly harvested cassava tubers are peeled, washed, and grated. The grated cassava mash is then bagged and subjected to a dewatering process, after dewatering to suitable moisture content, the mash is then sifted to obtain uniform particle size of cassava mash before garifying.

Sifting involves the separation of the coarse particles portion of cassava lumps from the fine and smoother ones (NCRI, 2006). Traditionally, sifting operation is carried out using locally made sieves which are made of materials from raffia palm or plastic based threads. The sieve made from raffia palm is not as durable as the plastic based threads because the cyanide present in the cassava mash attacks the raffia causing degradation of the material. While, the sieve made from plastic based threads woven around a rectangular wooden frame is durable and the effect of the cyanide present in the mash on the material is negligible. It is also very easy to clean after the day's work.

The dewatered mash is rubbed against the sieve while a collecting pan (rubber bowl) is placed beneath the sieve to collect the sifted mash. The unsifted mash or waste material remains on the sieve. This method is very slow and requires a lot of man hours.The use of raffia sieve for pulverizing and sifting cassava cake during flour processing is unhygienic and hazardous (Sani *et al.,* 2008).

The raffia sieve on the other hand has a major drawback in the sieving position because it require bending and stretching which result in aches and pains in the back and sometimes may injure the person carrying out the sieving operation (Olufemi, 2003).Sifting is the most time consuming operation after cassava peeling in garri production, attempts to mechanize this production stage deserves careful study.

Jackson *et al.*, (2013), worked on a sifting machine, evaluating its efficiency while varying the speed.The highest sifting efficiency achieved was 86.5% at an operating speed of 650 rpm while the lowest efficiency achieved was at 75.5% while operating at a speed of 450 rpm. Increasing operating speed increases the sifting efficiency of the machine.

Alabi, (2009) also developed a motorized cassava lump breaker and sifting machine but recommended that an outlet provision should be made for unsifted materials, cover for the hopper, and also a cover should be made for the pulley and electric motor for the protection of the operator.

Kudabo *et al.*, (2012) developed and evaluated a cassava mash sifter Test results showed that the sifter has the highest efficiency of 93.3% at 26% moisture content at a sifting speed of 410rpm. Output Capacity of 136.2kg/hr was obtained and this increased as the Feed rate increases at 26% moisture content.

Sifting is the most tedious and most time consuming stage in garri production, attempts to optimally mechanize this processing stage needs to be careful study (NCAM, 2013), and hence the need to develop a Reciprocating Dewatered Cassava Mash Sifter and analyze the effects of the operating speeds and the Particles size of the mash on the evaluating parameters of the sifter.

II. MATERIALS AND METHODS

2.1. Description and Operation of the Reciprocating Dewatered Cassava Mash Sifter

The NCAM motorised reciprocating sifting machineis made up of the sifting component which comprises of the sifting screen, a wooden hopper and sifting frame. The power source, which is a 5.5hp, air-cooled gasoline engine, the power generated is transmitted to the sifting component by means of belt and pulley arrangement.

The main frame holds other components of the machine in a rigid position and a reciprocating mechanism, having an overall dimension of 1285.0mmx 750.0mm x 996.5mm.The sifting tray is a detachable component that is made up of a sifting screen attached to a rectangular wooden frame which serves as the hopper. The sifting tray is enclosed inside a sifting frame made from 50mm x50mm x50mm angle iron. This sifting frame has loaded springs attached to the front and the back of the frame and sits on ball bearings which enhance easy movement of the sieving frame. The machine has a delivery chute of 20cm wide through which the sifted mash is collected.

2.2. Design Considerations and Assumptions;

In the design of the NCAM Motorized Reciprocating Dewatered Cassava Mash Sifter, the following were taken into consideration:-

i. *Availability of materials*: low cost materials of adequate strength and durability were sourced locally and used for the fabrication of the machine.

ii. *Physical and mechanical properties*: relevant geometric mean diameter of some selected Cassava Mash was considered for the design of the machine.

iii. *Machine capacity*: Basic considerations were given to the design of the size, speed and capacity of the Reciprocating Dewatered Cassava Mash Sifter.

iv. *The Operational Factors:* High speed operational ranges were considered in order to achieve an efficient and effective process, which also made the machine easy to operate, while maintaining a high operational safety.

2.3. Design calculations

1. *Pulley design*

The diameter of the pulley of the shaft was calculated using the expression given by Khurmi and Gupta (2005) in equation (1)

$$N_1 D_1 = N_2 D_2 \quad (1)$$

Where, D_1 is diameter of bigger pulley (Driven Pulley) in (m), D_2 is diameter of smaller pulley (Driving Pulley) in (m),N_1 is the prime mover speed in (rpm) and N_2 is the machine operational speedin (rpm).

2. *Belt design*

The belt speed, v (m/s) and L, its total belt length, (m), were calculated using the expression given by Khurmi and Gupta (2005), respectively in the equations bellow.

$$V = \frac{\pi N D}{60} \quad (2)$$

$$L = \frac{\pi}{2}(D_1 + D_2) + 2C + \frac{(D_1 + D_2)^2}{4C} \quad (3)$$

$$C = \frac{D_1 + D_2}{2} + 0.05 \quad (4)$$

Where, D_1 is diameter of bigger pulley (Driven Pulley) in (m), D_2 is diameter of smaller pulley (Driving Pulley) in (m) and C is shaft to shaft centre in (m).

3. *Torque transmitted by the shaft*
The torque transmitted by the shaft was calculated using Khurmi and Gupta (2005), given equation (5).
T = F×r 5
Where F is the force developed in the shaft and r is the radius of stirrer/beater shaft.

4. *Power Requirement*
The power requirement for the Cassava Mash Sifter was determined using the expression given by Kurmi and Gupta (2005).
P=2ЛNT/60 6
Where P is the Power (Watt), N is the speed of shaft (rpm), T is the torque required to turn the shaft (Nm).
Hence the machine will involve shock load due to the Cassava Mash Sifter load, the factor of safety was selected to be 1.5.

5. *Tension in the V-belt*
The tension in the v-belt was deduced applying equation (7) according to Kurmi and Gupta (2005).
$T_1/T_2 = e^{\mu\theta}$ 7
Where T_1 is the tension on the tight side of the belt, T_2 isthe tension on the slack side of the belt, μ is the coefficient of friction and θ is the angle of wrap in radians.

6. *Shaft design*
The combine twisting moments and bending moments were used to determine the shaft diameter by applying the formula given by Khurmi and Gupta (2005)

$$T_e = ((K_B \times M)^2 + (K_T \times T)^2)^{0.5} = \pi \times S_S \times \frac{d^3}{16}$$ 8

Where,
T_e = equivalent twisting moment (Nm), M = resultant bending moment (Nm)
T = Torque transmitted by the gear shaft (Nm), Ss = Allowable Torsional stress with keyway = 40N/mm^2 as given by Khurmi and Gupta, (2005)
d = diameter of the shaft in mm
K_B= combined shock and fatigue factor applied to bending moment = 1.5 for minor shock
K_T= combined shock and fatigue factor applied to torsional moment =1.5 for minor shock

7. Design drawing. The orthographic, Isometric and Exploded viewof the developed Reciprocating Dewatered Cassava Mash Sifter was drawn using AUTO-CAD 2020 software version 23.1. The AUTO CAD drawings are shown in Figures 1-3.

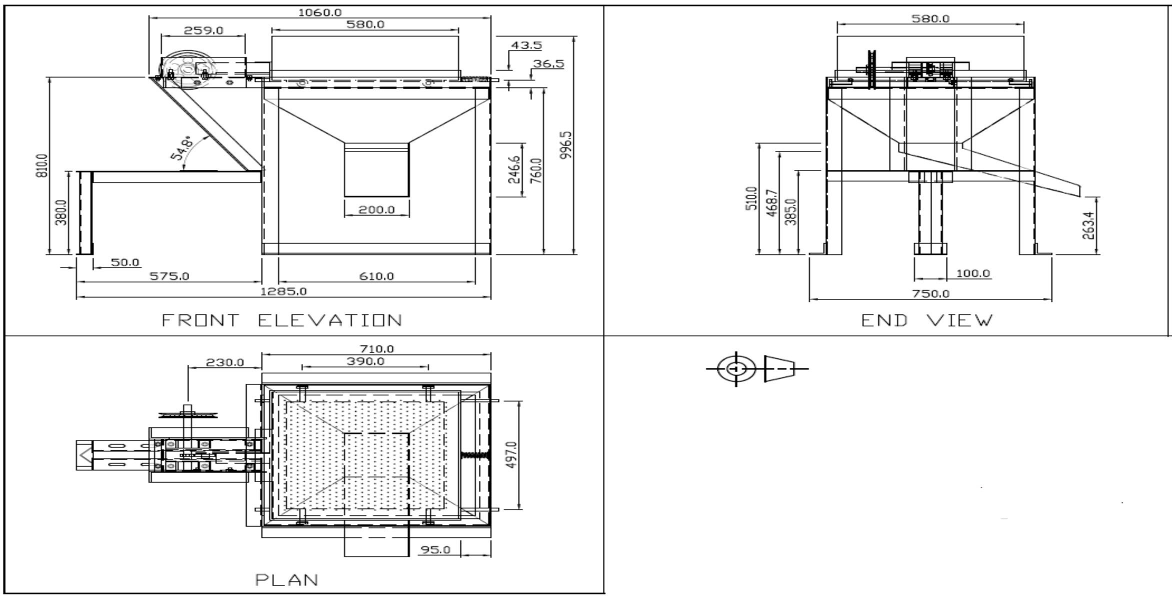


Fig. 1: Orthographic view of the Dewatered Cassava Mash Sifter

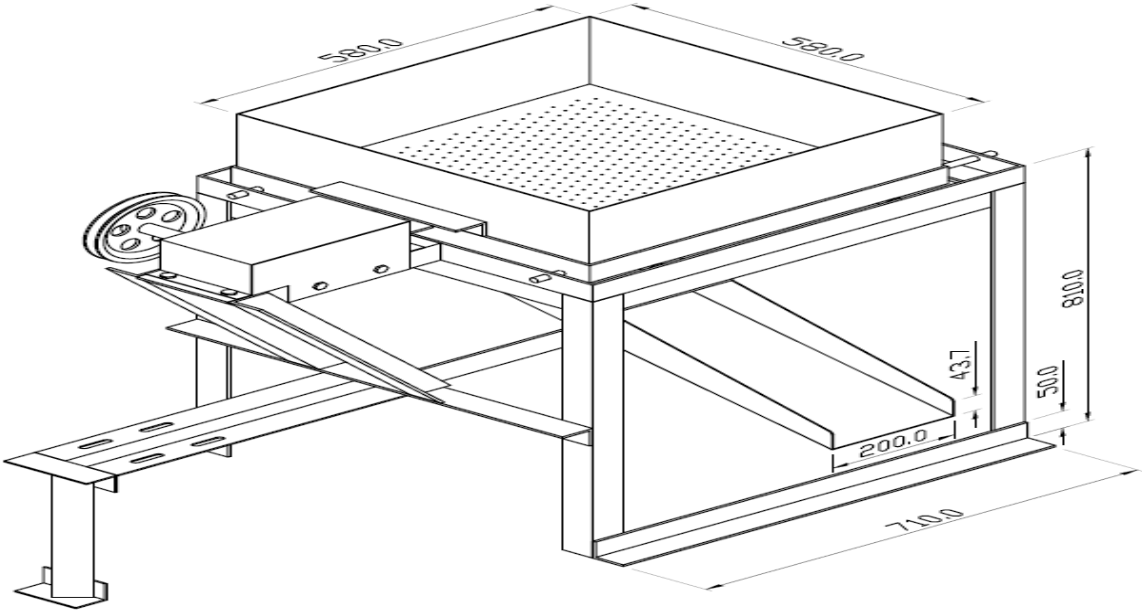
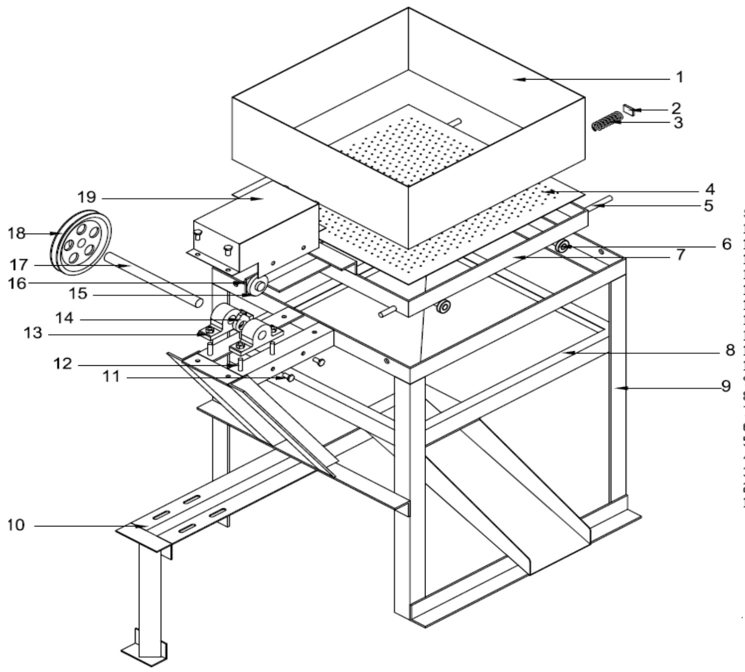


Fig.2: Isometric view of the Dewatered Cassava Mash Sifter



S/n	Description	Material
19	Guard	m.s sheet
18	Pulley	cast
17	cam shaft	m.s rod (Ø25mm)
16	Follower link	m.s angle bar
15	Follower	ball bearing (Ø60mm)
14	Cam	m.s plate
13	Pillow bearing	Ø25mm internal
12	Bearing bolt	M10 bolt
11	Guard bolt	M10 bolt
10	Engine seat	2" angle bar
9	Main frame	2" angle bar
8	Chute	galvanize sheet
7	Sifting frame	2" angle bar
6	Sifter bearing	ball bearing
5	Position stud	m.s rod
4	Sifting screen	stainless sheet
3	Return spring	
2	Spring support	m.s plate
1	Hopper	galvanize sheet

Fig.3: Exploded view of the Dewatered Cassava Mash Sifter

2.4. Performance Evaluation of the Dewatered Cassava Mash Sifter

2.4.1. Test Methodology

Cassava roots were harvested from NCAM farm, peeled (using NCAM cassava peeling machine), washed manually, grated (using NCAM cassava grater) and dewatered (using NCAM cassava dewatering press) to a moisture content of 31.25%mc (wb) as specified by Jackson *et al*., (2012) where all done at the NCAM processing shed and the Engineering Scientific Service (ESS) Department respectively . 2.0kg of dewatered mash were measured in two separate replicates and where run on the machine both in unpulverised and pulverised form respectively.

The NCAM motorised sifting machine was evaluated at various speeds using a 5.5hp air cooled petrol engine as the power source.

The weighed pulverized and unpulverised dewatered cassava mashes were fed into the sifting machine at various speeds of 500, 700 and 900rpm respectively.

The sifted mash at the outlet and the unsifted mash retained in the sieve after the sifting operation were also collected., weighed and recorded alongside the Time taken for the operational procedure was also noted.

2.4.2. Test Parameters

i. *Sifting Efficiency* (%): this determines how efficiently the sifting machine is carrying out the sifting of the dewatered cassava mash, according to (Keith, 2001), as expressed in equation (9).

$$S_e = \frac{w_3}{w_3 + w_4} x100 \qquad 9$$

Where w_4 = weight retained in the sieve and w_3 = weight of sifted mash

ii. *Sifted Mash Recovery* (%): this indicate the percentage of cassava mash that is been recovered after the sifting operation, according to (Keith, 2001), as expressed in equation (10).

$$S_r = \frac{w_3 + w_5}{w_1} x100 \qquad 10$$

Where w_3 = weight of sifted mash, w_5 = weight of unsifted mash and w_1 = weight at the mash outlet

iii. *Output Capacity* (Kg/hr): this determines the quantity of dewatered cassava mash that is discharged from the outlet per unit time, according to (Keith, 2001), as expressed in equation (11).

$$O_c = \frac{w_3}{t_1} \qquad 11$$

Where w_3 = weight of sifted mash and t_1 = time taken

iv. *Throughput capacity* (Kg/hr): this is the quantity of unsifted cassava mash fed into the sifting machine per unit time, according to (Keith, 2001), as expressed in equation (12).

$$I_c = \frac{w_1}{t_1} \qquad 12$$

Where w_1 = weight at the mash outlet, and t_1 = time taken

v. *Performance Index*: this indicates the general performance of the sifter in terms of sifting efficiency and sifted mash recovery percentage.

III. RESULTS AND DISCUSSION

Table 1 showed the performance of the sifting machine for unpulverised dewatered cassava mash. It was discovered that at operating speed of 500rpm the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, through put and performance index were 65.71 to 70.12%, 93.71 to 96.43%, 40.0 to 66.08kg/hr, 48.78 to 66.95kg/hr and 65.30 to 65.70 respectively, While also operating at 700rpm, the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, through put and performance index were 74.43 to 80.11%,95.43 to 96.73%, 53.45 to 73.33kg/hr,69.38 to 83.33kg/hr and 72.80 to 79.70 respectively.

At The highest operational speed of 900 rpm the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, through put and performance index were 83.24 to 88.28%, 97.13 to 97.77%, 71.62 to 79.54kg/hr, 86.51 to 90.90kg/hr and 81.00 to 86.20 respectively

The highest efficiency of 88.28% was attained at 900rpm on a 2.0kg Unpulverised cassava mash while the lowest efficiency was 65.71%, which was attained at 500rpm on a 2.0kg Unpulverised cassava mash. The sifted mash recovery, output capacity, throughput and performance index were highest at 900rpm with values of 97.77%,79.54kg/hr, 90.90kg/hr and 86.20 respectively, this is because as the operating speed increases the number of collisions between the mash particles increases which inhibits the formation of lumps and in turn aids the lumps in passing through the sifting screen.

Table 1: Performance Test using Unpulverised Dewatered Cassava Mash

S/N	Initial weight(kg)	Operating Speed (rpm)	Sifting Efficiency (%)	Sifted Mash Recovery (%)	Output Capacity (Kg/hr)	Throughput (Kg/hr)	Performance Index
1	2.00	500	70.12	93.71	40.00	48.78	65.70
2	2.00	500	65.71	96.43	66.08	66.95	65.30
3	2.00	700	80.11	95.43	53.45	69.38	79.70
4	2.00	700	74.43	96.73	73.33	83.33	72.80
5	2.00	900	83.24	97.13	71.62	86.51	81.00

6	2.00	900	88.28	97.77	79.54	90.90	86.20

Table 2 showed the performance results of the sifting machine for Pulverised dewatered cassava mash. It was observed that at operating speed of 500rpm the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, through put and performance index were 75.00 to 78.65%, 95.18 to 97.89%, 178.00 to 206.66kg/hr, 200.00 to 222.22kg/hr and 67.90 to 68.70 respectively. While operating at 700rpm, the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, throughput and performance index were 76.22 to79.78%, 96.73 to 98.37%, 200.00 to 225.00kg/hr, 233.33 to 285.71kg/hr and 72.90 to 74.40 respectively.

At The highest operational speed of 900rpm the evaluated parameters ranges of the sifting efficiency, mass recovery, output capacity, through put and performance index were 83.33 to 90.00%, 94.73 to 95.23%, 260.00 to 286.66kg/hr, 250.00 to 252.22kg/hr and 81.60 to 81.60 respectively.

The highest efficiency of 90.00% was attained at 900rpm on a 2.0kg Pulverised cassava mash while the lowest efficiency was 75.00%, which was attained at 500rpm on a 2.0kg Pulverised cassava mash. The sifted mash recovery, output capacity, throughput and performance index were highest at 900rpm with values of 98.37%, 286.66kg/hr, 285.71kg/hr and 87.10 respectively, this is due to the fact that the increased operating speed aided the lumps in passing through the sifting screen.

Table 2: Performance Test using Pulverised Dewatered Cassava Mash

S/N	Initial weight (kg)	Operating Speed(rpm)	Sifting Efficiency (%)	Sifted Mash Recovery (%)	Output Capacity (Kg/hr)	Throughput (Kg/hr)	Performance Index
1	2.00	500	75.00	97.89	206.66	222.22	68.70
2	2.00	500	78.65	95.18	178.00	200.00	67.90
3	2.00	700	76.22	96.73	225.00	233.33	74.40
4	2.00	700	79.78	98.37	200.00	285.71	72.90
5	2.00	900	83.33	95.23	286.66	250.00	81.60
6	2.00	900	90.00	94.73	260.00	252.22	87.10

IV. CONCLUSION AND RECOMMENDTIONS

4.1. Conclusion

The NCAM motorized Dewatered Cassava Mash sifter was developed and evaluated. The motorized Dewatered Cassava Mash sifter was developed using locally sourced materials with adequate strength and stability. A performance analysis was carried out on the sifter using three different speed levels for the sifting operation. Results obtained during evaluation showed that the highest sifting efficiency obtained for the machine was 90.00% at the speed of 900rpm utilizing the pulverised Cassava mash, also having the highest mass recovery, output capacity and performance index were 98.37%, 286.66kg/hr and 87.10 respectively. The results from the evaluation indicated that the sifting operational speed and Dewatered Cassava Mash particle size played significant role on the sifting efficiency and output capacity. This machine is safe and easy to operate and relatively cheap, and is capable of handling larger Dewatered Cassava Mash product in a continuous operation, thus, making it suitable for use by the small and medium scale processing industries in Nigeria.

4.2. Recommendation.

Further evaluations should be carried out on the machine using various moisture content with several Dewatered Cassava Mash samples, also further modification of the sifter is necessary in order to increase its Efficiency and output capacity.

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