Nigerian Journal of Technology (NIJOTECH)
Vol. 38, No. 2, April 2019, pp. **512 – 519**

Print ISSN: 0331-8443, Electronic ISSN: 2467-8821
www.nijotech.com
http://dx.doi.org/10.4314/njt.v38i2.30

EFFECTS OF SIEVE APERTURE MODIFICATION ON DEWATERED CASSAVA MASH SIEVING PROCESS

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ABSTRACT
Dewatered cassava mash (DCM) sieve aperture is fixed arbitrarily at 3mm by local craftsmen. This contributes to high energy and time consumption. This research focused on modifying this aperture experimentally and to assess its effect on sieving time, throughput capacity, and particle size dimension. Sieving was done with four replications using 2kg DCM across 3mm, 5mm and 7mm apertures. The result showed throughput capacity of 35kg/h, 59kg/h and 84kg/h respectively. The Anova, at 5% shows a significant difference among the means of the throughput capacity. Also, effective size D_{10} of garified sample, fineness modulus and average particle size of the sieves were close. The t_{cal} for the particles from 3mm compared to 5mm and 7mm sieve were 0.61 and 1.1 respectively whereas the t_{crital} was 2.15 showing that the particle sizes do not differ significantly. Sieve aperture can be modified to between 5mm to 7mm inclusive with good results.

Keywords: *Sieve, Aperture, Dewatered Cassava Mash, Throughput Capacity*

1. INTRODUCTION

Sieving operation is an important unit operation in garri processing. It is a size reduction and separation process in which the sieve is the active element. The sieve design in terms of mesh count and aperture has a feedback effect on the processors comfort or discomfort especially in traditional method of sieving and also on throughput capacity and machine efficiency in terms of mechanized sieve.

Sieving is done manually using sieves made from palm leaves, bamboo or raffia cane [1], it is a mechanical process which stratifies particles according to size [2]. A sieving media or surface is a sieving medium with predetermined openings used to classify two fractions of a feed material. It consists of forcing the mixture through a screen of a specific size aperture [3]. Mesh represents the sieve size of standard sieve. It is the holes number in 25.4mm which is the mesh count [4]. The larger the mesh size, the smaller the aperture [5]. By decreasing the space between holes, webbing or wire diameter, the open area may be increased, increasing capacity [6].

Ogunsina, *et al* [7] reported that over 92% of garri producers still use the traditional raffia sieve for pulverizing and sifting operation. On traditional sieving process, where the operator bends forward to apply a repetitive shearing and compressive force on the dewatered mash against the sieve, it might be true to say that the force exerted by the operator to sieve a given mass increases with a decrease in sieve aperture [2].

The mean sieve aperture currently developed by the local craftsmen for sieving dewatered cassava mash is 2.86mm [8]. The local processors who are accustomed to the use of this sieve aperture ignorantly believe that increasing the sieve aperture beyond the approximately 3mm aperture will make the garri grain extra coarse and hence unacceptable for consumption. The result is that the processors suffer great discomfort in an attempt to squeeze the DCM through

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the small aperture over a rather longer period of time in an awkward position.

Besides, the primary objective of the sieve as constructed by the local craftsmen is to trap the coarse ungrated particle during sifting of the dewatered lump. With this concept the fixing of sieve aperture, is a decision of the local craftsman who by his imagination and craftsmanship measure out the apertures with his eyes as he knit the individual strip of the raffia together. At the end, an irregular aperture is revealed throughout the sieve. There is no standardization of sieve aperture hence there may be variation depending on who and where it is obtained [8].

However, to reduce the drudgery inherent in traditional sieving process, a number of mechanized sieves have been developed. [9], designed and developed cassava lump breaking and sieving machine. [10], developed and evaluated motorized cassava mash sifter while [11], designed and fabricated an improved garri sifting machine. On the other hand, [12] designed a pedal driven pulverizing and sieving machine, and [13], developed NCAM reciprocating cassava mash sifter. These machines represent earnest efforts at reducing drudgery in cassava processing and enhance productivity. However these designs are silent on the sieve aperture or mesh used in developing them. This presents a challenge in terms of replacement, reproduction and sieve output capacity. This is true because, all other elements held constant, a change in sieve aperture or mesh might result in irregularity of discharged particle size and machine element malfunction.

Garri grain or particle size distribution is an important factor producers of garri give attention to during processing of cassava into garri. This is because the commercial value, appearance and suitability of garri for various purposes is tied in to this factor [14]. Since particle size distribution of garri which tells of the fineness or coarseness is a function of sieve aperture, analyzing the particle size distribution can provide insight as to the best sieve aperture to adopt [15].

This research therefore seeks to experimentally modify locally established sieve aperture as constructed by local developers (Fig.1) and to assess if there is statistically significant difference in the use of the locally fixed sieve aperture and the modified sieve with respect to sieving time, throughput capacity and Garri particle size distribution. In other words the researcher is working on the hypothesis that the particle sizes from the locally developed sieve and that from the modified sieve differ significantly.

Figure 1: Raffia sieve development by a local craftsman

It is believed that if processors are aware of the discomfort involved, energy and time wasted in the use of the traditional sieve, they may make a change in order to achieve higher productivity at a shortest possible time. This research also points out the need to give sieve aperture due consideration in the design of an improved manual or motorized sieve.

2. MATERIALS AND METHODS

2.1 Materials

The equipment used for developing the experimental sieves are:

a) A locally developed DCM sieve with 3mm sieve aperture
b) Galvanized metal sheet 1mm thick
c) Drilling machine
d) Drilling bits – 5mm, 7mm
e) Engineers square
f) Scriber
g) Centre punch

2.2 Development of research sieves

Each of the experimental sieves was constructed from 1mm galvanized metal sheet measuring 450mm x 350 mm. Engineers Square was used to square the plate and also guide in scribing horizontal and vertical lines to create inter hole spaces and the square space for drilling the hole. The centre punch was used to make the lines bolder. The drilling machine and bits were used to create round hole squared pitch drill pattern shown in Figure 2.

2.2.1 Determination of mesh number

The mesh number for each of the sieves was determined by selecting an in-between hole spacing that will give a larger open area. 1mm spacing was selected because it gave the least possible dimension to accommodate the drilling process while producing higher open area. The plates were marked, punched and drilled using round hole square pitch drill pattern shown in Fig 2.

2.2.2 Characteristics of experimental sieve

The two experimental sieves were made of round hole squared pitch drill pattern and was developed with the characteristics shown in Fig 2.

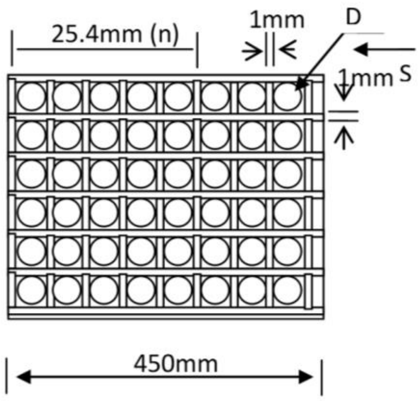

Fig 2: Round hole squared pitch drill pattern of the experimental sieve (D is the diameter of the experimental sieve aperture and S is the spacing between hole)

The mesh number n for experimental sieve was obtained from the formula given by [16]:

$$n = \frac{25.4}{(D + S)} \tag{1}$$

Here n is the mesh number; D is the Diameter (sieve aperture) and S is the spacing between aperture

Also, the percentage open area A_0 for the experimental sieve was obtained from the formula given by [17]:

$$A_0 = \frac{0.785d^2}{(s + d)^2} \times 100 \tag{2}$$

where: A_o = percentage open area, d = diameter (sieve aperture) and s = spacing between aperture

2.2.3 Characteristics of the locally developed sieve

The locally made sieve was of the woven wire mesh pattern and was developed with the characteristics shown in Fig 3.

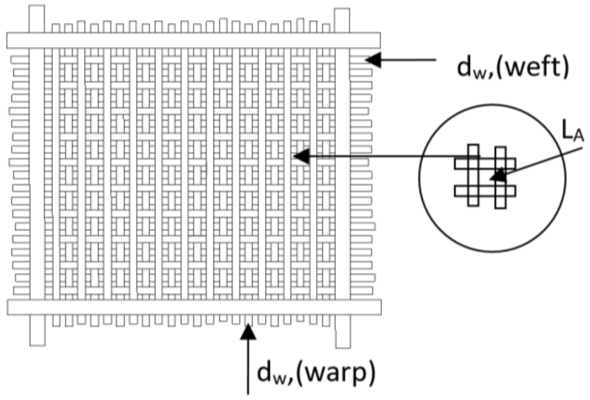

Fig 3: Woven wire mesh pattern of the locally developed sieve (L_A is the sieve aperture = 3mm; dw is the Horizontal width of raffia strip = 6mm)

Mesh number, M is defined by [16] as:

$$M = \frac{25.4}{(L_A + d_w)} \tag{3}$$

And Percentage open area, A_0 is given by [17] as:

$$A_o = \left(\frac{L_A}{L_A + d_w}\right)^2 \times 100 \tag{4}$$

2.3 Experimental design

Randomized complete block design (RCBD) was used for the experimentation. The experiment sought to determine the effect of modifying sieve aperture on sieving time, throughput capacity and particle size distribution. The dependent variable was the sieve size, while the independent variables were sieving time, throughput capacity and particle size distribution. Unit of treatment was 2 kg of DCM. This was used as a treatment for the different apertures of 3mm, 5mm and 7mm which were used in constructing the locally developed sieve and the experimental respectively. The sieve of 3mm aperture served as control sieve whereas sieves with 5mm, 7mm served as experimental sieves. The parameters measured were: sieving time, throughput capacity, and particle size distribution.

Table 1: Sieve aperture and sieving process replication in RCBD

Block1	Block 2	Block 3	Block 4
3mm	5mm	7mm	3mm
5mm	7mm	3mm	7mm
7mm	3mm	5mm	5mm

2.4 Experimental procedure

A processor was requested to use 2kg of DCM on each of the sieves and carry out sieving task manually in a normal and accustomed manner. The sieving process and replication followed the randomized complete block design shown in Table 1. The time to completely sieve the 2kg mash in each case was recorded and replicated 4 times for each of the sieves. The resultant throughput capacity with respect to time was calculated in each case:

$$T_{p\ 1\ldots n} = \frac{Q_{1\ldots n}}{t_1 \ldots n} \quad (5)$$

where: $T_{p\ 1\ldots n}$ is the throughput for the three different sieves; $Q_{1\ldots n}$ is the quantity sieved and and $t_{1\ \ldots\ n}$ = time to sieve the given quantity through the three sieves. To determine the grain size of the sieved particles and its acceptability, sieved samples from the controlled sieve and experimental sieves were subjected to garification. The particle size distribution of garified sample was analysed.

2.5 Analysis of Sieved Sample for Particle Size Distribution

Particle size distribution of the sieved DCM was obtained using IS 460 Sethi standard test sieve of diameters 1.70mm, 1mm, 0.85mm, 0.35mm, 0.30, 0.20 and pan. The test was carried out to determine particle size variation, fineness or coarseness of sieved particle with respect to control and experimental sieves of 3mm, 5mm and 7mm aperture respectively. The particles obtained from the control and experimental sieves were subjected to two tailed t-test to ascertain if the Garri particles obtained from the control and experimental sieves differ significantly in their sizes.

300g garified sample from each of the researched sieves was loaded on top the test sieve of six stack and pan. This was agitated for 10 minutes after which the weight retained in each of the sieves was recorded for each sample and replicated three times. From the weight retained measured with Pioneer plus analytical electronic balance Cp214, the cumulative weight, cumulative percentage, and fineness modulus were obtained. Also from the distribution curve, the effective sizes of Garri grain, coefficient of uniformity and gradation were obtained.

Percentage retained, r, on any sieve was given from the relation expressed by [15] as:

$$r = \frac{W_r}{W_t} \times 100\% \quad (6)$$

where W_r is the weight of gari retained and W_t is total weight of gari.

Uniformity coefficient c_u was calculated from the relation expressed by [7, 5]:

$$c_u = \frac{D_{60}}{D_{10}} \quad (7)$$

Where D_{60} is diameter corresponding to 60% finer in the particle size distribution curve.

On the other hand coefficient of gradation c_e was calculated from the relation expressed by [15]

$$c_e = \frac{D_{30}^2}{D_{10} \times D_{60}} \quad (8)$$

Where D_{30} is the diameter corresponding to 30% finer in the particle size distribution.

Average particle size D_p was calculated from the relation given by [18]:

$$D_p = 0.135(1.366)^{FM} \quad (9)$$

Where FM = Fineness Modulus

3. RESULTS AND DISCUSSION

Table 2 shows the effect of modifying sieve aperture on sieving time. The mean time in minutes required to sieve 2kg of DCM across the traditional sieve (control) and that of the modified sieve (experimental) are: 4.1, 2.6 and 1.5 respectively.

Table 2: Mean time required to sieve 2kg of DCM in research sieves

	Control sieve	Experimental sieve	
Sieve aperture	3mm	5mm	7mm
Time (2kg/min)	4.4	2.8	1.5
	4.4	2.6	1.5
	3.9	2.6	1.5
	3.7	2.5	1.3
Mean time (minute)	4.1	2.6	1.5

This shows that the traditional sieve consumes more time than the experimental sieves for the same quantity of DCM. This time consumption is also connected with the lower percentage open area which permits small quantity of the DCM to pass through the traditional sieve aperture. The results presented in the tables above actually shows the effect of modifying traditional sieve aperture and to what extent the aperture should be increased to.

Table 3 shows the effect of modifying sieve aperture on throughput capacity. From the table, observe that at 3mm, 5mm and 7mm sieve aperture, the throughput capacities are 39kg/hr, 59kg/hr and 84kg/hr.

From the Table 3, observe also that percentage open area of the locally made sieve is comparatively low whereas that of experimental is comparatively high.

This is attributed to the material development pattern. The low percentage open area noticed in the locally made sieve can be attributed to the material and development pattern of the sieve which was made by weaving rectangular strips of raffia material. The experimental sieve aperture was established by drilling a round hole with inter-hole spacing of 1mm. This comparatively small inter hole spacing results in a higher percentage open area and by extension a higher throughput capacity of 84kg per hour as oppose to the lower throughput capacity of 39kg/hr obtained by the use of the locally made sieve.

Increasing traditional sieve aperture from 3mm to 7mm gives a higher throughput capacity (39kg/hr to 84 kg/hr). However the 5mm sieve aperture is recommended though comparatively low in throughput capacity, its particle size proved to be closely related to that obtained using 3mm sieve and hence more acceptable than that from the 7mm sieve. This is in agreement with Ogunsina, *et al* [7] who obtained a throughput capacity of 55.46kg/hr, while sieving approximately 1kg of DCM with 3mm raffia sieve, but a throughput capacity of 227.71kg/hr while sieving an average of 1.6kg DCM with 5mm crank sieve at 67 rev/min. The difference in result is attributed to the fact that this research used 2kg and a motorized sieve at 100 revolutions per minute. Although, we use apertures of 3mm and 5mm respectively, the mesh count and percentage open area may not be the same. However the common ground is that the time of sieve using raffia sieve is high while the throughput is low. By increasing the aperture to 5mm the sieving time is reduced with a high throughput capacity.

3.1 Analysis of variance

Table 4 shows the result of sieving 2kg of DCM on three different sieve apertures replicated four times and the throughput capacity presented in ANOVA table. Table 5, shows the anova of throughput capacity and the result of comparing the control and experimental sieves at different sieve apertures. From table 5, the test statistic is the F value of 4.5. Using an α of 0.05, then $F_{.05,\,2,\,9} = 4.256$. But $F > 4.256$, hence there is a statistically significant difference among the population means of the throughput capacity.

3.2 Particle size distribution of garified sample

Table 6 to 8, shows the particle size distributions for the control and experimental sieves. Table 6 shows the percentage finer of a garified sample from standard test sieves. For the 3mm control sieve, this gives a fineness modulus of 3.37. Table 7 shows the percentage finer of a garified sample from standard test sieves. For the 5mm experimental sieve, this gives a fineness modulus of 3.72. Table 8 shows the percentage finer of a garified sample from standard test sieves. For the 7mm experimental sieve, this gives a fineness modulus of 3.90.

Table 3: Sieve characteristics and throughput capacity

	Diameter (mm)	Mesh number, n	Open area Ao (%)	Throughput capacity (kg/hr.)
Control sieve	3	3	11	39
Experimental sieve	5	4.2	55	59
	7	3.2	60	84

Table 4: Throughput capacity (Kg/hr) at different sieve apertures

Treatment Aperture/2kg	Replications				Total	Mean
	1	2	3	4		
La1(3*mm*)	32	33	37	39	141	35
La3(5*mm*)	54	55	64	62	235	59
La4(7*mm*)	84	87	80	85	336	84

Table 5: ANOVA of throughput capacity

Source of Variation	Sum of square(SS)	DF	Mean Square(MS)	F
Treatment	4,755	2	67.5	4.5
Error	135	9	15	
Total	4,890	11		

Table 6: Fineness modulus of 3mm aperture garrified sample

Sieve Size (mm)	Wt of garri retained(g)	cumu.wt. retained(g)	cumu (%) retained	%Finer
1.7	12.4	12.4	4.13	95.87
1.00	53.0	65.4	21.8	78.2
0.85	44.5	109.9	36.63	63.37
0.33	134.5	244.4	81.46	18.54
0.30	36.3	280.7	93.57	6.44
0.20	17	297.7	99.23	0.77
Pan	2.3	300	Total =	336.8
			FM =	3.37

Table 7: Fineness modulus of 5mm aperture garrified sample

Sieve Size (mm)	Wt of garri retained(g)	cumu.wt. retained(g)	cumu (%) retained	%Finer
1.7	45.4	45.4	15.13	84.87
1.00	58	103.4	34.46	65.54
0.85	36.2	139.6	46.53	53.47
0.33	110.2	249.2	83.26	16.74
0.30	35	284.8	94.93	5.07
0.20	14.2	299	99.66	0.34
Pan	1	300	Total =	372
			FM =	3.72

Table 8: Fineness modulus of 7mm aperture garrified sample

Sieve Size (mm)	Wt of garri retained(g)	Cumu.wt. retained(g)	Cumu (%) retained	%Finer
1.7	55.5	55.5	18.5	81.5
1.00	58.8	114.3	38.1	61.9
0.85	41.3	155.6	51.87	44.13
0.33	101.7	257.7	85.77	14.23
0.30	30.4	287.7	95.9	4.1
0.20	11.4	299.1	99.7	0.3
Pan	0.9	300	Total =	389.9
			FM =	3.90

Figure 4 show the particle size distribution curve of the garified samples from the three researched sieves under consideration, namely: 3mm, 5mm and 7mm. The percentage finer of the following distributions: 96.37, 78.20, 63.37, 18.54, 6.44 and 0.77 for 3mm sieve aperture, 84.87, 65.54, 53.47, 16.74, 5.07 and 0.34 for 5mm sieve aperture and 81.50, 61.90, 44.13, 14.23, 4.1 and 0.30 for 7mm, plotted against the particle sizes gave the characteristics of the garri particles shown in Table 9.

From Table 9, the effective particle size D_{10} of garified samples, the fineness modulus and average particle size from the 3mm, 5mm and 7mm sieve are 0.31, 0.33 and 0.34; 3.37, 3.72 and 3. 90; 0.39, 0.43, and 0.46 respectively. Observe that the effective sizes D_{10} for the three sieves are very close. It can also be observed that there is a progressive increase in fineness modulus (FM) from 3mm to 7mm sieve sizes but this does not translate to a large difference in their average particle size Dp.

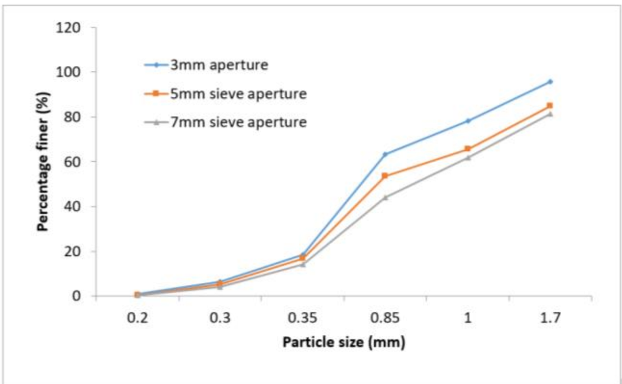

Figure 4: Particle size distribution of garified sample from different sieve aperture

Table 8: Characteristics of particle size distribution for garified samples

Sieve size	D_{10}	D_{30}	D_{60}	FM	Cu	Ce	D_p
3mm	0.31	0.47	0.79	3.37	2.55	0.90	0.39
5mm	0.33	0.54	0.94	3.72	2.85	0.94	0.43
7mm	0.34	0.62	0.99	3.90	2.91	1.14	0.46

For the three research sieve sizes, each have uniformity coefficient (Cu) less than four, and Coefficient of gradation (Ce) approximately 1 implying that they each contain uniformly graded particles although with 5mm and 7mm sieve having a slightly larger range of particle size.

3.3 Comparison of particles sizes

Table 10 shows the particle sizes of garified sample from the three research sieves derived from the particle size distribution curve. From Table 10, the mean particle sizes from the three research sieves 3mm, 5mm and 7mm are: 0.68, 0.79, and 0.88 with standard deviations of 0.31, 0.41 and 0.44 respectively. But do the particle sizes from each of these research sieves differ significantly? Table 10 shows the result of comparing the particle sizes from control sieve of 3mm and that of the experimental sieve of 5mm.

Table 10: Particle sizes from control and experimental sieves

Sample point	Control sieve	Experimental sieve	
	3mm	5mm	7mm
D10	0.31	0.33	0.34
D20	0.38	0.40	0.44
D30	0.47	0.54	0.64
D40	0.58	0.64	0.80
D50	0.68	0.80	0.90
D60	0.79	0.94	0.99
D70	0.94	1.18	1.30
D80	1.25	1.52	1.66
Mean (M)	0.68	0.79	0.88
SD	0.30	0.41	0.44

Table 11: Test of significance of particle sizes from sieve 3mm and sieve 5mm

Sieve type	N	M	SD	t-value
Control (3mm aperture)	8	0.68	0.31	0.61
Experimental (5mm)	8	0.79	0.41	

From the table, N is the sample size, M the mean of the sample and SD the standard deviation. Also from table 10, the calculated t- value of particle sizes from the control and that from the experimental sieve is 0.61. From t – table, the critical value at 5% level of significance and 14 degree of freedom is 2.15. Since the calculated t-value of 0.61 is far less than the critical value of 2.15, the hypothesis that the particle sizes from the control and the experimental sieve differ significantly is rejected. Thus the Garri particles from the control and that from the experimental sieve do not differ significantly in their sizes. Table 11 shows the result of comparing the particle sizes from control sieve of 3mm and that of the experimental sieve of 7mm.

Table 12: Test of significance of particle sizes from sieve 3mm and sieve 7mm

Sieve type	N	M	SD	t-value
Control (3mm aperture)	8	0.68	0.31	1.1
Experimental (5mm)	8	0.88	0.44	

From the table, the calculated t- value of particle size from the control and that from the experimental sieve is 1.1, whereas the critical value at 5% level of significance and 14 degree of freedom is 2.15. Since the calculated t-value of 1.1 is less than the critical value of 2.15, the hypothesis that Garri particles from the control and the experimental sieves differ significantly in their sizes is also rejected. Thus the Garri particles from 3mm sieve and that from the experimental 7mm sieve do not differ significantly in their sizes.

4. CONCLUSION

Through experiment, the locally established sieve aperture of approximately 3mm was modified to 5mm and 7mm with positive results. Throughput capacity at 5mm aperture was higher by 24kg/hr over the 3mm aperture. This was possible as the use of modified sieve at 5mm aperture reduced sieving time from

4.1min to 2.6min. The test statistics of F> 4.256 at $F_{0.5,\ 2,\ 9}$ shows that there is a statistical significant difference among the population means of the throughput capacities of the test sieves. The effective particle size D10, fineness modulus FM and Coefficient of gradation of the particles from the 3mm aperture differ slightly from that of 5mm but it does not translate to large difference. Considering that the calculated t- value of particle sizes from the control and that from the experimental sieves are 0.61 and 1.1 respectively for 5mm and 7mm sieve, whereas the critical value at 5% level of significance and 14 degree of freedom is 2.15, the observed difference with respect to the control sieve is not significant. This implies that the 5mm and 7mm sieves can be used to produce garri particles that do not differ significantly from that produced from the 3mm. Obviously, the notion held by the developer of traditional sieve and the processors who use them, that increasing the traditional sieve aperture beyond the approximately 3mm aperture will render the particle size extra coarse and unacceptable is unsubstantiated. Traditional sieve aperture can therefore be modified from 3mm to between 5mm and 7mm aperture inclusive with a positive effect of high throughput capacity at low input time and energy.

5. REFERENCES

[1] Wilhemina Q. J., Gayin, I. Y. and Plahar W.A. "Characteristics of Various Cassava Processing Methods and the Adoption Requirements in Ghana", *Journal of Root Crops,* Vol. 35, Number 1, 2009, pp. 59 – 68.

[2] James, F.S. *Screening Theory and Practice* Triple/S Dynamics, Inc. Texas, 2012, pp1-7, 12-20

[3] George F. "Screening for Maximum Accuracy" https://www.911metallurgist.com. Accessed on August 6, 2016.

[4] RMIG "Calculation of Open area", http://rmig.com /en/technical+info/formulae, Accessed on July 4, 2018.

[5] Arthur G. "Sieve Mesh – Sizes, Testing Standards, Certification & Calibration" https://www.google. com/search?q=Arthur G.*,* Accessed on August 6, 2018.

[6] David S. *An Introduction to the Principle and Importance of Proper Screening, Aggregates Equipment,* Inc. Leola, 2015.

[7] Ogunsina B. S., Sanni, L. A. and Oladigbo C. "Development of a Rotary Pulverizer for Cassava Cake in Garri Production" *Journal of Food Process Engineering*, Vol.13, Number 8, 2008, pp. 783–797.

[8] Ahiakwo A. A. "Ergonomic Intervention and Sieve Aperture Effects on Musculoskeletal Discomfort in Dewatered Cassava Mash Sieving Process". Unpublished Ph.D Dissertation Department of Agricultural and Bio-resources Engineering, 2018, Michael Okpara University of Agriculture, Umudike.

[9] Uthman F "Design and Fabrication of Cassava Lump Breaking and Sieving Machine", *Oasis Journal of Research and Development*, Vol.1, Number 2, 2011, pp42-50

[10] Kudabo, E. A; Onipede, E. A and Adegbenro, O. A "Design, Fabrication and Performance Evaluation of an Improved Cassava Mash Sifter", *Journal of Agriculture Vetnary Science,* 2012. Vol. 4, Number 2, pp. 53 – 64.

[11] Adetunji O.R., Dairo, O.U., Aiana, B and Osunlana A.S. "Development of an Improved Garri Sifting Machine", *Pacific Journal of Science and Technology*, Vol. 14, Number 2, 2013, pp. 67 – 75.

[12] Abubakar M., Olawale J. O., Abdulkadir B. H., Dele S. J "The Design of a Pedal Driven Pulverizing and Sieving Machine for Dewatered Grated Cassava" *International Journal of Scientific and Research Publications*, Vol.4, Number 4, 2014, pp. 45 – 49.

[13] Abiodun L.O., Oladipo N. O, and Bamidele B.L., "Development of NCAM Reciprocating Cassava Mash Sifter". *International Journal of Basic and Applied Science,* Vol.5, Number 3, 2016, pp. 10 – 13.

[14] Burubai W and Etekpe, G.W. "Particle Size Characterization of Garri Powder", *Advanced Journal of Agricultural Research*, Vol. 2 Number 12, 2014 pp. 197 – 202.

[15] 'Mechanical Analysis of Soils", www.cememphis. edu/1101/notes/filtration/sieve analysis, Accessed July 10, 2018.

[16] "Screen Technology Group Inc.(2009/2016) Wire cloth and Wire Mesh Technical Reference Index" www.wovenwire.com, Accessed on August 6, 2018

[17] "Belleville Wire Cloth Co., Inc.**"** www.bwire.com, Accessed on August 6, 2018

[18] Sayah, K.M and Singh, K.K. *Unit Operations of Agricultural Processing*. 2nd ed. Vikas Publishing House PVT Ltd., Jangpura, New Delhi, 2009, pp 222 – 223.