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Effect of Mesh Count and Percentage Open Area on Throughput Capacity in Developing Cassava Cake Screening Medium

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Research Article

Abstract

The screen is a medium for breaking cassava cake lump into fine particles before the heating process that turns the fine particles into garri. The objective of this research is ascertain the effect of mesh count and percentage open area on throughput capacity of cassava cake screening medium, with respect to two methods of development. To this end, six screens each of diameters 1.5, 3, 4.5, 6, 7.5 and 9mm were developed using perforated and the traditional woven wire mesh method respectively. Measurement was made of the mesh count and open area of the screens and screening was done with 2kg of cassava cake across each screening medium. Data was obtained from the mesh count and open area of the screens as well as the throughput capacities. The data obtained were analyzed using t test and regression analysis. Result showed that the mesh count for 3mm screen for the woven wire mesh was approximately 3 while the mesh count for a smaller diameter of 1.5mm for the perforated screen was 10.6. This resulted to percentage open area of 11 and 28.3 respectively. Also screening time was 4.1min for 3mm against 3.4 min for 1.5 mm, given throughput capacity of 24kg/hr and 35.6kh/hr, for the woven wire and perforated mesh respectively. The t-test showed that there is a statistical significant difference in the throughput capacity of the two methods. The perforated method has advantage of higher throughput capacity, lower time and energy input and hence is recommended for manual and motorized screening process.

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Cassava, screen, mesh count, open area, cassava cake processing

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1. Introduction

One of the crops that have contributed to sustenance of life in most communities in Nigeria today is cassava and its processed products. Processing cassava to garri, requires series of processes for which the research inputs of researchers through device modification, improvement and mechanization have resulted to great reduction of intense labour in this unit operation (Ahiakwo and Chijioke 2020; Screen Technology Group, 2016). However, one of these series of processes is the traditional sifting. For decades this process has been developed by the skill of the local craftsmen. To date the screening device material the rafia cane, bamboo etc are sourced from the forest and weaved by the craftsmen to apertures of their choice. Although the traditional screen has been developed with no empirical background, it may have served the traditional processors well. Currently and with the changing status of farmers and the need to meet up the increase demand for food availability with less stressful devices, there is need to investigate this age long device to identify subtle problems that may be hindering processing of cassava at a faster rate with less stress and higher output even at the manual level (Ahiakwo and Odinwa, 2021).

Research works have been done on screens applied to other fields as well as on cassava cake screening with precise formula for setting up the screen aperture which could ensure standardization, consistency, ease of replication and screening (Ahiakwo et al., 2019). The screen being the active platform upon which cassava cake screening process is carried out, consists of elements and parameters that cannot be overlooked in its development. These have been identified to includes lifting platform dimension, screen diameter, mesh count, percentage open area and method of development. Overlooking these would adversely affect the throughput capacity, ease and time of operation and efficient separation of dewatered cassava cake particles (James 2012). This implies that for effective screening operation, the screening surface should have predetermined openings of specific size as they will determine the amount of force a processor will apply and overall performance of the screening process (George, 2012; Tod *et al*., 2015).

It has been reported that some sieves are poorly developed and with analysis that are faulty. Establishing suitable sieve mesh requires measurement of opening of a sample in a recommended manner over a defined area. Effective screen size is more helpful in predicting sieve performance and when they are designed properly, It helps to determine sieving efficiency, throughput capacity and product quality. (Arthur, 2011; Yoshida *et al*., 2012; Casey, 2012).

In screen development, mesh represents the size of screen in standard sieve. In Tyler standard sieve, mesh is the number of holes in 25.4 mm length. It is the holes number in 25.4mm also considered as mesh count (Screen Technology Group, 2016). Open area on a screen is the ratio between hole areas and the sieve surface. By decreasing or increasing the space between holes, open area can be increased or decreased. Screens are developed from: (i) Plates mainly by drilling or punching to produce a perforated pattern, and or (ii) Woven wire surfaces to various designs (James, 2012; RMIG, 2015; Arthur, 2012).

In the research carried out by Ahiakwo et al., (2021) to investigate cassava cake screening devices developed by traditional skilled men in three Senatorial Zones of Rivers State, it was revealed that the necessary elements for effective performance of the screen were lacking. Among the deficiencies reported, includes lack of precise diameter for the screen they produced. According to the report, of the 108 locally made screens surveyed, the screen diameters varied between 1.5 to 4.7mm, with a mean value of 3.1mm and the most frequently produced screen of 2.9mm diameter. It is not surprising that Ahiakwo et al, (2019) in their assessment of processors level of exposure to work related musculo-skeletal discomfort in dewatered cassava mash sieving process, report that processors involved in screening of cassava cake were exposed to discomfort level of 66% [Quick Exposure checklist (QEC)]. From the report, the highest exposure was from wrist/hand. Among other factors to this high risk exposure was the screen diameter being smaller than what should be ideal, leading to the processors applying more force to sift than necessary.

It is therefore obvious that the local developers never give attention to mesh count and percentage open area in cassava cake screen development. Also some motorize cassava sieves are silent as to the mesh number and percentage open area used in developing their screens (Abiodun *et al.* 2016; Abubakar *et al*. 2014). Without given attention to the necessary elements, screening time and throughput capacity would be affected, discomfort level will be high in manual, while in motorize sieves, stress, malfunction, wear would be high because of using smaller screen. Also the bases for comparing the throughput capacity of one machine's efficiency to the other will be lost, all other elements being equal. Besides, consideration of these elements interaction provides insight to screening method to adopt.

It is therefore the objective of this research to assess the effect of mesh count, percentage open area and inter hole spacing on screening time and throughout capacity using two screen development methods, to highlight the need of considering these parameters screen development.

2.0 Materıals And Methods

2.1 Generating the Experimental Screens

In this research, two screens were developed using the woven wire mesh method and the perforated method. The 3mm screen diameter is mostly used in the locally made screen. This diameter was used to develop perforated screen of the series: y – 1.5, y + 1.5, y + 2(1.5), y + 3(1.5), y + 4(1.5) where y is the prevalent average traditional screen of 3mm diameter used locally (Ahiakwo and Odinwa, 2021). This gave test screens of 1.5, 3, 4.5, 6, 7.5 and 9.

2.2 Developing the Woven Wire Mesh

The woven wire mesh was developed in the traditional pattern by weaving the weft and warp made of raffia strip together by a local craftsman and locked between bamboo strips to reveal the screening holes. Weft and warp width used was 6 mm.

2.3 Establishing Mesh Count and Open area

The mesh number for the woven wire mesh for 1.5, 3, 4.5, 6, 7.5 and 9, was measured and calculated using Crowley. (2017):

$$M = \frac{25.4}{(L_A + d_w)} \quad (1)$$

Where M = Mesh number,
L_A = screen diameter = 1.5, 3, 4.5, 6, 7.5 and 9,
d_w = width of raffia strip (weft)

On the other hand the percentage open area (A_o) of the woven wire mesh was calculated for each of the screens developed using Screen Technology Group (2016):

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

Where A_o = Percentage open area
L_A = screen diameter = 1.5, 3, 4.5, 6, 7.5 and 9,
d_w = width of raffia strip (weft)

2.4 Developing the Perforated Screen

To develop the Screen, six plates of dimension 450mm x 350 mm each was cut out of 1mm galvanized metal sheet. Engineer's Square was used to square the plate and also guided in scribing horizontal and vertical lines to create inter hole spaces and the square space for drilling the screen holes. 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.

2.5 Determination of Mesh Number and Open area for the Perforated Screen

The mesh number for each of the sieves was determined by selecting an in-between hole spacing that would 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 (Crowley, 2017). The plates were marked, punched and drilled using round hole square pitch drill pattern

The mesh number for the Perforated Screen calculated for diameter developed using Screen Technology Group (2016)

$$n = \frac{25.4}{(D+S)} \quad (3)$$

Where: n = mesh number,
D = screen diameter 1.5, 3, 4.5, 6, 7.5 and 9
S = spacing between hole, mm

On the other hand the percentage open area for the experimental sieves was derived using Crowley, (2017).

$$A_o = \frac{0.785d^2}{(s+d)^2} \times 100 \quad (4)$$

Where: Ao = Percentage open area,
d = Screen diameter 1.5, 3, 4.5, 6, 7.5 and 9
S = Spacing between hole, mm.

2.6 Experimental Design

Complete Randomized Block Design (RCBD), was used for the experimentation. This was carried out ascertain effects of mesh count and open area percentage on throughput capacity and screening time. The independent variables were the screen diameters, while the dependent variables were throughput capacity and screening time. Unit of treatment was 2kg of cassava cake. This was used as a treatment for the different screens of 1.5, 3mm, 4.5mm, 6mm, 7.5mm and 9mm, which were used in constructing the woven wire and perforated mesh respectively.

2.7 Experimental Procedure

Screening was carried out using 2kg of cassava cake on each of the screens by a processor in a traditional screening method. The sieves were arranged such that during the screening process, the randomized pattern shown in Table 1 was followed ensuring that none of the sieves was unduly affected by the operator's factor.

Table 1: Screen diameter (mm) and screening process replication in RCBD

Block1	Block 2	Block 3	Block 4
1.5	9	4.5	6
3	7.5	3	1.5
4.5	6	1.5	7.5
6	4.5	9	3
7.5	3	6	9
9	1.5	7.5	4.5

The time to completely screen the 2 kg mash in each of medium was recorded and replicated 4 times for each of the sieves. The resultant throughput capacity with respect to time was calculated in each case:

2.8 Data analysis

Data obtained from mesh count, percentage open area, screening time and throughput Were analyzed using regression analysis and t test at 5% significant level

3.0 Result And Discussion

Table 2 shows the result of measurement and calculation of mesh count (M) for woven wire mesh (wwm), perforated mesh (n); percentage open area (A_o%) for woven wire mesh and perforated mesh (pm) as well as their throughput capacities. This measurement and calculations was done with respect to the screen diameters of 1.5, 3, 4.5, 6.0, 7.5 and 9.0 mm. The plot of the screen diameters against the mesh count, open area are presented in Figures 1 to 3 showing their effects on time spent and the throughput capacity.

Table 2: Sieve characteristics and throughput capacity

Diameter(mm)	M	n	Ao% (Wwm)	A_o% (Pm)	Throughput Capacity (Wwm)	(Pm)
1.5	3.37	10.6	4	28.3	24	35.6
3	2.82	6.40	11	44.26	29.27	41.38
4.5	2.42	4.62	18.37	52.3	40	56.1
6	2.12	3.63	25	57.7	57	66
7.5	1.88	2.99	30.86	61.1	70.58	97.8
9	1.69	2.50	36	63.6	109	171.1

Figure 1 shows the relationship between mesh count and screen diameter. As the diameter of the screen was increased, the mesh number decreases progressively for both woven wire mesh (M) and perforated mesh (N). The decrease was more pronounced with the use of woven wire mesh method, than for the perforated method for the same diameter. As shown, with 3 mm diameter which is prevalently developed and used by cassava processors locally, there were approximately 6 holes in 25.4 mm linear dimension but approximately 3 holes when the woven wire mesh method was used. As the diameter was decreased to 1.5 mm, there were approximately 10 holes for cassava cake particles to pass for perforated method but 3 holes for woven wire method though with a higher diameter. This implies that using half the diameter of the woven wire in a perforated mesh will result in a higher throughput capacity. Consequently, it would be more efficient to use the 1.5 mm for perforated than for woven wire mesh for the same diameter in terms of energy and time spent. This is also true as the diameter is increased from 4.5mm up to 9mm.

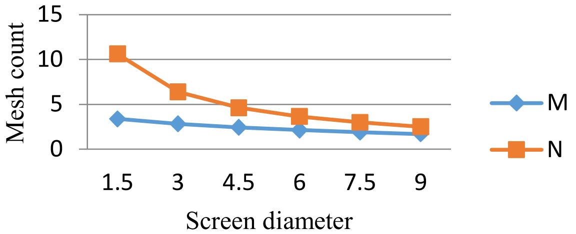

Fig. 1: Mesh count and screen diameter effect on development method

Figure 2 shows the effect of percentage open area on screen diameter and type of screen development method. From the figure, as the diameter of the screen was increased the open area of the screen progressively increases. This increase depended on the development method used. For the 3 mm diameter in Fgure 2, it means that available area for particle to pass through is just 11% where as for the perforated method, available area is 44%. This result applies weather the screen diameter is decreased or increased around 3mm. The difference observed resulted from the material used in developing the screens. For the woven wire mesh, it took a weft and warp of 5-6 mm weaved vertically and horizontal to make a square hole. For this reason, there is more closed area than open areas compared to the perforated method where the inter hole spaces is adjustable to a lower dimension. The perforated aperture was established by drilling a round hole with inter-hole spacing of 1mm. This comparatively small inter hole spacing resulted in a higher percentage open area. The traditional screen is built with diameter of 3mm using the woven wire mesh method and so has a lower percentage open area. In other words, it has more closed area than open area compared to perforated screen of the same diameter. This explains why processors using the traditional screen experiences more stress, pain at the biceps and more energy spent with relatively low throughput capacity compared to the perforated mesh (Ahiakwo et al. 2019).

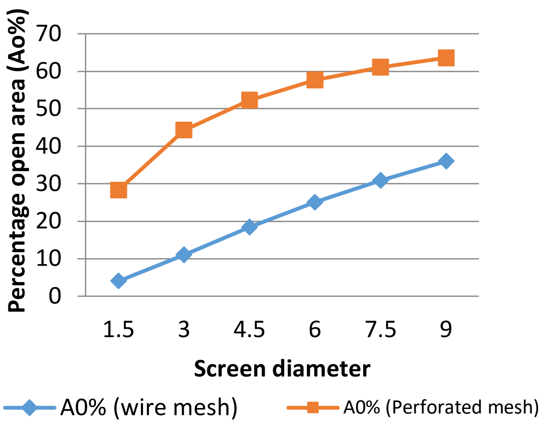

Fig. 2: Effect of open area on sieve type and aperture

Figure 3 shows the effects of considering mesh count and percentage open area on screen development method for cassava processing. As shown in the Figure, there is a progressive increase in throughput capacity with increase in screen aperture for the same quantity of cassava cake sifted across the screens. However, the increase depended on the mesh count and open area percentage as well as the method used.

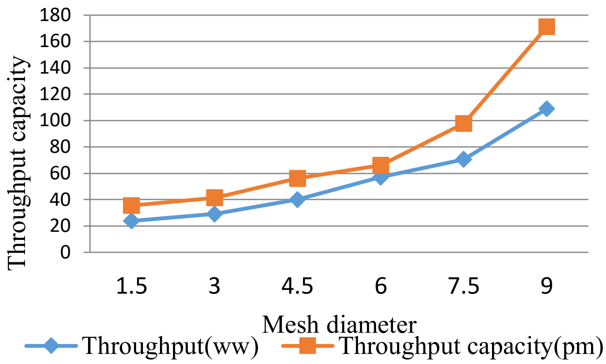

Fig. 3: Effect of mesh count, open area on throughput capacity

As shown in Figures 1, 2, and 3, at 1.5 mm perforated screen, the mesh count is 10.16 with percentage open area of 28.3% yielding a throughput of 35.6 kg/hr. whereas for the woven wire mesh, the mesh count is approximately 3 with 4% open area, yielding throughput capacity of 24kg/hr. For the 3mm perforated mesh the mesh count is 6.4 with open area of 44.26% yielding a throughput of 41.38% whereas for the woven wire mesh on the same diameter, the mesh count is approximately 3, open area 11% and yields throughput of 29.37kg/hr. As shown in Figure 3 the throughput at 1.5mm perforated method is higher than throughput capacity at a higher 3mm diameter with woven wire mesh method. This result is closely related to the work of Emmanuel and Opeyemi (2015). While the throughput for 3mm aperture here is 29.37kg/hr and 41.38 for woven wire mesh and perforated mesh respectively, their throughput for 3mm is 45.10kg/hr. Also while the throughput for 4.5mm in this work are 40kg/hr and 56.1kg/hr for woven wire and perforated mesh, their throughput capacity for 5mm was 56kg/hr. The difference results from difference in mesh number, percentage open, and the type of sieve used.

Table 2 shows the result when the throughput capacity (Table 1) from the woven wire mesh and perforated meshes were compared using the t-test at 5% significance level. The p value of the t test is less than 0.05, and the t-stat is greater than the t- critical. The result shows there is statistical significant difference at 5% level of significance among the population means of the throughput capacity

Table 3: Comparison of throughput capacity for cassava cake screen on woven wire and perforated mesh

	Variable 1	*Variable 2*
Mean	54.975	77.99666667
Variance	1002.15311	2564.408867
Observations	6	6
Pearson Correlation	0.985218016	
Hypothesized Mean Difference	0	

Df	5
t Stat	-2.792623918
P(T<=t) one-tail	0.019162951
t Critical one-tail	2.015048372
P(T<=t) two-tail	0.038325902
t Critical two-tail	2.570581835

Table 4: shows the mean time in minutes required to sift 2kg of dewatered cassava lump on the traditional woven wire mesh and perforated screen.

As shown the mean time to sieve the lump for the perforated mesh (pm) with screens of 1.5, 3, 4.5, 6 and 9mm diameter are 3.4. 2.9, 2.15min, 1.83min, 1.23min and 0.68min respectively. Whereas for the woven wire (ww) mesh, the mean time were 5, 4.1, 3, 2.1, 1.7 and 1.1 for the reference diameters

Table 4: Mean time required sifting 2kg of dewatered cassava cake lump

Aperture (mm)	Replications				Total	Mean	SD	CV
	1	2	3	4				
1.5	3.5	3.8	3.2	3.1	13.6	3.4	0.32	0.08
3	2.8	2.9	3	2.9	11.6	2.9	0.39	0.11
4.5	2.3	2	2.1	2.2	8.6	2.15	0.13	0.01
6	2	1.6	1.8	1.9	7.3	1.83	0.17	0.02
7.5	1.3	1.2	1.3	1.1	4.9	1.23	0.1	0.01
9	0.65	0.8	0.56	0.7	2.71	0.68	0.1	0.01

Figure 4 shows that the highest sifting time of 5 min occurs at the 1.5mm screen with woven wire mesh, whereas the lowest sieving time of 0.68 min occurred at the 9mm perforated sieve.

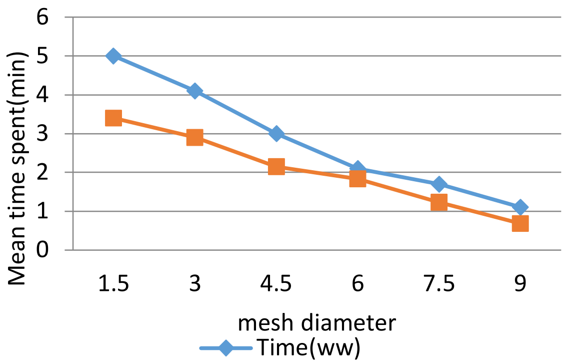

Fig. 4: Effect of Screen diameter on sifting Time

This shows that the woven wire screen takes more time than the perforated screen for the same quantity of dried cassava lump cake even for a lower diameter. This time difference is also connected with the lower percentage open area which permits small quantity of the lump to pass through the woven wire screen aperture at a given time.

4.0 Conclusion

The mesh count and percentage open area of a developed screen, be it woven wire mesh or perforated, affects the time spent on screening process and the throughput capacity. Increasing the screen diameter decreases the mesh number progressively for both woven wire mesh (M) and perforated mesh (N). The decrease is more pronounced with the use of woven wire mesh method, than for the perforated method for the same diameter. The inter hole spacing for woven wire mesh produced locally creates more percentage closed area than open area as well as mesh count that is comparatively low. The perforated method has advantage of higher throughput capacity, lower time of screening and energy input for equal dimension of screen and hence is highly recommended for traditional screening process and to be incorporated in motorized screen designs and development

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