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Review

Appraisal and projection of cassava mash sieving technology

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ABSTRACT

This paper focuses on the appraisal and projection of cassava mash sieving technology. Sieving operation, occupy an important position in the effective transformation of dewatered cassava mash into gari. However, traditionally, it consumes time and energy. Three versions of the sieve were considered, namely: traditional sieve, improved traditional sieve and mechanized sieve. Their constructions, use and associated problems were highlighted. The need to consider sieve aperture size in both traditional and mechanized sieve design and construction was emphasized. This was necessary as the speed of sieve and the strain on the operator has an inverse relation to this. From the expression derived for effective sieving technology, it was discovered that sieve aperture is directly proportional to sieving speed but inversely proportional to operators strain. This mean that as the aperture size is increased to the optimum, the speed of sieve will increase remarkably whereas on the other hand, the operators reciprocating shearing and compressive force and hence associated strain will reduce. For mechanized sieving machines utilizing shearing and compressive force principle, using an optimum aperture, while increasing sieving speed will reduce compressive impact and friction in the interacting surfaces which will prolong the machine life.

Keywords: Cassava mash, sieve, aperture, speed, operator.

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is almost entirely produced and consumed in developing countries. It is highly productive, tolerant of poor soils, periods of drought and is relatively disease free and pest resistant. It provides a major source of energy for over 500 million people world-wide (FAO, 2000). Cassava is diversified into different food products and these products are available all year round thus making cassava an important staple food for many rural households in Nigeria (Onabolu, 2001). Gari is the most popular of the Cassava products in Africa (Oluwole et al., 2004). It is a creamy-white, granular flour with a slightly fermented flavour and a slightly sour taste made from fermented, gelatinized fresh cassava tubers (ARSO, 2012). Cassava is the most perishable of roots and tubers and can deteriorate within two or three days after harvesting. In the words of Adzimah and Gbadam (2009), “the major limitation of cassava is its rapid post harvest physiological deterioration which often begins within 24 h after harvest”. Additionally, the roots need to have the cyanogenic glucocides reduced to a level which is acceptable and safe for consumption. For this reasons, cassava is usually sold as a processed product in form of gari, farinha, cassava bread, etc. Processing operations includes: peeling, washing, grating, fermentation, dewatering, sieving (sifting), garifying, cooling and storage.

After peeling, washing, grating, fermentation and dewatering, the resulting cassava mash is a conglomeration of particles bonded into a lump. Sieving is a necessary operation. It not only reduce the lump into fine particles (undersize) which pass through the sieve, it separate the coarse unwanted particles (oversize) which are discarded after each batch of sieving. The quality of gari produce and ultimately the texture of the end product – eba depend on two prime factors namely: (1) the sieve aperture size used and (2) the garifying process, which includes heat input regulation and the manipulative skill

of the operator. Considering these factors, if the sieve aperture size is too small, it not only result in the sieved cassava mash being too fine but also have a feedback effect on the operator who will exert more energy to shear and compress the mash over the sieve and at a higher time. On the other hand, if the aperture is larger than optimum, though sieving will be faster and the operator will be more at ease, the sieve may end up not eliminating unwanted particles. Evidently, an optimum sieve aperture size will be needed to marry time, operators comfort and a sieved particle that will produce an acceptable gari grain after garification.

ARSO (2012) classified gari into extra fine grain, fine grain, coarse grain and extra coarse grain gari. And, observed that "generally, for making eba, the fine grain or coarse grain gari are usually okay and the extra coarse grain for soaking". Also, the test sieves and tests required to arrive at these grain sizes were specified. But the bulk of gari consumed in both rural and urban areas are produced by rural cassava farmers who obtain dewatered cassava mash sieves from the local craftsmen. The rural cassava farmers may have no choice but to use the sieve size seemingly imposed on them by the local craftsmen until it is proved beyond reasonable doubt that increasing the sieve aperture to an optimum will benefit them in the cassava processing business and that gari produced will still retain its acceptable quality for making eba. Hence, Peter et al. (2010) observed that sieving is one of the major problems of gari processing over the years. It is therefore the objective of this paper to: (1) appraise available sieving technology, (2) make a projection for developing an effective sieving technology, and (3) derive an expression for developing an effective sieving technology.

APPRAISAL OF AVAILABLE SIEVING TECHNOLOGY

Traditional sieving technology

Cassava mash is a conglomeration of particles bonded into a lump after dewatering. Sieving is a necessary operation. It not only reduces the lump into fine particles (undersize) which pass through the sieve, it separates the coarse unwanted particles (oversize) which are discarded after each batch of sieving. In the traditional setting, this operation is accomplished using cane or raffia sieve. The craftsmen, who produce the sieves, set the aperture size by guess work or arbitrarily without consideration to the effect the size will have on sieving speed and the operators comfort. Sieving operation using traditional technology involves the followings:

i) A receptacle
ii) The raffia sieve or screen
iii) Dewatered cassava mash
iv) Human power

The receptacle

This is a container that receives the fine particles (undersize) that pass through the sieve as the dewatered cassava mash is crushed against it.

The sieve

This is usually square or rectangular in shape. It is made of cane, raffia palm or palm frond material. This is cut out into several pieces of flat rectangular flexible strip measuring about 0.5 × 60 cm, with thickness of about 1 mm. Whereas, 0.5 cm represent the width of a single sieve strip, 60 cm which represent the length of the sieve can vary depending on the length of the sieve. These are weaved by the native specialist craftsmen in such a way that an aperture (square holes) of about 2 to 3 mm^2 is revealed at alternate position throughout the sieve. The woven strip is secured over framework of thick material as shown in Figure 1. The alternating arrangement of the woven material provides a rough surface for crushing the lumps of cassava mash.

The siever

The siever is the source of power- human two palms. These serve two purposes; that of lifting the lumps of the mash onto the sieve and that of compressing and shearing the lumps against the sieve. This results in fine particle drifting down through the sieve apertures to the receptacle while retaining the coarse unwanted particle which will be discarded after each batch of sieving. The arrangement is shown in Figure 2.

Improved traditional sieving technology

Improvement on traditional technology has been on the aspect of change on the material used in constructing the sieve. Although sieves made of raffia palm are still available, improved versions such as those made from synthetic material, metal strips and aluminium are available and preferred (Figure 3). This is basically because of their durability.

Drawback of the traditional and improved sieving technology

Both the traditional and improved traditional sieving material has the following drawbacks:

1. Waist pain resulting from the operators sitting position, which involve bending and stretching.
2. Irritating sensation resulting from friction of rubbing the

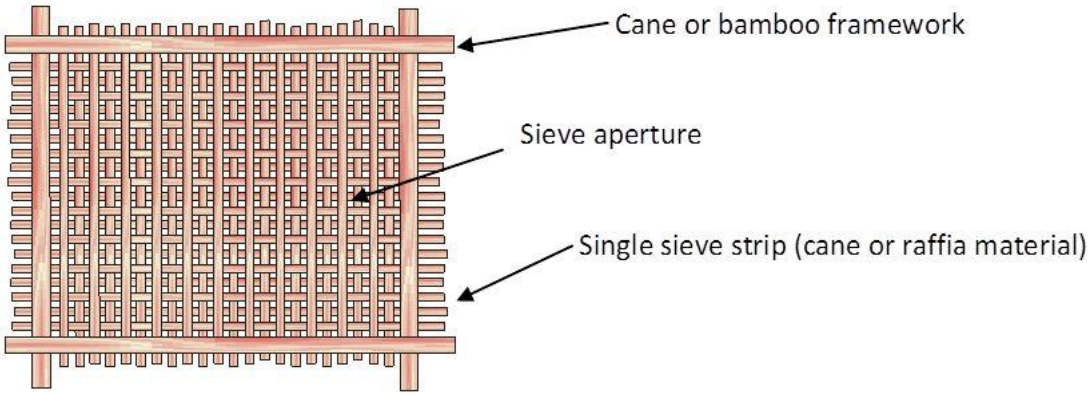

Figure 1. Traditional raffia sieve.

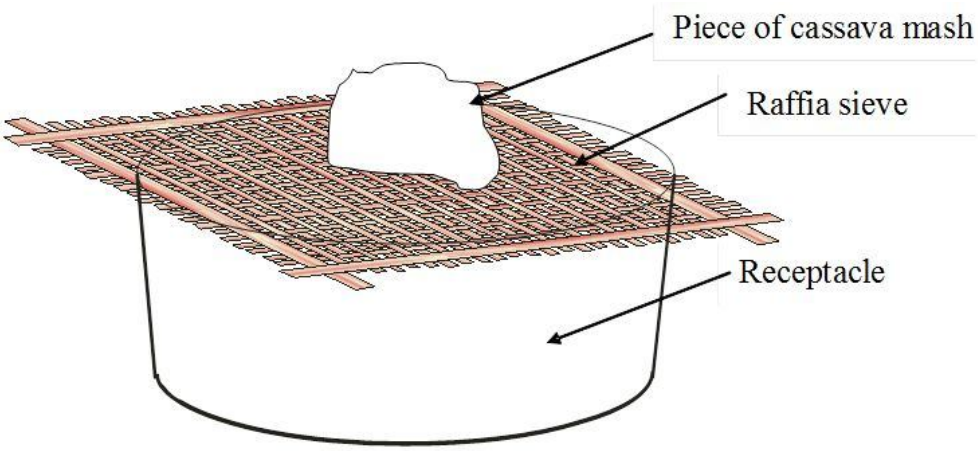

Figure 2. Assemblage of materials for traditional sieving arrangement.

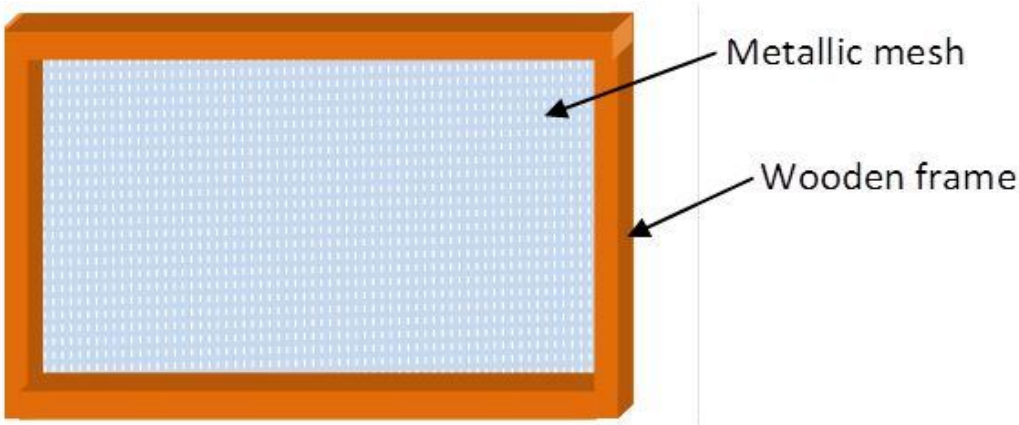

Figure 3. Improved traditional sieve.

palm against the sieve with broken lumps of cassava mash.

3. The process consumes time. For instance, to sieve a 30 kg worth of dewatered cassava mash may take about 60 to 90 min. This can translate to several hours in case of large scale production. (Olufemi, 2003)

4. Inhaling of poisonous dust-like particles.

5. Hygienic problems of the siever and the sieve's care.

According to Uthman (2011), the traditional method of lump breaking and sieving of cassava into gari is time wasting and energy consuming which invariably leads to low production.

Mechanized sieving technology

Mechanized sieves have been conceived and developed as a means of reducing human effort and time involved in sieving operation.

Kudabo et al. (2012) developed and evaluated a motorized cassava mash sifter, which was powered by an electric motor. The machine dimension was put at 915 mm × 455 mm × 630 mm. Test result according to the report show that the sifter has efficiency of 93.3% at 26% moisture content at sifting speed of 410rpm and output capacity of 135 kg/h.

Jackson and Oladipo (2013) developed a motorized dewatered cassava mash sifter at the National Centre for Agricultural Mechanization (NCAM) which was evaluated to determine the effects of operating speed on its sifting efficiency. Four operating speeds were chosen for the study, these are, 450, 500, 600 and 650 rpm. The machine was allowed to run, and the time required completing the sifting of 15 kg dewatered mash sample at all the tested speeds were noted and recorded. 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 and output of 200kg/h.

Sulaiman and Adigun (2008) fabricated a cassava lump breaker with locally available materials such as mild steel, stainless steel, etc but they failed to carry out a comprehensive performance evaluation in terms of the efficiency and throughput capacity on the machine. They recommended that the machine should be constructed with stainless steel materials because it prevents corrosion and allow hygienic operation. Orojinmi (1997) developed a cassava siever, he carried out a performance evaluation on the machine with an efficiency of 76% and output capacity of 69.12 kg/h. He suggested that the machine can be improved upon so as to increase the efficiency and capacity, to lessen the hectic aspect of the sieving operation. 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.

Considering the work of Kudabo et al. (2012) and Jackson and Oladipo (2013) which are more comprehensive, it is observed that while kudabo et al. (2012) used a 410 rpm to develop a sifter having 93.3% efficiency with an output of 135 kg/h, Jackson and Oladipo (2013) on the other hand working with a slightly higher rpm of 450, developed a sifter having an efficiency of 75.5% with an output of 200 kg/h. The contrast here is that the machine using 450 rpm and producing an output capacity of 200 kg/h is 75.5% efficient whereas the one using 410 rpm is 93.3% efficient. Both designs and the others are silent with respect to the sieve aperture sizes that were used to produce the speeds, outputs and efficiencies.

However, unlike the grating and dewatering operations which are presently mechanized, and are in the market and reducing farmers' drudgery; the sieving machines are yet to be seen in the market. Available commercial sieves are for large scale cassava producers. No doubt the concept may not have been perfected so as to produce affordable and reliable sieving machines.

PROJECTION FOR DEVELOPMENT OF TECHNOLOGY FOR EFFECTIVE CASSAVA MASH SIEVING

In other to develop a technology that can effectively screen cassava mash at a shortest possible time while reducing drudgery in this unit operation, it is important to review the theories of the interacting particles of cassava mash and mechanical separation using screen.

Cassava mash as a conglomeration of particles

Dewatered cassava mash consists of particles bonded into a lump during dewatering. The processing of cassava mash into gari requires that this lump of cassava mash be broken and crushed over a sieve or screen. 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.

Particle technology

A review of particle technology can be applied in the particle size separation in dewatered cassava mash. Particle technology is the technique for processing and handling particulate solids. Individual solid particles are characterized by:

1. Shape
2. Size and
3. Density (Donald, 2005).

Particle shape

The shape of an individual particle is expressed in terms of the sphericity Φs, which is independent of particle size. The sphericity of a particle is the ratio of the surface-

volume ratio of a sphere with equal volume as the particle and surface-volume ratio of the particle.

For a spherical particle of diameter Dp, Φ = 1; for a non-spherical particle, the sphericity is defined as:

$\Phi s = 6Vp / DpSp$ (Donald, 2005)

Where:
Dp = Equivalent diameter of particle (mm)
Sp = Surface area of one particle (mm^2)
Vp = Volume of one particle (mm^3)

The equivalent diameter is sometimes defined as the diameter of sphere of equal volume. For fine particles, Dp is usually taken to be the normal size based on screen analysis or microscopic analysis. The surface area is found from adsorption measurement or from the pressure drop in a bed of particles. For many crushed materials, Φs is between 0.6 and 0.8. For particles rounded by abrasion, Φs may be as high as 0.95 (Donald, 2005).

Particle size

Particle diameter may be specified for any equidimensional particles. Particles that are not equidimensional, that is, that are longer in one direction than in others are often characterized by the second longest major dimension. For needle like particles, Dp would refer to the thickness of the particle, not their length. Units used for particle size depend on the size of the particles:

i) Course particle: millimetre
ii) Fine particle: Screen size
iii) Very fine particle: Micrometers or nanometres
iv) Ultra fine particles: surface area per unit mass, m^2/g (Donald, 2005)

Mixed particle size and size analysis

In a sample of uniform particles of diameter Dp, the total volume of the particles is m/ρ_p,
Where:
m = mass of sample,
ρ_p = density.

Since the volume of one particle is Vp, the total number of particle in the sample is:

$N = m/ \rho_p v_p$
The total surface area of the particles is:
$A = NSp = 6m/\Phi s\rho pDp$ (Donald, 2005)

To apply the above two equations to mixtures of particles having various sizes and densities the mixture is sorted into fractions, each of constant density and approximately constant size using sieve (Jame, 2007).

PROJECTION FOR DEVELOPING AN EFFECTIVE SIEVING TECHNOLOGY

Deriving expression for sieve aperture and sieving speed

From the above discussion, an expression for determining the relationship between sieve apertures and sieving speed which can lead to reduction in sieving drudgery could be derived. This is done using 4 different sieves with different aperture sizes and the quality of gari produced subsequently determined for each case.

Let 4 sieves for screening dewatered cassava mash be designated S_1, S_2, S_3 and S_4 and let these have a square opening of mm^2 in the order of:

$x, \frac{3x}{4}, \frac{x}{2}$, and $\frac{x}{3}$

Also let W_t be a predetermined weight of dewatered cassava mash in kilogram (kg) that will be used for each of the sieves. For a given time t, an equal weight of W_t will be agitated over the screens, S_1, S_2, S_3 and S_4. Because the sieves have different apertures, the percentage of cassava mash particle retained by the sieves will vary. Let the weight of particles retained in the sieves be: for $S_1 = W_1$, $S_2 = W_2$, $S_3 = W_3$ and for $S_4 = W_4$. From this we can calculate the percentage of cassava mash particle retained and the percentage that passed through the sieve.

For S_1, percentage of particle retained $S1r = \frac{w1}{wt} \times 100\%$
Where w_t = predetermined total weight loaded onto sieve S1
w_1 = weight of particles retained in sieve S_1 after sieving within time t.
S_{1r} = percentage of particles retained in sieve S_1

Therefore the percentage of cassava mash particle that passes through sieve S_1

$S1p = 100 - \left(\frac{w1}{wt} \times 100\%\right)$

For S_2 percentage of particle retained $S2r = \frac{w2}{wt} \times 100\%$
Where w_2 = weight of particles retained in sieve S_2 after sieving within time t.

Therefore the percentage of cassava mash particle that passes through sieve S_2
$S2p = 100 - \left(\frac{w2}{wt} \times 100\%\right)$

For S_3 percentage of particle retained $S3r = \frac{w3}{wt} \times 100\%$
Where w_3 = weight of particles retained in sieve S_3 after sieving within time t.

Percentage of cassava mash that passed through sieve

S_3:

$$S3p = 100 - \left(\frac{w3}{wt} \text{ X } 100\%\right)$$

For S_4 percentage of particle retained $S4r = \frac{w4}{wt} \times 100\%$

Where w_4= weight of particles retained in sieve S_4 after sieving within time t
Percentage of cassava mash that passed through sieve S_4,

$$S4p = 100 - \left(\frac{w4}{wt} \times 100\%\right)$$

Let the particle of cassava mash retained be computed, and let it be: a for S_1, b for S_2, c for S_3 and d for S_4. The percentage of the particle retained will decrease in the order: a < b < c < d

This implies that the percentage of particles retained in 'a' is less than that retained in 'b' etc.

Similarly, if the quantity of particle passing the sieve expressed in percentage is denoted by e for S_1, f for S_2, g for S_3 and h for S_4, then the percentage of particle passing the sieve respectively will increase progressively in the order: e > f > g > h.

Estimation of percentage of oversize passing through increased sieve aperture

Since the weight of the quantity used for the sieving W_t in each case is the same, the coarse unwanted particles present in each of the samples are of the same quantity. Since the aperture varies for each of the sieves whereas the same quantity of cassava mash is sieved in each case at a given time t, it is obvious that some of the oversized particles that is supposed to be retained by one or two of the sieves may pass through the other sieves.

This can be estimated. Given that the percentage of unwanted coarse particle retained in the sieve for sieve S_1 and sieve S_2 are 'a' and 'b' percent respectively, and since the aperture size in sieve S_1 is greater than that of sieve S_2, then percentage of oversize passing through sieve S_1 but retained in sieve S_2 will be given by (b – a)%.

Result

Since the following are constant for the 4 sieves:

1. Weight of cassava mash screened
2. The time of agitation,

but the openings in each of the sieves vary, then the time at which the undersized particle passed through the openings will vary.

Now let the time for the undersize to pass through the sieve openings of x, $\frac{3x}{4}$, $\frac{x}{2}$, and $\frac{x}{3}$ be t_1, t_2, t_3, t_4. This implies that the time required for undersize drifting will decrease in the order of $t_1 < t_2 < t_3 < t_4$. This mean that the time spent sieving with sieve S_1 will be shorter. This reduction in sieving time will have a great positive effect on the operator which will include that:

1. The sieving operation will be faster.
2. The quantity of sieved cassava mash produced will be comparably higher.
3. The time the operator will spend sitting and stretching herself to accomplish the sieving operation will be reduced and so will the associated pains or discomfort.

The quality of gari produced using cassava mash sieved from each of these sieves representing percentages that passed: S_{1p}, S_{2p}, S_{3p}, S_{4p}, can be determined by garification in other to select the best of the sieves that will be appropriate for both speed of sieving and quality of gari produced.

CONCLUSION

Sieving with the traditional sieves and even the improved traditional sieves has drawbacks which among others is time consuming. From this paper, it can be seen that this time can be reduced. This can be done if the craftsmen can increase the sieve size from $\frac{x}{3}$ to x or to an optimum size. Other drawbacks or drudgery associated with traditional sieves are partly a function of time. So if sieving time is reduced, not only will this increase output capacity but will reduce associated pains and stress during the sieving operation.

However**,** as shown earlier, this increase need not be done arbitrarily to avoid problem of increasing the percentage of coarse particle (b – a)% passing through the bigger sieve aperture beyond acceptable limit. The limit to the aperture size increase can be obtained by subjecting samples from sieves S_1, S_2, S_3 and S_4 which are: S_{1p}, S_{2p}, S_{3p}, S_{4p} to garification and comparing grain size with ARSO (2012) for gari specification. This will help to obtain the best of fit sieve for acceptable gari quality.

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