DEVELOPMENT OF A WET YELLOW MAIZE MASH SIEVING MACHINE

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ABSTRACT

Wet sieving is still a manual operation in tropical crop processing. It is a time consuming operation. Most of the existing wet sieving machines are available in large scale industries and they are too sophisticated to operate and maintain by local processors. In this study, a low – cost simple prototype wet sieving machine was designed, fabricated and tested using locally available materials to solve the problems associated with sieving of wet agricultural products in Nigeria. The machine consists of a sieving compartment operated by a crank through vibratory and reciprocating mechanism obtained with the use of an eccentric cam and springs arrangement, collecting trays and outlets. The test considered feed rate Q, at three levels: 0.85 g/s, 1.7 g/s and 4.3 g/s and concentration X, at three levels 12.23%, 14.44% and 22.77%. The study showed that the machine performance coefficients and sieving capacity decreased with increasing concentration and feed rate. Higher performance and sieving capacity was achieved at a treatment combination X_2Q_2 where the performance coefficients and sieving capacity are 76.42% and 7.5 g/s respectively. A unit of the machine costs N9.780 as at April 2009. It requires little maintenance.

Keywords: starch, wet sieving operation, machine, design.

1.0 INTRODUCTION

The extraction and storage of starches from the organs of plants is an essential primary post harvest operation. It is one of the various methods for preventing post harvest losses, seasonal glut and shortages.

There are a number of techniques and equipment for carrying out this task. Among these methods are the uses of centrifuge, cyclone separators, sieves and perforated cylinders (Ihekoronye and Ngoddy, 1985; Henderson and Perry, 1976). In Nigerian homes, starch extraction is mostly carried out manually

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1.0 INTRODUCTION

The extraction and storage of starches from the organs of plants is an essential primary post harvest operation. It is one of the various methods for preventing post harvest losses, seasonal glut and shortages.

There are a number of techniques and equipment for carrying out this task. Among these methods are the uses of centrifuge, cyclone separators, sieves and perforated cylinders (Ihekoronye and Ngoddy, 1985; Henderson and Perry, 1976). In Nigerian homes, starch extraction is mostly carried out manually among the women folk, using the wet sieving method. Wet sieving allows for the washing of starch granules from other particles like fibres and hulls. Wet sieving is used for preparation of starch weaning diets, as well as diets like pap from different cereal crops like, guinea corn, millet, and fufu from cassava. When carried out manually, it is energy and time consuming, tedious and back straining.

Also, an offensive odour can be generated by fermented products and the acidic water content is both unhygienic and a discouragement to producers. The tendency is to drift away from wet sieving operation and resort to bad quality products from retail outlets. The crude methods in existence include the use of sieves, cloths and bags with polluted water in dirty environments. These manual methods makes storage very difficult reduces the desirable eating quality and suitability of the product for further processing.

It is essential that sieved products possess the required qualities, hence the need for efficient methods of extraction. Manual wet sieving can be improved upon by mechanizing it. This would improve the quality of the product, make it meet international standard and increase production. Sieves are effective provided they are made to vibrate (Fellows and Hampton, 1992). A wide variety of mechanical devices exist for wet sieving operations, differing in the complexity of their construction and efficiency of operation. Some of these devices incorporate screens. Basically rotating, vibrating screens and pusher-type centrifuges are used (Asiedu,1992).

Locally, some research efforts had been made on the development of a suitable mechanical system which incorporated a screen for one purpose or the other. An air – screen grain cleaner was investigated by Akintola and Braide (1995).This machine incorporated two screens, arranged horizontally and carried in separate racks; arranged one above the other as a unit with a sieve carrier assembly –among other things .The sieve racks have adjustable inclinations .The supporting hangers of the sieve carrier assembly are arranged at angle 15^0 to the vertical. A reciprocating motion is transmitted from an eccentric at each side of the machine by a pair of connecting rods. The evaluation of performance coefficient based on the National Institute of Agricultural Engineering (NIAE 1986) method for grain cleaning varied between 91.45% and 99.15% for the different treatments considered. The oscillation amplitude was fixed at 3.2cm.

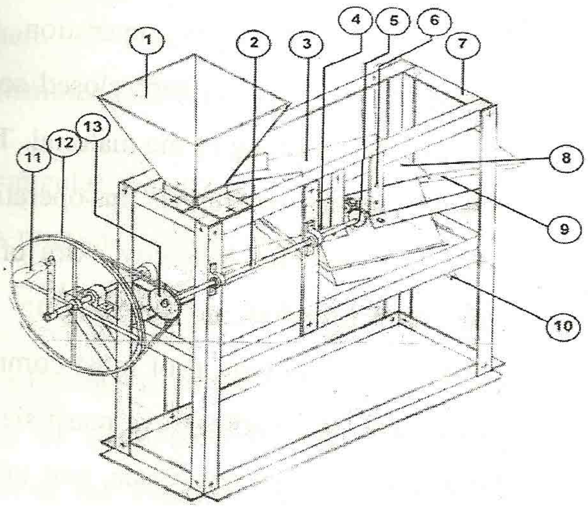
The throughput of sieves is dependent upon a number of factors, chiefly the nature and amplitude of the shaking; the methods used to prevent sticking of the sieve, the tension and physical nature of the sieve material (Earle, 1983). It is essential however, that equipment be developed from sound scientific principles which are economically feasible, simple and easy enough to be understood and used. A lot of work has been done locally to mechanize the milling and sieving of dry products. However, it is observed that no extensive work has been done locally to mechanize the sieving of wet agricultural food products. The aim of this study was to design, fabricate and test a mechanically operated wet sieving machine for small scale processing of some wet agricultural crops.

2.0 MATERIALS AND METHODS

2.1 MACHINE DESCRIPTION

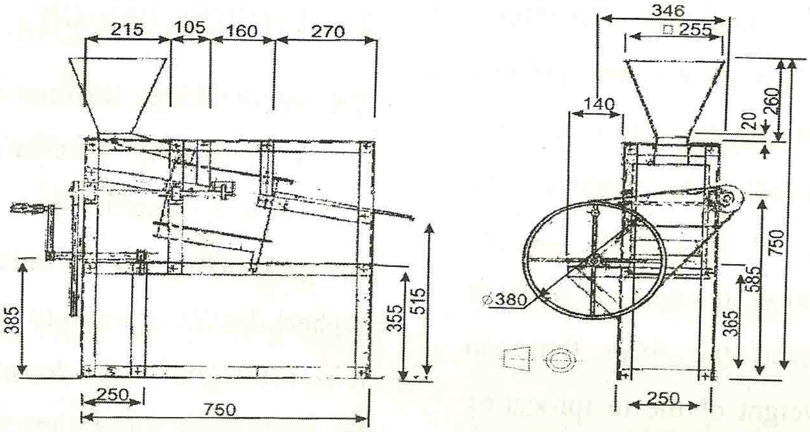
Figure 1 shows the isometric view while Figure 2 shows the orthographic view of the machine. The components of the machine include the hopper (1) fastened with bolts and nuts to the main frame (7), the sieving compartment (8), power transmission (11, 12, 13) and outlets (9, 10). The machine is inclined from the hopper end towards the outlet end at an angle of 10^0 to allow for easy flow of materials through it. It is made of galvanized sheet SWG 18 and painted because galvanized sheet is readily available and less expensive than stainless steel which is most appropriate. The hopper's outlet is fitted with a slider to control the flow of material through it. The dimension of the sieve (300mm x 145mm) was such that by the time the pulp travel through it, all the starch content would have been completely washed.

The machine has a single reciprocating sieve (8) with adjustable angles (6). The camshaft and hand crank shaft were mounted on ball bearings. Spring-loaded rods support the sieve.



LEGEND		
Item	Oty	Description
1	1	Hopper
2	1	Camshaft
3	1	Sliding Cover
4	4	Compression Spring
5	1	Cam and Follower
6	1	Angle Adjuster
7	1	Frame
8	1	Sieving Compartment
9	1	Trash Discharge Chute
10	1	Starch Discharge Chute
11	1	Hand Crank Lever
12	1	Driving Pulley
13	1	Driven Pulley

Figure 1: Isometric view of the sieving machine



Scale – 1mm: 7.5mm

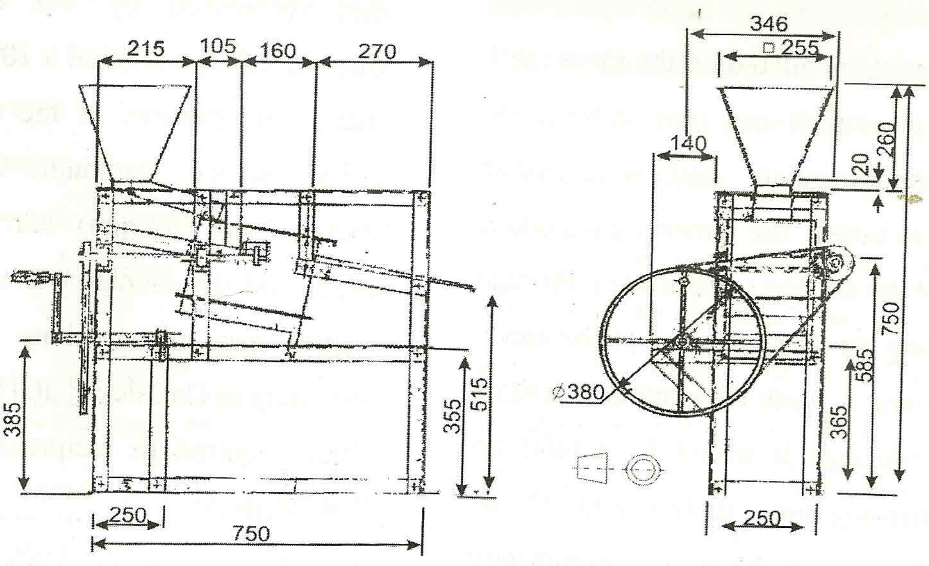


Figure 2: Orthographic view of the sieving machine

2.1 MACHINE DESIGN

Figure 2: Orthographic view of the sieving machine

The reciprocating motion of the sieve is transmitted from an eccentric cam (5) fixed at the end of a shaft from a pulley (12) driven by hand crank. According to Crossley et al. (1983), the rotational speed that the hand crank can produce is 60 rpm. This speed is insufficient for effective sieving because it cannot produce sufficient shaking amplitude. Therefore, transmission mechanism was incorporated at a maximum speed ratio of 1:5 (PSG.TECH, 1982) to produce the rotational speed of the crank for the reciprocating motion. A rotational speed of 300 rpm produced the force that can overcome the weight of the reciprocating mass.

The material is agitated on the sieve mesh so that the starch can pass through the mesh under gravity and is collected through an outlet. The remaining residue is let out of the sieving compartment through an opening on the outlet end of the sieve. The opening is made such that any residue flowing through it would have built up before flowing out. In this way, all the starch milk would have been completely washed into the down tray before the residue is ejected. The height of the main frame is 750 mm to avoid back straining of the operator. Also during operation, the sieving compartment is kept closed so as to avoid the splashing of the material. This machine, being continuous in operation, prevents a situation whereby extra effort will be expended in discharging the residue, which is typical of most common locally available gari/cassava mash sieves. Hence, it saves energy, space, and labour thereby giving room for easy control and uniformity of product.

2.2 MACHINE DESIGN

The major design features were done on the reciprocating mechanism and the transmission system. The machine was designed taking into consideration that the highest density of mash to be processed on it is 1090kg/m^3. This density observed to be the highest of all the common local diets processed by wet sieving was determined by weighing a 10mls of maize mash. The capacity of the machine was based on the maximum speed of an average man (60rpm) (Crossley et al., 1983) and the average power output of a healthy man in a working day (0.1KW) according to Crossley et al. (1983).

Force required to reciprocate the sieve,

$$F_r = M_r d r \omega^2 \quad \text{.....(1)}$$

Power required to drive the sieve,

$$P = Fv \quad \text{.....(2)}$$

$$v = \pi \delta n_V \quad \text{.....(3)}$$

Where P is the Maximum power transmitted (PSG, 1982),

ω=angular velocity $= \frac{2\pi n}{60}$ .... (4)

n = rotational speed (rpm)

$M_r = M_{sc} + M_m$ .... (5)

M_r is the total mass reciprocated, M_{sc} is the mass of sieve compartment, M_m is the mass of the mash on the sieve, d is the diameter of the driven pulley.

The components of the transmission system were designed according to PSG TECH (1982). The diameter of the camshaft was 18mm. The diameter of the cam was 6cm. The oscillation amplitude was fixed at 2cm.

2.3. MACHINE PERFORMANCE TEST

The machine was tested with cleaned 3kg yellow maize (12% moisture content w.b) and wet milled. The mash was divided into three and each portion mixed with different volumes of water to give three level of mash concentration (w/w) according to Lewis (2000).

$$= \frac{\text{Mass of Mash}}{\text{Total mass of mash solution}} \times$$

Concentration (w/w) ....(6)

The concentration levels are 12.23%, 14.44% and 22.77%. Each level of mash concentration is further divided into two to make samples A and B respectively. Also, the machine was tested using three levels of feed rate. These were 0.85 g/s, 1.7 g/s and 4.3 g/s. The feed rates were determined by varying the time taken to pour each sample into the machine. A 300 μm sieve mesh was used in each case. The mash was sieved using the machine and hand sieving done for the purpose of comparison. The performance criteria during the test are the sieving capacity(C) adapted from Fellow (2003) and performance coefficient (Akintola and Braide, 1993).

$$= \frac{\text{Mass of Sample}}{\text{Time taken to sieve the sample/Area of sieve}}$$

Sieving capacity, C...................... (7)

Performance coefficient,

$C = \frac{C_1 - C_{cg}}{C_1} \times \frac{G_1 - G_{wr}}{G_1} \times 100$ ....(8)

Where G_{wr} = weight of reject at rubbish outlet, G_1 = Total weight fed into machine, C_{cg} = weight of reject in the product, C_1 = Total weight of contaminant at input ≡ the weight of particles above 300μm.

Each sample A was sieved for 20 seconds and used to evaluate the performance coefficient while the time taken to completely remove all traces of starch from samples B were recorded to evaluate the sieving capacity. Total weight of contaminant at input was taken to be the weight of particles above 300 μm. Since the feed rate for hand sieving could not be varied, only one level was used for it. After each sieving, the product and reject were collected separately, filtered with filter paper, sun-dried and weighed. Each experiment was replicated three times.

3.0 RESULTS AND EVALUATION OF MACHINE

Table 1 shows the particle size distribution of the wet-milled mash used for the test.

Tables 2 and 3 show the results obtained from the tests using the machine and hand sieving respectively. Generally from Table 2, the performance coefficient decreased with increasing concentration and flow rate while highest value of sieving capacity was recorded for a treatment combination of X_2Q_2 where the performance coefficient is 76. 42% and the sieving capacity is 7.5g/s. Also, from the result of varying the flow rate, the performance coefficient and sieving capacity decrease with increasing flow rate. However, X_3Q_1, X_3Q_2, X_3Q_3 results show poor performance. This was because the high concentration of the samples as a result of which there was insufficient water to wash the starch through the sieve. Hence the material only flowed through the surface of the sieve. *X_3Q_2 was the case of sieving using the machine without shaking the sieve with the shaking mechanism. This shows the effectiveness of the reciprocating mechanism on the machine. The sieving capacity for X_1Q_1, X_1Q_2, X_1Q_3, were very low because it took a longer time to complete each sieving operation even though the coefficient of performance is high. The value of the performance coefficient and sieving capacity for the machine ranged from 29.69% - 76.42% and 2.5g/s - 7.5g/s while the respective value for hand sieving was 27.2% - 61.49% and 1.46 kg/s. The performance of the machine from these records is far better than hand sieving.

4.0. CONCLUSION AND RECOMMENDATION

A manually operated wet sieving machine has been developed. It was tested and found to be efficient in the processing of the mash of agricultural products such as maize for the production of food products such as "Ogi" and starch. It has the optimum performance of 76.42% performance coefficient and sieving capacity of 7.5g/s when used to sieve yellow maize mash of 14.44% concentration at.1.7 g/s feed rate. The respective value for hand sieving was 61.49% and 2.5g/s. The equipment is easy to operate and maintain. It is highly recommended for every household in Nigeria and beyond where the desirable eating qualities of "Ogi" and starch diets are valued compared with the bad quality products from retail outlets.

Table 1: - Particle Size Distribution of mash

PARTICLE SIZE (µm)	% BY WEIGHT
> 850	1.05
> 424	7.02
> 300	15.52
> 212	17.46
> 125	35.97
> 106	9.40
> 63	11.12
< 63	2.46

Table 2: Sieving capacity (C), Performance coefficient (PC), for the various treatment combinations using the sieving machine. C_1=12.97g, G_1=55g. Ccg = 0

No	Treatment	G_{wr} (g)	$\frac{C_1 - C_{cg}}{C_1}$	$\frac{G_1 - G_{wr}}{G_1}$	PC,%	Sieving Capacity, C (g/s)
1	X_1Q_1	12.97±0.3	1.00	0.764	76.42	2.5
2	X_1Q_2	12.97±0.1	1.00	0.764	76.42	3.9
3	X_1Q_3	15.02±0.1	1.00	0.727	72.69	4.3
4	X_2Q_2	12.97±0.3	1.00	0.764	76 42	6.7
5	X_2Q_2	12.98±0.1	1.00	0.764	76.42	7.5
6	X_2Q_3	17.62±0.2	1.00	0.680	67.96	5.3
7	X_3Q_1	34.33±0.1	1.00	0.376	37 58	4.2
8	X_3Q_2	36.33±0.2	1.00	0.339	33.95	4.9
9	X_3Q_3	38.67±0.1	1.00	0.297	29.69	6.8
10.	*X_3Q_2	42.00±0.1	1.00	0.236	23.46	ND

Mean ± standard deviation for 3 determinations

Table 3: sieving capacity(C), Performance coefficient (PC), X_1, X_2, and X_3 using hand sieving

	Treatment	Gwr (g)	Ccg (g)	$\frac{C_1 - C_{cg}}{C_1}$	$\frac{G_1 - G_{wr}}{G_1}$	PC,%	Sieving Capacity C, (g/s)
1	X1	17.21±0.2	1.440±0.3	0.895	0.687	61.49	1.46
2	X2	31.11±0.1	1.580±0.1	0.878	0.431	58.67	2.50
3	X3	36.10±0.1	2.930±0.2	0.791	0.344	27.20	1.85

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