The Development of a Multi Purpose Wet Food Sieving Machine

F.T.Fayose

Department of Agricultural Engineering Technology, Rufus Giwa Polytechnic, P.M.B. 1019

Owo, Nigeria.

E mail: fayosesayo@yahoo.com

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. Therefore, a motorized starch extracting machine, based on shaking mechanism was designed, fabricated and tested to solve the problem associated with sieving of starch and other agricultural crops in Nigeria. The machine consists of a hopper, a mixing compartment, a sieving compartment operated by a crank and spring arrangement, collecting trays and outlets. The volumetric flow rate and the capacity of the machine are 0.0206 m^3/h and 22.45 kg/h respectively. The test considered concentration at three levels 12.2 %, 14.44 % and 22.77 %. The study showed that the machine performance coefficients and sieving capacity increased with decreasing concentration. Also, highest performance coefficients of 98% was obtained for sieving of maize while sieving capacity of 16.90g/sm^2 was obtained when the machine was used to sieve cassava. A unit of the machine costs ₦19, 480.00 as at April 2007. The maintenance of the machine is simple and recommended for small holders, local processors and home use.

Keywords*:* Development, *s*tarch, soybeans, wet sieving operation, machine, Nigeria.

1. INTRODUCTION

Wet sieving as a primary operation in food processing is time consuming and labour intensive. A simple definition of sieving is the separation of fine material from coarse ones by means of meshed or perforated vessel. Wet sieving (sieving in water) or the separation of fines from the coarse portion in an aqueous medium (water) is an indispensable process to milling, a primary process that is used to extract biopolymers from cereal grains. The water is normally used to negate static charges, break down agglomerates and lubricates near size particles. Wet sieving allows for the washing of starch granules and milk from other particles like fibres and hulls. It is a process very prominent in processing both cereal grains like maize, guinea corn, millet and root tubers like cassava into local diets and beverages such as Ogi (pap), Kunun and Burukutu (Inyang and Dabot, 2007) Also, it is used in extracting milk from soybeans, a very important rich source of protein for the general populace.

Moisture is often applied to the mash to aid in its extraction. In contrast to dry milling, the primary aim of wet milling is to separate and extract the grain biopolymers. The medium of water allows much more milling as heat generation through friction is greatly reduced, and freeing the starch granules from their protein matrix. Water also enables better suspension of individual particles than air, facilitating their separation on the basis of density. Steeping enables a clean separation of the germ from the endosperm and weakens the bonds between the starch granules and protein matrix thereby allowing their separation.

When carried out manually, wet sieving 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 unhealthy and a discouragement to producers. The tendency is to drift away from wet sieving operation and resort to bad quality products which makes storage very difficult, reduces the desirable eating quality and suitability of the product for further processing. However, research work has been focused on the development of a suitable mechanical system for wet sieving of agricultural products. There are a lot of wet sieves around e.g Gari and cassava mash sieves (Nweke et al, 1986). But the majority of these local sieves are batch operated and do not incorporate a mixing compartment needed for thorough washing of the milk from the food sample. Also, a wide variety of designs for screens exist differing in the complexity of their construction and their efficiency of operation. Basically rotating, vibrating screens and pusher-type centrifuges are used (Asiedu, 1990; Ihekoronye and Ngoddy, 1985 and Henderson and Perry 1976). In fact, Tabatabaeefar et al, (2003) built an auxiliary sieving and grading machine (TAG machine) in the Agricultural Machinery Engineering Department of Tehran, Iran. The machine efficiency was 84 %. However, this machine was meant for cleaning and grading of dry products.

Mixing with water can be carried out more or less separately from screening, but more often the two operations are combined in “wet screening” that is’ the mass is rinsed with the excess water on a screen which is in continuous motion. Screening can also be done by many mechanical devices such as screen bends, screen pumps, jet washers, but these devices find application in large scale processing. A simple, cheap and portable wet sieving machine is therefore required by local farmers in the tropics for wet sieving of agricultural products. This would improve the quality of product, make it meet international standard and increase production. Sieves are effective provided they are made to vibrate (Fellows and Hampton, 1992). 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).

Although a lot of work has been done locally to mechanize the milling and sieving of dry products, it is however observed that no extensive work has been done locally to mechanize the sieving of wet agricultural food products on small scale and home use basis. The aim of this study is to design, fabricate and test a mechanically operated wet sieving machine for small scale processing of wet agricultural crops.

2. MATERIALS AND METHODS

2.1 Machine Description

The motorized wet sieving machine was designed and fabricated. Figure 1 shows the isometric while Figure 2 the third angle orthographic projections of the machine. The components of the machine include the hopper (A) fastened with bolts and nuts to the main frame (G), the sieving compartment,(C) mixing compartment, which consists of fins welded on a shaft and suspended in a pipe. Teflon material (R) is used to suspend the shaft and to seal the sides of the mixing compartment (B), power transmission (P, O, N) and outlets (E, H). The machine is inclined from the upper base towards the lower base at an angle of 10^0 to the horizontal. It is made of stainless steel sheet SWG 18. The length of the sieve was such that by the time the pulp travel through it, all the entire milk content would have been completely washed.

The machine has a single reciprocating sieve (D) with adjustable inclinations and opening sizes of the sieves, making it suitable for different crops. The shafts are mounted on ball bearings. The reciprocating motion of the sieve is transmitted from an eccentric cam (L) fixed at the end of a shaft from a pulley (P) driven by 1/4 Hp, 1325 rpm electric motor. Speed reducing gear ratio 1:4 (Q) is incorporated to reduce the speed of the sieve and mixer, transmit 90^o angular motion and to achieve the use of a single electric motor. Rollers (F) are incorporated below the shaking screen to ensure that the oscillatory motion is transmitted smoothly and with negligible friction. The sieve is also spring loaded to enhance its vibration. The material is agitated on the sieve mesh so that the filtrate can pass through the mesh under the force of gravity into a tray (H) beneath and is collected through an outlet. The remaining residue is let out of the sieving compartment through an opening on the outlet end (E) of the sieve. The opening is made such that any residue flowing through it would have accumulated 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 machine can be maintained by washing thoroughly with clean water immediately after use. The mesh must be removed, drained and kept in a safe place free from abrasion.

2.2 Machine Design

The major design features were done on the mixing, reciprocating mechanisms 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 of maize was observed to be the highest of all the common local diets processed by wet sieving. The density of a wet milled portion was determined by weighing a known volume of the maize mash. Also, an experiment was performed in the laboratory to determine the optimum frequency required for effective sieving of maize mash. 3 revolutions per second was estimated.

Force required to reciprocate the sieve, $F_r = M_r d r \omega^2$…………...(1)

Power required to drive the sieve, $P = Fv$……………………....(2)

$v = \pi \delta n V$ …………………………………………..……..(3)

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

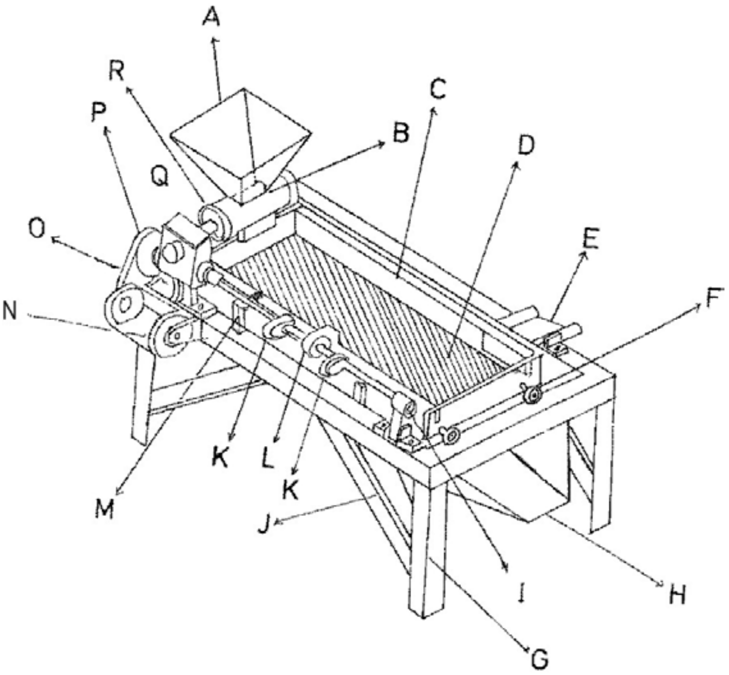
ω= angular velocity $= \frac{2\pi n}{60}$ ……………………………………. (4)

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 parameters that were determined during the design include shafts sizes, hopper capacity and dimension, pulley and belt sizes and belt tension. The power required to drive the machine is 0.16 kW. The diameter of the mixing shaft is 15 mm. The components of the transmission system are designed according to PSG TECH (1982). The diameter of the camshaft was estimated to be 15.2 mm. The diameter of the base circle of the cam is 6 cm while the rise is 2 cm.



LEGEND
A - HOPPER
B -MIXING COMPARTMENT
C -SIEVING COMPARTMENT
D -MESH
E -TRASH OUTLET
F -ROLLER
G -FRAME
H -MILK OUTLET
I -BEARING
J -BRACE
K -CAM BALANCE
L -CAM
M- SPRING HOLDER
N -ELECTRIC MOTOR
O -V-BELT
P -PULLEY
Q -SPEED REDUCTION GEAR
R -TEFLON

Figure 1. Isometric view of sieving machine.

2.3 Cost of Production

This comprise the cost of bought out components, cost of materials and parts fabricated and cost of machining and non machining job. The cost of production of the machine is presented in Table 1.

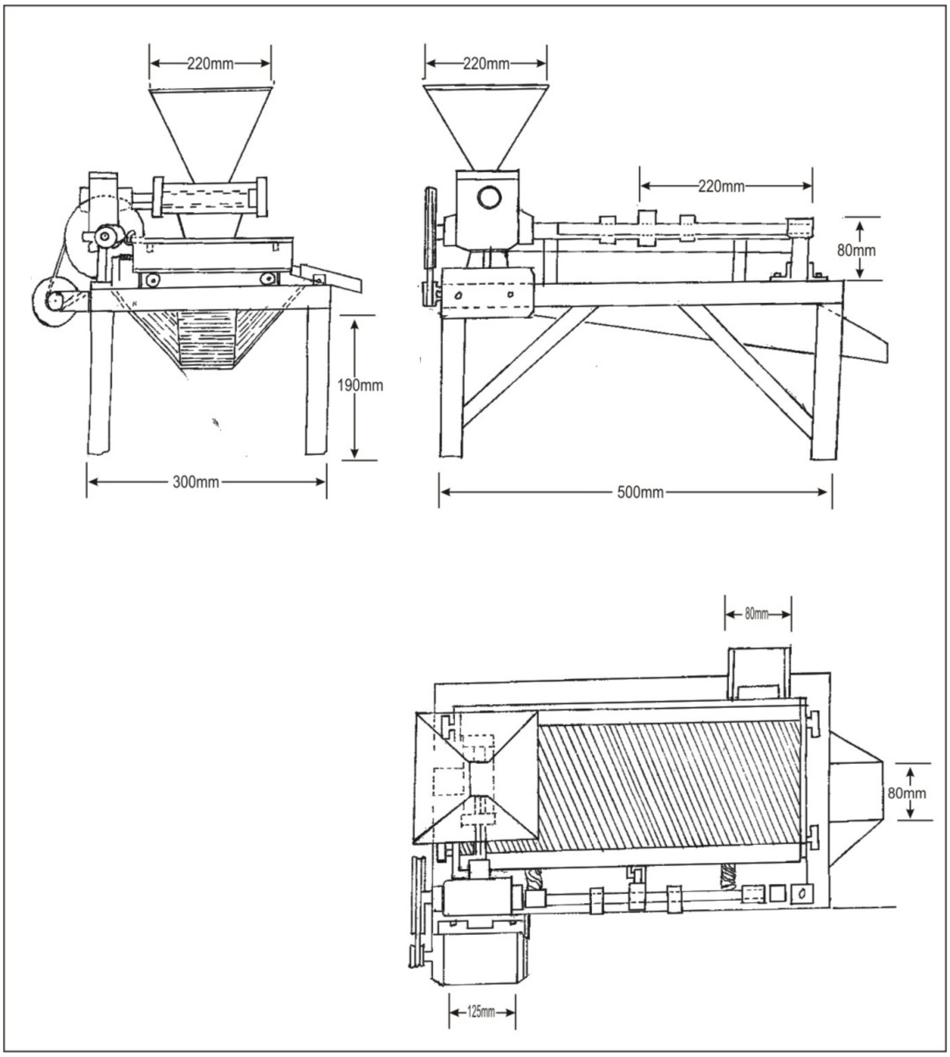


Figure 2. Third angle orthographic projection of sieving machine.

Table 1. Cost of Production of Machine

Description	Amount
Bought out components	₦8,600.00
Fabrication of parts and components	₦ 3,600.00
Machine and non machining jobs	₦ 6, 200.00
Other costs	₦ 1, 080.00
Total	₦ 19,480.00

2.4 Machine Performance Test

Samples of maize and soybeans were sourced from Owo main market and wet milled using standard methods (Asiedu, 1990; Ortherfor, 1978) while cassava tubers was sourced from Rufus Giwa Polytechnic Research Farm, prepared and grated according to Grace (2003). The mash of each crop 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). The concentration levels are 12.23%, 14.44% and 22.77%. Each level of mash concentration was further divided into two to make samples A and B respectively. A 300μm sieve mesh was used in each case. The performance criteria during the test are the sieving capacity(C) adapted from Fellow (2003) and performance coefficient.

$$\text{Sieving capacity, } C = \frac{\text{Mass of Sample}}{\text{Time taken to sieve the sample/Area of sieve}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The machine coefficient values were evaluated as described by Akintola and Braide (1993) as follows:

$$\text{Performance coefficient, } PC = \frac{C_1 - C_{cg}}{C_1} \times \frac{G_1 - G_{wr}}{G_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

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 milk from samples B was recorded to evaluate the sieving capacity. Table 1 shows the particle size distributions of the mashes used. After each sieving, the product and reject were collected separately, filtered with filter paper, sun-dried and weighed. Each experiment was replicated thrice.

3. RESULTS AND DISCUSSION

The machine was locally fabricated and assembled. Table 2 show the particle size distribution of the wet-milled mashes used for the test. Tables 3, and 4 show the results obtained from the testing of the machine. Generally from Table 2, Sieving capacity decreases with increasing concentration. The highest sieving capacity was observed for cassava at a concentration of 8.5 % where the sieving capacity is 16.90 g/s/m^2. Also, from Table 4, the performance coefficient decreased with increasing concentration. The highest value of performance coefficient was observed for maize at a concentration of 8.5 % where the performance coefficient is 98 %. Sieving with concentration 3 generally showed poor performance for all crops under consideration. This is because the high concentration of the samples does not allow for complete washing of the starch through the sieve. Hence the material only flowed through the surface of the sieve. The observation from the data in Table 3 that cassava has the lowest performance coefficient may be due to the fact that fresh cassava tuber has much more lower dry matter content than grains, especially, maize. Figure 3 shows that 12.23% is the optimum sieving concentrations that would give best performance in terms of capacity and performance coefficients (PC) for cassava, the same applies to maize and soybeans.

Table 2. Particle size distribution of foods samples.

Size of sieves µm	Maize mash % by wt.	Soybean % by wt.	Cassava % by wt.
>600	7.25	7.00	12.35
>425	22.55	27.55	3.20
>212	7.25	14.75	9.50
>170	11.50	8.75	10.25
>118	28.45	18.80	29.55
>106	4.60	7.55	17.25
>75	4.80	5.30	11.40
>63	11.15	8.05	1.50
>63	2.45	2.25	-

Table 3. Underflow of B samples, time spent in completely washing off the milk and sieving capacity.

Samples	Conc %	Underflow(g)	Sieving time (s)	Sieving capacity g/sm^2
Cassava	12.23	45.62 ± 0.05	45.00	16.90
-	14.44	45.62 ± 0.05	48.00	15.84
-	22.77	45.62 ± 0.05	52.00	14.62
Maize	12.23	67.9 ± 0.44	90.00	12.57
-	14.44	67.9 ± 0.44	101.00	11.20
-	22.77	67.9 ± 0.44	111.00	10.19
Soybeans	12.23	66.50 ± 0.20	80.00	13.85
-	14.44	66.50 ± 0.20	84.00	13.19
-	22.77	66.50 ± 0.20	87.00	12.74

Table 4. Performance Coefficient (PC) of cassava, maize and soybeans.

Crop	No	Treatment	G_{wr} (g)	C_1-C_{cg}/C_1	(G_1-G_{wr})/G_1	PC %
Cassava	1	12.23	24.38	1.00	0.65	65
	2	14.44	24.38	1.00	0.65	65
	3	22.77	30.60	1.00	0.56	56
Maize	4	12.23	1.14	1.00	0.98	98
	5	14.44	1.14	1.00	0.98	98
	6	22.77	4.92	1.00	0.92	92
Soybeans	10	12.23	3.50	1.00	0.94	94
	11	14.44	3.50	1.00	0.94	94
	12	22.77	11.11	1.00	0.84	84

C_1 = 0, G_1 = 70, C_{cg} =0

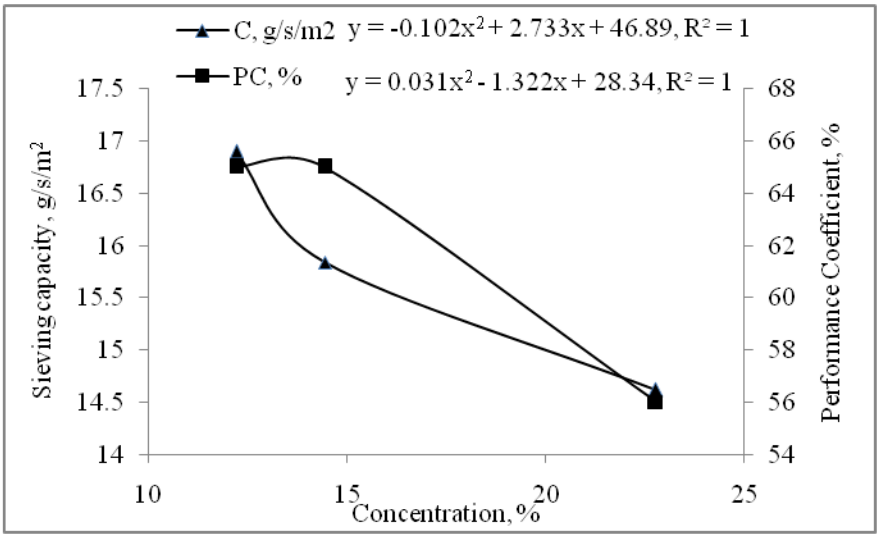


Figure 3. Variation of concentration with sieving capacity and Performance coefficient for cassava.

4. CONCLUSION AND RECOMMENDATION

A multi – purpose 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, cassava and soybean for the production of food products such as “Ogi”, soymilk and starch .Generally, sieving capacity and performance coefficients decreased with increasing mash concentration. The highest performance coefficient was observed with maize, followed by wheat and lastly cassava. 12.23% is the optimum sieving concentration that would give best performance in terms of capacity and performance coefficients (PC). 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 outlet.

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