DEVELOPMENT OF A SPRING-LOADED CASSAVA DEWATERING PRESS

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Abstract

Cassava is a perishable commodity with a shelf life of less than 3 days after harvest. Processing provides a means of producing shelf stable products thereby reducing losses, adding value, reducing the bulk to be marketed and increasing the shelf life. To arrest its perishable nature, size and moisture reduction of the wholesome tuber is important to process it into stable commodities such as flour, garri, etc. Seventy percent (70%) of cassava processed as human food is garri (Oduro et. al., 2000). Its wide consumption is attributed to its relatively long shelf life and its easy preparation as a meal. It is the most consumed and traded of all food products made from cassava roots. Dewatering is an important process in the processing of fresh cassava to garri.Stones and log of wood has been in use locally which is laborious and time consuming. Mechanizing this process over the years has evolved with several dewatering machines designed and fabricated to ease the rigoursand time wastage associated with it.The dewatering press designed, fabricated and tested in this research has helical springs incorporated to its base upon which the bagged cassava mash to be dewatered sits. This allows better compaction pressure on it and aid the dewatering processing. During the preliminary test, a dewatering rate of 8.18 Kg/H, final moisture content of 21.09% and dewatering efficiency or water loss of 64.78% was achieved.

Key Words: *Development, Dewatering, Spring-loaded, efficiency and evaluation*

1.0. INTRODUCTION

Cassava (*Manihot esculenta* Crantz*)* is a tuberous root crop grown in the tropics, with low cost vegetative propagation. It belongs to the family of *Euphorbiaceae* and originated from South America (Nhassico *et al.*, 2008). The root is drought resistant and capable of growing in different types of soil and seasons (Taiwo, 2006). As one major staple food in the tropical and subtropical region, cassava provides food for a population of more than 500 million across Africa, Latin America and Asia (Opara, 1999; Montagnac *et al*., 2009).The two broad markets for cassava in Nigeria are traditional food and industrial products. Most of the cassava grown in Nigeria is processed and sold as traditional food. Just as production of cassava is spread across all Nigeria's agro-ecological zones, so also are the markets for the common cassava food products, especially gari.Gariis a partially gelatinized (by toasting), free-flowing granular flour with a slightly fermented flavor and sour taste. In West Africa, it is the most consumed and traded of all food products made from cassava roots. It is consumed either soaked in cold water or stirred in boiling water to make a stiff paste and consumed with choice soup(Oti et al, 2010). Seventy percent (70%) of cassava processed as human food is *gari* (Oduro *et. al.*, 2000). Its wide consumption is attributed to its relatively long shelf life and its easy preparation as a meal.

Nigeria is widely acknowledged as the largest cassava producer in the world, accounting for over 70% of the total production in West Africa (NBS, 2007).Cassava rootsdeterioraterapidly within 72 hours of harvest, the post harvest losses of cassava in developing countriesaccording to FAO (2011) ranges between 26- 40%.

In a bid to arrest this trend, cassava is processed into more viable products; first reducing the size of the wholesome tuber by chipping or flaking then drying to increase the shelf life. Also the tubers are processed into a coarse granule flour called Garri in Nigeria and Farinha in Brazil.The production of fresh cassava to garri involves various processes as highlighted in figure 1, the aspect this research focuses on is the dewatering of the grated cassava mash.

According to Sinha et al., (2000), dewatering is a pre-drying alternative that deserves investigation. The most simple and common traditional cassava mash dewatering process involves the use of logs of wood and heavy stones, which serve as load, arrangedon, bagged and tied cassava mash for pressing out the moisture. In Latin America, cylindrical shaped basket specially woven so that the shape can be varied called Tipiti is the common traditional dewatering equipment. The basket is filled with fresh cassava pulp and hung from a tree branch. The basket is then pulled down until it is narrow and long thereby applying considerable pressure to drain off the cyanide containing fluid (FAO, 2013). More recently, screw presses and hydraulic presses have been introduced into dewatering of cassava mash. The only snag is the need to intermittently apply pressure to the mash so as to ensure adequate dewatering.

This operation is mainly carried out locally by loading bagged cassava mash to expel water and cyanides; this is not only tasking and ineffective, but also time consuming. This often result in a very poor quality of the products, the conditions during processing are generally unsanitary and unwholesome (Hahn and Keyser, 1985; Hahn et al., 1986).

To minimize the level of drudgery, improve processing hygiene and ensure the wholesomeness of processed cassava products, serious attention is needed to develop appropriate processing equipment for the various unit operations in cassava processing. In answer to this call several efforts has been made in the mechanization of cassava processing, hence the development of processing machines such as cassava grater, chipper, dewatering press, etc.

The moisture content of the cassava root is high, such that dewatering of the roots mash is a vital aspect in any of its processing line. According to Kolawole et. al. (2010), cassava contains 70% moisture content, which must be reduced to acceptable level for the processing of the mash to be convenient.

Dewatering as a unit operation plays a major role in processing cassava roots into high quality cassava flour and garri. It hastens the drying of the mash, where the rate of drying determines the quality of the flour produced. Dewatering usually is aimed at reducing cyanide level, improving processing convenience, storability and palatability is a vital unit of most cassava processing lines.

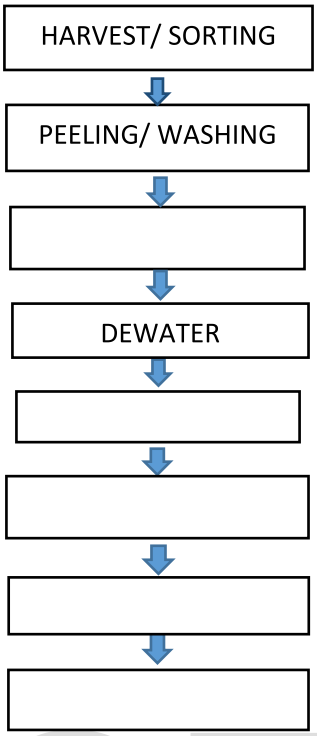

Figure 1: Block diagram for the processing of fresh Cassava tuber to Garri.

The major objective of this research is to improve the efficiency of dewatering process by incorporating springs into the press base to increase the compaction of the product and aid the pressure distribution under load thereby enhancing dewatering operation.

2.0. MATERIALS AND METHODS

2.1. Design Consideration

In the design of the spring loaded dewatering press the following were put into consideration,

i. Availability of the materials
ii. The cost of the materials
iii. The spring parameters of the helical springs.
iv. The maximum load capacity of the dewatering press per batch.
v. Dewatering time.

2.1.1. Construction Materials

i. Angle iron (50 x 50mm; 25 x 25mm)
ii. Channel bar
iii. Helical spring
iv. Electrode
v. Wooden planks
vi. Hydraulic press

2.2. Working Principle and Description of the Spring LoadedDewatering Press.

The spring loaded press is manually operated. The dewatering process is achieved by applying pressure on the grated pulp to reduce its moisture content; the cassava mash particles are constrained while the liquid is free.

It has a rectangular main frames, big enough to accommodate a maximum of six 50kg bags of cassava mash. The spring loaded was constructed with angle iron and braced on three sides by two to three stripes of angle iron while the fourth side is left open for loading.

Two U-channel bars sit side by side on the top of the frame. Two wooden platforms were placed between the top frame and the base of the main frame. One of the platforms was attached to the four helical springs fixed to the base of press. Bags of cassava mash to be dewatered would be arranged on this surface. The other platform which is removable and would be placed on the bags during dewatering. A hydraulic jack sits on this platform with its head on the U channel to apply pressure on the cassava mash.

Four compression helical springs arranged on damper pipe attached to the base of the press who store kinetic energy due to the force exerted by the hydraulic jack and the weights of the loaded cassava mash store energy in form of potential energy. The stored energy will subsequently be released later to close up pressure gaps as the bags of cassava mash reduces in size and weight as a result of water loss during dewatering. This will keep the cassava mash under the pressure required to drain its fluid throughout the dewatering process. These forces exerted by the springs and the hydraulic jack would also be evenly distributed over the surface of the platform and consequently transferred to the bags.

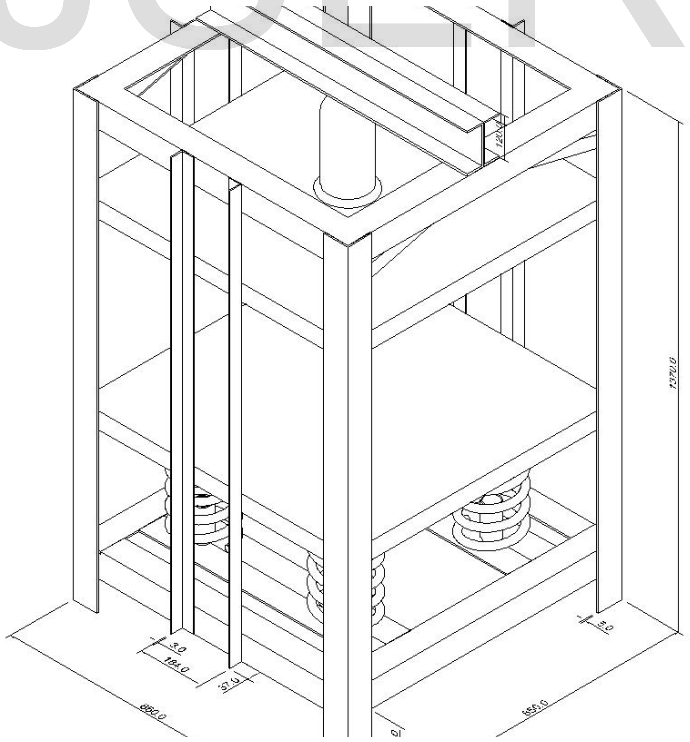

Figure 2: Isometric view of the spring loaded dewatering press

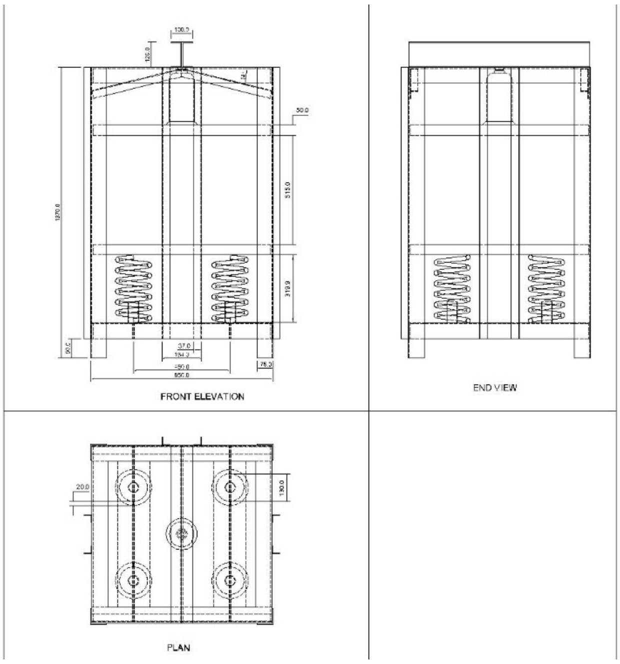

Figure 3: Orthographic projection of the spring loaded dewatering press.

2.3. Design calculations

The following were considered in the design of the shaft using equations as described by Khurmi and Ghupta (2004) as follows:

Spring Design

a. The stress induced in the spring due to the load was determined by,

$$S_s = K\frac{8FD}{\pi d^3} = K\frac{8FC}{\pi d^2} \quad (1)$$

Where, S_s *is total shear stress*, N/m^2, D *is mean diameter of coil*, m.

$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$, *called the Wahl factor*, F *is axail load*, N, d *is diameter of spring wire*, m; and

$C = \frac{D}{d}$, *called the spring index.*

b. The deflection in the spring due to the applied load was determined by

$$y = \frac{8FD^3n}{d^4G} = \frac{8FC^3n}{dG} \quad (2)$$

Where, n is number of active coils, y is axial deflection, m, and G is modulus of rigidity, N/m^2.

c. The spring rate or spring constant which is the force in Newton per meter of deflection:

$$k = \frac{F}{y} \quad (3)$$

d. The energy stored in the spring is determined by

$$E_s = \frac{S_s^2}{4G} J/m^3 \quad (4)$$

Where, S_s *is shear stress*, N/m^2 and G *is modulus of rigidity*, N/m^2

e. Solid Length of spring

When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be solid.The solid length of a spring is the product of total number of coils and the diameter of the wire.

Mathematically, Solid length of the spring (LS),

$$\text{LS} = n'd \quad (5)$$

Where, n' *is total number of coils* and d is the diameter of the coils, m.

f. Free length of spring

The free length (LF) of a compression spring, is the length of the spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflection or compression of the spring and the clearance between the adjacent coils (when fully compressed).

Mathematically,

$$LF = Solid\ lenght + \text{Maximum compression} + clearance\ between\ adjacent\ coils \quad (6)$$

The clearance between the two adjacent coils is taken as 1 mm.

g. Spring index

The spring index is defined as the ratio of the mean diameter of the coil to the diameter of the wire.

Mathematically,

$$spring\ Index, C = D/d \quad (7)$$

Where, *D* is Mean diameter of the coil and *d* is diameter of the wire.

h. Spring rate

The spring rate (k) (or stiffness or spring constant) is defined as the load required per unit deflection of the spring.

Mathematically,

$$k = \frac{W}{\delta} \quad (8)$$

Where, W is Load, δ is deflection of the spring.

i. Pitch: is the axial distance between adjacent coils in uncompressed state.

Mathematically,

$$pitch\ of\ coil\ p, = {}^{Free\ Lenght}/_{n'} - 1 \qquad (9)$$

The pitch of the coil may also be obtained by using the following relation, *i.e.*

$$pitch\ of\ coil\ p, = \frac{L_F + L_S}{n'} + d \qquad (10)$$

Where, L_F is Free length of the spring, L_S is Solid length of the spring, n' is total number of coils, and d is diameter of the wire.

j. Buckling

The critical axial load (Wcr) that would cause buckling in the spring was calculated using the following relations,

$$Wcr = k \times KB \times LF \qquad (11)$$

Where, k is spring rate or stiffness of the spring = W/δ, LF is Free length of the spring, and KB is buckling factor depending upon the ratio LF / D.

k. Energy Stored in spring

Assuming, W is the load applied on the spring, and δ is the deflection produced in the spring due to the load W.

The energy stored in a spring is, calculated as

$$u = \frac{1}{2} W.\delta; \qquad (12)$$

Maximum stress induced in the spring is given as,

$\tau = K \times \frac{8W.D}{\pi d^3}$ and deflection in the spring is given as, $\delta = \frac{\pi.\tau D^2.n}{K.d.G}$

Therefore,

$$u = \frac{\tau^2}{4K^2.G} \times V \qquad (13)$$

Where, V *is* Volume of spring wire, m^3 (i.e. length of spring wire x cross sectional area of spring wire)= $\pi.D.n\left(\frac{\pi}{4} \times d^2\right)$.

2.4. Test Procedures.

2.4.1. Test Materials

The preliminary evaluation of the spring loaded cassava mash dewatering press was carried out using the following materials:

Motorized cassava grater, electric oven, digital stopwatch, digital weighing scale, fresh cassava tubers, woven bags, collection bowls, analog weighing scale, knives, etc.

2.4.2. Procedure

After grating the fresh peeled cassava, samples were taken for moisture content analysis; it was bagged into six (6) woven bags tagged 1 to 6, weighed on the analog weighing scale and recorded. The bags were tied and loaded into the press and padded with a wooden frame from sides and top to serve as seat for the hydraulic jack.Itwas jacked to its maximum capacity (2 tons) and collection bowl was placed at the outlet pipe to collect the effluence. The cassava mash was left on jack for 24 hours to allow fermentation. The final weight of the dewatered bags were measured and recorded. Sample from each bag was taken for moisture content analysis.

2.4.3. Evaluation Parameters

The following parameters were determined from the test,
(i.) **Dewatering rate (DR) kg/s:** this represents the quantity of effluent the machine expresses from the cassava mash per unit time.
It is determined by the expression;

$$DR = \frac{W_i - W_f}{t} \quad (14)$$

Where, $W_i$is weight of cassava mash before dewatering/kg, W_f is weight of cassava mash after dewatering /kg and t is time taken to dewater/s.

$$DR = \frac{302.85 - 106.65}{24} = \frac{196.20}{24} = 8.18 Kg / H$$

(ii.) **Moisture content (MC) %:** the percentage of moisture (in wet base) in the cassava mash before and after dewatering expressed by,

$$MC = \frac{W_b - W_a}{W_b} \times 100 \quad (15)$$

Where, $W_b$is the weight of cassava mash sample before oven drying/ Kg, $W_a$is weight of cassava mash sample after oven drying/Kg.
iii. **Water Loss orDewatering efficiency (ED) %:** This is the efficiency at which the press dewaters, it is expressed as,

$$E_D = \frac{W_e}{W_i} \times 100 \quad (16)$$

Where, W_e is weight of effluence water expelled by the machine (Kg) given as

$$W_e = W_i - W_f = 302.85 - 106.65 = 196.20 Kg$$

$$E_D = \frac{196.20}{302.85} \times 100 = 64.78\%$$

3.0. RESULTS AND DISCUSSIONS

From table 1, the preliminary evaluation of the machine showed the following:

i. **Dewatering rate:**The dewatering rate of 8.18 Kg/H was recorded during the experiment.Olusegun and Ajiboye, 2009, reported a dewatering rate of 16.56 Kg/H from their Vertical Squeeze Cassava Pulp Dewatering Machine. This is because the machine was electrically operated thereby giving a double dewatering rate.

ii. **Reduction in moisture content:**There was a reduction in moisture content from 59.87% to 21.09%.

iii. **Dewatering efficiency or water loss:**The dewatering efficiency of 64.78% was recorded. This shows an improvement over Oladipo et al, 2015manually operated single pole dewatering press which reported an efficiency of 38.15% and percentage for fermented cassava mash. Hence higher pressure was generated in the spring to aid the dewatering process.

Table 1: Test Parameters for the Preliminary Test of Spring Loaded Dewatering Press.

S/N	W_i (Kg)	W_f (Kg)	W_e (Kg)	$M.C_f$ (%)
1	50.60	17.40	33.20	20.59
2	51.00	17.72	33.28	20.80
3	50.80	18.80	32.00	22.16
4	49.40	17.00	32.40	20.60
5	48.85	18.68	30.17	21.43
6	52.20	17.09	35.11	20.95
	302.85	106.65	196.20	21.09

Initial Moisture Content ($M.C_i$) = 59.87%

Final Moisture Content on the average ($M.C_f$) = 21.09%

Dewatering Time/H =24H

4.0. CONCLUSION

An efficient dewatering press was designed, fabricated and tested which showed improved result in performance with 8.18Kg/H dewatering rate, 64.78% efficiency and an end product moisture content of 21.09% wet base. This machine will no doubt improve dewatering as a unit process in gari production by producing a well dewatered mash for frying into gari which also in turn increase the yield of mash to gari ratio as reported by Kolawole, et al, 2007.

ACKNOLEDGEMENTS

We thank the management the National Centre for Agricultural Mechanization (NCAM) for making funds available for this research; also staff of engineering and scientific services (ESS) for their support all through the period.

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APPENDIX

Plate 1: Pictorial View of the Spring Loaded Dewatering Press.