DEVELOPMENT OF A CASSAVA STARCH EXTRACTION MACHINE

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Abstract
Cassava starch extraction machine that is easy to assemble, operate and maintain was developed and tested. The major components of the machine are hopper, mixing unit, extraction chamber which houses the screw conveyor (auger) and sieve, discharge outlets and the power unit. The machine was powered by 2kw electric motor. The working principle of the machine is by feeding cassava mash and water through the hopper, under gravity they both fall freely into the mixing unit, the rotated stirrers mixed the mash and water properly before it is discharged to the extraction chamber where the screw conveyor move and rotates it over a sieve thereby causing the moist starch to viberate.The machine was tested with 5kg TMS 30572 cassava mash with different water quantity (10 – 22)litres. It was observed that at 18litres of water and 120rpm stirrers speed. The output capacity was 25.2kg/hr and the extraction efficiency was 80%. The total cost of production of the machine was ₦86,400.00. The machine is recommended for small and medium producers of cassava starch.

Keywords: Development, cassava starch, extraction, machine, production cost

1. INTRODUCTION

Cassava (*manihotesculentacrantz*) is a perennial tuber plant widely grown in many tropical countries including Nigeria (Adejumo, *et al*, 2011). Olukunle, (2005) reported that cassava is a major source of carbohydrate in most developing nations of the world. Sheriff, *et al*, (2005) described cassava as a wonder crop due to its potential use in several agro and agro-allied industries. Since 1990 Nigeria has surpassed Brazil as the world's leading producer of cassava with an estimated annual production of 54 million metric tons from 30million hectares of land (FAO, 2012). Starch is a polymer of glucose found in most plant (Thebaudin, *et al*, 2005). It is produced from various plants or crops like potatoes, cassava roots, rice, wheat etc. Starch is one of the most abundant substances in nature, it is almost unlimited resources. Starch is used as food (Sriroth and Peterson, 2000) it is also used to produce diverse products like textiles, adhesives; pharmaceuticals etc. Cassava starch is preferred amongst other starches because of its gelling property. FAO (2007) captioned cassava starch as native and modified starches. It is native starch when it is produced by the separation of natural occurrence, like starch from cassava roots can be use directly to produce certain food, such as noodles. While modified starch is a native starch that has been changed in its physical or chemical properties.. Modified starches are needed to improve textural paste and gels and also to modify cooking characteristics.

Starch production in Nigeria is dominated by cottage industries (Olukunleand Olukunle, 2007). Adepomola, (2004) identified ten large scale starch industries in Nigeria, Only one (Matna food company, Ogbese, Ondo state, Nigeria) is functional. The survey conducted by Adepomola, (2004) reported by Olukunle and Olukunle (2007) shows that the processing of cassava to starch is largely done using traditional or manual method.

Olukunle and Olukunle (2007) designed a cassava starch extractor, which is a modification of a fruit juice extractor. The machine consists of the milling/extraction mechanism, the transmission system, the upper half of the extraction chamber (cage), the perforated lower half of the extraction chamber (basket), the hopper, water pump and water delivery system, fiber outlet and the starch collector. The machine mills the peeled cassava tubers and conveys the mash into a stream of water flowing with high pressure; starch is separated through the perforated concave into the starch sedimentation tank.

Godwin (2013), said that the small- to medium scale production of starch in Brazil is schematically similar to that of starch in Colombia, He described that fresh roots cassava are delivered to the plant and fed into a rotary washer fitted with overhead water sprays for part of its length. As well as washing off dirt and debris, the tumbling action of the roots as they pass along the washer also removes most of the bark. Washed roots are transferred to the hopper-feed, roof disintegrator, via an inspection conveyor, at which an operator cuts up excessively large roots and removes remaining bark and stems.

(Grace, 2003) also designed a cassava starch extraction machine, this machine consist of a hollow cylindrical drum with tooth – edged steel blades sandwiched between local hardwood slats fixed longitudinally to its surface. The drum is mounted between two circular steel endplates on a central shaft and housed inside a steel casing, the base of which includes a screening plate. Recycled liquor from starch separators is continuously fed into the disintegrator. The resultant slurry of crushed roots passes through the screening plate into a sump tank from which it is pumped to the separators.

Bruinsma*et al.* (2001) designed two-stage separation cassava starch extraction machine. This is used to remove the liberated starch from the fibrous pulp (Massa). These employ two centrifugal separators, which have replaced the traditional rotating brush – and – screen washers. The centrifugal separator consists of a rotating conical screen, housed inside a shaped mild – steel casing, tapering from front to back the conical screen is a metal frame covered with a nylon mesh. The narrow end of the cone is closed with a fixed metal plate connected to the drive shaft. Slurry is pumped into the center of the separator (toward the fixed plate) and forced through the screen to an outlet at the bottom of the casing into a sump tank. Water is spraying into the slurry from jets positioned around the screen. In the sump tank, the slurry receives extra water to facilitate pumping it over aflatbed reciprocating screen to remove any remaining fiber (large plants employ an additional centrifugal separator). The slurry then enters second separator for further starch extraction. Liquor discharged from the second separator is returned to the disintegrator and the suspension of pulp or “starch milk: is discharged to storage tanks.

Trim, *et al*. (2003) reported his cassava starch extraction machine dimensions for the channels vary considerably from plant to plant; in length ranged from 150 m to 200m; in width, 0.6 m to 1.0m and depth ranged from 0.4 m to 0.6m. The channels are usually lined with ceramic tiles because both starch and starch milk attack concrete. The channels are roofed to protect the starch from rain or direct sunlight. After fermentation, the starch is removed from the tanks, broken up with a spike mill and dried on hessian sacks laid on raised drying tables usually made of bamboo. The drying starch is agitated manually at regular intervals. When dry, the starch is collected, milled to a powder and packaged into bags.

In India, tanks are used instead of channels for sedimentation, because of historical reasons. After overnight settling and removal of the supernatant liquor, the starch cake had a concentration of solids at 50%, but after washing, the concentration was 55%, starch and crude fiber concentrations of the settled cake in two plants were similar, averaging 96.7% for starch and 0.3% for crude fiber (dry matter basis). The changes occurring in the starch, this is as a result of fermentation which is the subject of much recent research (Kurmi and Guptal, 2005). Although a minimum fermentation time of 30days is necessary, starch often remained in the tanks at the two plants for longer periods because of the lack of available drying space. Such prolonged fermentation had no detrimental effect on starch quality. The temperature of the fermenting starch at the two plants ranged between 12^0C and 13^0C.

However, then new technologies have been introduced and existing ones improved, to increase processing efficiency and open new markets for both cassava starch and flour. These new technologies include improved equipment for starch processing includesrappers with saws, continuous flow washer-pesters, vibrating screens and sedimentation channels.

2. MATERIALS AND METHODS

2.1 Design Machine Features

The machine (plate 1.) consists essentially of the following components; mixing unit, extraction chamber, discharge unit, frame and power unit.

2.1.1 The Hopper

This is the unit where the input materials (cassava mash and water) are fed into the machine. It is constructed with Galvanized Iron Sheet gauge 14

2.1.2 Mixing Unit

This unit consists of 16 stirrers attached to a single solid shaft. It is use for proper mixing of cassava mash and water.

2.1.3 Extraction Chamber

This consists of screw conveyor (auger) and sieve, the conveyor moves and rotates the diluted mash over a sieve thereby causing the moist starch to liberate.

2.1.4 Discharge units

This is where the moist starch and chaff are discharged out it is constructed with Galvanized Iron Sheet gauge 14.

2.1.5 Frame

This unit bears the load of the machine. It is also give support to the machine during operation. It is made from 150mm angle iron.

2.1.6 Power Unit

This unit supplied power that rotates both the stirrers and the screw conveyor with 2Kw electric motor through chain and sprocket

Plate 1: Pictorial view of cassava starch extraction machine

2.2 Operational Principle of the Machine

Cassava mash and water were fed into the machine through the hopper, under gravity the cassava mash water fall freely into the mixing unit, power was provided by an electric motor, which drive the stirrers and the screw conveyor, the rotated stirrers mixed the cassava mash and water properly to a desirable cassava mash : water ratio, the diluted cassava mash is discharge through the stopper to the extraction unit where the conveyor move and rotates it from one end to the other over a sieve thereby causing the moist starch to liberate through the sieve and the chaff is also discharge at the other outlet.

2.3 Design Analysis

The major designs were on the feeding chute, stirrers, screw conveyor, shaft selection, and power requirement.

2.3.1 Feeding Chute

The cassava starch extraction machine is expected to have a 30kg/hr. therefore, a hopper that is a pyramidal frustum with 45^0 angle of inclination was selected, with top opening of 400mm x 400mm, bottom opening of 150mm x 150mm and a side length of 200mm, angle 45^0 was used for the inclination to allow easy flow of the input material.

$$\alpha = tan^{-1}\mu ------------------------ (1)(Kolawole, 2012)$$

α= angle of inclination and μ = co-efficient of friction of cassava mash

2.3.2 Stirrers/Mixing Unit

16 stirrers were attached to a single solid shaft for proper mixing of cassava mash and water.

F_t and F_s are two forces acting on the stirrers

$$F_t = \frac{MV^2}{r} \text{ and } F_s = F_t tan\theta -------------- (2)(Hall, et\ al, 1980)$$

Where,

M = mass of the stirrer, V = velocity, r = radius and θ = 20^0

2.3.3 Screw Conveyor

The conveyor moves and rotates the diluted mash over a sieve thereby causing the moist starch to liberate.

Capacity of the conveyor $Q = \pi D^2 Sn\Psi\rho C ----- (3)(Hall\ et\ al, 1980)$

Where,

D = Screw diameter, S= Pitch, n = speed, Ψ = loading efficiency $\rho =$ Bulk density and c = Factor for inclination to horizontal

2.3.4 Power requirement

The power requirement of the machine was determine with the expression by Khurmi and Gupta (2005)

$$P = \frac{2\pi nT}{60} ------------ (4)$$

Where, P = power (watt), n = shaft speed (rpm) and T = torque required to turn the shaft. Therefore, an electric motor of 2Kw (2hp) was selected.

2.3.5 Shaft Selection

The diameter of the shaft used was selected using the expression by (Hall et al, 1980)

$$D^3 = \frac{16}{\pi S_S}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \text{-------------(5)}$$

Where,

D = Diameter of the shaft (mm), Ss = Allowable stress, 40 x 10^6N/m^2

M_b = Maximum bending moment, 1051.26Nm, M_t = Maximum torsional moment, 136.05Nm, K_b = Shock and fatigue to bending moment, 2.0, K_t = Shock andfatigue factor to torsional moment, 1.5 calculated shaft diameter was 34.60mm.

Therefore shaft of 35mm was selected for both.

2.4 Machine Production Cost

The production cost of cassava starch extraction machine was given under the following sub-heading below. It was calculated by using the concept of labour and machine hour rate (Godwin, 2013) for the overall production process involved in the fabrication of the machine.

i. the cost of Bought-Out components, ₦40,500
ii. the cost of materials, ₦30,200
iii. the cost of machining jobs, ₦10,500
iv. the cost of non-machining jobs, ₦5,200

The total cost of the production was ₦86, 400k

2.5 Test Procedure

The machine was tested following these procedures

i. 5Kg of TMS 30572 cassava mash was prepared at different quantity (10- 22) litres of water
ii. The weight of the mash and water input into the machine
3 The weight of the starch and chaff discharges after oven dried at 10.08 moisture content was also recorded.
4 The duration for each operation was noted.

3. RESULTS AND DISCUSSIONS

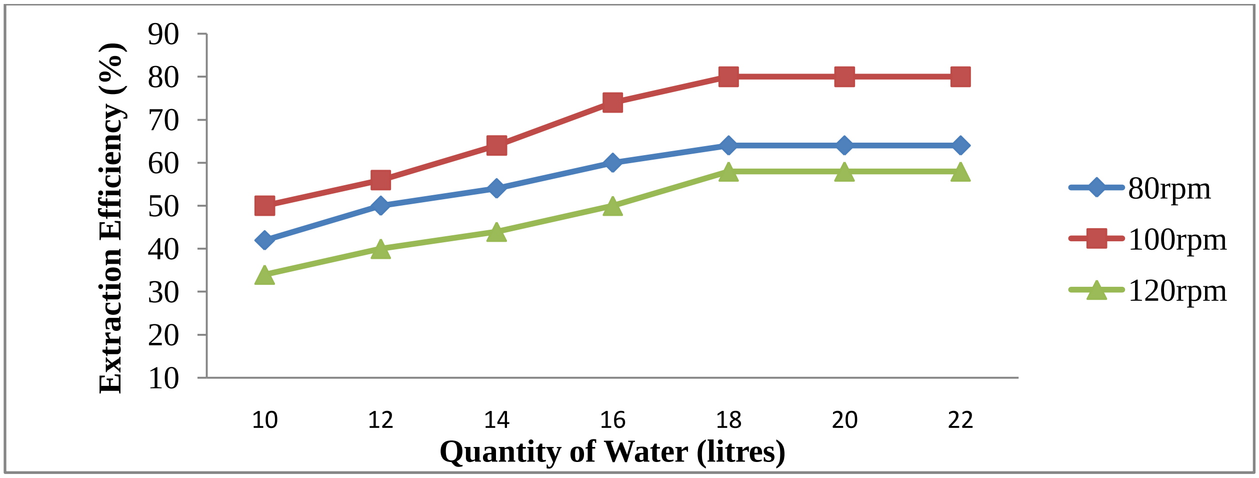

Fig. 1: Effect of stirrers' speed and water quantity on extraction efficiency

3.1. Performance Evaluation of the Machine

In Fig. 1, it was observed that the extraction efficiency for 80rpm stirrers speed ranged from 42% to 64%, whereas it was 50% and 80% extraction efficiencies for 100rpm while the extraction efficiency for 120rpm stirrers speed ranged from 34% to 58%.

Therefore, it can be deduced from the foregoing that the stirrers speed of 100rpm with appropriate water quantity of 18 litres have a significant effect on the extraction performance of the machine. Figure 1 shows view of the machine.

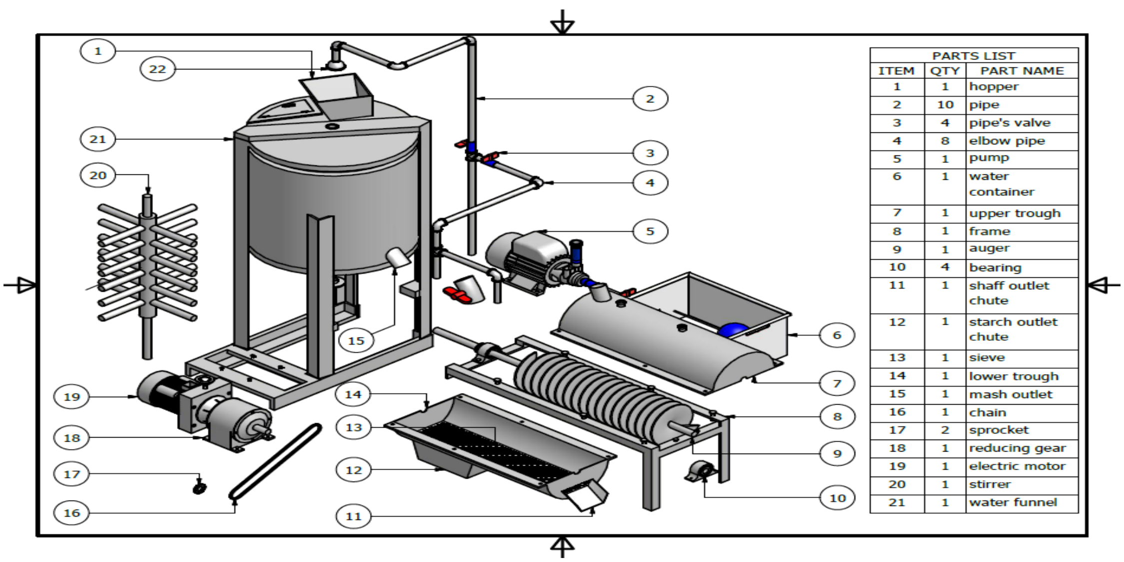

Figure 1: Exploded View of the Machine

4. CONCLUSIONS

A cassava starch extraction machine was developed and evaluated. The machine had an output capacity of 20.2kg/hrwith extraction efficiency of 80%. A 3.5kg dried starch was obtained from 5kg TMS 30572 cassava mash. The highest starch discharged was obtained when the stirrers speed was 120 rpm and 18 litres

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