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Development and performance evaluation of a motorized globulator for tapioca production

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Abstract: A research was conducted to improve the appearance of locally produced tapioca in Nigeria. A motorized sago globulator, reciprocating at about 7.4 cm amplitude and 274 rev/minute being powered by a 2Hp electric motor was developed to produce globules of tapioca. The efficiency of the globulator with respect to the 2 mm globules sizes was determined with moisture content variation of starch granules, variation in starch weight supplied into the globulator and the sagging depth of the jute cloth in the globulator. From the results obtained, the moisture content of starch granules at the point of loading into the machine is directly related to the globulation efficiency with respect to the 2 mm grade size. Moisture content of about 44.5 – 46.3 % was found optimum for globulation above which starch granules lump together after globulation. Loading weight of about 150 g was rated best as higher values may result in congestion in the action zone hence, inefficient globulation. The sagging depth of the jute bag has no effect on the globulation efficiency. The globulator has production capacity of 163.20 kg per man-day operation for tapioca production.

Keywords: Tapioca, globulator, efficiency, moinsture content

Introduction

Cassava root (*Manihot esculenta* (Cranz)) is probably the most important food crop in tropical and sub-tropical regions of the world. It constitutes the major source of dietary energy for over 500 million people (Cock, 1985; Jackson and Jackson, 1990). It is estimated to provide approximately 37 % of the total calorie consumed in Africa, 11 % in Latin America and 6 % in Asia (Dixon, 1979; Lancaster *et al*., 1982; FAO, 1998). There are also many agronomic (relative resistance to pests and diseases, flexibility in planting and harvesting, etc.) and social reasons (income earner for women, flexible labour requirements) why cassava has become so important (Phillips *et al*., 2004). A major constraint is that cassava deteriorates rapidly. Cassava has a shelf life that is generally accepted to be of the order of 24-48 hours after harvest. Hence, fresh cassava roots must be processed into a more shelf stable form within 2 to 3 days from harvest. One of such cassava product is tapioca grits.

Tapioca grit is a partly gelatinized dried cassava starch, which appears as flakes or irregularly shaped granules (Adebowale *et al*., 2006). It is usually soaked, and cooked in water to form tapioca meal while sugar and/or milk are added before consumption. It is consumed in many parts of West Africa and widely accepted as a convenience (Adebowale *et al.,* 2006). Oyewole and Obieze (1995) reported some preliminary works on the traditional processing of cassava to tapioca grits. Onitilo (2003) provided other baseline information on varietal and roasting influences on some chemical and pasting properties of tapioca grits while Adebowale *et al.* (2006; 2007) reported the effect of roasting methods and cassava variety on the sorption isotherms of tapioca grits. Unlike West Africa region, tapioca or 'sago' has been developed into different grades in some other parts of the world. Uniform size of tapioca grits will encourage consumers' preference, reduce associated rigor of preparation to meal, shorten preparation time, and enlarge domestic, regional and international marketing of newly branded Nigerian tapioca grits. Hence, this project reports our findings on the development and performance evaluations of a motorized globulator for tapioca grits processing.

The machine consists of a wooden tray of

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specific dimensions which is partitioned into four compartments. A jute clothe is loosely fitted (i.e. sagged within the compartments some distance down) to the edges of each compartments. The jute bag is meant to hold starch granules for globulation. The globulator is designed to oscillate at a frequency of 208 rev/minute with amplitude of 37 mm. The oscillatory movement of the wooden tray and effect of the coarseness of the jute cloth enable the starch granules to adhere together and form globules after some minutes depending on the globules sizes required.

A pair of wooden plank of 600 mm length by 50 mm width by 50 mm breadth and another pair of planks of 500 mm length by 50 mm width by 50 mm breadth is formed into rectangle such that it has the area of 300,000 mm^2. Each of the planks is coupled together with the aid of angle iron, bolt and nuts to form the tray. Slots of about 10 mm deep are created on the internal part of the wooden tray to harbor the stainless strips which are used to secure the jute bag. The frame made of angle iron supports the tray and electric motor. The pieces of angle iron that forms the frame were welded together to form a single entity member. The angular rotation of a 2 Hp electric motor is expected to be translated into rectilinear motion which effects the oscillation of the tray. This tray also is expected to oscillate with amplitude of 7.4 cm. To effect this conversion, a circular metal plate is drilled at the center to a diameter of 2 cm. From the center of this drilled an offset distance of 3.2 cm was measured and at this point, another drill was made to harbor a short length shaft, also 2 cm in diameter.

A longer shaft is inserted through the first drill in the circular plate while a pair of bearing and housing systems secures the end of the shaft to the support as shown in Figure 1.A pulley is attached to the extreme end of the long shaft. A v-belt connects the pulley of the electric motor to the pulley of the long shaft and this forms the transmission system which converts an angular motion into a linear oscillatory motion. A connecting rod having a cylindrical section at the two ends connects the transmission system to the tray. The distance between the two bored cylindrical sections provided the required amplitude of the tray. This forms the crank mechanism shown in Figure 2 and Plate 1. As the pulley rotates (being powered by the electric motor) it transmits the rotational motion to the linear oscillatory motion of the tray via the shaft crank and connecting rod in the required frequency. The connecting rod is fitted to the tray such that it can be easily dismantled at any time.

The movement of the tray is guided in a rail. This movement of the tray is enhanced by welding of four pieces of short length of shaft to the four corners of the tray and four ball bearings are secured into these four short shafts to allow the free rolling of the tray within the rails without obstruction. The surface of the rails is ensured to have enough friction to allow smooth movement without slipping and skipping of the ball bearings. The jute clothes are cut correspondingly to the dimension of the compartments of the globulator such that two compartments of the globulator has jute clothes loosely fitted about 13.5 cm deep from the center of the tray and the other two fitted loosely about 11cm deep from the center of the tray to the bottom. The edges of the jute clothes are secured by studs such that the cloth can easily be replaced when worn. The stainless strips were arranged along the edge of the tray to prevent contamination of the starch granules by the wooden or the metal material which may hence, constitute health hazard to consumers. At all levels of fabrication, the design specifications of the machine was properly monitored and ensured strict adherence so that the required end is not missed out.

Design calculations

The dimensions and configurations of the components defined in the design of the globulator was calculated and checked to see if they can meet the various requirement stated. The electric motor (2Hp) was a medium speed electric motor with the frequency of 1440 rev/minute. The required frequency of the tray is at least 208 rev/minute. To achieve this, there has to be a reduction of the frequency of the electric motor and this was done by transmitting the angular rotation to a larger pulley and this resulted in a lower frequency of the tray.

$$\frac{1440}{208} = 6.923$$

With this value, the required pulley should be about 7 times larger than the pulley on the shaft of the electric motor.

From our design calculation, the pulley on the shaft of the electric motor was about 8 cm in diameter and the other pulley is about 42 cm in diameter. Hence,

$$\frac{42cm}{8cm} = 5.25$$

This results in having a frequency reduction of about 5.25 times lower than the original frequency. i.e.

$$\frac{1}{5.25} \times 1440 = 274.28 \text{ rev. /minute}$$

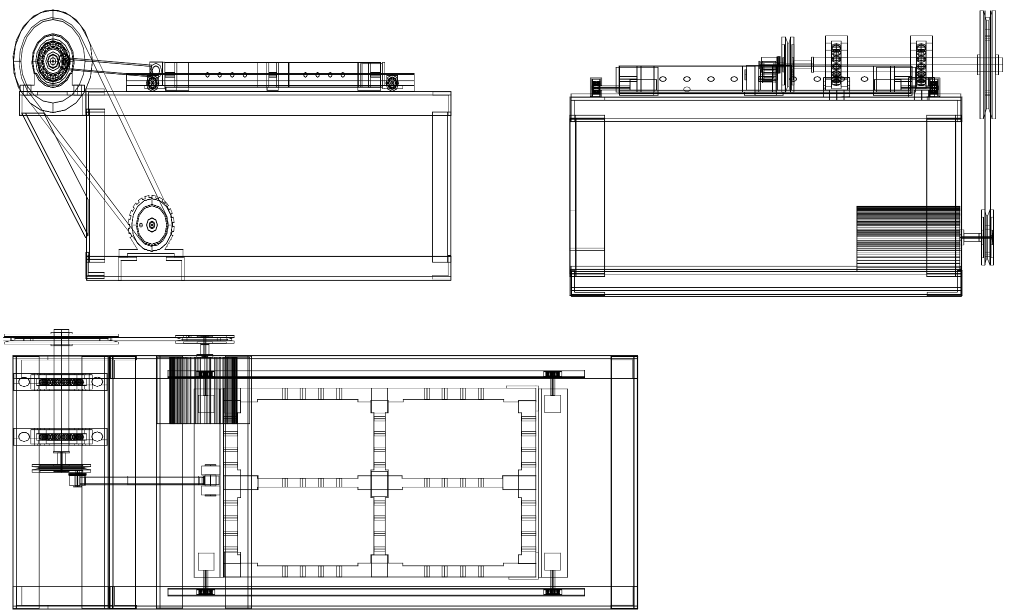

Figure 1. The orthographic projection of the globulator

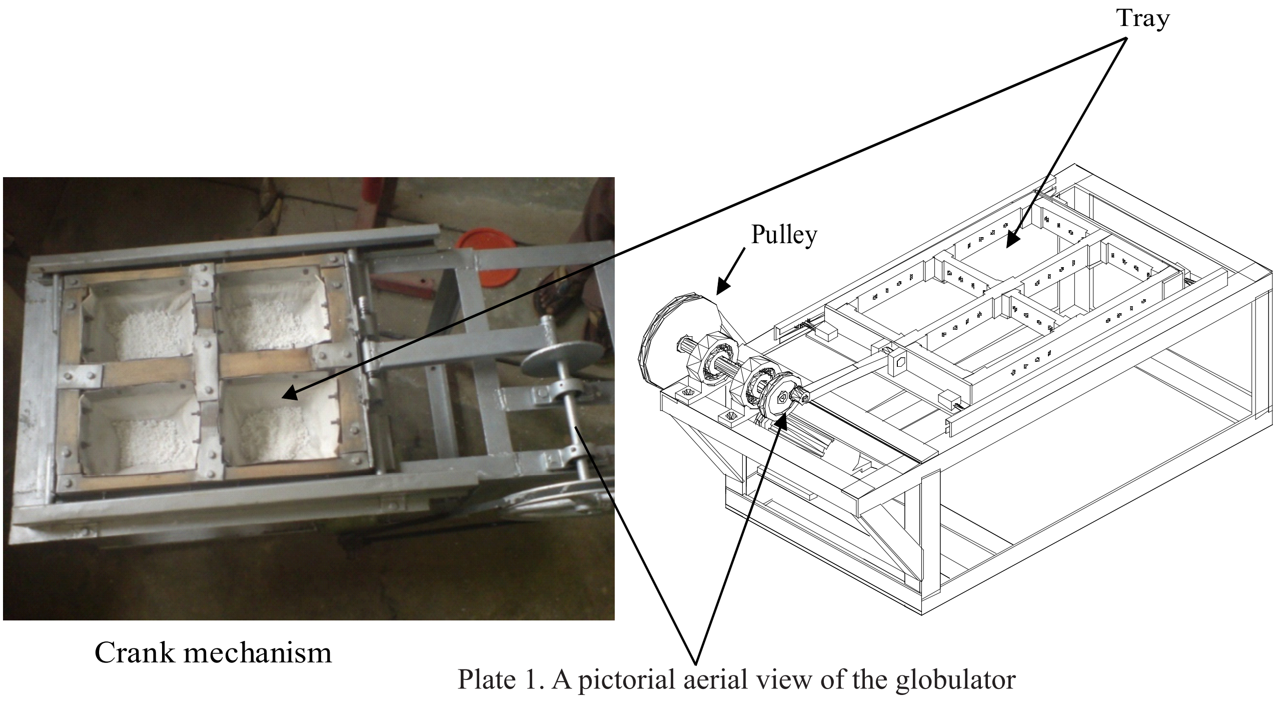

Figure 2. Isometric view of the globulator.

Hence this results in the tray frequency of about 274 rev/minute.

Also, the required amplitude was ensured by accurate measurement of the distance between the centers of the two drilled holes on the circular plate. About 3.2 cm is measured between the centers and this definitely produces amplitude of about 7.4 cm of the tray. The choice of electric motor needed to drive the globulator is a function of the applied load on the machine. Power requirement of the machine hence, was calculated for safe and efficient operation of the globulator. To select the appropriate capacity of the electric motor for the globulator the following factors were considered in the design calculation:

(i) The weight of the wooden tray
(ii) The density of the cassava starch at about 40 – 46 % moisture content and
(iii) The frictional force acting on the reciprocating tray.

$$P = F \times V \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

P = Power
F = Force
V = Velocity

The total force required to operate the globulator can be estimate to be

$$F_V = F_T + F_R + F_p \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

F_V = Total force required to drive the machine
F_T = Force required to drive the tray
F_P = Force required to move the tray when filled with moist starch
F_R = Force required to overcome the frictional force

Since, $$V = \frac{\pi n r}{30} \ldots\ldots\ldots\ldots 3$$

Where V = Velocity for the electric motor
r = radius of pulley attached to the electric motor (0.03m)
n = angular speed of the electric motor (1440 rpm)

Hence, $$V = \frac{\pi x\ 1440 x 0.03}{30} \ldots\ldots\ldots\ldots\ldots\ldots 4$$

$= 4.516$ m/s

To calculate the forces

F_T = mass × acceleration due to gravity
= 10.3 kg × 9.81 m/s^2

Since the weight of the wooden tray = 10.3 kg
= 101.043 N

$$F_R = \propto (F_T + F_P) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

∞ = 0.07 (frictional coefficient of metal to metal surface)

F_P = Density of starch × Volume of tray × acceleration due to gravity

Density of starch = 1200 kg/m^3 (determined using Archimedes' principles)

Volume of tray = 0.45 × 0.6 × 0.05 m^3
= Dimension of the tray and the depth of the jute bag

F_P = 1200 kg/m^3 × (0.45 × 0.6 × 0.05) m^3 × 9.81m/s^2
= 158.922 N

Hence, F_R = (101.043 + 158.922) 0.07
= 18.19755 N

Since $F_V = F_R + F_T + F_P$
= 18.19755 + 101.043 + 158.922
= 278.16255 N

Since P = $F_V \times V$
= 278.16255N × 4.516 m/s
= 1256.18 watt
= 1.685Hp
(since 1.34Hp =745.7watt)

Materials and Methods

Cassava roots

Cassava variety TMS30572 was obtained from the Teaching and Research Farm of the University of Agriculture, Abeokuta, Nigeria. The roots were harvested at 12 months after planting and processed within 60 minutes after harvesting.

Production of tapioca globules using fabricated globulator

The component parts of the Globulator is shown in Figure 1.After the fabrication of the machine the performance of the machine was assessed. After the extraction of the starch, the starch was drained to about 40-43% moisture content. The starch clods were broken down into smaller sizes and fed into the globulator for globulation. The starch was supplied at different moisture content for globulation. About 2 minutes was selected and at this time, several globule sizes were adequately formed. Globulation aids the buildup of starch granules to attractive spheres. Grading was done manually with the aid of standard screens of 0.8 mm, 1.6 mm and 2.0 mm mesh diameter and the globules were thereafter dried.

Effect of quantity of starch supplied on globulation efficiency

Wet starch samples were supplied into each compartment in the quantity of 50 g, 100 g, 150 g and 200 g per globulation period of 2 minutes. After globulation the globules were graded into different sizes and the percentage of globulation determined.

Effect of moisture content of starch supplied on globulation efficiency

Two hundred gram (200 g) of wet starch samples of different moisture content (30.3, 39.3, 42.0, 43.3%) were supplied into each compartment and globulated for 2 minutes. After globulation the globules were graded into different grade sizes and the percentage of globulation determined.

Effect of sagged jute cloth distance on starch globulation

The effect of the distance of the sagged jute cloth from the centre of each compartment to the base of the tray on the globulation efficiency was also determined. The loosely fitted jute clothe were attached to the compartment at about 11 cm down the base of the tray and at about 13.5 cm down the base of the other two compartments. The efficiency of globulation in each compartment was compared after the specified globulation period.

Result and Discussion

Globulator efficiency using weight as a varying criterion

Figure 3 presented the effect of feed weight on particle size distribution of the tapioca globules. From the figure, globulation efficiency is highest at 150 g and drops again when the feed weight increased to 200 g. This may be due to congestion at the action zone. If smaller grades globules are needed, starch weight may not be the parameter of concern as this has little or no effect on the grade sizes formed.

Effect of moisture content on starch globulation efficiency

The effect of moisture content on particle size distribution of the tapioca globules is presented in Figure 4. Starch globules above 2 mm grade sizes reduce as the moisture content reduces. Hence, moisture content can be said to enhance globulisation of starch granules. Higher globulation period is required when lower moisture content of starch granules is used. Unlike weight variation, moisture content was found to have more significant effect on the globulation efficiency of the fabricated globulator in this study. The globulation efficiency with respect to 2mm, 0.8mm and the underglobules size grades were discovered to be directly proportional to moisture content reduction but the 1.6mm grade sizes are relatively constant at all moisture content levels studied. Generally, lower turnout is recorded in compartment 2 and 3. This is because larger percentage loss is recorded because of the lower sagging depth of about 11cm. As the machine reciprocates, some starch granules were thrown out of the compartment, resulting in lower turnout.

Conclusion

The study showed technical feasibility of design, fabrication and test performance of a globulator for tapioca grits production in Nigeria. The locally fabricated globulator produces full globules of various grade sizes at about 2 min globulation period. The globulator has production capacity of 163.2 kg per man-day operation for tapioca production. The machine can easily be operated with limited technical knowledge as no formal training is required for the operation. The simplicity in the fabrication of the globulator enhances cleaning and maintenance as various machine parts can be easily dismantled in case of wear and tear. Factors that were discovered to affect the globulation of the machine include feed moisture content, amount of starch granules supplied per cycle, contact between the starch and the action zone, speed and amplitude of the reciprocating tray and nature of the jute cloth.

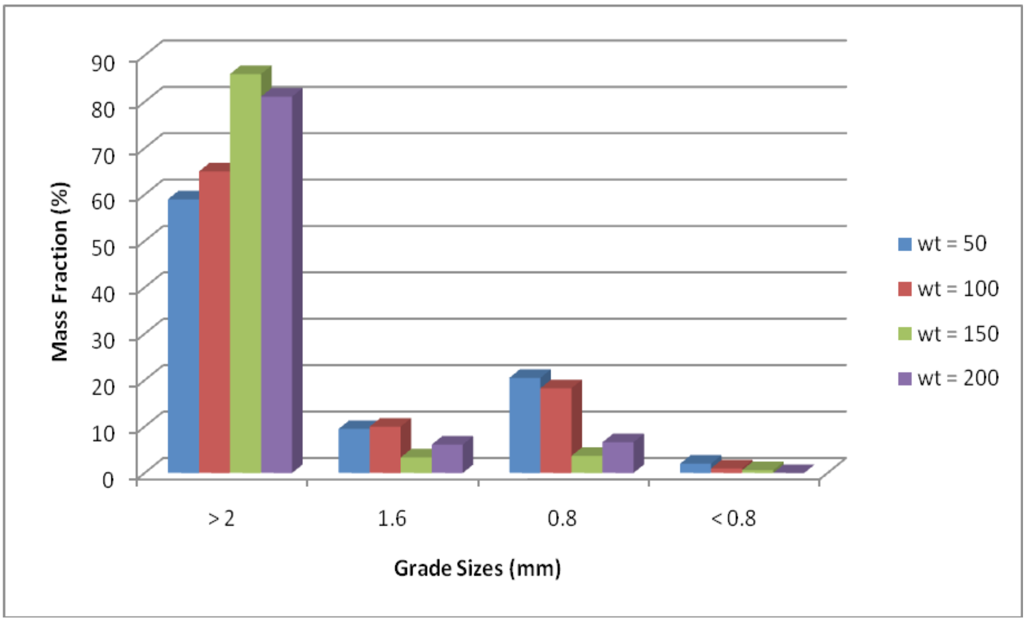

Figure 3. Effect of feed weight on particle size distribution of the tapioca globules

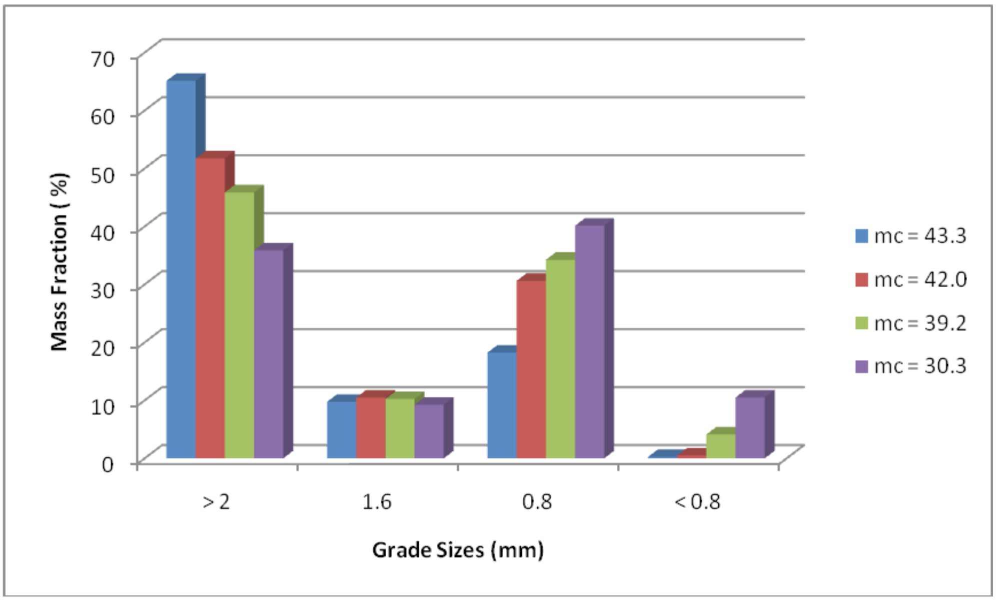

Figure 4. Effect of moisture content on particle size distribution of the tapioca globules

Reference

Adebowale, A. A., Sanni, L. O.and Kuye, A. 2006. Effect of roasting methods on sorption isotherm of tapioca grits. Electronic Journal of Environmental, Agricultural and Food Chemistry 5 (6): 1649-1653.

Adebowale, A.A., Sanni, L O., Awonorin, S. A., Daniel, I. O. and Kuye, A. 2007. Effect of cassava varieties on the sorption isotherm of tapioca grits. International Journal of Food Science and Technology 42 (4): 448–452.

Cock, J.H. 1985. *Cassava, New Potential for a Neglected Crop*; USA: West View Press.

Dixon, J.A. 1979. Production and Consumption of Cassava in Indonesia; Bulletin of Indonesia Economic Studies, November 1979.

FAO. 1998. *Food Outlook*; Rome: Food and Agricultural Organisation (FAO).

Jackson, F.L.C. and Jackson, R.T. 1990. The Role of Cassava in Famine Prevention; Food Nutrition History Anthropology 7: 207-225.

Lancaster, P.A., Ingram, J.S., Lim, M.Y. and Coursey, D.G. 1982. Traditional Cassava-based Foods: Survey of Processing Techniques. Economic Botany 36(1):12-45.

Onitilo, M. O. 2003. Effects of cassava varieties and processing methods on tapioca quality. M. Sc. Thesis, University of Agriculture, Abeokuta. pp.36, 38 – 39.

Oyewole O.B. and Obieze N. 1995. Processing and Characteristics of Tapioca Meal from Cassava. Tropical Science 35:401-404.

Phillips, T., Taylor, D. S., Sanni, L, and Akoroda, M. 2004. A Cassava Industrial Revolution in Nigeria. The potential for a new industrial crop. 43 pp. IFAD/FAO, Rome, 2004.