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DESIGN AND FABRICATION OF A HOME SCALE PEDAL-POWERED CASSAVA GRATER

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ABSTRACT: A home scale pedal-powered cassava grater was designed, fabricated and tested. Most of the common graters are electrically powered and hence depends on electricity which in Nigeria, is presently erratic in supply or not available at all in most rural areas. The erratic power supply, scarcity and high cost of petroleum products necessitate the need to address this issue to certain extent by developing a mechanism that will make life easier in food processing for rural dwellers and improve their economic wellbeing. This pedal-powered cassava grater consists of pedal chain mechanism connected to a belt drive which turns the shaft on which the grater drum is mounted; where the cassava tubers are grated. About 60 kg of peeled cassava tubers can be grated per hour and the machine is cheap, economically viable and can be used by unskilled workers.
KEYWORDS: cassava grater, electrically powered, rural dwellers, chain mechanism, unskilled workers

INTRODUCTION

Cassava (Manihot esculenta) is a major source of calories and, for that matter, the number one staple food for millions of people in Asia and Africa especially in Nigeria. Cassava is also used to produce starch for industrial used and its peels are also fed to livestock. The crop is in recent years more popular and now replacing yam in some part of Nigeria [1].

A major limitation of cassava is its rapid post harvest physiological deterioration, which often begins within twenty four hours after harvest. To reduce this level of losses, it is very necessary that the tubers are processed as early as possible. Cassava processing into starch and garri (a local staple food) using traditional methods is tasking, ineffective, time consuming and also inefficient. Such difficulties arise in the grating and draining of the starchy fluid from the cassava dough since the conventional methods available involve processes that require a lot of labour and man hour. The problems become worsen when the quantities to be produced are very large [2].

The transformation of cassava tubers into pulp form is known as grating of cassava. Already peeled cassava tubers are fed into the hopper made of metal sheet then to the grating drum which rotates at constant speed. Graters which operate short residence time tend to produce more coarse grains than those which operate longer residence time. A grater is characterized by a cylinder which contains a grinding surface rotating in a horizontal axis. The most common type of grater is made of horizontal axis cylinder with serrated metal surface. When cassava is fed into the machine, the abrasive action of cylinder surface grinds against the cassava roots reducing them into a mash. The relative efficiency of a cassava grater tends to decrease as the size of material decreases [3].

A pedal is the part of a bicycle that the rider pushes with his feet to propel the bicycle. It provides the connection between the cyclist shoe and crank allowing the leg to turn the bottom bracket spindle and propel the bicycle wheels. Pedals usually consists of a spindle that threads into the end of the crank and a body, on which the feet rests or are attached, that is free to rotate on a bearing with respect to the spindle. Pedals were initially attached to the crank directly to the driven wheel. The safety bicycle, as it is known today came into being when the pedals were attached to a crank driving a sprocket that transmitted power to the driven wheel by means of roller chain [4].

A person can generate four times more power (1/4 horse power) by pedaling than by hand cranking. At the rate of ¼ hp, continuous pedaling can be done for only about 10 minutes. However, pedaling at half this power can be sustained for about 60 minutes [5].

Maximum power produced by leg is generally limited by adaptations within the oxygen transportation system. On the other hand the capacity for arm exercise is dependent upon the amounts of muscle mass engaged and that is why a person can generate more power by pedaling than hand cranking. Pedal power enables a person to drive devices at the same rate as achieved by hand cranking but with less effort and fatigue [6].

CASSAVA PRODUCTION AND PROCESSING IN NIGERIA

The total area under cassava production in Nigeria is about 3.6 million hectare. All states include the Federal Capital Territory (FCT) Abuja, cultivates appreciable quantities of cassava. However, Akwa-Ibom, Cross-River, Edo and Delta states are major producers of cassava in Nigeria. Most of the cassava produced in Nigeria are processed and consumed in various forms locally with little processed for export [7].

In traditional bush-fallow system, some cassava plants are always left to grow with fallow which is long enough to enable the cassava to flower and set seed. The natural out-crossing habit of cassava leads to production of numerous new hybrid combinations from self-sown seeds from which farmers select and propagate desirable types. By this process, pools of new local varieties are continuously created which are adapted to different agro-ecological zones of the country. As these selections are made on account of their excellent cooking qualities, low HCN (Hydro-cyanide) content and high yields, they are used as parent in breeding programs mainly to improve pest and disease resistance [7].

Flour or starch from roots and tubers, especially cassava are utilized in the preparation of various food gels, snacks and baked goods. Such traditional products from cassava include garri, industrial starch, cassava flour, etc. Garri is widely consumed in Nigeria, Ghana and other West African countries. Some of the processing steps such as grating, milling and water expressions are mechanized. Palm oil is often added during frying (toasting) operation. Addition of palm oil prevents burning during frying and it has additional desirable effect of changing the colour of the product to yellow. The average urban consumer prefers garri because it is a pre-cooked food product [2].

Cassava starch is the starting point for so many important industrial products such as dextrin, glucose syrup, etc. Cassava starch is preferred amongst other types because of its good gelling property. Traditionally, cassava starch is produced by first washing the peeled root manually and then grating to produce starch milk from which the fiber is separated through special strainers or sieved through muslin cloth and washed thoroughly and the starch will then collect and settle down [2].

MATERIALS AND METHOD

Fabricated component parts such as the main frame and hopper were welded while other parts were fastened together using bolts and nuts. Other parts such as shafts and flywheel were turned and bored respectively using centre lathe machine. The shaft serves as a rotating machine element which transmits power from one place to another.

The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power to be transferred to various machine components linked up to the shaft.

In order to transfer the power from one shaft to another, the various members such as pulleys, bearings and drum are mounted on it. These members along with the forces exerted upon them causes the shaft to experience bending. Therefore, we may say the shaft in this case is exposed to bending moment and torsional forces since it is utilized for torque transmission and bending moment.

The average power produced by a man is approximately 75W (0.1hp) for a healthy non-athlete. A simple rule is that most people engage in delivering power for an hour or more will be most efficient when pedaling in the range of 50 to 60 revolutions per minute (rpm). Therefore for simplicity sake, we will make use of the average which is 60 rpm [8].

$$Torque, T = \frac{Power}{AngularAcceleration, \omega} \tag{1}$$

$$\omega = \frac{2\pi N}{60} \tag{2}$$

$$\text{Torque } T = \frac{P}{\omega} = \frac{P \times 60}{2\pi N} \tag{3}$$

$$\text{Equivalent Twist Moment} \quad T_e = \frac{\pi}{16} \times \tau \times D_S^3 \tag{4}$$

where, τ = permissible shear stress of the shaft material
D_s = diameter of shaft
But,

$$T_e = \sqrt{M^2 + T^2} \tag{5}$$

where, M = maximum bending moment

$$D_e N_e = D_d N_d \tag{6}$$

D_e = diameter of the driver pulley
D_d = diameter of the driven pulley
N_e = speed of the driver in rpm
N_d = speed of the driven in rpm

The length L of belt is calculated using the expression below;

$$L = \frac{\pi(D_d + D_e)}{2} + 2C + \frac{(D_d - D_e)^2}{4C} \quad (7)$$

where, C = distance between the center of the two pulleys

The lap angle of the belt over the pedal driver pulley,

$$\theta = (180^0 - 2\alpha)(\frac{\pi}{180})rad \quad (8)$$

where,

$$\alpha = \sin^{-1}\left[\frac{D_e - D_d}{2C}\right] \quad (9)$$

The assembled cassava grater shown in Figure 1 below was then tested as reported in the next section.

(1a). Peeling using knife

(1b) Washing

(1c) Pedal-powered grating

Figure 1: Cassava tuber processing

RESULTS AND DISCUSSION

The power and the speed from the pedal is transmitted through the chain drive then, further transmitted to grater through belt drive mechanism. Flywheel was incorporated on the transmission shaft that connects the chain drive and the belt drive mechanisms. The flywheel serves as a reservoir which stores energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than supply. It also serves as means of relief to the operator for a reasonable interval.

The machine does not grate when started from rest; it is allowed to gather momentum before it is loaded. It makes use of both the gravitational movement of cassava as well as gradual loading during grating.

Therefore it does not require the cassava to be hand-pressed as done on the conventional graters. Also, to avoid bearing breakage and other related problems, the shaft drum doing the work was made parallel between the adjacent bearings using a spirit level for its alignment.

There are several methods of testing for the output capacity of machines but with respect to this small scale cassava grater, the output capacity of the cassava grater was examined as follows: 27.5kg of cassava was used for ten different input values of mass. The time taken for each input was checked and recorded. Each tuber of cassava was weighed and the weight of the whole input of cassava obtained, the following measuring parameters were obtained:

Table 1: Number of Cassava Loading and Time Taken to Grate

Number of Loading	Mass of Cassava (kg)	Time Taken to Grate (sec)
1	0.5	30
2	1.0	62
3	1.5	91
4	2.0	119
5	2.5	149
6	3.0	180
7	3.5	213
8	4.0	241
9	4.5	272
10	5.0	359
Total	27.5	1716

Therefore for test machine;

$$\text{Output capacity} = \frac{mass.of.cassava.(kg)}{time.taken.(second)} = \frac{27.5x3600\,(kg)}{1716\,(hrs)} = 57.69\ \text{kg/h} \qquad (10)$$

CONCLUSIONS

A small scale pedal powered cassava grating machine was designed, fabricated and tested. It was found to be effective and efficient enough and could grate about 57.7kg of cassava tuber per hour. This machine can be used at home-scale for domestic application and it is affordable since the cost of production is low compared to the automated one.

The machine is also economically viable. Thus, it can be used in small-scale production especially in rural settlements and for subsistence farmers. But the output capacity and speed at which the machine operates should be improved upon.

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