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Design, Fabrication and Performance Evaluation of a Cashew Nut Roasting Machine

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ABSTRACT

The cashew nut roasting machine was design, fabricated and tested in Auchi Polytechnic, Auchi. The cashew nut roasting machine consist of the roasting drum, a paddle attached to a shaft which rotates and stir the cashew nuts constantly inside the drum. A charcoal box incorporated with a blower forms the heating chamber was beneath the roasting drum which uses charcoal as the source of heat for roasting the cashew nuts. The shaft was directly driven by the gear reduction electric motor with the help of a belt. An outlet was made for the discharge of the roasted nuts. The materials for machine production were source locally. The various components were carefully assembled and the total cost of the machine production amounted to sixty four thousand naira only (N64, 000.00). The machine was tested with cashew nuts. The machine roasting capacity was found to be 13.8kg/h, functional efficiency was 68% and effective roasting time was 8.13 minutes. Efficient and improved cashew nut roasting can be achieved with this machine, for a small scale production process.

Keywords: Cashew nut, roasting machine, Evaluation, Fabrication

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INTRODUCTION

Cashew nut is a fruit cashew tree (*Anacardium, Occidentale*); the cashew tree is a tropical green perennial crop that is mainly cultivated for its nut (Cashew nut) and Pseudo fruit (Cashew fruit). It is however a multipurpose species that provides a broad range services. About 30-40% Cashew Kernels are discarded during the process of roasting. They are then feed to livestock, (Coulter, J. 1982).

The cashew tree (*Anacardium, Occidentale*) can grow as high as 14 meter but dwarf cashew grows up to 6metres and has proved to be more profitable, with earlier maturity and higher yields. Or used in recipes, like other nut, although it is actually a seed. The cashew tree, native to Brazil was introduced to Mozambique then to India in the Sixteenth Century by the Portuguese, as a means of controlling erosion (Asiedu, 1989). Cashew is known by many names.

In Mozambique, the maconde tribe refer to it as the "Devil's nut". It is estimated that 60 percent of Cashew kernels are consumed in the form of snacks while the

remaining 40 percent are included in confectionary. The cashew competes in the same market as other edible nut including almonds, hazels, walnuts, pecans, macadamias, pistachios and peanuts, Errington, & Coulter, (1989).

Cashew nut processing allows for the development of an important by-product which can increase its added value. The liquid inside the shell (CNSL) represent 15 percent of the gross weight and some attractive possible medicinal and industrial uses. CNSL is one of the few natural resins that is highly heat resistant and is used in braking systems and in paints manufacture. It contains a compound known's as *anacardium*, which is used to treat dermatological disorders. The main markets for CNSL are United state, the European Union (mainly the United Kingdom), Japan and the republic of Korean. Together these accounts for over ninety percent of world trade most of which is supplied by India and Brazil, Errington & Coulter, (1989).

Since the 1960s, advancements in mechanization have

introduced various equipment to streamline cashew processing operations, including roasting, cashew nut shell liquid extraction, and shelling. Despite these technological developments, certain aspects of the process, such as grading, have largely remained labor-intensive and reliant on manual operations. This is particularly evident in India, the world's largest producer of cashew kernels, where traditional methods involving skilled and semi-skilled workers continue to dominate the industry. The integration of mechanized systems has undoubtedly improved efficiency in specific stages of processing, yet the reliance on manual labor for critical tasks underscores the balance between technological innovation and traditional practices in this sector. Traditionally, extraction of the kernel from the shell of the cashew nut has been a manual operation as this is very harmful to the operator as heat from the furnace can cause body damages, also the cashew nut shell liquid CNSL, can explode during the process which has harmful effect on the skin. This stage (manual operation) is unlikely to take place due to high cost of the special roasting equipment. If the nuts are being manually shelled, gloves need to be used or alternatively, the nut must be tumbled in sawdust or ashes to absorb the liquid coating from burning the skin. Roasting of cashew is really a problem, since many lack technologies for cashew nut processes.

Roasting is one of the most methods for processing nut. The application of heat to the nut serves to release the nut shell liquid and renders the shell brittle, thereby facilitating the efficient extraction of the kernel during the shell-breaking process. There are three primary methods employed for roasting: open roasting, drum roasting, and hot oil roasting. Each method offers distinct advantages and is selected based on specific operational requirements and desired outcomes in the processing of nuts. This paper aims at designing, fabricating and evaluating the performance of a cashew nut roasting machine. This project effectively addresses the challenges of time consumption and monotonous tasks, providing a streamlined solution that enhances efficiency. Furthermore, it fosters opportunities for self-employment by enabling individuals to establish small-scale businesses without the need for labor-intensive manual operations, thus promoting entrepreneurial growth and economic sustainability.

MATERIALS AND METHODS

Design Considerations

A new and better machine is one which is more economical in the overall cost of production. Adoption of new materials and manufacturing method is needed. In order to obtain high efficiency and reliability, the machine was design based on the following considerations;

1. The machine should be relatively cheap and be afforded by local cashew nut processors.
2. It should be able to reduce drudgery associated with the traditional method of roasting cashew nuts.
3. The machine should be able to roast cashew nut at a faster effective time
4. The machine should be made of strong and available local materials that can withstand load.

Principle of operation of the cashew nut roasting machine

The cashew nut roasting machine is made up of roasting chamber, heating chamber, blower and pulley (power transmission) mechanism. The heating chamber has a charcoal box that uses charcoal as a source of heat, a blower will be on the side of the machine to supply continuous air to the heating chamber to maintain the heat intensity through continuous rotating fan that was channel towards the heating chamber. Belt and pulley mechanism was the means of power transmission. The roasting drum is cylindrical in shape with one end cut open as the discharge outlet.

A shaft passes through the roasting drum that connects the pulley with the help of pillow bearing. A stirrer was attached to the shaft that helps to stir the cashew nut as it rotates in order to prevent burning of the nut and for even roasting. A 1hp gear reduction electric motor was used to provide rotary power to the shaft through the use of belt and pulley. A detailed drawing of the machine is as shown on the appendix.

Design of the hopper

The hopper is made from a mild steel of 1.5mm thickness. It is an outlet for feeding the raw cashew nut into the machine.

$$\text{Volume} = L \times B \times H$$

Eq. (1)

$$V = 7410000 \text{ mm}^3$$

Design of the roasting drum

The drum is made of mild steel of 1.5mm thickness which was cut into required dimension. The drum is cylindrical in shape and it is the chamber where roasting takes place.

The volume can be determined as follows:

$$\text{The volume of a cylinder is} = \text{Area} \times \text{length}$$

Eq. (2)

$$\text{But Area} = \frac{\pi d^2}{4}$$

Eq. (3)

Where d = diameter of the drum = 250mm
 L = length of the drum = 650mm
 $V = 31910938 \text{ mm}^3$

Design of discharge chute

The discharge chute is made of angle bar of 4mm thickness. The discharge chute is a packer-like shape which aid in collection of the roasted cashew nut. It is also known as the discharge outlet. In consideration of the size, the volume of the discharge chute can be determined as:

$$V = 2450000 \text{ mm}^3$$

Design of ash tray

Tray is made of mild steel materials of 3mm. It is used to collect the ashes from the burnt charcoal. It is located at the bottom of the charcoal box.

Volume of the ash tray can be determined as follows:

$$V = 13000000 \text{ mm}^3$$

Design of chimney

The chimney is made of mild steel of 2mm with a diameter of 60mm. It is placed on top of the roasting chamber to enable the release of burnt gases from the roasting chamber. The volume of the chimney can be determined as follows:

$$V = 240363 \text{ mm}^3$$

Design of frame

The frame is made of an angle bar of 4mm thickness cut into a selected dimension. The frame supports all other component of the machine due to its rigidity.

The volume of the frame can be determined as follows:

$$V = 83250000 \text{ mm}^3$$

Design of charcoal box

The charcoal box is made of mild steel of 3mm thickness. It has a height of 180mm which aid in housing the charcoal for generating the heat required for roasting the cashew nuts; hence it is the heating chamber.

The volume can be determined as follow:

$$V = 31824000 \text{ mm}^3$$

Power required for rotating the shaft

$$Power = \frac{2\pi NT}{60} \quad \text{Equation (4)}$$

$$= 357.8 \text{ W} \cong 0.5 \text{ hp}$$

Hence, due to factor of safety a 1hp gear reduction electric motor will be used to power the machine.

Selection of ball bearing

Bearing are machine components intended to support shaft, axis and other rotating part which take up radial loads. The main types of rolling bearing commonly used in engineering are single row ball bearings, double row bearing, spherical roller bearing, pillow bearing etc. Ball bearing with diameter and width of 30mm and 9mm respectively has been selected for the design.

Selection of belt

Belts are used to transmit power from one pulley to another. V-belt are mostly used in domestic, factories and workshops where great amount of power is to be transmitted from one pulley to another and where two pulleys are very near to each other Khumi and Gupta, (2006). The table below shows the belt types and its thickness.

Determination of the speed required for rotating the shaft

$$N_1 D_1 = N_2 D_2$$

Where: N_1 = speed of electric motor = 16rpm

D_1 = Diameter of driver pulley = 85mm = 0.085m

D_2 = Diameter of follower pulley = 170mm = 0.170m

$$N_2 = \frac{N_1 D_1}{D_2} = \frac{16 \times 0.085}{0.170} = 8 \text{ rpm} \quad \text{Eq (5)}$$

Shaft design

The shaft design will be based on maximum shear theory (Hall, 1988).

Diameter of the shaft is given as

$$d^3 = \frac{16}{\pi \delta_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad \text{Eq (6)}$$

Where: δ_s = allowable shear stress = 42mN/m² (maximum allowable stress for shaft ASME code design of transmission shaft). A shaft diameter of 43mm was designed and selected

Source of heat

Charcoal is a lightweight, black residue, consisting of

Table 1: Material selection for the components

Machine Component	Criteria for Selection	Most suitable material	Material actually selected	Reason for selecting material
Machine frame	Must be strong, very rigid, minimize distortion, and absorb impact shock.	Angle iron	Angle iron	High strength and rigidity, suitable enough to avoid buckling
Pulley Belt	Resistance to wear, strong and rigid. Have elasticity to absorb shock without breaking	Steel Rubber	Steel Impregnated rubber	Greater machinability and cheap Readily available, safe, adaptable, high allowable stress
Driving and driven shaft	High wear resistance and enough strength	Carbon steel	Medium carbon steel	Possess high strength and rigidity.

carbon and any remaining ash, obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually produced by slow pyrolysis-the heating of wood or other substances in the absence of oxygen (Wikipedia, 2016).

Materials selection for the component

Choice of materials depends on many factors such as intensities and types of stress to which the components are subjected to, whether it is to be flexible or rigid, whether it has experience high temperature or corrosive action and how it lends itself to process of manufacture. Also, the physical, mechanical and chemical properties of the materials are very important for consideration. The materials selected for each of the machine component and reason for selecting such material is presented in (Table 1).

Fabrication of the machine components

Various production processes were done during the fabrication and assembling of the components. These include marking out, cutting, machining and assembling.

Marking out

After the selection of the appropriate materials for each component, the selected shapes and sizes were marked according to the design specifications, the marking out tools used for this operation include, the tri-square, vernier caliper, pair of divider, scribe and centre punch. The measurement was done using the steel rule and the scribe for metal components. The marked out line were centre punched at desirable point for easy identification during cutting.

Cutting of materials to selected shapes

Roasting drum and charcoal tray of (1.5mm thickness) of mild steel was cut at different selected dimensions and marked out using angle disc with the aid of a vice. 2mm

thickness of mild steel was cut at different selected dimensions to form other components such as hopper, discharge chute, chimney and the ash tray.

All the marked out section on each component were cut to the selected shapes and sizes using the following tools.

- (i) The hack saw/power saw for cutting metal plates.
- (ii) Grinding machine for removing sharp edges and smoothening rough surfaces of metal component.
- (iii) Sand paper for smoothing rough surfaces of metal after cutting and fabrication
- (iv) Oxy-acetylene for cutting metal plates and drilling holes.

Machining

The shaft was machined on the lathe machine in order to have the selected diameter parts subjected to rotary motion and fatigue loads were produced by milling using milling machine.

Assembling of the machine components

This is the process of arranging together all fabricated parts to form the cashew nut roasting machine. Some of the parts were fastened together with the help of bolts and nuts while other parts were welded. The fastened parts will allow easy disassembling for maintenance work to be carried out. Bolts and nuts were used in tightening the electric motor to the frame and also for fastening the bearing that holds the shaft. The blower was incorporated at the side of the box and was channeled to the heating chamber by a galvanized pipe.

Description and mechanics of operations of the machine

The isometric view of the machine is shown in figure 4, the components by components and the orthographic drawings of the machine are also shown in figures 5 and 6 respectively.

Description of the machine

The machine frame

This is made of 45mm x 45mm angle iron of (4mm thickness) with length of 740mm and breadth of 150mm. The rectangular angle irons were firmly fixed together by welding, and it carries the motor, the roasting drum, horizontal shaft, the discharge chute, charcoal box and the ash tray. Its design enables less vibration during operation.

The roasting chamber

It consists of the hopper, roasting drum and a horizontal shaft with paddle (attached). The drum is made of 1.5mm thickness of mild steel. It is cylindrical in shape with a diameter of 250mm and length of 650mm. The cashew nuts will be introduced to the roasting drum via the hopper. The paddle is rotated by the shaft to stir the nuts for even roasting and to prevent the nut from burning since the temperature of the drum is very high.

The heating chamber

The charcoal box, ash tray and blower form the heating chamber. The charcoal box is rectangular in shape. It is made of 1.5mm thickness of mild steel supported by the angle iron at the bottom of the roasting chamber. It houses the coal that produces the heat for roasting. The blower is incorporated at the side of the box and it was channeled by a galvanized pipe that sends continuous air current to keep the coal burning. The blower is powered by the electric motor.

The discharging unit

The discharging unit is the outlet chute for the roasted cashew nuts from the drum to a collecting bowl.

Mechanics of operation of the machine

Power is supplied to the machine from an external source through a 3-phase speed reduction electric motor of about 16rpm. It rotates at a low speed, thus providing the rotary motion to the shaft, which turns the stirrer in order to ensure that the cashew nuts are stirred uniformly. Pre heating of the machine will take place for about five minutes after which the cashew nuts can be fed into the roasting drum for roasting. The roasted cashew nuts are discharge through the chute to a bowl and are allowed to cool after which it is shelled peeled and ready for sales or consumption.

Production cost analysis

Most components of the machine were sourced locally.

The production cost analysis of the machine is presented as shown in the (Table 2). The cost of the machine amounted to Sixty Four Thousand Naira only (₦ 64, 000).

Maintenance of the machine

Maintenance is an important operation which is carried out in order to prevent sudden break down. The machine needs regular maintenance either daily or weekly depends on the usage of the machine. Oil and grease should be applied always on the bearing to reduce friction and wear due to rubbing action. Also prevent corrosion by painting and regular cleaning. The roasting drum is fabricated in parts, with on side locked with inches and the other can be open to enable cleaning of the cashew nut shell liquid (CNSL). The bolts and nuts should be tightened on regular basis to ensure rigidity of machine because vibration can lead to many mechanical problems which may cause total failure of the machine.

RESULTS AND DISCUSSION

Testing of the machine

The cashew nut roasting machine was tested in the Department of Agricultural and Bio-Environmental Engineering Technology Workshop, Auchi Polytechnic, Auchi. The testing was carried out in two phases: The first was a free run test (without load), the second was test with load (i.e. cashew nuts). A weighing balance was used for measuring the quantity of the cashew nuts while a stop watch was used to determine the duration of the roasting.

Free run (without load) testing of the machine

The machine was operated without any load of cashew nuts. The machine was set to run freely for about 5minutes to check for abnormal vibration and noise, and for any other malfunctioning.

Testing with cashew nuts

The machine was tested with cashew nut. The testing was replicated with different mass of cashew nuts i.e. (1.75kg, 1.85kg, 1.90kg and 2.00kg). The heating chamber was loaded with charcoal and the effective roasting time was recorded with the use of a stop watch. Below are the result obtained during testing of the machine (Table 2).

Determination of machine capacity

The machine capacity was determined by the ratio of the

Table 2: The following result obtained.

Weight of cashew nut in the drum(kg)	Effective time of roasting(min)	Weight of roasted nut(kg)	Weight of nut broken(kg)	Weight of nut burnt(kg)
1.75	7.0	1.15	0.10	0.02
1.85	7.5	1.20	0.11	0.04
1.90	8.0	1.32	0.05	0.03
2.00	10.0	1.40	0.03	0.07
(Average) 1.88	8.13	1.27	0.29	0.16

average quantity of cashew nuts in kilogram (kg) in the drum to the average time taken to roast the cashew nut in hours (hr).

$$\text{Machine Capacity (kg/min)} = \frac{Q_c}{t}$$

Where; Q_c = Average quantity of cashew nuts in the drum = 1.88kg

t = average time taken to roast the cashew nuts = 8.13 min = $\frac{8.13}{60} = 0.1355 \text{ hr}$

$$\text{Machine Capacity} = \frac{1.88}{0.1355} = 13.8 \text{ kg/hr}$$

Determination of functional efficiency

The efficiency of the machine was determined by the ratio of the average weight of roasted nuts (output) to the average weight of nuts in the drum (input).

$$\text{Functional Efficiency} = \frac{\text{output}}{\text{input}} \times \frac{100}{1}$$

Output = average weight of roasted nuts = 1.27kg
Input = average weight of nuts in the drum = 1.88kg

$$\text{Functional Efficiency} = \frac{1.27}{1.88} \times \frac{100}{1} = 67.5 \cong 68\%$$

Conclusion

The cashew nut roasting machine, developed and tested at the Department of Agricultural and Bio-Environmental Engineering Technology Workshop, Auchi Polytechnic, demonstrated an operational efficiency of 68%. While the machine performed effectively, it is recommended that the lower section of the heating chamber be insulated with ceramic material to mitigate the risk of excessive heat damaging the electric motor, thereby enhancing the machine's durability and operational reliability.

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