DEVELOPMENT OF CASHEW NUT PROCESSING MACHINE

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Abstract: The stress, injuries and hazardous effects incurred during processing of cashew nut is huge. This work considered the design and development of cashew nut processing machine to help farmers improve the process efficiency. Cashew nuts were fed into the machine containing the heating and shelling chamber. The designed machine dried, roast and shelled the nuts. The shelled cashew nuts were then cooled, and kernels separated from shell manually. An efficiency of 80% was determined in terms of number of whole kernel recovery, roasting and cracking time.

Keywords: cashew nut, cashew processing, efficiency, heating, impact force, shelling

1. INTRODUCTION

Cashew tree (*Anacardium occidentale L.*) was said to have originated from Brazil [1] in the sixteenth century. It was introduced to Mozambique and India by the Portuguese to control coastal erosion [2, 3]. Elephants propagated the fruits within these countries by eating the bright cashew fruits and dropping the attached nuts elsewhere. The nuts were too hard to digest; they were therefore expelled as part of their excrement. In the nineteenth century, other Africa countries, including Asia and Latin America were propagated after plantations were developed [4].

In the first half of the twentieth century, India began the use of manual techniques in processing of cashew nut. The processed cashew nuts were exported to the United States amidst other wealthy western markets. In the 1960s, rather than exporting the cashew nut to India for processing, some countries in East Africa began processing the nuts domestically, allowing them to benefit from both the sales of processed cashew nut and extracted liquid from cashew nut shell [4].

Processed cashew nuts quality has decreased due to the local method of production [5]. For quality cashew nuts, extra energy and capital are consumed in its production. The process in producing cashew nuts requires special skills and with the help of an effective and efficient cashew nut processing machine, the cost of production, reduction in product's quality, time and energy consumed can be greatly reduced. Cashew nut processing main objective is to remove with insignificant damage the valuable cashew kernel from the shell without contamination, this process is called shelling. Drying cashew nuts by heating is a critical and most difficult unit operation in this process. This is because the hard shell containing the nut when heated produces harmful fumes and caustic oil that can burn the skin [6], and also due to irregular shape and brittleness of the kernel [7]. Cashew drying is therefore usually carried out using sophisticated steam, solar and electrical dryers. The drying usually occurs on perforated

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trays in a controlled heating environment with temperature ranging from 45 to 70°C for about 4 to 8 hours. This reduces the raw kernel moisture content from 9% to 3%.

Approaches used in shelling roasted cashew nuts include Sturtevant and the Oldsmar system [8]. While the later involved holding well graded nut in a nut-shaped blade to cut the nut along the natural line, resulting in poor shelling efficiency. The former involved throwing of the roasted cashew nuts against the plate of a metal by centrifugal force for shelling. In Oldsmar system, the shelling capacity was very low as each nut would be placed for cutting separately, thus, increasing the set up time. Like in India where average shelling capacity of 7-8 kg/worker/day with 34% broken nuts, 30% Half-splits nuts and 36% undamaged nuts was reported [7, 9, 10], many Nigerian farmers, in spite of these developments still uses manual approaches in shelling. It is therefore pertinent to develop a mechanized cashew nut sheller, in order to meet cashew nut shelling requirements, improve safety of the workers, reduce drudgery and improve the quality of cashew nuts.

2. MATERIALS AND METHODS

2.1. Materials list and procurement

The materials selection for the components was based on mechanical properties which includes strength, durability, toughness and reliability. Motors, guides, shaft, electric motor, etc. were also selected based on the mechanical and the electrical criteria.

2.2. Definition of terms

The machine designed has three major parts and it is motorized. The heating part, the frame and the roasting and cracking chamber. Mild steel was used in the fabrication of parts

2.2.1. Mild steel sheet

This is a low carbon steel, strong and tough. It can be strengthened in the process of carburizing-heat treatment using a source of carbon. Mild steel is malleable, weld able and ductile. It has approximately 0.005-0.25% carbon which enhance its malleability and ductility. It is also cheap, has relatively low tensile strength and easy to form with good surface hardness when carburized.

2.2.2. Heating element

The heating element plays the role of energy conversion from electrical energy to heat energy.

2.2.3. The frame

It is the major rigid component that carries all other components of the machine, or all other components are attached to it. It is designed in such a way to withstand the vibration of the machine during operation. A rod is used to brace the legs for rigidity, stability and firmness.

2.2.4. The roasting and cracking

The cracking chamber is made up a fenestrated cylinder which rotate together with the shaft holding the blade at the same speed, forcing the roasted cashew nut to rotate evenly, in the process cracking the shell open to release the kernel.

2.3. Materials

During operation, the machine designed will crack cashew nuts by impact driven with the motorized part. The cashew nuts were lunched against hardened fixed wall by an impeller.

2.4. Fabrication technique

Electric arc welding was used to join most parts together and it is the major metal joining process employed in the fabrication. All joints were welded together using grade 10 and 12 electrodes. The plates were welded to the angle iron. It is being used and preferred than gas welding because it is more economical with fewer hazards. Figure 1. shows the assembled drawing of the machine designed.

2.5. Design analysis

The design analysis consists of the following.

2.5.1. Design of impeller and shaft

Assumption: Implying there is no conservation of kinetic energy, that is we assumed the shell of the cashew nut, when an impact load from the impeller is applied should crack the nut plastically. That is, no loss in energy.

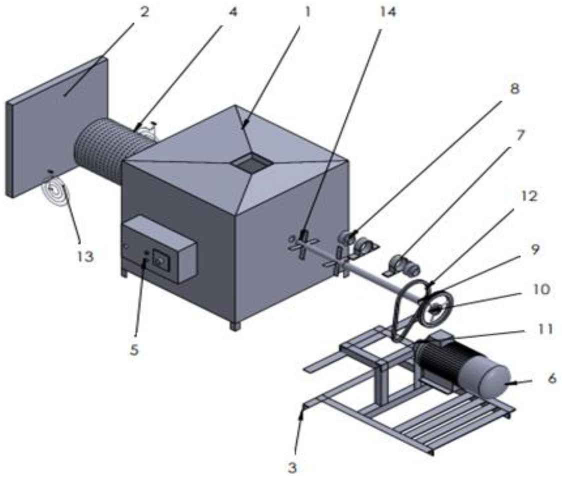

Fig. 1. The design cashew nut shelling machine:
1-Chamber; 2-Cover; 3-Frame; 4-Fenstrated cylinder; 5-Control panel; 6-Motor; 7-Bearing support; 8-Bearing; 9-Shaft; 10-Pulley; 11-Motor Shaft; 12-Belt; 13-Heating element; 14-Agitator.

Calculation of the impact velocity

According to [1]:

$$I = ke\ (J) \tag{1}$$

where *I* is impact energy and ke is kinetic energy.

$$I = \frac{mv^2}{2}\ (J)$$

where *m* is the mass and v is the velocity.

From the samples measured, average mass of the nut was 4.1 gram.

Thus,

$$I = \frac{0.0041v^2}{2}\ (J)$$

From the assumption that the colliding force of the nut with the shelling wall is entirely plastic in nature, then: work used in shell deformation = impact energy

But according to [1]:

$$W = \frac{1}{2} F \times e\ \text{(J)} \tag{2}$$

where *W* is the work of deformation, *F* is the applied force and e is the deformation.

$$F = P \times \frac{f'}{f} \times N\ (\text{kg.m.s}^{-2}) \tag{3}$$

$$F = P \times \frac{e'}{e} \times N \tag{4}$$

Where f' is the stress under impact, e' is the deformation under impact, f is the direct stresses, e is corresponding deformation, P is the load applied under impact and is equal to the impact load required to shell the nut [1].

but:

$$f' = 2\left(\frac{P}{A}\right) N/m^2 \quad (5)$$

Implying that:

$$f' = 2f$$

and

$$e' = 2e$$

Hence:

$$F = 2P \quad (6)$$

Thus implying:

$$W = (P \times e)\ (\mathrm{J})$$

[2] had earlier reported a cracking force of 99.8 N for roasted pre-damaged nuts. In 2007, [3] reported that force of 108.8 N was required to fracture the nutshell in the dorsal orientation. More recently [4] reported highest impact load of 115 N. Using this impact load of 115 N which is closest to the laboratory obtained load of 114.8 N in this study.

$$W = (115 \times e)\ (\mathrm{J})$$

where e is the maximum deformation of the nut taken to be the difference in the sizes of the shell and the nut [3].

e = 7.25mm [3], that is, e = 0.00725m.

$$W = (115 \times 0.00725)\ (\mathrm{J})$$

$$W = 0.83\ (\mathrm{J})$$

2.5.2. Design of shaft speed
Equating to the *e*:

$$0.00205v^2 = 0.83$$

$$v^2 = \frac{0.83}{0.00205}$$

$$v = 20.12\ (m.s^{-1})$$

Without the obstructing shelling wall, the resulting motion of the hurled nut form the impeller is projectile in nature. The motion velocity is uniform with no acceleration component. Hence, the impact velocity equals the impellers velocity, which is tangential. Therefore, with impeller of 200mm diameter selected, the impeller angular speed can be calculated from:

$$v = \omega r\ (m.s^{-1}) \quad (7)$$

$$\omega = \frac{v}{r}\ (rad.s^{-1})$$

$$\omega = \frac{20.12}{0.1}$$

$$\omega = 201.2\ (rad.s^{-1})$$

The speed of the shaft in revolutions per minute can be calculated from:

$$Speed = \frac{\omega \times 60}{2\pi}\ (rev.min^{-1}\ ) \tag{8}$$

Since a motor with speed of 1921.32 rpm is needed to impact a force of 115 N. A motor of this magnitude was used.

3. RESULTS AND DISCUSSIONS

3.1. Testing and performance

The views of the cashew nut shelling machine designed and fabricated is shown in Figure 2.

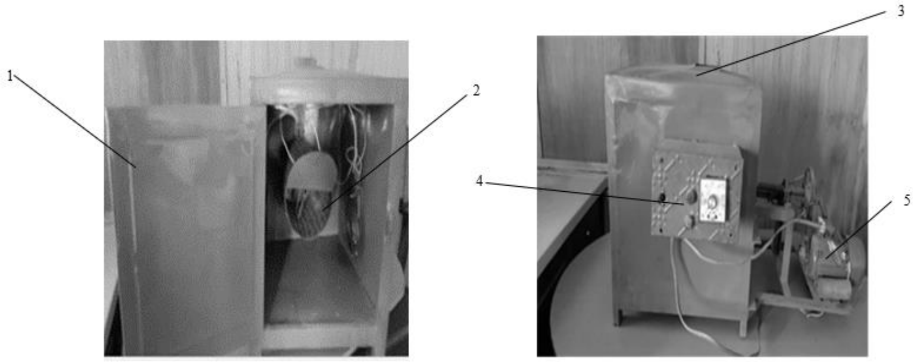

Fig. 2. Inside and back view of the fabricated machine:
1 - door; 2-fenestrated cylinder; 3-chamber; 4-control panel; 5-motor.

The shelling efficiency, shelling rate, whole kernel recovery and throughput were analysed using equations (8), (9), (10) and (12) respectively. This was to examine its operation and performance.

$$S_e = \frac{\text{completely shelled nuts (average)}}{\text{total feed}} \times 100\% \tag{9}$$

$$s_r = \frac{\text{completely shelled nut}}{\text{shelling time}} \tag{10}$$

$$Wk_r = \frac{\text{whole kernels recovered (average)}}{\text{total feed}} \times 100\% \tag{11}$$

and

$$T_p = \text{mass} \times \text{shelling rate} \times \text{1hour} \tag{12}$$

where *Se* is shelling efficiency, *Sr* is the shelling rate, *Wkr* is the whole kernel recovery and *Tp* is the throughput.

The performance of the shelling machine was tested using a total of 100 pieces of cashew nuts shown in Figure 3.

Fig. 3. Specimen of cashew nuts in tens for the experiment.

10 pieces of dried cashew nut were fed into the machine for testing per session. The average longitudinal and transverse length of each nut (using venier caliper) and the average weight (using weighing balance) were measured. The time at which each group roasted, totally cracked out of the shell, and released out of the shell were recorded. The number of damaged and undamaged kernel were computed and analysed. The test was repeated ten times. This was done to test whether the objective of the design was achieved or not.

3.2. Test results

The Average Mass/10nuts (AM), in gram, Roasting Temperature (RT), in °C, Roasting time (Rt), in seconds, Cracking Time (Ct), in seconds, Average Longitudinal Size (ALS), in mm, Average Transverse Size (ATS), in mm and Average Thickness (AT), in mm were measured and recoded as shown in Table 1 for each feed of cashew nut fed into the machine.

Table 1. The test result of the cashew nut shelling machine.

S/N	AM(g)	RT(°C)	Rt(sec)	Ct(sec)	ALS(mm)	ATS(mm)	AT(mm)
1	69.8	170	18	30	36	28	19.0
2	52.0	160	16	22	32	24	18.0
3	53.8	150	14	23	33	25	19.0
4	45.2	148	15	20	32	24	18.4
5	46.0	146	14	20	32	25	18.8
6	62.8	150	16	28	35	27	19.2
7	43.5	144	14	20	31	24	18.2
8	50.0	154	15	23	32	25	18.6
9	42.8	148	13	22	30	23	17.4
10	62.0	152	15	27	35	27	19.0
Average of parameter	52.8	152.2	15	23.5	32.8	25.2	18.7

$$\text{AM of dried cashew nuts} = \frac{527.9}{10} = 52.8g$$

$$Average\ RT = \frac{1522}{10} = 152.2 \pm 0.5°C$$

$$Average\ Ct = \frac{235}{10} = 23.5 \pm 0.2sec$$

$$Average\ Rt = \frac{150}{10} = 15min$$

The optimal roasting temperature after series of test with cashew nut of varied mass, Longitudinal and transverse section of a dried cashew was found to be 152.2 ℃.

From equations (8) and (9), we have:

$$S_e = \frac{\text{completely shelled nuts (average)}}{\text{total feed}} \times 100\% \ = \frac{80}{100} \times 100 = 80\%$$

$$s_r = \frac{\text{completely shelled nut}}{\text{shelling time}} = \frac{80}{25.2} = 3.2 \text{ Units/sec}$$

The processed cashew nuts obtained from the machine are shown in the Figure 4.

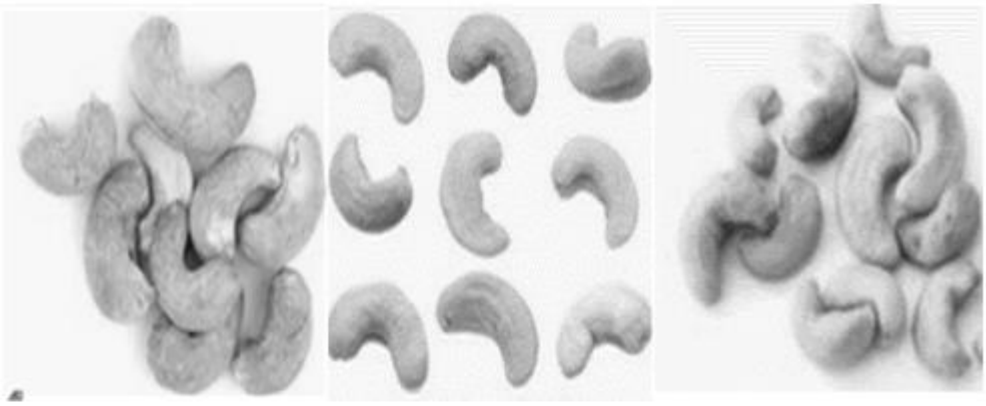

Fig. 4. Sample of processed cashew nuts.

3.2. Discussion

The result, based on the sample of cashew nut used for testing which has average longitudinal sizes in the ranges of 31 to 36mm, transverse size in the ranges of 23 to 28mm and average weight of 52.8g. It was observed that the machine can roast the cashew nut within an average of 15min at 152.2 ℃. The shelling efficiency of the machine was computed using the total number of whole kernel recovery after roasting and shelling with respect to the total number of cashew nut fed into the machine and it was found to be 80%. Given the hazardous effect of doing this manually or using previously developed machines, this value is really encouraging.

4. CONCLUSIONS

The machine was found to be effective in roasting and shelling cashew nut at an average temperature of 152.2℃ which is the optimum temperature. The machine was also found to operate at an efficiency of 80% which is an improvement. It has reduced setup time, hazards free, less fatigue and no risk like usually encountered during manual processing method. It can therefore gain application with small and medium scale cashew farmers as well as industries for cashew nut processing.

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