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A Study on A Novel Nut Cracker to Determine the Bulk Density, Sphericity and the Aspect Ratio on the Physical Properties of Cashew Nuts

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ABSTRACT

Over the years, the method of cracking cashew nuts using hammer or knife-cutter as a manual process has been a labour-intensive, which is very slow and tedious in production and application; besides mechanical crackers do not give satisfactory result in terms of whole kernel percentage. Therefore, in this paper, a new nutcracker is introduced to determine the force, length, width, sphericity and the aspect ratio on (physical properties) roasted cashew, boiled cashew and raw cashew nuts to crack the shell, leaving the nuts were investigated. The results of the effect of force on the various samples of nut show that the force required to crack the raw nuts was 0.78 N which was averagely lesser than both the roasted and boiled nuts with their corresponding values of 1.297 N and 1.952 N. This shows that the boiled nuts had almost perfect cracking characteristics. Therefore it is recommended that it should be used other than the roasted and the raw nuts. The effects of sphericity of the various samples of nuts. The raw nuts had the highest sphericity value of 5.361 mm, then the roasted nuts also had the next highest value of 5.057 mm, and finally, the boiled nuts also had a corresponding value of 4.961 mm respectively. This shows that the roasted nut had poor cracking characteristics, which had some shells cracked together with the nuts. The effect is that; the target will not be met if this type of nut is used. A preliminary test was conducted to determine the force and energy consumed in cracking a roasted cashew nut, and it was revealed that an average of 20 seconds and 0.28m distance is assumed for the cracking lid to make contact with the feeding tray. Finally, the mean value for the required power was calculated, and the results obtained was 6.84 W.

Keywords : cashew nut, knife-cutter, roasted nut, boiled nut, raw nut, aspect ratio, energy consumption.

I. INTRODUCTION

Cashew is an evergreen tropical tree from northern Brazil, which produces a valuable nut that is widely consumed as snacks all over the world [1]. Cashew nut ranks third among the edible tree nuts of the world with an output of about 700000 metrics tones nut in shell, monthly [2]. Presently five African countries are among the major producers of cashew nuts in the world. Nuts may be sold raw or as processed kernels and may be further processed into value-added products such as fried, roasted or chocolate-coated kernel and confectioneries, etc. The international market price in general influenced by certain quality standards (e.g. kernel size and percentage of broken kernels) in accordance with the specifications of the International Organization for Standardization [3, 4]. Due to the low capacity for cashew nut processing in Ghana, the bulk of the harvested nuts are exported to some countries in Asia where the processing capacity is large. Local consumption and demand by importing countries for cashew kernels continue to increase providing opportunities for expansion of the industry worldwide [5]. Traditionally, cashew nut shelling is a manual process. The irregular shape of the cashew nut, the presence of a tough outer shell and the corrosive Cashew Nut Shelling Liquid (CNSL) make processing a dirty and arduous task. Also, for the same reasons, it has been extremely difficult to mechanize this process while at the same time maintaining a high quality of the product. Nuts are both heated with steam or roasted dry or in a bath of CNSL and cooled to make the shell brittle and enhance loosening of the kernel from the inner surface of the pericarp during shelling [6]. Cashew cultivation has the potential to increase the income of producers, to create employment opportunities during harvesting of processing, and to increase export [7]. However, as with all small-scale and medium-scale processing operations, cashew processing is not without risk or problems. In order for the small scale and medium scale processor to succeed, research is carried into the various properties of the nut and to come out with a proposed design mechanism that will aid farmers in cracking the nut.

In recent years there have been many studies on cashew and its production all over the world. Ojolo and coauthor [8] predicted a cracking of cashew nut using contact stress theory hertz to predict the exact cracking force of cashew nut using a mathematical model. Their results showed that there were 34.31 mm, 24.86 mm, 16.55 mm, 6.13 g, 24.13 mm, 0.70, 1834.65 mm^2 and 0.73 physical properties of varieties of cashew nut such as length, width, thickness, density, geometric mean diameter, sphericity index, surface area and aspect ratio. Also at loading orientations (X, Y and Z) (355,288 and 289 N), (1.396, 1.5002 and 1.815 mm), and (313, 195 and 160 N / mm) at 5 mm/min, and (458, 276 and 480 N), (2.28, 1.767 and 3.7197 mm) and (202, 162 and 146 N / mm) at 10 mm / min respectively, mechanical parameters such as cracking strength, deformation and steadiness modules were also obtained from the control deformation curve. Rêgo et al. [9] conducted a study of cashew wine and volatile compounds formed during fermentation by the non-Saccharomyces and Saccharomyces yeast. They concluded that during fermentation, concentrations of acetic acid were within the range of 0.2–0.5 g / L, which is considered desirable to contribute to fruit wine aromas and flavors. These results highlighted the role of fruit leaf isolates in the fermentation of cashew juice and the development of desirable volatile compounds for the processing of cashew wine. Sawadogo et al. [10] also conducted a case study on cleaner manufacturing in Burkina Faso, on fuel briquettes generated from cashew waste as biomass for electricity generation. Their results indicated that the combustion of briquette produces a very strong flaming quality. A comparison of the briquettes and charcoal thermal yields showed that the fireplace's thermal output using briquettes (33.9 per cent) was similar to that of charcoal (33.7 per cent). Asiru et al. [11] studied on a thin layer dried cashew kernels' mathematical modelling with drying air temperature was 70-110 °C. They concluded their results that the multiple regression analysis using linear and non-linear form models estimated the effects of the drying air temperature and time on the constants and coefficients of the drying model. In addition, the page model was found to be the best among the models to explain the drying behavior of cashew kernels with the values R^2, MSE and P of 0.9830, 0.00311 and 5.046 respectively. Vedharaj et al. [12] investigated on Synthesis and the use of catalytically crushed cashew nut shell liquid in a diesel engine where CC-CNSL20 (20 per cent CC-CNSL and 80 per cent diesel) was tested at different fuel injection pressures such as 200 bar, 235 bar, 270 bar and 300 bar to maximize its use in a single cylinder diesel engine. It was observed that from the engine experimental analysis, the CC-CNSL20 was found to demonstrate better engine efficiency than diesel and the composite emissions of CO (carbon monoxide), HC (hydrocarbon), NOX (nitrogen oxides) and smoke, measured on the basis of the standard ISO 8178 D2 test cycle, were found to be better than diesel and were inconsistent with the genset legislation. Over the decades, the pedal-operated knife cutter was put into existence but can only shell one nut at a time which is slow and tedious, also a motorized sheller was developed and could only shell one to ten nuts and could not separate the broken shell from the nut. Sheller's are prone to injury by the knife-like cutting edges of the machine.

The purpose of this paper is to study the current global drive towards sustainable development in third world countries call for the development of technology, which makes it possible for the establishment of cottage industries in rural and urban areas and even the establishment of fully functional processing factory in the cities and big towns to reduce the rural and urban migration problems. As a third world country, the rural and urban agricultural communities and young industries in Ghana cannot afford sophisticated cashew nut shelling machines due to the high initial cost. Therefore, it is imperative to study into the properties of the nuts and propose the development of a cashew nut shelling machine which is commensurate with the needs of an average rural-urban user. This study proposes the design of a new nutcracker to determine the bulk density, sphericity and the aspect ratio on the physical properties of cashew nuts.

II. MATERIAL AND METHOD

2.1 Experimental material and process

The equipment used were: moisture dishes made of aluminium; the pre-shelling treatments used were steam boiling and roasting in a bath of cashew nut shell liquid; raw samples of cashew nuts were reserved for use as the control.

2.2 Methods of obtaining cashew

The raw cashew nuts (from yellow apples) were obtained from plantations in Sekyere and Asokore of Juaben area in Ashanti Region of Ghana. Two plantations with ages ranging from 10 to 15 years (when cashew trees should be producing at maximum capacity under favorable conditions) were randomly selected in each area. About 250 g of nuts per tree were picked from 20 randomly selected trees in each of the plantations. The samples were prepared according to the methods described below;

(a) Two batches of 250 g weight of raw cashew nuts were drawn from the lot. Each of the two batches was steam boiled for 30 mins, one after another, after which they were allowed to cool naturally for 24 hours.

(b) Two batches of 250 g weight of raw cashew nuts were drawn from the lot. Each of the two batches was roasted one after another by heating cashew nut shell liquid to 190-200 ^{0}C. The roasted nuts were allowed to cool naturally for 24 hours. The following physical properties were determined for each of the two categories of pre-treated cashew nut, i.e. roasted and steam boiled-dimensions, sphericity index, and aspect ratio.

(c) For each replicate of the heat-treated cashew nuts, 50 nuts were picked randomly from each replicate of the heat treatment, and the principal axes, i.e. a-length, b-width, and c- thickness were determined as shown in the formula. The width and thickness were measured perpendicular to the major axis. The sphericity index (Sp) and aspect ratio (Ra) was calculated as [13, 14]:

$$Sp = \left(\frac{abc}{a}\right)^{1}/_{3} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

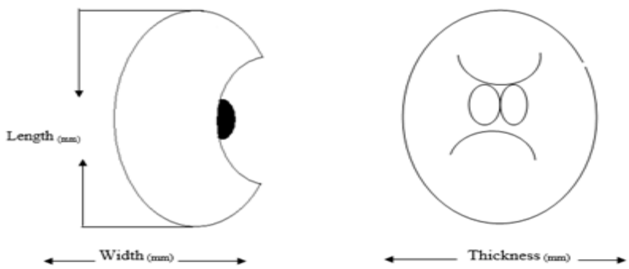

Figure 1. Schematic diagram showing the characteristic dimension of cashew nut

(a) From the values obtained for true and bulk density, the porosity (p) of each sample was calculated as [13]:

$$P = \frac{Pi - Pb}{Pi} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

(b) Moisture measurement was carried out following the ASAE Standards [15]. The test samples for which moisture content was determined were the nut, the kernel and the shell. Two moisture dishes were obtained, and approximately 250 g of each of the test samples weighed to the nearest 0.01 g was spread evenly over the base of each of the moisture dishes. The initial weight of each of the moisture dishes plus the sample was taken. The dishes with their lids beside them were placed in an oven at 103 ^{0}C for 1 hour. At the end of oven-drying, the two dishes were removed quickly and covered with their lids and placed in desiccators. The final weight of each of the moisture dishes plus the oven-dried sample it contained was taken after they reached room temperature. The moisture content (wet basis) for each sample was calculated by dividing the loss in weight due to oven drying by the initial weight of the sample [15]. The experiment was repeated two per test sample for each replicate of the heat treatment:

$$m = \frac{100Wm}{Wi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

Where: m = moisture content, wet basis (%), Wm = moisture loss, wi = initial weight of test sample.

(c) A regular cylindrical container open at both ends and placed on a galvanized steel surface was filled with cashew nuts to the brim. Afterwards, the container was lifted gradually and finally emptied to form a conical heap with the nuts. This was repeated ten times for each replicate of the heat treatment. The tangent of the angle of inclination to the horizontal was calculated from the height (h) and base radius (r) of the formed heap as:

$$Tan\theta = \frac{h}{r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

(g) Coefficient of static friction is the tangent of the angle of inclination at which a material begins to slide on a surface. Five nuts were placed on an inclined plane apparatus with mild steel, galvanized steel and plastic surfaces by applying the Asian industrialization methods [16]. The plane portion of the apparatus was raised. The angle of inclination to the horizontal, as soon as the nuts began to slide, was measured from the protractor, the tangent of which is the coefficient of static friction. This was repeated ten times for each replicate of the heat treatment. The results obtained were analyzed using Duncan's multiple range grouping Statistical Analysis Software (SAS).

2.3 Experimental procedure

Usually, the cashew nut is cracked manually using a hammer, or mechanically by knife cutters which often affect the wholesomeness of the kernels. Good quality cashew kernels must be wholesome and defects-free during processing. Once the kernel is removed from the shell, it is dried, peeled and graded for packing. CNSL which is released as a by-product during roasting, has valuable industrial uses as a raw material for the manufacture of resins, paints, dyes and insecticides wood preservatives etc. The traditional manual method of shelling cashew nut using a hammer is a labour-intensive, slow and tedious process. It also has health implications due to the corrosive action of CNSL on human skin.

2.4 characterization process of the nuts

The Brignell hardness testing machine was used to determine the hardness of various types of metal. It has a lower arm which is movable, and an upper arm which is stationary with a ball fitted it. The handle is turned in a clockwise direction which causes the lower arm to move up against the upper arm compressing the metal in between together. The ball fixed in the upper arm creates an indentation in metal depending on the force applied or the hardness of the metal.

III. RESULTS AND DISCUSSION

The dimensions of cashew nut as influenced by pre-shelling heat treatment are shown in Table 1. With raw cashew nuts as control, it was observed that the physical dimensions of the pre-treated cashew nuts varied considerably. For all the nut sizes considered, a decrease in the dimensions was observed when the nuts were roasted. This was due to loss of moisture from the cashew nuts and shrinkage during roasting. An increase in the physical dimensions was observed when the nuts were steam boiled. This was due to the addition of moisture during steam boiling. The two pre-treatments provided are for moisture removal and moisture addition. The size distribution for raw cashew nuts compared reasonably with Balasubramanian [17] who had earlier carried out similar work on raw India-grown cashew nuts. From Table 1, the differences in the mean length and width are significant; however, there was a significant difference in the mean thickness, aspect ratio and sphericity. The difference indicated by the pre-shelling treatment is not significant. The heat applied during roasting caused the release of cashew nut shell liquid and moisture loss from the raw cashew nut. This obviously accounts for the decrease in the nut weight and, consequently, the density of roasted nuts. Figure 2 shows the released of cashew nut liquid from the shell.

Table 1. The various cashew nuts

	Roasted Nuts			Boiled Nuts			Raw Nuts		
	Nuts no	mean(X)	SD	nuts no	mean(X)	SD	nuts no	mean(X)	SD
Force	20	0.729	1.927	20	0.497	1.95	20	0.78	1.922
Length	20	30.62	1.062	20	30.396	1.04	20	27.5	0.752
Width	20	23.62	0.362	20	20.066	0.01	20	18.8	0.123

Thickness	20	16.228	0.377	20	15.214	0.48	20	19.3	0.066
Sphericity	20	70.565	5.057	20	69.608	4.96	20	73.6	5.361

Figure 2. Release of cashew nut liquid from the shell

3.1 The effect of force on the various samples of nuts

The results of the effect of force on the various samples of nut show that the force required to crack the raw nuts was 0.78 which was averagely lesser than both the roasted and boiled nuts with their corresponding values of 1.297 and 1.952. this shows that the boiled nut had the highest effect of force, as shown in Figure 3.

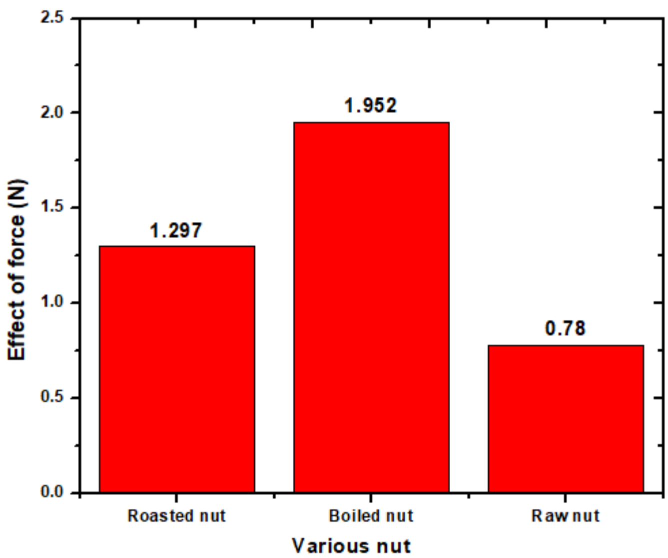

Figure 3. The effect of force on the various samples of nuts

3.2 The sphericity ratio results and the force application results

Figure 4 shows the effects of sphericity of the various samples of nuts. The raw nuts had the highest sphericity value of 5.361, then the roasted nuts also had the next highest value of 5.057, and finally, the boiled nuts also had a corresponding value of 4.961, respectively.

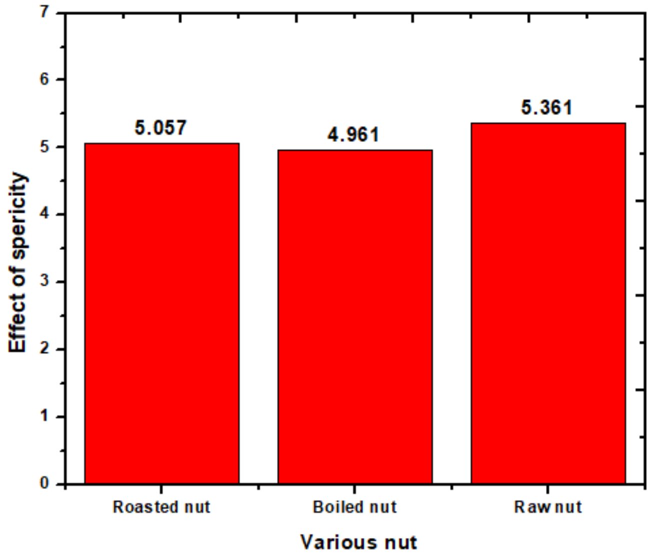

Figure 4. The effect of sphericity on the various samples of nuts

3.3 Observations after the experimental study

The following observations were made after an experimental study carried out: (a) The nuts were slipping during the measuring process; therefore a lot of time was consumed; (b) the nuts were observed to be slipping in force testing machine; therefore it made the testing process to be slow and tedious; (c) when the shell liquid gets in contact with the fingers it turns the fingertips dirty brown. In this effect, it will be appropriate to wear hand groves for this process; (d) the boiled nuts had almost perfect cracking characteristics. Therefore it is recommended that it should be used other than the Roasted and the Raw nuts; (e) the roasted nut had a poor cracking characteristic, it has some its shells cracked together with the nuts. The effect is that; the target will not be met if this type of nut is used.

3.4 Proposed design and construction

The machine is conceived as a rural and urban-level, low-cost, simple and easy to be operated manual device, capable of cracking many cashew nuts at a time. This machine allows for adjustment and proper alignment of the nuts before cracking. It comprises four major components assembled together by welding to form a compact device. The components are the metal casing, the feeding tray supported by a mild steel box, the cracking lid, and the lever arm.

3.5 Proposed design

3.5.1Grooves on the feeding tray

Roasted cashew nuts are considered as an approximate ellipsoid with the major diameter equivalent to mean length and the minor diameter equivalent to mean width of the cashew nut, and this dimension with some tolerance defines the grooves of the tray. However, the average depth of the grooves is calculated as ½ (thickness of seed) + 2/3 (thickness of the nut).

3.5.2 The cracking lid

A preliminary test was done to determine the force and energy consumed in cracking a roasted cashew nut revealed that;

1. An average of 20 seconds and 0.28m distance is assumed for the cracking lid to make contact with the feeding tray.
2. The power P required to crack each cashew nut was calculated as follows [18]:

$$P = Fv$$

Where F = the average force to crack 20 nuts

$$V = \text{Velocity}$$

$$V = d/t$$

Where d = Distance

$$T = \text{Time}$$

$$V = \frac{0.28}{20}$$

$$V = 0.01 \text{ m/s}$$

$$P = 488.8 \times 0.014$$

$$P = 6.84 \text{ W}$$

Hence, F = mean cracking force for a single nut = 488.80 N. The mean value for required power was calculated to be 6.84 W. In order to determine the allowable tensile force on the plate, the cross-section of the plate is taken as a square length, 180mm cross-sectional area A of a plate containing 25 nuts = 180 mm × 180 mm = 32400 mm^2. Therefore, the average stress across the plate is calculated as [19].

$$\tau = \frac{F}{A}$$

Where F = average force to crack the 20 nuts in a batch

$$\tau = \frac{488.8}{34200}$$

$$= 0.0143 \text{ N/mm}^2$$

From Table 2 shows the value was less than the tensile stress of mild steel metal, hence mild steel was chosen for the cracking lid and also for its low cost relative to other common metals.

Table 2. Proposed construction (Part List)

Part	Dimension	Material
Metal Handle	60mm by 5mm	Mild Steel
Spring Luck	400mm	High-Speed Steel
Feeding Tray	400mm by 400mm by 20mm	Mild Steel
Bracket or Brace	50mm by 400mm	Mild Steel
Stands or Legs	50mm by 50mm by 600mm	Mild Steel
Cracking Lid	400mm by 400mm by 15mm	Mild Steel

IV. CONCLUSION

In this study, the design of a new nutcracker to determine the bulk density, sphericity and the aspect ratio on the physical properties of the nut were investigated. The various results were obtained after the experimental study. The results of the effect of force on the various samples of nut show that the force required to crack the raw nuts was 0.78 which was averagely lesser than both the roasted and boiled nuts with their corresponding values of 1.297 and 1.952. This shows that the boiled nuts had almost perfect cracking characteristics.

Therefore it is recommended that it should be used other than the roasted and the raw nuts. The effects of sphericity of the various samples of nuts indicated that the raw nuts had the highest sphericity value of 5.361, then the roasted nuts also had the next highest value of 5.057, and finally, the boiled nuts also had a corresponding value of 4.961 respectively. This shows that the roasted nut had poor cracking characteristics, which had some shells cracked together with the nuts. The effect is that; the target will not be met if this type of nut is used. A preliminary test was conducted to determine the force and energy consumed in cracking a roasted cashew nut, and it was revealed that an average of 20 seconds and 0.28m distance is assumed for the cracking lid to make contact with the feeding tray. Finally, the mean value for the required power was calculated, and the results obtained was 6.84 W.

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