

Development of a Cashew Nut Cracking Device

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ABSTRACT

The traditional method of cracking roasted cashew nuts manually, using harmer or knife cutter is labour-intensive, slow and tedious; besides, most mechanical crackers do not give satisfactory results in terms of whole kernels percentage. A prototype machine was developed to crack roasted cashew nuts. The box-like machine has a hinged and spring-loaded mild steel cracking lid with grooves to hold a cast aluminum feeding tray which was machined to hold 25 nuts at a time. Nuts get cracked by the impact of the lid against the feeding tray. The lid provides for a minimum clearance from the feeding tray on which nuts are preloaded; this prevents the applied force from being in excess of the required cracking force. The machine was tested with various cashew nut sizes, and placement orientations. The percentage of whole kernels produced was 66.66 %. The capacity of the machine was estimated to be about 18.3 kg/hr. A device of this nature can be manufactured for small entrepreneurs and village-level applications in the developing countries where bulk of the world cashew is produced.

Keywords: Roasted cashew nut, cracker, kernel, village-level, Nigeria.

1. INTRODUCTION

Cashew (*Anacardium occidentale L.*) is an evergreen tropical tree from northeast Brazil, which produces a valuable nut that is widely consumed as snacks all over the world. Cashew nut ranks third among the edible tree nuts of the world with a current output of about 700,000 metric tonnes nut in shell (FAO, 2004). Presently, Nigeria and five other African countries are among the major producers of cashew nuts in the world; other countries are: Vietnam, India, Brazil, and Indonesia (FAO, 2004). 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 kernels and confectioneries, *etc.* International market price is generally 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 (AFI, 1990; Nouwligbèto and Jérôme, 2003). However, in view of the low capacity for cashew nut processing in Nigeria (Ogunsina and Odugbenro, 2005), bulk of the harvested nuts goes to India and other countries in Asia where the processing capacity is large (Adetunmbi, 2001). Local consumption and demand by importing countries for cashew kernels continue to increase, providing opportunities for expansion of the industry worldwide (Ohler, 1988).

Traditionally, cashew nut shelling is a manual process. Nuts are either heated with steam or roasted dry or in a bath of cashew nut shell liquid (CNSL) and cooled to make the shell brittle and enhance loosening of the kernel from the inner surfaces of the pericarp during shelling (Noomhorm *et al.*, 1992; Andrighetti, *et al.*, 1994; Sivala *et al.*, 1994; Jain and Sivala, 1997; Ajav, 1996). Roasted nuts are first soaked in water to raise the moisture content of the kernel thereby reducing the risk of being scorched during roasting and making it more flexible so it is less likely to crack. Usually 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 packaging. Cashew shell nut liquid (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, insecticides, wood preservatives, *etc.* (Chacko, *et al.*, 1990; Andrighetti *et al.*, 1994). The manual traditional method of shelling cashew nuts using harmer is a labour-intensive, slow and tedious process. It also has some health implications due to the corrosive action of CNSL on human skin.

Some past works notably include the pedal-operated knife-cutter (Ajav, 1996), the motorized cashew nut sheller (Jain and Sivala, 1997) and the bambara groundnut sheller (Atiku *et al.*, 2004). The whole kernel percentage obtainable using the motorized sheller is low (50 %) and not satisfactory. The pedal-operated knife-cutter can only shell one nut at a time. An average Sheller can crack one nut in about six seconds or ten nuts per minute. In an eight-hour working day, this corresponds to about 21 kg/day or about 7 metric tones/yr (Azam-Alli and Judge, 2001). The method is therefore slow and labour intensive; besides, Shellers are prone to injury by the knife-like cutting edges of the machine. However, the current global drive towards sustainable development in third world countries call for the development of technology, which encourage the establishment of cottage industries and promote rural/village level processing of cashew nuts into value-added products. Most rural/agricultural communities in Nigeria cannot afford sophisticated cashew nut shelling machines due to the high initial cost. It is therefore imperative to develop a cashew nut shelling machine which is commensurate with the needs of an average rural user. The development of a village level cashew nut cracking device to be operated requiring no electrical or mechanical energy is reported in this paper.

2. DESIGN AND CONSTRUCTION

2.1 Philosophy of Design

The machine was conceived as a village-level, low-cost, simple-to-operate and easy-to-fabricate manually-operated device capable of cracking many cashew nuts at a time.

2.2 Prototype Machine Description

The machine is a simple device, which allows for adjustment and proper alignment of the nuts before cracking. It comprises of four major components assembled together by welding to form a compact device. The components are: the metal casing, the feeding tray which is supported by mild steel box, the cracking lid, and the lever arm.

The Metal Casing: The metal casing is made of mild steel welded into a rectangular box, with an opening on the opposite side for easy handling. The welded mild steel base serves as the path for moving the feeding tray in and out and as a guide to reduce excessive pressure on the feeding tray.

The Feeding Tray: This is a cast aluminum flat plate of dimension 190 mm × 190 mm with grooves dimensioned to accommodate 25 cashew nuts of various sizes in a single run. The actual depth of the grooves inside which the nuts sit ranges from 6-8 mm and a maximum clearance of 2 mm. It is supported at the base by a flat plate of mild steel welded to the metal case to allow the tray to slide easily in it. The tray is pulled out to be loaded with cashew nuts and after loading it is pushed back into the metal case.

The Cracking Lid: The mild steel cracking lid is machined and dimensioned to provide a minimum clearance with the feeding tray. It consists of two sections: the working part, and the guide. The working part is 200 mm square and it is extended by 20 mm outward into the box and a clearance of 20 mm on each side to serve as a guide. Once the lid comes in contact with the metal case, the working part must have moved 10 mm down into the box and this prevents it from damaging the kernel during nut cracking.

The Lever Arm: The lever arm is welded to the end of the cracking lid, which cracks the preloaded nuts on the feeding tray when closed. The cracking force is applied through the lever arm and the guide on both sides of the cracking lid prevents the applied force from being in excess of what is required to crack the shell to avoid crushing of kernels after the nut is cracked. From compression tests, the average force required to crack the nut was determined to be 600 N. On activating the lever, the lid compresses the nuts, leaving it partially closed with a maximum clearance of 2 mm, to prevent crushing the embedded kernels. At this instance all the nuts must have been cracked but the lid will not close up enough to crush the kernels. Immediately the lever is released, the spring returns the cracking lid back to the opening position. When not in use the lid is locked in position with the aid of the hook provided on the casing.

The complete machine assembly is shown in Figure 1



Fig. 1: A complete assembly of the village-level cashew nut sheller

2.3 Preliminary Investigation

Dry-roasted cashew nuts were obtained from ABOD cashew nut processing factory in Ikorodu, Lagos, Nigeria. Some properties such as dimension (length, thickness and width), cracking force and absorbed energy of the roasted nuts were determined; these nuts were shelled and the dimension of the kernels were determined (Tables 1).

2.4 Design

2.4.1 Grooves on the Feeding Tray

The roasted cashew nuts were 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 these dimension with some tolerance defined the grooves of the feeding tray. The average depth of the groove was calculated as $\frac{1}{2}$ (thickness of seed) + $\frac{2}{3}$ (thickness of the nut)

2.4.2 The Cracking Lid

Preliminary tests were carried out to determine the force and the energy absorbed in cracking roasted cashew nuts. The results are shown below. An average of 20 seconds was assumed for the cracking lid to make contact with the feeding tray. According to Shigley (2004) the power P required to crack each cashew nut was calculated as follows:

$$P = Fv \quad (1)$$

But

$$v = \frac{d}{t} = 0.014 \text{ m/s}$$

$$P = 488.8 \times 0.014 = 6.84 \text{ W}$$

Table 1: Some Properties of Roasted Cashew Nuts

Parameters	Mean	Mean deviation	Std deviation
Nut			
Length (mm)	30.40	1.36	1.61
Width (mm)	20.45	1.14	1.48
Thickness (mm)	18.71	0.89	1.08
Kernel			
Length (mm)	26.38	1.38	1.56
Width (mm)	13.43	0.68	0.86
Thickness (mm)	8.00	1.30	1.47
Cracking parameters			
Nut weight (g)	5.67	0.83	0.98
Cracking force (N)	488.80	33.94	42.31
Absorbed Energy (MJ)	1.36	1.14	0.89
Required power (W)	1.61	1.48	1.08

F = mean cracking force for a single nut = 488.80 N

The mean value for the required power was calculated to be 6.84 W.

To determine the allowable tensile force on the plate, the cross section of the plate is taken as a square of length 180 mm.

Cross sectional area A of plate containing 25 nuts = $180 \text{ mm} \times 180 \text{ mm}$
 $= 32400 \text{ mm}^2$

From Rolyance (2000), the average stress across the plate τ is calculated as:

$$\tau = \frac{F}{A} \quad (2)$$

Where, F = average force to crack the 25 nuts in a batch.

$$\begin{aligned} \tau &= \frac{488.8}{34200} \\ &= 0.0143 \text{ N} / \text{mm}^2 \end{aligned}$$

From Tables, this value is less than the tensile stress of mild steel metal, hence mild steel was chosen for the cracking lid due to its low cost and availability relative to some other common metals.

2.4.3 Return Spring Selection

The pressure due to the applied force is the pressure due to the weight of the mild steel of a dimension $180 \text{ mm} \times 180 \text{ mm} \times 20 \text{ mm}$, and the pressure required to be applied operate the machine. This was estimated as 193.47 kN/m^2 . The power stroke must produce a minimum torque of $6.90 \times 0.2828 \text{ Nm}$ at the lever arm, and give an angular motion of approximately 90° to the lever arm. The lever arm is approximately 282.84 mm , which implies that the length of the stroke is 282.84 mm . The spring therefore must have a minimum deflection (δ) of 282.84 mm under a maximum compressive load L of 1.074 kN . The spring rate 'S' is given as:

$$\begin{aligned} S &= \frac{L}{\delta} \\ &= \frac{1074}{282.84} = 3.797 \text{ N/mm} \end{aligned} \quad (3)$$

but, from Gupta (2006) S is given by the expression below

$$S = \frac{Gd^4}{\delta D^3 n} \quad (4)$$

Where G = modulus of rigidity taken as 80 GN/m^2

Using a shaft of diameter 20 mm to support the spring, and a wire of diameter 4.5 mm , then $d = 4.5 \text{ mm}$ and the mean diameter, D , of the coil is $(20 - 4.5) = 15.5 \text{ mm}$. Therefore, number of coils $n = 8.2$, so 9 coils was chosen. Allowing for the two ends the spring will have 11 coils each of diameter 4.5 mm and length which equals to $11 \times 4.5 \times 140 = 6930 \text{ mm}$.

The spring index: $c = D/d = 3.4$

$$k = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

Therefore, $k = 1.49$

However, $\tau = \frac{8FDk}{\pi d^3} \quad (5)$

$$= 691 \text{ MPa}$$

For this purpose 4140 Q & T steel was selected.

3. TESTING

3.1 Machine Testing

Preliminary tests were carried out with dry-roasted cashew nuts to determine the alignment, position, and nuts placement in the grooves for which the machine gives the best percentage of whole nuts without crushing the kernels. Nuts were placed in the grooves using three different orientations arranging the nuts face down; face up and side way. For each orientation, 25 nuts were cracked, and the percentage of the whole kernels produced was determined. The throughput of the machine was determined as the weight of nuts cracked per unit time.

4. RESULTS AND DISCUSSION

The results of the tests carried out are reported in Tables 2 and 3. The performance of the machine was

Table 2: Summary of Test Results

Exp. Number	Whole kernel	Broken Kernel
1	12	8
2	11	9
3	14	6
4	14	6
5	14	6
6	15	5
Mean	13.33	6.67
Percentage	66.67 %	33.33 %

Table 3: Rate of Cashew Nut Shelling

S/N	No of Nuts Cracked	Weight of Cracked Nuts (g)	Time of Operation (s)
1	25.00	84.90	19.12
2	25.00	81.06	15.64
3	25.00	80.70	18.60
4	25.00	83.10	17.40
5	25.00	101.00	16.60
6	25.00	105.22	15.24
7	25.00	111.04	18.44
8	25.00	103.10	15.12

9	25.00	97.70	15.24
10	25.00	101.66	19.20
11	25.00	117.26	18.32
Mean	25.00	87.78	17.26

measured using the percentage of the nuts cracked and the whole kernels produced. Nuts arranged face

up in the grooves cracked best {Figures 2 (a) and (b)} and gave the highest percentage of whole kernels compared to the two other positions. This orientation was chosen to determine the efficiency of the machine. The average percentage of whole and broken kernels produced is presented in Table 2. There were 66.66 % whole and 33.33 % broken kernels; this is less than 80% whole kernel recovery obtained by Jain and Sivala (1997) for a semi-automated sheller and 67-75% cracking efficiency obtained by Ajav (1996) for a manual sheller. However, the percentage whole kernel recovery is also affected by the method and condition of heat treatment (Oloso and Clarke, 1993; Jain and Sivala, 1997; Thivavarvongs et al., 1995 and Noormhorm et al., 1992). If the nuts are excessively roasted the percentage whole kernel recovery will be low. The results in Table 3 show that an average of twenty nuts weighing 87.78 g was cracked in one run in an average of 17.26 seconds. This implies that the machine has an average throughput of 18.31 kg/hr which is far above 21 kg of nuts /day (*i.e.* 0.875 kg/hr) achievable by manual shelling of nuts one by one (Azam-Alli and Judge, 2001).



(a)



(b)

Figure 2(a): Nuts placement and loading orientation before cracking
 (b): A view of the cracking device showing cracked nuts

5. CONCLUSION

A cashew nut cracker has been developed to improve the efficiency of the shelling operation in cashew nut processing. The performance of the machine is fairly satisfactory but an improvement on the percentage of whole kernels is achievable with further modification and testing. A device of this nature can be manufactured in small machine shops in the developing countries for small entrepreneurs and village level applications.

REFERENCES

- Adetunmbi, O. 2001. Nigerian cashew industry: Curbing the waste. A paper delivered at the pre-conference meeting of the National Cashew Association of Nigeria. Lagos, Nigeria.
- Ajav, E.A. 1996. The design and testing of a low-cost cashew-nut cracker for peasant farmers. *Tropical Agriculture*. 73:180-186.
- Andrighetti, L; G.F. Bassi; P. Capella; A.M. De Logu; A.B. Deolalikar; G. Haeusler; F.M.C. Franca; G. Rivoira; L. Vannini and R. N. Deserti. 1994. *The World Cashew Economy*. (2nd ed.). Linchiostroblu, Italy. p 11-16, 33-48, 79-80.
- Association of Food Industries (AFI). Nut and Agricultural Products Section. 1990. Specification for cashew kernels. New York.
- Atiku, A.A., N.A. Aviara and M.A. Hague. 2004. Performance evaluation of a bambara groundnut sheller. *Agricultural Engineering International. The CIGR Ejournal*. Manuscript PM 04 002 Vol IV.
- Azam-Alli, S.H. and Judge, E.C. 2001. Small scale cashew nut processing. ITDG. FAO, Rome.
- Chacko, E.K., Baker, I. and Downton, J. 1990. Towards a sustainable cashew industry for Australia. *Agricultural Science*. (New Series) 3: 30 – 43.
- FAO Statistics. Cashew. www.uga.edu/fruit/cashew.html. Accessed on June 14, 2006.
- Gupta, J.K. 2006. *Engineering Mechanics and Strength of Materials*. New Delhi: S. Chand & Co.
- Jain, R.K. and Kumar, S. 1997. Development of a cashew nut sheller. *Journal of Food Engineering* 32: 339-345.
- Nouwligbèto, F.D. and Jérôme, A. 2003. African cashew nut in a harsh world Infosud-Syfia publication. No 196 January-February.

- Noomhorm, A., H.T. Sabarez; V.M. Salokhe; S. Gajendra and S.G. Ilangantileke. 1992. Studies on parameters affecting cashew nut processing. Proceedings of an International Agricultural Engineering Conference held in Bangkok, Thailand. 2: 449-454.
- Ogunsina, B.S. and Odugbenro, P.O. 2005. Prospects for cashew nut processing industry in Nigeria. *Landwards*. Institution of Agricultural Engineers Journal, UK. 60(4) 2-6.
- Ohler, J.G. 1988. Cashew. KIT Publications, India.
- Oloso, A.O. and Clarke, B. 1993. Some aspects of strength properties of cashew nut. *Journal of Agricultural Engineering Research*. UK 55(1) 27-43.
- Roylance, D. 2000. *Mechanics of Materials*. New York: John Wiley & Sons.
- Shigley, J. E. 2004. *Mechanical Engineering Design*. McGraw Hill Inc. New York.
- Sivala, K., P.P. Srivatav and R.K. Jain. 1994. Cashew nut processing in Midnapur district of West Bengal: A case study of Bombay, India. *Beverage and Food World*. 21(5)25-27. 1994.
- Thivavarnvongs, T., T. Okamoto and O. Kitani. 1995. Development of compact sized cashew nut shelling machinery (Part 1). Synthesis of effective manual and semi- automatic shelling methods. *Journal of the Japanese Society of Agricultural Machinery*. 57(2) 57-65.