A Table Mounted Device for Cracking Dika Nut (*Irvingia gabonensis)*

B.S. Ogunsina[1*] O.A. Koya[2], and O.O. Adeosun[1]
[1]Dept. of Agricultural Engineering, Obafemi Awolowo University, Ile Ife, Nigeria
[2]Dept. of Mechanical Engineering, Obafemi Awolowo University, Ile Ife, Nigeria,
*Corresponding author: Phone: +234 802 3842354, 805 9881048.
E-mail: babsina@oauife.edu.ng, bsogunsina@yahoo.com

ABSTRACT

A simply designed machine for cracking dika nut was fabricated. The nut is fed by hand in-between a toggle mechanism comprising of the slider and a fixed block. Fracture mechanism was based on the deformation characteristics of dried dika nut under uni-axial compression. When actuated, the slider compresses the nutshell to failure along its line of symmetry. The experimental machine gave 100% cracking efficiency but with 24% kernel breakage in cracking sun-dried dika nut at 6.6% moisture content (w.b). The machine provides a viable and effective technique for safe dika kernel extraction.

Keywords: Dika nut, cracking device, machine design, kernel extraction, compression, Nigeria.

1. INTRODUCTION

The dika tree (*Irvingiacea spp*) is very valuable for its edible yellow mango-like fruit and the termite-resistant-wood (Ayuk, *et al.,* 1999 and Harris, 1996). The tree grows naturally in the humid, lowland forests of tropical Africa but is widely planted in Central and Western Africa (Ladipo *et al.,* 1995; White and Abernethy, 1996). The fruit (Figure 1a) is a drupe with a thin outer skin, soft fleshy pulp when ripe, and a hard stony nut encasing an extremely soft kernel (Okafor, 1978). Two species of the tree: *Irvingia gabonensis,* which has a sweet edible pulp and *Irvingia wombolu,* which has a bitter inedible pulp (Ejiofor, 1994) are common; however, kernels from both species exhibit similar valuable food properties (Omogbai, 1987 and Ejiofor, 1994). The kernel contains about 8.9% protein, 19.7% carbohydrate, 62.8% lipids, 5.3% dietary fibre and 3.2% ash by weight (Osagie and Odutuga, 1986). It constitutes an important part of the rural diet in West Africa (Ekpe *et al.,* 2007) for controlling dietary lipids and weight gain (Ngodi *et al*., 2005; Leakey *et al*., 2005 and Ogunsina *et al.,* 2008). Powdered dika kernel is commonly cooked with vegetables into *ogbono* soup, a valuable local delicacy in Nigeria, Ghana, and Gabon especially (Eka, 1980). The kernel meal and derivable edible oil are base materials for manufacturing pharmaceutical binders, confectioneries, edible fats, soaps and cosmetics (Okafor, 1978; Agbor, 1994 and Ayuk *et al*., 1999).

The major limitation in the exploitation of dika kernel is the drudgery involved in its extraction. Rural women who do most of the cracking hold the wet nut, one at a time, against a hard/stony surface to split it open with a machete along its natural line of cleavage; or when sufficiently dried, it is broken one at time between two hard surfaces. The nut cracking process is, therefore, cumbersome and usually, a large percentage of the kernels are broken.

In a previous work (Ogunsina *et al.,* 2008) on the deformation and fracture of dika nut under uni-axial compressive loading, the nut evolved pronounced elastic deformation prior to a catastrophic brittle failure. The cracking force was lower when loaded along the transverse axis. Some samples of dika nuts are shown in Figure 1 (b). In comparison, roasted or steam boiled cashew nut, cooked walnut and conditioned balanites experienced lower deformation prior to nutshell fracture (Oloso and Clarke, 1993; Koyuncu, 2004 and Mamman *et al.,* 2005). Consequently, the proprietary nutcrackers (for palm nuts, cashew nuts bambara groundnuts) and existing patented devices (Ojolo and Ogunsina, 2007; US Patents 6786142 and 4843715) which are adequate for most nuts are not appropriate for dika nuts which have a stony shell. Also, existing palm nut crackers do not appear suitable for cracking dika nut because the nutshell is weaker than that of palm nut and the embedded kernel is more brittle than palm kernel (Koya and Faborode, 2005). This work was therefore undertaken to develop, test and evaluate a simple device for cracking dika nut more efficiently with a view to reducing the drudgery involved in manual cracking.

(a) (b)

Figure 1. (a) A ripe dika fruit, partly exposed to show the soft fleshy pulp (Ogunsina *et al.,* 2008); (b) Samples of dika nuts

2. MACHINE DESIGN AND PERFORMANCE TEST

2.1 The Experimental Machine

The machine was conceived as a safe and simple device for splitting the nutshell of sufficiently dried dika nuts. The experimental dika nut cracker (Figure 2) is basically a toggle mechanism. The machine consists of a sliding block which when actuated compresses the nut against a fixed block at its extremum position. The nut is fed manually in-between the two blocks and the nutshell is compressed to failure along its line of symmetry. In the design, the force which can be applied and delivered safely by a fit young man, to operate the machine in sitting position was taken from Davis and Stubbs (1977).

The essential material-based design parameters (appropriate clearance between block and slider at the extremum positions of the mechanism; force required to crack the 'toughest' nut; and the maximum nut deformation at failure) were obtained from Ogunsina *et al* (2008). Machine parts were designed following standard engineering practice. The major components of the machine are briefly described below.

The slider is a solid 50 × 60 × 50 mm steel block. It is equipped with two anchors which slide through the spindles to keep the block floated about 2 mm above base plate in order to reduce surface friction.

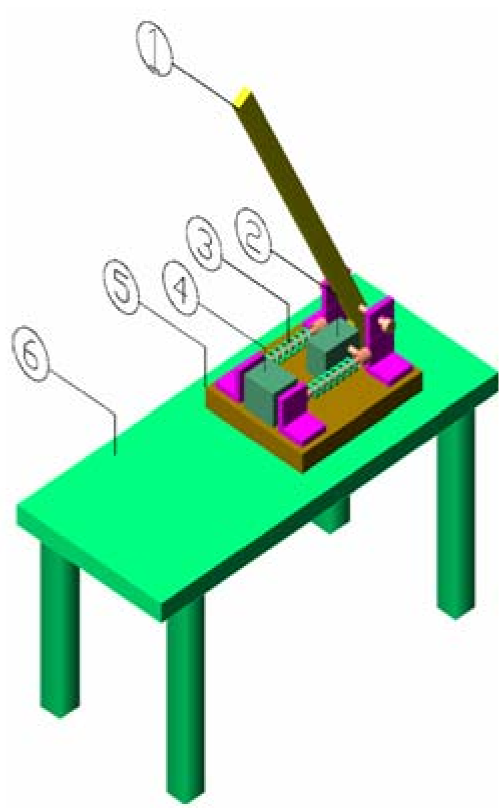

Figure 2. Isometric drawing of the Table mounted dika nut cracking device
(1) control lever, (2) slider, (3) return spring (4) feed block (5) base plate (6) bench

The spindles are smooth 15 mm diameter steel rods fitted with compression springs to return the block after nut cracking.

The control lever was made from a 20 × 6 mm flat bar bent through an angle of 28^o for 70 mm of its length to actuate the slider. The remaining section 500 mm long is the handle. The design therefore provided for large mechanical advantage which is characteristic of a toggle mechanism (Shigley and Vicker, 1981).

The nut is compressed between the slider and the fixed block until it gives with a "creak" sound that connotes cracking. The fixed block is made of 50 × 50 × 50 mm steel. At one extremum position, the clearance between the fixed block and the slider is 50 mm, being the space required to hold the largest nut before it cracks; and 15 mm at the other extremum position, for the smallest kernel after cracking the nut (Ogunsina *et al.,* 2008). The nut cracks with a discernible creak sound and the travel of the sliding block is limited by the clearance at the extremum position.

The machine was mounted on a base plate of 250 × 200 mm made from a 5 mm thick steel plate. The base plate was fixed onto a wooden structure, with sufficient provision to sit while operating the machine.

2.2 Test Procedure

The experimental machine (Figure 3) was tested with 100 sun-dried dika nuts which were randomly selected from a lot obtained from a local market in Ile Ife, Nigeria. The moisture content of the nuts was determined by oven-drying at 130^{o}C for 6 hours (ASAE, 2003). The sample was divided into three batches of 20 nuts each, to provide for replications. Each of the nuts was compressed along the transverse axis as suggested in a previous report (Ogunsina *et al.,* 2008). The actual deformation of the nut before it was cracked was measured as the change in the position of the slider. Based on the relationships reported earlier (Ogunsina *et al.,* 2008) energy utilized in cracking the nut was estimated, using the deformation.

Figure 3. The table mounted experimental machine during testing

Machine performance was quantified in terms of its cracking efficiency and percentage kernel breakage. Cracking efficiency (η %) is a measure of successfully cracked nuts, with or without kernel breakage, compared with the total number of nuts in the sample. It was expressed as:

$$\eta = \frac{n}{N} \times 100 \qquad (1)$$

where, n is the number of cracked nuts (Figure 4), and N is the total number of nuts in the sample.

Percentage kernel breakage (k_b %) assesses the quantity of broken kernels in the cracked nuts sample. It is desirable to have this parameter as low as possible. It was defined as:

$$K_b = (1 - \frac{w}{N})100 \qquad (2)$$

where *w* is the number of whole kernel after nut cracking, and N is the number of nuts in the sample.

3. RESULTS AND DISCUSSION

The moisture content of the nuts at the time of the experiment was 6.6% (wet basis). It was observed that some of the kernels were audibly shaking inside the nutshell, indicating that the kernel had shrunk

(a) (b)

Figure 4. (a) Samples of cracked nuts during machine testing
(b) Samples of dika kernels after separation from the shell.

away from the shell-wall as earlier reported (Ogunsina *et al.,* 2008). This enables a reduction in kernel breakage during the cracking process.

The performance characteristics of the machine were: cracking efficiency (η) 100%; kernel breakage (k_b) 24%; estimated fracture energy along transverse axis for small size nuts 8.70 kJ; medium, 9.76 kJ; and large, 14.11 kJ.

Although, the ease and the safety in operating the device are commendable, the percentage of broken kernels can be reduced with further investigations. It is possible that the kernels, being extremely brittle (at the 6.6% moisture content) were sometimes broken during the deformation, prior to nutshell fracture.

In cashew nut shelling, nuts are subjected to certain pre-treatments to improve the crackability of the nutshell (Ogunsina and Bamgboye, 2007). Oluwole *et al* (2007) conditioned bambara groundnuts to various moisture levels to improve its crackability in a centrifugal cracker. Similarly, in the de-hulling of melon seed, which has a thin hull embedding a brittle kernel, the dried seeds were rewetted to improve shelling efficiency (Odigboh, 1979). Dika nut may also require some pre-treatment to improve crackability and wholesomeness of the kernel.

4. CONCLUSION

Mechanisation of dika nut processing is feasible; compressing the nut between two solid blocks, with much ease and safety than the prevailing manual cracking. The proprietary machine is simple in design, low cost, safe and easy to operate. Although, 100% cracking efficiency was obtained, the need to reduce kernel breakage further is a challenge for future modifications.

REFERENCES

Agbor, L. O. N. 1994. Marketing trends and potentials for *Irvingia gabonensis* products in Nigeria. ICRAF-IITA Conference on *Irvingia gabonensis*; Ibadan, Nigeria; May 1994.

American Society of Agricultural Engineers. 2003. ASAE Standard S352.2. Moisture measurement of ungrounded grain and seed.

Ayuk, E.T; Duguma, B; Franzel, S; Kenge, J; Mollet, M.T and P. Zenteng. 1999. Uses, management and economic potential of *Irvingia gabonensis* in the humid lowlands of Cameroon. *Forest Ecology and Management.* 113(1):1-9

Davis, P.R and D.A. Stubbs. 1977. *Applied Ergonomics*. 8(4): 219-228

Eka, O.U. 1980. Proximate composition of seeds of bush mango tree and some properties of dika fat. *Nigerian Journal Nutritional Science*. 1:33-36

Ekpe, O.O; Umoh, I.B and O.U. Eka. 2007. Effect of a typical rural processing method on the proximate composition and amino acid profile of bush mango seeds *(Irvingia gabonensis) African Journal of Food Agriculture Nutrition and development.* 7(1)

Ejiofor, M. A. N. 1994. Nutritional values of *Ogbono* (*Irvingia gabonensis* var. *excelsa*). International Centre for Research in Agroforestry and InternationaI Institute of Tropical Agriculture Conference on *Irvingia gabonensis*. Ibadan, Nigeria.

Harris, D. J. 1996. A revision of the *Irvingiaceae* in Africa. Bulletin du Jardin Botanique

Koya, O.A and M.O. Faborode. 2005. Mathematical modeling of palm nut cracking based on Hertz's theory. *Journal of Biosystems Enginering.* 95(3): 405-412

Koyuncu M A; Ekinci, K and E. Savran .2004. Cracking characteristic of walnut. *Biosystems Engineering.* 87:305–311

Ladipo D.O; Fondour J.M and N. Garga. 1995. Domestrication of bush mango (*Irvingia spp*).International Centre for Research in Agro forestry. IRA/CRAF projects

Leakey R.R.B; Greenwell, P; Hall, M.N; Atangana, A.R; Usoro, C; Anegbeh, P.O; Fondoun J.M and Z. Tchoundjeu. 2005. Domestication of *Irvingia gabonensis*: 4. Tree-to-tree variation in food-thickening properties and in fat and protein contents of dika nut. *Food Chemistry*. 90(3):365-378.

Mamman, E; Bobboi, U and N.A. Aviara. 2005. Effect of moisture content and loading direction on the mechanical properties of *Balanite aegyptica* nuts. Agricultural Engineering International. *The CIGR E-journal*. Manuscript FP 04 015, Volume. VII. December, 2005.

Ngodi, J.L; Oben J.E and S.R. Minka. 2005. The effect of *Irvingia gabonensis* seeds on body weight and blood lipids of obese subjects in Cameroon. *Lipids Health Discover*. 4(12)

Odigboh E.U. 1979. Impact of egusi shelling machine. *Transactions of the ASAE*. 22(6):1264-1269.

Ogunsina, B.S and A.I. Bamgboye. 2007. Effects of pre-shelling treatment on the physical properties of cashew nut (*Anacardium occidentale*). *International Agrophysics,* 21(4):385-389. Institute of Agrophysics. Polish Academy of Sciences. Poland.

Ogunsina, B.S; Koya, O.A. and O.O. Adeosun. 2008. Deformation and fracture of dika nut (*Irvingia gabonensis*) under uni-axial compressive loading. *International Agrophysics*. 22:3 Institute of Agrophysics. Polish Academy of Sciences. Poland. (Article in press)

Okafor J.C. 1978. Development of forest tree crops for food supplies to Nigeria. *Forest and Management* 17:1-11.

Oloso, A.O and B. Clarke. 1993. Some aspects of strength properties of cashew nut. *Journal of Agricultural Engineering Research.* 55(1):27-43.

Omogbai, F.E. 1990. Lipid composition of tropical seeds used in the Nigerian diet. *Journal of the Science of Food and Agriculture* 50(2):253-255.

Oluwole, F.A; Abdulrahim, A.T and R.K. Olalere. 2007. Effect of moisture content on crackability of bambara groundnut using a centrifugal cracker. *International Agrophysics.* 21: 179-184. Institute of Agrophysics, Polish Academy of Sciences.

Osagie, A.U and A.A.Odutuga. 1986. Chemical characterization and edibility of the oil extracted from dika kernel. *Nigerian Journal of Nutritional Science* 1(1):33-36

Patent storm. 2008. Lever actuated nutcracker. US Patent 4843715. http://www.patentstorm.us/patents/4843715/fulltext.html accessed on August 15, 2008

Patent storm. 2008. Manually operated nut-cracking device. US Patent 6786142 http://www.patentstorm.us/patents/6786142/claims.html accessed on August 15, 2008.

Shigley, J.E. and J.J. Uickers Jr. 1980. *Theory of Machines and Mechanisms*. McGrawHill series in Mechcanical Engineering. McGrawHill Book Company.

White, L and K. Abernethy. 1996. Guide de la végétation de la Réserve de la Lopé, Gabon. ÉCOFAC Press, Gabon.