EFFECT OF MOISTURE CONTENT ON CRACKING CHARACTERISTICS OF AFRICAN WALNUT (*TETRACARPIDIUM CONOPHORUM*)

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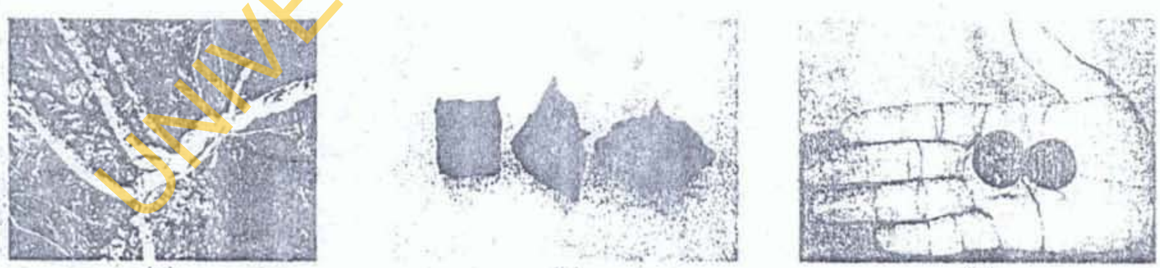
ABSTRACT

The influence of moisture content (9.6 - 30.8% wet basis) on cracking characteristics: cracking force, specific deformation and energy requirement for cracking of African walnuts (*Tetracarpidium conophorum*) was investigated. The nuts were loaded along the major, intermediate, and minor diameter and the data was subjected to ANOVA. Results showed that cracking force decreased significantly ($p<0.05$) with increased moisture content, while there was no significant difference in specific deformation and energy requirement for cracking in the three loading directions. The average cracking forces required along the major, intermediate and minor diameter were 118.60, 122.75, and 138.80 N, respectively.

Keywords: African walnut, Moisture content, cracking properties, machine design

1.0 INTRODUCTION

African walnut, commonly called Nigerian walnut or conophor, is a perennial climber often found growing wildly in the moist forest zones of sub–Saharan Africa. It is widely distributed in the southern part of Nigeria (Dalziel, 1937). It is botanically unrelated to the Black (American) walnut (*Juglans nigra*) found in the eastern states and extending northward to Canada and also different from the European (English) walnut (*Juglans regia*) found growing wildly in Himalayas and China (Hemery & Popov, 1998). Fig. 1 shows the pictures of the plant, ripe fruits and nuts of African walnut.



(a) (b) (c)

Fig. 1: The plant (a), ripe fruits (b) and nuts (c) of African walnut

The nuts contain edible kernels which are cooked and consumed as snacks along with boiled corn (Oke and Fafunso, 1975). The roasted kernels are eaten in the general diet, or added as flavour to cakes. When the kernel is eaten raw, it gives a bitter taste and when eaten cooked, a bitter flavour is also experienced upon drinking water (Ajaiyeoba and Fadare, 2006). This bitter taste has been attributed to the presence of alkaloids and other anti-nutritional and toxic factors present in the kernel (Dalziel, 1937). In Gabon, the consumption of the kernels by husbands of wives already pregnant is believed to mitigate the risk of miscarriage and it is also believed to improve fertility in males (Walker & Sillans, 1961). The ethnomedicinal potential of the leaf, stem bark, kernel and root as source for drug discovery for antimicrobial agents has been reported by Ajaiyeoba and Fadare (2006).

The kernels are also oil-bearing yielding 48–60% of light golden coloured oil with a taste of linseed oil. The oil obtained from the nut is used in lowering cholesterol and thus contribute in reducing the risks of heart attack (Heaton, 1984). The oil is also useful in the formulation of wood varnish, stands oil, vulcanized oil for rubber and for leather substitute (Akpuaka and Nwankwor, 2000). A biscuit-like snack has been developed from the nut (Adebona *et al.*, 1988). The cake left after expression of the oil contains 45% protein. It is a good source of protein for man and livestock. The nut is also a good source of vitamins (Odoemelam, 2003). The oil from the seeds has been reported to contain over 60% linolenic acid (Adesioye, 1991) which makes it useful in baking and confectionery, as salad oil, soap making and as drying oil in paints and varnish.

The defatted walnut cake is used as animal feed. The shell, when reduced to a powder of various mesh sizes, is used as fillers in synthetic resin adhesives, plastics and industrial tile. The shell is also used in a drilling mud in oil field, and as an abrasive for polishing metal casting (Aransiola, 2007). Hence, there is an increasing demand for processing of nuts of African walnuts.

Nigeria, as a developing nation is faced with a great challenge of meeting the current demand for walnut production as the processing operations such cracking and sorting are still being done manually. Therefore, there is a great need for the design and construction of mechanized handling units such as cracking and sorting machines. As a first step towards the design of cracking machines, the effect of moisture of the nuts and loading direction on the cracking characteristics of nuts was investigated in this study. Aydin (2001) has reported the effect of loading direction on the cracking force of Hazel nuts, while Sen (1985) has reported that the loading direction affected the extraction quality for walnuts. The effect of moisture contents on properties of linseed seeds (Gowda *et al.*, 1990) and pigeon pea, chicken pea, cowpea, soybean seeds (Kanawade *et al.*, 1990) has also been reported.

2.0 MATERIALS AND METHOD

2.1 Collection of nuts

Samples of African walnuts were purchased from the local market in Akoko, Ondo State of Nigeria. Prior to analysis, nuts were cleaned manually and visually inspected to remove foreign objects, fractured and immature nuts.

2.2 Determination of Moisture Content

Samples were prepared at five different moisture content levels: 9.6, 12.0, 16.8, 21.0, and 30.8% on wet basis (w.b). Moisture content of sample was determined using hot-air oven method in accordance to American Society of Agricultural Engineering (ASAE) Standard S352.2 (ASAE, 1998). Samples with lower moisture content levels were prepared by drying in the sun for 2-5 days, while samples with higher moisture levels were prepared by wetting the samples with quantities of water required to obtain the desired moisture levels and then kept in a sealed jar which is refrigerated at -5°C for two days (Mohsenin, 1978).

2.3 Determination of Cracking Characteristics

2.3.1 Cracking force

Cracking test was performed in triplicate at five different moisture contents (9.6 to 30.8%) with loading along the major, intermediate and minor diameter of the nut using a compression testing machine, Tensometer (Monsanto, Type W, England). The experimental setup is shown in Fig. 2. Fig. 3 shows the schematic of the geometry of the nut and the tri-axial loading directions used in the cracking test. The force (F), specific deformation (S_d) and energy required (E) to facture the nuts were determined.

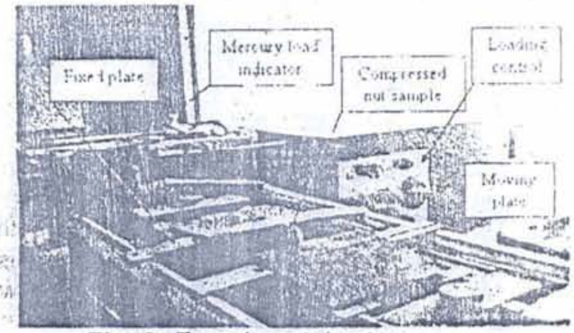


Fig. 2: Experimental setup

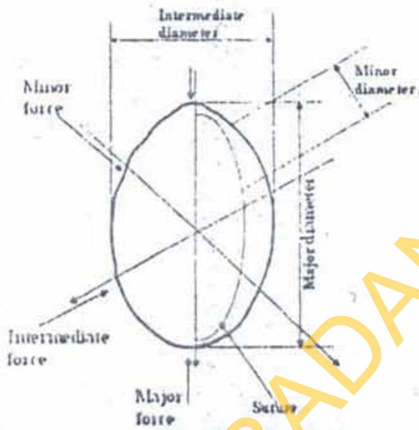


Fig. 3: Schematic showing of the tri-axial loading directs used for cracking test

2.3.2 Estimation of energy required for cracking the nuts

The energy required to crack the nuts at five different moisture content levels along the tri-axial loading directions were determined as the area under the compression curve. The cracking energy was computed as:

$$E = \frac{1}{2} F \times e \qquad \ldots(1)$$

where E, energy requirement for cracking the nut, F is cracking force and e is the deformation.

2.3.3 Determination of specific deformation

The deformation of the nut was measured with a dial gauge and linear force-deformation relationship was used to determine the specific deformation of the nut as:

$$S_d = \frac{L - L_F}{L} \qquad \ldots(2)$$

where S_d is the specific deformation, L is the original length of the nut and L_F is the length of the nut at rupture in the direction of loading.

3.0 RESULTS AND DISCUSSION

The forces required to crack the nuts at different moisture content levels are presented in Table 1. In all the loading directions, higher cracking forces were required to crack the nuts at lower moisture content as the shell tended to be tougher and less brittle at higher moisture content levels. The results of ANOVA (Table 2) showed that the effect of moisture on cracking force was significantly different ($p<0.05$) in the three loading directions.

Tables 3 – 5 present the summary results of the average, maximum, minimum and standard deviation of nut diameter, shell thickness, specific deformation, cracking force, specific deformation and energy requirement for cracking the nuts in the major, intermediate, and minor diameter respectively. It can be observed (Tables 3 – 5) that cracking the nuts along the major diameter required the least cracking force (118.60 N) with a relatively low deviation of ±12.07 compared with the force required along the intermediate diameter (122.75 N) and minor diameter (138.80 N). These results were in agreement with some nuts, such as Hazelnut (Aydin, 2002) and Macadamia nut (Braga *et al.*, 1999). The ANOVA results (not shown) indicated that there was no significant difference ($p<0.05$) in cracking energy and specific deformation in the three loading directions.

Table 1: Mean cracking force along the tri-axial loading directions with respect to moisture content

Moisture Content (%) / Loading direction	Racking force (N)		
	Major	Intermediate	Minor
9.6	130.2	154.8	135.6
12.0	127.8	153.7	122.5
16.8	125.8	151.5	114.8
21.0	123.5	149.6	106.9
30.8	120.4	145.2	90.6

Table 2: Summary of ANOVA for comparison between the cracking force and moisture content

Parameter	Source of variation	Cracking force (N)		
	Moisture content	Major	Intermediate	Minor
Mean	18.04	125.54^{s}	150.96^{s}	114.08^{s}
Variance	70.21	14.36	14.39	284.35
F		681.19	1044.18	130.07
P		4.93E-9	9.17E-10	3.16E-6

s →significant means for, $P < 0.05$

Table 3: Summary results of cracking properties of African walnut taking along the major diameter

Parameter	DIAMETER L (CM)	SHELL THICKNESS T (mm)	DEFORMATION e (mm)	CRACKING FORCE F (N)	SPECIFIC DEFORMATION S_d (%)	ENERGY E (KJ/kg)
Maximum	3.27	1.20	3.13	135.00	9.60	0.16
Minimum	2.47	0.90	1.61	100.00	5.80	0.10
Average	2.91	1.04	2.23	118.60	7.63	0.13
Standard deviation	0.26	0.10	0.39	12.07	0.98	0.02

Table 4: Summary results of cracking properties of African walnut taking along the intermediate diameter

Parameter	DIAMETER W (CM)	SHELL THICKNESS T (mm)	DEFORMATION e (mm)	CRACKING FORCE F (N)	SPECIFIC DEFORMATION S_d (%)	ENERGY E (KJ/kg)
Maximum	3.18	1.20	2.80	178.00	11.00	0.22
Minimum	2.21	0.80	2.03	95.00	6.50	0.10
Average	2.64	0.92	2.27	122.75	8.60	0.15
Standard deviation	0.26	0.10	0.22	21.87	1.22	0.03

Table 5: Summary results of cracking properties of African walnut taking along the minor diameter

Parameter	DIAMETER T (CM)	SHELL THICKNESS T (mm)	DEFORMATION e (mm)	CRACKING FORCE F (N)	SPECIFIC DEFORMATION S_d (%)	ENERGY E (KJ/kg)
Maximum	2.80	1.20	1.91	152.00	7.80	0.134
Minimum	2.23	0.85	1.58	125.00	6.20	0.107
Average	2.51	1.00	1.79	138.80	7.14	0.124
Standard deviation	0.19	0.10	0.11	8.21	0.35	0.010

4.0 CONCLUSIONS AND RECOMMENDATIONS

The study has shown that the cracking force decreased significantly ($p<0.05$) with increase in moisture content, while there was no significant difference in specific deformation and cracking energy in the three loading directions. The cracking forces required in the three loading directions were ranged in the order: minor>intermediate>major. Thus indicating that it is easier to crack the nuts at lower moisture contents and along the major diameter. The design parameters for the cracking machine must be based on the highest cracking force (152.00 N), specific deformation (7.80%) and energy requirement (0.134 KJ/kg) obtained at moisture content of 30.8% along the minor diameter.

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Table 5: Summary results of cracking properties of African walnut taking along the minor diameter

Parameter	DIAMETER T (CM)	SHELL THICKNESS T (mm)	DEFORMATION e (mm)	CRACKING FORCE F (N)	SPECIFIC DEFORMATION S_d (%)	ENERGY E (KJ/kg)
Maximum	2.80	1.20	1.91	152.00	7.80	0.134
Minimum	2.23	0.85	1.58	125.00	6.20	0.107
Average	2.51	1.00	1.79	138.80	7.14	0.124
Standard deviation	0.19	0.10	0.11	8.21	0.35	0.010

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