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Mechanical and Bio-Chemical Characteristics of Cashew (*Anacardium Occidentale L.*) Nut Sizes

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Abstract— *Dried cashew nuts at 8.2% moisture content from the store of Cocoa Research Institute of Nigeria, Ibadan were used for this study. The cashew nuts were categorized into sizes following reported standard and processed according to the recommended procedures. Kernels obtained were also similarly processed. Mechanical related and biochemical characteristics of the nuts and kernels were investigated. True density of the nut sizes showed wide range average values which were statistically not significantly different ($P \leq 0.05$). Co-efficient of friction among nut sizes was significantly different with average values that were marginally different. Shelling or whole kernel recovery after shelling and percentage white whole kernel after peeling indicated wide range difference according to nut sizes. Peelability decreased from 0.93 to 0.14 Kg/hr from extra large to madras nut sizes. Almost all the biochemical characteristics were marginally different. The oil content of the kernels was 45.5- 48.5% (w/w) which were 2.2:1 – 2.1:1 kernel to oil ratio. Cashew Nut Shell Liquid (CNSL) content ranged from 39 -49.7% (w/w). Differences in kernel and testa contents were also marginal ranging from 29.4 to 36.2% and 7.3 to 13.2% respectively. Similarity and differences in the characteristics of cashew nut sizes as revealed can be a good tool for decision-making by engineers, producers and processors for general development in cashew business.*

Keywords*— *Cashew, characteristics, bio-chemical, mechanical, nut sizes, variability.

I. INTRODUCTION

1.1 Importance of cashew

Cashew is an economic crop and a major source of income and employment for many nations. Cashew is currently popular for consumption in forms of apples and kernels. It is also medicinal because of its high Vitamin C content and other related constituents. Recent development in technology has led to production of cashew milk from the kernel and meat from the apple through value addition. Cashew kernel and nut contain oil and Nut Shell Liquid (CNSL) by [1] and [2] respectively in reasonable amount comparable to other crop of importance. The kernel oil which stands out among other oil seeds because of its high crude fat content [3], has great use in coking and pharmaceutics [1]. CNSL is a natural resin, hosted in the structure of the shell, containing 90% anacardic acid and 10% cardol [4]. The shell oil (CNSL) is used in brake linings due to its efficient heat absorption. CNSL is also useful in paint production for enamels and lacquers as further reported. Nuts are very important in diets of many civilizations and cultures since long because of their high energy and nutritional values, huge flavour varieties and distinct taste with chemical constituents and bioactive substances of vital health benefits [5]. The most important economic part of cashew nut is the white or creamy coloured edible kernel. Consumption of cashew kernel is held in high esteem in various customs as its nut ranked third among tree nuts in world production. Cashew kernel is first among the world nut snacks because of its nutritional advantages: it has high amount of protein, soluble sugar and rich in polyunsaturated fatty acid that lowers blood cholesterol [6]. Globally, the kernel which is highly priced food delicacy due to its pleasant taste and flavour is often eaten roasted with either light addition of salt or sugar or coated with chocolate [5]. It was added that many beneficial effects on health conditions: hypertension, coronary heart diseases and diabetes were linked to high unsaturated fatty acids content of the kernels according to research findings.

1.2 Cashew Nut Production in Nigeria

Nigeria was second among the top ten cashew producing countries in the World [3]. Nigeria ranked 2nd in the World cashew nut production and top in Africa with 0.95 million tonnes export in 2013 according to [5] and [6], but Cote d'Ivoire became the top African producer in 2014 with 109,583MT nuts [5]. This is a signal to dwindling

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production which may call for improvement in production, processing and utilization. Cashew thrives well in nearly all the agro-ecologies of Nigeria from North to South as it flourishes at Lat. 6^0 21' North in West Africa with yearly average rainfall of 1,331mm and about 88% RH [7]. Expanse land area of Nigeria has been reported suitable for commercial cashew production as this can be done in 27 out of 36 States. But the country's production potential has been adversely affected by poor capacity building and lack of relevant machines to carry out some tedious operations, including processing, among others. Lack of relevant machines has led to high field losses and drudgery. Sales of nuts have also been poor owing to low nut quality [6]. The cashew nut is the source of the delectable kernels and serves as seed which generally differ in their sizes, shape, colour and other morphometric characters; metric measurement which are important in characterization and evaluation [8]. Cashew varieties cultivated in Nigeria are of variable nut sizes which were introduced at different periods between 16th century and 1982 by Portuguese explorers. Most of this introduction has grown in the wild very old plantations, usually referred as 'local variety' while the most recent introduction from Brazil is termed 'exotic'. Oro Cashew collection which currently serves a lot of Nigerian farmers and processing companies were grown from local and Brazilian varieties [6]. Cashew nut weight corresponded with the nut categories while cashew tree is an out-crosser, producing variable nut sizes due to segregation as further stated. Moreover, most cashew farms in Nigeria are grown from seeds rather than grafted productive varieties, thus exhibiting much variation in all traits including nut yield and size. Differential cashew nut sizes, shapes, shell thickness and proportion of kernel within the raw nuts are dependent on many factors such as genetics, edaphic and the climate.

1.3 Cashew nut processing procedures

Nut size and quality of kernel are determinants of acceptability and pricing; such that larger nuts and kernel command higher prices. Criteria for the assessment of the quality and price of the raw cashew nuts may involve physical appearance of nuts and kernels. Nut appearance include colour, shape and brightness while important kernel quality are the nut count (nuts/Kg), the defective nuts rate, moisture and Kernel Output Ratio (KOR) as reported by African [9] and [10]. The smaller the nut count, the bigger are the nuts and it ranges from 150 to 240 nuts/Kg. KOR fluctuates between 40 and 50 pounds per 80kg nuts while the moisture content of the raw nuts should be 7 - 10% w.b. The kernel colour and the quantity of kernel making up a pound (454g) provide the grade ratings in the world cashew market [6]. The highest and the least grade range of kernel is W160-180 and W450 whole, white kernel count in one pound respectively. Jumbo nut is believed to possess the highest kernel grade of W180 (266-395 kernels/Kg). However, very large nuts usually have inferior kernel with low density and poor germination as further reported. Kernels are separated into good (100% accepted), spotted/premature (50% accepted) and mouldy/stunted (100% rejected) during processing according to [10], and [11]. Increased profitability will be greatly enhanced by the establishment of plantations with clones of high quality and productivity potentials, such as cashew with larger nut and high kernel proportion [6]. Cashew production and processing in Nigeria, therefore, requires a boost for better income generation. Specifically, increased production of quality cashew nuts and their products will assist the current economic diversification and poverty alleviation policy of government.

The primary processing of raw cashew nuts includes drying to storable moisture content and removal of the outer hard shell (Shelling) and inner thin silver testa (Peeling). This stage is followed by roasting/frying, milling/grinding depending on the tradition and product to be obtained. The nuts are boiled or steamed for about 30 minutes or roasted in oil, then air-cooled while kernels are oven-dried, occasionally humidified, and air-dried to make shelling and peeling comfortable [3], [9] and [11]. Kernels were dried at 70 – 80^0C for about 6 – 8 hrs in a cross-flow drier [12] or at 50 - 70^0C for 4 hrs in a mud oven [5] to make peeling easier and effective. The time required to peel is normally used as an indicator to determine the ease of removing testa (peelability) according to [12]. Most of these operations are currently performed manually in Nigeria resulting in poor quality products [9] and [11]. Cashew nuts have been grouped into six size categories of Madras, Small, Medium, Large, Extra Large and Jumbo based on weight of individual nut [9], [11] and [13]. Morphological and structural characteristics of seeds are important component in the determination of yield, protein, and seed oil content [6]. Moreover, physical properties of the seed are important in the determination of their shape which is required for the development of equipment for post-harvest operations and industrial processing [8].

1.4 Relevance of this study

Mechanical properties of agricultural products play a crucial role in predicting design parameters of machine components. Coefficient of friction, true density and axial dimensions are important for designing machine components such as hopper, fan and sieve/concave designs. Although drying impart positively on the taste of kernels, increased brittleness results in high percentage of broken kernels during subsequent processing stages, including peeling, due to reduction in compressive strength of the kernels. Low whole kernel yield of less than 50% and 25 – 40% was reported for mechanical peelers by [12] and [3] respectively. Machines are usually evaluated on such parameters as efficiencies, grain damage/breakage and seed losses. Grain breakage is dangerous for grain storage because of possible microbial infestation. Uniformity is also very crucial in processing activities such as drying, separation and roasting for good results. Uniform products also attract high premium in the market as merchants/industrialists highly desire products of high uniformity. This is why most processing operations involve activities such as separating, sorting, grading using sizes, colour and density among others. Commercial processing operations for export require machines with precision as there is a global standard for acceptability of kernels in term of grades (white wholes, white pieces and scorched) reported [11].

Understanding relevant properties of cashew nut and kernel, and relationship between the nut and kernel could provide a significant insight into economic and mechanical valuation of cashew nut as the kernel is currently the most economic part of cashew in Nigeria. [6] investigated the diversity in the quantitative and phenotypic traits of six cashew nut sizes in commercial cultivation in Nigeria. Crackability and chemical composition of three cashew nut sizes (small, medium and large) was studied by [3], using major axis dimensions, of nuts from a farmer's plantation in Iwo, Southwest of Nigeria. [14] studied some physical and mechanical properties of cashew nuts and kernels grown in Ghana. Effect of moisture on engineering properties of cashew nuts of Ivory Coast was investigated by [4]. The study of some engineering and biological properties of nut categories which is relatively scarce is necessary, particularly nuts from Cocoa Research Institute of Nigeria, the only institution which has research mandate of the crop in Nigeria, considering the out-crossing nature of cashew tree. This study investigated the similarity and variability in mechanical and bio-chemical properties of some cashew nut categories to determine possible areas of comparative advantage. This information will be useful for effective machine and technology development by assisting both the producers and processors in selection of nuts with the best comparative advantage for improved production and utilization.

II. MATERIALS AND METHODS

Dried cashew nuts were obtained from the store of Cocoa Research Institute of Nigeria (CRIN) which has plantations with various sizes of cashew nuts. These plantations were grown from materials collected from the germplasm of this Institute. Some quantity of the nuts was drawn, foreign materials were removed and bad nuts were sorted out based on physical appearance. The nuts at 8.2% wet basis (w.b) moisture content were categorized into 5 sizes Madras, Small, Medium, Large and Extra-large as described in Table 1 by measuring the weight of individual nut, using a digital weighing balance of 0.01g accuracy (KERRO BL5002 electronic digital scale).

Table 1: Categorization of raw Cashew Nut sizes

Categories	Sizes (g)
Jumbo	≥16
Extra large	>12<16
Large	>8≤12
Medium	≥6≤8
Small	>2<6
Madras	≤2

Source: Adeyemi, 2017 and Ogunwolu *et al.*, 2019

The co-efficient of friction and true density of individual nut selected randomly were determined using inclined plane and water displacement respectively as reported in previous studies such as [4], [12] and [15]. Each o f the measurements was replicated 10 times and the means were used as the representative result. Data obtained were used as in the following expressions (1) and (2):

$$\rho = M/V \quad (1)$$

ρ, M and V are true density of the nut, mass of sample and volume of water displaced or true volume of sample respectively.

$$\mu = \tan\alpha \quad (2)$$

μ and α are co-efficient of friction and angle of tilt of the inclined plane respectively.

Standard methods for cashew nut processing described by [5], [9] and [11] were followed prior to shelling, peeling and oil and CNSL extraction. All categories of nuts under investigation were steamed over hot water at 75^0C for 20 minutes at once to avoid biasness. Nut samples were then air-cured under room temperature so as to warm up to this condition. Shelling was done with a locally fabricated manual cutting knife. The kernels obtained were oven-dried for 5 hours at 70^0C which was within the range reported by [5] and [12]. Kernels were later refrigerated briefly for sudden cooling to make

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peeling easier. Humidification of kernels for shrinkage of testa and easy peeling had been reported [11]. The kernels were re-dried in open air before peeling was carried out with stainless knife. Good kernels (wholesome without flaws) which were described as 100% accepted by [7] and [10] were taken from small, medium, large and extra-large categories for oil and CNSL extraction. Equal weight of shells and peeled kernels of each of the categories were used for the extraction. The standard procedure reported by [1] and [2] was employed for the extraction, using soxhlet apparatus and n-hexane as solvent. Peelability was determined by dividing the amount of whole kernel by the time taken to peel equal weight of whole kernels of each nut categories given in (3):

$$\text{Peeleability} = \frac{\text{Weight of whole kernel x 60}}{\text{Time taken in minutes x 1000}}\ \text{Kg/hr} \qquad (3)$$

Owing to high premium placed on whole kernels, percentage white whole kernels recovered after peeling operation as compared to the total white kernels peeled was determined to measure the effect of peeling action on the kernels. Whole kernel recovery after shelling operation, testa, oil and CNSL contents were also determined as the amount of each of the respective parameters in one hundred of its processed corresponding material quantity.

III. RESULTS AND DISCUSSION

3.1 Mechanical related characteristics of cashew nut

The nut count Table 2 ranged from about 79 to 623 nuts/Kg from Madras to Extra large respectively. These values agree with 197 recorded by [3] and reports of earlier studies that the higher the nut count, the smaller the nut [10] and [11]. Table 2 shows the values obtained for mechanical related properties as investigated. Static coefficient of friction on mild steel which increased as nut size increased, ranged between 0.41 and 0.53, showing marginal variation among nut categories. Similar observation and figures, ranging 0.44 – 0.52 for graded nuts and 0.55 – 0.63 for ungraded nuts, were reported by [4]. Coefficient of friction of 0.45-0.65 on galvanized steel at varying moisture contents for cocoa beans, 0.45 on mild steel for parchment coffee and 0.51 on galvanized steel for palm kernel have also been reported by [16], [15] and [17] respectively. Similar and uniform shape of the nut sizes, irrespective of the categories which made them to slide alike on the structural surface, might have been responsible for the close values. [14] and [4] respectively had reported sphericity of cashew nut as 0.637 - 0.64 and 0.64 – 1.18 at different moisture. It implies that cashew nuts will flow similarly on the surface of a particular engineering material irrespective of nut sizes and mixture of nut sizes does not pose a serious problem in this respect. The true density in Table 3 was between 1,028.6 and 1,518.9 Kg/m^3. These values are comparable with 1100.16 to 1209.51 and 1066.2 to 1107.3 Kg/m^3 recorded by [14] for cashew nut in Ghana and [4] for graded nuts of Ivory Coast respectively. Similar values of 1051, 1143.8, 1082.8 and 1090 - 1170 Kg/m^3, based on varieties, were reported by [18], [19], [20] and [17] for avocado pear, fresh coffee berry, kola nut and palm kernel respectively. Apparently, smaller nuts had higher particle densities as madras had the highest of 1518.9 followed by large with 1259.0 Kg/m^3, while small, medium and extra large marginally range from 1028.6 to 1040.7 Kg/m^3. True density of nuts increased as moisture content increased from 6 to 10% (w.b) as stated by [4]. Practical observation had revealed that the bigger the nut size, the more the tendency of its higher proportion to float in water, but floated nuts germinated well into plants with good vigour, implying nut quality may be irrespective of floatation. Wide range of sizes within nut categories might have resulted in the pattern of the density observed, which may require further investigation. Wide range of variation can be utilized in separation of mixture of cashew nut sizes. The mean significant difference at $P \leq 0.05$ in Table 3 revealed no significant difference in the true density of nut categories studied but they were significantly different in regard to the coefficient of friction. Extra large had the highest statistical mean of coefficient of friction of 0.53 while madras was the lowest with 0.39 which was statistically different from other nut categories. It could be deduced that despite the close margin in the average of coefficient of friction of these nut sizes, there was some difference which has to be noted when handling mixtures of nut sizes. Highest peelability of 0.93 Kg/hr was comparable with 0.75 – 1 Kg/hr reported by [12] and difference may be attributed to categorization of nut sizes which might made removal of smaller nut's kernel more difficult as earlier stated. Peelability decreased with decrease in nut weights, implying that testa removal becomes more difficult for smaller nuts. Percentage white whole kernel increased with increase in nut sizes as white broken kernel (in parentheses) increased with decrease in nut sizes. [3] had stated that larger nut generally gave higher whole kernels. Whole kernel recovery after shelling, which is similar to crackability described by [3], portrays the ease of removing kernel from the shell (shelling efficiency). Considering 82 and 52% obtained for Extra-large and Madras respectively, and relative high decrease among the nut sizes, it may be deduced that shelling became more difficult as nut sizes reduced. Similar trend was reported by [3], but higher values were obtained. The difference in values may be due to sources of materials, pre-treatment and machine, including operators. However, this factor should be given reasonable consideration when designing machine for this operation, especially when handling mixture of nut sizes.

Table 2: Mechanical characteristics of cashew nut sizes

Nut Sizes	Coefficient Friction	True Density Kg/m^3	Whole kernel recovery after shelling (%)	Peelability (kg/hr)	White whole kernel recovery after peeling (%)
XL	0.53	1040.7	81.6	0.93	92.7 (7.6)
LG	0.50	1259.0	78.7	0.57	84.3 (15.7)
MD	0.46	1037.9	69.2	0.34	82.8 (17.2)
SM	0.43	1028.6	54.5	0.29	76.1 (23.9)
MR	0.41	1518.9	51.9	0.14	56.5 (43.5)

XL – Extra large, LG – Large, MD – Medium, SM – Small and MR – Madras, Percentage broken kernels are in parentheses.

Table 3: Mean values of true density and coefficient of friction of cashew nut categories

Nut categories	True density	Coefficient of friction
XL	1350.7a	0.53a
LG	1035.1a	0.50ab
MD	1032.1a	0.46bc
SM	1970.6a	0.44cd
MR	1350.7a	0.39d

Means with the same letter along the column are not significantly different at $P \leq 0.05$

XL - Extra large, LG – Large, MD – Medium, SM – Small and MR – Madras

3.2 Bio-chemical characteristics of cashew nuts

Bio-chemical characteristic values obtained for this study are described in Table 4. Percentage kernel content varied marginally from 29.4 to 36.2. Medium and Madras respectively had the highest and lowest content of kernel. Testa composition varied slightly and apparently increased as nut size decreased; extra large was the minimum with 7.3% while madras recorded the highest figure of 13.2%. The variation may be due to genetic factor. These results will be useful for machine design such as capacity determination and for making appropriate decision for selection by farmers and processors. Each of oil and CNSL occurred in the kernels and shells of cashew nuts respectively in almost equal proportion of 40 - 50% but with slight differences among nut categories. Small and Large sizes had the highest content of oil (48.5%) and CNSL (49.7%) respectively while the least oil and CNSL was contained in the Medium (45.5%) and Extra large (39%) respectively. Kernel/oil ratio of 2.1:1 – 2.2:1 implied that each category of kernel can approximately produce at most oil equals one-half of its weight. These values were in the range of the findings of [1] for cashew kernel oil (48.8%) and [2] for CNSL (30.23%). The slight variation may be due to sources of nuts and nut categorization. Relatively high oil content had been reported by [18] for avocado pear (74-75%), [21] for oleander seed (60-65%), [22] for Almond nut (50%) and [17] for palm kernel (44-53%).

Table 4: Bio-chemical characteristics of cashew nut sizes

Nut Sizes	Nut Count Kg/hr	Oil Yield (%)(w/w)	Kernel oil ratio (w/w)	CNSL Yield (%)(w/w)	Kernel Content (unpeeled) (%)	Testa content (%)
XL	78.95	46.3	2.2 : 1	39.0	34.2	7.3
LG	107.36	46.0	2.2 : 1	49.7	30.5	8.5
MD	151.38	45.5	2.2 : 1	46.0	36.2	9.0
SM	247.13	48.5	2.1 : 1	48.0	32.5	8.1
MR	622.95	-	-	-	29.4	13.2

XL - Extra large, LG – Large, MD – Medium, SM – Small and MR – Madras

IV. CONCLUSION

Nut categories were similar in some mechanical related characteristics but shelling percentage and peelability were affected by nut sizes. Most bio-chemical properties of the nuts indicated no serious differences. However, there were relative areas of comparative advantage of nut classes that can be utilized for processing and production. Generally, bigger nuts are comparatively at better advantage according to the characteristics studied. The variation indicated among nut sizes is a signal that care is required in handling operation and machine design, particularly precision operations. Revelation of variation and similarity in the characteristics of nut sizes can be useful for making the right decisions by farmers, processors and engineers for overall development of cashew business.

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