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QUANTITATIVE DESCRIPTORS OF CASHEW NUT CATEGORIES IN NIGERIA: PROVIDING INDICES FOR SUPERIOR NUT SELECTION

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ABSTRACT

The most important economic part of cashew tree is the nut and kernel. Quality of cashew nut and kernel determines its acceptability and price in the world market. Six sizes of nut have been identified in Nigeria. This study aims at investigating diversity in the cashew nut sizes in commercial cultivation in Nigeria in relation to kernel and shell ratios. Six categories were examined for their nut, shell and kernel properties. Analysis of variance was employed to detect variability among the group for each trait while Principal Component Analysis was used to identify distinguishing traits and to group the different sizes based on similarities. Nut weight ranged from 2.95 to 23.20g while kernel weight ranged from 0.04 to 6.88g. Two groups evolved from the classification: the larger and the smaller nut groups. Kernel weight was a function of the nut girth (r=0.93) and nut weight (r=0.87). Nut Weight, Nut Length, Nut Girth, and Nut Width respectively had the highest broad sense heritability of 99.25, 99.01, 98.82 and 98.74. In this study, Extra-large and Small nuts were best in shelling percentages of 32.46% and 37.29% respectively, however, the former had bigger and bolder kernel. The 'Jumbo' had the highest mean nut weight (17.86g), much of it was attributed to the shell compared to extra-large nuts. Identification and characterization of the six categories for kernel and nut properties will be of paramount practical significance in direct selection of superior genotype for subsequent use in cashew improvement programmes.

Keywords: cashew nut, cashew kernel, ratio, nut variability.

INTRODUCTION

Cashew (*Anarcardium occidentale* L.) is an economic plant of Brazilian origin. The multipurpose tree crop is grown extensively in four continents: South America, Australia, Asia and Africa. World production of cashew nut in 2012 was estimated at 4.2 million metric tonnes from over 30 different countries (FAOSTAT, 2013). Nigeria is ranked among the top ten cashew producing countries of the world; coming second after Vietnam. The others in order of production are India, Cote d'lvoire, Benin, Philippines, Guinea Bissau, Tanzania, Indonesia and Burkina Faso (FAOSTAT, 2013). Cashew varieties cultivated in Nigeria are of variable nut sizes. These were introduced into the country at different periods between 16th century to 1982 by Portuguese explorers, from India, Tanzania, Mozambique and Brazil (Aliyu, 2012). Most of the initial introductions have grown in the wild and in very old plantation. These are usually referred to as 'local variety' by farmers, while the most recent Brazilian introductions are termed 'exotic'.

The most important economic part of the cashew nut is the white or creamy coloured edible kernel. 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.

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. Nut size and quality of kernel are determinants of acceptability and pricing; such that larger nuts and kernel command higher prices. The kernel colour and the quantity of kernel making up a pound (equivalent to 454g) provide the grade ratings in the world cashew market. The highest grade range of kernel is 160-180 whole, white, kernel count in one pound. Jumbo nuts is remarked to possess the highest kernel grade of W180, however, CTCS (1993) reported that very large nuts usually have inferior kernel with low density and poor germination.

Income generation from cashew production in Nigeria needs a boost. This is because most sales of nut have been poor owing to low nut quality (Nugawela and Oroch, 2005; Oroch, 2005; Topper, 2008). Increased profitability will be greatly enhanced by the establishment of plantations with clones of high quality productivity potentials, such as cashew with larger nut and high kernel fill capacity. The cashew nut which is the source of the delectable kernels also serves as seed of the cashew tree. Seeds generally differ in their size (weight, length, breadth and thickness), shape, colour and other morphometric characters, metric measurement of which are important in characterisation and evaluation (Adewale *et al*., 2010). Morphological and structural characteristics of seeds are important component in the determination of yield (Omokhafe and Alika, 2004), protein, and seed oil content (Kaushik *et al*., 2007). 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 (Balkaya and Odabas, 2002; Adewale *et al*., 2010; Dash *et al*., 2008). A previous study by Ogunsina (2013) was directed at determining the physio-chemical properties of three cashew nut sizes (small, medium and large).

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Six categories of cashew nut sizes are identifiable in Nigeria. They are Jumbo, Extra-large, Large, Medium, Small and Madras. Information is scarce on the proportion of kernel in each of the six nut size categories. Since the kernel is the most economic part of the nut, understanding kernel to nut ratio and its relative relationship with the other metric measures of the nut could provide a significant insight to economic valuation of cashew nut. Identification and characterization of genotypes within these categories will be of paramount practical significance in direct selection of superior genotypes for subsequent use in crop improvement programmes and wider distribution for high economic resources production. The present study therefore looks at the variation in some quantitative traits relating to the cashew nut, shell and kernel and the diversity of six nut size categories based on the phenotypic quantitative traits.

MATERIALS AND METHODS

The cashew nuts used in the present study were obtained from Kosoni-Ola farm (Long. 04^0 29^1E and Lat. 08^0 26^1N) Oro, Kwara state, Nigeria. Oro is in the southern guinea savannah agro-ecology of Nigeria. The 350 ha Cashew plantation hosts a very large population of local varieties and Brazilian introductions. Twelve kilograms of Cashew nuts were collected for six cashew nut categories (Jumbo, Extra Large, Large, Medium, Small and Madras) during the peak of harvest in 2013. The nuts were sundried to 8% moisture content. From the lot of each category, 80 nuts were randomly selected. The experimental design was completely randomized design of four replications. Metric measurements were taken on the nuts at the Crop Improvement Laboratory of Cocoa Research Institute of Nigeria, Ibadan, Nigeria.

Individual weight of the nuts was recorded. The shell was carefully separated from the kernel by a cashew nut cutter and weighed. Measurement in weight was done using a digital weighing balance (WT-H Zhongxin, China) whose sensitivity was regulated to 0.001g. The nut length (distance between the points of attachment to the apple and the apex), width (the maximum distance between shoulders) and thickness/girth (maximum distance between flanks) were measured in millimeters using the vernier caliper (See Figure-1 for the description of the metric measurements on cashew nuts).

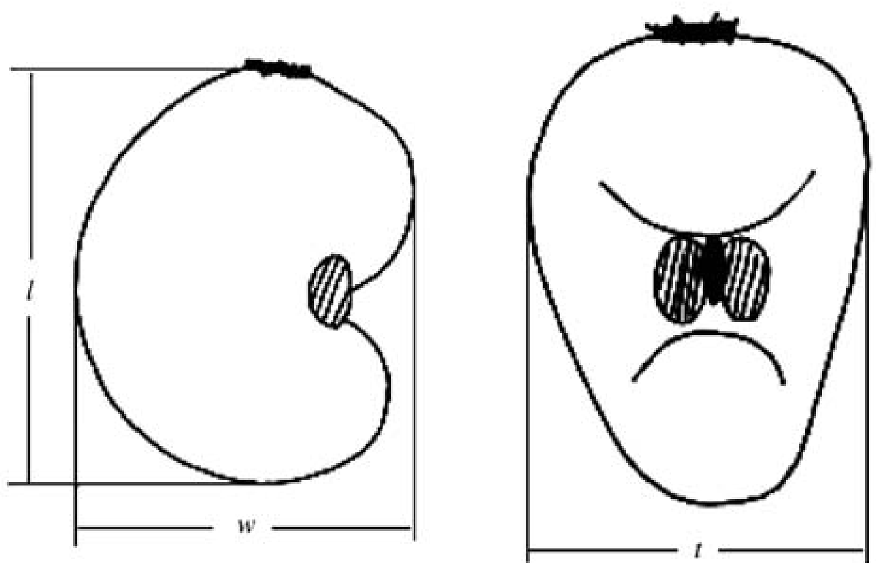

Figure-1. Cashew nut dimensions: *l* = length; *w* = width and *t* = girth or thickness. Adapted from Ogunsina (2013).

Shell thickness was taken from the thickest part of the shell in millimeters using the vernier calliper. Shelling percentage was estimated as the ratio of kernel weight to nut multiplied by 100. Means of the sampling units in each of the four replications was generated for the nine measured variables and used for the analysis of variance (ANOVA) to understand variability among the six nut lot categories. The genotypic and phenotypic coefficients of variation were estimated from the variance component. Ratio of the genotypic to the phenotypic variance was used to describe broad sense heritability for each variable. A data matrix of the means of the six nut lot categories and the nine variables was generated and standardized with mean=0 and standard deviation=1 following Adewale *et al.,* (2010) for Principal Component Analysis (PCA). Tridimensional graph were generated from the scores of the first three principal components axes. Pearson Correlation analysis was estimated to understand the relationship between pairs of traits. ANOVA, PCA and tridimensional graph were made using the procedures of PROC GLM, PRINCOMP and g3d respectively in SAS-Version 9.2 (SAS Institute Inc., 2007).

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RESULTS AND DISCUSSIONS

A wide range of variation was observed among the six cashew nut categories for the nine traits assessed. Nut weight ranged from 2.95 to 23.20g while kernel weight ranged from 0.035 to 6.88g (Table-1).

Table-1. Information on the variability of the 6 nut sizes genotypes for the nine phenotypic traits.

Trait	Mean	Min.	Max.	MS	**PCV** (%)	**GCV** (%)	**Hb** (%)
NW	11.45	2.95	23.20	1737.41***	61.76	61.53	99.25
NL	37.19	21.70	56.10	3873.92***	51.22	50.96	99.01
NWD	24.51	11.70	40.20	3128.92***	56.76	56.40	98.74
SHTK	2.72	0.40	6.61	92.28***	29.61	28.95	95.59
KL	26.83	9.20	40.40	1906.83***	42.51	42.02	97.70
KWD	15.17	2.80	30.70	805.15***	37.29	36.13	93.87
KWT	3.23	0.035	6.88	95.07***	27.40	27.03	97.27
KGT	11.75	1.00	22.70	378.88***	29.30	28.08	91.85
NGT	20.96	10.7	39.00	2114.35***	50.44	50.14	98.82

NW - Nut weight; NL - Nut length; NWD - Nut width; SHTK - Shell thickness; KL - Kernel length; KWD - Kernel width; KWT - Kernel weight; KGT - Kernel girth, NGT - Nut girth, Hb – Broad sense heritability, MS – Mean squares

Since kernel is the most economic part of cashew, selection focus on genotypes with higher kernel weight will enhance greater production and profit from cashew farming business. The nine parameters significantly ($p \leq 0.001$) differentiated the six cashew groups. For all the traits, the PCV was higher than the GCV, though with very close margin. The high proportion of genotypic component in the total phenotypic variation among the six cashew groups for the traits depicts that the role of the environment in the phenotypic expression of the nine nut parameters was minimal; hence, genetic effect was more implicated on the nine traits. This was corroborated by the high heritability estimates. In this study, the broad sense heritability estimates for the nine traits were very high, ranging between 91.85 (KGT) to 99.25 (NW). Traits with high broad sense heritability estimates have high genetic potential. If the effect of the environment in determining them is low, additive gene effect is playing a predominant role in their expression; genotype selection based on high heritability estimate for traits could be dependable (Adeigbe *et al.,* 2011; Adewale *et al.,* 2010 and Singh *et al.,* 1994).

The means and standard error of the nut and kernel properties is presented in Tables 2(a) and 2(b) respectively while the shelling percentage is presented in Table-2(c).

Table-2(a). Means of nut dimensions of the six cashew nut sizes.

Categories	**Nut weight** (g)	**Nut length** (mm)	**Nut width** (mm)	**Nut girth** (mm)	**Shell thickness** (mm)
Jumbo	17.86±0.22	44.52±0.49	33.63±0.31	22.98±0.26	2.29±0.11
Extra large	14.82±0.22	43.15±0.58	19.99±0.30	29.91±0.37	2.73±0.10
Large	13.33±0.25	42.24±0.35	31.11±0.24	22.85±0.25	4.83±0.09
Medium	9.44±0.20	32.52±0.37	22.69±0.46	17.09±0.29	2.01±0.10
*Small	7.48±0.13	29.72±0.24	19.20±0.40	16.93±0.27	1.94±0.07
*Madras	5.73±0.11	30.54±0.26	22.71±0.22	16.97±0.18	2.51±0.19

n= 80
*= not the typical small and madras nuts

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Table-2(b). Means of kernel dimensions of the six cashew nut sizes.

Categories	Kernel weight (g)	Kernel length (mm)	Kernel width (mm)	Kernel girth (mm)
Jumbo	3.98±0.11	31.86±0.35	18.00±0.46	10.89±0.30
Extra large	4.81±0.08	30.35±0.55	14.42±0.45	13.16±0.37
Large	3.44±0.08	31.01±0.38	19.91±0.34	15.50±0.23
Medium	2.58±0.09	24.05±0.38	14.12±0.40	10.89±0.28
*Small	2.79±0.06	22.88±0.26	12.27±0.37	9.63±0.38
*Madras	1.74±0.07	20.59±0.39	11.88±0.37	10.28±0.36

n= 80
*= not the typical small and madras nuts

Table-2(c). Shelling percentage of the six cashew nut sizes assessed in the study.

Categories	Jumbo	Extra large	Large	Medium	*Small	*Madras
Shelling (%)	22.28	32.46	25.81	27.33	37.29	30.36

Mean nut weight corresponded with the size categories i.e there was gradation from the highest (17.86±0.22g) observed in the largest size Jumbo to the least (5.73±0.11g) observed in the smallest size Madras. Mean nut weight has been found most stable across environments in cashew (Aliyu *et al.,* 2014), thus it could be a dependable trait for selection. Highest value for nut weight (17.86±0.22g), as well as nut length (44.52±0.49mm) and kernel length (31.86±0.35mm) was observed in the Jumbo nut category, while Extra-large nuts possess the largest kernel weight (4.81±0.08g) and nut girth (29.91±0.37mm). The largest kernel width (19.91±0.34mm), kernel girth (15.50±0.23mm) and shell thickness (4.83±0.09mm) was found in the large nut category. The Small nuts have the highest shelling percentage (37.29), probably due to the thin shell thickness (1.94±0.07mm) recorded for the category. The Larger nuts were however better at giving whole kernel out-turn than Medium and Small nuts (Ogunsina, 2013). Extra-large nuts had a shelling percentage of 32.46%. The small nuts with mean of 7.48g and Madras nuts with mean 5.73g observed in this study were larger than the typical size ranges of 2 - 3.9g and ≤ 2g respectively (Adeigbe *et al*., 2015); thus they are not true representatives of the group. Oro Cashew collections which currently serve a lot of Nigerian farmers and processing companies were grown from local and Brazilian varieties. Due to their miniature sizes, Madras nuts were found mainly in the wild, rather than on commercial farms. Selection focus on Extra-large nuts for both large nut and larger kernel traits will enhance the production of cashew in Nigeria. The cashew tree is an out crosser. It produces variable nut sizes due to segregation. Moreover, most cashew farms in Nigeria are grown from seeds instead of grafted productive varieties, thus exhibiting much variation in all traits including nut yield and size. The Jumbo and Extra-large nuts may be used to establish polyclonal seed gardens to enhance the production of uniformly large nuts with larger kernel.

Figure-2 represents a three dimensional space figuration of the six cashew nut size categories.

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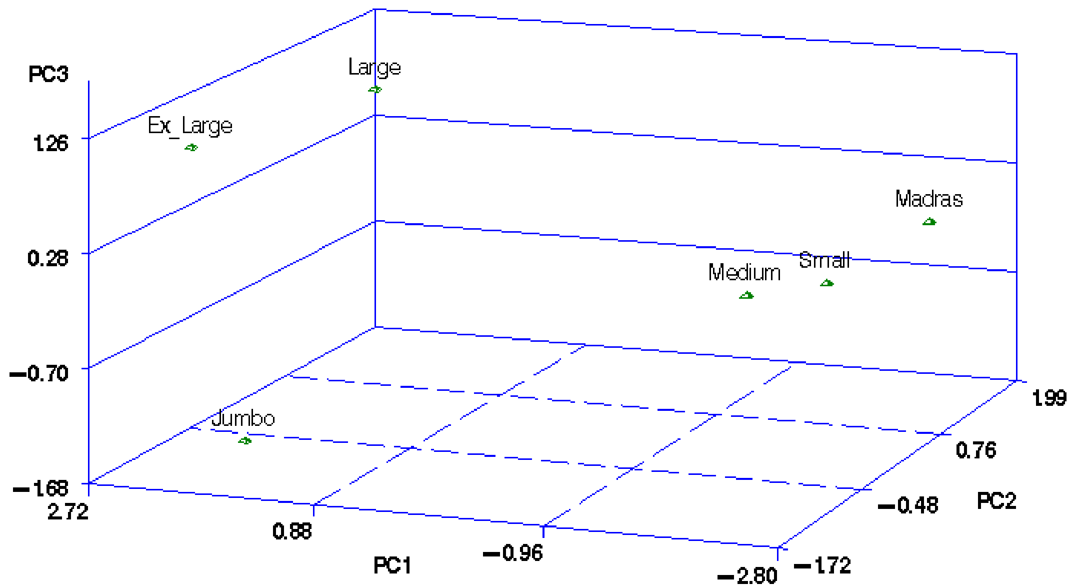

Figure-2. Tri-dimensional graph showing the grouping of the six cashew nut sizes.

Differences in nut sizes clearly distinguished the six cashew categories. The genetic distance across the plane between the Medium, Small and Madras categories were short, likewise the distance between Jumbo, Extra-large and the large categories. Though each category is distinct, two main clusters (each with three members) emerged. The two clusters are: cashew categories with large nut (comprising the Jumbo Extra-Large and Large) and those with small nuts (i.e. Medium, Small and Madras). A further investigation by genomic may be necessary to confirm the present phenotypic classification.

Eigenvalues representing the proportion of variation explained by each PC axis and the eigenvector of each of the nine variables are presented in Table-3.

Table-3. The principal components showing the eigen value, proportions of variation and the eigenvectors.

PC axes	PC1	PC2	PC3	PC4	PC5
Eigenvalue of each axis	6.37	1.54	0.97	0.88	0.02
Proportion of variation explained	0.70	0.17	0.10	0.01	0.00
Total cumulative variation across axes	0.70	0.87	0.98	0.99	1.00
Eigenvectors					
Nut weight	0.36	-0.22	-0.27	-0.02	-0.20
Nut length	0.38	-0.12	-0.04	0.45	-0.12
Nut width	0.28	0.30	-0.58	0.23	0.11
Shell thickness	0.24	0.54	0.39	0.18	0.58
Kernel length	0.39	-0.09	-0.08	-0.28	0.14
Kernel width	0.35	0.31	-0.21	-0.28	-0.16
Kernel weight	0.32	-0.41	0.12	-0.52	0.41
Kernel girth	0.30	0.31	0.48	-0.21	-0.59
Nut girth	0.30	-0.40	0.34	0.49	-0.02

The percentage contribution to the total variance by the first three PC axes was: 70, 17 and 10 respectively (Table-3). All the nine traits significantly (Eigenvector ≥ 0.2) distinguished the six cashew nut size in PC1. In PC2, seven traits were significant (Eigenvector ≥ 0.2) in discriminating the nut sizes except nut length and kernel length. Six traits excluding nut length, kernel length and kernel weight were significant (eigenvector ≥ 0.2) in distinguishing the six cashew nut sizes

Table-4 revealed the relationship between the nine traits assessed.

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Table-4. Pearson correlation coefficient of nine nut and kernel traits of cashew.

	NL	NW	SHTK	KL	KWD	KWT	KGT	NGT
NW	0.957**	0.713^{ns}	0.278^{ns}	0.965***	0.772^{ns}	0.873*	0.479^{ns}	0.763^{ns}
NL		0.674^{ns}	0.485^{ns}	0.978***	0.807*	0.868*	0.665^{ns}	0.846*
NW			0.482^{ns}	0.709^{ns}	0.904**	0.317^{ns}	0.422^{ns}	0.178^{ns}
SHTK				0.498^{ns}	0.730^{ns}	0.213^{ns}	0.920**	0.283^{ns}
KL					0.856*	0.881*	0.679^{ns}	0.789^{ns}
KWD						0.521^{ns}	0.753^{ns}	0.414^{ns}
KWT							0.503^{ns}	0.930**
KGT								0.561^{ns}

NW - Nut weight; NL - Nut length; NW - Nut width; SHTK - Shell thickness; KL - Kernel length; KWD - Kernel width; KWT - Kernel weight; KGT - Kernel girth; NGT - Nut girth; *, **, and *** - Level of significance at $p \leq 0.05$, 0.01, 0.001 respectively; ns - not significant

Nut weight significantly ($p \leq 0.001$) and positively correlated with kernel length (r = 0.965), nut length (r = 0.957), and kernel weight (r = 0.873). Nut length was positively and significantly ($p \leq 0.05$) correlated with kernel length, width, weight and nut girth. Positive and significant ($p \leq 0.01$) correlation exists between nut width and kernel width (0.904). Shell thickness was positively and significantly correlated with kernel girth (0.919). Significant ($p \leq 0.05$) and positive correlation existed between kernel length, width and weight; and between kernel weight and nut girth at $p \leq 0.01$ (0.930). In this study, kernel weight is a function of nut girth and weight while nut length was a good determinant of the kernel size (length by width) and weight.

The six nut categories differ from each other in their nut and kernel attributes. Generally, the weight of nut is correlated with it length and kernel weight, except in the extra-large nut which had the largest kernel weight. The largest nut size (jumbo) did not possess the largest kernel but second to the largest followed by the large nuts. Thus to get maximum yield of kernel in terms of quality and quantity, selection of jumbo, extra-large and large nut is suggested. They may be considered for both clonal multiplication and seed production through polyclonal planting to increase the productivity of cashew in Nigeria.

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