SOME TECHNOLOGICAL PROPERTIES OF CASTOR SEEDS (RECINUSCOMMUNIS) OF IMPORTANCE IN THE DESIGN OF ITS PROCESSING OPERATIONS

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ABSTRACT

This study was designed to evaluate technological attributes of castor seeds being evaluated under varietal improvement programmes in Nigeriathat may be useful in designing production, processes, oil extraction equipment and overall postharvest handling. The average seed major, intermediate, and minor lengths were considered and ranges from 9.42±0.36 mm, 5.62±0.22 mm and 4.27±0.14 mm respectively. The average seed weight was 116.17±19.46 g/1000 seed. While, the arithmetic, geometric, square and equivalent mean diameters were 6.43±0.20, 6.09±0.18, and 6.25±0.19 and 6.26±0.19 mm respectively. However, sphericity was 65% and aspect ration was 95%. Seed volume was 12.60±1.22 g/cm3 and particle density was 9.29±1.69. A knowledge of these properties constitute important and essential engineering data in design of machines, processes and controls; in analyzing and determining the efficiency of machine or an operation, in developing new plant as well as in evaluating and retaining the quality of final product.

Keywords: Aspect ratio, castor seed, physical properties, sphericity, seed weight

INTRODUCTION

Castor plant (*Recinuscommunis*), also called castor beans and Palma christi is a species of flowering plant in the *spurge* family, *Euphorbiaceae*. It belong to a monotypic genus, *Recinus*, and sub-tribe, *Ricininae* Castor seeds contains between 40% to 60% oil that are used with its derivatives in the production of paints, varnishes, lacquers and other protective coatings, lubricants, and greases, hydraulic fluids, soaps, printing inks, linoleum, oil cloth and as raw material in the manufacturing of various chemicals such as sebacic acid, undecylenic acid, used in the production of plasticizers and nylons (Dole and Keskar, 1950; Lewis and Elvin-Lewis, 1977. Marter, 1981; Oyeyemi*et al*., 2007).

Although castor is indigenous to the southeastern Mediterranean Basin, Eastern Africa and India, today it is widespread throughout tropical regions. Castor establishes itself easily as an apparently "native" plant and can often be found on wasteland. It is often seen along the road sides and on dump sites or heaps throughout the tropics and subtropics. The unripe seed capsules clusters when harvested are spread on the ground to dry, split open and the seeds falls out (Oyeyemi*et al*., 2007).

Annual global castor seed production is estimated at one million tons with India accounting for over 60% total yield. In Nigeria, there is no available statistics suggesting the level of production, but experts observed that the plant grow well in the North-western states of Yobe, Borno, Adamawa and Gombe, because of their Sahelian weather and prolong dry season. Nigeria spends between four to six hundred million dollars annually importing castor oil despite the abundant land, ecological and climatic conditions which are favorable to castor production (Oyeyemi*et al*., 2007; Iyabosa, 2009). Improvement program on local accessions of castor are being carried out at the National Cereals Research Institute (NCRI), Badeggi and other research centers across the country. Evaluation of processing and technological qualities of the collected germplasm is one of first research priorities.

Agricultural products attributes can be constituted into two basic categories (i) technological or processing qualities which determines the suitability of a specific product for industrial or home processing resulting to a product of defined commercial value and (ii) consumption quality which indicates the suitability of agricultural produce for consumption or its commercial value. Ahmadi, *et al*

(2009) give some specific technological qualities traits of seeds that may influence its behavior during processing which include seed size, shape, weight, arithmetic mean diameter, square mean diameter, geometric mean diameter, equivalent mean diameter, sphericity, aspect ratio, angle of repose, surface area, density, and porosity.

Principal axial dimensions of rough rice grains have been reported to be useful in selecting sieve separators and in calculating power during the seed milling process. They are also used to calculate surface area and volume of kernels, which are critical during modeling of grain drying, aeration, heating and cooling (GhasemiVarnamkhasti, *et al*., 2007). The physical properties of apricot was also reported to be important for the design of equipments for harvesting, and post-harvest transporting, sorting, cleaning, separation, sizing, packaging and processing into different items (Ahmadi*et al*., 2009).

Shape is exploited singly or together with other characteristics to determine the free flowing or bridging tendencies of seed mass in many separators used in cleaning (Eke *et al*., 2007). Arithmetic mean diameter and terminal velocity was used by Tabatabaeefar*et al*., (2003) to design a sieving and grading machine, by measuring the three perpendicular diameters of chickpea. They also reported means, standard deviation, maximum and minimum diameter. Shape and size also refers to the characteristics of an object which determines how much space it occupies and within limits can be described in terms of length, width and thickness (Eke, *et al*., 2003). Asoegwu*et al* (2006) and Eke *et al*. (2007) reported the geometric mean diameter, square mean diameter, equivalent diameter and sphericity together with the length, width and shape for African Oil bean seed. Because of the irregular nature of the shape and sizes of agricultural products, coefficient of variation (CV) may be used to characterize the quality of dispersion of the measured parameters about their means. Low CVs indicate more uniform dispersion (Eke *et al.,* 2007). Post-harvest physical properties of cheat such as axial dimensions, weight and shape (sphericity and aspect ratio) and bulk density was used by Hauhouot-O'Hara *et al*., (1999; 2000) and Eke *et al.,* (2007) to establish machine design and operating variables for roller hammer mills, selecting the optimum gap between rolls and optimum screen opening size for the hammer mill. Because castor oil production may require roasting, heating and crack process, its size, surface area and volume are required in different handling and processing operations such as heat transfer, heating, cooling, and oil press.

This present study, therefore, attempts to evaluate some physical characteristics of castor seeds which may influence post-harvest handling operations, with the objective of documenting these technological characteristics for engineering design of seed processing equipment and machines for increased national castor oil production.

MATERIALS AND METHODS

Castor seeds were obtained from the germplasm collection of the Oil Seed Division store of the National Cereals Research Institute (NCRI), Badeggi, Nigeria. They were from different sources, and therefore were thoroughly mixed, before packaging in a paper bag and kept under refrigeration for 72 hours to equilibrate. The moisture content of the seeds was determined using the procedure detailed by Henderson *et al.,* (1997) and was found to be 3.7±1.0%. Thirty (30) seed were selected at random and numbered 1 to 30. Axial dimension in terms of major diameter (D_1), intermediate diameter (D_2), and minor diameter (D_3) were measured on each side in triplicate using a Vanier caliper reading to 0.01mm precision. Mean values were used in calculating D_1, D_2 and D_3 and their standard deviations. While D_1, D_2 and D_3 were used to evaluate arithmetic mean diameter (AMD), the geometric mean diameter (GMD), square mean diameter (SMD), equivalent diameter (EQD), the sphericity (Sc) and the aspect ratio (AR) of the castor seeds using the equations (Mohsenin, 1986; Ciro, 1997; Eke, *et al*. 2007).

$$AMD = X = \frac{1}{3}[D_1 + D_2 + D_3] \quad \text{-------------------------- (1)}$$

$$GMD = Y = [D_1 \times D_2 \times D_3] \quad \text{-------------------------- (2)}$$

$$SMD = Z = [(\frac{D1D2+D2D3+D3D1}{3})]^{1/2} \quad \text{-------------------------- (3)}$$

$$\text{EQD} = \frac{X+Y+Z}{3} \quad \text{------------------------- (4)}$$

$$\text{Sc} = \frac{Y}{D1} \quad \text{-------------------------- (5)}$$

$$\text{AR} = D_2/D_1 \quad \text{-------------------------- (6)}$$

Seed weight was determined using an electronic balance to an accuracy of 0.001g. Weight of 100 seeds were determined before multiplying with 10 to obtain 1000-seed weight. While the method described by Dutta*et al*. (1988) was used to measure the volume and hence density of the seed. 100 seeds of known weight were dropped into a measuring cylinder filled with water to known volume. The displaced water which rise in the cylinder was used to calculate the equivalent volume of seed (V_{100}). As a result of the short duration of the procedure, the seeds were not coated to prevent moisture adsorption since it did not result in significant increase in weight as reported by Olajide and Ade-Omowaye (1999). The true density was determined from the result of weight and volume of 100 seed.The surface area (S_a) was determined by the following relationship given by McCabe *et al*. (1986).

$$\text{Surface Area } (S_{a)} = \pi \text{GMD}^2 \quad \text{---------------------------- (7)}$$

All the data generated were subjected to descriptive statistics analysis using Microsoft Excel, 2007 at 95% confidence level.

RESULTS AND DISCUSSION

Physical, processing or technological characteristics of agricultural produce are important in solving problems involving the design of specific machine for material handling. What shape is to be assumed for the material and which dimension is to be employed in calculations are two first problem to solved before solving the problem of separation of agricultural produce from undesirable materials by pneumatic or electrostatic devices. The result of the analysis of the three dimensions of castor seeds is given in Table 1. The average major, intermediate and minor lengths of castor seeds were 9.42±0.36 and range between 8.80 -9.87 mm, 5.62±0.22 (range, 5.33-6.03) and 4.27±0.14 (range, 3.97-4.40) mm respectively. The mean one thousand seed weight (W_{1000}) was found to be 116.17±19.46 g/1000 seeds and ranges between 94.00 to 210 g/1000 seeds. These values are most relevant to the design of seed sorters, screens hole and containers (Simonyan*et al.,* 2007).

The weight of agricultural products is exploited in the design of cleaning equipment using aerodynamic forces (Oje and Ugbor, 1991). The high variation in seed weight may likely be attributed to presence of immature seeds, damaged or unfilled seed (Adu-Kwarteng*et al*., 2003). Mohsenin (1970) and Jayan and Kumar (2004) highlighted the imperativeness of axial dimension in machine design such as seed flow through a planter, and comparison of this data with existing work on other similar seeds can be sufficient in projecting process and machine adoption.

Table 1.Means, Standard Deviation and Coefficients of Variation of principal dimensions of Castor seeds

Physical properties	*Unit*	*Minimum value*	*Maximum value*	*Mean*	*Standard deviation*	*Coefficient of variation (CV) (%)*
Major diameter (D_1)	mm	8.80	9.87	9.42	0.36	3.8
Intermediate diameter (D_2)	mm	5.33	6.03	5.62	0.22	3.8
Minor diameter (D_3)	mm	3.97	4.40	4.27	0.14	3.2
1000 seed weight (W_{1000})	g/1000 seed	94.00	210	116.17	19.46	1.7

The data on Table 2 is the means, standard deviation and CV of calculated values of various diameters of the seed. All the values has low coefficient of variation ranging from 1.70% for sphericity to 9.68% for volume. GMD range from 5.73 to 6.32 mm with a mean value of 6.089 mm, AMD has a mean of 6.435 mm, ranging between 6.05 to 6.69 mm. The SMD ranged from 5.87 to 6.50 mm with a mean score of 6.249 mm. The low CV of these parameters is an indication of uniform dispersion of these properties about their mean values. The closely related values obtained for AMD, GMD, SMD and EQD in this study are the same as observed by Eke *et al*., (2007) and Atiku*et al*., (2004). Sphericity and aspect ratio ranged from 0.62 to 0.66 and 0.94 to 0.95 and mean values of 0.650 and 0.947 respectively. Low aspect ratio, Eke *et al*., (2007) reported is a tendency of seed to being oblong in shape. However with aspect ratio of greater than 90%, castor seed is more likely to roll than slide during conveying or other process operations. Sphericity of greater than 60% is an indication of how close castor seed is to sphere. This information Eke *et al*., (2007) reported is critical for hopper, separator and conveyor design.

The particle density was ranged between 7.57 to 16.15 g/cm^3 and surface area between 108.74 to 132.87 cm^2. However, mean values were 9.29±1.69 g/cm^3 and 123±7.50 cm^2 respectively. High density is an indication of degree of seed filling during seed development and therefore an indication of quality. Density has been used in grain research for the determination of dielectric properties of cereal grains (Nelson and You, 1989).

Table 2.Means, Standard deviation and coefficient of variance of some physical properties of castor seed

Calculated properties	*Unit*	*Minimum value*	*Maximum value*	*Means*	*Standard deviations*	*Coefficient of variation CV (%)*
Arithmetic mean diameter	mm	6.05	6.69	6.435	0.200	3.10
Geometric mean diameter	mm	5.73	6.32	6.089	0.182	2.98
Square mean diameter	mm	5.87	6.50	6.249	0.193	3.10
Equivalent mean diameter	mm	5.88	6.50	6.258	0.190	3.10
Sphericity	%	0.62	0.66	0.650	0.011	1.70
Aspect ratio	%	0.94	0.95	0.947	0.004	4.50
Volume	cm^3	11.00	15.00	12.60	1.220	9.68
Density	g/cm^3	7.57	16.15	9.288	1.688	1.82
Seed caruncle	mm	1.70	2.80	2.500	0.205	8.20
Surface area	mm^2	108.74	132.87	123.178	7.504	6.00

When castor seed data are compared with other seeds and pods (Table 3), the D_1, D_2 and D_3 are closely related to Chicken pea split and African bread fruits (Omobuwajo et al., 1999). While Jack bean and Bambara groundnut D_1, D_2, and D_3 are twice that of castor seeds. AMD, GMD SMD and EQD followed same trend. Castor seed has higher aspect ratio (greater than 90%) than all the seeds compared with, indicating high rolling tendency of the test seed. Its sphericity (65%) is lower than that of Jack bean seed (73%) and Bambara groundnuts (86%) (Table 3).

The frequency distribution in terms of skewness and kurtosis of castor seeds are shown on Table 4. Positive skewness indicates a distribution with an asymmetric tail extending towards more value. Negative skewness indicates a distribution with an asymmetric tail extending towards more negative value. Zero value indicates symmetrical distribution. While kurtosis on the other hand, characterized the relative peackness or flatness of distribution in relation to normal distribution. Positive value indicates leptokurtic distribution. Negative value indicates platykurtic distribution. Zero value is an indication of normal or mesokurtic distribution.

Table 3.Comparison of castor seed physical parameters with other similar seeds

Property	*Seeds and pods*				
	Castor seed	*Chickpea split (cicerarietinum L.)*[1]	*Jackbean seed (canavaliaensiformis)*[2]	*Bambara groundnut*[2]	*African bread fruits*[2]
D1	9.420	6.250	18.662	18.90	11.91
D2	5.621	5.310	13.141	15.70	5.69
D3	4.270	2.910	10.224	14.40	4.64
AMD	6.435	4.823	14.009	16.33	7.41
GMD	6.089	-	13.563	16.23	57.10
SMD	6.249	-	13.780	16.28	7.06
EQD	6.258	-	13.784	-	-
W1000	116.17	69.50	1.591	-	-
Volume	12.60	0.055	1.324	-	-
Sphericity	0.650	-	0.727	85.86	57.10
Aspect ratio	0.947	-	0.706	0.831	0.478
Particle density	9.288	-	1.190	0.755	0.979
Surface area	123.178	-	-	-	-

[1]Ghadge et al.,(2008); Eke et al., (2007)

Table 4. Frequency distribution of castor seeds properties as skewness and kurtosis

Parameter	[a]*Skewness*	[b]*Kurtosis*
Major diameter (D_1) mm	-0.297	-1.049
Minor diameter (D_2) mm	0.437	-0.273
Intermediate diameter (D_3) mm	-1.216	1.406
Arithmetic mean diameter (AMD) mm	0.536	-0.166
Geometric mean diameter (GMD) mm	-0.633	0.388
Square mean diameter (SMD) mm	-0.526	0.062
Equivalent mean diameter (EQD) mm	-0.563	0.092
One thousand seed weight (W_{1000}) g/1000 seeds	4.063	19.716
Volume (V) cm^3	0.361	0.849
Sphericity (Sc)	-1.928	5.026
Aspect ratio (AR)	-1.890	4.107
Particle density g/cm^3	2.550	8.796
Surface area (S) cm^2	-0.496	-0.046

a = Skewness show lack of symmetry about the mean in a frequency distribution.

b = Kurtosis shows the extent the frequency distribution is concentrated about the mean.

Eight of the physical characteristics of castor seeds measured (D_1, D_3, GMD, SMD, EQD, S_c, AR and S_a) were moderately skewed to the left, while five (D_2, AMD, W_{1000} V and D_p) were positively skewed. Sc has the highest negative skewness (-1.928) and D1 the lowest (-0.297). W1000 has an exceptionally high skewness (4.063) indicating spreading of the seed weight toward more positive direction when compared with normal distribution.

The D_1, D_2, AMD and S_a had a platykurtic distribution with values -1.049, -0.273, -0.166 and -0.046 respectively. The platykurtic distribution of D_1 was also observed in for African oil bean seeds (-0.2699) (Asoegwu*et al*., 2006) and jack bean (-1.0620) (Eke *et al*., 2007). But all other measured parameters indicate positive (leptokurtic) distribution ranging from 0.062 in SMD to 19.716 in W_{1000}.

CONCLUSION

In this work, some postharvest physical properties of castor seeds grown in Nigeria including linear dimensions, 1000 seed weight, seed volume, spericity, aspect ratio, particle density, arithmetic mean diameter, geometric mean diameter, square mean diameter and equivalent mean diameter are reported. Linear dimension were 9.42±0.36, 5.62±0.22 and 4.27±0.14 for D_1, D_2 and D_3 respectively. While AMD, GMD, SMD and EQD were closely related as reported for most closely spherical agricultural crops.Sphericity was 65% and aspect ratio above 90% indicating spherical nature of the seed and its tendency to roll instead of slide during processing operations. General low CV were also observed, indicating uniform dispersion of the seed data about their mean. This characteristics are neccessary for the design of equipments and machines for the transportation, sorting, cleaning, handling, drying and storage of the seed. When compared with results of other similar crop, it could be used to adopt other machines for castor processing and cultivation.

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