EVALUATION OF SOME DESIGN RELATED PROPERTIES OF *KANANNEDO* BEAN SEED

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ABSTRACT

Knowledge of physical properties of agricultural products plays a vital role in the design of machinery for mechanization of post-harvest handling operations. This study was conducted to evaluate some design related properties of *kanannedo* bean seeds, a local variety of cowpea, at the moisture content of 8.67% ± 0.90 (wb). The results obtained revealed that the mean length, width and thickness of the bean grains were 10.09±0.32mm, 7.00± 0.71mm and 7.75± 0.58mm, respectively, while the mean arithmetic mean diameter, geometric mean diameter, sphericity, surface area and aspect ratio were estimated at 8.28±0.40 mm, 8.17±0.33 mm, 209.95±0.18 mm^2, 0.79 ±1.60 and 69.38±2.22%, respectively. The true density, bulk density and porosity of the grains were estimated at 0.94 ± 0.01g/cm^3, 0.83± 0.01g/cm^3 and 52.45±0.60%, respectively. While the angle of repose of the grains was 51.69±1.26^o, the coefficient of static friction of the grains against plywood, galvanized iron and plastic glass surfaces were 0.453±0.01, 0.428±0.01 and 0.426±0.00, respectively. This result could be used as a reference data for design and development of post-harvest equipment and machines for the *kanannedo* bean and other related crops.

Keywords: Cowpea variety, Data base, *kanannedo grain*, Physical properties, Post-harvest handling
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INTRODUCTION

Kanannedo bean, a local variety of cowpea (*Vigna unguiculata* L.), grows predominantly in the north-western part of Nigeria. Cowpea constitutes about 60% of protein which is rich in amino acids, lysine and tryptophan as well as vitamins A, B, and E [1]. Although cowpea is grown in other parts of the world, Nigeria remains the largest producer and consumer of cowpea in the world, with Kano state being among the world largest cowpea producing areas, with a cultivated land area of about 4,050 ha and yield estimate of above 1,000 kg/ha, compared with the national average production of 212 kg/ha [2]. According to Irtwange [3], Nigeria alone produces 61% (760,000 tons) of the world's total production of cowpea. Cowpea seed is a nutritious component in the human diet which qualifies among staple crops in Nigeria that provide much needed protein requirement in the dietary table [4]. It could be prepared in several ways for consumption such as boiling, grinding and processing it into 'akara' ball', 'moin-moin' and so on [5].

There are a lot of problems facing Nigeria farmers on the issue of cowpea threshing. Currently, threshing of cowpea is predominantly manual which involves placing the harvested bean pods on the muddy or concrete floor or filling the bean pods in jute or bacco bag and beating with stick or flailed. Other methods include pounding the bean pods using mortar and pestle to remove the seeds [6]. Manual system of threshing is characterized with time wastage, threshing losses, relatively low work done and laborious, and predominantly engages mostly women and children. This method of threshing also results in grain breakages due to the impact of pressure applied during beating process thereby leading to low quality of threshed cowpea [7]. Poor post-harvest handling methods often leads to the introduction of contaminants such as stones, sticks, chaff and dust which necessitates cleaning of the seeds [8]. Attempts have been made to solve the problems associated with cowpea threshing in Nigeria through the development of both manually and mechanically operated threshers which help to reduce threshing losses, increase work done, eliminate drudgery and improve quality of threshed cowpea [9].

Threshing operation, either by mechanical or manual method, involves the removal of seeds from the pods and separation of impurities and contaminants from seeds [10]. But neither of these technologies has been be efficient due to inadequate knowledge of physical properties of agricultural materials. To achieve effective processing of cowpea in order to maintain high quality of final processed products with minimum drudgery, using efficient post-harvest handling facilities, equipment and machines, there is need for adequate knowledge of physical properties of the bean pods and seeds [11].

The knowledge of physical properties of biological materials constitutes important and essential engineering data that is useful and necessary in the design as well as selection of appropriate facilities, equipment and machines employed for postharvest handling, processing and storage of agricultural materials [12]. Information on these properties also helps in the analysis and determination of the efficiency of equipment and machines or operations, development of new products and final product quality [13]. Literature on determination of physical properties of some agricultural materials in recent times include: maize [14], soybeans [15], Neem seeds [16] and bambara nut [17].

Although studies on physical properties of many agricultural materials have been conducted, there is little or no information on the physical properties of cowpea, particularly the locally developed varieties. It is on this basis that this study attempts to evaluate some physical properties of *kanannedo* bean seeds, a local variety of cowpea, grown most predominantly in the north-west zone of Nigeria, particularly Zaria area of Kaduna state.

MATERIALS AND METHODS

Physical properties of agricultural materials are those morphological attributes which when evaluated are relevant to the design and development of harvesting, handling, processing and storage equipment for that particular material [18]. The properties considered relevant to the design and development of threshing, cleaning and storage of *kanannedo* bean seeds in this study include mass, size, shape, surface area, volume, aspect ratio, sphericity, true density, bulk density, porosity, angle of repose and coefficient of static friction

Sample collection and preparation

Seed sample of *kanannedo* bean seeds obtained from Samaru ultra-modern market, was used for the experiments in this study. The bulk seed sample was sorted manually to remove stones, straw, and other foreign materials and then sieved to remove broken and immature seeds [19]. The physical properties evaluated include the tri-axial dimensions, mean diameters, surface area, sphericity, aspect ratio, bulk density, true density, porosity, angle of repose, and static coefficient of friction [13].

Moisture content

The *kanannedo* bean seed moisture content was determined by drying 100 seeds in a standard oven dryer at 130ºC for 24 hours [18]. Loss in weight of the dried sample was recorded and the moisture content determined in per cent dry basis, as expressed below [13].

$$M_{db\%}=\frac{Wi-Wf}{Wi}100 \qquad (1)$$

Where, Mdb% = per cent moisture content in dry basis, W_i = initial weight of sample in gram(g) and Wf = final weight of sample in gram (g)

Experimental procedures

1000 seed weight was determined by weighing 50 seeds randomly selected from the bulk sample. The average weight per seed was obtained by dividing the value by 50. One hundred grains randomly selected were measured for length, width, and thickness using a micrometer screw gauge (Kanon Instruments, Japan) of 0.01 mm sensitivity. Subsequently, arithmetic mean diameter (Da), geometric mean diameter (Dg), surface area (As) and the sphericity (∅) and aspect ratio were computed using mean values of the tri-axial dimensions. Measuring the unit mass(ms), unit volume (vs), bulk mass(mb) and bulk volume (vb) by use of electronic weigh balance, liquid displacement method apparatus and 25ml calibrated cylinder, true density (ρT), bulk density (ρB) and porosity (ε), of the seeds were determined [19]. To determine the angle of repose, an open-end cylindrical frame of 15 cm diameter and 50cm height and a pair of dividers and a metre rule were used, while for coefficient of static friction, a hollow cylindrical frame and adjustable tilting surfaces of plywood, galvanized iron and plastic glass were used [20]. All the physical properties were evaluated at

Geometric properties

The tri-axial dimensions (L, W and T) of each of the 100 seeds picked randomly from the bulk seed sample were used to derive the values of geometric mean diameter (Dg), arithmetic mean diameter (Da), surface area (As), sphericity (∅) and aspect ratio (Ra), as expressed in the equations below [21, 22].

$$D_g = \sqrt[3]{abc} \qquad (2)$$

$$D\frac{a+b+c}{3} \qquad (3)$$

$$A_s = \pi (D_g)^2 \qquad (4)$$

$$\emptyset = \frac{\sqrt[3]{(abc)}}{a} \qquad (5)$$

$$R_a = \frac{b}{a} \text{ x } 100\% \qquad (6)$$

Where, Dg= geometric mean diameter, Da = arithmetic mean diameter, As = surface area, ∅ = Sphericity, Ra = aspect ratio and L, W and T, for major diameter, intermediate diameter and minor diameter, respectively.

Gravimetric properties

The mean values of solid mass (Ms) and volume (vs) and the bulk mass (Mb) and volume (vb) were used to determine the true density (ρT), bulk density (ρB) and porosity (ε) of the seeds, as presented in the equations below [23].

$$\rho T = \frac{ms}{vs} \quad (7)$$

$$\rho B = \frac{mb}{vb} \quad (8)$$

$$\varepsilon = (1 - \frac{\rho B}{\rho T}) \times 100\% \quad (9)$$

Where, ρT = true *density*, ρB = bulk density, and ε = porosity

Frictional properties

The angle of repose and coefficient of static friction of the seeds on plywood, galvanized iron and plastic glass surfaces were evaluated as expressed below.

Angle of repose (θ)

The container filled with seeds on a flat and smooth surface was gradually raised above the surface until the seeds formed a cone-shaped pile of seeds on the surface. Using the height (H) and diameter (D) of spread of the seeds, the angle of repose was evaluated as follows [24].

$$\theta = \text{Tan}^{-1} [\frac{2H}{D}] \quad (10)$$

Where, $\boldsymbol{\theta}$ = angle of repose, H= height (mm) of pile and D= diameter (mm) of spread of the seeds on a horizontal platform.

Coefficient of static friction

The cylindrical hollow frame filled with seeds on the test surface was raised slightly so as not to touch the test surface until the cylinder with seeds began to slide down. The angle of inclination (α) with the horizontal base was measured and the coefficient of static friction was determined using the following equation [25].

$$\boldsymbol{\mu} = \tan\alpha \quad (11)$$

Where, μ = coefficient of static friction and α = angle of inclinationan

Statistical analysis

Descriptive statistics was used to compute and compare the data drawn during the study, using SPSS 11.5 for Windows [26].

RESULTS AND DISCUSSION

Physical properties of *kanannedo* seeds

The summary of the results of the evaluated physical and mechanical properties of the *kanannedo* seeds at the moisture content of 8.67±0.90% dry basis is presented in Tables 1-3.

Linear dimensions of *kanannedo* grains

The length, width and thickness of the *kannnedo* bean seeds are detailed in Table1. The mean values of the length, width and thickness of the seeds were found to be 10.09±0.32mm, 7.00± 0.71 mm and 7.75± 0.58 mm in the range of 10.11-10.40 mm, 6.67-7.41 mm and 7.09-7.88 mm, respectively. These values were close in size with the mean values of the tri-axial dimensions of IT716, Ife Brown, Sokoto red, Oloka and White estimated at 8.64, 6.21 and 5.05 mm; 7.56, 6.20 and 4.25 mm; 10.83, 7.49 and 5.14 mm; 9.19, 7.42, and 5.46 mm, and 8.24, 5.62 and 4.39 mm, and African breadfruit and gram seeds at 11.91, 5.69, 4.64 mm and 7.98, 5.95, 5.82 mm, respectively. The tri-axial dimensions of *kanannedo* seeds being close in range with those of the other cowpea varieties and those African breadfruit and gram seeds, suggests that a single multivariate machine could be used in handling, cleaning and grading of *kanannedo* grains and other crop varieties with similar axial dimensions [13]. This conforms to reports that knowledge of axial dimensions of the seed crops is important in determining aperture sizes in the design of grain handling machinery [18].

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Table 1: Mean geometric properties of *kanannedo* bean seeds

Physical property	No. of observations	Replication			Mean (μ)	SD (σ)	CV (%)
		R1	R2	R3			
Moisture content % (db)	100	9.55	7.75	8.70	8.67	0.90	10.39
Major dia. (a) mm	100	10.11	9.76	10.40	10.09	0.32	3.2
Intermediate dia. (b) mm	100	6.67	6.93	7.41	7.00	0.71	10.10
Minor dia. (c) mm	100	7.09	8.21	7.88	7.75	0.58	28.82
Geometric mean dia (D_2) mm	100	7.82	8.22	8.47	8.17	0.33	4.04
Arithmetic mean dia (D_1) mm	100	7.97	8.30	8.56	8.28	0.40	4.84
Surface area (A_s) mm^2	100	192.14	212.30	225.41	209.95	0.18	2.02
Sphericity (∅)	100	0.75	0.82	0.80	0.79	1.60	2.98
Aspect ratio (R_a) %	100	65.97	71.00	71.25	69.38	2.22	3.16

Geometric properties of *kanannedo* bean seeds

Computing the mean tri-axial dimensions of the seeds, the arithmetic mean diameter, geometric mean diameter, surface area, sphericity and aspect ratio of the seeds were estimated at 8.28±0.40 mm, 8.17±0.33 mm, 209.95±0.18 mm^2, 0.79 ±1.60 and 69.38%±2.22, and in the range of 7.82-8.47mm, 7.97-8.56, 192.14-225.41mm^2, 0.75-0.80 and 65.97-71.25%, respectively. As the mean tri-axial dimensions varied significantly ($p>0.05$), all geometric properties of the grains varied. This conforms to Ndukwu and Adama [20] who reported that variation in mean tri-axial dimensions of a cowpea variety resulted in variation of the mean values of the geometric mean diameter and arithmetic mean diameter. Comparing the sphericity (0.79±1.60%) and aspect ratio (69.38±2.22%) of the *kanannedo* seeds with those of oil bean (60%), African breadfruit (61%) and soybean(74%), the study suggests that the high sphericity and aspect ratio values indicate that the shape of *kanannedo* grains is close to a sphere. Thus, the seeds have the tendency to roll, a property essentially important in the design of hoppers for seed handling machines [13]. Sphericity and aspect ratio relate to shape and are needed for analytical prediction of the drying behaviour of agricultural materials [26].

Gravimetric properties of *kanannedo* seeds

The result of evaluation on gravimetric properties of *kanannedo* bean grains is presented in Table2. The true density, bulk density and porosity of the grains range between 0.94 ± 0.01 and 0.95 ± 0.01 g/cm^3, 0.82 ± 0.01 and 0.84 ± 0.01g/cm^3 and 47.72 ±0.60 and 59.54±0.60% with the mean values estimated at 0.94 ± 0.01g/cm^3, 0.83± 0.01g/cm^3 and 52.45±0.60%, respectively. The mean true density and bulk density for the seeds indicate that the seeds are lower in density than water (1.0g/cm^3), thereby establishing the fact that *kanannedo* seeds can float in water at room temperature [27]. Density is an essential property in the design of cleaning and washing machines as well as soaking process for bean cake production [11]. The interaction of bulk density with angle of repose and coefficient of static friction of seed crops helps in the theoretical prediction of pressure and loads in the design of storage structures and handling facilities [18]. Given the porosity at 52.45%, it shows that *kanannedo* seeds can dry faster as stream of heated drying air passes easily through seed piles to effect drying. The high porosity in *kanannedo* seeds explains why they absorb water and swell easily when soaked to remove the hulls [11].

Table 2: Mean gravimetric properties

Physical Property	No. of observations	Replication			Mean (μ)	SD (σ)	CV (%)
		R1	R2	R3			
Moisture content%(db)	100	9.55	7.75	8.70	8.67	0.90	10.39
True density (g/mm3)	100	0.94	0.94	0.95	0.94	0.01	0.75
Bulk density (g/mm3)	100	0.84	0.82	0.84	0.83	0.01	1.48
Porosity (%)	100	47.72	59.54	49.51	52.45	0.60	5.20

Frictional properties of *kanannedo* bean seed

The angle of repose of *kanannedo* bean seeds was measured and estimated in the range of 49.27-53.26º with a mean value of 51.69±1.26º. The angle of repose estimated at 51.69±1.26º indicates that *kanannedo seeds* fall within the non-easy flowing materials with angle of repose at 45-55º [28]. The static coefficients of friction of the seeds against plywood, galvanized iron and plastic glass surfaces indicated that plywood structural surface had the highest value of static coefficient of friction in the range of 0.447-0.458±0.01, with a mean value of 0.453±0.01, followed by galvanized iron in the range of 0.425-0.431±0.01, with a mean value 0.428±0.01 and plastic glass with the least static coefficient of friction in the range of 0.419-0.429±0.00, with a mean value of 0.426±0.00.

Table 3: Mean frictional properties of *kanannedo* seeds

Physical Property	No. of observations	Replication			Mean (μ)	SD (σ)	CV (%)
		R1	R2	R3			
Moisture content	3	9.55	7.75	8.70	8.67	0.90	10.39
Angle of repose (θ)	3	49.27	52.55	53.26	51.69	1. 26	2.17
Static coefficient of friction;							
Plywood	3	0.447	0.453	0.458	0.453	0.01	1.22
Galvanized iron	3	0.425	0.427	0.431	0.428	0.01	1.44
Plastic glass	3	0.419	0.427	0.429	0.426	0.00	0.47

On determination of physical properties of water melon, the highest and least static coefficients of friction was also highest on plywood and least on plastic glass, suggesting that the highest value of coefficient of static friction on plywood could be due to the roughness of the surface and probably least on plastic glass surface [29]. Similarly, in determining the static coefficient of friction for soybean seeds with respect to surfaces of plywood, galvanized iron sheet, concrete and glass, the least coefficient of friction was also observed with glass, implying that the smoother the structural surface the lower the coefficient of friction of agricultural products [30].

CONCLUSION

A study was conducted to evaluate some design related properties of *kanannedo* bean seeds. The following conclusions are drawn from the evaluation some physical properties of *kanannedo* bean seeds at 8.67±0.90% db:

1. The mean length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area and aspect ratio were respectively estimated at 10.09±0.32 mm, 7.00± 0.71mm, 7.75± 0.58 mm, 8.28±0.40 mm, 8.17±0.33 mm, 209.95±0.18 mm^2, 0.79 ±1.60 and 69.38±2.22%.
2. The mean true density, bulk density and porosity of the grains were estimated at 0.94 ± 0.01 g/cm^3, 0.83± 0.01 g/cm^3 and 52.45±0.60%, respectively.
3. The mean angle of repose of the grains 51.69±1.26º, while coefficient of static friction of the grains against plywood, galvanized iron and plastic glass surfaces were 0.453±0.01, 0.428±0.01 and 0.426±0.00, respectively.
4. The result obtained from study could be used as a reference data for design of development of post-harvest equipment and machines for *kanannedo* bean and other related crops.

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