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EFFECT OF MOISTURE CONTENT ON SOME PHYSICAL PROPERTIES OF COWPEA (*Vigna unguiculata*)

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ABSTRACT

The effect of moisture content on the physical properties of three of the most popular Nigerian cowpea varieties namely Ife 98-12, IT90K-277-2 and Ife Brown was determined with a view to obtain data useful for the design of handling and processing equipment for the crop. Physical properties such as linear dimensions, geometric mean diameter, sphericity, aspect ratio, bulk density, true density, projected area, porosity and 1000 grain mass were studied in the moisture range of 8 to 18% w.b. which covers the moisture range from harvesting to storage. The length of the grains ranged from 9.36 to 9.74mm, 7.70 to 8.49mm and 8.01 to 8.49mm for the three varieties respectively. The width ranged from 6.34 to 6.53mm, 6.08 to 6.45mm and 6.01 to 6.46mm while the thickness ranged from 5.24 to 5.33mm, 5.00 to 5.24mm and 4.42 to 4.75mm respectively for the three varieties. The results show that variety and moisture content had significant effects ($p \leq 0.05$) on all the physical properties studied except aspect ratio on which the effect of moisture content was not significant. Regression equations that could be used to express the relationships existing between the physical properties and grain moisture content were established.

Keywords: Cowpea (*Vigna unguiculata*), physical properties, sphericity, aspect ratio, bulk density, projected area, moisture content, variety

INTRODUCTION

Cowpea, *vigna unguiculata,* is a very important grain legume consumed in all parts of West Africa. Cowpea grains contain about 25% protein and 64% carbohydrate (Bressani, 1985; Singh, 2003) making it a rich source of protein in the diet of both rural and urban population. Over 75% of world's cowpea production is from Africa and West Africa is the key producing zone with Nigeria being the largest producer and consumer of cowpea in West Africa and also in the world (FAOSTAT 2005; Coulibay and Lowerberg-DeBoer, 2003).

Cowpea, due to its high protein content has the potential to be used in nutritional products for infants and children's food and to compensate for large proportion of carbohydrate often contained in African diets. However, a major constraint to such industrial use is the poor quality of cowpea available in the market (Taiwo, 1998; Lambot, 2003). They often contain stones, foreign particles and defective grains due to traditional methods of handling and processing employed by many local farmers. There is thus need for the development of handling and primary processing equipment for cowpea to improve the quality of cowpea available for industrial use as well as for human consumption. The high cost of imported machines for processing of crops if available is another factor inhibiting the availability of high quality products in most developing countries. This has led to the promotion of design and production of these machineries locally. However, there is lack of appropriate data on the properties of most seeds and grains varieties available in developing countries required in the designs.

Physical properties of a crop are very important in the design of machines and analysis of the behaviour of the crop during agricultural process operations such as cleaning, sorting, drying, handling, planting, harvesting and threshing (Akaimo and Raji, 2006). Kutte (2001) also reported that in the design of any agricultural handling and processing machine, properties of the crop such as the grain size, shape, mass, hardness, angle of repose, grain-straw ratio, moisture content, kernel and bulk density must be taken into account.

Bulk and true densities are essential in knowing the weight of the crop per unit volume and are useful in handling operations. They are also useful in the design of silos, storage bins and design of specific gravity separators. The porosity or the percentage of voids of grains is useful in airflow, heat flow and drying studies such as determining the Reynolds number in pneumatic and hydraulic handling of grains, and in calculating thermal diffusivity in drying and other heat transfer problems (Nalladurai *et al.,* 2003).

The shape and physical dimensions are useful data for the design of separating or cleaning machines. The aspect ratio gives an indication of the tendency of a seed towards being oblong in shape (Omobuwajo *et al*., 1999). Its knowledge is important in the design of hoppers, separation and conveying equipment. Furthermore, the sphericity and geometric mean diameter that are computed from the physical dimensions are used in determining aerodynamic properties such as terminal velocity, drag coefficient and Reynolds number (Tado *et al*., 1999).

Many researchers have investigated the physical properties of different crops and food materials which include soybean (Deshpande *et al*., 1993), cumin seed (Singh and Goswani, 1996), paddy rice (Nalladurai, 2003), sheanut (Aviara *et al*., 2005), green wheat (Al-Mahasneh and Rababah, 2006) and corinder seed (Coskuner and Ersankarababa, 2007). However, literature is sparse on the physical properties of Nigerian cowpea varieties as well as their dependence on moisture content.

The objective of this study is to determine some physical properties of three varieties of Nigerian cowpea, namely, linear dimensions, geometric mean diameter, sphericity, aspect ratio, bulk density, true density, porosity, 1000 grain weight and projected area and to investigate the effect of moisture content on these physical properties. The moisture content range was selected from 8 to 18% w.b. as harvesting and most of the processing operations of cowpea are performed in this range.

MATERIALS AND METHODS

Three varieties of cowpea namely Ife brown, Ife 98-12 and IT90K-277-2 were used for the study. The crops were grown in 2007 season at the experimental farm of the Institute of Agricultural Research and Training, Moor Plantation, Ibadan, Nigeria. The crops were cleaned manually for chaff, immature and broken grains. The initial moisture content of grains was determined by oven drying method using ASAE standards (1998). Calculated amount of distilled water was added to the grains to bring them to the desired moisture contents of 8, 12, 14, and 18% w.b. using equation (1) (Olayanju, 2002).

$$Q = \frac{A(b-a)}{(100-b)} \quad (1)$$

Where

A=initial mass of the sample, g

a= initial moisture content of the sample,% wet basis (w.b.)

b= final (desired) moisture content of sample % w.b.

Q= mass of water added to be added, g

Each sample of cowpea varieties was sealed in a separate polythene bag. The samples were kept at 5^{o}C in a refrigerator for a week to enable the water to distribute uniformly (Akinoso *et al*., 2006).

To determine the linear dimensions, 50 grains were randomly selected from each of the three varieties at each moisture level and the three principal dimensions of each grain, namely, length (*L*), width (*W*) and thickness (*T*) were measured using a micrometer screw gauge reading to 0.01 mm. The geometric mean diameter, D_m, and the degree of sphericity, Ψ, were calculated using the following relationships

(Mohsenin ,1986; Desphande *et al*., 1993; Lucas and Olayanju, 2003):

$$D_m = (LWT)^{1/3} \quad (2)$$

$$\Psi = \frac{(LWT)^{1/3}}{L} = \frac{D_m}{L} \quad (3)$$

The aspect ratio, R_a , was calculated as follows (Mohsenin ,1986; Hauhouot-O'Hara *et al*., 2000):

$$R_a = \frac{W}{L} \tag{4}$$

Since cowpea is ellipsoidal in shape (Nwuba *et al.*, 1994), the projected area, A_p, was calculated from the following relationship:

$$A_p = \frac{\pi LW}{4} \tag{5}$$

A 3 X 4 factorial experiment in Completely Randomized Design (CRD) with a total of 600 observations (3 varieties x 4 moisture content levels x 50 samples) was used for each of the parameters.

One thousand grain mass was determined by an electronic beam balance reading to 0.001g. The true density of grain is defined as the ratio of the mass of a sample of the grain to the volume occupied by the same sample. A weighed quantity of cowpea was poured into a 100 cm^3 fractionally graduated cylinder containing 50 cm^3 of distilled water. The volume of water displaced by the grains was noted. The true density was calculated as:

$$\text{True density} = \frac{m_s}{v_w} \tag{6}$$

Where m_s = mass of sample, g

v_w = volume of water displaced, cm^3

The bulk density was determined by filling a container of known mass and volume to the brim with each variety of cowpea. The net mass of cowpea was obtained by subtracting the mass of the container from the mass of the container and cowpea. To achieve uniformity in bulk density, the container was tapped 10 times in the same manner in all measurement to consolidate as reported by Irtwange and Igbeka (2002). The bulk density was then calculated as

$$\text{Bulk density} = \frac{m_s}{v_o} \tag{7}$$

Where m_s = mass of sample, g

v_o = volume occupied, cm^3

The porosity defined as the space in the bulk grains which is not occupied by the grains was calculated from the following relationship (Singh and Goswami, 1996):

$$P_f = 100\left(1 - \frac{\rho_b}{\rho_t}\right) \quad (8)$$

Where P_f = porosity, %

ρ_b = bulk density, g/cm^3

ρ_t = true density, g/cm^3

A 3 X 4 factorial experiment in Completely Randomized Design (CRD) with a total of 36 observations (3 varieties x 4 moisture content levels x 3 replications) was used for each of the gravimetric properties. The results obtained from the study were subjected to analysis of variance (ANOVA), correlation and regression analyses using SPSS 15 and Microsoft Excel software.

RESULTS AND DISCUSSION

Seed dimensions

The axial dimensions, geometric mean diameter, sphericity, aspect ratio and projected area are presented in Table 1. It was observed that the linear dimensions namely length (L), width (W) and thickness (T) of the three varieties of cowpea increased as the moisture content increased from 8% to 18% w.b. The effects of variety and moisture content were significant ($p \leq 0.05$) on the three principal dimensions. The interaction effect of variety and moisture content however was not significant ($p \leq 0.05$) on linear dimensions (Table 2). The regression equations in the moisture range of 8 to 18% w.b. as presented in Table 4 show a positive correlation of linear dimensions with moisture content with high correlation coefficients. A similar trend was exhibited by the geometric mean diameter. The increase in the linear dimensions of the grains with increase in moisture content may be due to increase in the volume of the grains as moisture content increases. Other investigators such as Despande *et al.* (1993) and Nalladurai *et al.* (2003) have reported similar observations for soybean in the moisture range of 8.7 to 25% d. b. and rice in the moisture range of 14.3 to 25.7% w.b. respectively.

Table 1: Summary of the physical properties of three cowpea varieties at different moisture content Levels

Variety	Moist Cont. %	Bulk density, g/cm^3	True density, g/cm^3	Porosity %	Thousand Grain Mass, g	Bulk density, g/cm^3	True density, g/cm^3	Porosity %	Thousand Grain Mass, g
Ife 98-12	8	0.694 (0.004)*	1.253 (0.001)	44.61 (0.26)	191.600 (2.440)	0.694 (0.004)	1.253 (0.001)	44.61 (0.26)	191.600 (2.440)
	12	0.678 (0.002)	1.159 (0.001)	41.52 (0.15)	198.936 (1.171)	0.678 (0.002)	1.159 (0.001)	41.52 (0.15)	198.936 (1.171)
	14	0.676 (0.002)	1.136 (0.002)	40.49 (0.25)	203.975 (1.220)	0.676 (0.002)	1.136 (0.002)	40.49 (0.25)	203.975 (1.220)
	18	0.672 (0.002)	1.127 (0.001)	40.35 (0.21)	213.963 (1.242)	0.672 (0.002)	1.127 (0.001)	40.35 (0.21)	213.963 (1.242)
IT90K-277-2	8	0.778 (0.002)	1.247 (0.001)	37.61 (0.24)	166.040 (0.420)	0.778 (0.002)	1.247 (0.001)	37.61 (0.24)	166.040 (0.420)
	12	0.758 (0.002)	1.200 (0.002)	36.83 (0.24)	173.794 (0.207)	0.758 (0.002)	1.200 (0.002)	36.83 (0.24)	173.794 (0.207)
	14	0.731 (0.003)	1.195 (0.001)	38.83 (0.24)	177.624 (0.420)	0.731 (0.003)	1.195 (0.001)	38.83 (0.24)	177.624 (0.420)
	18	0.725 (0.001)	1.193 (0.001)	39.23 (0.12)	186.499 (0.210)	0.725 (0.001)	1.193 (0.001)	39.23 (0.12)	186.499 (0.210)
Ife Brown	8	0.756 (0.002)	1.216 (0.002)	37.83 (0.15)	147.547 (1.680)	0.756 (0.002)	1.216 (0.002)	37.83 (0.15)	147.547 (1.680)
	12	0.738 (0.001)	1.214 (0.001)	39.19 (0.11)	155.089 (1.680)	0.738 (0.001)	1.214 (0.001)	39.19 (0.11)	155.089 (1.680)
	14	0.731 (0.003)	1.201 (0.002)	39.15 (0.20)	157.993 (0.160)	0.731 (0.003)	1.201 (0.002)	39.15 (0.20)	157.993 (0.160)
	18	0.725 (0.001)	1.199 (0.001)	39.53 (0.12)	166.373 (0.840)	0.725 (0.001)	1.199 (0.001)	39.53 (0.12)	166.373 (0.840)

( )*-Standard deviation

Table 2: Summary of analysis of variance for seed dimensions ($p \leq 0.05$)

Source of Variation	Degree of Freedom	Length mm	Width mm	Thickness mm	Geom. Dia, mm	Aspect Ratio	Sphericity %
Variety	2	277.91*	12.67*	128.71*	76.59*	196.49*	675.68*
Moist. Cont	3	15.63*	14.35*	5.96*	38.74*	1.34 NS	29.05*
Interaction	6	1.05NS	1.83NS	0.59 NS	5.39NS	1.46 NS	27.03*
Error	588						

* = Significant difference NS = Non significant difference

Sphericity (Ψ) and aspect ratio (R_a)

Sphericity is an expression of the shape of a solid relative to that of a sphere of the same volume whereas the aspect ratio relates the width of a seed to its length which is indicative of its tendency towards being oblong in shape (Omobuwajo *et al.*, 1999). Both variety and moisture content had significant effects on sphericity but only variety significantly ($p \leq 0.05$) affected aspect ratio. The sphericity is observed to decrease at moisture content levels of 8% to 18% w.b. for Ife 98-12 and IT90K-277-2. It decreased at moisture content level of 8% to 12% w.b. and increased from 12% to 18% w.b. for Ife Brown (Table 1). This variation in sphericity may be due to the slight differences in the shapes of the three varieties. Furthermore, the high aspect ratio obtained for the three varieties indicate that they can roll easily. This information is useful in the design of hoppers, separators and conveyors.

Projected area (P.A.)

The projected area for the three varieties increased as the moisture increased from 8 to 18% w.b. (Table 1). The linear regression equations presented in Table 4 show that projected area was positively correlated with moisture content with high correlation coefficient for the three varieties.

Bulk and true densities (B.D. and T. D.)

The bulk and true densities decreased as the moisture content increased from 8 to 18% w.b. as shown in Figs. 1 and 2. The effects of variety and moisture content were significant ($p \leq 0.05$) on the bulk and true densities of the three cowpea varieties. The interaction effect of variety and moisture content was also significant ($p \leq 0.05$) on the bulk and true densities.

This decrease in bulk density and true density of cowpea with increase in moisture content is similar to observations made by other investigators such as Visvanathan *et al.*, (1996) for neem nut, Lucas and Olayanju (2003) for beniseed and Irtwange (2000) for African yam bean. The decrease in true density with increase in moisture content could be adduced to the fact that the increase in the volume of the grains as they absorbed moisture is greater than the corresponding weight gained. Furthermore, the same weight of the material occupies more volume of the container thus decreasing the bulk density.

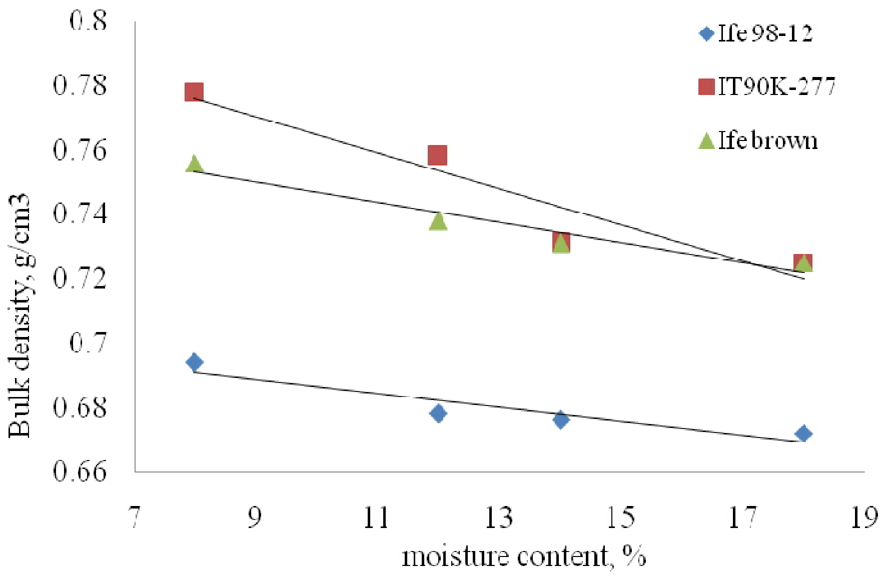

Fig. 1: Effect of moisture content on the bulk densities of three cowpea varieties

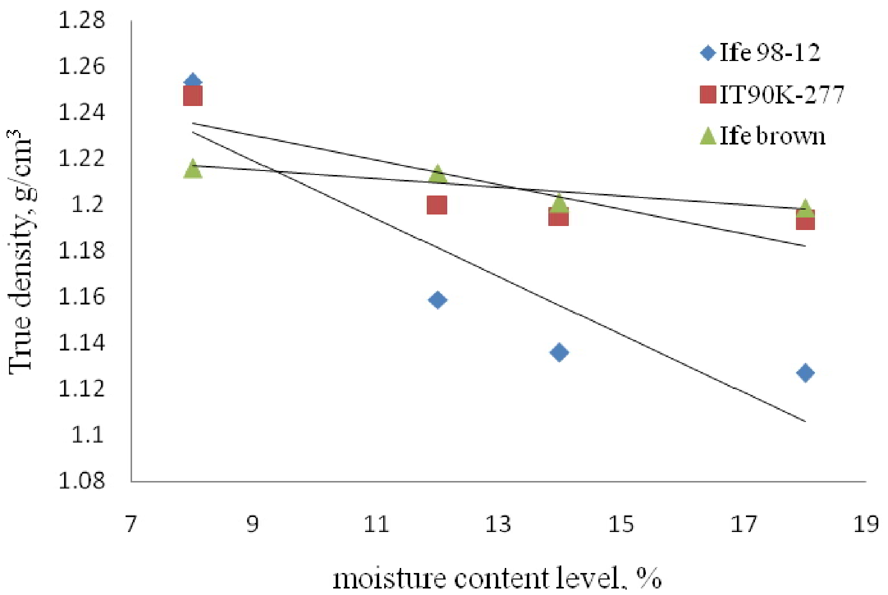

Fig. 2: Effect of moisture content on true density of three cowpea varieties

Table 3: Summary of analysis of variance for bulk and true density, porosity and thousand grain mass ($p \leq 0.05$)

Source of Variation	Degree of Freedom	Bulk Density kg/m^3	True Density kg/m^3	Porosity %	Thousand Grain Mass, g
Variety	2	3783.76*	3662.37*	1238.85*	4939.75*
Moist. Cont.	3	519.76*	4815.08*	31.86*	522.42*
Interaction	6	50.59*	1200*	228.77*	1.36 NS
Error	24				

* = Significant difference NS = Non significant difference

Porosity (P)

The porosity of IT90K-277-2 and Ife Brown varieties increased with an increase in moisture content while that of Ife 98-12 decreased with an increase in moisture content (Table 1). Analysis of variance showed that the effect of variety and moisture content is significant ($p \leq 0.05$) on porosity. The interaction effect of variety and moisture content was also significant ($p \leq 0.05$) on porosity. Other investigators have also made similar observations for different seeds. Gupta and Das (1997) observed an increase in porosity with increase in moisture content for sunflower seeds while Visvanathan *et al.* (1996) and Desphande *et al.* (1993) observed a decrease in porosity with increase in moisture content for neem nut and soybean.

Thousand grain mass (TGM)

The thousand grain mass for the three varieties increased linearly with increase in moisture content and are in the range of 191.600 to 213.963g for Ife 98-12, 166.040 to 184.499g for IT90K-277-2 and 147.547 to 166.373g for Ife Brown when the moisture content increased from 8 to 18% w.b. (Fig. 3). Similar observations were made by Lucas and Olayanju (2003) for beniseed, and Irtwange and Igbeka (2002) for African yam bean.

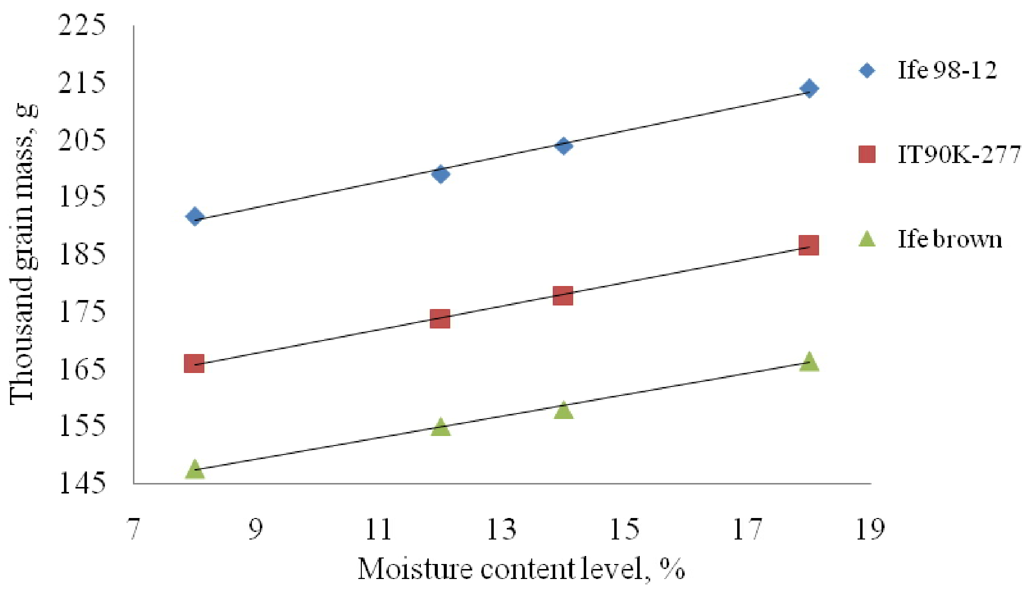

Fig. 3: Effect of moisture content on thousand grain mass of three cowpea varieties

Table 4: Regression Equations for Some Physical Properties of Cowpea

Variety	Ife 98-12		IT90K-277-2		Ife Brown	
Property	L.R.E	r	L.R.E	r	L.R.E	r
L	9.07 + 0.04M	0.96	7.05+ 0.08M	0.97	7.62 + 0.05M	0.99
W	6.16 + 0.02M	0.94	5.74+ 0.04M	0.87	5.64 + 0.05M	0.99
T	5.16 + 0.01M	0.95	4.82+ 0.02M	0.99	4.11 + 0.03M	0.96
GMD	5.67 + 0.08M	0.89	5.79+ 0.04M	0.96	5.62 + 0.04M	0.99
Ψ	84.65- 0.85M	-0.80	82.25-0.24M	-0.97	73.95+0.07M	0.75
B.D	0.70 – 0.02M	-0.74	0.82- 0.01M	-0.95	0.78 – 0.003M	-0.97
T.D.	1.33 – 0.01M	-0.91	1.75– 0.05M	-0.85	1.232 – 0.002M	-0.90
P. A.	43.82+0.36M	0.98	31.55+0.60M	0.93	33.820+0.51M	0.99
P	47.33- 0.43M	-0.90	35.60+0.19M	0.73	36.820+0.16M	0.73
T.G.M.	172.91+2.25M	0.99	149.46+2.04M	0.97	132.49+1.87M	0.99

M- moisture content, % w.b., L.R.E.- Linear Regression Equation, r- correlation coefficient

CONCLUSION

The following conclusions were drawn from the study:

1. The linear dimensions (length, width and thickness) of the three varieties of cowpea are linearly related to their moisture contents and increased with increase in moisture content in the moisture content range of 8 to 18% w.b. However, the linear dimensions differ significantly among the three varieties.
2. Variety and moisture content significantly affected ($p \leq 0.05$) the physical properties of the three cowpea varieties investigated at with the exception of aspect ratio on which the effect of moisture content is not significant.

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