Effects of moisture content on some physical and mechanical properties of three varieties of cowpea (v*igna unguiculata (L)walp*)

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Abstract: The effects of moisture content on the physical, mechanical and frictional properties of three varieties of cowpea, *Ife Brown*, *IT86D-1010* and *IAR-339-1* were investigated at four different moisture content levels (15%, 20%, 25% and 30% dry basis). These properties are important in the design of appropriate machines for harvesting, processing, transporting, separating, packaging and storage processes. The axial dimension, mean diameter, sphericity, surface area, porosity, true and bulk density, angle of repose, coefficient of friction of the three varieties of cowpea were determined by using a standard method. The results obtained from the study revealed that length, width, thickness, arithmetic and geometric diameter, sphericity, surface area and 1000 unit mass ranged from 9.87-15.21 mm, 7.00-10.88 mm, 5.49-8.47 mm, 7.45-11.52 mm, 7.24-11.19 mm, 0.67-0.79, 164.70-393.43 mm^2, 253.80-671.4 g accordingly. The mean porosity, true and bulk densities, hardness and angle of repose were investigated for the three varieties. The obtained results ranged from 31.4-38.6, 1 010.83-979.59 kg/m^3, 1 054.88-1 014.54 kg/m^3 and 1 083.12-1 037.53 kg/m^3, 703.49-636.41 kg/m^3, 689.29-622.12 kg/m^3 and 726.91-672.05 kg/m^3 and 24.3-29.7^o. The static coefficient of friction was determined for two structural surfaces namely, glass and plywood. The plywood as structural surface had higher coefficient of static friction for all the three varieties of cowpea investigated. Data obtained were subjected to analysis of variance (ANOVA), Duncan Multiple Range (DMR), linear regression analysis and descriptive statistics using Statistical Analysis System. All the engineering properties of the three varieties of cowpea studied were significantly different (P<0.05).

Keywords: cowpea, geometric mean diameter, arithmetic mean diameter, moisture content, axial dimensions

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1 Introduction

Cowpea belongs to leguminous plant with edible seeds contained in long, narrow and dehiscent pods that developed from pundicles (Arthur, 2009). According to Henshaw (2008), Nigeria is the largest producer of cowpea. The greater percentage of these productions are being utilized for various food preparations such as bean pudding, bean cake, baked beans, fried beans, bean soup etc., while small quantities are being processed for industrial processes. Arthur (2009) mentioned that cowpea is the second most important pulse crop after groundnut, cultivated in Africa, and about 50% of the world's annual production is made of 850 000 tons by Nigeria and 271 000 tons from Republic of Niger. Cowpea has been reported to contain an average of 23.4% of protein, 11% of water, 3.6% of ash, 1.3% of fat and 56.8% of carbohydrate. It has potential to alleviate malnutrition and serves as a source of income for the farmers. Henshaw (2008) classified cowpea varieties into size categories based on their 100-seed weight. Varieties with seeds 10-15 g are described as small, 15.1-20 g as medium-sized seeds while large seeds have 20.1-25.0 g. Seeds weighing over 25 g are described as very large seeds. There are different varieties of cowpea and they vary greatly in their growth habits. Seed colours vary from white, cream, yellow, and red, purple, brown to black and may be smooth or wrinkled according to Arthur (2009).

Some of the varieties as reported by the IITA include;

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TVX 3236 (Danknarda), IT82 E-60 (Ezorowo), Ife Brown L-25, Vita 4, ER-7, CA-I, II, III, IV (Henshaw 2008). Others are Texas Cream 40, IFE BPC, Kanannado, Moola, L-80, IT86D-1010 etc. These seeds differ in all physical properties which include hilum colour and seed coat texture. Seed shapes vary from the typical kidney shape for beans to globose, ovoid and rhomboid shapes (Henshaw 2008).

Henshaw (2008) reported the varietal differences in physical characteristics and proximate composition of cowpea and showed that seed size dimensions, namely seed lengths, width and thickness had range values of 6-10 mm, 4-7 mm and 3-5 mm respectively. Seed hydration index had values between 95 and 135, 100-seed weight ranged between 11 g and 26 g and seed hardness recorded values from 6-8 kgf. Seed weight was the most discriminating variable, accounting for 93% variance in physical properties. The physical and chemical variables identified as the most discriminating may find application as indices for the selection of cowpea varieties for processing into different products.

Despite the economic importance of cowpea, little is known about its physical properties. The processing operations are predominantly done manually. For cowpea, whose food and industrial uses are growing fast, there is much need to develop appropriate production machines and equipment for various unit operations in its processing, to minimize the drudgery and to improve the sanitation of the processing conditions. The engineering properties have been studied for various agricultural products by other researchers such as legume grains (Altuntas and Demirtola, 2007), sweet corn (Coskun, Yalcin and Ozarslan, 2005) soybean (Davies and El-Okene, 2009a), barley (Ozturk and Esen, 2008), fenugreek (Altuntas, Ozgoz and Taser, 2008), bambara groundnut (Adejumo, Alfa and Mohammed, 2007), white speckled kidney bean (Isik and Unal, 2007), Bombay bean (Tekin et al. 2006), rough rice (Ghasemi Varnamkhasti et al. 2008), arigo seed (Davies, 2010), sainfoin, grasspea and bitter vetch (Altuntas and Kacadag, 2006), red bean (Kiani, Deh, Kiani et al. 2008) and pea (Yalcin, Ozarsalan and Akhas, 2007).

The purpose of this study was to investigate the effect of variety and moisture content on the physical and mechanical properties of the three varieties of cowpea seeds such as axial dimension, geometric and arithmetic mean diameter, sphericity, roundness, surface area, unit mass, 1 000-grain mass, true volume, true and bulk densities, porosity, angle of repose, static coefficient of friction, compressive force of cowpea seeds.

2 Materials and methods

2.1 Sample preparation and moisture content determination

The three varieties of cowpea were bought from Yenegoa market in Bayelsa State, Niger Delta, Nigeria on 4th October, 2009. The sample was selected and cleaned manually. It was ensured that the seeds were free of dirt, broken and immature ones and other foreign materials. The experiments were conducted for the three varieties of cowpea: brown beans (*Ife Brown*), Iron beans (*IT86D-1010*) and small beans (*IAR-339-1*) at the moisture content levels of 15%-30% dry basis respectively. Three samples each weighing 15 g was placed in an oven set at 103% for 72 hours. Thereafter, seeds samples of the desired moisture level were prepared by adding calculated amount of distilled water and sealed in separate polythene bags. The seed was kept in refrigerator at a temperature of 5℃ for one week to enable the moisture to distribute uniformly (Davies and El- Okene 2009a). All the physical properties of cowpea were at moisture level of 15%, 20%, 25% and 30%. Three replications of each test were made of each moisture level. The quantity of distilled water was calculated using the following equation:

$$M = W_s\left(\frac{M_1 - M_2}{100 - M_1}\right) \quad (1)$$

Where, W_s - weight of sample, kg; M - weight of distilled water added, kg; M_1 - initial moisture content, %; M_2 - final moisture content, %.

2.2 Geometric properties

For each of the moisture level, 100 cowpea seeds were randomly selected for measurement of length (*L*), width (*W*) and thickness (*T*) using a micrometer screw gauge with a resolution of 0.01 mm. The arithmetic and geometric average diameters of cowpea seed were calculated using the following relationships (Kiani Deh Kiani et al. 2008).

$$D_a = (L+W+T) \quad (2)$$

$$D_g = (LWT)^{0.333} \quad (3)$$

Where, D_a – Arithmetic mean diameter, mm; D_g – geometric mean diameter, mm; L – length, mm; W – width, mm; T - thickness, mm. The sphericity φ(%) was calculated by using the following relationship (Davies 2010).

$$\varphi = (LWT)^{0.333} \quad (4)$$

The surface is (S) of cowpea seed was found by analogy with a sphere of the same geometric mean diameter using the expression cited by Arthur (2009).

$$S = \pi D_g^2 \quad (5)$$

2.3 Gravimetric characteristics

The 1 000 unit mass was determined using precision electronic balance to an accuracy of 0.01 g. The grain volume and true density, ρ_t as a function of moisture content were determined by water displacement method (Adejumo, Alfa and Mohammed, 2007). A bunch of 100 seeds of known average weight was dropped into a container filled with water. The bulk seeds were put into a container with known mass and volume (500ml) from a height of 150mm at a constant rate bulk density was calculated from the mass of bulk seeds divided by the volume containing mass (Tekin et al. 2006). This was achieved by filling a container of 500ml with grain from the height 0.15 m striking the top level and then weighing the contents and the bulk density was determined from the measured mass and volume (Davies 2010). For each of the moisture content, 10 replications were done and average was taken. The porosity (ε) of the bulk seed was computed from the values of the true density (ρ_t) and bulk density (ρ_t) of the seeds by using the relationship given by Karababa (2006).

$$\rho_t - \rho_b \varepsilon = -100 \quad (6)$$

2.4 Static coefficient of friction

The static coefficient of friction for cowpea seeds was determined with respect to two selected surfaces (plywood and glass). A glass box of 150 mm length, 100mm width and 40 mm height without base and lid was filled with sample and placed on an adjustable tilting plate, faced with test surface. The surface was raised gradually until cylinder started to slide down. The angle of inclination (α) was read from graduated scale. The static coefficient of friction (μ_s) was calculated based on this equation Altuntas and Yildiz (2007).

$$\mu_s = \tan\alpha \quad (7)$$

2.5 Angle of repose

The angle of repose was determined based on the method used by Tunde-Akintunde and Akintunde (2007).

2.6 Determination of seed hardness

The compressive force required to fracture cowpea seed along the thickness at different moisture content were determined using Instron universal testing machine according to Tavakoli, Rajabipour and Mohtasebi (2009).

2.7 Statistical analysis

The result obtained from the study carried out on the three varieties of cowpea seeds at four different moisture content with at least five replications at each moisture content were subjected to analysis of variance (ANOVA), Duncan multiply range test and as well as Linear regression analysis using Statistical Analysis System.

3 Results and discussion

3.1 Seed dimensions

The moisture content, mean axial dimensions, arithmetic and geometric mean diameter, sphericity and surface area are presented in Table 1. It was observed that the axial dimensions increased with an increase in moisture content. In the sample IAR-339-1 about 87% had a length in the range of 9.80-13 mm, about 82% had a width of 7-9 mm while about 79% had a thickness in the range of about 6-8 mm. IT86D-1010 recorded about 74% of its length fall into the range of 12-15 mm, about 89% had a width of 8-10 mm and about 69% had a thickness 7-9 mm. The experiment also revealed that 76% of Ife Brown had its length in the range of 10%-14%, likewise, 89% of the measured width was in the range of 7-9 mm and 76% had a thickness fall within the range of 5-7 mm. The analysis of variance ANOVA result indicated that the differences among the moisture content level were significantly different at 5% probability level for the three varieties. This trend was in agreement with the result reported by Arthur (2009). Table 1 showed that Arithmetic mean diameter of the IAR-339-1, IT86D-1010 and Ife brown varieties increased from 7.84 to 10.08, 9.14 to 11.52 and 7.69 to 9.87 respectively. Similarly, geometric mean diameter of IAR-339-1, IT86D-1010 and Ife brown increased from 7.69 to 9.87, 8.94 to 11.19 and 7.24 to 9.89 as moisture content increased respectively. The variations among the values are significantly different at 5% probability level.

Table 1 Mean and standard error for axial dimension surface area and sphericity

Variety	Moisture content /%	Length /mm	Width /mm	Thickness /mm	Geometric mean diameter/mm	Arithmetic mean diameter/mm	Surface area /mm²	Sphericity
IAR-339-1	15	9.89(0.23)*	7.46(0.09)	6.17(0.10)	7.69(0.32)	7.84(0.28)	177.40(10.05)	0.778(0.009)
	20	12.06(0.46)	8.16(0.53)	7.24(0.18)	8.93(0.34)	9.15(0.21)	250.56(18.21)	0.741(0.001)
	25	12.58(0.31)	8.93(0.22)	7.83(0.15)	9.58(0.21)	9.78(0.35)	288.36(12.53)	0.7692(0.002)
	30	13.01(0.45)	9.10(0.63)	8.15(0.25)	9.87(0.54)	10.08(0.39)	306.09(17.23)	0.759(0.007)
IT86G-1010	15	11.93(0.33)	8.20(0.47)	7.30(0.19)	8.94(0.54)	9.14(0.67)	251.12(11.43)	0.749(0.005)
	20	14.84(0.84)	10.79(0.81)	8.05(0.20)	10.88(0.34)	11.22(0.73)	371.93(7.89)	0.733(0.008)
	25	15.02(0.33)	10.82(0.94)	8.19(0.43)	11.00(0.34)	11.34(0.17)	380.18(9.17)	0.73241(0.005)
	30	15.21(0.75)	10.88(0.57)	8.49(0.34)	11.19(0.15)	11.52(0.40)	393.43(14.21)	0.736(0.009)
IFE BROWN	15	9.87(0.65)	7.00(0.74)	5.49(0.32)	7.24(0.29)	7.45(0.21)	164.70(5.93)	0.7335(0.003)
	20	10.14(0.29)	7.95(0.13)	6.80(0.44)	8.06(0.38)	8.20(0.36)	204.12(15.34)	0.795(0.009)
	25	12.94(0.58)	8.16(0.15)	7.03(0.35)	9.05(0.31)	9.38(0.28)	257.34(9.38)	0.700(0.004)
	30	14.87(0.63)	8.76(0.28)	7.42(0.34)	9.89(0.41)	10.35(0.65)	307.33(10.56)	0.665(0.009)

Note: (*); Standard deviation values are in parentheses.

3.2 Surface area and sphericity

The effect of moisture content on the surface area of cowpea varieties IAR-339-1, IT86D-1010 and Ife brown were presented in table1. The obtained result indicated that the surface area increased linearly with increasing in grain moisture content. The surface area of the cowpea varieties IAR-339-1, IT86D-1010 and Ife brown increased from 177.40 to 306.09 mm^2, 251.12 to 393.43 mm^2 and 164.70 to 307.33 mm^2 respectively. The observed values were significantly different (p<0.05). Similar trend was reported by Tunde-Akintunde and Akintunde (2007) for beniseed.

The effect of moisture content on sphericity of IAR-339-1 decreased from 0.778 to 0.741 between 15% and 20% moisture content, but later increased to 0.762 at 25% moisture content dry basis, and subsequently, reduced to 0.759 at 30% moisture content. IT86D-1010 decreased linearly at moisture content range of 15%-20% (i.e 0.749 to 0.732) and subsequently increased at 30% moisture content. Ife brown increased from 0.734 to 0.795 between 15% and 20%, and later decreased from 0.700-0.665 at 30% moisture content dry basis. The decrease in sphericity of seeds agreed with that reported by Adejumo et al. (2007) for Kano White variety of bambara groundnut, Altuntas and Yildiz (2007) for faba bean and Cetin et al. (2007) for barbunia; while the increase observed in IAR-339-1 and Ife brown corresponds with that reported by Davies and El- Okene (2009a) for soybean.

3.3 1 000-seed mass

1 000-seed mass of IAR-339-1, IT86D1010 and Ife brown varieties increased linearly as moisture content increased as shown in the Figure 1. 1 000-grain mass for IAR-339-1 increased from 279.12 to 478.23 g, while IT86D-1010 and Ife brown increased from 311.7 to 671.4 g and 253.8 to 468.1 g respectively. The values were statistically different (p<0.05). The similar result was reported by Davies and El -Okene (2009a) for soybean, Tekin et al (2006) for Bombay bean and Cetin et al (2007) for barbunia. Henshaw (2008) reported 100-unit mass of 20 different varieties of cowpea range from 11-26 g at 9%-12% moisture content. The relationship existing between 1 000-grain mass and moisture content can be represented by the following regression equation:

M_{1000}=13.97M_C +53.64, R^2 = 0.9878 Ife brown (8)

M_{1000}=12.686M_C +98.309, R^2 = 0.976 IAR339-I (9)

M_{1000}=23.599M_C+26.237, R^2=0.976 IT86D-1010 (10)

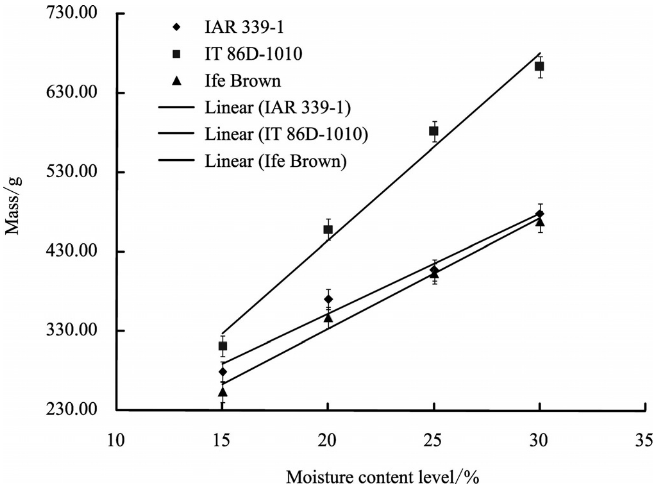


Figure 1 Effect of moisture content on thousand seed mass of cowpea

3.4 Volume properties

The mean volume of 100-seed of the three varieties of cowpea increased linearly from 2.79×10^{-5} m^3 to 4.7×10^{-5} m^3 for IAR-339-1, 2.95×10^{-5} m^3 to 6.51×10^{-5} m^3 for IT86D-1010 and 2.41×10^{-5} m^3 to 4.67×10^{-5} m^3 for Ife brown with increase in moisture content from 15%-30% dry basis (Figure 2). The volumetric expansion observed may be adduced to moisture absorption which increases axial dimensions of the seeds. The variation in the mean value of volume of 100-seed was statistically important at 5% probability level. This trend was similar to Davies and El- Okene (2009a). The variation of moisture content and volume of 100-seed was represented by the following equation:

$V_{100} = 0.1492M_C + 0.313,\ R^2 = 0.9755$ Ife brown (11)

$V_{100} = 0.1294M_C + 0.731,\ R^2 = 0.9781$ IAR 339-I (12)

$V_{100} = 0.2390M_C + 0.855,\ R^2 = 0.9760$ IT86D-1010 (13)

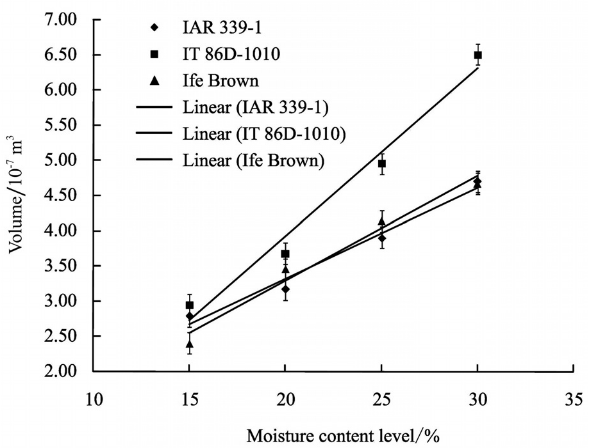


Figure 2 Effect of moisture content on hundred seed volume

3.5 Bulk and true densities

The bulk densities of the cowpea varieties decreased linearly with an increase in moisture contents levels. Values obtained showed that bulk densities decreased from 703.49 to 636.41 kg/m^3, 689.29 to 622.12 kg/m^3 and 726.91 to 672.05 kg/m^3 for IAR-339-1, IT86D-1010 and Ife beans respectively (Figure 3). It was observed that Ife brown with smallest linear dimensions had the greatest bulk density. This could be adduced to the fact that small seeds are likely to be well compacted than the larger size. This is in agreement with findings of Adegbulugbe and Olujimi (2008) for three varieties of cowpea (TVX3236, Ife brown and IT81D-994), Altuntas and Yildiz (2007) for faba bean. This is contrary to corresponding report by Tunde-Akintunde and Akintunde (2007) that smaller seeds enjoined smaller bulk density than the bigger seeds. The analysis of variance revealed that effect of moisture content, variety and interaction on bulk density were significantly important at 5% probability level. The relationship between bulk density and moisture can be represented by the following regression equations

$\rho_b = -3.6816M_C + 776.97,\ R^2 = 0.9364$ Ife brown (14)

$\rho_b = -4.6M_C + 774.12,\ R^2 = 0.9924$ IAR 339-I (15)

$\rho_b = -4.3432M_C + 745.23,\ R^2 = 0.8907$ IT86D-1010 (16)

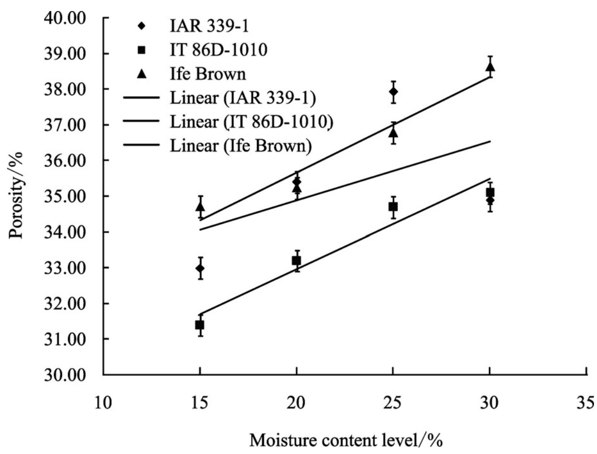


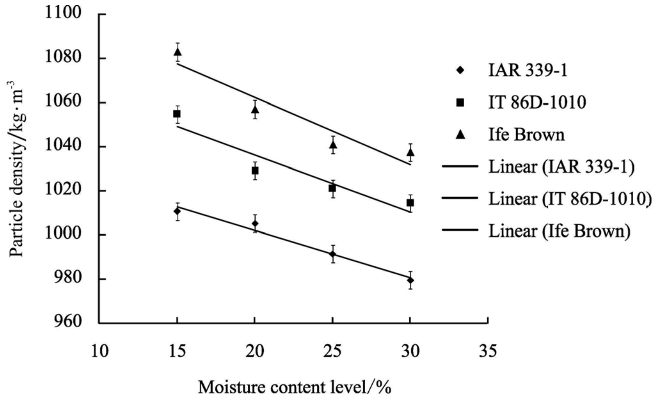
Figure 3 Effect of moisture content on porosity of cowpea

True densities of these varieties decreased with an increase in moisture contents from 1 010.83 to 979.59 kg/m^3, 1 054.88 to 1 014.54 kg/m^3 and 1 083.12 to 1 037.53 kg/m^3 for IAR-339-1, IT86D-1010 and Ife brown respectively (Figure 4). This means that relative increase in the weight of cowpea is lower than the corresponding volumetric increase owing to moisture absorption. A negative correlation between the true density and moisture content was also reported by Tunde-Akintunde and Akintunde (2007) for beniseed. The resulted relationships between the true density of the cowpea and moisture content are shown below:

ρ_t = -3.048M_C+1123.3, R^2=0.9009 Ifebrown (17)

ρ_t = -2.150M_C+1045.2, R^2=0.9934 IAR339-I (18)

ρ_t = -2.5818M_C+1088, R^2=0.8896 IT86D-1010 (19)



Figuer 4 Effect of moisture content on particle density of cowpea

3.6 Porosity properties

Porosity of IT86D-1010 and Ife brown had values which increased with moisture contents ranging from 31.40% to 35.10% and 34.71% to 38.64%, except for IAR-339-1 which produced values that increased from 33.0% to 37.93% between 15% and 25% moisture content d.b. and later reduced to 34.89% at 30% moisture content d.b. (Figure 5).

The linear decrease in bulk and particle densities with increased moisture level producing higher values of porosity was also reported by Adegbulugbe and Olujimi (2008), for cowpea varieties (TVX 3236, Ife Brown and IT81D-994). Porosity is an essential characteristic used in the calculation of rate of aeration and cooling and drying and heating and design of heat exchangers and packaging equipment. The relationship between porosity and moisture content can be represented mathematically:

ε=0.267M_C+30.375, R^2=0.9491 Ife brown (20)

ε=0.164M_C+31.615, R^2=0.9715 IAR 339-I (21)

ε=0.252M_C +27.93, R^2 = 0.9383 IT86D-1010 (22)

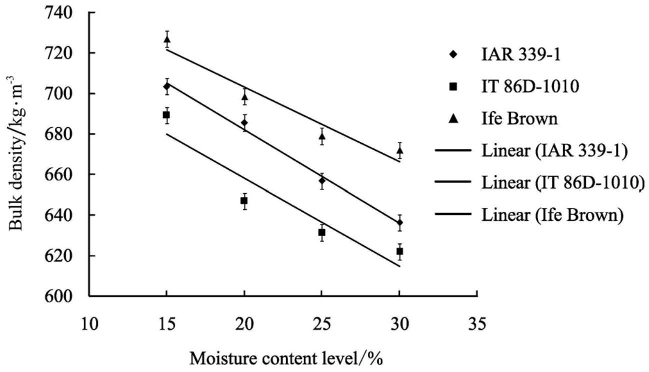


Figure 5 Effect of moisture content on bulk density of cowpea

3.7 Seed hardness properties

The forces required to cause fracture on seeds axial loading under different moisture content were represented in Figure 6. It can be observed that the required fracture force decreases with increase in moisture content of the seeds for the three varieties. The fracture forces ranges from 64-40 N for IAR-339-1, 63-38 N for IT86D-1010 and 70 to 46 N for Ife Brown (statistically important (p<0.05). The decrease observed from fracture force at higher moisture content showed that cowpea is sensitive to moisture content. Henshaw (2008) reported seed hardness in the range of 6-8kgf for 20 different varieties of cowpea at moisture content of 9%-12%. The relationship between moisture content and seed hardness (H_n) can be represented by the following linear equation:

H_n = -1.54M_C +91.9, R^2 = 0.9792 Ife brown (23)

H_n = -1.52M_C + 88.7, R^2 = 0.9724 IAR 339-I (24)

H_n = -1.78M_C + 90.3, R^2 = 0.9642 IT86D -1010 (25)

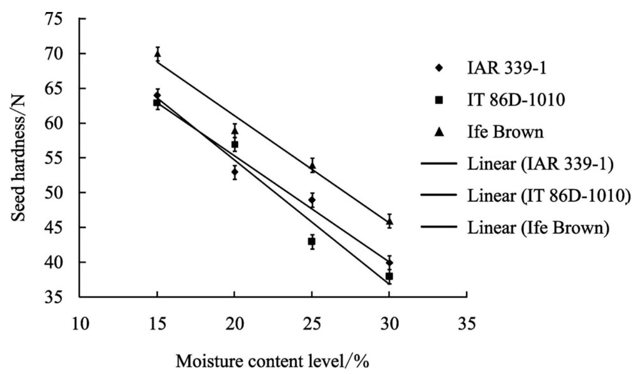


Figure 6 Effect of moisture content on seed hardness of cowpea

3.8 Angle of repose and static coefficient of friction

The angle of repose for the randomly selected seeds of the cowpea varieties (IAR-339-1, IT86D-1010 and Ife Brown) increased with moisture content and values obtained were between 25° to 28.3°, 26.4° to 29.7°, and 24.3° and 27.5° respectively (Figure 7). The increase of the angle of repose for these cowpea varieties is attributed mainly to increase in size of the seeds as reported by Olalusi et al. (2009) and Arthur (2009). This implied that forces of solid friction at grain-material interface were generally lower in the oil bean compared with the cowpea seeds. This is similar to that reported by Olalusi et al. (2009) for Tiger nut. The relationship between angle of repose and moisture content were represented below:

$$0.208M_C+20.87,\ R^2=0.912 \quad \text{Ifebrown} \qquad (26)$$

$$0.208M_C+20.07,\ R^2=0.964 \quad \text{IAR339-I} \qquad (27)$$

$$0.212M_C+23.03,\ R^2=0.9458 \quad \text{IT86D-1010} \qquad (28)$$

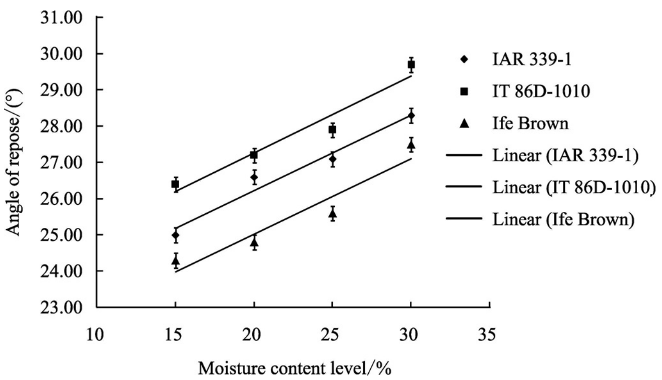


Figure 7 Effect of moisture content on angle of repose of cowpea

The results obtained for the static coefficients of friction for the three cowpea varieties (IAR-339-1, IT86D-1010 and Ife Brown) on the two structural (glass and plywood) surfaces (Table 2). It was observed that static coefficient of friction on glass and plywood surfaces, increased with increase in moisture levels. The IAR-339-1 increased from 0.257±0.009 to 0.433±0.014, IT86D-1010 and Ife Brown varieties increased from 0.301±0.007 to 0.516±0.007, and 0.241±0.009 to 0.456 ± 0.009 on glass surface respectively. IAR-339-1, IT86-1010 and Ife Brown varieties all increased from 0.306±0.012 to 0.602±0.016, 0.343±0.017 to 0.612± 0.021 and 0.363±0.053 to 0.582±0.026 respectively. The obtained results showed that static coefficient of friction of IT86D-1010 variety was higher than IAR-339-1 and Ife brown varieties respectively. This observation could be attributed to the cohesive force exerted by the seeds on the surface of contact at higher moisture levels. The increase in static coefficients of friction with increased moisture levels is similar to that obtained by Coskun et al. (2005) for sweet corn.

Table 2 Effect of moisture content on static coefficient of friction

Variety	Moisture Level /%	Coefficient of Friction	
		Glass	Plywood
IAR 339-1	15	0.2570 ± 0.0091	0.3064±0.0123
	20	0.3128 ± 0.0066	0.4107±0.0201
	25	0.3494 ± 0.0103	0.4984±0.0095
	30	0.4330 ± 0.0137	0.6015±0.0164
IT 86D-1010	15	0.3013 ± 0.0069	0.3427±0.0171
	20	0.3578 ± 0.0211	0.4369±0.0135
	25	0.4349 ± 0.0131	0.5474±0.0075
	30	0.5163 ± 0.0074	0.6118±0.0216
Ife Brown	15	0.2410 ± 0.0088	0.3631±0.0153
	20	0.3263 ± 0,0875	0.4429±0.0178
	25	0.3886 ± 0.0101	0.5023±0.0098
	30	0.4564 ± 0.0087	0.5819±0.0257

4 Conclusions

Based on investigation conducted on the some physical and mechanical properties of three varieties of cowpea seeds namely IAR-339-1, IT86D-1010 and Ife Brown at moisture content of 15%, 20% and 25% and 30% dry basis the following conclusion were drawn:

1) The mean major, intermediate, minor, arithmetic and geometric mean diameter, sphericity, surface area, 1000-seed unit mass, for the three varieties of cowpea were significantly different (P<0.05)

2) The mean porosity, true and bulk densities, hardness and angle of repose were investigated for the three varieties were significantly different at 5% probability level.

3) The coefficient of static friction of cowpea was determined for two different surfaces, glass and plywood. plywood surface was observed to have higher coefficient of static friction for the three varieties.

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