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Studies on the Moisture Dependent Physical Properties of Cowpea

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ABSTRACT

Cowpea is a very important legume in Nigeria that is being utilized to Substitute high-cost animal protein for low-income people. The knowledge of some physical properties of various moisture contents is of utmost importance in the design of its handling and processing equipment and machinery, which is the aim of this work, which studied the physical properties of IT99K-573-1-1 (SAMPEA14) variety of Cowpea within 8.77 to 21.58 % db moisture content. The properties studied include Major, Intermediate, and Minor diameters, Sphericity, Surface area, Specific gravity, Volume, Bulk density, 50-tap density, 100-tap density, 1250-tap density, seed mass, Angle of repose, Geometric mean diameter, and Arithmetic mean diameter. The obtained results indicate that the Size, Sphericity, Geometric, Arithmetic diameter, Surface area, and seed mass increase linearly with an increase in moisture content by 13.8%, 27.4%, and 16.1% for the size, respectively. While sphericity rises by 7.5% and geometric mean diameter, arithmetic mean diameter, surface area, and grain mass increase by 22.2%, 20.7%, 24.9%, and 16.11%, respectively. Specific gravity, density, and repose angle were inversely linearly related to moisture content. Regression equations for each of the properties related to the grains' moisture content were developed.

Keywords: Cowpea, Physical properties, Sampea 14, Moisture content, Regression equation

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دراسات حول الخواص الفيزيائية التي تعتمد على الرطوبة في اللوبيا

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الخلاصة

اللوبيا من البقوليات المهمة جدًا في نيجيريا والتي يتم اســــتخدامها لتحل محل البروتين الحيواني عالي التكلفة للفقراء. معرفة بعض الخصائص الفيزيائية لمحتويات الرطوبة المختلفة تعتبر ذات أهمية قصوى في تصميم معدات وآلات المناولة والمعالجة ، وهو الهدف من هذا العمل الذي درس الخصائص الفيزيائية لـــ **IT99K-573-1-1 (SAMPEA14)** اللوبيا ضمن 8.77 إلى 21.58٪ ديسيبل محتوى رطوبة. تشمل الخصائص المدروسة الأقطار الرئيسية والمتوسطة والصغرى ، الكروية ، مساحة السطح ، الثقل النوعي ، الحجم ، الكثافة الظاهرية ، كثافة 50 صـنبور ، كثافة 100 صـنبور ، كثافة 1250 صـنبور ، كتلة البذور ، زاوية الراحة ، متوسط القطر الهندسي و حسابي متوسط القطر. تشير النتائج المتحصل عليها إلى أن الحجم والكروي والهندسـي والقطر الحسـابي ومسـاحة السـطح وكتلة البذور تزداد خطيًا مع زيادة محتوى الرطوبة بنسـبة 13.8٪ و 27.4٪ و 16.1٪ للحجم على التوالي. بينما تزداد كروية بنسبة 7.5٪ ومتوسط القطر الهندسي ، يزداد المتوسط الحسابي للقطر ومساحة السـطح وكتلة الحبوب بنسـبة 22.2٪ و 20.7٪ و 24.9٪ و 16.11٪ على التوالي. تم العثور على الثقل النوعي ، والكثافة ، وزاوية الراحة لتكون مرتبطة خطيًا عكسـيًا بمحتوى الرطوبة. تم تطوير معادلات الانحدار لكل من الخواص من حيث صـلتها بالمحتوى الرطوبي للحبوب.

الكلمات المفتاحية: اللوبيا، الخواص الفيزيائية، سامبيا 14، محتوى الرطوبة، معادلة الانحدار

1. INTRODUCTION

Cowpea (vigna unguiculata) is a very important grain legume consumed in all parts of West Africa. It contains about 25% protein, 64% carbohydrate, fibers, vitamins, and nutrients, with a low-fat content (1%) and bioactive compounds, such as phenols and polyamines **(Aderinlewo et al., 2011; Kirse and Karklina, 2015; Moreira-Araújo et al., 2017)** making it a very important protein source for the medium and low-income families who cannot afford animal protein. **(Kebede and Bekeko, 2020)** reported that cowpea is grown annually over an estimated land area of about 14.5 million hectares of land with an estimated annual production of 6.2 million metric tons, with over 83.4% coming from Africa. **(Faostat, 2015)** reported that in 2014 cowpea was grown on about 12.3 million ha of land in Africa, with over 10.6 million hectares being in West Africa, particularly Nigeria, Niger, Burkina Faso, Mali, and Senegal. **(Moses and Zibokere, 2011; Henshaw, 2008)** reported Nigeria as being the largest producer of cowpea in the world.
Cowpea is consumed in many forms, ranging from processed at home and/or industrial processes. It is consumed as food ranging from bean pudding, cake, baked beans, fried beans,

bean soup, etc. **(Moses and Zibokere, 2011)**. Cowpea seeds are boiled and eaten with soup or stew **(da Silva et al., 2021)**. The tender leaves, and fresh pods are also consumed **(Erana and Zelalem, 2020),** while industrially, it is processed into canned and preserved foods and in the production of isolated proteins with various applications(e.g., production of additives in flour, supplements for athletes and functional foods) **(da Silva et al., 2021; Elhardallou et al., 2015)**. **(Aderinlewo et al., 2011)** stated that due to the high protein content of cowpea, it has the potential to be used in nutritional products for infant's and children's food as well as to compensate for the large proportion of carbohydrates often contained in African diets. Cowpea also provides feed, forage, hay, and silage for livestock, and green manure and cover crops, which maintain the productivity of soils **(Alemu et al., 2016)**. It is reported to fix atmospheric nitrogen into the soil, replacing the nitrogen absorbed by the plant and poses weeds suppressing ability.

In Nigeria, several varieties of cowpea were recommended for production, including T99K-573-1-1, IT99K-573-2-1, UAM09 1055-6, UAM09 1051-1, T89KD-288, T07K-292-10, T07K-313-18, T07K-297-13 and T08-150-12 **(Omoigui et al., 2020)**. Among all the listed varieties, T99K-573-1-1 also known as SAMPEA14 (having medium seed size with rough seed coat, white color with brown helium) is the most produced variety in Northern Nigeria due to its early maturity (70 – 75 days), high yield (2.6 t/ha), multiple disease resistance to Fusarium wilt, Alectra and Striga and high drought tolerant **(Dugje et al., 2009; Omoigui et al., 2020)**

In harvesting and other post-harvest operations such as cleaning, sorting, conveying, transporting, and drying, among others, crops' physical and mechanical properties must be utilized for the safety and success of the operation. Shape and size are used in cleaning, sorting, grading, and heat transfer, among other operations, while density and mass may be utilized in designing silos, storage bins, and gravity separation. Porosity is used in airflow through the materials, heat flow, drying, and other transfer problems **(Aderinlewo et al., 2011)**. Sphericity, geometric, and arithmetic mean diameter determine the aerodynamic properties such as drag coefficient, terminal velocity, and Reynolds numbers **(Aderinlewo et al., 2011; Tado et al., 1999)**. **(Strochine, 1998)** reported that these properties can be drastically affected and differ with the moisture content of the material. The size and mass of the material will increase with an increase in moisture content and vice versa, while density decreases with the increase in moisture content. Several researchers studied the changes in the properties of agricultural material with changes in moisture: Maize **(Sangamithra et al., 2016)**, Gram **(Chowdhury et al., 2001)**, White Sesame Seed **(Darvishi, 2012)**, soybeans **(Davies and El-Okene, 2009)**, Groundnut **(Firouzi et al., 2009)**, wild pistachio nut and kernel **(Nazari Galedar et al., 2008)**, watermelon seed **(Koocheki et al., 2007)** among others.

The effect of moisture content on various varieties of cowpea was also studied by researchers **(Yalcın, 2007)** who studied the properties of Vigna sinensis L. Type of cowpea in the moisture range of 12.01% to 38.90% db the results showed that the 1000 seed mass, projected area, sphericity, porosity, and terminal velocity increases linearly by 22.77, 44.84, 2.3, 1.68 and 8.24% respectively as the moisture content increase while bulk density and true density decreased linearly by 6.02 and 4.29% respectively with an increase in moisture content. **(Thomas and Olugbemi, 2009)** reported a similar linear reduction in the bulk density and particle density of the TVX3236 variety of cowpea by 23.32 and 8.99%, the IFE Brown variety of cowpea by 19.55 and 7.96%, and the IT81D-994 variety of cowpea by 19.5 and 9.71% respectively with 24.08, 17.4 and 16.51% increase in porosity for the respective varieties. **(Bart-plange et al., 2012)** carried out on the Asontem variety of cowpea within the moisture range of 19.% and 9.58% wb and reported a linear decrease of 12.87 % in length, 1.26% in width, and 3.35% in thickness as the seeds dry out within the studied moisture range. The result also shows that the geometric mean diameter, surface area, volume, and 1000 grain mass decreases nonlinearly by 13.24%, 11.64%, 17.05%, and 8.98% as the seeds dry while the true density decreases nonlinearly by 11.48% within the studied moisture contents.

However, such studies on the variation of the physical and mechanical properties with variation in moisture content for IT99K-573-1-1 variety of cowpeas are unavailable. Hence, the objectives of this study are to investigate the variation of the physical properties (major, intermediate, and minor diameters, sphericity, surface area, specific gravity, volume, bulk density, 50 tap density, 100 tap density, 1250 tap density, seed mass, angle of repose, geometric mean diameter and arithmetic mean diameter) for the grains of IT99K-573-1-1 cowpea variety with variation in moisture content.

2. MATERIALS AND METHODS

The materials used and the methods adopted for studying the physical properties of IT99K-573-1-1 (SAMPEA14) variety of cowpea at four different moisture contents of 8.77, 14.35, 17.84, and 21.58 % db are presented in this section.

2.1 Materials

The materials used for this work include:

- IT99K-573-1-1 (SAMPEA14) variety of Cowpea
- Planix 5 planimeters (model number: 008754, measuring range: 30 cm x 30 cm, Resolution: 0.1 cm^2 with a resolution of ±0.2%).
- Pfeuffer seed counter
- Adam weighing balance (model number: PGL2002, maximum: 2000g, accuracy: 0.01g
- Quantum overhead projector (Model number: 2523)
- Genlab oven (model number: N53C, serial number: 98ko30, Load: 0.75 kW

2.2 Sample Acquisition and Preparation

The cowpea (*Vigna unguiculata*) IT99K-573-1-1 (SAMPEA14) variety samples used for this experiment were procured from local farmers in the Bauchi metropolis, Bauchi State, Nigeria, in their pods. The cowpea was manually threshed, winnowed, and cleaned to remove dust, sticks, and broken and immature kernels. The initial moisture content of the sample was determined by oven drying the sample in a hot air oven at 130 ^{0}C for 2 hours following the method prescribed by ISO 712. The initial moisture content of the sample was found to be 8.77 % db, which was used to determine all the other properties, which include (major, intermediate, and minor diameters, sphericity, surface area, specific gravity, volume, bulk density, 50-tap density, 100 tap density, 1250 tap density, seed mass, angle of repose, geometric mean diameter and arithmetic mean diameter) after which the moisture content of the sample was raised by putting the sample on a screen in an oven at the topmost layer at 40 ^{0}C with a bowl of water at the bottom layer to humidify it for 24 hours which raises the moisture content of the sample to 21.58 % which were again used to determine all the abovelisted properties. The samples were then allowed to dry under the atmospheric conditions to the other two required moisture contents of 17.84 and 14.35 by regularly weighing the sample until the required weight was attained, which was determined using Eq. 1 **(FOA, 2011)** and used to assess their properties at those moisture levels. All the properties defined were carried out in three (3) replications, and the average was reported as the property of samples at those moisture contents.

$$W_2 = W_1 - \left(\frac{W_1(M_1 - M_2)}{100 - M_2}\right) \quad (1)$$

where: W_1 is the Weight of un-dried grain, kg
W_2 is the Weight of dried grain, kg
M_1 is the Moisture content of un-dried grain, %
M_2 is the Moisture content of dried grain, %

2.3 Determination of Kernel Physical Dimensions

The major (a), intermediate (b), and minor (c) diameters of the kernel were determined following the method prescribed by **(Mohsenin, 1986)** by randomly picking 50 kernels and projecting their maximum and minimum projected areas using a quantum overhead projector with model number 2523 and tracing the projected areas on a paper as shown in

Figure 1. The longest and shortest dimensions of the maximum projected area were then measured and divided by the magnification factor to obtain the significant diameter (a) and intermediate diameter (b) of the kernels respectively as shown in

Figure 1 while the minor diameter (c) of the kernels were obtained by measuring the shortest dimension of the minimum projected area and dividing them by the magnification factor as described by **(Mohsenin, 1986)** shown in

Figure 1.

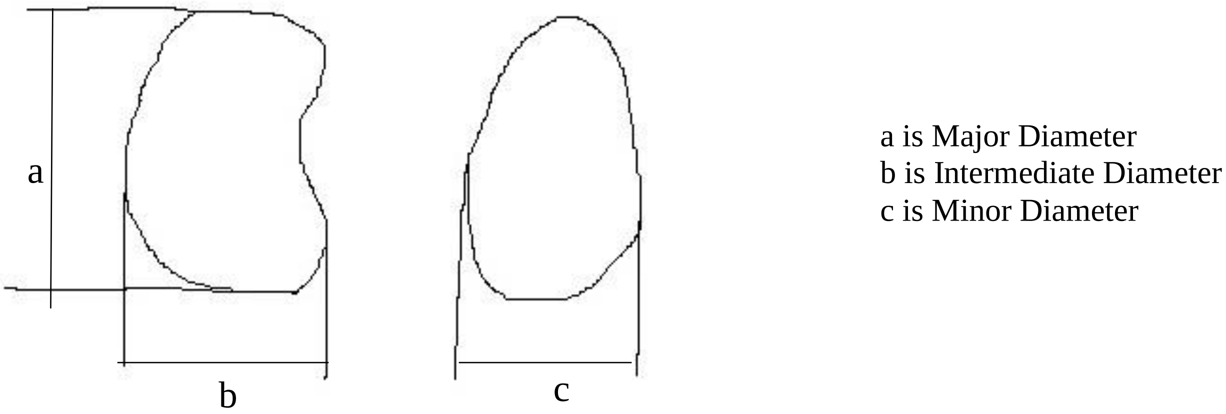

Figure 1. Major and minor projected areas of cowpea

The geometric (D_g) and arithmetic (D_a) mean diameter of the kernels was calculated using their Major (a), Intermediate (b), and Minor (c) diameters using Eqs. 2 and 3, respectively, as given by **(Strochine, 1998; Sangamithra et al., 2016)**

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

$$D_a = \frac{(a+b+c)}{3} \tag{3}$$

2.4 Determination of Seed Mass

The mass of ten (10), hundred (100), and one thousand (1000) cowpea kernels was determined by weighing them on a precision (aeADAM) weighing balance having an accuracy of 0.01 g; the experiment was carried out at room temperature.

2.5 Determination of Sphericity

The sphericity (ϕ) of the kernel at various moisture contents was determined following the method described by **(Mohsenin, 1986)** by selecting the projected area of the kernel using a planimeter and then determining the area of the smallest circle that circumscribes the projected shape of the kernel and calculating the sphericity of the kernel using Eq. 4.

$$\phi = \frac{Projected\ area}{Circumscribed\ area} \times 100 \tag{4}$$

2.6 Determination of Specific Gravity and Volume

The specific gravity and volume of the cowpea kernel at the four moisture contents were determined using the fluid displacement method using toluene and pycnometer as described by (**Mohsenin, 1986)** and calculating the specific gravity of grains using Eq. 5 while the volume of the seed was calculated using Eq. 6:

$$\gamma_s = \frac{(\gamma_T \times m_s)}{m_{TD}} \tag{5}$$

where: γ_s is the specific gravity of the seed
γ_T is the specific gravity of toluene
m_s is the mass of seeds, g
m_{TD} is the mass of toluene displaced by seeds, g

$$V_s = \frac{m_s}{(\gamma_s \times n_s)} \tag{6}$$

where: V_s is the volume of seed, cm^3
m_s is the mass of seeds, g
γ_s is the specific gravity of seed
n_s is the number of seeds

2.7 Determination of Bulk Density, 50 Tap Density, 100 Tap Density, and 1250 Tap Density

The bulk density of the cowpea kernel was determined following the method described by (**Moses and Zibokere, 2011)** by filling a container of known mass and volume (400 cm^3) with the grains from a height of 150 mm when the grains overflow the container. The grain was then leveled with the upper rim of the container with a scrapper in a zigzag motion, and then the Bulk density was calculated using Eq. 7**.**

$$\rho_s = \frac{m_s}{V_C} \tag{7}$$

where: ρ_s is the density of grains, g/cm^3
m_s is the mass of seed, g
V_C is the volume of the container, cm^3

The density of the cowpea kernel after tapping the filled container with grains 50 times, 100 times, and 1250 times from a specific height (1.5 cm) and topping up the container with grains is described as 50 tap density, 100 tap density, and 1250 tap density respectively, they were also determined following the method used in the determination of the bulk density with tapping the container for the required number of times.

2.8 Determination of Angle of Repose (θ_r)

The angle of repose (θ_r) of the kernel was determined using the funnel on beaker method as described by (**Mohsenin, 1986)** reported by (**Chukwu and Sunmonu, 2010)** by filling a funnel of known diameter placed on a beaker resting on a flat surface from a height of 150 mm until when it makes a cone on the funnel and measuring the height of the cone from the flat surface and that of the upper rim of the funnel from the flat surface. The angle of repose was then calculated using Eq. 8.

$$\theta_r = tan^{-1}\left(\frac{2(H_c - H_f)}{D_f}\right) \tag{8}$$

where: θ_r is the angle of repose, degree
H_c is the height of the cone from a flat surface, cm
H_f is the height of the funnel from a flat surface, cm
D_f is the diameter of the funnel, cm

2.9 Determination of Surface Area (S)

The surface area (S) of the kernel was determined using the major (a), intermediate (b), and minor (c) diameter as expressed in Eq. 9 **(Kibar and Öztürk, 2008)**.

$$S = \frac{\pi \times B \times a^2}{2 \times a - B} \tag{9}$$

where: $B = (b \times c)^{0.5}$

3. RESULTS AND DISCUSSION

The results obtained for the physical properties of the IT99K-573-1-1 (SAMPEA14) variety at the moisture contents of 8.77, 14.35, 17.84, and 21.58 % db are presented in **Table 1**. It was observed that the cowpea kernel's physical properties increase with the moisture content increase. The major, intermediate, and minor diameter of the kernel increases linearly by 13.8% (from 8.08 to 9.15 mm), 27.4% (from 6.14 to 7.82), and 16.1% (from 5.10 to 5.92 mm), respectively as the moisture content increases from 8.77 to 21.58% following the linear equations presented in Eqs. 10 to 12. This result is in consonant with the result obtained by (**Moses and Zibokere, 2011)** for three varieties of cowpea, **(Sangamithra et al., 2016)** for Maize kernel, and (**Kibar and Öztürk, 2008)** for Soybean. ANOVA for the kernel's major, intermediate, and minor diameters indicated that the difference between the various moisture contents was significantly different at a 95% confidence level.

$$a = 0.0837Mc + 7.4241 \qquad R^2 = 0.9173 \tag{10}$$

$$b = 0.13Mc + 5.027 \qquad R^2 = 0.997 \tag{11}$$

$$c = 0.0637Mc + 4.5692 \qquad R^2 = 0.9903 \tag{12}$$

where: a is the Major Diameter, mm
b is the intermediate Diameter, mm
c is the Minor Diameter, mm
Mc is the Moisture content, %

Table 1. Geometric properties of cowpea kernel

Moisture Content	Major Diameter (mm)	Intermediate Diameter (mm)	Minor Diameter (mm)	Sphericity (%)	Geometric Mean Diameter (mm)	Arithmetic Mean Diameter (mm)	Surface area (mm^2)
8.77	8.05 (0.94)[a]	6.14 (0.58)[a]	5.10 (0.46)[a]	78.79 (5.17)[a]	6.31 (0.54)[a]	6.43 (0.56)[a]	109.32 (2.11)[a]
14.35	8.82 (0.97)[b]	6.95 (0.55)[b]	5.53 (0.41)[b]	80.36 (9.01)[b]	6.96 (0.51)[a]	7.09 (0.54)[b]	117.24 (1.77)[b]
17.84	8.91 (0.95)[b]	7.33 (0.43)[c]	5.71 (0.44)[c]	81.41 (9.66)[c]	7.43 (0.47)[b]	7.36 (0.49)[c]	122.17 (3.28)[c]
21.58	9.15 (0.93)[c]	7.82 (0.51)[d]	5.92 (0.39)[d]	84.72 (9.87)[d]	7.71 (0.48)[b]	7.62 (0.47)[d]	136.54 (2.33)[d]

- Values in a column bearing different letters significantly differ at a 95% confidence level.
- Values in parenthesis are standard deviation values.

The Sphericity (ϕ) also increases linearly by 7.5% from 78.79% to 84.72% as the moisture content increases from 8.77% to 21.58% following the linear relationship presented in Eq. 13. The ANOVA for the sphericity indicated that there are significant differences among them for the various moisture contents. Similar trends were obtained by **(Moses and Zibokere, 2011)** for IAR-339-1 and Ife brown cowpea varieties below 20% moisture content and **(Davies and El-Okene, 2009)** for Soybeans.

ϕ = 0.4384Mc + 74.465 R^2 = 0.9055 (13)

The geometric mean diameter (D_g), arithmetic mean diameter (D_a) and surface area (S) of the kernel all increase as the moisture content increases by 22.2% from 6.31 to 7.71 mm, 20.7% from 6.43 to 7.76 mm, and 24.9% from 109.32 to 136.54 mm^2 respectively following the regression equations presented on Eqs. (14) to (16) respectively. ANOVA for the geometric mean diameter indicated no significant difference between the geometric mean diameter of the kernel at 8.77% and 14.35% moisture content, as well as between 17.84 and 21.58% moisture content. However, it indicated a significant difference between the arithmetic mean diameter and surface area for all the moisture contents. Similar results were obtained by **(Sangamithra et al., 2016)** for maize, **(Tavakoli et al., 2009)** for soybeans, and **(Karaj and Müller, 2010)** for jatropha seeds

D_g = 0.1119Mc + 5.3529 R^2 = 0.9907 (14)

D_a = 0.093Mc + 5.6707 R^2 = 0.9814 (15)

S = 2.0226Mc + 89.694 R^2 = 0.9262 (16)

The results of the effect of moisture content on Specific Gravity, Bulk Density, Tap densities, Seed mass, and Angle of repose are all presented in **Table 2**.

Table 2. Specific Gravity, Bulk Density, Tap densities, Seed mass, and Angle of repose of Cowpea Kernel

Moisture Content	Specific Gravity	Bulk Density (g/cm^3)	50 Tap Density (g/cm^3)	100 Tap Density (g/cm^3)	1250 Tap Density (g/cm^3)	10 Seed Mass (g)	100 Seed Mass (g)	1000 Seed Mass (g)	The angle of Repose (deg)
8.77	1.27 (0.04)^a	0.77 (0.04)^a	0.85 (0.03)^b	0.87 (0.04)^b	0.91 (0.03)^c	1.49 (0.12)^a	14.8 (1.11)^a	147.19 (5.20)^a	31.59 (0.51)^b
14.35	1.24 (0.05)^a	0.74 (0.07)^a	0.81 (0.05)^{ab}	0.85 (0.06)^{ab}	0.86 (0.04)^{bc}	1.57 (0.08)^{ab}	15.59 (1.23)^{ab}	155.56 (4.17)^b	29.97 (0.62)^a
17.84	1.21 (0.07)^a	0.70 (0.06)^a	0.79 (0.06)^{ab}	0.81 (0.03)^{ab}	0.82 (0.02)^{ab}	1.67 (0.10)^{ab}	16.02 (0.89)^{ab}	162.22 (3.12)^b	29.68 (0.47)^a
21.58	1.19 (0.06)^a	0.68 (0.03)^a	0.75 (0.04)^a	0.77 (0.04)^a	0.79 (0.04)^a	1.73 (0.09)^b	17.04 (1.10)^b	170.92 (1.71)^c	29.42 (0.32)^a

- Values in a column bearing different letters significantly differ at a 95% confidence level.
- Values in parenthesis are standard deviation values.

The specific gravity and densities of the kernel have an inverse linear relationship with moisture content, as presented in Eqs. 17 to 21. The specific gravity (γ_s) of the kernel was 1.27 when the moisture content was 8.77%, which dropped linearly to 1.24 (2.36%), 1.21 (2.42%), and 1.19 (1.65%) as the moisture content increased to 14.35, 17.84 and 21.58 respectively. The bulk density (ρ_b), 50 tap density (ρ_{50}), 100 tap density (ρ_{100}) and 1250 tap density (ρ_{1250}) all decrease linearly by 11.69% from 0.77 to 0.68 g/cm^3, 11.76% from 0.85 to 0.75 g/cm^3, 11.49% from 0.87 to 0.77 g/cm^3, and 13.19% from 0.91 to 0.79 g/cm^3

respectively as the moisture content of the kernel increase from 8.77 to 21.58% which agrees with the result of density obtained by **(Kibar and Öztürk, 2008)** for soybean, **(Aderinlewo et al., 2011)** and **(Moses and Zibokere, 2011)** for all the three varies of cowpea they used but is in contrast to that obtained by **(Sangamithra et al., 2016)** for maize. ANOVA indicated no significant differences for the specific gravities and bulk densities, but there is a significant difference for the 50, 100, and 1250 tap densities.

$$\gamma_s = 1.3286 - 0.0064\mathrm{M}_c \qquad R^2 = 0.9943 \qquad (177)$$

$$\rho_b = 0.8369 - 0.0073\mathrm{M}_c \qquad R^2 = 0.9764 \qquad (18)$$

$$\rho_{50} = 0.9148 - 0.0073\mathrm{M}_c \qquad R^2 = 0.9928 \qquad (19)$$

$$\rho_{100} = 0.9489 - 0.0079\mathrm{M}_c \qquad R^2 = 0.9348 \qquad (20)$$

$$\rho_{1250} = 0.994 - 0.0095\mathrm{M}_c \qquad R^2 = 0.9967 \qquad (21)$$

The seed masses increase linearly, as shown in **Eqs. 22** to **24** from 1.49 to 1.73 g for ten seed mass, 14.8 to 17.04 g for 100 seed mass, and 147.19 to 170.92 for 1250 seed mass, respectively, as the moisture content increases from 8.77 to 21.58 %. ANOVA indicated significant differences between the masses at the various moisture contents. A similar result was reported for maize **(Sangamithra et al., 2016)**, soybeans **(Davies and El-Okene, 2009; Tavakoli et al., 2009)**, jatropha seeds **(Bamgboye and Adebayo, 2012)** and Ife Brown, IT86D-1010 and IAR-339-1 varieties of cowpea **(Moses and Zibokere, 2011)**.

$$M_{10} = 0.0196Mc + 1.3098 \qquad R^2 = 0.9819 \qquad (22)$$

$$M_{100} = 0.1687Mc + 13.226 \qquad R^2 = 0.9652 \qquad (23)$$

$$M_{1250} = 1.838Mc + 130.23 \qquad R^2 = 0.9884 \qquad (24)$$

The angle of repose was found to reduce from 31.59 to 29.42 degrees linearly as the moisture content reduced from 8.77 to 21.58% following the relationship presented in **Eq. 25**. ANOVA indicated no significant differences between the angle of repose between the moisture content of 14.35, 17.84, and 21.58%.

$$\theta_r = 32.81 - 0.1693\mathrm{M}_c \qquad R^2 = 0.8887 \qquad (25)$$

4. CONCLUSIONS

This work determined some physical properties of cowpeas about the moisture content of 8.77, 14.35, 17.84, and 21.58% db. The major, intermediate, and minor diameters were found to increase with the increase in moisture content by 13.8, 27.5, and 16.1%, respectively. Similarly, sphericity, geometric mean diameter, arithmetic mean diameter, and the surface area also increase linearly by 7.5, 22.2, 20.7, and 24.9%, respectively, as well as seed mass, which increases by 16.11% for ten seeds, 15.14% for 100 seeds, and 16.12% for 1000 seeds. On the contrary, specific gravity, densities, and angle of repose reduce by 6.2%

for specific gravity. Bulk density, 50 tap density, 100 tap density, and 1250 tap density reduces by 11.69%, 11.76%, 11.49%, and 13.19%, respectively, as the moisture content of the kernel increases from 8.77 to 21.58 % while the Angle of repose reduces by 6.87% as the moisture content of the kernels increases from 8.77 to 21.58%.

NOMENCLATURE

Symbol	Description
db	Dry basis
wb	Wet basis
ANOVA	Analysis of Variance

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