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Moisture-Dependent Physical and Aerodynamics Properties of Cowpea Seeds

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ABSTRACT

This study focuses on the significant impact of moisture content on the engineering properties of cowpea seeds, which is vital for designing effective agricultural tools, equipment, and machines. We specifically examined two cowpea seed varieties, SAMPEA-16 and SAMPEA-14, across different moisture levels (10, 15, 20, 25, and 30% wb). Our findings show distinct variations in the physical characteristics of these seeds as the moisture content changes. For both SAMPEA-16 and SAMPEA-14, we observed changes in average length, width, and thickness at each moisture level. At moisture contents ranging from 10% to 30% wb, the dimensions for SAMPEA-16 were 11.20 mm by 9.10 mm by 8.61 mm, gradually changing to 10.60 mm by 8.80 mm by 8.50 mm, and for SAMPEA-14, they ranged from 8.30 mm by 6.50 mm by 6.50 mm to 8.40 mm by 6.50 mm by 6.40 mm. Significantly, the 1000 seed mass for SAMPEA-16 increased from 302.30 g to 404.80 g within the 15% to 30% moisture range, while the sphericity varied from 0.849 to 0.877. For SAMPEA-14, similar trends were observed with the sphericity shifting from 0.848 to 0.852. Additionally, the true density for SAMPEA-14 and SAMPEA-16 changed from 1034.12 kg m^{-3} to 1074.40 kg m^{-3} and 1089.61 kg m^{-3} to 1116.87 kg m^{-3}, respectively. Another notable finding is the increase in the angle of repose with moisture content. For SAMPEA-16, it rose from 22.40° to 30.23°, and for SAMPEA-14, from 23.22° to 34.28°, as moisture content increased from 10% to 30%. Furthermore, the terminal velocity for both varieties increased with moisture, with SAMPEA-14 ranging from 4.92 to 5.25, and SAMPEA-16 from 5.72 to 6.16, at 10% to 25% moisture content. The insights from this study are crucial for the design of agricultural machinery, processing units, and storage facilities, aiming to enhance the quality and quantity of cowpea produce.

Keywords: *Density, Evaluate, Repose, Sphericity, Terminal Velocity, Varieties*

INTRODUCTION

In Africa, Latin America, South-East Asia, and the southern United States, cowpea (*Vigna unguiculata* L.), an annual legume crop with African origins, is a common crop (Adekanye and Olaoye, 2018). Cowpea, an annual diploid legume, is renowned for its high protein content, which ranges from 18-25%, comparable to various types of meat (Narayana and Angamuthu, 2021). Due to the unique agronomic structure of its seeds, cowpea is particularly susceptible to the impact of loading and is significantly affected during threshing with iron beaters (Adewumi *et al.*, 2007). Often referred to as the 'hungry-season crop,' cowpea is harvested before grains and plays a crucial role in bridging food gaps. In Nigeria, cowpea production serves as a direct or indirect source of income for many individuals. Furthermore, cowpea contributes significantly to agricultural sustainability in sub-Saharan Africa. It offers multiple agronomic benefits, such as ground cover and plant residue, nitrogen fixation, and weed suppression. These qualities not only enhance soil fertility, particularly in marginal lands, but also support the livelihoods of numerous small-holder farmers in the region (Muhammed-Bashir *et al.*, 2018).

Cowpea is a versatile crop in Africa since it may be grown for human use, animal food, and to encourage the growth of other crops. Cowpeas, often known as "blackeyed peas" in the Americas, are mostly consumed in West Africa and are highly high in protein. Attempts to pinpoint the origin of cowpea cultivation are hampered by inadequate archeological documents (Gómez, 2004). When prepared (either boiled, grinded and made into "Akara ball," "moinmoin," etc.), cowpea is eaten in a variety of ways. Among the crucial processes in agricultural processing are post-harvest procedures include cleaning, grading, drying, dehydrating, storing, milling, handling and transport, and thermal processing of foods. Agricultural materials' engineering qualities are crucial for processing (Chukwu and Sunmonu, 2010). Engineers, food scientists, and processors must investigate these qualities in order to build efficient techniques and instruments. Numerous studies have been conducted to define some of the engineering features necessary in handling agricultural products after production in their dry condition without taking the impact of moisture into account Loss in the quality and deterioration in the threshed seeds occurs when properties are not considered before developing the threshers. According to Timothy and Olaoye (2013), high moisture content of cowpea seeds increases the mechanical damage while low moisture content reduces the mechanical damage. They also report moisture content affects the machine efficiency and the percentage damage. In spite of the economic importance of cowpea, there is little knowledge on its physical properties because it appears that there is not much published research on the physical properties of cowpea seed that are dependent on moisture. This has affected the effectiveness of the developed machines, leading to little or no progress in the mechanization of cowpea processing. Davies and Zibokere (2011) reported that most of the cowpea processing are done manually. As the domestic and industrial use of cowpea continues to expand, so does the need for efficient processing equipment and machines for unit operations required. As a result, this study examined the impact of moisture content on the physical and aerodynamic characteristics of cowpea seeds, which would help engineers create better equipment for mechanizing the production of cowpeas.

MATERIALS and METHODS

Materials

One of the earliest crops to be domesticated is the cowpea. Cowpeas grow well in up to 85% sand soil and do well in arid, unfavorable environments. Since cowpeas grow best at 30°C, they are only available as a summer crop in most of the world. It thrives in areas with 400-700 mm of annual precipitation. Compared to most other crops, it can withstand infertile and acid soils better in sandy soils. For erect varieties, 133,000 seeds are typically planted per hectare, while for climbing and trailing varieties, 60,000 seeds are planted per hectare. After roughly 100 days, the seeds can be collected, and after 120 days, the entire plant can be used for fodder. In this study, a variety of equipment, instruments, and materials were utilized, including a KD-TBE-1200 electronic weighing balance and a Gallenkamp laboratory oven. Measurement tools comprised a compass, a ruler, and a vernier caliper, alongside a thermometer for temperature monitoring. Chemical and storage materials included toluene and desiccators, as well as a measuring cylinder for volume measurements. The angle of repose was determined using a specialized device, and air flow was measured with a hot wire anemometer. Additionally, a measuring can was used, and the subject of our study was cowpea.

Collection and Preparation of Samples

Two varieties of cowpea seeds were procured from Oba Ile, Ondo State, South Western Nigeria, after quality assurance test was carried out. Each sample was inspected for infested seeds as well as other foreign objects like dust, stones, chaff, immature, broken, and damaged seeds. Two hundred (200) seeds were selected randomly from each of the variety and were numbered to avoid repetition of measurements.

Determination of moisture content of the cowpea seeds

To determine the moisture content of the cowpea pods, we employed a laboratory oven, digital weighing balance, and sample tray. Initially, the weight of the freshly harvested, wet samples denoted as (W_w) was recorded. These samples were then dried at a temperature of 105˚C. The moisture content was calculated using Equation 1, following the guidelines recommended by the Association of Official Analytical Chemists (AOAC, 1995). This process ensures accurate and standardized moisture content determination for the cowpea pods.

$$M_c = \frac{W_w - W_d}{W_d} 100\% \tag{1}$$

Where M_c is the moisture content of seeds (dry basis) in %, W_w is the wet weight of the cowpea seeds in g and W_d is the dry weight of the cowpea in g.

The initial moisture content of the seeds used was 10.0% db. It was conditioned to enable samples of different moisture levels and thereafter kept in the refrigerator at 5˚c for at least 24 hours to ensure evenly distribution of moisture.

Experimental Procedures

Determination of the physical properties of the cowpea seeds

To accurately measure the dimensions of the cowpea seeds, we used a vernier caliper with a precision of 0.01mm. This instrument was employed to determine the length (L), width (W), and thickness (T) of 60 randomly selected seeds. Each of these dimensions was meticulously recorded. This measurement process was replicated thrice at moisture contents of 20%, 25%, and 30%. Furthermore, we assessed both the mass and the angle of repose of the sample at varying moisture levels, specifically at 15%, 20%, 25%, and 30%. These measurements are crucial for understanding how moisture content affects the physical properties of cowpea seeds.

Sphericity

Sphericity is defined as the ratio of the diameter of a sphere with the same volume as the particle to the diameter of the smallest sphere that can completely enclose the particle, or more commonly, to the particle's maximum diameter. Essentially, it is a measure of how closely an object resembles a perfect sphere. For our study, the sphericity of the cowpea seeds was calculated using Equation 2, as outlined by Olukunle and Akinnuli (2012), and subsequently cited by Adetola *et al.* (2020).

The ratio between the diameter of a sphere with the same volume as the particle and the diameter of the smallest circumscribing sphere or, more commonly, the particle's maximum diameter is known as sphericity. It is the measure of how spherical (round) an object is. The sphericity of the cowpea was calculated using Equation 2 Olukunle and Akinnuli (2012) cited by Adetola *et al.* (2020).

$$S = \frac{D_g}{L} \tag{2}$$

Where S is the sphericity in percent, D_g is the seed's geometric mean diameter in centimeters, and L is the seed's length in centimeters.

The Geometric mean diameter (D_g)

Equation 3 was used to get the geometric mean Diameter (D_g) Olukunle and Akinnuli (2012) quoted by (Adetola *et al.* 2020).

$$D_g = (LWT)^{1/3} \tag{3}$$

Where, D_g is the geometric mean diameter in centimeters, L is the length of the seed in centimeters, W is the width of the seed in centimeters, and T is the thickness of the seed in centimeters.

Determination of gravimetric properties of cowpea seeds

Krishnakumar (2019) emphasizes that the knowledge of density, specific gravity, and porosity is crucial in designing equipment and systems for separation, handling, drying, processing, storage, and transport of agricultural products. Understanding these properties ensures the efficiency and effectiveness of such equipment and processes.

True density

The liquid displacement method was used to calculate the true density using Equation 4 as recommended by by Olukunle and Akinnuli (2012). Cowpeas of a known mass were placed within a measuring cylinder that was completely filled with toluene. The volume of the cowpea seed was discovered to be the volume of toluene that was displaced. Because seeds absorb toluene less thoroughly than water, it was used instead of water. Additionally, because of its low surface tension and poor dissolution power (Mohsenin, 1978) referenced by Isa and Aderotoye (2017) it fills even small dips in the cowpea seeds.

$$\rho_t = \frac{W_t}{V_t} \tag{4}$$

Where ρ_t is the true density in kg m^{-3} W_t is the actual weight in kilograms (kg), and V_t is the actual volume (m^3).

Determination of Angle of Repose of Cowpea Seeds

Tilting box which consist of an iron rod for the frame, a plywood box with a fixed stand attached, a protractor was used to determine angle of repose for cowpea seeds, and an adjustable plate at the surface. In order for the seed to follow and acquire a natural slope, it was placed on the adjustable surface and allowed to progressively incline (Tabatabaeefar, 2003; Heidabeigi *et al.*, 2009). Four different surfaces-wood, mild steel, stainless steel, and galvanized sheet-were used for these. One of the criteria used to calculate the angle of inclination of the hopper or chute for cowpea discharge is the value of the angle of repose.

Static Friction Calculation

The static coefficients of friction for cowpea seeds were evaluated on four different surfaces: mild steel, galvanized sheet, wood, and stainless steel. To determine these coefficients, we employed Equation 5, as outlined in the study by Heidabeigi *et al.* (2009).

$$\mu = \tan \alpha \tag{5}$$

Where μ is the coefficient of static friction and α is the angle of repose in degrees.

Determination of the Aerodynamic Properties of the Cowpea Seeds

To determine the terminal velocity of cowpea seeds, we utilized a vertical air tunnel at the agricultural engineering workshop of the Federal University of Technology, Akure. For each test, a single seed was released from the top of the air tunnel into the air stream. The speed of the blower's connected fan was gradually increased to raise the airflow rate until the seed remained suspended in the air stream. A hot wire anemometer, with a precision of 0.1 m s^{-1}, was used to measure the air velocity that effectively suspended the seed.

A total of twenty seeds, selected based on their moisture level, were tested. Each sample underwent three replications, in line with methodologies established by

Sacilik *et al.* (2003) and Gupta and Das (1997). The terminal velocity values for the cowpea seeds were meticulously recorded.

Statistical analysis

The analysis of variance (ANOVA) and Duncan Post-Hoc Multiple Comparison Test test were performed on the data acquired from the three replications at each moisture content using Mini Tab Software.

RESULTS AND DISCUSSION

Physical Properties of Cowpea Seeds

The findings detailing the impact of moisture content on various physical and aerodynamic properties of cowpea seeds are systematically presented in Tables 1 to 8 and Figures 1 to 4. These results demonstrate that the moisture content significantly influences both the physical and aerodynamic characteristics of the cowpea seeds.

Dimensions of the cowpea seeds

The average length, width and thickness of the cowpea seeds increased with an increase in the moisture content. At 10% moisture content, the average length and breadth were 9.00 mm, and 8.00 mm for SAMPEA-16 variety respectively. After conditioning, their dimensions were: 10.40 mm and 8.20 mm; 10.70 mm and 8.50 mm; 10.60 mm and 8.70 mm; 11.20 mm and 8.80 mm at moisture content of 15% wb; 20% wb; 25% wb and 30% wb respectively (Table 1). The result obtained in Table 1 is in agreement with the result reported by (Davies and Zibokere, 2011). Table 2 shows the average length, width and thickness for the SAMPEA-14 variety for the 10% moisture content was 8.10 mm, 6.30 mm and 6.20 mm, there was in increase in the seed dimensions at the 15%, 20%, 25% and 30% moisture content having the average value of 8.20 mm, 6.40 mm and 6.30 mm at 15%, 8.30 mm, 6.50 mm and 6.30 mm at 20%, 8.40 mm, 6.50 mm and 6.40 mm at 25%, 8.50 mm, 6.70 mm and 6.50 mm at the 30%.

Table 1. *Physical properties of SAMPEA-16 of cowpea at different moisture content.*

Dimension	Moisture content	Maximum Value	Minimum Value	Mean	Standard Deviation
Length	10	12.9	8.00	9.00	0.09
	15	13.00	8.60	10.40	0.09
	20	13.10	9.10	10.70	0.10
	25	16.00	9.20	10.60	0.08
	30	17.80	9.50	11.20	0.08
Width	10	12.90	7.0	8.00	0.05
	15	9.80	7.10	8.20	0.05
	20	9.90	7.00	8.50	0.05
	25	9.90	7.20	8.70	0.05
	30	10.20	7.60	8.80	0.06

Table 2. *Physical properties of SAMPEA-14 of cowpea at different moisture content.*

Dimension	Moisture content	Maximum	Minimum Value	Mean	Standard Deviation
Length	10	10.00	7,00	8.10	0.05
	15	10.00	6.60	8.20	0.06
	20	10.00	6.90	8.30	0.05
	25	10.01	8.40	8.40	0.08
	30	9.90	6.00	8.50	0.06
Width	10	7.80	4.30	6.30	0.07
	15	8.10	5.50	6.40	0.04
	20	8.30	5.60	6.50	0.05
	25	8.50	5.80	6.60	0.04
	30	8.50	5.90	6.70	0.04
Thickness	10	7.70	1.90	0.65	0.06
	15	8.00	5.00	0.62	0.04
	20	8.00	5.10	0.63	0.04
	25	8.20	5.80	0.64	0.04
	30	8.30	5.70	0.64	0.04

Volume

The volume of the Cowpea seeds has a linear relationship with moisture. This result is in line with the result obtained by Davies and Zibokere (2011).When the moisture content changed from 10.0% to 30.0% wb, the volume increased from 0.3424 mm^3 to 0.4038 mm^3 for SAMPEA-16 and from 0.1997 mm^3 to 0.2122 mm^3 for SAMPEA-14. The increase in volume is a result of the increase in moisture. This is depicted in Figure 1. Table 3, the effect of volume on the two varieties of cowpea, SAMPEA-16 and SAMPEA-14, was statistically significant ($p<0.05$).

Table 3. *Analysis of variance for volume for varieties 1 and 2.*

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.020447	72.77%	0.020447	0.005112	6.68	0.007
Error	10	0.007650	27.23%	0.007650	0.000765		
Total	14	0.028096	100.00%				
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.016071	64.71%	0.016071	0.004018	4.58	0.023
Error	10	0.008765	35.29%	0.008765	0.000876		
Total	14	0.024836	100.00%				

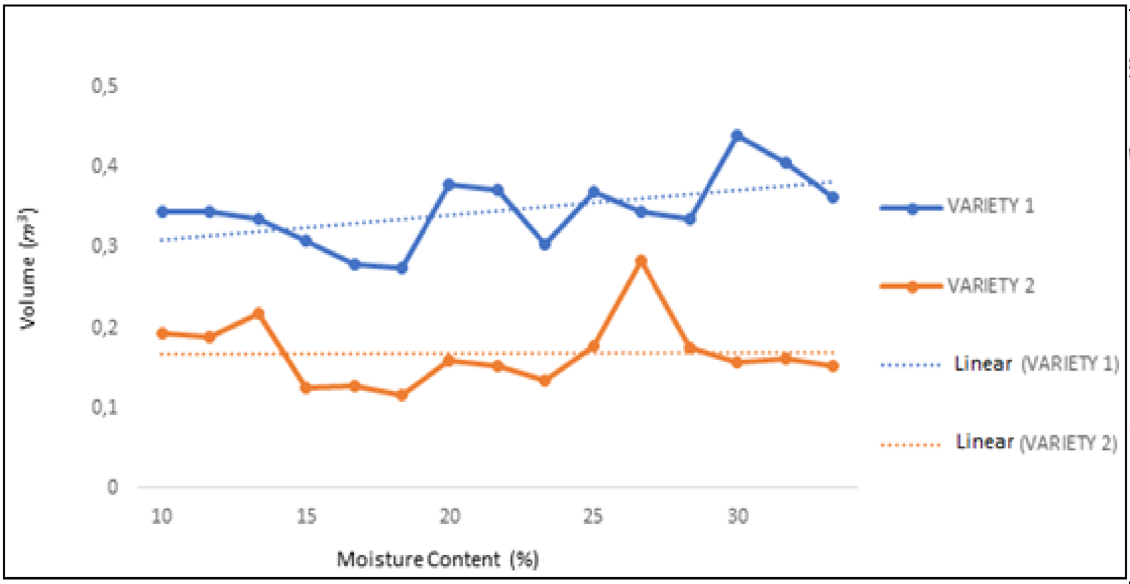

Figure 1. *Effect of moisture content in % on volume in m³.*

Sphericity

Between 10% and 15% moisture content, the effect of moisture content on the sphericity of SAMPEA-16 increased from 0.849 to 0.877; however, at 20% and 25% moisture content dry basis, the effect of moisture content decrease to 0.8730 and 0.866 respectively; and finally, it increased to 0.877 at 30% moisture content. For SAMPEA-14, the moisture content range between 10% and 15% showed a linear reduction from 0.848 to 0.838, but later increased at 20% to 25% from 0.842 to 0.852 and at 20% moisture content dry basis, before decreasing to 0.838 at 30% moisture content (Figure 2). Yalçın (2007) reported that sphericity of cowpea has a direct relationship with the moisture content of cowpea. The sphericity of cowpea increases as the moisture content of cowpea increases. Aydin *et al.* (2002) for Turkish mahaleb, Gupta and Das (1997) for sunflower seed, Sacilik *et al.* (2003) for hemp seed, Baumler *et al.* (2006) for safflower, and Dursun and Dursun (2005) for caper seed have all reported similar trends. While the increase reported in IAR-339-1 and Ife brown seeds is consistent with that obtained by Davies and El- Okene (2009) for soybean, the decline in sphericity of seeds is in line with that obtained by Adejumo *et al.* (2007) for the Kano White variety of bambara groundnut, Altuntas and Yildiz (2007) for faba bean, and Cetin (2007) for barbunia. A similar result was obtained by Olawale *et al.* (2018) and Isa and Aderotoye (2017). Table 4, the effect of moisture on SAMPEA-16 cowpea was statistically significant ($p<0.05$) while Table 5 shows that SAMPEA-14 cowpea was not statistically significant ($p<0.05$).

Table 4. *Analysis of Variance of Sphericity for Variety 1 Cowpea, SAMPEA-16*

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.001728	64.84%	0.001728	0.000432	4.61	0.023
Error	10	0.000937	35.16%	0.000937	0.000094		
Total	14	0.002665	100.00%				

Table 5. *Analysis of Variance of Sphericity for Variety 2 Cowpea, SAMPEA-14.*

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.000444	30.21%	0.000444	0.000111	1.08	0.416
Error	10	0.001026	69.79%	0.001026	0.000103		
Total	14	0.001470	100.00%				

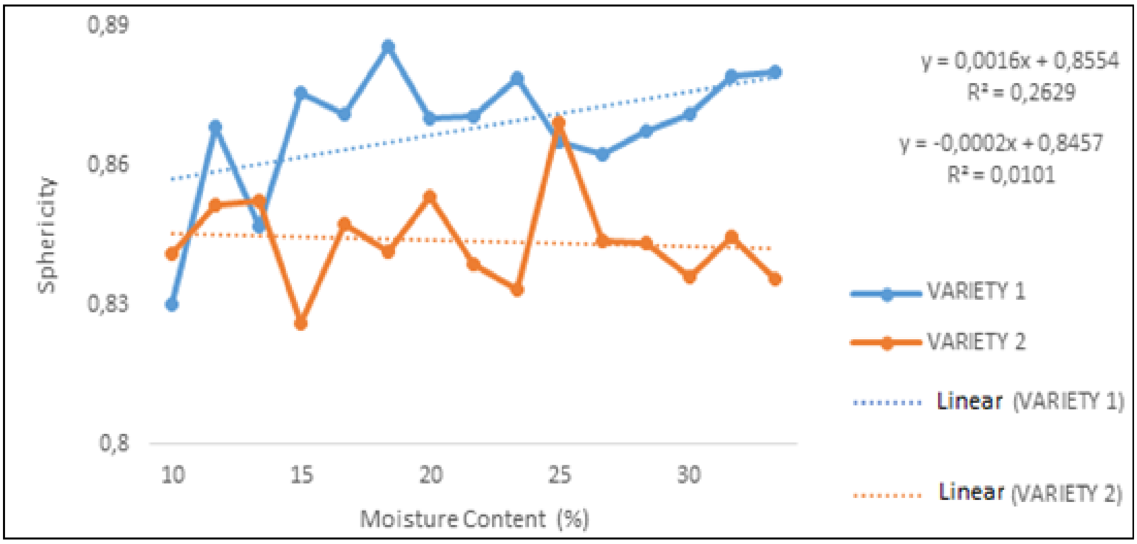

Figure 2. *Effect of moisture content in % on the sphericity.*

True Density

True densities increased as moisture levels rose from 1034.12 to 1074.40 kg m^{-3} for SAMPEA-14 and SAMPEA-16, respectively, and from 1089.61 to 1116.87 kg m^{-3} for SAMPEA-16. Figure 3 demonstrates that the real densities of the two varieties grew and then declined as moisture levels rose. This indicates that initially, due to moisture absorption, the relative rise in cowpea weight was equal to the corresponding volumetric increase, but with an increase in moisture, the relative increase in weight was not equal to the corresponding increase in volume. The true density decreases as the moisture content of cowpea seed increases. Similar results were obtained for cotton seed by Ozarslan (2002), hemp seed by Sacilik *et al.* (2003), soybean by Deshpande *et al.* (1993), and hemp seed by Abalone *et al.* (2004); Davies and Zibokere (2011) also noted a negative association between true density and moisture content. According to Table 6's statistical analysis, there was a significant difference in the true density for SAMPEA-14 but not for SAMPEA-16, as indicated by the P-value.

Table 6*. Analysis of variance of true density for SAMPEA-16 and SAMPEA-14 cowpea varieties.*

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.01014	36.21%	0.01014	0.002535	1.42	0.297
Error	10	0.01787	63.79%	0.01787	0.001787		
S	14	0.02801	100.00%				
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	0.06870	73.73%	0.06870	0.017175	7.02	0.006
Error	10	0.02447	26.27%	0.02447	0.002447		
Total	14	0.09318	100.00%				

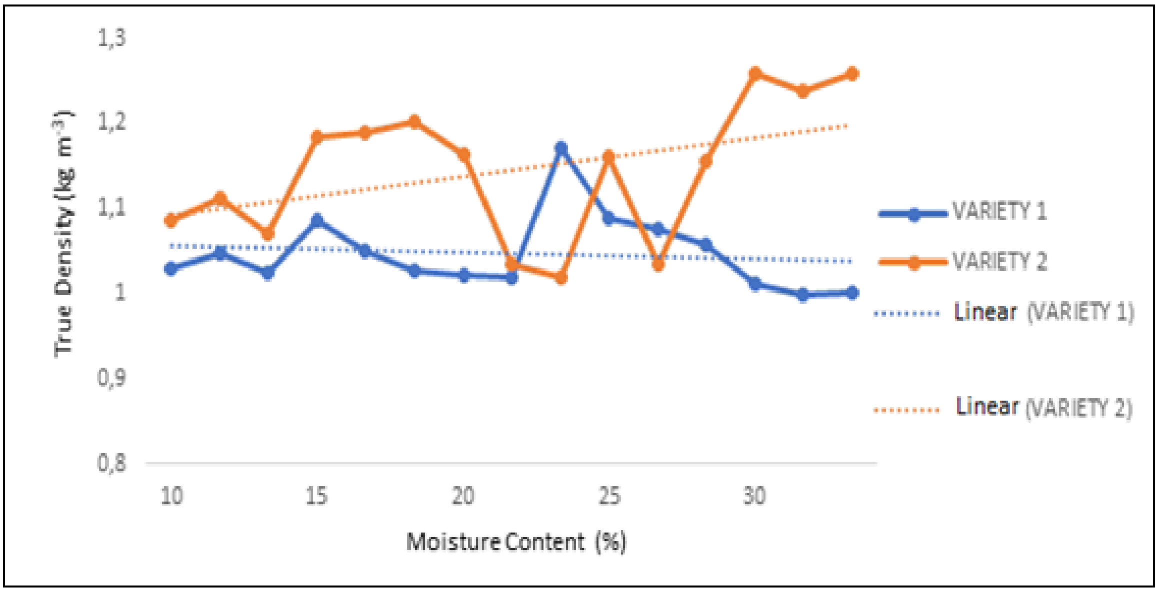

Figure 3. *Effect of moisture content in % on the true density in kg m^{-3}.*

Angle of repose

Table 7's statistical analysis reveals from the P-value that the angle of repose for the SAMPEA-16 and SAMPEA-14 cowpea types was significantly different from one another. The two types' angles of repose grew as the moisture content grew. When the moisture content increased from 10% to 30%, Table 8 shows that the angle of repose for the SAMPEA-16 increased from 22.40°±0.82^{b} to 30.23°±0.52^{a}. The angle of repose went from 23.22°±0.50^{d} to 34.28°±0.81^{a} for the same increase in moisture in SAMPEA-14. Olalusi *et al.* (2009) and Davies and Zibokere (2011) reported that the primary cause of the increase in angle of repose for these cowpea varieties is the larger size of the seeds. This suggested that, in comparison to cowpea seeds, the forces of solid friction at the grain-material interface were generally lower in oil bean seeds. This is comparable to the data on Tiger nut published by Olalusi *et al.* (2009).

Table 7. *Analysis of variance of angle of repose for SAMPEA-16 and SAMPEA-14 cowpea variety.*

Source	**DF**	**Seq SS**	**Contribution**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
MC	4	141.532	94.85%	141.532	35.3830	46.09	0.000
Error	10	7.677	5.15%	7.677	0.7677		
Total	14	149.209	100.00%				
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
MC	4	228.947	97.34%	228.947	57.2368	91.33	0.000
Error	10	6.267	2.66%	6.267	0.6267		
Total	14	235.214	100.00%				

Table 8. *Mean values for the physical properties for SAMPEA-16 and SAMPEA-14 cowpea varieties.*

Property	**Moisture Content (%)**	**Variety 1**	**Variety 2**
True density	10	1.03 ± 0.01^{a}	1.09 ± 0.02^{b}
	15	1.05 ± 0.03^{a}	1.20 ± 0.01^{ab}
	20	1.07 ± 0.09^{a}	1.07 ± 0.08^{b}
	25	1.07 ± 0.02^{a}	1.12 ± 0.07^{b}
	30	1.00 ± 0.01^{a}	1.25 ± 0.01^{a}
Angle of repose	10	22.40 ± 0.82^{b}	$23.23 \pm (0.50^{d})$
	15	23.56 ± 0.89^{b}	$25.69 \pm (0.96^{c})$
	20	24.57 ± 1.34^{b}	$25.90 \pm (0.31^{c})$
	25	28.91 ± 0.56^{a}	$30.12 \pm (1.11^{b})$
	30	30.23 ± 0.52^{a}	$34.28 \pm (0.81^{a})$
Volume	10	$0.34 \pm (0.01^{ab}$	0.20 ± 0.02^{ab}
	15	$0.29 \pm (0.02^{b}$	0.12 ± 0.006^{b}
	20	$0.35 \pm (0.04^{ab}$	0.15 ± 0.012^{ab}
	25	$0.35 \pm (0.02^{ab}$	0.21 ± 0.06^{a}
	30	$0.40 \pm (0.04^{a}$	0.16 ± 0.004^{ab}
Sphericity	10	$0.\ 85 \pm 0.02^{b}$	$0.85 \pm (0.01^{a}$
	15	0.88 ± 0.01^{a}	0.84 ± 0.01^{a}
	20	0.87 ± 0.005^{ab}	0.84 ± 0.01^{a}
	25	0.86 ± 0.002^{ab}	0.85 ± 0.01^{a}
	30	0.88 ± 0.005^{a}	0.84 ± 0.005^{a}

Values are means of triplicate and standard error. Means values having different superscript within the same row are significantly different (P<0.05).

Aerodynamic properties of cowpea seeds

Figure 4 reveals that as the moisture increased, terminal velocity of the cowpea seeds for the two varieties increased. The terminal velocity of each variety increased with the increase in moisture. The terminal velocity of SAMPEA-14 increased from 4.92 m/s to 5.25 m s^{-1}, and the terminal velocity for SAMPEA-16 increased from 5.72 m s^{-1} to 6.16 m s^{-1} at 10% to 25% moisture content. The finding was to that of cowpea studies conducted by Aderinlewo *et al.* (2011). In the cases of sunflower, karingda, cumin, lentil, and melon seeds, respectively, similar findings were reported by Gupta and Das (1997), Suthar and Das (1996), Singh and Goswami (1996), Carman (1996).

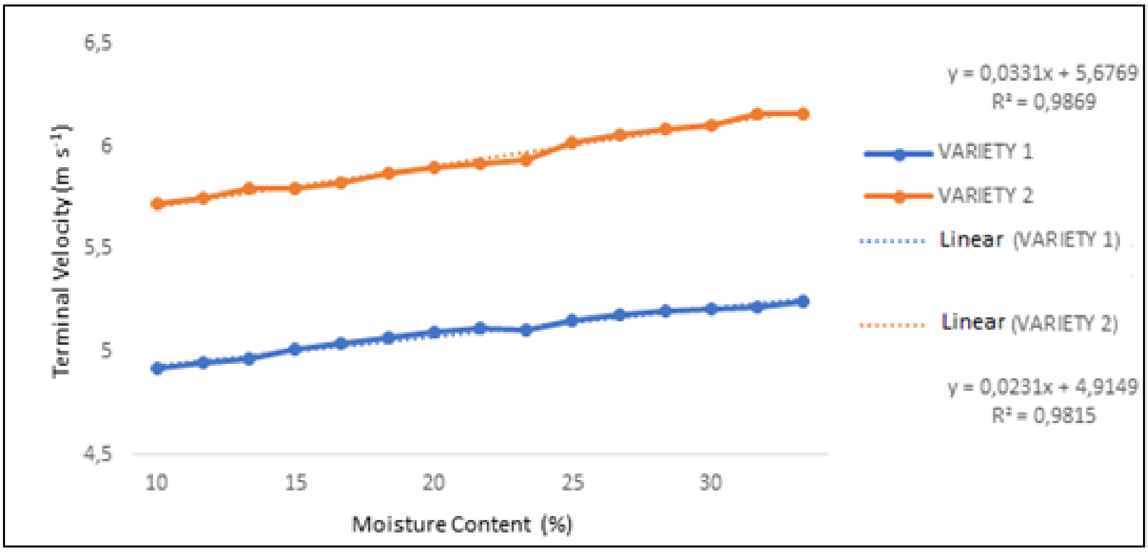

Figure 4. *Impact of moisture content on the terminal velocity.*

CONCLUSION

The study's findings indicate a linear relationship between the dimensions of cowpea seeds and their moisture content. As moisture increases, there is a corresponding growth in the seed's length, width, and thickness. However, it's important to note that regardless of the moisture level, the shape of the cowpea seeds, as indicated by their sphericity results, remains significantly non-spherical. This implies that cowpea seeds would not effectively pass through a separating machine equipped with circular holes. Additionally, moisture content positively correlates with the volume of the seeds; an increase in moisture leads to an expansion in volume. This study also observed that the angle of repose for the seeds increased on all tested surfaces as moisture content rose. Furthermore, there is a positive relationship between the terminal velocity of the cowpeas and their moisture content, indicating that as moisture increases, so does the terminal velocity.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Olufemi Adeyemi ADETOLA: Conceptualization, writing-original draft, review, and editing and validation.
Adenike Mary ADEROTOYE: Writing-original draft and data curation.

Marvellous Oluwaseun LAWAL: Investigation, methodology, formal analysis, writing-original draft and data curation.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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