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EFFECT OF MOISTURE CONTENT ON THE PHYSICAL AND ENGINEERING PROPERTIES OF MUCUNA BEANS FOR PROCESSING APPLICATIONS

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Abstract
The physical characteristics of biomaterials are those that are readily ascertained without putting the materials through any force and that are evident to the naked eye, sense, or touch. Using standard experimental protocols, this study was conducted to investigate the various physical attributes of two types of Mucuna (Pruriens and Veracruz), commonly known as Agbara, under varying moisture contents ranging from 6.04% to 15.82% (db). For this investigation, a sample of 1000 seeds were used. The experimental electronics weighing balance was used to determine and record the mass of each sample (g). Venire Callipers were used to measure the major diameter (length), a., intermediate diameter (width), b., and minor diameter (thickness), c. The methods described in [10] were used to determine all the physical characteristics of the Mucuna (Prureins and Veracruz) seeds with three replications for each moisture content. According to the findings, Mucuna Veracruz grew linearly from 1.42 to 1.86, 1.12 to 1.26, and 0.76 to 0.82 cm, respectively, while major, intermediate, and minor seed diameters varied from 1.4 to 1.83, 1.09 to 1.29, and 0.78 to 0.8 cm, respectively. Likewise, it was found that the square, geometric, and arithmetic mean diameter values for both species were statistically identical (p = 0.005). However, when the moisture content rose from 6.04% to 15.82% for Mucuna pruriens and from 1.62 to 1.14 (3). For Veracruz, the bulk density changed from 1.66 to 1.10 (3). As the moisture content rose from 6.04 to 15.82%, the seed volume for Veracruz and Pruriens increased from 0.48 to 0.64 (3) and from 0.47 to 0.62, respectively. The physical characteristics of two Mucuna types (Pruriens and Veracruz) with varying moisture levels (6.04 to 15.82%(db)) were concluded. These characteristics are essential for designing processing machinery and managing these biomaterials after harvest. To determine how these bio-materials can be utilized in the food and processing sectors, it is suggested that further studies be conducted on their proximal and functional characteristics.

Keywords: *Mucuna Prureins, Mucuna Veracruz, Moisture Content, Physical Properties, and Bulk Density.*

Introduction

Mucuna (Pruriens and Veracruz) Agbara is an annual climbing legume that is a member of the Fabaceae family, which is a subfamily of the Papilionaceae. The Igbo people in the eastern portion of the country name it thus. Although this legume originated in Asia, it is currently grown in many tropical locations, including South America, Africa, and the West Indies. Currently found in tropical and sub-tropical areas, Mucuna Pruriens and Veracruz are two of the many underutilised wild legumes.

To manufacture coffee alternatives, the genus Mucuna beans are roasted and ground into flour in several tropical nations [1]. In the state of Enugu, its leaves are cooked and consumed as a blood tonic, and it is used to thicken soup. Up to 30 tons/ha of organic matter may be added to soils by using ***Mucuna*** plants as a highly efficient green manure [2]. Due to its high protein content (25– 38%), ***Mucuna*** is considered a significant source of plant proteins [3]. According to [3], ***Mucuna*** beans have a very high carbohydrate content (39–41%). For this reason, ***Mucuna*** is regarded as a healthy dietary source for both people and animals.

The species of ***Veracruz*** and ***Mucuna*** pruriens that are grown in tropical climates most likely originated in Asia. Nonetheless, there are more than 120 species of these annual and perennial legumes, and there are several crosses and hybrids available. Pods, seed colour, and the number of days it takes to reach maturity are the main distinctions between these farmed species. Velvet bean, cowitch, cowhage, and lacuna bean are some of its frequent English names. Because their pods contain serotonin, these long-haired varieties are infamous for being extremely itchy upon touch [1].

When supported, the plant's long, slender vines may reach a length of almost 18 meters, and when grown on the ground, they can reach 5.5 meters [4]. It also features white flowers with a bluishpurple corolla that resembles a butterfly and lanceolate leaves. The thickly haired pods, which are 4–13 cm long and 1-2 cm broad, hold 4–9 seeds each. The seeds might be speckled, glossy black, creamy white, or grey-brown. After being roasted or repeatedly boiled to eliminate anti-nutritional elements, the ripe seeds are traditionally eaten as food. The majority of Mucuna cultivars can tolerate severe climatic conditions, including drought, high soil acidity, and low soil fertility [5].

Below 1500m, above sea level, and in areas with abundant rainfall, the plant thrives in warm, humid circumstances. Mucuna pruriens and Veracruz species, like most of legumes, can fix atmospheric nitrogen by forming a symbiotic connection with soil microbes. When cultivated for seed production in the tropics, several cultivars are typically available for harvesting 180–280 days following culture. However, the plants are often ready for harvesting 90–120 days after culture when planted for fodder [2].

Other competitive plants are suppressed by the plant's allelopathic activities [6]. Furthermore, the extremely low vulnerability of Mucuna seeds to insect infection during storage might be explained by the toxicity of the unprocessed seeds [5]. Like certain other legumes, mucuna seeds contain both anti-nutritional and pro-nutritional substances. Finding the most economical methods to lessen or eradicate Mucuna seeds' anti-nutritional qualities while maintaining their nutritional value is one of the difficulties in marketing them for use by humans and animals.

"Levo-Dopa," a dopamine neurotransmitter that is useful in the therapy and management of Parkinson's disease, is the most significant of these anti-nutritional qualities. Mucuna is used commercially as a source of L-DOPA (2-7) % due to its high content [7].

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One crucial component of biomaterials that affects their stability, safety, and quality is their moisture content. Large volumes of water are often present in recently harvested items, which speeds up the process of degradation. Even though their nutritional value may have been diminished after drying, baked or dried agricultural goods are more stable than fresh items while having a lower water content [8].

[8] discussed how roasting affected the size and moisture content of cashew nuts, causing them to shrink. This resulted from the cashew nuts losing moisture when roasting; as a result, the nuts' size drops as their moisture level does. Because consumers prefer nuts with a very low moisture level, this benefits the product's market.

The physical attributes of a biomaterial are those that are readily apparent through touch, sight, or sensation and that are also perceptible. These characteristics are simply ascertained without putting biomaterials and agricultural products under any kind of force. When building equipment for the separation process, cleaning, processing, and transportation of biomaterials, the axial dimensions of agriculture and biomaterials are crucial. When transporting or processing solid items by air or water, the determination of terminal velocity, drag coefficient, and Reynolds number requires knowledge of the surface area. When classifying the morphologies of grains or seeds, the aspect ratio is helpful. The design of silos, storage bins, hoppers, discharge mechanisms, and conveying and handling equipment all depend on bulk density [9]. While moisture content is crucial in determining the shelf life and storability of agricultural commodities, specific gravity is crucial in applications like the drying and heat treatment of biomaterials.

The impact of moisture content on the physical characteristics of the two Mucuna types has not been extensively studied in the literature. To carry out engineering design of storage, handling, and processing structures and equipment for this significant bio-material, information on physical properties such as major, intermediate, minor, arithmetic mean, geometric mean, harmonic mean, square mean, equivalent mean diameters, sphericity, surface area, volume, solid density, and aspect ratio will be required. This will improve productivity, cut down on time waste, improve product quality, and eliminate drudgery.

In order to carry out the engineering design of storage, handling, and processing structures and equipment for this bio-material under varying moisture content levels, the study aims to identify some of the physical attributes that will be required.

Materials and Methods

Sample Collection: ***Mucuna*** Pruriens ripe seeds were collected straight from a farm in Orba, Enugu State, Nigeria's Udenu Local Government Area. The coordinates of its location are east and north. A farm in Enugu Ezike, Igboeze North Local Government Area, Enugu State, Nigeria, provided the Mucuna Veracruz seeds. The coordinates of its location are east and north. To get rid of any unwanted objects, such as chaff, immature seeds, and fragments of stone, the samples were hand cleaned.

(A) (B)

Figure 1: Mucuna seeds varieties (a = Pruriens and b = Veracruz)

Orba in Udenu LGA

Fig .2a: Map of Orba GPS

Enugu Ezike in Igboeze LGA

Fig. 2b: Map of Enugu- Ezike

Sample Preparation: To get rid of any unwanted objects, such as chaff, immature seeds, and fragments of stone, the samples were hand cleaned. The physical characteristics of the samples were assessed after they were secured in bags and transported to the bioprocess laboratory located in the Agricultural and Bio-Resources Engineering Department at Enugu State University of Science and Technology (ESUT), Enugu. With three replications for every moisture content, every physical characteristic of the Mucuna (***Prureins*** and ***Veracruz***) seeds was identified. The moisture content of Mucuna seeds was measured using the oven method described in [10]. Samples were dried for six hours at three different moisture levels in an oven set at 105°C to investigate the effects of moisture content on the physical characteristics.

Materials used for the determination of the physical properties

Major diameter (length) a, intermediate diameter (width) b, and minor diameter (thickness) c of the seeds were measured using digital vernier callipers (Mitutoyo, Japan) with an accuracy of 0.01mm. A Mettler Toledo electronic weighing scale (model XP204) with a 0.0001g sensitivity was used to measure each sample's mass separately. The total weight of the samples was determined by repeating the measurements thirty times.

Determination of the physical properties

For this investigation, a sample of 100 seeds was used. The experimental electronics weighing scale was used to determine and record each sample's mass (g). Venire Callipers were used to determine the major diameter (length), a. intermediate diameter (width), b., and minor diameter (thickness), c.

- Arithmetic mean diameter (AMD),
- Square mean diameter (SMD),
- Equivalent diameter (EQD),
- Harmonic mean diameter (HMD),
- Sphericity (SPH), and
- Aspect Ratio (AR) of *Mucuna* samples using the formulas given by [10].

$a+b+c$

AMD = ______ **(1) GMD =** $\sqrt[3]{abc}$

(2) SMD = $\sqrt{\frac{(a\times b)+(b\times c)+(c\times a)}{3}}$ **(3) EQD =** ______________

(4) HMD = + + (5)

3

AMD+SMD+ GMD

3

$\frac{1}{a}$ $\frac{1}{b}$ $\frac{1}{c}$

$\sqrt[3]{abc}$

SPH = (6)

a

b

AR = (7) a

The tracing method was used to determine the largest projected areas and the smallest circumscribing circle of the *Mucuna* seeds in their natural rest position, and roundness was evaluated [12].

AP

Roundness = (8)

AC

AC = area of the least circumscribing circle

The surface area of the seed was determined as [12,13].

$$A = \frac{\pi D^2}{4} \quad (9)$$

Where A = surface area of the seed of the biomaterial

D = minor diameter of the seed

π = (3.142)

Determination of moisture content.

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A biomaterial's moisture content, which is typically impacted by the kind of food material, age or maturity, diversity, or geographic location, shows how much water is present in the material. The starting moisture content, as calculated by the method suggested by [11], was 15.82% db, and samples were chosen at random. This involves drying each Mucuna seed in an oven set to 105°C for a whole day. After cooling, an electronic weighing scale was used to measure the moisture losses in the Mucuna samples. The following formulae were used to determine the seed's moisture content in percentage terms (wet basis) and dry basis [10].

$M_w = 1(WW^{w}{}_{w}{}^{-W_d})$ **(10)**

Where M_w= Moisture content wet basis

W_w= weight of wet materials = weight of dry materials

M_d = $1(WW^{w}{}_{d}{}^{-W_d})$ **(11)**

Where M_d = Moisture content dry basis

The samples were further dried to obtain other moisture content levels of 10.37 and 6.04% dry basis.

Determination of the bulk density of *Mucuna (Pruriens* and *Veracruz)*

The weight of the sample divided by the capacity of the container is the bulk density of an agricultural material. This was assessed as [10,15] by weighing a measuring cylinder with a known volume that was filled with Mucuna samples.

$$\rho_s = \frac{m}{v} \quad (12)$$

g

Where ρ_b= bulk density of the seeds ($\frac{}{cm^3}$)

m = mass of the seed (g) V = volume of the cylinder (cm^3)

Determination of the solid density of the samples

The true or solid density of an agricultural material is the ratio of the weight of the sample to its true volume [10].

$$\rho_s = \frac{m}{n.V_u} \quad (13)$$

Where m = mass of the sample (g) ρ_s= the solid density of the sample ($_{cm3}$) n= number of seeds in the sample V_u= unit volume of one seed

g

$$NB: V_u = \frac{\pi\sqrt[3]{(abc)}}{6} \quad (14)$$

Determination of the Porosity of the ***Mucuna Samples***

The porosity in % indicates the number of pores in the bulk materials [10, 15] and presents a formula for its calculation as

$$\varepsilon = 100\left(1-\frac{\rho_b}{\rho_s}\right) \quad (15)$$

Where = porosity (%) ρ_b= bulk density ($\frac{g}{cm^3}$) ρ_s= solid density ($\frac{g}{cm^3}$)

Results

Tables 1, 2, 3, and Tables 4 and Figs. 1, 2, 3, and 4 respectively, as well as tables with descriptive statistical methods and graphs are used to present and analyse the results of the physical characteristics of Mucuna Pruriens and Veracruz that were investigated at three different moisture contents of 6.04%, 10.37%, and 15.82% (dry basis). Tables 5, 6, and 7 present the analysis of variance. Additionally, the physical property plots at various moisture content levels are displayed in Figures 1 through 4. ***Mucuna Prurien***s and ***Veracruz*** size parameters are displayed in Tables 1 through 4 at varying moisture content levels of 6.04%, 10.37%, and 15.82% (dry basis).

Table 1. Results of physical properties (axial dimensions) of *Mucuna pruriens*

Moisture content (%)	Major diameter (cm)	Intermediate diameter (cm)	Minor diameter (cm)	Geometric mean diameter (cm)	Arithmetic mean diameter (cm)	Square Mean diameter (cm)
6.04	1.4	1.09	0.78	0.89	0.09	0.91
10.37	1.7	1.17	0.79	1.07	1.05	1.07
15.82	1.83	1.29	0.80	1.19	1.19	1.19

Table.2: Results of physical properties (axial dimensions) of *Mucuna Veracruz (white)*

Moisture content (%)	Major diameter (cm)	Intermediate diameter (cm)	Minor diameter (cm)	Geometric mean diameter (cm)	Arithmetic mean diameter (cm)	Square Mean diameter (cm)
6.04	1.42	1.12	0.76	0.85	0.08	0.87
10.37	1.68	1.15	0.80	1.06	1.12	1.09
15.82	1.86	1.26	0.82	1.2	1.21	1.17

Table 3. Results for other physical properties of *Mucuna pruriens*

Moisture content (%)	Equivalent mean diameter (cm)	Harmonic mean diameter (cm)	Porosity	Sphericity	Weight (g)	Bulk density (g/cm^3)	Surface Area (cm^2)	Aspect ratio

6.04	0.79	2.61	0.22	0.81	0.49	1.66	0.32	0.91
10.37	0.95	2.91	0.27	0.76	0.72	1.49	0.48	0.78
15.82	1.06	3.45	0.33	0.68	1.35	1.10	0.64	0.65

Table 4. Results for other physical properties of *Mucuna Veracruz (white)*

Moisture content (%)	Equivalent mean diameter (cm)	Harmonic mean diameter (cm)	Porosity %	Sphericity %	Weight (g)	Bulk density (g/cm^3)	Surface Area (cm^2)	Aspec t ratio
6.04	0.78	2.63	0.25	0.80	0.43	1.62	0.28	0.88
10.37	0.93	2.90	0.28	0.77	0.68	1.29	0.43	0.73
15.82	1.04	3.42	0.41	0.69	1.45	1.14	0.59	0.68

Analysis of Variance:

Analysis of variance ANOVA was carried out for test sample results to see if there was a statistical difference in values of tested properties. The results are presented in the Tables.

Table 5: ANOVA for Physical Properties (Major, Minor diameter, intermediate diameter, AMD, GMD, square mean)

Source of Variation	SS	Df	MS	F	P-value	F crit
Within Prop	9.169267	2	4.584633	1.697108	0.224358	3.885294
Within MC	221.5344	6	36.9224	13.66768	$9.61E^{-05}$	2.99612
Error	32.41727	12	2.701439			
Total	263.1209	20				

All observed attributes differed considerably as the moisture content rose, according to the analysis of variance for the physical properties indicated in Table 5. The qualities under examination did not differ much from one another. The computed F-values were below the critical values for characteristics but much higher than the critical values for moisture content. This may suggest that the moisture content had a significant impact on the sample's axial dimensions.

Table 6: ANOVA for Equivalent mean diameter and Harmonic mean diameter,

Source of

Variation	SS	Df	MS	F	P-value	F-crit
Within Prop	17.11402	2	8.557011	1.429032	0.340186	6.944272
Within MC	146.5144	2	73.25721	12.23405	0.019743	6.944272
Error	23.95191	4	5.987978			
Total	187.5804	8				

The observed variations for moisture content were statistically significant, according to the analysis of variance for various physical parameters, including equivalent and harmonic mean diameter (Table 6). This also applied to other physical characteristics, including surface area, sphericity, and porosity. The measured parameter was statistically significant 95% of the time, according to the computed F-value for these attributes, which was greater than the F-critical.

Table 7: ANOVA for physical properties (porosity, sphericity, weight, bulk density, surface area, and aspect ratio)

Source of Variation	SS	Df	MS	F	P-value	F-crit
Within Prop	6.263152	2	3.131576	1.071708	0.373045	3.885294
Within MC	237.9898	6	39.66497	13.5744	9.95E-05	2.99612
Error	35.06451	12	2.922043			
Total	279.3175	20				

The observed changes from the preceding table were determined to be significant for moisture content but not statistically significant at a 95% confidence range for the other characteristics.

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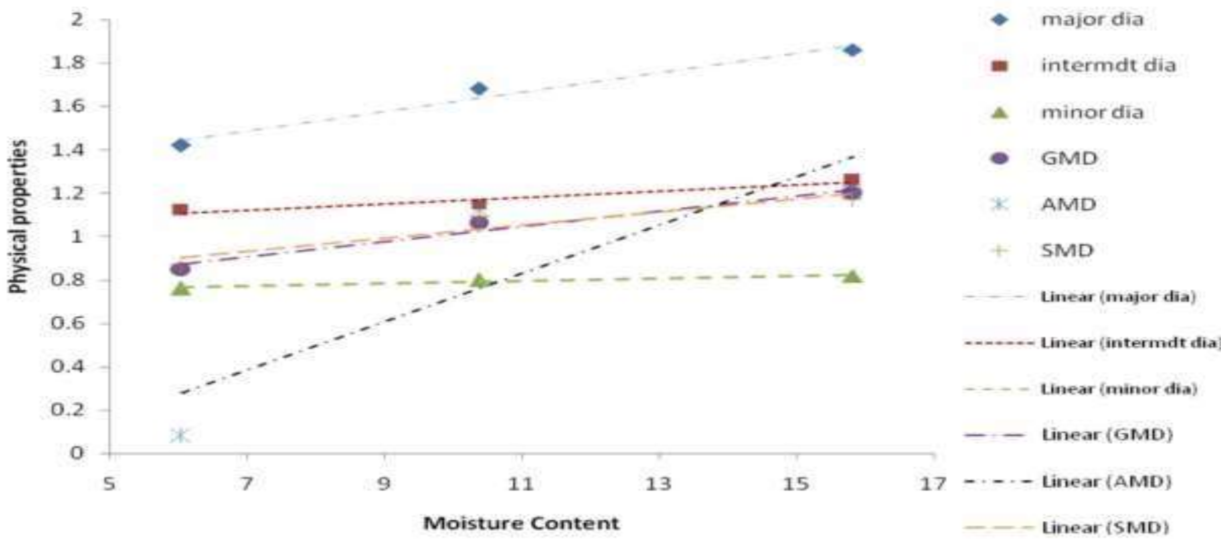

Fig.1. The Plot of the effects of Moisture Content on The Physical Properties of *Mucuna Veracruz*
MD = 0.044MC + 1.175 $R^2 = 0.971$
ID = 0.014MC + 1.020 $R^2 = 0.937$ MnD= 0.006MC + 0.728
$R^2 = 0.935$ SMD = 0.03MC + 0.721 $R^2 = 0.895$ GMD = 0.035MC + 0.656 $R^2 = 0.967$ AMD = 0.111MC - 0.392
$R^2 = 0.754$

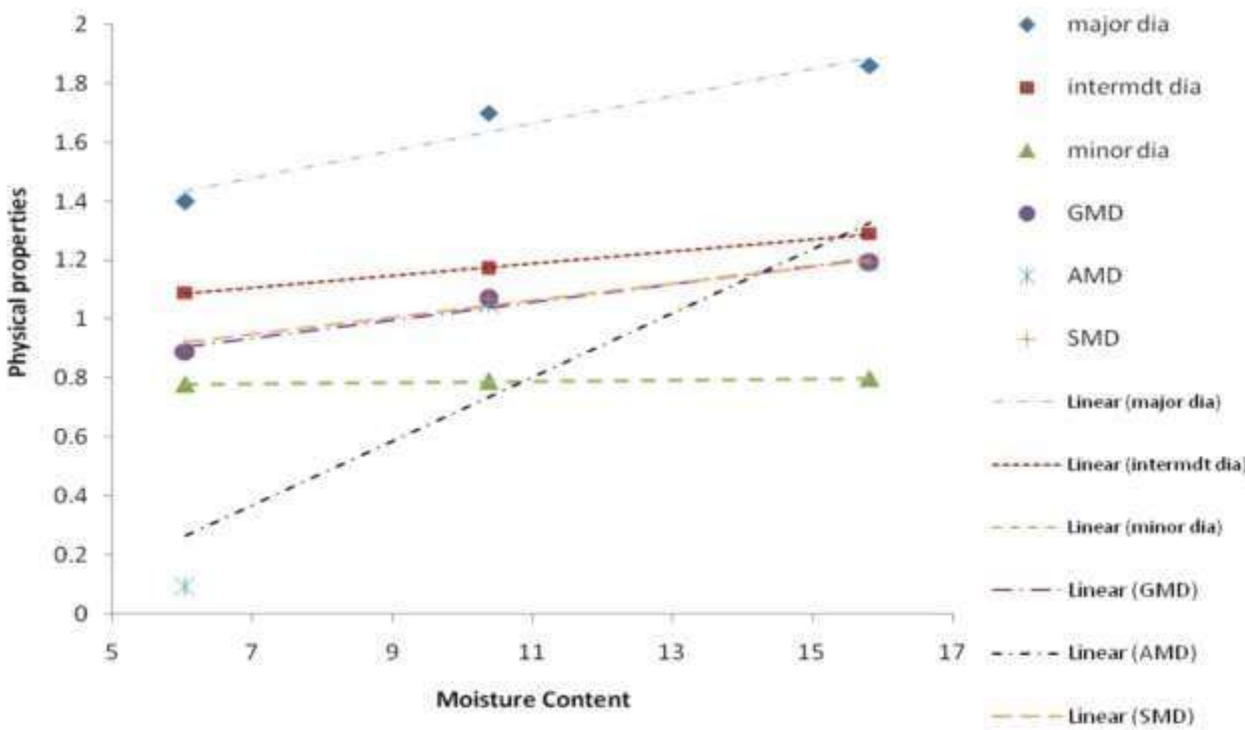

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Fig. 2: Plot of effects of moisture content on axial dimensions of *Mucuna pruriens*
MD = 0.046MC + 1.156 R^2 = 0.943
ID = 0.020MC + 0.962 R^2 = 0.997 MnD = 0.002MC + 0.768 R^2 = 0.995 AMD = 0.108MC - 0.392 R^2 = 0.792 GMD = 0.030MC + 0.724 R^2 = 0.967 SMD = 0.028MC + 0.752 R^2 = 0.978

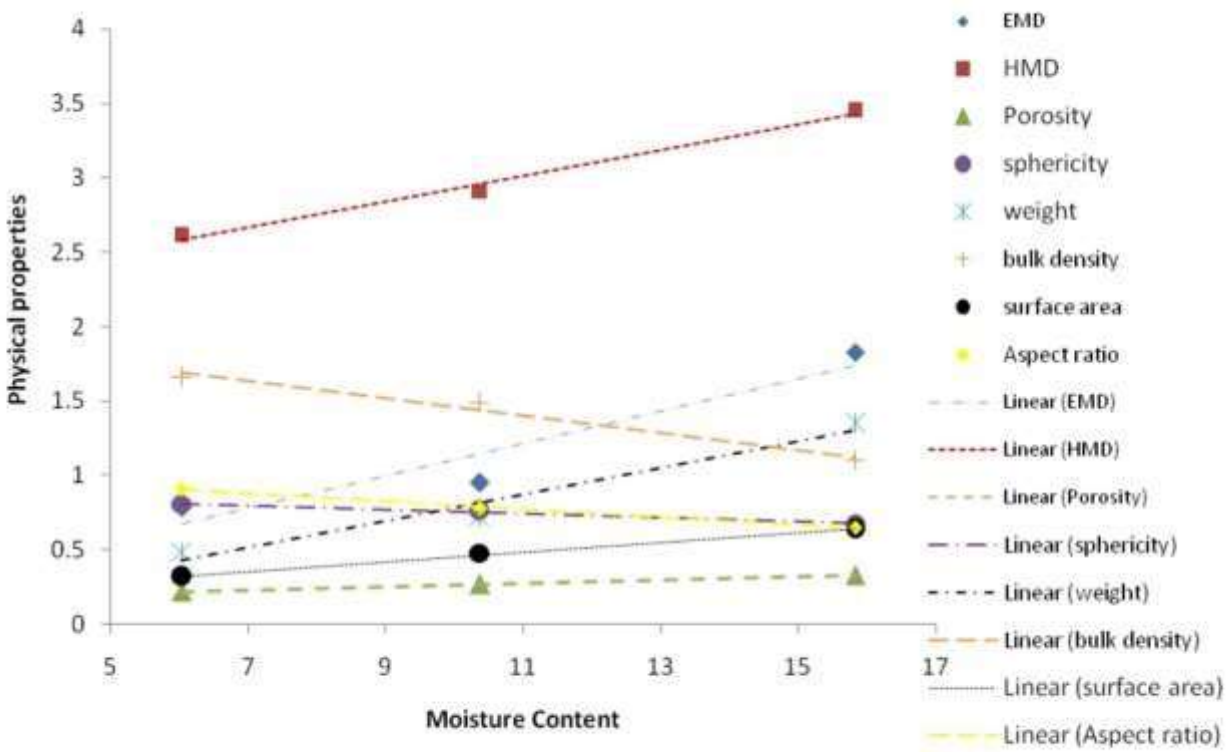

Fig. 3: Plot of Effects of Moisture Content on Other Physical Properties of *Mucuna Pruriens* AR = -0.026MC + 1.064 R^2 = 0.995 HMD = 0.086MC + 2.061 R^2 = 0.990 BD = -0.057MC + 2.038 R^2 = 0.975 EQD = 0.108MC + 0.022 R^2 = 0.904 Wgt = 0.089MC - 0.104 R^2 = 0.961 Psty = 0.011MC + 0.152 R^2 = 0.999 Sphty = -0.013MC + 0.893 R^2 = 0.995 SA = 0.032MC + 0.13 R^2 = 0.995

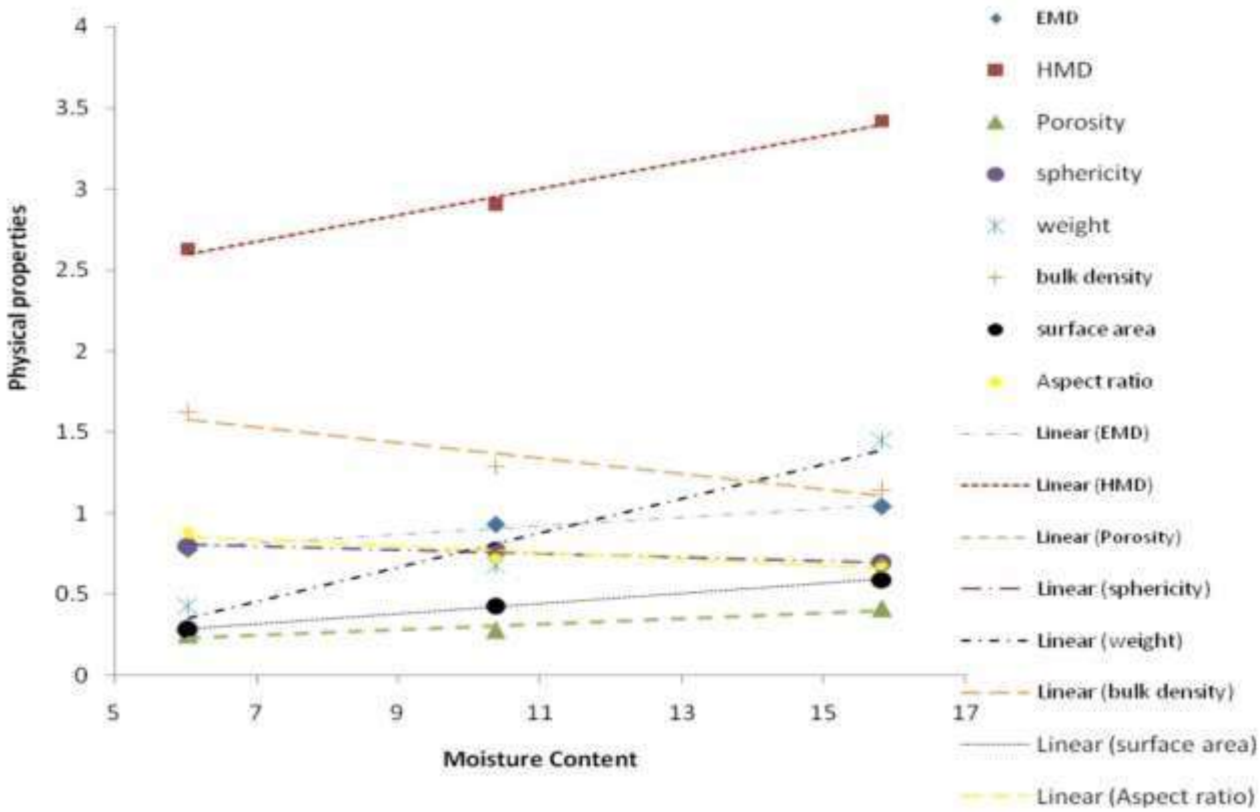

Fig. 4: Plot of Effect of Moisture Content on the Physical Properties of *Mucuna Veracruz* AR = -0.02MC + 0.977 R^2 = 0.884 HMD = 0.081MC + 2.108 R^2 = 0.986 BD = -0.048MC + 1.867 R^2 = 0.924 EQD = 0.026MC + 0.634 R^2 = 0.976 Wgt = 0.105MC - 0.284 R^2 = 0.952 Prsty = 0.016MC + 0.134 R^2 = 0.923 Sphrty = -0.011MC + 0.875 R^2 = 0.964 SA = 0.031MC + 0.093 R^2 = 0.997

Discussions

The axial dimensions, such as the major, intermediate, and minor diameters, increased linearly with increases in moisture content, according to the tables and graphs above. The numbers obtained ranged from 1.4 to 1.83, 1.09 to 1.29, and 0.78 to 0.8 cm, respectively, because the Mucuna Pruriens seeds expanded as a result of moisture intake, while Veracruz increased linearly from 1.42 to 1.86, 1.12 to 1.26, and 0.76 to 0.82 cm, respectively. Similar to what was seen for African oil beans, the mean values of the AMD, GMD, and SMD were found to be statistically identical (p=0.005) for both species [15].

As the moisture content rose from 6.04% to 15.82% for Mucuna pruriens and from 1.62 to 1.14

g *g*

(cm_3) for Veracruz, the bulk density changed from 1.66 to 1.10 **(cm___$_3$).** This suggests that the moisture in the seeds increased the samples' weight, but this increase was less than the Mucuna samples' volumetric expansion.

For Jatropha seeds, the same declining tendency was documented [16]. As the moisture content rose from 6.04 to 15.82%, the seed volume for Veracruz and Pruriens increased from 0.48 to 0.64 **(cm^2)** and from 0.47 to 0.62, respectively. This increase in volume may be explained by the seeds' increased size dimension as a result of their moisture consumption. As the moisture content rose from 6.04 to 15.82%, the surface area increased from 0.33 to 0.64 **(cm^2)** and from 0.28 to 0.59
(cm^2).

A similar downward trend was seen for Jatropha seeds [16]. Veracruz and Pruriens seed volumes grew from 0.48 to 0.64 **(cm^2)** and from 0.47 to 0.62, respectively, as the moisture content increased from 6.04 to 15.82%. The increased size dimension of the seeds due to their moisture consumption may account for this volume increase. The surface area increased from 0.33 to 0.64 cm^2 and from 0.28 to 0.59 cm^2while the moisture content increased from 6.04 to 15.82%.

Similar to cowpeas, the increase can be the result of their dependence on the size dimension of Mucuna beans [12]. However, the sphericity and aspect ratio decrease with increasing moisture content, as in the case of African Yam Bean [17]. Similar to what researchers discovered with chicken pea, it was demonstrated that the porosity increased as the moisture level increased [18].

Conclusion

Given that the physical characteristics of both studied species changed linearly with moisture level, it was determined that the information derived from Mucuna Pruriens' physical characteristics may be utilised to build Veracruz's food processing, handling, and storage systems. Except for bulk density, sphericity, and aspect ratio, which all decreased with increasing moisture content, most were found to rise.

According to Oluka (2009), the axial dimensions of both tested species, including the major diameter (MD), intermediate diameter (ID), minor diameter (MnD), geometric mean diameter (GMD), arithmetic mean diameter (AMD), equivalent mean diameter (EQD), square mean diameter (SMD), and harmonic mean diameter (HMD), increased as the moisture content rose. As the moisture content rises, the porosity also rises, which is comparable to what researchers found with chicken pea [18]. However, when the moisture content increases, bulk density, sphericity, and aspect ratio decrease, as demonstrated by the African Yam Bean [17]. Blaise [19] is also in agreement with this conclusion.

Recommendations

It was suggested that more studies be done on the functional and proximate characteristics of these biomaterials in order to determine how they may be used in the food and processing sectors with a higher moisture content.

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