Journal of Experimental Research

March 2018, Vol 6 No 1

Email: editorinchief.erjournal@gmail.com
editorialsecretary.erjournal@gmail.com

Received: ***Dec. 2017***
Accepted for Publication: *March 2018*

Determination of Physical Properties of A*fzelia africana* Seeds.

Eze OC[1]. and Igwillo UC[1].

[1]Department of Agricultural and Bioresources Engineering, Enugu State University of Science and Technology, Enugu.

Author for Correspondence:** ***ugoigwillo@yahoo.com

Abstract

Selected physical properties of *Afzelia africana* seeds were determined at four moisture levels: 10.60%, 12.80%, 15.20% and 18.40% wet basis (w.b). The seeds were categorized in three batches according to their weights: Batch I (2g<m<2.99g), Batch II (2.99<m<3.99g) and Batch III (3.99<m4.99g) respectively. As moisture content ranged from 10.60%-18.40 %(w.b), the mean values of length, width and thickness ranged from 21.7820.91-25.2251.11mm, 10.5500.92-12.9700.17mm and 7.9461.03-10.6070.82mm from batch I – III respectively. Arithmetic and geometric mean diameters, sphericity and projected area ranged from 13.5700.43-15.8230.41mm, 12.2450.33-14.4300.39mm, 57.800.07-75.600.03% and 186.21828.42-256.03712.98mm^2 respectively. Unit mass, unit volume, aspect ratio and surface area ranged from 2.5450.23g-4.5150.09g, 7.8970.89-12.7951.03cm^3, 49.2465.37-51.5191.97% and 467.28525.72-657.73435.59mm². Porosity, true and bulk densities ranged from 41.85110.57-45.8247.72%, 0.6560.28-1.0900.30g/cm^3 and 0.3050.08-0.4310.18g/cm^3 respectively. The highest mean value of coefficient of static friction (0.460.07) was recorded for iron steel structural surface for batch III, batches I and II recorded the lowest (0.32±0.04) for plywood surface. The highest mean value of angle of repose (32.1388^o) was recorded for plywood surface for batch I while the lowest 25.3569^o was recorded for batch II on iron steel surface among the three batches.

Keywords: Physical properties, *Afzelia africana* seeds, moisture content.

INTRODUCTION

Afzelia africana seed (called akpalata in Igbo, apa in Yoruba, kawo in Hausa and gayoki in Fulani) is a largely cultivated crop in savannah forest and the drier parts of the forest regions of Africa. The tree is a widespread specie with a broad rather open crown and massive branches (most readily recognized by the conspicuous hard blackish fruits), up to 30.5m high and a girth up to 3 m. It produces a flat pod 12-17 x 5-8 x 3.5 cm hard, slightly rounded, dark brown to black, and gladiolus with a distinct beak at one end. Each pod contains several black seeds. The seeds have waxy orange cup-like structure at their base and are used in Nigeria generally as soup thickener and for other industrial uses.

To meet up with the demand of the seeds and its consumption need of the populace, as regard to its nutritive and industrial uses, it is essential to determine the physical characterizations of the seeds which would be useful in design of processing equipment and machines for its processing and handling operations. These parameters are also important for the design and fabrication of all equipment involved in processing such as harvesting, sorting, grading and extraction of the kernels from the seeds (Gursoy and Guzel, 2010).

Studies of physical properties are necessary to determine the appropriate equipment design for processing, transportation, separating, storing and drying systems (Liny et al. 2013; Izuchukwu and Folarin, 2013). Access to scientific information on the physical characteristics of seed for the design of the equipment storage, transportation, cleaning, processing and packaging seems necessary (Azadbakht et al. 2015). Shape, size, volume, surface area, density, porosity, color and appearance are some of the physical characteristics which are important in many problems associated with design of a specific machine or analysis of the behaviour of the product in handling the material (Mohsenin, 1986). The fundamental knowledge of seed dimensions is useful in calculating and creating a machine (Suwanpayak et al. 2016). The shape and size are important in the separation from foreign material and in the design and development of grading and sorting machineries (Singh et al. 2010). Bulk and true densities of agricultural materials are important in order to design equipment for its processing, sorting, grading, transporting and storing (Idowu et al. 2012). Some studies on the effect of moisture content on physical properties of some agricultural materials have been conducted intensively, examples include: African breadfruit seeds var. *Inversa* (Igwillo et al. 2017), horse eye bean (Eze and Eze, 2017); *Pofaki* variety of pea (Azadbakht et al. 2015); *Moringa oleifera* seeds (Ndukwe et al. 2014); doum palm fruit (Aremu and Fadele, 2010); some varieties of wheat, barley, chickpea and lentil seeds (Gursoy and Guzel, 2010); African yam bean (Asoiro and Ani, 2011); barnyard millet grain and kernel (Singh et al. 2010); cowpea (Davies and Zibokere, 2011; Faleye et al. 2013); soybean (Kibar and Ozturk, 2008; Tavakoli et al. 2009); pigeon pea (Khanbarad et al. 2014); castor seed (Gharibzahedi et al. 2011), corn (Seifi and Alimardani, 2010a), sunflower seeds (Seifi and Alimardani, 2010b), sandbox seeds (Idowu et al. 2012), NERICA paddy (Agu and Oluka, 2013), coriander seeds (Sharanagat and Goswami, 2014); pistachio nuts (Peyman et al. 2013); sorghum (Simonyan et al. 2007) et cetera.

However, little, if any, is available in literature about the physical properties of Afzelia africana seeds. Therefore, the actual significance of this study is that it would provide useful information from the determined physical properties of Afzelia africana seeds which would be relevant in designing handling, storage and processing equipment and systems for the seeds.

Fig. 1: Afzelia africana seed pod.

Fig. 2: *Afzelia africana* seeds.

MATERIALS AND METHODS

Ripe *Afzelia africana* (akpalata) seeds that were used for this research were obtained from Abakpa market in Enugu, Enugu East local Government Area of Enugu State. The seeds were identified by Prof. A.I. Izundu and Dr. Mbaekwe of the Department of Botany, Nnamdi Azikiwe University, Awka. It was ensured that the seeds were free of dirt and other foreign materials. The seeds were later taken to bio-processing laboratory of the Department of Agricultural and Bioresources Engineering, Enugu State University of Science Technology where research was conducted to ascertain the physical properties of *Afzelia africana* seeds. An electronic digital weighing balance (Mettler Toledo) of model XP204 and an accuracy of ±0.001 g was used to weigh hundred samples of *Afzelia africana* seeds. The method of Karaj and Muller (2010) was used in sorting the seeds according to batches based on their unit weights. The batches were arranged in this form: first batch was all seeds mass greater than 2.00g and less than 2.99g; second batch was all seeds mass greater than 2.99g and less than 3.99g; and third batch was all seeds mass greater than 3.99g and greater or equal to 4.99g. That is, Batch (I): $2g<m<2.99g$; Batch (II): $2.99g<m<3.99g$ and Batch (III): $3.99g<m\geq4.99g$.

Oven-drying method (Aremu and Fadele, 2011; Asoiro and Ani, 2011; Ndukwe et al. 2014; Igwillo et al. 2017; Eze and Eze, 2017) was used to determine the initial moisture content of the seeds. 100 seeds were picked randomly and oven-dried at $103\pm1^{o}C$, using electric oven (model: OKH-HX-1A) for 72 hours until there was no change in its mass. A desiccator plate was used to avoid moisture absorbance of the seeds from the atmosphere. Initial moisture content was determined as 8.2% (w.b). Soaking seed samples in water for 12 hours, 18 hours, 24 hours and 36 hours gave a moisture level of 10.6%, 12.8%, 15.2% and 18.4% (w.b) respectively. A 0-25mm range Vernier caliper with an accuracy of ±0.01mm was used to measure the axial dimensions: length (L), width (W), and thickness (T) of the seeds. Arithmetic mean diameter (AMD) was calculated using the relationship (Mohsenin, 1986; Eke et al. 2007; Tavakoli et al. 2009; Seifi and Alimardani, 2010a; Davies and Zibokere, 2011; Suwanpayak et al. 2016):

$$AMD = \frac{L + W + T}{3} \quad - \quad - \quad - \quad (1)$$

Where:
AMD = arithmetic mean diameter (mm), L = length (mm), W = width (mm), T = thickness (mm). Geometric mean diameter (GMD) was calculated as (Singh et al. 2010; Khanbarad et al. 2014):

$$GMD = (LWT)^{\frac{2}{3}} \quad - \quad - \quad - \quad (2)$$

Where: GMD = geometric mean diameter (mm), L = length (mm), W = width (mm), T = thickness (mm).

Sphericity (S_p) was calculated using the equation (Davies and Zibokere, 2011; Gharibzahedi et al. 2011; Liny et al. 2013):

$$\frac{(LMT)^{0.333}}{L} \quad - \quad - \quad - \quad (3)$$

Where: S_p = sphericity (%), L,W,T = length (mm), width (mm) and thickness (mm).
Aspect ratio was calculated using the formula (Seifi and Alimardani, 2010b):

$$R_\alpha = \frac{W}{L} \times 100 \quad - \quad - \quad - \quad (4)$$

Where:
R_a = Aspect ratio (%), W,L are width and length (mm).
Unit volume (V_u) of the seeds was determined based on the assumption that *Afzelia africana* seeds are similar to scalene ellipsoid where L>W>T. The formula was derived from the triaxial ellipsoid volume with the equation (Mohsenin, 1986)

$$V\mu = {}^{4}/_{3\pi}\,(LWT)/100 \quad - \quad - \quad - \quad (5)$$

Where: V_u = unit volume (cm^3), π= 3.142, L,W,T, = length, width and thickness (mm).
Surface area (A_s) of the seeds was calculated using the formula (Nwuba, 1994)::

$$As = d_1 d_2 \quad - \quad - \quad - (6)$$

Where: A_s = Surface area (mm^2), d_1, d_2 = length of orthogonal minor and major axes (mm).

Projected area (A_p) was determined using the equation (Aremu and Fadele, 2011):

$$A_p = ({}^{4}/_{\pi})\, LW \quad - \quad - \quad - \quad (7)$$

Where: A_p = projected area (mm^2), L,W = length and width (mm).

Water displacement method (Aremu and Fadele, 2011; Dadvar et al. 2017) was used to determine the true density of the seeds. The true density (ρ_t) of the seed was evaluated by finding the ratio of the mass to that of volume of water displaced, as shown below:

$$\rho_t = {}^{m}/_{v} \quad - \quad - \quad - \quad (8)$$

Where: m is the mass of seed (g), and v is the volume of water displaced (cm^3).
Bulk density was also calculated as (Eze and Eze, 2017; Aremu and Fadele, 2011):

$$\rho_b = {}^{M_b}/_{V_b} \quad - \quad - \quad - \quad (9)$$

Where: $_b$ = Bulk density (g/cm^3), M_b = bulk mass (g) and V_b= bulk volume (cm^3).
Porosity (ε) was calculated using the equation (Igwillo et al. 2017):

$$\varepsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \times 100 \quad - \quad - \quad (10)$$

Where: ε = porosity (%),ρ_t, ρ_b = true and bulk densities (g/cm^3).

Duncan's new multiple range test statistical tool was used to group the seeds according to their seed size. This grouping in batches aided the sorting of the seeds according their unit mass.

RESULTS

Results obtained from the experiments are presented in tabular forms. Mean values of *Afzelia africana* seeds are categorized according to moisture levels and according to batches using Duncan's Multiple Range Test mean comparison technique. Table 1 shows mean comparison of moisture content on length, width, thickness, unit mass, AMD and GMD of the seeds.

An Official Publication of Enugu State University of Science & Technology ISSN: (Print) 2315-9650 ISSN: (Online) 2502-0524

Table 1: Mean effect comparison of moisture content on length, width, thickness, unit mass, AMD and GMD of *Afzelia africana* seeds.

Moisture content level (%) w.b	Length (mm)	Width (mm)	Thickness (mm)	Unit Mass (g)	AMD (mm)	GMD (mm)
10.60	**23.412±177[a]**	**11.658±1.29[a]**	**9.298±1.40[a]**	**3.551±0.87[a]**	**14.839±1.11[a]**	13.563±1.11[a]
12.80	23.432±1.79[a]	11.666±1.28[a]	9.305±1.40[a]	3.569±0.85[a]	14.856±1.10[a]	13.631±1.09[a]
15.20	23.487±1.79[a]	11.742±1.26[a]	9.304±1.40[a]	3.572±0.85[a]	14.880±1.11[a]	13.668±1.06[a]
18.40	23.478±1.84[a]	11.844±1.04[a]	9.339±1.39[a]	3.605±0.82[a]	14.888±1.11[a]	13.6799±1.06[a]
Batch						
I	21.782±0.91[a]	10.550±0.92[a]	7.946±1.03[a]	2.545±0.23[a]	13.570±0.43[a]	12.245±0.33[a]
II	23.349±1.18[b]	11.663±0.70[b]	9.375±0.59[b]	3.663±0.17[b]	15.204±0.66[b]	14.231±0.37[b]
III	25.225±1.11[c]	12.970±0.17[c]	10.607±0.82[c]	4.515±0.09[c]	15.823±0.41[c]	14.430±0.39[b]

Batches size: (I) 2g<m<2.99g, (II) 2.99g<m<3.99g, (III) 3.99g<m≥4.99g. Each value is the mean of 30 test samples. Means and standard deviation (±) in columns with the same superscript are not significantly different at $p \leq 0.05$. AMD = Arithmetic mean diameter and GMD = geometric mean diameter.

The mean effect comparison of moisture content and batches on sphericity, projected area, unit volume and aspect ratio of *afzelia africana* seed are shown in Table 2.

Table 2: Mean effect comparison of moisture content and batches on sphericity, projected area unit volume and aspect ratio of *Afzelia Africana* seeds.

Moisture content level (%) w.b	Sphericity (%)	Projected area (mm^2)	Unit volume (cm^3)	Aspect ratio (%)
10.60	0.572±0.08[a]	219.451±37.69[a]	10.803±2.44[a]	50.396±4.51[a]
12.80	0.593±0.07[a]	219.437±37.77[a]	10.815±2.44[a]	50.408±4.51[a]
15.20	0.590±0.05[a]	219.445±37.77[a]	10.827±2.44[a]	50.689±3.99[a]
18.40	0.602±0.07[a]	219.460±37.76[a]	10.851±2.43[a]	50.437±3.80[a]
Batch				
I	57.80±0.07[a]	186.218±28.42[a]	7.897±0.89[a]	49.246±5.37[a]
II	63.40±0.06[b]	216.089±25.99[b]	11.780±1.32[b]	50.683±4.12[a]
III	75.60±0.03[a]	256.037±12.98[c]	12.795±1.03[c]	51.519±1.97[a]

Batches size: (I) 2g<m<2.99g, (II) 2.99g<m<3.99g, (III) 3.99g<m≥ 4.99g. Each value is the mean of 30 test samples. Means and Standard deviation (±) in columns with the same superscript are not significantly different at p ≤ 0.05

Table 3 shows the mean effect comparison of moisture content and batches on true/bulk densities, porosity and surface area of *Afzelia africana* seeds.

Table 3: Mean effect comparison of moisture content and batches on true and bulk densities, porosity and surface area of *Afzelia africana* seeds

Moisture content level (%) w.b.	True density (g/cm^3)	Bulk density (g/cm^3)	Porosity (%)	Surface area (mm^2)
10.60	1.126 ± 1.74^{a}	0.338 ± 0.13^{a}	46.001 ± 8.22^{ab}	585.405 ± 92.96^{a}
12.80	0.722 ± 0.30^{a}	0.340 ± 0.13^{a}	46.886 ± 8.31^{b}	585.417 ± 95.004^{a}
15.20	0.728 ± 0.32^{a}	$0.3510.15^{a}$	42.803 ± 8.66^{ab}	585.471 ± 94.002^{a}
18.40	0.756 ± 0.33^{a}	0.376 ± 0.18^{a}	40.653 ± 9.12^{a}	585.502 ± 94.98^{a}
Batch				
I	0.656 ± 0.28^{a}	0.305 ± 0.08^{b}	41.851 ± 10.57^{a}	467.285 ± 25.72^{a}
II	0.752 ± 1.51^{a}	0.318 ± 0.13^{a}	45.824 ± 7.72^{a}	631.328 ± 50.29^{b}
III	1.090 ± 0.30^{a}	0.431 ± 0.18^{a}	44.583 ± 7.57^{a}	657.734 ± 35.59^{c}

Batches size: (I) 2g<m<2.99g, (II) 2.99g<m<3.99g, (III) 3.99g<m≥ 4.99g. Each value is the mean of 30 test samples. Means and standard Deviation (±) in columns with the same superscript are not significantly different at p ≤ 0.05.

Table 4 shows the mean values of coefficient of static friction of the seeds on three structural surfaces.

Table 4: Mean effect of coefficient of static friction of *Afzelia africana* seeds

	Coefficient of Static friction		
Moisture content levels (%) w.b	**Plywood**	**Iron Steel**	**Aluminium**
10.60	0.34 ± 0.05^{a}	0.45 ± 0.05^{a}	0.40 ± 0.06^{a}
12.80	0.33 ± 0.03^{a}	0.45 ± 0.07^{a}	0.39 ± 0.06^{a}
15.20	0.32 ± 0.04^{a}	0.46 ± 0.07^{a}	0.38 ± 0.06^{a}
18.40	0.32 ± 0.05^{a}	0.41 ± 0.07^{a}	0.37 ± 0.05^{a}
Batch			
I	0.32 ± 0.04^{a}	0.44 ± 0.07^{a}	0.37 ± 0.07^{a}
II	0.32 ± 0.04^{a}	0.43 ± 0.07^{a}	0.39 ± 0.06^{a}
III	0.34 ± 0.05^{a}	0.49 ± 0.07^{a}	0.39 ± 0.06^{a}

An Official Publication of Enugu State University of Science & Technology ISSN: (Print) 2315-9650 ISSN: (Online) 2502-0524

sphericity value of 75.600.03% obtained in batch III at a moisture level of 18.40% (w.b) indicated that Afzelia africana seeds are more spherical than a maximum value of 40.900.075% obtained at a moisture level of 18% (w.b) for FARO 52 variety of NERICA paddy (Agu and Oluka, 2013) and 39.310.58% obtained at a moisture level of 4.16% (w.b) for Maephurng variety of upland rice seed (Suwanpayak et al. 2016). Afzelia africana seeds are more spherical than a maximum value of 62.31% obtained for corn (Seifi and Alimardani, 2010a) at moisture level of 4.73% (w.b); 69% obtained at a moisture level of 52.5% (w.b) for sandbox seeds (Idowu et al. 2012); 60.06.00% obtained at a moisture level of 20.10% (w.b) for African breadfruit seeds var. Inversa (Igwillo et al. 2017), 67.00.03% obtained by Karaj and Muller (2010) and 68.440.63% obtained by Bamgboye and Adebayo (2012) for Jatropha curcas seeds at a moisture level of 8.0% (w.b) and 25.85% (d.b) respectively. The seeds are less spherical than the maximum value of 85.933% obtained for African yam bean by Asoiro and Ani, (2011); 107.00% for African kidney bean by Izuchukwu and Folarin, (2013); 87.25% for soybean grains by Tavakoli et al. (2009); 92.00.02% for sorghum grains by Simonyan et al. (2007); 91.00% for doum palm fruits reported by Aremu and Fadele, (2011); 88.20% for horse eye bean by Eze and Eze, (2017) and 89.0% for pigeon pea by Khanbarad et al. (2017). The sphericity of the seeds was found to be within the same range of 67.60-74.18% obtained for dika nuts by Orhevba et al. (2013); 75.70% for coriander seeds by Sharanagat and Goswami, (2014); 73.62-77.07% for pistachio nuts by Peyman et al. (2013); 72.880.03% for Jackbean seeds by Eke et al. (2007) and 74.35% for black gram obtained as reported by Liny et al. (2013).

Table 3 shows that the true and bulk densities, porosity and surface area of Afzelia africana seeds increased from 0.6560.28 – 1.0900.30g/cm^3, 0.3050.08-0.4310.18g/cm^3, 41.85110.57-45.8247.72% and 467.28525.72-657.73435.59mm^2 from batch I to batch III respectively as moisture content increased from 10.60-18.40% (w.b). Igwillo et al. (2017) reported a similar trend for African breadfruit seeds var. Inversa as true and bulk densities and surface area of the seeds increased from 1.0990.1-1.1100.3g/cm^3, 0.8350.43-0.9380.21g/cm^3 and 64.1912.64-114.2510.00mm^2 as moisture content increased from 10.50-20.10%(w.b). An increase in porosity has been similarly observed from 0.6206-2.6854% for African yam bean (Asoiro and Ani, 2011); 43.2-51.02% for corn (Seifi and Alimardani, 2010a) and from 43.290.35-44.480.11 for soybean grains (Tavakoli et al. 2009) as moisture content ranged from 2.84-3.13% (w.b); 4.73-22% (w.b) and 6.92-21.19% (d.b) respectively. At a maximum true density of 1.0900.30g/cm^3 Afzelia africana seeds are likely to sink in water. The seeds are less dense than the maximum values of 2.1059g/cm^3 obtained for African yam bean (Asoiro and Ani, 2011); 1.2279g/cm^3 for African kidney bean (Izuchukwu and Folarin, 2013); 1.20951g/cm^3 for cashew nut (Bart-Plange et al. 2012) and 1.1125g/cm^3 for Dura variety of oil palm fruit (Owolarafe et al. 2007), but denser than the maximum value of 0.6580.035g/cm^3 for Moringa oleifera seeds obtained by Ndukwe et al. (2014); 1.035g/cm^3 for Jatropha curcas seeds obtained by Bamgboye and Adebayo, (2012); 1.02g/cm^3 obtained for Samaru sorghum grains by Simonyan et al. (2007); 0.98333g/cm^3 for soybean obtained by Kibar and Ozturk (2008) and 0.91278g/cm^3 for pistachio nuts obtained by Peyman et al. (2013).

Table 4 shows that the mean range of values of coefficient of static friction of Afzelia africana seeds obtained on plywood (0.320.04-0.340.05), iron steel (0.440.07-0.460.07) and aluminium (0.390.06-0.370.07) structural surfaces increased as moisture content ranged from 10.60-18.40% (w.b). This is in tandem with the trend obtained by Sharanagat and Goswami (2014) for coriander seeds within a moisture range of 8.73-15.85% (w.b); IAR-339-1, IT86D-1010 and Ife Brown varieties of cowpea within a moisture range of 15-30% (d.b) obtained by Davies and Zibokere, (2011). The range of static coefficient of friction obtained on plywood surface is less than the range 0.4030.016-0.4600.016 for Giza 3 variety of chickpea seeds reported by Eissa et al. (2010) at a moisture range of 11.6-25.4% (d.b); 0.55 for Jatropha curcas seeds obtained by Bamgboye and Adebayo (2012) at a moisture level of 25.85% (d.b); 0.48-0.60 for Sc 704 variety of corn (Seifi and Alimardani, 2010a) at a moisture range of 4.73-22%(w.b). However, it is within the range of 0.300.004-0.430.007 for dika nuts (Orhevba et al. 2013) within a moisture range of 8.74-13.75% (w.b). The range is greater than the mean values of 0.16940.0264 for African yam bean (Asoiro and Ani, 2011) as moisture content ranged from 2.84-3.13% (w.b) and mean value of 0.130.01 reported by Izuchukwu and Folarin (2013) for African kidney bean. The range 0.440.07-0.460.07 obtained for iron steel is greater than the range of 0.3250.010-0.3760.010 for Giza 195 variety of chickpea seeds for stainless steel surface obtained by Eissa et al. (2010); 0.100.01 for African kidney bean for galvanized steel surface (Izuchukwu and Folarin, 2013) and 0.390.003 for dika nuts for galvanized steel surface at a moisture level of 13.75% (w.b) obtained by Orhevba et al. (2013); but less than the range of 0.4800.001-0.6740.005 for Moringa oleifera seeds obtained at a moisture range of 10.250-32.343% (d.b) by Ndukwe et al. (2014). Similarly, the range 0.370.07-0.390.06 of static coefficient of friction obtained for Afzelia africana seeds on aluminium surface follows a similar trend but greater than the range 0.097-0.1996 obtained by Asoiro and Ani (2011) for African yam bean at a moisture range of 2.84-3.23% (w.b).

Table 5 shows that the mean dynamic angle of repose of Afzelia africana seeds increased from 25.8891±1.99-32.1388±2.57^o for batch I on plywood surface, 25.3569±1.91 - 26.101±2.05^o for batch II on iron steel surface, and 27.0756±1.94 - 28.1938±1.86^o for batch III on aluminium surface respectively. The increase of dynamic angle of repose was due to increase of internal friction with increase of contact surface area among the seeds. It is a known fact that any increase in internal friction among seeds will bring a resultant increase in the angle of repose of the seeds. The maximum dynamic angle of repose (32.1388^o) was recorded for batch I on plywood structural surface. This was higher than the maximum value of 29.430.76^o for African kidney bean (Izuchukwu and Folarin, 2013); 24.50^o for African yam bean (Asoiro and Ani, 2011); 26.2^o for sandbox seeds (Idowu et al. 2012); 29.7^o for IT86D-1010 variety of cowpea seeds (Davies and Zibokere, 2011); but lower than 50.45^o for pigeon pea moisture level of 30% (w.b); 60.10^o reported by Igwillo et al. (2017) for African breadfruit seeds var. Inversa at a moisture level of 20.10% (w.b); 58^o and 57^o reported by Seifi and Alimardani, (2010a) and Seifi and Alimardani, (2010b) for Sc 704 variety of corn and SHF8190 variety of sunflower seeds at maximum moisture levels of 22% (w.b) and 22% (w.b) respectively.

CONCLUSION

In conclusion, this study has shown that increase in moisture content of Afzelia africana seeds have resultant effects on the physical properties of the seeds. All the physical properties studied were found to increase with increase in moisture content of the seeds. Sorting and ranging the seeds according to their weights and categorizing them into batches were helpful in determination of their physical properties. The physical properties studied: length, width, thickness, surface area, projected area, volume, arithmetic and geometric mean diameters, aspect ratio, sphericity, coefficient of static friction, dynamic angle of repose et cetera will provide useful and fundamental information in agricultural machine design for postharvest technology and engineering.

RECOMMENDATION

Since the cracking of Afzelia africana seeds is still done manually with stones with consequent breakages and staining of the seeds, it is recommended that the mechanical properties of the seeds be determined which would be used in the design and development of machines for handling and processing the seeds.

REFERENCES

Agu OS, Oluka SI. (2013). Selected physical and mechanical properties of NERICA paddy. Journal of Experimental Research.1;(6):25-38.

Aremu AK, Fadele OK. (2011). Study of some properties of Doum palm fruit (Hyphaene thebaica Mart.) in relation to moisture content. African Journal of Agricultural Research. 6;(15):3597-3602.

Asoiro FU, Ani AO. (2011). Determination of some physical properties of African yam beans. Pacific Journal of Science and Technology. 12;(1):374-380.

Azadbakht M, Ghajarjazi E, Amiri E, Abdigaol F. (2015). Determination of some physical and mechanical properties of pofaki variety of pea. International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering. 9;(5):486-493.

Bamgboye AI, Adebayo SE. (2012). Seed moisture dependent on physical and mechanical properties of Jatropha curcas. J. Appl. Environ. Biol. Sci. 7;(11):157-164.

Bart-Plange A, Mohammed-Kamil AP, Teye E. (2012). Some physical and mechanical properties of cashew nut and kernel grown in Ghana. International Journal of Science and Nature. 3;(2):406-415.

Dadvar AA, Bayati M, Afkari-Sayyah AH, Rasekh M. (2017). Some physical and mechanical properties of bergamot (Citrusaurantium). J. Appl. Environ. Biol. Sci. 7;(11):157-164.

Davies RM, Zibokere DS. (2011). Effect of moisture content on some physical and mechanical properties of three varieties of cowpea (Vigna unguiculata (L) Walp. Agricultural Engineering International: CIGR Journal, Manuscript No. 1700.13;(1):1-16.

Eke CNU, Asoegwu SN, Nwandikom GI. (2007). Some physical properties of jackbean seed (Canavalia ensiformis). Agricultural Engineering International: the CIGR Ejournal Manuscript FP 07.9;(14):1-11.

Eissa AHA, Mohamed MA, Moustafa H, Alghannam ARO. (2010). Moisture dependent physical and mechanical properties of chickpea seeds. Int J Agric & Biol Eng.. 3; (4):80-93.

Eze PC, Eze CN. (2017). Determination of some physical and mechanical properties of horse eye bean (Mucuna sloanei) from south eastern Nigeria. Journal of Experimental Research. 5;(1):33-41.

Faleye T, Atere OA, Oladipo ON, Agaja MO. (2013). Determination of some physical and mechanical properties of some cowpea varieties. African Journal of Agricultural Research. 8;(49):6485-6487.

Gharibzahedi SMT, Mousavi SM, Ghahderjani M. (2011). A survey on moisture-dependent physical properties of castor seed (Ricinus communis L.). Australian Journal of Crop Science. 5;(1):1-7.

Gursoy S, Guzel E. (2010). Determination of physical properties of some agricultural grains. Research Journal of Applied Sciences, Eng. and Technology. 2;(5):492-498.

Idowu DO, Abegunrin TP, Ola FA, Adediran AA, and Olaniran JA. (2012). Measurement of some engineering properties of sandbox seeds (Hura crepitans). Agriculture and Biology Journal of North America. 3;(8):318-325.

Igwillo UC, Eze PC, Eze CN. (2017). Selected physical and aerodynamic properties of African breadfruit (Treculia africana) seeds from south eastern Nigeria. Journal of Experimental Research.5;,(1):7-17.

Izuchukwu AC, Folarin AA. (2013). Physical properties of African kidney bean (Phaseolus vulgaris L) and their processing impact. Food Biology. 2;(2):18-23.

Karaj S, Muller J. (2010). Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha curcas L. Industrial Crops and Products.04;(001):1-10.

Khanbarad SC, Joshi ND, Mohapatra D, Sutar RF, Joshi DC. (2014). Effect of moisture content on some selected physical properties of pigeon pea (Cajanus cajan). Journal of Grain Processing and Storage. 1;(1):06-12.

Kibar H, Ozturk T. (2008). Physical and mechanical properties of soybean. Int. Agrophysics. (22):239-244.

Liny P, Manish SK, Shashikala M. (2013). Geometric and gravimetric characteristics of black gram. International Journal of Development Research. 3;(9):013-016.

Mohsenin NN. (1986). Physical Properties of Plant and Animal Materials. 2nd Edition (revised) Gordon and Breach Science Publishers. New York, USA. pp.1, 79-127.

Ndukwe KS, Nwuba EIU, Nwajinka CO, Ngwanga NV, Amaefule DO. (2014). Moisture-dependent properties of unshelled Moringa oleifera seed. International Journal of Agriculture and Biosciences. 3;(4):149-157.

Nwuba EIU, Arinze EA, Braide FG. (1994). Development of whole crop cowpea thresher as affected by grain and stalk properties. Journal of Agricultural Engineering and Technology. 2; 67-79.

Orhevba BA, Idah PA, Adebayo SE, Nwankwo CC. (2013). Determination of some engineering properties of dika nut (Irvingia gabonensis) at two moisture content levels as relevant to its processing. International Journal of Engineering Research and Applications. 3;(2):182-188.

Owolarafe OK, Olabige MT, Faborode MO. (2007). Physical and mechanical properties of two varieties of fresh oil palm fruit. Journal of Food Engineering. 78;1228-1232.

Peyman L, Mahmoudi A, Ghaffari H. (2013). Some physical properties of pistachio nuts. International Journal of Agriculture and Crop Sciences. 5; (7):704-711.

Seifi MR, Alimardani R. (2010a). The moisture content effect on some physical and mechanical properties of corn (sc 704). Journal of Agricultural Science. 2;(4):125-134.

Seifi MR, Alimardani R. (2010b). Moisture-dependent physical properties of sunflower seed (SHF8190). Modern Applied Science. 4;(7):135-143.

Sharanagat VS, Goswami TK. (2014). Effect of moisture content on physio-mechanical properties of coriander seeds (Coriandrum sativum). Agric Eng Int: CIGR Journal, 16;(3):166-172.

Simonyan KJ, EL-Okene AM, Yiljep YD. (2007). Some physical properties of Samaru sorghum 17 grains. Agricultural Engineering International: the CIGR Ejournal Manuscript FP 07008. (9): 1-15.

Singh KP, Mishra HN, Saha S. (2010). Moisture-dependent properties of barnyard millet grain and kernel. Journal of Food Engineering. 96;598-606.

Suwanpayak N, Wijitpap T, Srisongkram P, Nokkou R. (2016). Some physical and mechanical properties of upland rise seed (Maephurng variety). International Journal of Advances in Agricultural & Environmental Engineering (IJAAEE). 3;(2):336-338.

Tavakoli H, Rajabipor A, Mohtasebi SS. (2009). Moisture-dependent some engineering properties of soybean grains. Agricultural Engineering International: the IGR Ejournal Manuscript 1110. 11;1-14.