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SELECTED PHYSICAL AND AERODYNAMIC PROPERTIES OF AFRICAN BREADFRUIT (*Treculia africana*) SEEDS FROM SOUTH EASTERN NIGERIA

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ABSTRACT

Physical and aerodynamic properties of African breadfruit (*Treculia africana*) seeds were studied at four moisture levels: 12.50, 15.00, 17.50 and 20.10% dry base (w.b). As moisture content increased from 10.50 to 20.10% (w.b), the average weight, major diameter, minor diameter, intermediate diameter, geometric mean diameter, arithmetic mean diameter of the seeds ranged from 0.35±0.08 to 0.60g±0.04g, 8.08±0.90 to 10.05±0.60mm, 4.04±0.53 to 5.00±0.10mm, 2.96±0.43 to 4.60±0.40mm, 4.52±0.45 to 6.03±0.20mm, 5.03±0.45 to 6.55±0.50mm respectively. Also the equivalent diameter, surface area, sphericity, projected area and aspect ratio of the seeds ranged from 4.75±0.42 to 6.03±0.41mm, 64.19±12.64 to 114.25±10.00mm^2, 56±8.00 to 60±6.00%, 25.64±5.10 to 39.47 ± 3.80mm^2, and 50±0.08 to 50±0.01mm respectively. The volume ranged from 0.35 ± 0.014 to 0.73 ± 0.014cm^3, while the true and bulk densities ranged from 1.099 ± 0.141 to 1.110±0.424g/cm^3 and 0.835±0.43 to 0.938±0.21g/cm^3. Porosity decreased from 15.01±1.5 to 5.60±0.4% as moisture content increased from 10.50 to 20.10% (w.b). The angle of repose ranged from 39.80 to 60.10^0 with increase in moisture content. The optimum parboiling time, temperature and moisture content for hulling African breadfruit seeds were determined as 7.5minutes, 57.5^{o}C and 20.10% (w.b) respectively. The terminal velocity of the seeds and kernels ranged from 12.5 to 17.02m/s and 11.40 to 13.36m/s. Drag coefficient and drag force of the hulls ranged from 0.1 to 0.7 and 0.518×10^4 to 0.858×10^4N, while the drag coefficient and drag force of the seeds and kernels ranged from 0.09 to 0.2, 4.50 ×10^4 to 6.00×10^4 N; 0.2 to 0.3 and 4.0×10^4 to 5.10×10^4 N respectively. This indicates that optimum separation can be achieved effectively without any loss of the seeds if the results obtained are properly applied in processing of African breadfruit.

Keywords: African breadfruit seeds, moisture content, physical properties, aerodynamic properties.

INTRODUCTION

African breadfruit (*Treculia africana*) *is a monoecious dicotyledonous plant which* belongs to the botanical family *Maraceae* and genus *Treculia. The tree is* a great economic asset which produces large, hard, fibrous and spongy fruit-heads covered with rough pointed outgrowths, which contain seeds embedded at various depths in the fleshy, spongy and pulpy part of the fruit-head. The fruit-head lies between 0.1-0.3m long × 0.9-0.2m wide, varies in shape, size and skin texture - which ranges from smooth thorough to spiny, usually round, spherical, oval or oblong in shape with a diameter of up to 0.5m, weighing 0.25 – 6 kg. The fruit-head is usually light green, yellowish green or yellow in colour when mature. The fleshy pulp is used for fodder while the wood of the tree crop has potential use in paper manufacturing. A mature African breadfruit seed, which is essentially ellipsoidal in shape (Nwigbo et al. 2008), or roughly oval and spherical in shape (Omobuwajo et al. 1999), is made up of an outer covering, the hull and the inner edible endosperm. The hull is usually *light or dark brown in colour,* coated with a gummy and sticky substance which must be removed during processing*. The fruit-heads are usually harvested, stored to ferment for about 3-5 days, then mashed and separated by washing the solubilized pulp off the seeds in a basket with running water, and later sun dried. Sometimes a machete and/or an axe is used to crack open the fruit-head before the seeds are extracted from the fruit-head. The dried seeds are processed in a manner somewhat similar to paddy rice through parboiling or some sort of moist heat treatment prior to hulling. When hulled, the seeds may be cooked and eaten as the main dish* *like rice, or roasted and eaten as snack in the same way as peanut. It could also be cooked with fresh corn into porridge*. Several researchers determined the nutritional properties of African breadfruit seeds such as Nwigbo et al. (2008) and Osabor et al. (2009). There are three varieties of African breadfruit seeds namely: var. A*fricana*, var. *Inversa* and var. *Mollis*, (Wikipeadia, 2014). V*ar. Africana and var. Inversa* are the most widely cultivated, consumed and readily obtainable varieties in our environment (Wikipeadia, 2014). Several researchers studied physical and aerodynamic properties of agricultural materials such as *NERICA* grains (Eze and Oluka, 2014), soy grains (Maria, 2004), acorn nuts (Mahbobeh, 2011), some varieties of wheat, barley, chickpea, and lentil (Gürsoy and Güzel, 2010). The aerodynamic properties of *Turgenia latifolia* seeds and wheat kernels, as well as wheat kernel and straw materials have been studied by (*Nalbandi* et al. 2010 and Khoshtaghaza and Mehdizadeh, 2006) respectively. In order to design equipment for the handling, conveying, separation, drying, aeration, storing and processing of agricultural materials, it is necessary to determine their physical properties as a function of moisture content. Undesirable materials such as light grains, weed seeds, chaff, etc can be removed with air flow. If the air speed is high, the product will be blown off along with undesirable materials; if the air speed is low, the materials would not be separated from each other and there will be undesirable materials with the product. Therefore, for pneumatic conveyance of agricultural products, the range of proper air streams should be used, which can be determined from their aerodynamic properties especially terminal velocity, drag coefficient and drag force. These properties are indispensable in the design and development of appropriate post-harvest processing machinery for agricultural products. The objective of this study was to study some physical and aerodynamic properties of African breadfruit seeds var. *Inversa* as a function of moisture content, to experimentally determine the optimum parboiling temperature and time of the seeds as well as the terminal velocity of the hulls using a set of prototype machines.

MATERIALS AND METHODS

Determination of Physical Properties:

Sample preparation:

A sample of fresh, raw, cleaned and unshelled African breadfruit (*Treculia africana*) seeds var. *Inversa* was bought at Eke Awka market in Awka, Anambra State, Nigeria. Figures 1, 2, and 3 show samples of African breadfruit seeds, kernels and hulls.

Fig. 1: A sample of African breadfruit seeds var. *Inversa*.

Fig. 2: A sample of African breadfruit kernels var. *Inversa*.

Fig. 3: A sample of African breadfruit hulls var. *Inversa*.

The initial moisture content was determined using oven method set at 103 ±1°C for 72 hours and cooled with a desiccator using the method as reported by Gbadam et al. (2009) and according to ASAE, (1999) standards. The weight loss of the sample was recorded and the moisture content in percentage was calculated using the relationship given by Simonyan et al. (2007):

$$Mc_{wb}\% = \frac{w_i - w_d}{w_i} \times 100 \quad - \quad (1)$$

Where: MC_{wb} = moisture content, wet basis, %; W_i = initial mass of sample, kg; W_d = dried mass of sample, kg.

The initial moisture content of the sample was found to be 10.50% (w.b). The sample was subdivided into five smaller samples and conditioned to moisture levels: 12.50, 15.00, 17.50 and 20.10% (w.b) by parboiling for 1.5, 2.5, 5.0 and 7.5 minutes respectively. The amount of water used for parboiling was determined using the relationship given by Simonyan et al. (2007):

$$Q = \frac{W_i\,(M_f - M_i)}{100 - W_f} \quad - \quad - \quad (2)$$

Where: Q = Amount of water added, kg; W_i = Initial mass of sample, g; M_i = Initial moisture content of sample, % (w.b); M_f = Final moisture content of sample, % (w.b).

Determination of size

For each sample, 30 seeds were randomly selected. For each seed, the axial dimensions were measured namely, a = major diameter, b = minor diameter, and c = intermediate diameter using a Venire caliper (Gilson Tools, Japan) with accuracy 0.01mm.

Determination of shape

The shape of the seed was expressed in terms of its sphericity and aspect ratio expressed in percentage. The dimensions obtained for the 30 randomly selected seeds were used to compute the index based on the recommendations of (Mohsenin, 1986; Owolarafe et al. 2007 and Davies, 2009).

$$\Psi = \frac{(a \times b \times c)^{1/3}}{a} \times 100 \quad - \quad - \quad (3)$$

Where: Ψ Sphericity (%); a, b, c = mean values of major diameter (mm), minor diameter (mm) and intermediate diameter (mm) respectively.

The aspect ratio was calculated using the equation given by Owolarafe et al. (2007) and Kheiralipour, (2008):

$$Ra = \frac{b}{a} \times 100 \quad - \quad - \quad (4)$$

Where: R_a = Aspect ratio (%); b and a rare mean values of minor diameter (mm) and major diameter (mm) respectively.

Determination of seed mass

An electronic scale (sensitivity 0.01g) was used to measure the individual weight (W_t) of 30 randomly selected seeds of each sample. The mean weight of the seeds was determined and recorded.

Determination of arithmetic mean diameter (D_a), equivalent diameter (D_p) and geometric mean diameter (D_g)

Arithmetic mean diameter was calculated using the formula as given by Eke et al. (2007) and Liny et al, (2013):

$$Da = \frac{(a + b + c)}{3} \quad - \quad - \quad (5)$$

Geometric diameter was calculated using the formula as reported by (Davies, 2009):

$$Dg = (a \times b \times c)^{1/3} \quad - \quad - \quad (6)$$

Equivalent diameter was calculated using the equation as reported by (Seifi and Alimardani, (2010a):

$$Dp = \frac{[a(b+c)^2]^{1/3}}{4_i} \quad - \quad - \quad (7)$$

Where: *a, b, c* are mean values of major diameter (mm), minor diameter (mm) intermediate diameter (mm) respectively.

Determination of projected area (A_p) and surface area (A)

The projected area of African breadfruit seeds was calculated using the formula given by *Nalbandi et al, (2010)*:

$$Ap = \frac{\pi}{4} \times a \times b \quad - \quad - \quad (8)$$

Where: A_p= projected area (mm^2), = pi; a and b are mean values of major diameter (mm) and minor diameter (mm).

Surface area was calculated using the formula as reported by Ismail et al, (2009), Eze and Oluka, (2014), Davies and Zibokere, (2011), and Mahbobeh et al, (2011):

$$A = \pi D_g^2 \quad - \quad - \quad - \quad (9)$$

Where: *A* = Surface area (mm^2); π = pi; D_g = geometric mean diameter (mm).

Determination of bulk density ($_b$), Volume (V), true density (t) and porosity (g)

The true density (t) was calculated by dividing the unit mass of the seed by its volume according to the formula as reported by Davies, (2009); Eze and Oluka, (2014):

$$P_t = M/V \quad - \quad - \quad - \quad (10)$$

Where: P_t = true density (g/cm^3); *M* = unit mass (g); *V* = volume (cm^3).

Porosity of the seeds was calculated using the equation given by Mohsenin, (1986); Varnamkhasti et al, (2007); Seifi and Alimardani, (2010a); and Owolarafe et al, (2007):

$$\varepsilon = \frac{Pt - Pb}{Pt} \times 100 \quad - \quad - \quad (11)$$

Where: ε = (%); ρ*b* = = bulk density (g/cm^3); ρ*b* = true density (g/cm^3).

Determination of dynamic angle of repose ($_r$)

The height and diameter of the conical heap were measured and the angle of repose was calculated using the formula reported by Jideani et al, (2009); Davies, (2009); Chukwu and Sunmonu, (2010):

$$\theta r = \tan^{-1} {}^{2H}/D \quad - \quad - \quad (12)$$

Where: θ_r = Dynamic angle of repose (°); *H* = height of the heap (m); *D* = diameter of the heap (m).

Determination of Aerodynamic Properties

Terminal velocity (V_t)

A set of prototype machine was developed and used to experimentally determine the terminal velocity of African breadfruit hulls. The 2800rpm 2-in-1 positive-displacement electric blower, powered by a 2700rpm single-phase electric motor, was used to construct a vertical wind tunnel system using a transparent hollow cylinder. The lower end of the cylinder was covered with 1.5mm wire netting to prevent test samples from falling into the blower. An air velocity meter, (Lutron AM10 Anemometer, range 0 – 30m/s; accuracy ±5%) attached at the base of the cylinder, was used to measure the velocity of air required to lift test samples. Each sample was put into the lower end of the cylinder before the blower was switched on. Air velocity was varied by varying the height of the cylinder from the blower (at 0.10m, 0.20m and 0.30m); however, the velocity of air could not lift up the seeds because the blower is small. The blower could not lift the seeds and kernels but could lift the hulls. The equation below was then used to determine the terminal velocity of the seed and kernel as given by Mohsenin, (1986); *Nalbandi et al. (2010)*:

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$$Vt = \left[\frac{2w\,(Pt - Pf)}{CApPtPf}\right]^{1/2} \quad - \quad - \quad - \quad (13)$$

where: Vt = terminal velocity (m/s); w = weight of particle (kg); $_t$ = density of particle (kg/m^3); $_f$ = density of air (1.1644kg/m^3 at room temp; C = drag coefficient (dimensionless); A_p = projected area of particle (m^2).

Reynolds number (R_e)

Reynolds number was calculated using the equation given by Nwigbo et al. (2008):

$$Re = \frac{DVtPf}{\mu f} \quad - \quad - \quad (14)$$

Where: R_e = Reynolds number (dimensionless); D = arithmetic mean diameter of particle (m).

V_t = terminal velocity (m/s); ρf = mass density of air (1.1644 kg/m^3 at room temperature, 30^{o}C); ρf = absolute viscosity of air (1.983 × 10^{-5}kg/ms at room temperature, 30^{o}C).

Drag coefficient (C) and Drag force (F_d)

Drag force was calculated based on the formula given by Mohsenin, (1986):

$$Fd = CAp\rho f \frac{Vt^2}{2} \quad - \quad - \quad (15)$$

Where: F_d = drag force (N); C = drag coefficient (dimensionless); A_p = projected area (m^2). $_f$ = mass density of air at room temp. (1.1644kg/m^3); V_t = terminal velocity (m/s).

RESULTS AND DISCUSSION

Physical Properties:

Table 1: Physical Properties of African breadfruit seeds var. *Inversa* at different moisture contents (% w.b).

Moisture Contents, (% w.b)	10.50 (control)	12.50	15.00	17.50	20.10
Weight, W_t (g)	0.35±0.113	0.45±0.085	0.51±0.085	0.55±0.071	0.60±0.057
Major Diameter (mm)	8.08 ±0.90	8.16±0.91	9.02±1.22	9.50±0.50	10.05±0.60
Minor Diameter (mm)	4.04±0.53	4.08±0.38	4.11±0.52	4.40±0.60	5.00±0.10
Intermediate Diameter (mm)	2.96±0.43	3.66±0.56	3.89±0.78	4.00±0.71	4.60±0.40
Geo. Mean Diameter, D_g (mm)	4.52±0.45	4.88±0.37	5.16±0.57	5.42±0.30	6.03±0.20
Arith. Mean Diameter, D_a (mm)	5.03±0.45	5.30±0.39	5.67±0.60	5.97±0.40	6.55±0.50
Equivalent Diameter, D_p (mm)	4.75±0.42	4.85±0.36	5.16±0.57	5.42±0.50	6.03±0.41
Surface Area, A (mm^2)	64.19±12.64	74.82±11.45	83.66±18.55	92.30±15.50	114.25±10.00
Sphericity, Ψ (%)	56±8.00	57±7.00	57.4±7.00	58±2.00	60±6.00
Projected Area, A_p (mm^2)	25.64±5.10	26.15±3.94	29.12±5.76	32.83±4.50	39.47±3.80
Aspect Ratio, R_a (mm)	50±0.08	50±0.08	46±0.09	50±0.01	50±0.01
Volume, V (cm^3)	0.35±0.014	0.45±0.014	0.53±0.015	0.64±0.017	0.73±0.014
True Density, (g/cm^3)	1.099±0.1	1.103±0.2	1.105±0.2	1.108±0.3	1.110±0.3
Bulk Density, ρ (g/cm)	0.835±0.43	0.851±0.25	0.878±0.28	0.908±0.25	0.938±0.21
Porosity, ε (%)	15.01±1.5	13.51±1.4	11.04±1.5	8.30±0.5	5.60±0.4
Angle of Repose, θ_r (°)	39.80	44.90	53.40	55.00	60.10

Table 1 shows mean physical properties of African breadfruit seeds var. *Inversa* within the studied moisture range (w.b). Axial dimensions and other physical properties increased with increased in moisture content. Figure 3 shows the effect of moisture content on axial dimensions of African breadfruit seeds and on other physical properties followed a similar trend. The geometric mean diameter, arithmetic mean diameter, equivalent diameter, surface area, sphericity, projected area, volume, true and bulk density all increased with increased in moisture content. The increasing trend in axial and geometric dimensions was due to filling of capillaries and voids upon absorption of moisture and subsequent swelling. Simonyan et al (2007), reported a similar trend for Samaru sorghum 17 grains; Seifi and Alimardani, 2010a, reported a similar trend for sunflower seed var. *SHF8190*, Agu and Oluka, (2013), reported a similar trend for *NERICA* paddy. True and bulk densities of African breadfruit seeds increased with increased in moisture content. Seifi and Alimardani, (2010b), reported that the true density of two corn varieties var. *Sc 704* and var. *Dc 370* increased from 1250kg/m^3 to 1325kg/m^3, and 997kg/m^3 to 1170kg/m^3 as moisture content increased from 4.73-22% (w.b) for *Sc 704* variety and 5.15-22% (w.b) for *Dc 370* variety respectively. Karaj and Müller, (2010), reported that the bulk density of *Jatropha curcas* seeds and kernels increased from 0.250±0.007g/cm^{3}to 0.441±0.005g/cm^3, and 0.306±0.014g/cm^3 to 0.481±0.07g/cm^3 respectively. Figures 4, 5 and 6 shows the effect of moisture content on parboiling, axial dimensions and bulk densities of African breadfruit seeds respectively. Porosity decreased with increase in moisture content. Seifi and Alimardani, (2010a), reported a similar trend for sunflower seeds var. *SHF8190*.

3.2 Aerodynamic Properties

Table 2: Aerodynamic Properties of African Breadfruit var. *Inversa* Seeds, Kernels and Hulls at different moisture contents (w.b).

Moisture Content, M.C % (w.b)	Terminal Velocity, V_{tseeds} (m/s)	Terminal Velocity, $V_{t\ kernels}$ (m/s)	Terminal Velocity, V_{thulls} (m/s)	Drag Coeff. C_{seeds}	Drag Coeff. $C_{kernels}$	Drag Coeff. C_{hulls}	Drag Force $F_{d\ seeds}$ (N)	Drag Force $F_{d\ kernels}$ (N)	Drag Force, $F_{d\ hulls}$ (N)
12.50	12.15*	11.40*	3.0±0.18	0.2#	0.3#	0.7	4.50×10^{-4}	4.00×10^{-4}	0.518×10^{-4}
15.00	12.30*	11.50*	6.1±0.20	0.2#	0.3#	0.2	5.13×10^{-4}	4.50×10^{-4}	0.623×10^{-4}
17.50	16.96*	11.70*	8.5±0.21	0.1#	0.3#	0.1	5.50×10^{-4}	4.80×10^{-4}	0.635×10^{-4}
20.10	17.02*	13.36*	9.5±0.25	0.09#	0.2#	0.1	6.00×10^{-4}	5.10×10^{-4}	0.858×10^{-4}

Table 2 shows the aerodynamic properties of African breadfruit seeds, kernels and hulls. The terminal velocity of seeds, $V_{t\ seeds,}$ kernels $V_{t\ kernels,}$ and hulls $V_{t\ hulls}$ increased from 12.15 to 17.02m/s, 11.40 to 13.36 m/s, 3.0 to 9.5m/s respectively as moisture content increased from 12.50 to 20.10% (w.b). The drag coefficient of the seeds, C_{seeds}, kernels $C_{kernels}$, hulls C_{hulls} ranged from 0.09 to 0.2, 0.2 to 0.3 and 0.1 to 0.7, while the drag force of the seeds, $F_{d\ seeds}$, kernels, $F_{d\ kernels}$ and hulls, $F_{d\ hulls}$ increased from 4.50 $\times 10^4$ to 6.00 $\times 10^4$ N, 4.00 $\times 10^4$ to 5.10 $\times 10^4$ N and 0.518 $\times 10^4$ to 0.858 $\times 10^4$N respectively. Increase in terminal velocity was due to increase in weight of the materials caused by absorbance of moisture and consequent increase in the amount of air required to lift the materials. This is in agreement with some published literature: Nalbandi et al (2010), reported that the terminal velocity of wheat (*Triticum aestivum*) kernels increased nonlinearly from 9.587 to 9.25m/s for an increase in moisture content from 7 to 20.8% (w.b), while terminal velocity of *Turgenia latifolia* seeds varied from 6.775 to 6.877m/s with increased in moisture content from 7 to 20.8% (w.b). Similarly, Khoshtaghaza and

Mehdizadeh (2006), reported that by increasing the mass of wheat kernels from 0.02 to 0.05g and moisture content from 7 to 20% (w.b.), its terminal velocity increased linearly from 7.04 to 7.74 m/s and 6.81 to 8.63 m/s respectively. Peyman et al (2013), also reported that the terminal velocity of pistachio nuts increased from 7.19 to 10.93m/s as moisture content increased from 3.70 to 30% (w.b). Nalbandi et al (2010), found that reduction in projected area of wheat kernels from 23.021 to 21.151mm^2 produced a corresponding decrease in terminal velocity from 9.58 to 9.25m/s for grade A, while reduction in projected area from 14.831 to 13.718mm^2 produced a corresponding decrease in terminal velocity from 8.75 to 8.35m/s in grade B respectively. Bart-Plange et al (2012), reported a similar result for "*Asontem*" variety of cowpea.

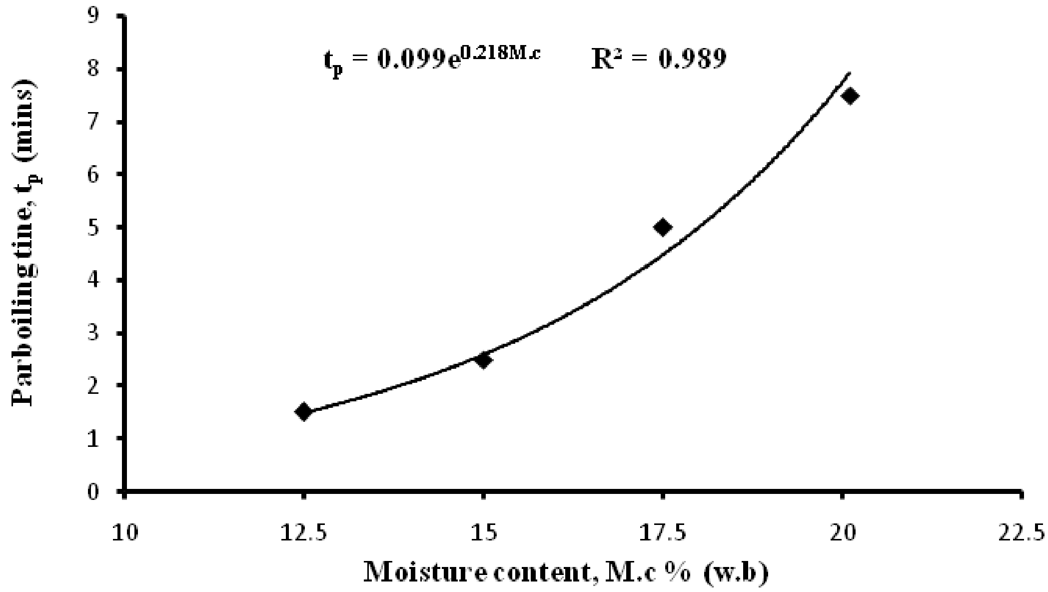

Fig. 4. Effect of parboiling time on moisture content of African breadfruit (*Treculia africana*) seeds var. *Inversa*.

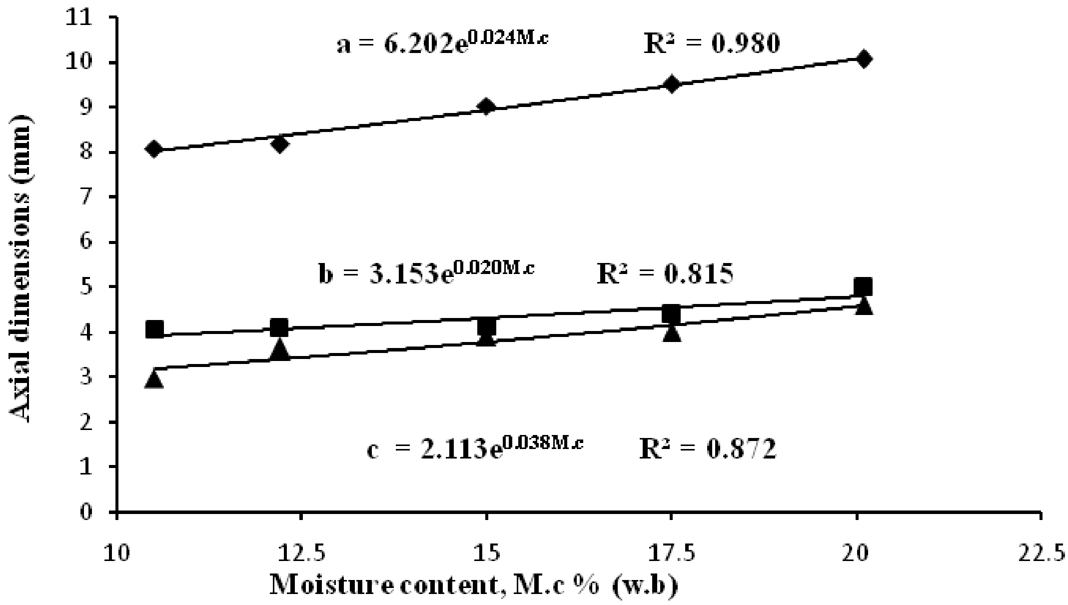

Fig. 5. Effect of moisture content on axial dimensions of African breadfruit (*Treculia africana*) seeds var. *Inversa*.

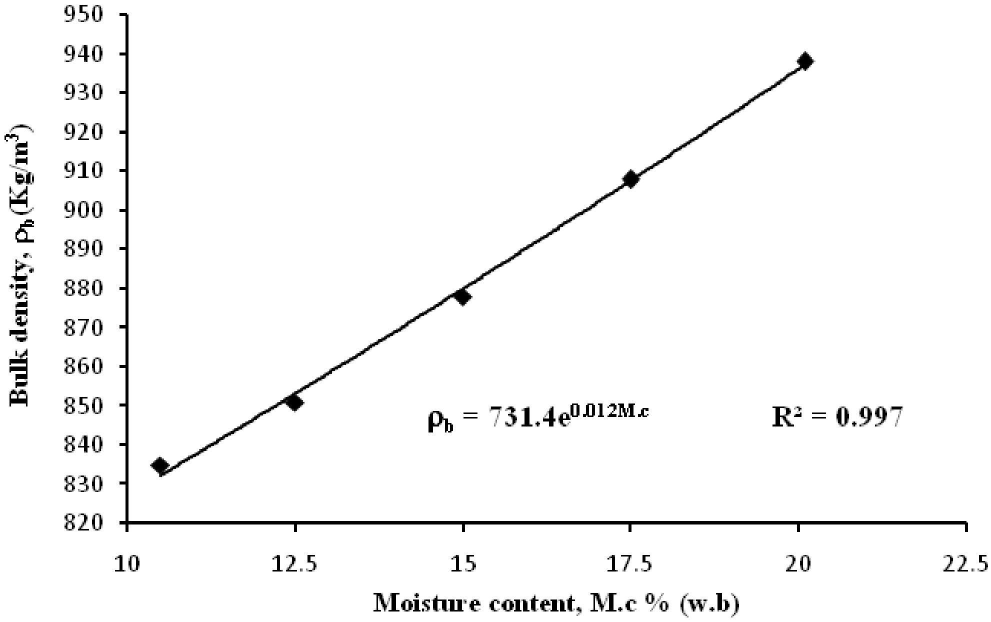

Fig.6. Effect of moisture content on bulk density of African breadfruit (*Treculia africana*) seeds var. *Inversa.*

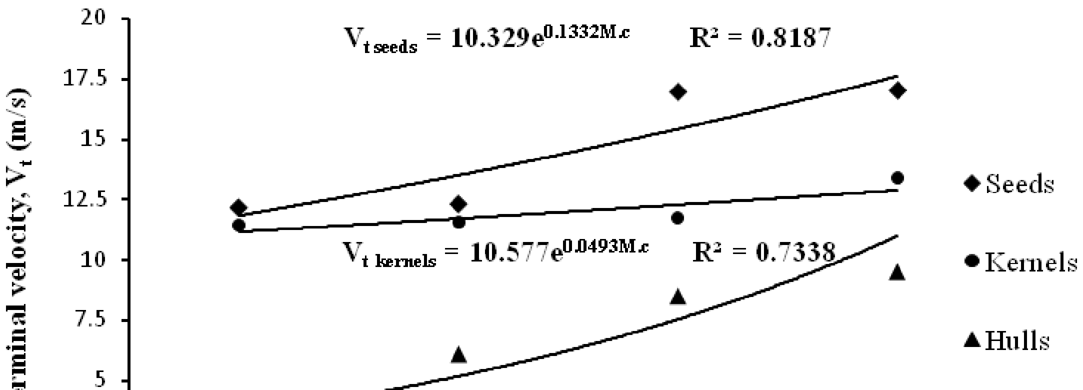

Fig. 7. Effect of moisture content on terminal velocity of African breadfruit seeds, kernels and hulls.

The moisture content of raw, fresh, cleaned and unshelled African breadfruit (*Treculia africana*) seeds var. *Inversa* is about 10.50% (w.b) immediately after harvest. Four other moisture levels obtained after condition the seeds were 12.50, 15.00, 17.50 and 20.10% (w.b). Parboiling the seeds prior to hulling increases the temperature, moisture content, axial dimensions and consequently affects other physical properties of the seeds. The maximum values of length, width, thickness of African breadfruit seeds were found to be 10.05mm, 5.00mm and 6.03mm at 20.10% m.c (w.b). These values are in tandem with the results obtained by Omobuwajo et al. (1999) and also Eze and Oluka (2014). In comparison, African breadfruit seeds are bigger than sorghum grains having principal dimensions for major diammeter, minor diammeter and intermediate diammeter as 3.70 – 4.62mm, 3.18

– 4.53mm, and 3.08 -3.44mm Simonyan *et al*., (2007), rice kernels var. *PR-106* with principal dimensions 6.61mm, 1.75mm and 1.40mm, Ghadge and Prasad, (2012), wheat grains with principal dimensions 6.78- 7.04mm, 3.45 – 3.50mm, and 2.72 -2.82mm Kheiralipour et al. (2008), some varieties of cowpea with principal dimensions 6.36 – 9.18mm, 5.24 – 7.39mm, and 4.00 – 5.42mm Nwuba et al. (1994), as well as sorrel seeds with corresponding dimensions 5.6mm, 5.2mm and 2.8mm Omobuwajo et al. (1999). The seeds are smaller than fennel seed with principal dimensions 58.87mm, 18.96mm and 15.64mm Ahmadi et al. (2009), jackbean seeds with principal dimensions 18.662mm, 13.141mm and 10.224mm Eke et al, (2007), as well as morama beans with corresponding dimensions 18.6mm, 17.1mm and 13.2mm Jideani et al. (2009). A maximum sphericity of 60% indicates that African breadfruit seeds are in the same category with *Jatropha curcas* seeds and kernels with maximum sphericity of 67% and 64% respectively Karaj and Müller, (2010), acorn grains var. *Dc 370* and var. *Sc 704* with maximum sphericity of 62.31% and 63.77% Seifi and Alimardani, (2010b), and 63 – 69% and 68% for sandbox seeds and kernels Idowu et al. (2012), but more spherical than the reported value of 38.28% for rice kernels var. *PR-106* Ghadge and Prasad, (2012) and 39.9% for *NERICA* paddy (Agu and Oluka, 2013). African breadfruit seeds var. *Inversa* are however less spherical than doum palm fruit, palm nut varieities *dura* and *tenera*, cowpea grains, African yam bean seeds and drumstick nuts with mean sphericity values of 85.19%, 75%, 67%, 78%, 85.93% and 98.26% respectively Ghadge and Prasad, (2012); Gbadam et al. (2009); Nwuba et al. (1994); Idowu et al. (2012). The relatively low sphericity of African breadfruit seeds indicate that they would slide on their flat surfaces instead of rolling on an inclined platform; this is a very important design parameter in design of hoppers and hulling equipment. Gravimetric composition indicates the seeds have maximum weight, true density and bulk density of 0.60g, 1110kg/m^{3}and 938kg/m^{3}at 20.10% m.c (w.b). Therefore, there is tendency for the seeds to sink in water (density 1000kg/m^3). The true density of the seeds was lower than the reported values of 1177.2 - 1222.4kg/m^3 for wheat varieities (Kheiralipour et al. 2008), 1112.50 kg/m^3 for oil palm fruit var. *Dura* Owolarafe et al. (2007), 1250 - 1325 kg/m^3 for corn grains var. *Sc 704* Seifi and Alimardani, (2010b), 1193.38 kg/m^3 for paddy var. *Sazandegi* Varnamkhasti et al. (2007), 1170 kg/m^3 forsoy grains Maria et al. (2004), and 1190 for jackbean seeds Eke et al, (2007), but higher than 1028.33 kg/m^3 for acorn nuts Mahbobeh et al. (2011), and 1108kg/m^3 for rice seed var. *Sadri* Jouki and Naimeh, (2012). These properties may be useful in separation and transportation of the seeds by hydrodynamic means, they can also be employed in the design of separation and cleaning processes for agricultural materials since lighter fractions will float.. The maximum dynamic angle of repose of the seeds was found to be 60.10^{o}on cement surface; this was higher than the reported value of 58^o for sunflower seeds Seifi and Alimardani, (2010a), 47.33^o for wheat grains var. *Shiraz* Kheiralipour et al. (2008), 35.83^o for paddy Varnamkhasti et al. (2007), 29.7^o for cowpea Davies and Zibokere, (2011), 26.2^o for sandbox seeds Idowu et al. (2012), and 25.53^o for acorn Mahbobeh et al. (2011), but lower than the reported value of 85^o by Eze and Oluka, (2014) at a moisture level of 33.1% (w.b). The terminal velocities of African breadfruit seeds, kernels and hulls ranged from 12.05 – 17.02m/s, 11.40 – 13.36m/s and 3.0±0.18 – 9.5±0.25m/s respectively as moisture content ranged from 12.50 – 20.10% (w.b) respectively. The difference between the terminal velocities of the kernels and the hulls indicated that pneumatic separation of the kernels from the hulls is feasible within the specified moisture range. Since the minimum terminal velocity of the kernels was 11.40m/s and the maximum terminal velocity for the hulls was 9.50m/s, it implies that for pneumatic separation of the kernels from the hulls, the air flow should be between 9.50 and 11.40m/s. Again, the experimental terminal velocity of the hulls is in agreement with the reported value of 2.90±0.15m/s by Omobuwajo et al. (1999) at a moisture level of 9.21% (w.b). The terminal velocity of African breadfruit hulls of 3.0±0.18 – 9.5±0.25m/s is in the same category with the reported values of 3.08 – 3.96 for tef grains Zewdu, (2007), 8.69 for drumstick hulls Ogunsina, (2014), 8.54 – 9.73 for sorghum grains Poomsa-ad et al. (2014), but lower than 14.76 – 15.05m/s for soy grains (Maria et al. 2004).

CONCLUSION

In conclusion, this study reveals that changes in moisture content have a significant impact on the physical and aerodynamic properties of African breadfruit seeds var. *Inversa*, and it is important to determine these properties at different moisture levels. Apart from the determined properties, the optimum parboiling time, temperature and moisture content for hulling African breadfruit seeds were found to be 7.5minutes, 57.5°C and 20.10% (w.b) respectively. This information may be useful in design and development of machinery for processing African breadfruit seeds.

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