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Aerodynamic Properties of Jatropha Seeds

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Abstract— *Accurate scientific data are crucial to efficient design of machines for cleaning, separation, drying and postharvest handling of agricultural materials such as Jatropha seeds. Therefore this study was undertaken to determine the terminal velocity and drag coefficient of native and improved accessions of Jatropha seeds at four moisture content levels (4%, 8%, 12% and 16% db). The aerodynamic properties were determined using theoretical and experimental methods. The experimental method involves the use of a vertical wind tunnel. The values of terminal velocity obtained from the theoretical methods ranged from 5.72 – 13.24m/s for native accession and 6.45 – 13.45m/s for improved accession. On the other hand, values of terminal velocity obtained from the experimental method ranged from 7.98 – 11.08 m/s for native accession and 7.42 – 11.36 m/s for the improved accession. The drag coefficient values obtained from the theoretical methods ranged from 0.27 – 1.67 and 0.292 – 1.474 for the native and improved accessions, respectively. The experimental values of drag coefficient ranged from 0.07 – 0.173 for the native accession and 0.07 – 0.164 for the improved accession. Moisture content was observed to have a significant effect (p < 0.05) on both terminal velocity and drag coefficient. Conversely, the accession had no effect on any of the aerodynamic properties. Means separation using Duncan's Multiple Range Test showed that the difference, for the experimental terminal velocity, lies between 8 to 12% for native accession and 8 to 16% for improved accession. These moisture contents are the points at which the seeds gain significant weight to alter its terminal velocity. Regression equations for determination of terminal velocity and drag coefficient of Jatropha seeds were obtained for different moisture content levels using the mass of the seeds.*

Keywords— *Jatropha, terminal velocity, drag coefficients and moisture content.*

I. Introduction

The genus *Jatropha* belongs to tribe Joannesieae of Crotonoideae in the Euphorbiaceae family and contains approximately 170 known species. Jatropha is a drought-resistant plant which is widely cultivated in the tropics as a living fence. Many parts of the plants are used in traditional medicine. The seeds, however, are toxic to humans and many animals (Heller, 1996). According to Henning (2009), the Jatropha plant may produce several fruits during the year if soil moisture is good and temperatures are sufficiently high. The seeds of Jatropha contain between 30 -35 % of a non-edible oil. The kernel of these seeds contains about 45 to 50 % of oil.

In the postharvest handling and processing of Jatropha, as with other agricultural products, air or water is often used as a carrier for transport or for separating the desirable product from the unwanted materials (Mohsenin, 1986). According to Gursor and Guzel (2010) information on physical and aerodynamic properties of agricultural products is needed in design and adjustments of machines used during harvesting, separating, cleaning, handling and storing of agricultural materials and convert them into food, feed and fodder. The properties which are useful during design must be known and these properties must be determined at laboratory conditions. Also Polyak and Csizmazia (2010) is of the opinion that the knowledge of the aerodynamic characteristics of grains (floating velocity, aerodynamic resistance coefficient) is significant for the construction and operation of machines, which treat substances with air flow and in all cases when substances are moved in the air.

In fluid dynamics, the drag coefficient, Cd, is a dimensionless quantity that is used to quantify the drag or resistance of an object in a moving stream of fluid. A lower drag coefficient indicates a lesser aerodynamic or hydrodynamic drag of the object. Terminal velocity (V_t) is an important aerodynamic property of the seeds of agricultural crops necessary in the design of pneumatic conveying systems, fluidized bed dryer and for cleaning the product from foreign materials (Ghamari et al, 2010).

Various workers have studied the behavior of agricultural particles in a moving air stream. The particles studied vary from small sized seeds such as wheat and maize on one hand and separation of undesirable particles on the other hand. Mathematical relationships as well as time versus distance techniques have been used to determine terminal velocities. Aspirator air columns have also been used to determined terminal velocity and drag coefficient. Results of several of these studies are summarized in table I.

Grover and Kashyap (1980) reported the terminal velocity of Paddy and head rice, Paddy husk, broken rice, groundnuts pods, groundnuts shell using aspirator column. Other researcher includes: Sadynam and Grover (1983) for moong (vigna radiate), Urd (Vigna mungo), Gram dal (Cicer arientinum) and Lentil or Massar (Lens esculentum). Smith and Stroshine (1985), for Black pepper (Piper nigrum), Dhania dried (Coriandrum), Jeera (Carum carui) and Soanf (Foeniculum vulgare). Sviridov (1988) for Impurities and empty dewinged seeds of broad leaved tree, Pine and spruce seed and Larch. Coates and Yazici (1990) for Jojoba seeds. Sethi et al. (1992) for Oil seeds (Raya, Toria, Gobi & Sarson). Joshi et al. (1993) for Pumkin seeds and kernels.Kram and Szot (1999) for Amarantus seeds. Ayman (2009) for Flaxseeds. Nalbandi et al. (2009) for Turgenia latifolia seeds and wheat kernels. Khoshtaghaza and Mehdizadeh. (2006) for wheat. Gürsoy and Güzel (2010) for Wheat, Barley, Lentil and Chickpea. Polyak and Csizmazia (2010) for kernels of corn. Ghamari et al. (2010) for Chickpea, Lentil and Rice. layanju et al. (2008) for Beniseed. Gharib-Zahedi et al. (2010) for Black cumin seed (Nigella sativa L.). Mahbobeh et al. (2011) for Acorn (Quercus suber L.). Polat et al. (2006) for Soybean. seyed et al. (2007) for pistachio nuts and kernels. Irtwarge and

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Igbeka, (2003) for Afrcan yam beans. Karaj and Muller (2010) for Jatropha curcas.

II. Materials and Method

The theoretical methods used by Irtwange and Igbeka (2003) for calculating terminal velocity and drag coefficient were adepted for this study namely; the $C_dV_s.NR_e$ correlation and $C_dNR_e^2$ vs NR_e correlation. Some physical properties of Jatropha seed accession at 4%, 8%, 12% and16% moisture content were carried out to obtain data to calculate the theoretical terminal velocity.

TABLE I. Terminal velocity and drag coefficient of some agricultural materials.

Agricultural Materials	Terminal Velocity (m/s)	Drag Coefficient	Source
Paddy and head rice	5.50 – 10.50	*	*Grover and Kashyap (1980)*
Paddy husk	0.33 – 2.00	*	
Broken rice	1.10 – 8.80	*	
Groundnuts, pods	6.60 – 13.20	*	
Groundnuts, shell	0.33 – 3.30	*	
Pulses			*Sadynam and Grover (1983)*
Moong (Vigna radiata)	19.75 – 27.85	*	
Urd (Vigna mungo)	17.60 – 33.90	*	
Moong washed	12.65 – 25.30	*	
Urd washed	12.65 – 24.30	*	
Gram dal (Cicer arientinum)	17.60 – 27.85	*	
Lentil or Massar (Lens esculentum)	17.60 – 32.90	*	
Malka Massar (dehusked lentil)	12.65 – 30.35	*	
Masala Constituents			*Sadynam and Grover (1983)*
Black pepper (Piper nigrum)	10.90 – 32.90	*	
Dhania dried (Coriandrum)	5.50 – 13.75	*	
Jeera (Carum carui)	4.40 – 14.85	*	
Soanf (Foeniculum vulgare)	6.60 – 16.50	*	
Loose corn cob residues	10	*	*Smith and Stroshine (1985)*
Impurities and empty dewinged seeds of broad leaved tree species	2.8 – 3.3	*	*Sviridov (1988)*
Pine and spruce seed	3.5 – 5.5	*	
Larch	4 – 7	*	
Jojoba seeds	10		*Coates and Yazici (1990)*
Jatropha	8.1 – 10.8	*	*Karaj and Muller(2010)*
Oil seeds (Raya, Toria, Gobi Sarson)	5.5 – 10.45	*	*Sethi et al.(1992)*
Pumkin seeds	4.7 – 6.5	*	*Joshi et al. (1993)*
Pumkin kernels	4.27 – 5.25	*	
Amarantus seeds	3.10 - 4.25	0.6143 - 1.0245	*Kram and Szot (1999)*
Flaxseeds	2.46 - 3.56	0.53 - 0.83	*Ayman Hafiz Amer Eissa.(2009)*
Turgenia latifolia seeds	6.775 - 6.877	0.0458 - 0.0512	*Nalbandi et al (2009)*
wheat kernels	9.587 - 9.25	0.0543 - 0.0528	
wheat	7.04 - 7.74	0.88 - 1.01	*Khoshtaghaza and Mehdizadeh. (2006)*
Wheat	7.52 - 8.14	0.588 - 1.342	*Gürsoy and Güzel (2010)*
Barley	7.04 - 7.07	0.532 - 1.708	
Lentil	7.72 - 7.78	0.577 - 0.995	
Chickpea	11.15 - 12.01	0.687 - 0.915	
kernels of corn.	8.85 - 10	*	*Polyak and Csizmazia (2010)*
Chickpea	11.13	*	*Ghamari et, al.(2010)*
Lentil	5.08	*	
Rice	4.92	*	
Beniseed	2.48 - 3.05	2.67 - 2.78	*layanju et, al. (2008)*
Black cumin seed(Nigella sativa L.)	5.6 - 5.92	*	Gharib-Zahedi *et, al. (2010)*
Acorn (Quercus suber L.)		*	*Mahbobeh Fos'hat et, al. (2011)*
Nut	19.52	*	
Kernel	16.8	*	
Hull	4.07	*	
Soybean	7.13 - 9.24	*	*Polat et al (2006)*
pistachio nuts	9.8 - 12.44	*	*Seyed et, al. (2007)*
pistachio kernels	8.30 - 11.10	*	
Afrcan yam beans	9.9 – 18.7	*	*Itwange and Igbeka (2003)*

*Not Reported

size and shape of the seeds, the length, and width and breathe of 100 seeds were measured and used to determine the geometric mean, sphericity and equivalent diameter using the following equations:

$$Dg = (LWB)^{\frac{1}{3}} \quad (1)$$

$$\psi = \frac{(LWB)^{\frac{1}{3}}}{L} \quad (2)$$

Where

Dg = Geometric mean, ψ = Spericity, L = Length, W = Weight, B = Breath

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Bulk density was determined using a glass cylinder while the particle or true density was determined use the toluene displacement method.

While Projected Area (Frontal Area) = $\frac{\pi}{4}(Dg)^2$ (Moshenin, 1986)

Two accessions of Jatropha seeds were used for the experiment of terminal velocity and drag coefficient. The first was a Native Accession purchased from the local market in Makurdi Nigeria. The second was an Improved Accession imported from Israel by the Department of Agronomy University of Agriculture Makurdi Nigeria. These imported seeds were said to have been genetically improved to increase the oil bearing capacity of the seed. Oven drying method was used to determine the moisture content of the Jatropha seed accessions using *ASAE Standards* (1998). The seeds were conditioned to the desired moisture contents of 4, 8, 12, and 16% d.b. using methods described by Kachru et al. (1994). The Bickey John Moisture Meter, model-46239-1247 which gives indications that are within ±1% moisture content of the standard oven results was used prior to tests in order to verify the moisture content of the samples.

The terminal velocities were determined by means of a vertical air column (Figure 1) constructed in the Agricultural Engineering workshop of University of Agriculture, Makurdi. The air column consists of an upper chamber square in shape made of iron metal sheet, with vertical column of height 110cm and width of 10cm. A glass window on one side of the column makes the suspended seeds visible during an experiment. The lower part of the air column consist of an air plenum of height 11cm and width 10cm and a circular chamber 50cm in diameter with a width of 12cm made from an iron sheet , housing the fan that blows the air. Attached to the circular lower part is a 1 hp electric motor used for driving a variable speed fan. Also on the circular lower part is a circular hole of 18cm in diameter covered with rectangular wire gauze (25cm x20cm) that suck in air from the atmosphere. Supporting the lower circular part is a metal leg 10cm high with a base 20cm in length. Also along the upper square column are six circular tube holes with screw covers drilled at an interval of 20cm from each other (they will be used when measuring airflow resistance). During this experiment these holes were closed to avoid air leakage (See Plate 1).

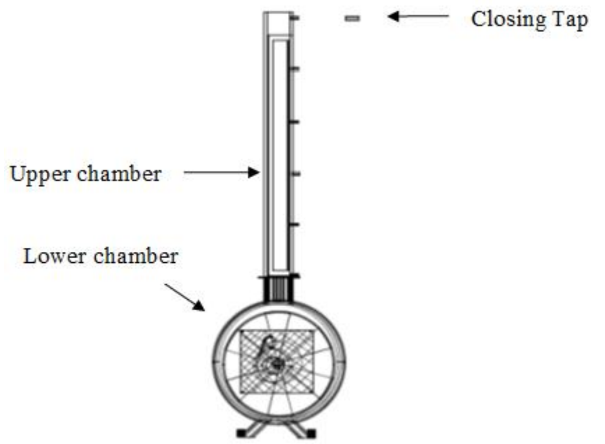

Fig. 1. Constructed air column for measuring aerodynamic properties.

The Jatropha seeds were divided into lots of 50g, 100g, 150g and 200g, for each accession and for each moisture content. The seeds in each lot were poured into the vertical column. The vertical column machine was turn on and the seed were lifted by the airstream until they became suspend in the air. A Digital Anemometer (model no. Am – 4812) was used to measure the velocity of the air that suspends the seeds. The experiments were replicated five times. The drag coefficient was calculated using the formula:

$$C_d = \frac{2W(\rho_p - \rho_f)}{V_t^2 A_p \rho_p \rho_f} \quad (3)$$

Where, W= weight of seed (Kg), ρ_p = seed density (Kg/m^3), ρ_f =Air density (Kg/m^3), V_t = terminal velocity(m/s), A_p = Projected Area (m^2)

Plate 1. Set up apparatus for terminal velocity measurement.

III. RESULT AND DISCUSSION

The results of the physical properties of two Jatropha accessions investigated at 4 to 16 % moisture contents are presented in table II. The average length of Jatropha seed ranged from 17.04 to 17.46 mm for native accession and 17.00 to 17.21mm for improved accession. The width was found to range from 11.24 to 11.58mm for native accession and 11.11 to 11.14mm for improved accession while the thickness was found to be from the range of 8.52 to 8.73mm for native accession and 8.58 to 8.79mm for improved accession. These results are close to those obtained by Karj and Müller (2010), Elepano et al. (2010**)**, and Bamgboye and Adebayo (2012). The geometric mean, equivalent diameter and sphericity range from 11.77 (0.074) to12.08 mm, 11.85 to12.17 mm and 0.691 to 0.692 mm respectively for native accession and 11.75 to11.89 mm, 11.81 to 11.95 mm and 0.691 to 0.692 respectively for improved accession. The bulk and true density range from 318.75 to 340.36 kg/m^3 and 928.2 to 1165.9 kg/m^3 respectively for native accession and 328.3 to 344.88 kg/m^3 and 836.5 to 1070.7 kg/m^3 respectively for improved accession.

The terminal velocities and drag coefficients of the two accessions of Jatropha seeds are presented in tables III and IV, respectively. These results were compared with the terminal velocities and drag coefficients of other agricultural seeds and grains in the literature (Table I). The results of terminal velocity obtained from experimental methods ranged from 7.98 to 11.08 m/s for native accession and 7.42 to 11.36 m/s for improved accession and are close to those reported by Karaj and Müller (2010) for Jatropha curcas seed of 8.1 – 10.8 m/s (Table I). The values of terminal velocity obtained from the theoretical methods were higher than those obtained experimentally. This values range from 5.72 – 13.24m/s for native accession and 6.45 – 13.45m/s for improved accession. This may be due to experimental errors from the physical properties data used to calculate them. Hence the use of theoretical method to calculate terminal velocity of Jatropha seeds is questionable.

The drag coefficient values from the theoretical methods ranged from 0.27 – 1.67 for native accession and 0.292 – 1.474 for improved accession, while that for the experimental methods ranged from 0.07 – 0.173 for native accession and 0.07 – 0.164 for improved accession. These values of drag coefficient fall within the same range as some agricultural seeds as shown in table I.

TABLE II. Selected physical properties Jatropha seeds.

Accession	Moisture Content (%)(db)	Length* (a)cm	Width* (b) cm	Thickness* (c) cm	Geometric* Mean (cm)	Equivalent* Diameter (cm)	Sphericity*	True density** (Kg/m^3)	Bulk density** (Kg/m^3)
Native	4	1.704 (0.147)	1.124 (0.060)	0.852 (0.087)	1.1775 (0.074)	1.185 (0.078)	0.691 (0.043)	928.2 (2.142)	318.75 (0.005)
	8	1.730 (0.089)	1.142 (0.096)	0.866 (0.050)	1.1959 (0.058)	1.203 (0.054)	0.6914 (0.022)	982.9 (1.105)	327.04 (0.003)
	12	1.737 (0.108)	1.151 (0.055)	0.867 (0.035)	1.2014 (0.038)	1.209 (0.040)	0.6916 (0.029)	1050 (1.517)	335.58 (0.002)
	16	1.746 (0.114)	1.158 (0.110)	0.873 (0.041)	1.2084 (0.046)	1.217 (0.048)	0.6921 (0.040)	1165.9 (9.294)	340.36 (0.002)
Improved	4	1.700 (0.135)	1.111 (0.090)	0.858 (0.049)	1.1746 (0.067)	1.181 (0.06)	0.6909 (0.038)	836.5 (7.138)	328.3 (0.011)
	8	1.710 (0.111)	1.113 (0.086)	0.868 (0.044)	1.1822 (0.058)	1.188 (0.054)	0.6913 (0.034)	891.4 (0.729)	336.34 (0.002)
	12	1.716 (0.098)	1.113 (0.060)	0.874 (0.052)	1.1866 (0.051)	1.192 (0.050)	0.6914 (0.028)	935.6 (0.912)	340.61 (0.003)
	16	1.721 (0.106)	1.114 (0.055)	0.879 (0.042)	1.1899 (0.052)	1.195 (0.049)	0.6915 (0.030)	1070.7 (1.268)	344.88 (0.003)

*****Average of 100 randomly selected samples
**Average of 5 replications (Standard Deviations are shown in parenthesis)

TABLE III. Effect of moisture content on terminal velocity of Jatropha seeds.

Moisture Content (%)(db)	Native						Improved					
	Theoretical Terminal Velocity (m/s)		Experimental Terminal Velocity (m/s)				Theoretical Terminal Velocity (m/s)		Experimental Terminal Velocity (m/s)			
	C_dV_s vs NR_e	$C_dNR_e^2$ vs NR_e	50g	100g	150g	200g	C_dV_s vs NR_e	$C_dNR_e^2$ vs NR_e	50g	100g	150g	200g
4	C_dV_s vs NR_e	10.01^A (0.0)	10.58^A (0.11)	9.68^A (0.31)	8.32^A (0.08)	7.18^A (0.08)	6.45^A (0.00)	11.47^A (0.00)	10.7^A (0.07)	9.7^A (0.00)	8.5^A (0.25)	7.42^A (0.04)
8	5.72^A (0.0)	11.27^B (0.0)	10.68^A (0.19)	9.76^{AB} (0.05)	8.42^A (0.08)	7.34^A (0.22)	7.84^B (0.00)	12.11^B (0.00)	10.98^B (0.28)	9.88^B (0.08)	8.6^{AB} (0.07)	7.56^B (0.13)
12	7.04^B (0.0)	12.62^C (0.0)	10.74^A (0.31)	9.86^{AB} (0.23)	8.53^B (0.13)	7.58^B (0.22)	9.94^C (0.00)	12.74^C (0.00)	$11.2B^C$ (0.22)	9.92^B (0.04)	8.78^B (0.16)	7.62^B (0.08)
16	9.81^C (0.0)	13.24^D (0.0)	11.08^B (0.16)	10^B (0.17)	8.71^B (0.04)	7.62^B (0.15)	12.74^D (0.00)	13.45^D (0.00)	11.36^D (0.05)	10.1^C (0.07)	8.88^B (0.16)	7.8^C (0.12)

TABLE IV. Effect of moisture content on drag coefficient of Jatropha seeds.

Moisture Content (%)(db)	Native						Improved					
	Theoretical Drag Coefficient (C_d)		Experimental Drag Coefficient				Theoretical Drag Coefficient (C_d)		Experimental Drag Coefficient			
	C_dV_s vs NR_e	$C_dNR_e^2$ vs NR_e	50g	100g	150g	200g	C_dV_s vs NR_e	$C_dNR_e^2$ vs NR_e	50g	100g	150g	200g
4	1.67^A (0.00)	0.38^A (0.00)	0.08^A (0.00)	0.095^A (0.01)	0.129^A (0.00)	0.173^A (0.00)	1.450^A (0.00)	0.317^A (0.00)	0.078^A (0.00)	0.096^A (0.00)	0.125^A (0.00)	0.164^A (0.00)
8	1.19^B (0.00)	0.32^B (0.00)	0.08^A (0.00)	0.095^A (0.00)	0.128^B (0.00)	0.168^A (0.01)	1.048^B (0.00)	0.304^B (0.00)	0.076^B (0.00)	0.094^B (0.00)	0.124^B (0.00)	0.161^B (0.01)
12	0.65^C (0.00)	0.27^D (0.00)	0.08^A (0.00)	0.090^B (0.00)	0.120^C (0.00)	0.152^B (0.01)	0.699^C (0.00)	0.293^C (0.00)	0.075^B (0.00)	0.096^A (0.00)	0.123^B (0.00)	0.163^A (0.00)
16	0.46^D (0.00)	0.28^C (0.00)	0.07^B (0.00)	0.083^C (0.00)	0.110^D (0.00)	0.144^B (0.01)	0.474^D (0.00)	0.294^C (0.00)	0.07^B (0.00)	0.088^C (0.00)	0.115^C (0.00)	0.147^C (0.00)

*Different letters within the same column indicate significant differences according to Duncan's New Multiple Range Test ($p<0.05$).

The effect of moisture content on the terminal velocity and drag coefficient of the two Jatropha accessions are shown in Tables IV and V. An Analysis of Variance (ANOVA) was performed to determine if moisture have a significant effect on

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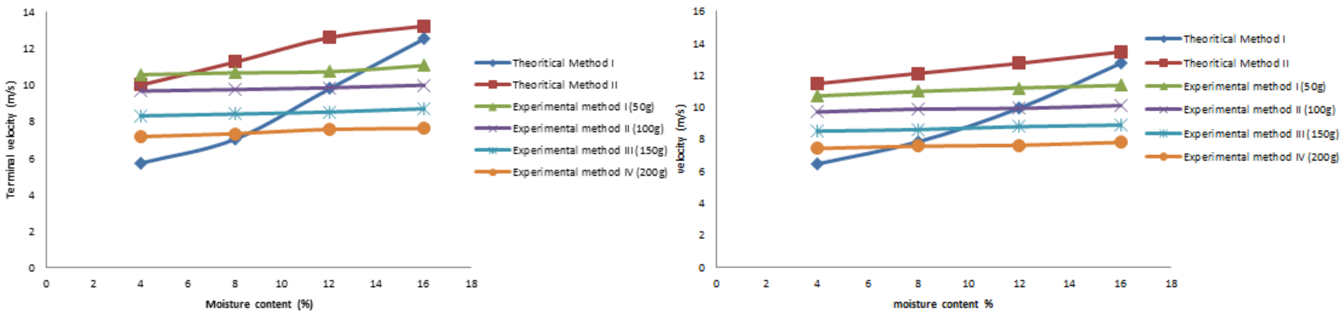
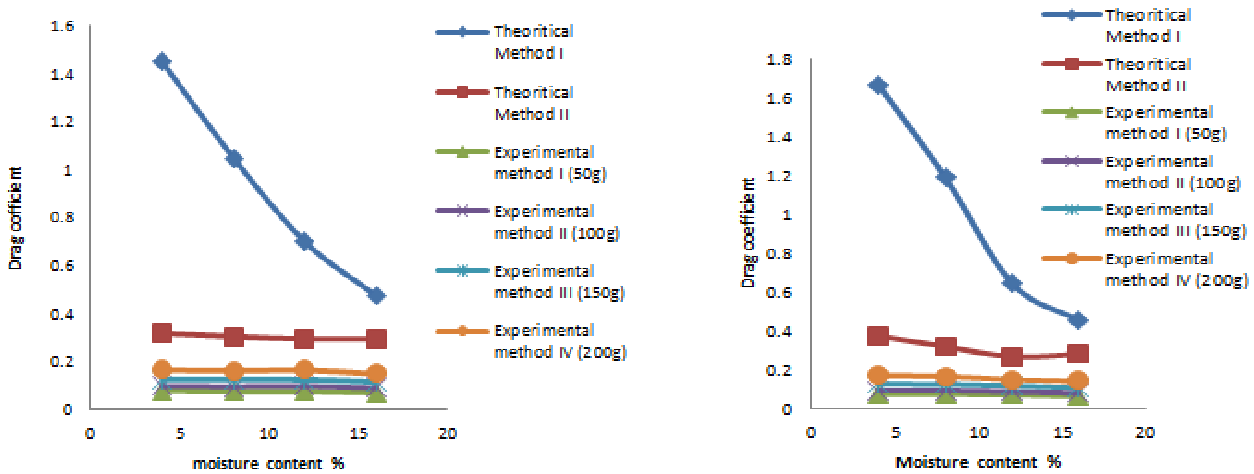
both the terminal velocity and drag coefficient of the Jatropha seeds. Tables VI show that moisture has a significant effect on the values of terminal velocity and drag coefficient obtained by the theoretical experimental methods at 5% confident level. The mean separations are also presented in table IV and V. For the experimental terminal velocity, the significant different appear between 8 to 12% for local accession and 8 to 16% for improved accession. These moisture contents are the points at which the seeds gain significant weight to alter its terminal velocity. Figures 2 and 3 show, a graphically representation of the effect of moisture content on terminal velocity and drag coefficient.

Regression equations for terminal velocity and drag coefficient of Jatropha seeds were obtained for different moisture content levels (Table V) using the mass of the seeds. Also obtained were their correlation coefficients and coefficients of determination. These regression equations only apply to the experimental methods. The ANOVA table (Table VI) shows that accession has no effect on the terminal velocity and the drag coefficient of Jatropha seeds.



(a) (b)

Fig. 2. Effect of moisture content on terminal velocity of Jatropha seeds: (a) Native accession (b) Improved accession.



(a) (b)

Fig. 3. Effect of Moisture Content on Drag Coefficient of Jatropha Seeds: (a) Native Accession (b) Improved Accession.

TABLE V. Regression equation for experimental terminal velocity and drag coefficient.

Moisture content (%)db	Native			Improved		
	Regression Equation	**R^2**	**r**	**Regression Equation**	**R^2**	**r**
4	V_t = - 0.023M + 11.83	0.994	-0.9972	V_t = - 0.022M + 11.84	0.998	-0.99945
	$C_d = 3x10^{-6}M^2 - 1x10^{-4}M + 0.077$	0.999	0.979343	$C_d = 2x10^{-6}M^2 + 2x10^{-5}M + 0.072$	1	0.985441
8	V_t = - 0.022M + 11.89	0.995	-0.99772	V_t = - 0.023M + 12.14	0.998	-0.99927
	$C_d = 3x10^{-6}M^2 - 5x10^{-5}M + 0.075$	0.998	0.98121	C_d = 2x10-6M^2 + 0.0M + 0.066	0.999	0.989211
12	V_t = - 0.021M + 11.88	0.993	-0.99696	V_t = - 0.023M + 12.35	0.999	-0.99965
	$C_d = 2x10^{-6}M^2 + 1x10^{-4}M + 0.066$	0.997	0.98836	$C_d = 2x10^{-6}M^2 + 9x10^{-5}M + 0.066$	0.999	0.988482
16	V_t = - 0.023M + 12.27	0.998	-0.99938	V_t = - 0.023M + 12.51	0.998	-0.99939
	$C_d = 2x10^{-6}M^2 + 7x10^{-5}M + 0.06$	0.999	0.987933	$C_d = 2x10^{-6}M^2 + 0.0M + 0.058$	1	0.991473

V_t = Terminal Velocity (m/s), M = weight of seeds (g), C_d = Drag Coefficient, R^2 = coefficient of determination, r = correlation coefficient.

TABLE VI. ANOVA Table for the effect of moisture content and accession on both terminal velocity and drag coeffient.

Sources of Variation		Sum of Squares	df	Mean Square	F	Sig.
C_dV_s vs NR_e (Native Accession)	Moisture Content	137.948	3	45.980	$1.86X10^{-33}$	0.000*
C_dNR_e vs NR_e (Native Accession)	Moisture Content	31.151	3	10.384	$9.0x10^{31}$	0.000*
Experimental Method 50g (Native Accession)	Moisture Content	.706	3	.235	5.410	.009*
Experimental Method 100g (Native Accession)	Moisture Content	.286	3	.095	2.080	.0143*
Experimental Method 150g (Native Accession)	Moisture Content	.466	3	.155	18.828	$1.69x10^{-5}$*
Experimental Method 200g (Native Accession)	Moisture Content	.646	3	.215	6.946	.003*
C_dV_s vs NR_e (Improved Accession)	Moisture Content	112.420	3	37.473	$1.01x10^{33}$	0.000*
Theoretical Method II (Improved Accession)	Moisture Content	10.799	3	3.600	$3.65x10^{31}$	0.000*
Experimental Method 50g (Improved Accession)	Moisture Content	1.140	3	.380	11.515	$2.85x10^{-4}$
Experimental Method 100g (Improved Accession)	Moisture Content	.404	3	.135	38.476	1.52x10-7*
Experimental Method 150g (Improved Accession)	Moisture Content	.314	3	.105	3.432	.042*
Experimental Method 200g (Improved Accession)	Moisture Content	.372	3	.124	11.810	$2.5x10^{-4}$*
Terminal velocity	Accessions	5.385	1	5.385	1.501	0.222^{NS}
C_dV_s vs NR_e (Native Accession)	Moisture Content	4.504	3	1.501	$2.6x10^{33}$	0.000*
C_dNR_e vs NR_e (Native Accession)	Moisture Content	.034	3	.011	$1.16x10^{32}$	0.000*
Experimental Method 50g (Native Accession)	Moisture Content	$3.75x10^{-4}$	3	$1.25x10^{-4}$	15.583	$5.25x10^{-5}$*
Experimental Method 100g (Native Accession)	Moisture Content	$3.82x10^{-4}$	3	$1.27x10^{-4}$	8.392	.001*
Experimental Method 150g (Native Accession)	Moisture Content	.001	3	$3.32x10^{-4}$	53.321	$1.5x10^{-8}$*
Experimental Method 200g (Native Accession)	Moisture Content	.002	3	.001	15.392	$5.64x10^{-5}$*
C_dV_s vs NR_e (Improved Accession)	Moisture Content	2.728	3	.909	$1.75x10^{33}$	0.000*
C_dNR_e vs NR_e (Improved Accession)	Moisture Content	.002	3	.001	$9.7x10^{30}$	0.000*
Experimental Method 50g (Improved Accession)	Moisture Content	$2.44x^{-4}$	3	$8.145x10^{-5}$	14.355	$8.43x10^{-5}$*
Experimental Method 100g (Improved Accession)	Moisture Content	$2.24z10^{-4}$	3	$7.47x10^{-5}$	70.963	$1.84x10^{-9}$*
Experimental Method 150g (Improved Accession)	Moisture Content	$2.85x10^{-4}$	3	$9.51x10^{-5}$	4.347	.020*
Experimental Method 200g (Improved Accession)	Moisture Content	.001	3	$2.93x10^{-4}$	19.153	$1.52x10^{-5}$*
Drag coefficient	Accessions	0.013	1	0.013	0.105	0.747^{NS}

*Significant ($p \leq 0.05$) NS Not Significant ($p \leq 0.05$)

IV. CONCLUSION

The conclusions that were drawn from this research work were based on aerodynamic properties which this research work was set out to investigate. These properties are Terminal velocity and drag coefficient determined for two accessions (native and improved) of Jatropha at four moisture content levels (4%, 8%, 12% and16% db).

The terminal velocity results of Jatropha seeds experimentally obtained ranged from 7.98 – 11.08 m/s for native accession and 7.42 – 11.36 m/s for improved accession while the drag coefficient obtained experimentally ranged from 0.07 – 0.173 for native accession and 0.07 – 0.164 for improved accession. It was discovered that for both the terminal velocity and drag coefficient the values obtained from the experimental methods lies between the values (terminal velocity of 5.72 – 13.24 m/s for native accession and 6.45 – 13.24m/s for improved accession, drag coefficient of 0.28 – 1.6 for native and 0.293 – 1.450 for improved accession) obtained from the two theoretical methods for both accessions. Moisture content was found to have significant effect ($p < 0.05$) on both terminal velocity and drag coefficient of Jatropha seeds for both accessions. Also increase in seed mass decreases the terminal velocity while increase in seed mass increases the drag coefficient for both accessions. The Jatropha accession has no significant effect on neither the terminal velocity nor the drag coefficients.

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