Effect of Moisture Content and Variety on Selected Physical Properties of Beniseed

T. Y. Tunde-Akintunde[1*] and B. O. Akintunde[2]

[1]Dept of Food Science and Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria
[2]Federal College of Agriculture, I.A.R. and T., P.M.B. 5029, Ibadan, Nigeria.

∗ Corresponding author address and E-mail address:
Dept of Food Science and Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria. Email: toyositunde@yahoo.co.uk

ABSTRACT

The effects of moisture content and variety on selected physical properties of two varieties of beniseed were investigated within the moisture content range of 3.5 to 25.0% dry basis (d.b.). The ranges of the three linear dimensions of the seed of the two varieties were 2.80 to 3.28 mm for length, 1.69 to 2.32 mm for width and 0.80 to 0.94 mm for thickness. An increase in moisture content resulted in a decrease in bulk density of the seeds from 659 to 617 kg/m^3 and 618 to 557 kg/m^3, decrease in porosity from 46 to 22.3% and 36 to 25.1% and an increase in angle of repose from 17.42 to 19.94^0 and 16.97 to 19^0 for varieties A and B respectively. In the above moisture range, the static coefficient of friction varied from 0.39 to 0.712 and 0.367 to 0.59 on different structural surfaces, while the terminal velocity increased from 4.2 to 4.9 m/s and 4.3 to 5.0 m/s for varieties A and B respectively. Analysis of variance (ANOVA) showed that the moisture content had a significant effect ($P<0.01$) on only the coefficient of friction of both varieties of beniseed. Relationship between the physical properties and moisture content were expressed by linear equations.

Keywords: Physical properties, beniseed, moisture content, variety, Nigeria

Nomenclature

A *initial mass of sample, kg*

a *initial moisture content of the sample, % d.b.*

b final moisture content of the sample, % d.b.
D_e geometric mean diameter, mm
L length of seed, mm
M moisture content, % d.b.
m_{100} hundred seed mass, kg
P_t porosity, %
Q mass of water to be added, kg
R^2 coefficient of determination
S surface area of kernel, mm^2
T thickness of seed, mm
V_{100} volume of 100 seeds, mm

V_t terminal velocity, m/s
W width of seed, mm
Θ angle of repose, deg
μ static coefficient of friction, decimal
ϕ sphericity of seed, decimal
ρ_b bulk density
ρ_t true density

1. INTRODUCTION

Beniseed also known as sesame seed (*Sesamum indicum L.*) is an oilseed with a chemical composition of about 50-52% oil, 17-19% protein and 16-18% carbonhydrate (Ustimenko-Bakumovsky 1983). Beniseed is an excellent source of high quality oil and protein, its oil is odourless and close in quality to olive oil. It is used widely as cooking oil and as a raw material in the manufacture of inks, paints, margarine and pharmaceuticals. Beniseed oil extraction is done traditionally by pounding the seeds in a mortar and pouring water into it. This causes the oil to float to the surface from where it can be removed by skimming. The method is slow and laborious and results in low oil yield. There is therefore the need to develop equipment that will remove the drudgery involved in oil processing and optimize oil yield. Kachru et al. (1994) observed that for proper design of equipment for handling, conveying, separation, dehulling, drying and mechanical expression of oil, some of its physical properties have to be known. The physical properties of the seed include the sphericity, porosity, true and bulk density, as well as terminal velocity and their values are moisture dependent. The knowledge of the moisture dependence of these properties is important during equipment design in order to construct equipment that can be used for processing beniseed whether the seeds are dried or freshly harvested or at moisture content ranges in between these extremes. This was collaborated by Atiku et al. (2004) who constructed a bambara groundnut sheller based on the physical properties determined for the nut.

The effect of moisture content on the physical properties of seeds such as sunflower seed, neem nut, pumpkin seed, gram, pigeon pea, soybeans, karingda, canola seed (Desphande et al., 1993; Dutta et al., 1988; Gupta and Das 1997; Joshi et al., 1993; Kukelko et al., 1988; Shepherd and Bhardwaj 1986; Suthar and Das 1996; Viswanathan et al., 1996) have been investigated. The 1000 grain mass and single grain volume increased with increase in moisture content for soybean seeds (Desphande et al., 1993) while the linear dimensions of sunflower seeds increased with increase in moisture content (Gupta and Das 1997). The sphericity of oilbeans was observed to determine the rolling or sliding of oilbeans on selected surfaces (Oje and Ugbor 1991). A decrease in bulk density with increase in moisture content was reported for soybeans, gram seed, sunflower seed, pigeon pea, neem nut and lentil seeds (Desphande et al., 1993; Dutta and others 1988; Gupta and Das 1997; Shepherd and Bhardwaj 1986; Viswanathan et al., 1996; Amin and others 2004), whereas an increase in bulk density have been observed for pumpkin seed, karingda seed and squash seed (Joshi et al., 1993; Suthar and Das 1996; Paksoy and Aydin 2004). The true particle density of sunflower seed was also reported to increase with an increase in moisture content as well as that of cocoa beans (Gupta and Das 1997; Bart-Plange and Baryeh 2003) while a decrease in true density with increase in moisture content was observed for gram seed, karingda seed and neem nut (Dutta et al., 1988; Suthar and Das 1996; Viswanathan et al., 1996). The angle of repose was observed to increase as the moisture content increased for soybeans and the same trend was also reported for sunflower seed, pumpkin seed, neem nut and cocoa beans respectively (Desphande et al., 1993; Gupta and Das 1997; Joshi et al., 1993; Viswanathan et al., 1996; Bart-Plange and Baryeh 2003). The studies carried out on gram seed, sunflower seed, pumpkin seed and on lentil seeds further confirmed that the angle of repose of agricultural materials increased with increase in moisture content (Dutta and others 1988; Gupta and Das 1997; Joshi and others 1993; Amin et al., 2004). An increase in moisture content was observed to increase the coefficient of static friction against plywood, mild steel, galvanised steel and glass for sunflower seed and for neem nut (Gupta and Das 1997; Viswanathan et al., 1996). The terminal velocity of pumpkin seed, kernel and hull as well as wheat kernel was reported to increase linearly with its moisture content (Joshi et al., 1993; Khoshtaghaza and Mehdizadeh, 2006).

This study was thus carried out to determine the effect of increase in moisture content and variety on the selected physical properties of beniseed namely angle of repose, coefficient of friction, and terminal velocities.

2. MATERIALS AND METHODS

The beniseed used in the study were obtained from a local market in Ibadan, Oyo state, Western Nigeria. The seeds were cleaned manually by the removal of all foreign matter such as stones, dirt and broken seeds. The experiments were conducted in the moisture range of 3.5 – 25.0% d. b. The initial moisture content of the seeds was determined using a moisture meter and the average moisture content was 3.5% d.b. The amount of water to be added (Q) to condition the samples to the different moisture levels was determined using the following expression:

$$Q = \frac{A(b - a)}{100 - b} \qquad (1)$$

where Q is the mass of water to be added in kg, A is the initial mass of sample in kg, a is the initial moisture content of sample in % d.b. and b is the final (desired) moisture content of sample % d.b.

The conditioned samples were packed separately in polythene bags and stored in a refrigerator at a low temperature of 277± 2^0K .For each test the required quantity of samples was taken out and allowed to warm up for approximately 2hr (Joshi et al, 1993). After this the moisture content of the seeds was determined using a MB 53 Halogen Ohaus moisture analyser.

The three linear dimensions namely, length (*L*), width (*W*) and thickness (*T*), of twenty seeds randomly selected from the bulk was measured using a micrometer screw gauge with a reading of 0.01mm. At each moisture content, the dimensions of twenty different seeds were determined and mean value was taken. The geometric mean diameter (*De*) and sphericity (ϕ) were determined using the equations below given by Mohsenin (1970).

$$D_e = (LWT)^{1/3} \qquad (2)$$

$$\phi = \frac{(LWT)^{1/3}}{L} \quad (3)$$

The surface area (*S*) was found by the following relationship given by McCabe *et al* (1986).

$$S = \pi D_e^2 \quad (4)$$

The hundred seed mass was determined using an electronic balance to an accuracy of 0.01 g. The method described by Dutta et al. (1988) was used to determine volume and hence density of each seed. A group of 100 seeds of known average weight was dropped into a can filled with water. The displaced water which was collected and weighed was used to calculate equivalent volume of water and hence volume of seed. Due to the short duration of experiment, the seeds were not coated to prevent moisture adsorption since it did not result in a significant increase in weight as reported by Olajide and Ade- Omowaye (1999). The true density was determined from the weight and volume of 100 seeds. The bulk density was determined by filling a 50 ml container with seeds from a height of 150 mm striking the top level and then weighing the contents and the bulk density was determined from the measured mass and volume (Shepherd and Bhardwaj 1986). For each moisture content, 10 replications were done and the mean value was taken. The porosity was calculated using the following relationship:

$$P_t = \frac{(1 - \rho_b)100}{\rho_t} \quad (5)$$

where: P_t is the porosity in %; ρ_b is the bulk density in kg/m^3 and ρ_t is the true density in kg/m^3.

The static coefficient of friction against different structural surfaces (mild steel, galvanised steel, glass and plywood) was determined using a topless and bottomless round tin of radius 70 mm and depth 70 mm which was filled with the tin resting on the surface (Oje and Ugbor, 1991). The surface was raised gradually until the tin just started to slide down and the angle of inclination was read from a graduated scale. The experiment was replicated ten times for each moisture content. The angle of repose (Θ) was determined by allowing the seeds to fall on a circular plate of diameter 130 mm from a height of 150 mm so that a natural heap was formed (Viswanathan et al., 1996). The angle of repose was calculated from the diameter and height of heap.

The terminal velocities of the seed at the five different moisture contents were measured using the air column of a wind tunnel similar to that described in Omobuwajo et al., (2000). For each test, a small sample was dropped into the air stream from the top of the air column and the velocity at which air is blown in the upward direction was varied and the air velocity at which the seeds are suspended in the air stream was taken as the terminal velocity. Five replications were made for the terminal velocity determination.

3. RESULTS AND DISCUSSION

The mean values for the length, width and thickness measured at different moisture contents in the range of 3.5 – 25% d.b. for the two varieties are given in Table 1. As the moisture content increased, the three linear dimensions increased due to the swelling of the seed. This increase in linear dimensions was also observed for millet in which the length increased from

3.522 to 4.163 mm, width 2.735 to 3.211 mm and thickness increased from 2.18 to 2.788 mm for a moisture content increase from 5 – 22.5% d.b.(Baryeh 2002), while a similar increase was reported in length, width and thickness of soybean from 6.32-6.75 mm, 5.23-5.55 mm and 3.99-4.45 mm respectively (Desphande et al., 1993).

Table 1. The axial dimensions of beniseed at different moisture contents

	Moisture content									
	Variety A					**Variety B**				
	3.5	8.2	13.1	19.3	25	3.5	8.2	13.1	19.3	25
Length (*L*)	2.80	2.87	2.91	3.01	3.02	3.023	3.10	3.16	3.22	3.28
	(0.06)*	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.08)	(0.09)	(0.09)
Width (*W*)	1.69	1.84	1.93	1.99	2.07	1.93	2.00	2.13	2.25	2.32
	(0.07)	(0.125)	(0.06)	(0.04)	(0.06)	(0.06)	(0.08)	(0.06)	(0.05)	(0.04)
Thickness (*T*)	0.81	0.83	0.85	0.84	0.88	0.87	0.90	0.91	0.93	0.94
	(0.04)	(0.05)	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.04)	(0.03)
Mass of 100 seeds,	1.22	1.29	1.34	1.42	1.54	1.74	1.82	1.89	1.92	2.01
(m_{100})	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
Volume of 100 seeds, (V_{100})	1.00	1.30	1.55	1.70	1.94	1.80	2.00	2.30	2.55	2.70
	(0.04)	(0.04)	(0.03)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.04)	(0.03)
Geometric mean diameter (*De*)	1.50	1.56	1.59	1.62	1.67	1.63	1.67	1.72	1.77	1.80
	(0.03)	(0.05)	(0.05)	(0.02)	(0.03)	(0.03)	(0.05)	(0.04)	(0.02)	(0.02)
Sphericity (ϕ)	0.56	0.57	0.58	0.58	0.59	0.57	0.57	0.58	0.58	0.59
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Surface mass area (*S*)	7.05	7.62	8.00	8.22	8.74	8.34	8.81	9.33	9.86	10.2
	(0.36)	(0.45)	(0.53)	(0.27)	(0.36)	(0.39)	(0.53)	(0.45)	(0.32)	(0.31)

* Values in brackets are standard deviations

The length and thickness of the two varieties were significantly different (P<0.05), while there was no significant difference in the width (Table 2) and this implies that the swelling as a result of increase in moisture was more pronounced in the length and thickness axis. The linear dimensions of each variety however were not significantly different (P<0.05) at the various levels of moisture content. This implies that the values can be used as a representation of the linear dimensions at any moisture level without any significant effect on the seeds (Table 3).

Table 2. Means of the physical properties of the two varieties of beniseed

	Length (L)	Width (W)	Thickness (T)	True Density (ρ_b)	Bulk Density (ρ_t)	Angle of Repose AOR	Coefficient of Static Friction, μ			
							Glass	Galvanised Steel	Mild Steel	Wood
Variety A	2.908[b*]	1.904[a]	0.846[b]	0.942[a]	0.5802[b]	18.42[a]	0.4704[a]	0.5118[a]	0.6008[a]	0.632[a]
Variety B	3.154[a]	2.126[a]	0.909[a]	0.839[a]	0.6356[a]	17.816[a]	0.4732[a]	0.4932[a]	0.5548[a]	0.5678[a]

* - Means followed by the same letter are not significantly different

Table 3. Means of the physical properties of beniseed at different moisture contents

	Length (L)	Width (W)	Thickness (T)	True Density (ρ_b)	Bulk Density (ρ_t)	Angle of Repose AOR	Coefficient of Static Friction, μ			
							Glass	Galvanised Steel	Mild Steel	Wood
3.5	2.910[a*]	1.8080[a]	0.8420[a]	1.0930[a]	0.6385[a]	17.195[c]	0.3785[e]	0.4195[c]	0.5340[a]	0.5485[a]
8.2	2.9750[a]	1.9200[a]	0.8635[a]	0.9500[ab]	0.6130[a]	17.540[bc]	0.4405[d]	0.4610[bc]	0.5590[a]	0.5725[a]
13.1	3.0359[a]	2.0300[a]	0.8805[a]	0.8460[b]	0.6040[a]	17.820[bc]	0.4790[c]	0.4890[b]	0.5710[a]	0.5955[a]
19.3	3.097[a]	2.1220[a]	0.8935[a]	0.7965[b]	0.5970[a]	18.565[ab]	0.5540[a]	0.5540[a]	0.5935[a]	0.6320[a]
25.0	3.1450[a]	2.1950[a]	0.9080[a]	0.7670[b]	0.5870[a]	19.470[a]	0.5890[a]	0.5890[a]	0.6315[a]	0.6510[a]

* - Means followed by the same letter are not significantly different

The geometric mean diameter (*De*), sphericity (ϕ) and surface mass area (*S*) also increased with increase in moisture content (Table 1). This is because it is dependent on the three linear dimensions, which were observed to increase. The sphericity of the beniseed ranged from 0.56 – 0.59 is similar to that of sunflower seed but is lower than that of millet, 0.783-0.83 and soybean seeds which is 0.806- 0.816 (Desphande et al., 1993; Gupta and Das 1997; Baryeh 2002). This is because the shape of beniseed (round at bottom and taper at top) is similar to that of the sunflower seed (Gupta and Das, 1997) while that of millet and soybean seed are more spherical (Desphande et al., 1993; Baryeh 2002).

The bulk density (ρ_b) of the seed decreased from 659 – 557 $kglm^3$ with an increase in moisture content from 3.5 – 25% d. b. (Fig. 1) and the correlation between the bulk density (ρ_b) and moisture content of the two varieties are as follows:

$$\rho_b = 659.82 - 1.75M \quad \text{for variety A} \quad (6)$$

$$\rho_b. = 615.75 - 2.57M \quad \text{for variety B} \quad (7)$$

with values for the coefficient of determination R^2 of 0.93 and 0.87, respectively.

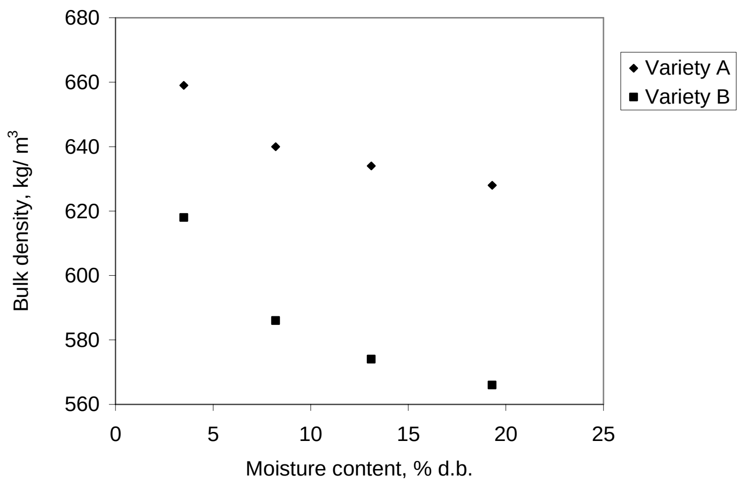

Fig. 1. Effect of moisture content and variety on bulk density of beniseed

The variety with larger linear dimensions had a greater bulk density which may be as a result of its greater weight. This is contrary to the observations for pumpkin seed and karingda since the bulk density of the seed was less than that of its kernel which is of a smaller weight (Joshi et al., 1993; Suthar and Das 1996). This may be as a result of the fact that the comparison is between the seed and kernel and not seeds of different dimensions in this case. The observations for cocoa beans shows that though cocoa beans had larger dimensions (length 22.41-22.5 mm, width 12.2-12.86 mm and thickness 7.36-7.70 mm) than that of beniseed, it has a lower weight and thus smaller bulk density (560-505 kg/ m^3), therefore the bulk density of seeds may be related to the weight of the seed (McCabe et al., 1986)

The true density (ρ_t) varied from 966 – 1220 kg/m^3 with an increase in moisture content (Fig. 2) and the correlation between true density and moisture content are as follows:

$$\rho_t = 1192.32 - 18.17M \quad \text{for variety A} \quad (8)$$

$$\rho_t = 991.06 - 11.00M \quad \text{for variety B} \quad (9)$$

with values for R^2 of 0.81 and 0.94, respectively.

The directly proportional increase in true density with that of moisture content is similar to that reported for sunflower seed and karingda seeds respectively (Gupta and Das 1997; Suthar and Das 1996). The bulk density was observed to be lower than that of true density because of the air spaces in grain bulk increases the volume while the weight is the same. This is also the same effect was observed in lentil seed and squash seeds (Amin et al., 2004; Paksoy and Aydin 2004). Comparison of means revealed a significant difference (P<0.05) between the mean values of bulk density for the beniseed varieties and no significant difference between mean values of the true density (P<0.05) (Table 2).

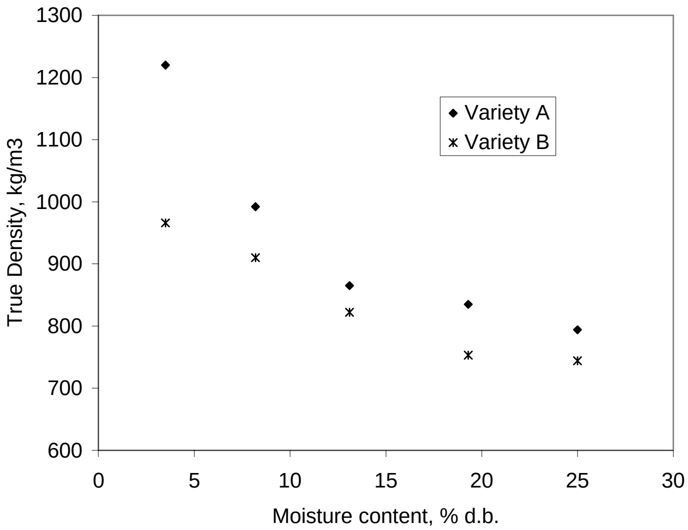

Fig. 2. Effect of moisture content and variety on true density of beniseed

It also revealed a significant difference (P<0.05) between the mean values of true density at different moisture contents for the beniseed varieties while the bulk density had no significant difference (P<0.05) for both varieties (Table 3). The vales for the bulk and true density of beniseed shows that it will float in water while karingda with a true density of 1148-1004 kg/m^3 will sink in water (Suthar and Das 1996). This property is useful in the hydrodynamic separation and transportation of the seeds.

The porosity (P_t) calculated from relevant experimental data decreased from 46.0 to 22.3% and from 36.0 to 25.1% for the varieties A and B respectively as the moisture content increased from 3.5 to 25.0% d.b. (Fig. 3). This decrease in porosity with increase in moisture content was also observed for other grains e.g. for pumpkin seed and pigeon pea (Joshi et al., 1993; Shepherd and Bhardwaj 1986). The porosity decreases because an increase in moisture content results in a more significant increase/swelling of the linear dimensions, thus reducing the airspaces and giving a more compact arrangement of seeds, invariably reducing the porosity of the grain bulk.

The relationship existing between porosity and moisture content can be represented by the following regression equation:

$$P_t = 45.59 - 1.05M \quad \text{for variety A} \tag{10}$$

$$P_t = 38.66 - 0.60M \quad \text{for variety B} \tag{11}$$

with values for R^2 of 0.86 and 0.90, respectively.

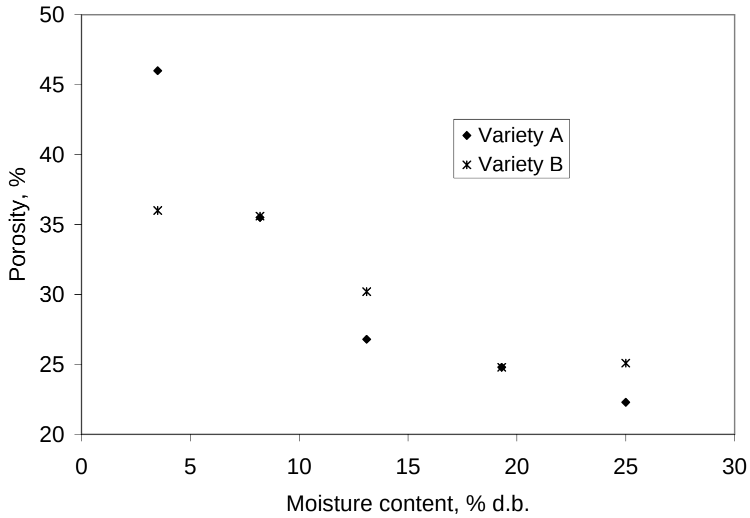

Fig. 3. Effect of moisture content and variety on porosity of beniseed

The angle of repose (Θ) increased with increase in moisture content (Fig. 4). The variations of the angle of repose of the varieties with moisture content are represented by the following relationship:

$$\Theta = 16.81 + 0.12M \quad \text{for variety A} \qquad (12)$$

$$\Theta = 16.55 + 0.09M \quad \text{for variety B} \qquad (13)$$

with values for R^2 of 0.96 and 0.97, respectively.

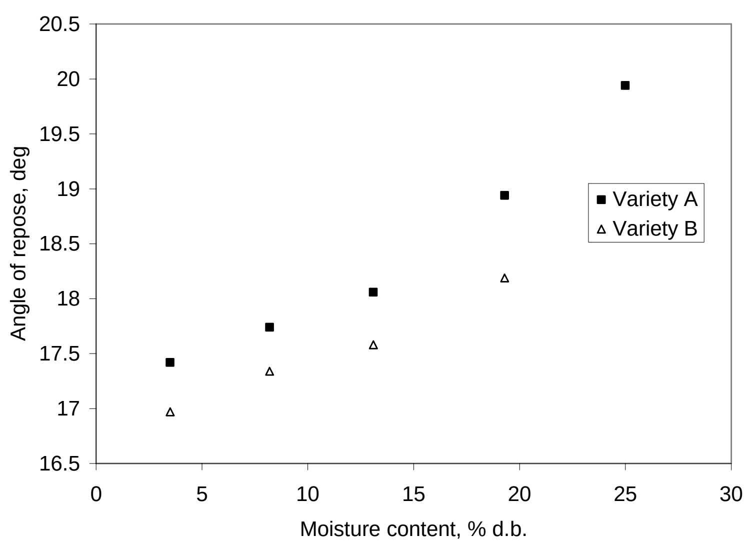

Fig. 4. Effect of moisture content and variety on angle of repose

The angle of repose of beniseed ranged from 16.97 – 19.94^{O} which is lower than that of gram, 25.5- 30.4^{O}; sunflower, 34-41^{O}; and lentil seeds, 24.8-27.78^{O} of similar moisture contents (Dutta et al., 1988; Gupta and Das 1997; Amin et al., 2004). This may be due to the small size of the seeds and the smoothness of the flat surface of the seed, which facilitates sliding of the seeds on one another easily, thus resulting in a lower value of angle of repose. Comparison of means revealed no significant difference (P<0.05) between the mean values of angle of repose for the beniseed varieties (Table 2), thus the angle of repose of any of the varieties can be used in the design of processing and handling equipment.

The effect of the moisture content of beniseed on the static coefficient of friction (μ) against plywood, mild steel, galvanised steel and glass are shown in Figs. 5 and 6. From the figures it is observed that as moisture content increased, the static coefficient of friction against the selected surfaces increased. This same increase in coefficient of friction with moisture content was observed for sunflower seeds and for millet (Gupta and Das 1997; Baryeh 2002).

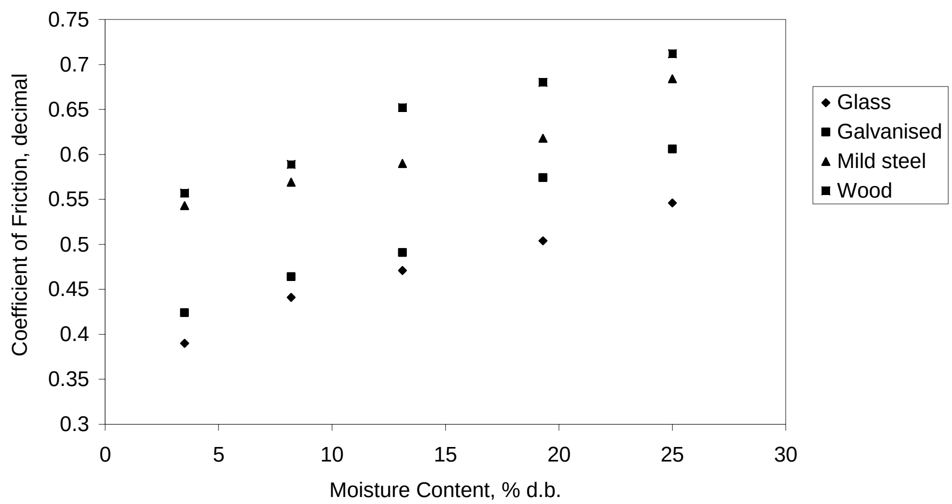

Fig 5. Effect of moisture content on coefficient of friction of Variety A against selected surfaces

This may be due to the fact that an increase in moisture content increased the cohesion between the seeds, thus increasing the friction the seed experiences during its flow/movement on the selected surfaces. Generally, the maximum friction was experienced with the use of wood surface as reported for karingda seeds (Suthar and Das 1996), while minimum friction occurred with the use of glass as reported for lentil seeds (Amin et al., 2004). This difference in coefficient of friction is due to the roughness of the various surfaces. Comparison of means revealed no significant difference (P<0.05) between the mean values of coefficient of friction for the beniseed varieties (Table 2), this indicates that the value of the coefficient of any of the varieties can be used as a representative for beniseed. Comparison of means from Table 3 shows significant difference (P<0.05) for coefficient of friction on glass at the different moisture levels while there was no significant difference (P<0.05) on mild steel and wood.

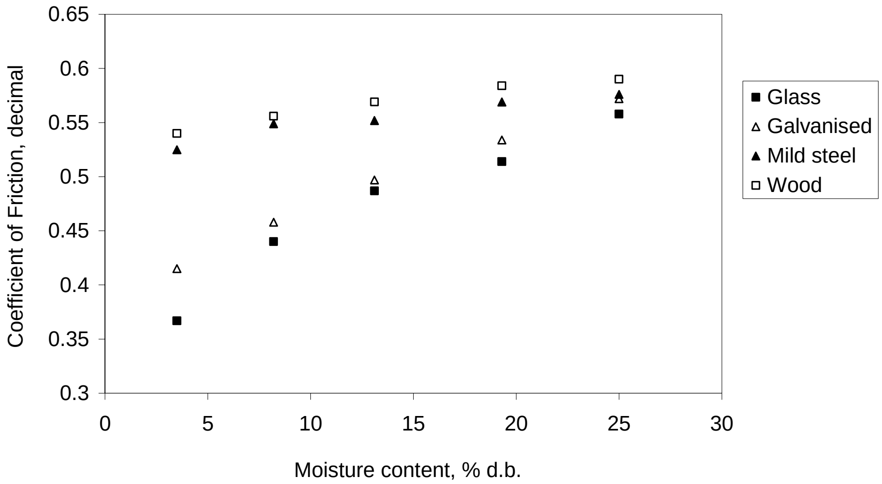

Fig 6. Effect of moisture content on coefficient of friction of Variety B against selected surfaces

This is because the effect of moisture content is more significant with decrease in roughness of the selected surface since the smoother the surface, the less the friction. Thus the effect of moisture content increase, which is cohesion between the seeds, becomes more pronounced on smoother surfaces since the coefficient of friction on the glass surface is smallest. The static coefficient of friction of beniseed on the selected surfaces is close to that of gram, and karingda seeds, whereas that of pigeon pea is lower (Dutta et al., 1988; Shepherd and Bhardwaj 1986; Suthar and Das 1996).

The linear equations for the static coefficient of friction on all test surfaces can be formulated to be:

$$\mu = K + F M \tag{14}$$

where μ is the static coefficient of friction and K and F are regression coefficients, these values are given in Table 4.

Table 4. Regression coefficients and coefficients of determination of Eqn. (14) for the static coefficient of friction on various test surfaces

Surface	Regression coefficient K	Regression coefficient F	Coefficient of determination (R^2)
Variety A			
Glass	0.37	0.0069	0.98
Galvanised steel	0.39	0.0088	0.98
Mild steel	0.52	0.0062	0.95
Wood	0.54	0.0074	0.97
Variety B			
Glass	0.36	0.0083	0.95
Galvanised steel	0.40	0.0072	0.99
Mild steel	0.52	0.0022	0.93
Wood	0.54	0.0023	0.97

The experimental results of the terminal velocity (V_t) for the two varieties in moisture content range of 3.5 – 25.0% d.b. are presented in Fig. 7. As the moisture content increased, the terminal velocity also increased for both varieties from 4.2 to 5.0 m/s. This increase is similar to the observations of other authors (Joshi et al., 1993; Gupta and Das, 1997; Paksoy and Aydin 2004; Khoshtaghaza and Mehdizadeh, 2006). The range for the terminal velocity is within the range observed for pumpkin seed, 4.7-6.5 m/s and 4.37- 6.18 m/s for squash seeds (Joshi et al., 1993; Paksoy and Aydin 2004) while that of sunflower seed and wheat kernels were observed to have a higher terminal velocity range of 5.8-7.6 m/s and 6.81 to 8.63 m/s for wheat kernels respectively (Gupta and Das, 1997; Khoshtaghaza and Mehdizadeh, 2006).

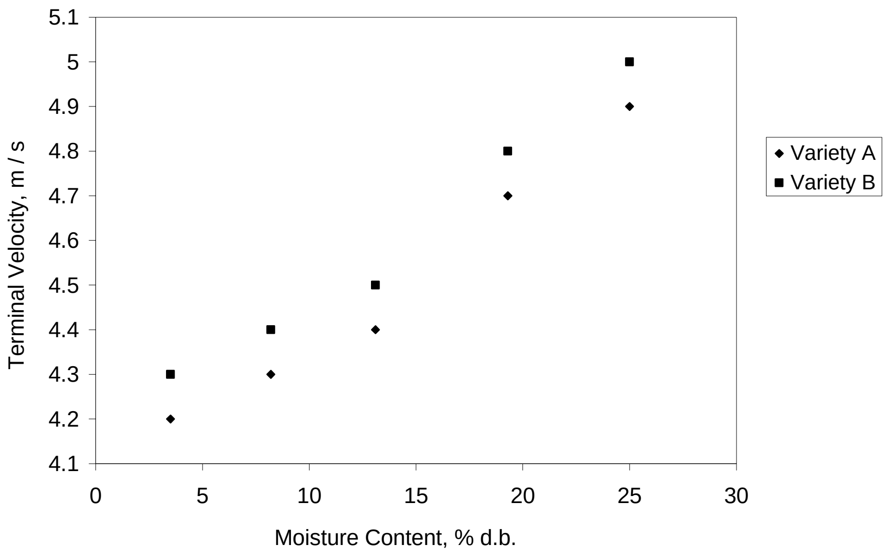

Fig. 7. Effect of moisture content and Variety on Terminal Velocity of Beniseed

The variation in the terminal velocity with moisture content can be correlated as follows:

$$V_t = 4.04 + 0.03M \quad \text{for variety A} \qquad (15)$$

$$V_t = 4.14 + 0.03M \quad \text{for variety B} \qquad (16)$$

with values for R^2 of 0.97 and 0.97, respectively.

4. CONCLUSIONS

1. The moisture content of the beniseed varieties affected the different physical properties measured.
2. The values of the physical properties; linear dimensions, true density, angle of repose, coefficient of friction and terminal velocity increased directly proportional to increase in moisture content while that of bulk density and porosity decreased.
3. The mean values of the physical properties were not significantly different ($P<0.05$) for the varieties, while the mean values of coefficient of friction on glass

and galvanized steel for the different moisture contents were significantly different (P<0.05).

4. The effect of moisture content on coefficient of static friction of beniseed for both varieties were expressed by linear equations.

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