Moisture dependent physical properties of *Lagenaria siceraria* seed

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Abstract: The investigation was done to evaluate the effect of moisture content on some physical properties of *Lagenaria siceraria* seed. The study was conducted at five moisture levels including 8.84%, 10.10%, 11.89%, 12.60% and 15.10% (w. b.). Results showed that the mean value of principal dimensions, average diameters, surface area and 1000 seed mass increased linearly but aspect ratio decreased with increase in moisture content. The sphericity increased in the moisture range of 8.84% to 11.89% but decreased with further raise in the moisture up to 15.10%. Gravimetric properties like bulk density increased with increase in moisture content however true density and porosity decreased linearly with increase in moisture content. Angle of repose and terminal velocity increased linearly with moisture content of the seed. The coefficient of friction increased linearly with seed moisture content on five experimental surfaces (plywood, galvanized iron, glass and plastic). The information pertaining to moisture dependant physical properties of *Lagenaria siceraria* seeds may become an essential part in design of processing machines and its unit operations, design of dehulling, oil expression and other processing equipments.

Keywords: *Lagenaria siceraria*, physical properties, angle of repose, aspect ratio, gravimetric properties, sphericity
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1 Introduction

Cucurbit seeds have high nutritional quality mainly in terms of its protein and oil content and hence creating considerable interest for its study. *Lagenaria siceraria* belongs to family cucurbitaceae. It is an herbaceous, climbing or tailing plant. *Lagenaria siceraria* fruits are having globular, bottle, or club shape hence named as bottle gourd[1,2]. They are fleshy and multi seeded.

Lagenaria siceraria seeds contain the highest amount of protein (24%-38%) and lipid (35%-46%). Hence seeds are having prime role in the human nutrition[3]. The bottle gourd seeds are encapsulated with innumerable phytochemicals, such as vitamins, minerals and essential amino acids along with saponin and essential fatty acids (especially n-3 which helps to promote energy level and functional activity of brain)[4]. Lagenin is a ribosome inactivating protein and can be isolated from lyophilized water extracts of seeds. The Lagenin possesses pharmaceutically important properties such as antiproliferative, immunosuppressive and antifertility[5]. It was reported that the seed coat has highest level of crude fiber (59.05%), while it is deficient in all the essential amino acids except for valine. The dehulled seeds contained highest amount essential amino acids compared to whole seeds and the amount is higher than

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WHO/FAO/UNU recommendations[6].

To extract the seed nutrient or for further processing, the seeds are processed through various agricultural unit operations with the help of different equipments. The knowledge of physical properties of *Lagenaria siceraria* seeds pertaining to moisture content is essential requirement for the appropriate design of equipments for unit operations *viz*., dehulling, shelling, grinding, oil extraction and material handling, etc[7].

Moisture dependant physical properties of various crop seeds such as chick pea seeds[8,9], edible squash seed[10], faba bean[11], groundnut kernel[12], guar seeds[13], jatropha fruit[14], jatropha kernels[15], jatropha seed[16], karingda seeds[17], locust bean seed[18, 19], melon[20], oil bean seed[21], okra seed[22], pigeon pea[23,24], pumpkin[25], red kidney beans[26], Tung seeds[27] and watermelon seed[28] have been reported by various researchers.

In spite of different literature on moisture dependant properties of other fruits, grains, and seeds, there is lack of published work on moisture dependant physical properties of bottle gourd seeds. Hence the present study aimed to investigate the effect of moisture on physical properties of *Lagenaria siceraria* seeds *viz*., principal dimensions, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, aspect ratio, 1 000-seed mass, bulk density, true density, porosity, angle of repose, volume, true density, porosity, angle of repose, terminal velocity, and coefficient of friction on various surfaces in the moisture content range from 8.84% to 15.10% (w. b.).

2 Materials and methods

2.1 Sample preparation

The *Lagenaria siceraria* Seeds were procured from local market of Varanasi, India. The sample was cleaned manually to remove all foreign matters and impurities such as dust, dirt, husk, immature seeds and broken seeds. The initial moisture content of seeds was determined by using the standard hot air oven method at (105±1) ℃ for 24h and was found to be 10.1% (w.b.)[29]. The cleaned and graded seeds were sun dried and stored in double layered LDPE bags of 100 μm at (5±1) ℃ to avoid lipid oxidation in the seeds.

Test samples were prepared by adding pre-determined amount of tap water followed by thorough mixing and packing in LDPE bags. The amount of water to be added was calculated based on Equation 1[30-32].

$$Q = \frac{W_0(M_f - M_0)}{(100 - M_f)} \tag{1}$$

where, Q is the quantity of water to be added (kg); W_0 is the initial mass of the sample (kg); M_0 is the initial moisture content of the sample (%, d.b.); and M_f is the desired moisture content of the sample (%, d.b.).

The moistened samples were then conditioned to attain the desired moisture content levels. The conditioned samples were kept in a refrigerator at 5 ℃ for seven days to facilitate uniform distribution of moisture throughout the sample. After equilibration, the moisture content was determined for each experiment using the method mentioned above. Accordingly, moisture levels of 11.89%, 12.6% and 15.1% (w.b.) were obtained. The sample was dried at 50 ℃ for 10 h to obtain the lower moisture content (8.84%) for study. Two hour before initiating tests, desired quantity of the seeds was taken out and reconditioned to attain temperature equilibrium with room temperature[33-36]. Though, the study was conducted at five moisture contents (8.84%, 10.10%, 11.89%, 12.60% and 15.10%) as seed processing operations like transportation, storage and handling are performed in this moisture range. All the test were performed using 10 replications for each moisture content (except principal dimensions and its associated properties like geometric mean diameter, sphericity, etc, which was determined using 100 randomly selected seeds).

2.2 Determination of physical properties

To estimate average dimension of flat shaped *Lagenaria siceraria* seeds, 100 seeds were randomly picked and principal dimensions *viz*., length (L), width (W), and thickness (T) of the seeds were measured using a digital vernier caliper having least count of 0.01 mm. All the measurements were taken at room temperature (27±2) ℃. The arithmetic mean diameter (D_a) and geometric-mean diameter (D_g) of *Lagenaria siceraria* seeds were calculated from principal dimensions by using the following relationships, respectively[37]:

$$D_a = \frac{(L + W + T)}{3} \tag{2}$$

$$D_g = (LWT)^{1/3} \tag{3}$$

Sphericity (Ø) of the seed was estimated using Equation (4) as given below[37]:

$$Ø = \frac{(LWT)^{1/3}}{L} \tag{4}$$

The aspect ratio (R_a), which is function of width and length, was calculated using Equation (5):

$$R_a = \frac{W}{L} \times 100 \tag{5}$$

The surface area (S, mm^2) of seed sample was calculated from the following expression[38]:

$$S = \pi D_g^{\,2} \tag{6}$$

The 1000 seeds mass (M_{1000}) was evaluated through weighing of about 100 randomly selected seeds using an electronic balance (Sartorius, Model No. BSA224S-CW, Made in Germany) with an accuracy of 0.001 g. The formula used for calculation of 1000-seed mass is given below (Equation (7)). The reported value is mean of 10 replications.

$$M_{1000} = \frac{M}{n} \times 1000 \tag{7}$$

The average bulk density was calculated by transferring the seeds into cylinder of known volume (1 000 cm^3) with continuous tapping glass rod at the bottom of the container but compaction of seeds were avoided. The tapping was done with a view to fill cylinder without any gap. The filled seeds were then weighed by means of an electronic balance having an accuracy of 0.001 g. The bulk density was calculated accordingly as a function of the mass of the seeds and the volume of the container[39].

The true density defined as ratio of mass of *Lagenaria siceraria* seeds to its true volume using toluene (C_7H_8) displacement method. Toluene was used instead of water because of its low surface tension, since it is absorbed comparatively lower than water[37]. A graduated glass-cylinder (1 L capacity) was filled with known volume of toluene (500 mL) and then known quantity of seeds was immersed in it. The amount of displacement was noted to calculate true density from its definition.

The porosity (%) is the indicator of porous space in the bulk materials. It was calculated from the bulk and true density using the equation as given below[37].

$$Porosity\ (\%) = \frac{(True\ density - Bulk\ density)}{True\ density} \times 100\% \tag{8}$$

The angle of repose is the angle between the horizontal and slope of cone formed on the free vertical fall of seed and it indicates the cohesion among the individual units of a material. The angle of repose was determined by using an open ended cylinder of 15cm diameter and 50 cm height. The cylinder was kept at the centre of a circular plate (diameter = 70 cm) and was filled with bottle gourd seeds. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was recorded to calculate the angle of repose (θ) using the Equation (9):

$$\theta = \tan^{-1}(2H / D) \tag{9}$$

where, θ is angle of repose (degree); H is the height of the cone (cm) and D is the diameter of cone (cm).

The terminal velocity of *Lagenaria siceraria* seeds at different moisture contents was measured by using an air column. For each test, the few seeds were dropped into the air stream from the top of the air column having dimensions like 75 mm in diameter and 1 m in length. When major fraction of seed sample was remained in suspended state due to upwardly blown air velocity, that minimum air velocity was recorded by an electronic anemometer (EUROLAB, AM4205 Anemometer, Made in Germany, Range: 0.4-30.0 m/s and Accuracy ± 2%). The test was replicated 10 times for each moisture content.

The coefficients of friction for *Lagenaria siceraria* seeds were calculated with respect to four test surfaces *viz.*, galvanized iron sheet, plywood, plastic sheet and glass. An open-ended plastic cylinder having 65 mm in diameter and 40mm in height was filled with the seed and placed on the adjustable tilting platform (350 mm× 120 mm). The cylinder was raised slightly (0.5 mm -1 mm) so that it will not touch the surface. The platform along with surface was inclined gradually using a screw device (screw pitch 1.4 mm), until the cylinder just started to slide down. The tilt angle was recorded from a graduated scale[16,40]. The coefficient of friction (μ_s) was calculated using the Equation (10):

$$\mu_s = \tan\alpha \tag{10}$$

where, μ_s is Co-efficient of friction and α is Angle of inclination of material surface

2.3 Statistical tool

The results were analyzed using statistical tools, namely regression analysis and analysis of variance to evaluate effect of the moisture content on physical properties of the seeds. The data analysis was carried out by using Microsoft excel and SPSS 16.0 for windows packages[41].

3 Results and discussion

3.1 Principal dimensions

The average values of the physical properties of *Lagenaria siceraria* seeds at initial moisture content (10.10 %, w.b.) are presented in Table 1. The length (L), width (W) and thickness (T) of seeds vary linearly with the moisture content (Figure 1). The seed dimensions were found higher for high moisture content and least for lower moisture content. The drying operation may reduce seed dimensions through shrinkage. The linear increases in seeds dimensions were reported for melon seeds [20], pumpkin seed[25,42], karingda seeds[17], sunflower[39], pigeon pea[23] and squash seed[10]. The functional relationship between the principal dimensions and moisture content of seeds was represented by linear equations as follows:

$$\text{Length } (L) = 0.181M_c + 10.39 \ (R^2 = 0.980) \tag{11}$$

$$\text{Width } (W) = 0.065M_c + 7.034 \ (R^2 = 0.972) \tag{12}$$

$$\text{Thickness } (T) = 0.065M_c + 2.609 \ (R^2 = 0.960) \tag{13}$$

where, M_c is moisture content, % (w.b.).

Table 1 Physical properties of *Lagenaria siceraria* seeds at 10.10% (w.b.)

Physical properties	N	Mean ±SE	Minimum	Maximum	SD
Principal dimensions, mm					
Length (L)	100	12.26±0.13	10.30	16.20	1.32
Width (W)	100	7.71±0.05	6.30	9.20	0.60
Thickness (T)	100	3.28±0.05	2.30	4.70	0.46
Average diameters, mm					
Arithmetic mean diameter (D_a)	100	7.75±0.05	6.63	9.67	0.54
Geometric mean diameter (D_g)	100	6.74±0.05	5.78	8.33	0.47

Note: ^{N} Number of observations; ^{SE} Standard Error; ^{SD} Standard Deviation.

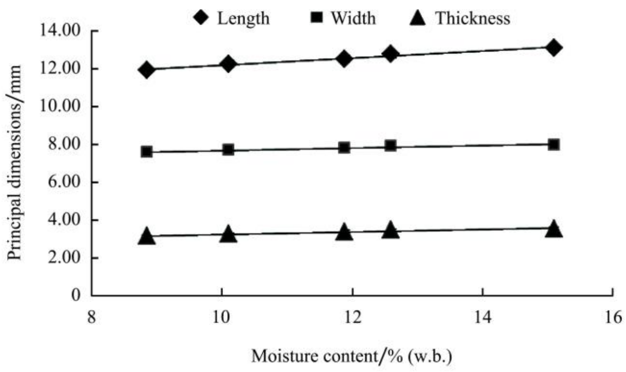

Figure 1 Effect of moisture content (w.b.) on principal dimensions of *Lagenaria siceraria* seeds

3.2 Average diameters

The average diameters increased with moisture content this indicates linear relationship between average diameters (D_a and D_g) and moisture content (Figure 2). The arithmetic mean diameter increased from 7.56 to 8.21 mm and geometric mean diameter increased from 6.57 mm to 7.18 mm as the moisture content increased from 8.84% to 15.10% (w.b.), respectively. The relation between moisture content and average diameters can be expressed mathematically as:

$$\text{Arithmetic mean diameter } (D_a) = 0.104M_c + 6.677 \quad (R^2 = 0.975) \tag{14}$$

$$\text{Geometric mean diameter } (D_g) = 0.097M_c + 5.743 \quad (R^2 = 0.975) \tag{15}$$

The similar trends of linear increment were also reported in pumpkin seeds[25], edible squash seeds[10], chiny cucurbit seeds[43] and jatropha seed[16].

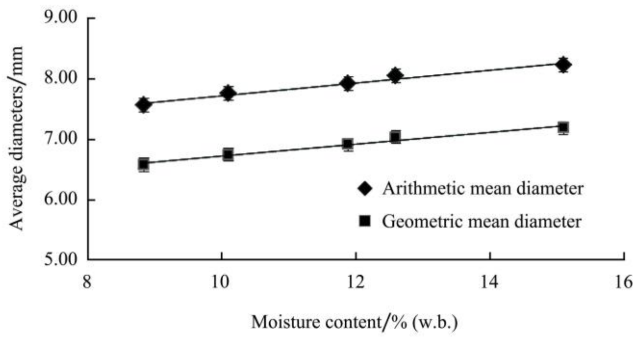

Figure 2 Effect of moisture content (w.b.) on average diameters of *Lagenaria siceraria* seeds

3.3 Sphericity

The sphericity is the property which gives knowledge about the product shape and affects the flow ability characteristics. The average sphericity for different moisture contents was calculated separately with Equation (4). The flat shaped bottle gourd seed showed increase (55.36% to 55.43%) in sphericity with increase in moisture content from 8.84% to 11.89% (w.b.) and then decreased with further increase in moisture content (Figure 3). The initial increase in sphericity may be due to proportional increase in dimensions in all direction with increase in moisture content. But later decrease in sphericity was probably due to greater increase in length as compared to width. This indicated that seeds should slide rather than roll in the hoppers and separators with increase in moisture content. The sphericity and moisture content can be expressed using following regression equation:

$$\text{Sphericity } (\varnothing) = 53.01 + 0.435M_c - 0.019M_c^2 \quad (R^2 = 0.790) \tag{16}$$

An initial increase followed by a decrease in sphericity was reported for okra seed[22], while reverse trend was observed in case of tef seed[44]. The decrease in the sphericity was reported[45] and[21] on gram and oil seed, respectively. However, an increase in the sphericity with increase in moisture content was reported[46,47] on fenugreek seeds and pistachio kernel, respectively.

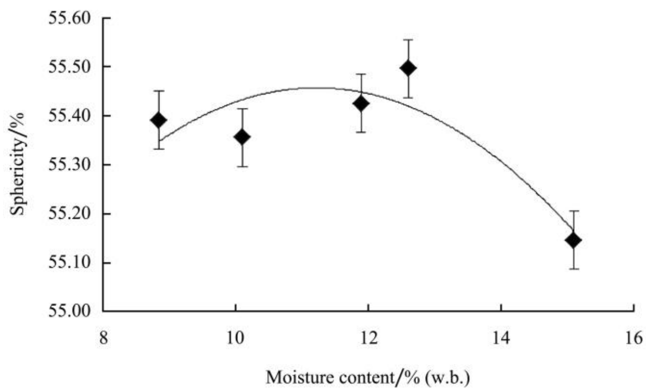

Figure 3 Effect of moisture content (w.b.) on sphericity of *Lagenaria siceraria* seeds

3.4 Aspect ratio

The aspect ratio which is ratio of width and length in percentage was decreased from 64.22% to 62.50% with increase in moisture contents (Figure 4). The negative linear relationship between moisture content and aspect ratio of bottle gourd seed can be expressed mathematically as follows:

$$\text{Aspect ratio } (R_a) = 69.99 - 0.795M_c + 0.015M_c^2 \quad (R^2 = 0.998) \tag{17}$$

The surface area (S) of the seed was determined using Equation (6). The surface area is important property to calculate characteristic length which plays an important role to determine the projected area of the irregular shaped objects moving in turbulent air stream. The property is useful in designing seed cleaners, separators, and pneumatic conveyors. The surface area values were increased linearly from 136.19 mm^2 to 162.42 mm^2 when moisture content increases from 8.84% to 15.10% (w.b.) (Figure 5). The variation in surface area with moisture content can be represented using following equation:

$$\text{Surface area } (S) = 4.208M_c + 100.4 \quad (R^2 = 0.975) \tag{18}$$

The similar relationship was observed[13,14] for jatropha fruit and guar seed, respectively.

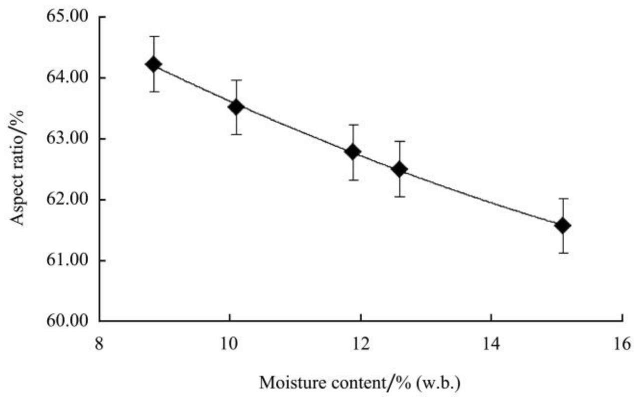

Figure 4 Effect of moisture content (w.b.) on aspect ratio of *Lagenaria siceraria* seeds

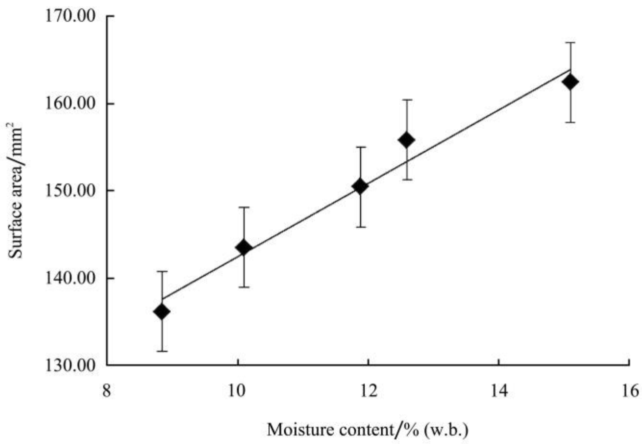

Figure 5 Effect of moisture content (w.b.) on surface area of *Lagenaria siceraria* seeds

3.5 1 000 seed mass

The 1 000 seed mass (M_{1000}) of bottle gourd seeds increased linearly from 106.00 g to 117.50 g with corresponding increase in the moisture content from 8.84% to 15.10% (Figure 6). The regression equation can be derived to explain relationship between moisture content and 1 000 seed mass as below:

$$1\ 000 \text{ seed mass } (M_{1000}) = 1.846M_c + 90.50 \quad (R^2 = 0.938) \tag{19}$$

Such linear relationship among 1000 seed mass and moisture content was reported for barbunia beans[34], jatropha seed[16], jatropha fruit[14] bitter melon seeds[48] and locust bean seed[19].

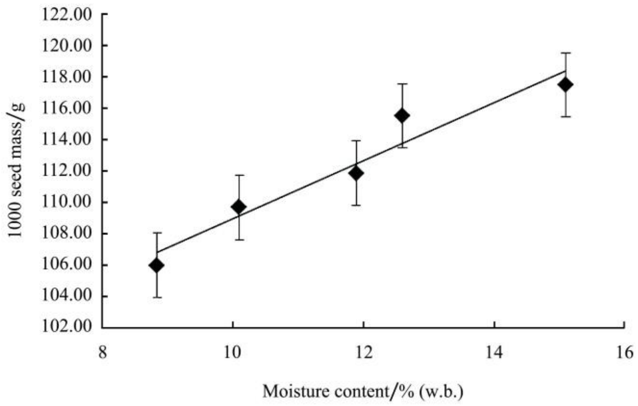

Figure 6 Effect of moisture content (w.b.) on 1 000 seed mass of *Lagenaria siceraria* seeds

3.6 Densities

The bulk density of bottle gourd seeds increased from 436.46 to 481.49 kg/m as the moisture content increased from 8.84% to 15.10% (w.b.) (Figure 7). This showed linear relationship between moisture content and bulk density. The increase in bulk density with the moisture content is probably due to higher mass gain resulting from the moisture absorption compared to accompanying volumetric expansion of the bulk. The relationship between bulk density and moisture content can be represented by the following regression equation:

$$\text{Bulk density } (\rho_b) = 9.728M_c + 352.6 \ (R^2 = 0.974) \tag{20}$$

A similar trend i.e. similar linear relationship has been reported for melon seed[42], pumpkin seed[25] and karingda seed[17]. However, a negative linear relationship between bulk density and moisture content was observed for chickpea[8] and locust bean seed[19].

The true density of bottle gourd seed decreased from 777.83 kg/m to 699.69 kg/m as the moisture content increased from 8.84% to 15.10% (w.b.) (Figure 7). The decrease in true density may be due to relatively higher increase in true volume compared to the weight gain resulting from moisture gain. This negative linear relationship between true density and moisture content can be represented with following regression equation:

$$\text{True density } (\rho_t) = 893.6 - 14.28M_c + 0.091M_c^2 \quad (R^2 = 0.978) \tag{21}$$

The negative linear relationship was reported[17,25,34,49,50] for barbunia seeds, sugar beet seed, pumpkin seed, melon seed and beniseeds, respectively. However, the linear relationship between true density and moisture content were reported[51,39] for faba bean and sunflower, respectively.

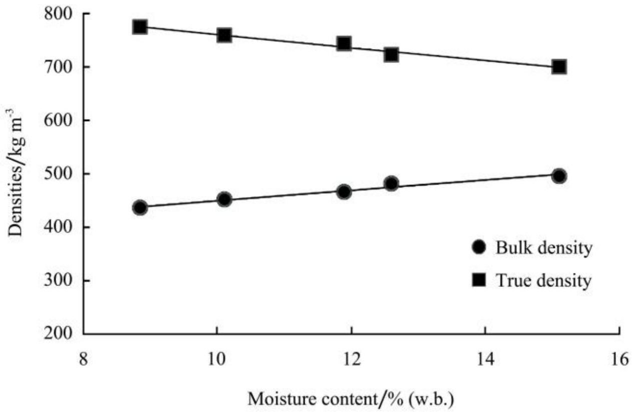

Figure 7 Effect of moisture content (w.b.) on densities of *Lagenaria siceraria* seeds

3.7 Porosity

The porosity of bottle gourd seed was calculated from bulk density and true density using Equation (8). The porosity of seeds decreased from 43.60% to 33.31% as moisture content increased (Figure 8). The volumetric expansion of seeds may decrease inter-granular spaces leading to more compact arrangement of seeds which ultimately results in reduction in the porosity. The

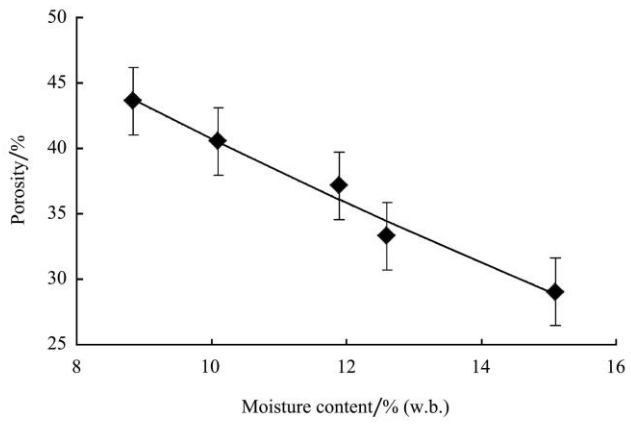

Figure 8 Effect of moisture content (w.b.) on porosity of *Lagenaria siceraria* seeds

porosity exhibits polynomial relationship with moisture content as expressed below:

$$\text{Porosity } (\varepsilon) = 70.11 - 3.347M_c + 0.040M_c^2 \quad (R^2 = 0.981) \tag{22}$$

The declining trend of porosity with respect to moisture content was also reported[25] for pumpkin and for karingda seed[17], for edible squash kernel[10] and for cucurbit seeds[43].

3.8 Angle of repose

The angle of repose of bottle gourd seed with respect to moisture content showed linear relationship are shown in Figure 9. The angle of repose increased from 38.80° to 44.80° as moisture content increased from 8.84% to 15.10% (w.b.). As moisture content increase, stickiness between the seed surfaces increases which confines the ease of seeds sliding on each other and thus increase the angle of repose. The regression equation between angle of repose and moisture content as represented below:

$$\text{Angle of repose } (\theta) = 1.008M_c + 30.17 \quad (R^2 = 0.948) \tag{23}$$

The linear relationship between angle of repose and moisture content was also reported[25] for pumpkin seed, for karingda seed[17], for edible squash kernel[10], for cucurbit seeds[43] and for bitter melon seeds[48].

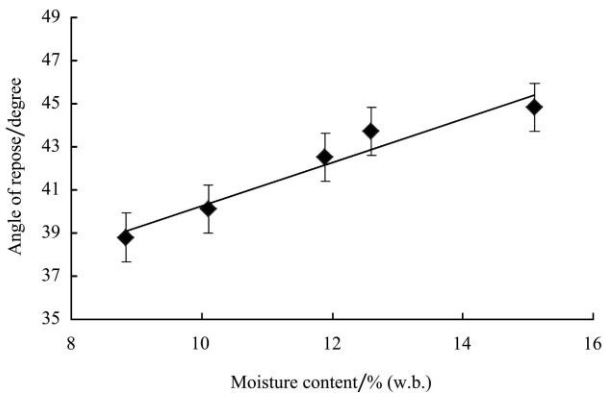

Figure 9 Effect of moisture content (w.b.) on angle of repose of *Lagenaria siceraria* seeds

3.9 Terminal velocity

The experimental result showed that terminal velocity increased (from 5.74 m/s to 7.36 m/s) linearly with increase in moisture content (from 8.84% to 15.10% (w.b.)) (Figure 10). The terminal velocity may be due to increase in mass of individual seed per unit frontal area presented across the stream of airflow. The variation in terminal velocity with moisture content can be expressed mathematically using following regression equation:

$$\text{Terminal velocity } (V_t) = 0.264M_c + 3.44 \quad (R^2 = 0.973) \tag{24}$$

Increase in terminal velocity of sunflower, pumpkin and karingda seeds with increase in moisture content were reported[17,25,39].

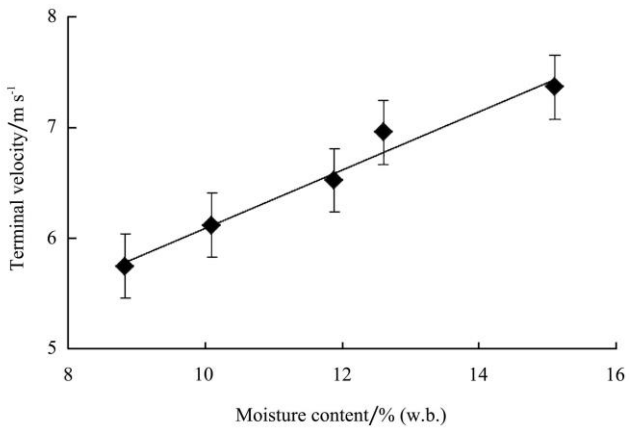

Figure 10 Effect of moisture content (w.b.) on terminal velocity of *Lagenaria siceraria* seeds

3.10 Coefficient of friction

The coefficient of friction of bottle gourd seeds was estimated for four different surfaces *viz.*, plywood, galvanized iron sheet, plastic and glass and results were recorded. The value of coefficient of friction increased on all experimental surfaces as moisture content increased from 8.84% to 15.10% (w.b.). Accordingly, coefficient of friction increased from 0.669 to 0.742, 0.591 to 0.704, 0.580 to 0.640 and 0.569 to 0.640 for plywood, galvanized iron, glass and plastic surfaces, respectively. This was probably due to cohesive force offered by absorbed moisture on the contact surfaces. The coefficient of friction on plastic surface was determined as a least while most on plywood surface at all moisture levels. This may be owing to smoother plastic surface compared to all other experimental surfaces. The linear relationships between moisture content and coefficient of friction on different surfaces were plotted as per Figure 11. The relation between coefficient of friction and moisture content on plywood, galvanized iron, plastic and glass was presented by the following regression equations:

$$\text{Plywood, } \mu_{pw} = 0.011M_c + 0.569 \; (R^2 = 0.954) \tag{25}$$

Galvanized iron, $\mu_{gi} = 0.018M_c + 0.434$ (R^2 = (0.974) (26)

Glass, $\mu_g = 0.013M_c + 0.463$ ($R^2 = 0.970$) (27)

Plastic, $\mu_p = 0.011M_c + 0.468$ ($R^2 = 0.957$) (28)

Such linear relationship between coefficient of friction and moisture content was reported in pumpkin seeds[52], for oil bean seed[21], for karingda seeds[17] and for squash[10].

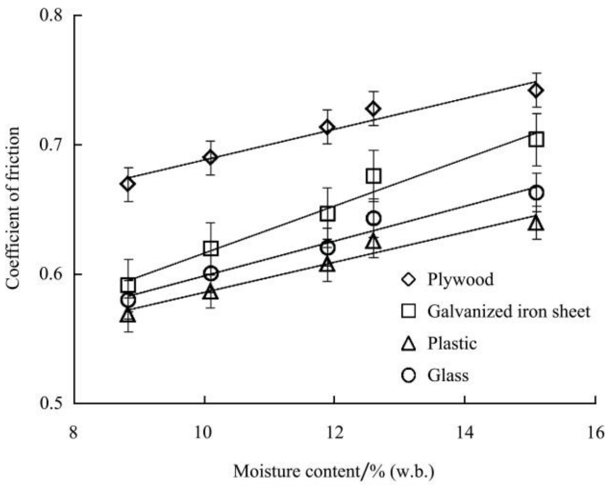

Figure 11 Effect of moisture content (w.b.) on coefficient of friction of *Lagenaria siceraria* seeds

4 Conclusions

The investigation illustrated that the physical properties of *Lagenaria siceraria* seeds were varied as a function of moisture content. The following variations in the physical properties were observed in the moisture range of 8.84% and 15.10% (w.b.):

1) The principal dimensions (length, width and thickness), average diameters (arithmetic mean diameter and geometric mean diameter) and surface area of *Lagenaria siceraria* seeds increased linearly with increase in seed moisture content. While the sphericity of seeds increased up to moisture level of 11.89% (w.b.) and then decreased further. The aspect ratio of *Lagenaria siceraria* seed decreased as moisture content increased.

2) The 1 000-seed mass increased from 106.00 g to 117.50 g as moisture content increased and followed linear relationship with moisture content.

3) The bulk density increased linearly with moisture content from 436.46 kg/m^3 to 496.42 kg/m^3; however, true density decreased linearly from 773.83 kg m^{-3}to 699.69 kg m^{-3} as moisture varies from 8.84% to 15.10% (w.b.). The negative linear relationship was observed between porosity and moisture content due to increased compaction.

4) The angle of repose and terminal velocity of the seed increased linearly as moisture content increased.

5) At all moisture levels, coefficient of friction on different material surfaces (plywood, galvanized iron, glass and plastic) increased linearly. The least coefficient of friction was observed on plastic surface and most on plywood surface compared to other experimental surfaces.

6) The data on moisture dependant physical properties of *Lagenaria siceraria* seeds may be used in the design of seed-processing machines and its unit operations, dehulling, oil expression and other processing equipments. Some properties may be helpful in selection of proper material for handling and conveying of seeds.

[References]

[1] Decker-Walters D S, Chung S M, Staub J E. Discovery and genetic assessment of wild bottle gourd [*Lagenaria siceraria* (Mol.) Standley, cucurbitaceae] from Zimbabwe. Economic Botany, 2004; 58(4): 501-508.

[2] Salunkhe D K, Kadam S S. Handbook of vegetable science and technology: production, composition, storage and processing. Marcel Dekker, Inc, New York, 1998. pp. 279.

[3] Habibur Rahaman A S. Bottle gourd (*Lagenaria siceraria*) - vegetable for good health. Natural Product Radiance, 2003; 2(5): 249-256.

[4] Warrier P K, Nambiar V P K, Ramankutty C. *Lagenaria siceraria* (Mol.) standley, In: *Indian Medicinal Plants*, 3rd Ed. Orient Longman Limited, Madras. 1995.

[5] Wang H X, Ng T B. Lagenin: A novel ribosome inactivating protein with ribonucleolytic activity from bottle gourd (*Lagenaria siceraria*) seed. Life Sciences, 2000; 67: 2631-2638.

[6] Hassan L G, Sani N A, Dangoggo S M, Ladan M J. Nutritional value of bottle gourd (*Lagenaria siceraria*) seeds. Global Journal of Pure and Applied Sciences, 2008; 14(3): 301-306.

[7] Sahay K M, Singh K K. Unit Operation of Agricultural Processing, Vikas Publishing House Pvt. Ltd.: New Delhi, India, 1996. pp. 6-14.

[8] Konak M, Carman K, Aydin C. Physical properties of chickpea grains. Biosystems Engineering, 2002; 82(1): 73-78.

[9] Nikoobin M, Mirdavardoosti F, Kashaninejad M, Soltani A. Moisture-dependent physical properties of chickpea seeds. Journal of Food Process Engineering, 2009; 32: 544-564.

[10] Paksoy M, Aydin C. Some physical properties of edible squash (*Cucurbita pepo* L.). Journal of Food Engineering, 2004; 65: 225-231.

[11] Haciseferogullari H, Gezer I, Bahtiyarca Y, Menges H O. Determination of some chemical and physical properties of Sakiz faba bean (*Vicia faba* L. Var. Major). Journal of Food Engineering, 2003; 60(4): 475-479.

[12] Olajide J D, Igbeka J C. Some physical properties of groundnut kernels. Journal of Food Engineering, 2003; 58: 201-204.

[13] Vishwakarma R K, Shivhare U S, Nanda S K. Physical properties of guar seeds. Food Bioprocess Technology, 2012; 5: 1364-1371.

[14] Pradhan R C, Naik S N, Bhatnagar N, Vijay V K. Moisture-dependent physical properties of jatropha fruit. Industrial Crops and Products, 2009; 29: 341-347.

[15] Sirisomboon P, Kitchaiya P. Physical properties of *Jatropha curcas* L. kernels after heat treatments. Biosystems Engineering, 2009; 102: 244-250.

[16] Garnayak D K, Pradhan R C, Naik S N, Bhatnagar N. Moisture-dependent physical properties of jatropha seed (*Jatropha curcas* L.). Industrial Crops and Products, 2008; 27: 123-129.

[17] Suthar S H, Das S K. Some physical properties of karingda [*Citrullus lanatus* (Thumb) Mansf] seeds. Journal of Agricultural Engineering Research, 1996; 65: 15-22.

[18] Olajide J O, Ade-Omowage B I O. Some physical properties of locust bean seed. Journal of Agricultural Engineering Research, 1999; 74: 15-22.

[19] Sobukola O P, Onwuka V I. Effect of moisture content on some physical properties of locust bean seed (*Parkia fillicoidea* L.). Journal of Food Process Engineering, 2011; 34: 1946-1964.

[20] Makajuola G A. A study of some of physical properties of melon seeds. Journal of Agricultural Engineering Research, 1972; 17(1): 128-137.

[21] Oje K, Ugbor E C. Some physical properties of oil bean seed. Journal of Agricultural Engineering Research, 1991; 50: 305-313.

[22] Sahoo P K, Srivastava A P. Physical properties of okra seed. Biosystems Engineering, 2002; 83(4): 441-448.

[23] Baryeh E A, Mangope B K. Some physical properties of QP-38 variety pigeon pea. Journal of Food Engineering, 2002; 56: 59-65.

[24] Shepherd H, Bhardwaj R K. Moisture dependent physical properties of pigeon pea. Journal of Agricultural Engineering Research, 1986; 35: 227-234.

[25] Joshi D C, Das S K, Mukherjee R K. Physical properties of pumpkin seeds. Journal of Agricultural Engineering Research, 1993; 54: 219-229.

[26] Isik E, Unal H. Moisture-dependent physical properties of white speckled red kidney bean grains. Journal of Food Engineering, 2007; 82: 209-216.

[27] Sharma V, Das L, Pradhan R C, Naik S N, Bhatnagar N, Kureel R S. Physical properties of Tung seed: An industrial oil yielding crop. Industrial Crops and Products, 2011; 33: 440-444.

[28] Koocheki A, Razavi S M A, Milani E, Moghadam T M, Abedini M, Alamatiyan S, et al. Physical properties of watermelon seed as a function of moisture content and variety. International Agrophysics, 2007; 21: 349-359.

[29] AOAC. Official methods of analysis (13th Ed.). Association of Official Analytical Chemists, Arlington. 1980.

[30] Balasubramanian D. Physical properties of raw cashew nut. Journal of Agricultural Engineering Research, 2001; 78: 291-297.

[31] Coskun M B, Yalcin I, Ozarslan C. Physical properties of sweet corn seed (*Zea mays saccharata* Sturt.). Journal of Food Engineering, 2006; 74(4): 523-528.

[32] Dursun E, Dursun I. Some physical properties of caper seed. Biosystems Engineering, 2005; 92(2): 237-245.

[33] Arman K. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, 1996; 63(2): 87-92.

[34] Cetin M. Physical properties of barbunia bean (*Phaseolus vulgaris* L. cv. 'Barbunia') seed. Journal of Food Engineering, 2007; 80: 353-358.

[35] Deshpande S D, Bal S, Ojha T P. Physical properties of soybean. Journal of Agricultural Engineering Research, 1993; 56(2): 89-98.

[36] Singh K K, Goswami T K. Physical properties of cumin seed. Journal of Agricultural Engineering Research, 1996; 64(2): 93-98.

[37] Mohsenin N N. Physical properties of plant and animal materials, 2nd Ed. Gordon and Breach Science Publishers, New York. 1986.

[38] Sacilik K, Ozturk R, Keskin R. Some physical properties of hemp seed. Biosystems Engineering, 2003; 86(2): 191-198.

[39] Gupta R K, Das S K. Physical properties of sunflower seed. Journal of Agricultural Engineering Research, 1997; 66(1): 1-8.

[40] Nimkar P M, Mandwe D S, Dudhe R M. Physical properties of moth gram. Biosystems Engineering, 2005; 91(2): 183-189.

[41] SPSS Base 16.0 User's Guide. Statistical Package for Social Scientists (SPSS), Prentice Hall, Chicago, IL. 2007. pp. 551.

[42] Teotia M S, Ramakrishna P. Densities of melon seeds, kernels and hulls. Journal of Food Engineering, 1989; 9(3): 231-236.

[43] Milani E, Seyed M, Razavi A, Koocheki A, Nikzadeh V, Vahedi N, et al. Moisture dependent physical properties of cucurbit seeds. International Agrophysics, 2007; 21(2): 157-168.

[44] Zewdu A D, Solomon W K. Moisture-dependent physical properties of tef seed. Biosystems Engineering, 2007; 96(1): 57-63.

[45] Dutta S K, Nema V K, Bhardwaj R K. Physical properties of gram. Journal of Agricultural Engineering Research, 1998; 39(4): 259-268.

[46] Altuntas E, Ozgoz E, Taser O F. Some physical properties of fenugreek (*Trigonella foenum-graceum* L) seeds. Journal of Food Engineering, 2005; 71(1): 37-43.

[47] Kashaninejad M, Mortazavi A, Safekordi A, Tabil L G. Some physical properties of Pistachio (*Pistacia vera* L.) nut and its kernel. Journal of Food Engineering, 2006; 72(1): 30-38.

[48] Bande Y M, Adam N M, Azmi Y, Jamarei O. Moisture-dependent physical and compression properties of bitter melon (*Citrullus colocynthis* Lanatus.) seeds. International Journal of Agricultural Research, 2012; 7(5): 243-254.

[49] Dursun I, Tugrul K M, Dursun E. Some physical properties of sugarbeet seed. Journal of Stored Products Research, 2007; 43(2): 149-155.

[50] Tunde-Akintunde T Y, Akintubde B O. Effect of moisture content and variety on selected properties of beniseed. Agricultural Engineering International: The CIGR E-journal. Manuscript FP 07021, 2007; 9: 1-14.

[51] Altuntas E, Yildiz M. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains. Journal of Food Engineering, 2007; 78(1): 174-183.

[52] Teotia M S, Ramakrishna P, Berry S K, Kaur S. Some engineering properties of pumpkin (*Cucurbita moschata*) seeds. Journal of Food Engineering, 1989; 9(2): 153-162.