Moisture-dependent physical properties of kokum seed (*Garcinia indica* Choisy)

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Abstract

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Designing the equipment for processing, sorting and sizing of agricultural crops requires information about the crops' physical properties. The physical properties of kokum seed were evaluated as a function of moisture content in the range of 7.35 to 25.79% d.b. (dry basis). The average length, width, thickness and one thousand seed mass were 17.17 mm, 10.66 mm, 5.87 mm and 410 g, respectively, at a moisture content of 7.35% d.b. The average value of geometric mean diameter and sphericity were 10.19 mm and 59.75%, respectively, at moisture content of 7.35% d.b. As the moisture content increased from 7.35 to 25.79% d.b., the bulk density increased from 345 to 396 kg/m^3, true density decreased from 1179 to 1070 kg/m^3, and the corresponding porosity decreased from 65.73 to 55.46%; the repose angle and terminal velocity increased from 32.1 to 42.3° and 4.30 to 6.73 m/s, respectively. The static coefficient of friction increased on three structural surfaces namely, glass (0.59–0.73), stainless steel (0.81–0.87) and plywood (0.74–0.83) in the moisture range from 7.35 to 25.79% d.b. Linear regression equations were used to express the physical properties of kokum seeds as a function of moisture content.

Keywords: kokum butter; engineering properties; angle of repose; terminal velocity; static coefficient of friction

Kokum (*Garcinia indica* Choisy) which belongs to the Guttifereae family is a slender evergreen small tree with drooping branches which attains a pyramidal shape at maturity. It is a dioecious tree growing up to 18 m in height. The fruit is spherical, as large as a small orange, purple throughout, having 5–8 seeds compressed in an acid pulp (Krishnamurthy et al. 1982; Patil 2005). The seed contains about 32 to 35% fat. Seeds are traditionally decorticated by wooden mallets that need be crushed to obtain kernels. The kernels are 60% of seed by weight and contain 44% fat. Kernels are crushed by boiling of pulp and then alkali and bleaching process is used to get fat. This fat is called Kokum Butter. Its colour is light grey or yellowish. It has food and non-food applications. Kokum butter is mainly used as edible fat, it remains solidified at room temperature (Sampathu, Krishnamurthy 1982). It is used as vaseline for cracks of skin of consumed for dysentery. For its properties similar to pine tallow it is useful in manufacture of ointments, cosmetic preparations, suppositories and pharmaceutical products; for medicinal purposes it is considered nutritive, demulcent, astringent and emollient. It is also used as confectionery butter, and also for candle and soap manufacture. It can be used for production of stearic acid from the fat with a yield of 45.7%. It can also be employed in the sizing of cotton yarn. The cake left after the extraction of oil is used as manure (Peter 2001).

In 2008–2009, about 119 t of kokum fat was exported with Free On Board (F.O.B.) earnings of 550,000 USD by India. F.O.B. prices mean all cost involved for exports upto vessel or plane etc. except freight.

Knowledge of kokum seeds' physical properties and their dependence on moisture content is essential to facilitate and improve the design of processing equipment as well as harvesting and storage procedures and facilities. During the process of extracting the kokum butter and its derivatives, the seeds undergo a series of unit operations. At each step, various types of cleaning, grading, separation and oil-extraction equipment operate on the basis of the seeds' physical properties.

Research on physical and engineering properties was reported for different types of seeds, such as soybeans (Deshpande et al. 1993) and sunflower (Gupta, Das 1997).

To our knowledge, detailed measurements of kokum seeds' principal dimensions and the variation of their physical properties at various moisture levels have not been reported. During this investigation some moisture-dependent physical properties of kokum seed were determined in the moisture range of 7.35 to 25.79% d.b. These parameters are important for the design of processing and handling equipment for processes such as oil extraction.

MATERIALS AND METHODS

Sample preparation. The kokum seed was used for all the experiments in this study (Fig.1). The seeds were obtained from the market of Kudal (Maharashtra State, India) during April–May, 2010 from a city located in the Sindhudurg district of Maharashtra and kept in cooled bags during transportation to the laboratory. The seeds were cleaned in an air screen cleaner to remove all foreign materials such as dust, dirt and chaff as well as immature and damaged seeds. The initial moisture content of the seeds, as brought from the market, was determined by drying samples in a hot air oven (Laboratory Quality Instruments, Kudal, India) set at 105°C (± 1°C) for 24h and was found to be 7.35% d.b. The drying condition was decided based on preliminary studies and in reference to the ASAE standards S352.3 (ASAE 1994). In order to achieve the desired moisture levels for the study, samples were conditioned by adding a calculated amount of water based on Eq. (1) (Balasubramanian 2001) followed by a thorough mixing and sealing in plastic bags:

$$Q = \frac{W_i(M_f - M_i)}{100 - M_f} \quad (1)$$

where:

Q – mass of water to be added (kg)

W_i – initial mass of the sample (kg)

M_i – initial moisture content of the sample (% w.b.)

M_f – is the final moisture content (% w.b.)

The samples were kept in a refrigerator at 5°C (±1°C) for 7 days for the moisture to distribute uniformly throughout the seed (Carman 1996). The moisture content of samples after equilibration was determined before each test was conducted. Accordingly, moisture levels of 7.35, 10.82, 16.15, 20.75 and 25.79% d.b. were obtained. The required amount of sample was withdrawn from the refrigerator and reconditioned at room temperature (≈25°C) before conducting each test. Every test was repeated five times to determine mean values.

Dimensions and one thousand seeds weight. To determine average seed size, 100 seeds were randomly picked and their three linear dimensions namely, length (L), width (W) and thickness (T) were measured using a 200 mm long, Digital Vernier Caliper (Mitutoyo, Kawasaki, Japan) with an accuracy of 0.01 mm. In order to determine the one thousand seeds weight (W_{1000}), one hundred seeds of kokum seeds were counted manually and

Fig. 1. Kokum seeds (*Garcinia indica* Choisy)

weighed by an electronic scale (Contech, Mumbai, India) with 0.01 g accuracy; this weight was extrapolating to 1,000 seeds.

The average seed diameter was calculated using the arithmetic mean and geometric mean of the three axial dimensions. The arithmetic mean diameter (D_a, mm) and geometric mean diameter (D_g, mm) of the seed were calculated by using the following relationships (MOHSENIN 1986):

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

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

where:
L – length (mm)
W – width (mm)
T – thickness (mm)

Sphericity, volume and surface area. The sphericity is defined as the ratio of the surface area of a sphere with the same volume as the seed to the surface area of the seed. This measurement was determined using the following equation (MOHSENIN 1986):

$$\varphi = \frac{(LWT)^{\frac{1}{3}}}{L} \tag{4}$$

where:
ϕ – sphericity (ratio, dimensionless)

Seed volume (V) and surface area (S) were calculated using the following equations (JAIN, BAL 1997):

$$V = 0.25\left[\left(\frac{\pi}{6}\right)L(W+T)^2\right] \tag{5}$$

$$S = \frac{\pi BL^2}{(2L-B)} \tag{6}$$

where:

$$B = \sqrt{WT} \tag{7}$$

where:
B – breadth (mm)

True density, bulk density and porosity. The bulk density (ρ_b) of kokum seeds was measured by filling an empty glass container of predetermined volume and net weight with seeds poured from a constant height, striking off the top level and weighing. The ratio of the mass and volume was expressed as bulk density. During the experiment, care was taken to avoid any compaction of the material in the container.

The true density (ρ_t) was determined using the toluene displacement method (MOHSENIN 1986). Toluene (C_7H_8) was used because seeds absorb it to a lesser extent than water. In addition, its surface tension is low, so that it fills even shallow dips in a seed, and its dissolution power is low (KABAS et al. 2007).

The porosity of kokum seeds at various moisture contents was calculated from bulk density and true density using the relationship given as follows:

$$\varepsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \times 100 \tag{8}$$

where:
ε – porosity (%)
ρ_b – bulk density (kg/m^3)
ρ_t – true density (kg/m^3)

Angle of repose and coefficient of static friction. The angle of repose is the angle with respect to the horizontal at which the material will stand when piled. This was determined by using an apparatus consisting of a plywood box of 140 × 160 × 35 mm and two plates: fixed and adjustable. The box was filled with the sample, and then the adjustable plate was inclined gradually allowing the seeds to follow and assume a natural slope, this was measured as emptying angle of repose (GHARIBZAHEDI et al. 2010).

The static friction coefficients against glass, plywood and stainless steel were determined using a cylinder of diameter 75 mm and depth of 50 mm filled with seeds. With the cylinder resting on the surface, the surface was raised gradually until the filled cylinder just started to slide down (RAZAVI, MILANI 2006).

Terminal velocity. Terminal velocity (V_t) was measured by using an air column system. For each experiment, a sample was dropped into the air stream from the top of the air column, up which air was blown to suspend the material in the air stream. The air velocity near the location of the seed suspension was measured by a hot wire anemometer having a least count of 0.01 m/s (resolution of anem.).

Statistical analysis. The results obtained were subjected to analysis of variance (ANOVA) and Duncan's test using SPSS 13 (SPSS Inc., Chicago, USA) software and analysis of regression using Microsoft Excel 2007 (Microsoft Corp., Redmond, USA).

Table 1. Means with standard error of the axial dimensions of kokum seeds at different moisture contents

Moisture content (% d.b.)	Axial dimension (mm)			Average diameter (mm)	
	length (L)	width (W)	thickness (T)	arithmetic mean (D_a)	geometric mean (D_g)
7.35	17.17 ± 0.200	10.65 ± 0.126	5.86 + 0.088	11.23	10.19
10.82	17.33 ± 0.202	10.82 ± 0.128	6.07 ± 0.087	11.41	10.40
16.15	17.63 ± 0.202	11.13 ± 0.125	6.42 ± 0.088	11.73	10.76
20.75	17.81 ± 0.199	11.32 ± 0.129	6.65 ± 0.088	11.93	10.99
25.79	18.00 ± 0.144	11.47 ± 0.097	6.86 ± 0.087	12.12	11.21

RESULTS AND DISCUSSION

Table 1 shows the experimental data on seed dimensions. The three axial dimensions increased with moisture content. The increase in the dimensions is attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the seeds. The length, width and thickness of seeds ranged from 17.17 to 18.00 mm, 10.65 to 11.47 mm and 5.86 to 6.86 mm, respectively, as the moisture content increased from 7.35 to 25.79% d.b. Differences between values are statistically important at $P < 0.05$. The average diameters increased with moisture content, with the arithmetic and geometric mean diameters increasing from 11.23 to 12.12 mm and from 10.19 to 11.21 mm, respectively, as the moisture content increased from 7.35 to 25.79% d.b

One thousand kokum seed mass increased linearly from 434.7 to 501.7 g as the moisture content increased from 7.35 to 25.79% d.b. (Fig. 2a). Accordingly, an increase of 15.41% in the one thousand seed mass was recorded within this moisture range. This parameter is useful in determining the equivalent diameter, which can be used in the theoretical estimation of seed volume and in cleaning using aerodynamic forces. The linear equation for one thousand seed mass (W_{1000}; g) can be formulated as:

$$W_{1000} = 416.02 + 17.08M_C \quad (R^2 = 0.997) \qquad (9)$$

Similarly, a linear increase in one thousand seed mass as the seed moisture content increases was noted by Isik and Izli (2007) for sunflower seed.

Sphericity of kokum seed increased from 59.75 to 62.40% as a result of increasing moisture content (Fig. 2b). The relationship between sphericity (ϕ; %) and moisture content (M_C; % d.b.) can be represented by the following equation:

$$\phi = 59.12 + 0.696M_C \quad (R^2 = 0.972) \qquad (10)$$

Similar trends were reported by Sahoo and Srivastava (2002) for okra seed, and by Altuntas et al. (2005) for fenugreek seed.

The volume of kokum seed was increased linearly from 624.46 to 801.22 mm^3 with the increase in moisture content (Fig. 2c). The linear equation for seed volume (V) can be formulated as:

$$V = 577.0 + 45.97M_C \quad (R^2 = 0.989) \qquad (11)$$

The surface area of kokum seed (S) was increased from 277.29 to 333.30 mm^2 as the moisture content increased from 7.35 to 25.79% d.b. (Fig. 2d). The relationship between moisture content and surface area appears linear and can be represented by the regression equation:

$$S = 262.30 + 14.50M_C \quad (R^2 = 0.990) \qquad (12)$$

Similar increase in volume and surface area with increase in moisture content was reported by Baryeh (2002) for millet.

Bulk density increased from 345.66 to 396.05 kg/m^3 as the moisture content increased from 7.35 to 25.79% d.b. (Fig. 3). The bulk density increased with an increase in moisture content for kokum seed. This could be a combined effect of void space and volumetric expansion of seed. As volume of the container used was constant and the total number of seeds in the container remained practically the same, the mass had to increase, thereby increasing the bulk density. The relationship between bulk density (ρ_b) and moisture content can be represented by the following regression equation:

$$\rho_b = 347.7 + 4.484M_C \quad (R^2 = 0.976) \qquad (13)$$

Similar increasing trends were reported for watermelon seed (Teotia, Ramakrishna 1989), for gram (Dutta et. al. 1988), pigeon pea (Shepherd,

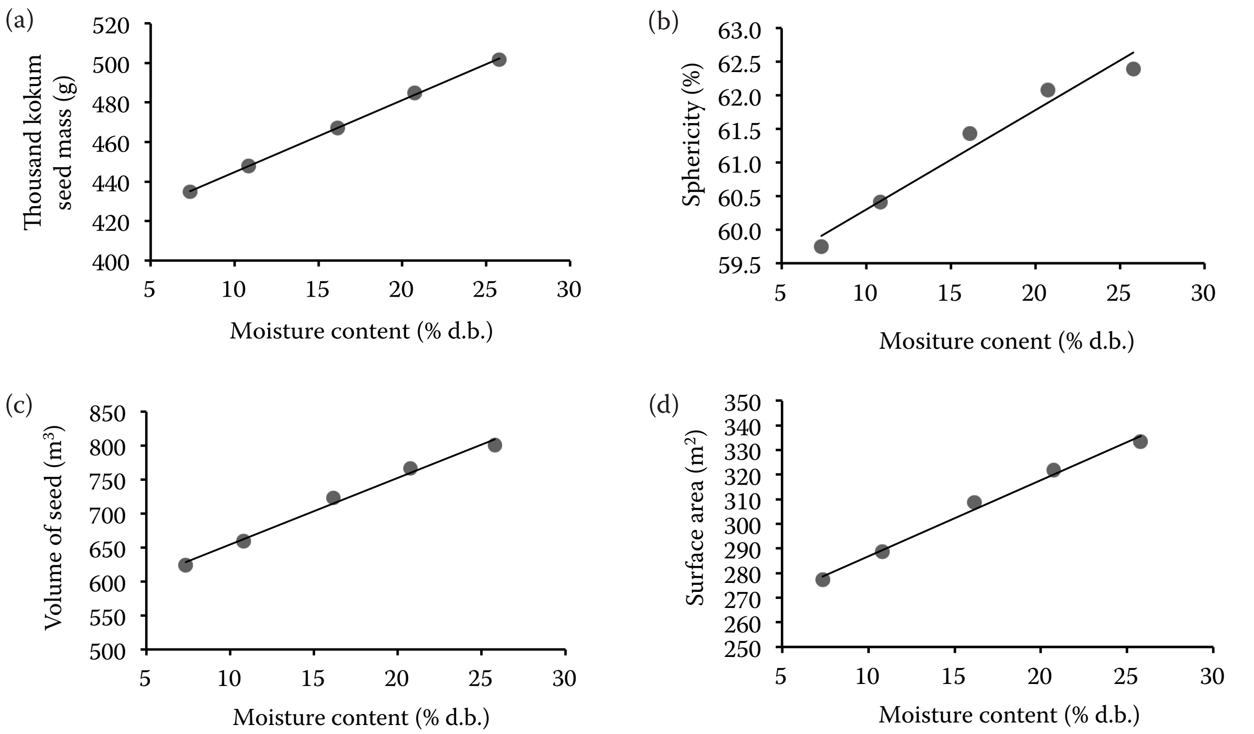

Fig. 2. Effect of moisture content on (a) one thousand seed mass, (b) sphericity, (c) volume and (d) surface area of kokum seed

Bhardwaj 1986) and faba bean (Fraser et al. 1978); their bulk density increased with an increase in moisture content.

The true density varied from 878.69 to 917.36 kg/m^3 as the moisture level increased from 7.35 to 25.79% d.b. ($P < 0.05$) (Fig. 3). The increase in true density might be attributed to the relatively lower true volume as compared to the corresponding mass of the seed attained due to the adsorption of water. Seeds' true density (ρ_t) and moisture content can be correlated as follows:

$$\rho_t = 876.4 + 2.035M_C \quad (R^2 = 0.983) \qquad (14)$$

The results were similar to those reported by Singh and Goswami (1996) for cumin seed.

The porosity decreased from 60.66 to 56.83% with the increase in moisture content from 7.35 to 25.79% d.b. (Fig. 4a). The relationship between porosity (ε) and moisture content can be represented by the following equation:

$$\varepsilon = 60.88 - 0.205\,M_C \quad (R^2 = 0.961) \qquad (15)$$

This could be attributed to the expansion and swelling of seeds that might have created more voids between the seeds and increased bulk volume. This is also exhibited in the reduction of bulk density with an increase in moisture content.

As the moisture content increased, the terminal velocity was found to increase linearly from 4.30 to 6.73 m/s in the specified moisture range (Fig. 4b). The increase in terminal velocity with increase in moisture content within the range studied can be attributed to the increase in mass of an individual seed per unit frontal area presented to the air stream. The relationship between moisture content and terminal velocity (V_t) can be represented by the following equation:

$$V_t = 3.951 + 0.202M_C \quad (R^2 = 0.978) \qquad (16)$$

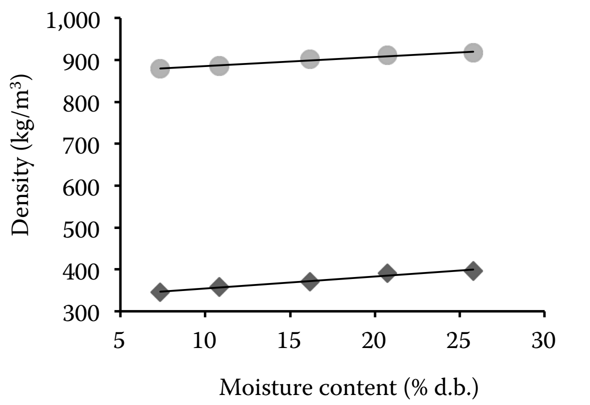

Fig. 3. Effect of moisture content on the bulk (◆) and true (●) density of kokum seed

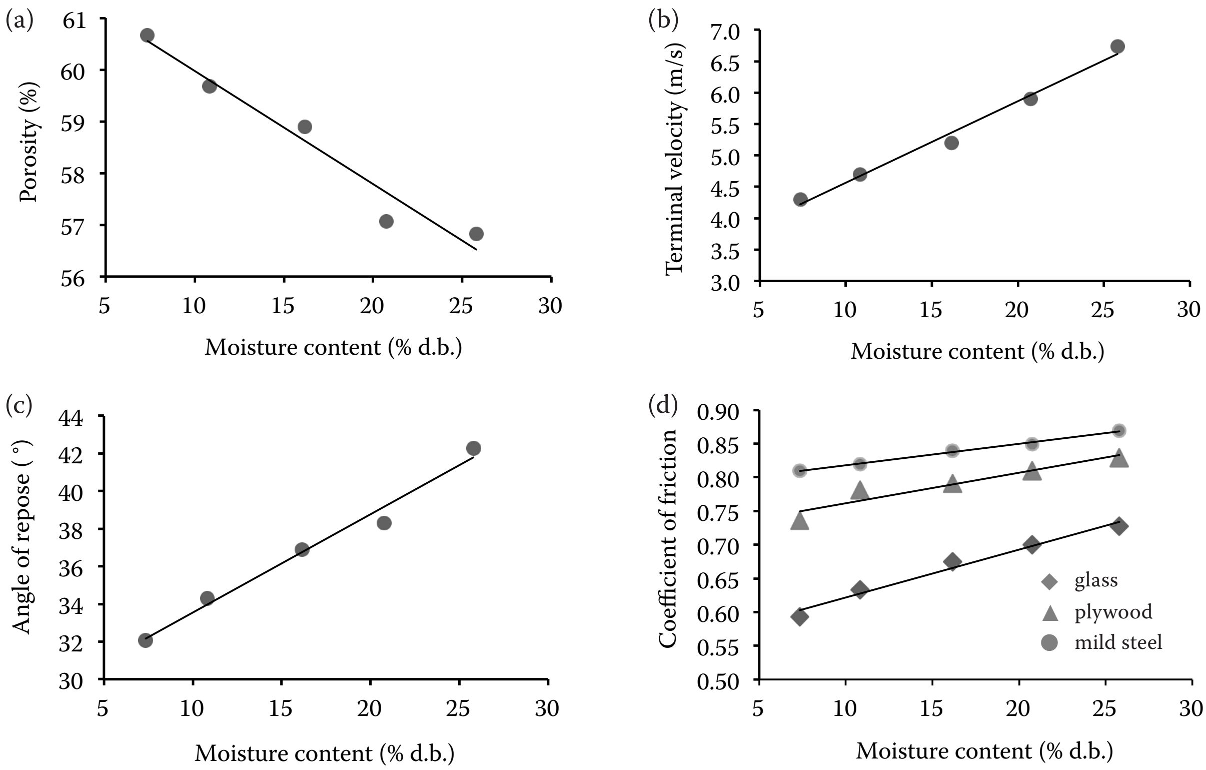

Fig. 4. Effect of moisture content on (a) porosity, (b) terminal velocity, (c) angle of repose and (d) static coefficient of friction of kokum seed

Singh and Goswami (1996), Suthar and Das (1996) and Nimkar and Chattopadhyay (2001) reported a linear increase in terminal velocity with increased moisture content for cumin seed, karingda seed and green gram respectively.

The angle of repose increased from 32.05° to 42.27° in the moisture range of 7.35% to 25.79% d.b. ($P < 0.05$) (Fig. 4c). At higher moisture content seeds might tend to stick together due to the plasticity effect (stickiness) over the surface of seeds, resulting in better stability and lower flowability, thereby increasing the angle of repose; the latter is of paramount importance in designing hopper openings, storage-bin side wall slopes and chutes for bulk transport. Therefore, moisture content of seeds should be taken into account while designing such equipment and structures. The relationship between angle of repose (α; in °) and moisture content can be represented by the following regression equation:

$$\alpha = 31.06 + 0.814M_C \quad (R^2 = 0.979) \qquad (17)$$

Singh and Goswami (1996), Nimkar and Chattopadhyay (2001), Baryeh (2002), Amin et al. (2004) and Altuntas et al. (2005) reported a linear increase in angle of repose with increase in the moisture content for cumin seed, green gram, millet, lentil and fenugreek, respectively. The static coefficient of friction increased with increase in moisture content on all surfaces (Fig. 4d). Differences between the values were statistically significant ($P < 0.05$). The increased value is due to increased adhesion between the seed and the surface at higher moisture values. Dutta et al. (1988) and Joshi et al. (1993) reported that as the moisture content increased, so did the coefficient of static friction.

The design of hoppers, bunker silos and other bulk solid storage and handling structures should ensure non-arching (that is avoiding stoppage of flow of bulk solids). The coefficient of mobility, which represents the freedom of motion of a substance, is inversely related to the coefficient of friction (tangent of angle of internal friction). The higher the coefficient of friction, the lower the mobility coefficient, and hence the larger the hopper opening and hopper side wall slope and the steeper angle of inclination is required in inclined grain transporting equipment. Optimum design will avoid immature flow (where some depth of granular particles remains stationary) and the arching phenomena to ensure a fully developed sliding flow (Gharibzahedi et al. 2010).

Table 2. Intercepts, regression coefficients and coefficient of determination (R^2) of Eq. (18) for static coefficient of friction on various test surfaces

Surface type	Intercept	Regression coefficient	R^2
Plywood	0.739	0.007	0.936
Mild steel	0.802	0.005	0.984
Glass	0.587	0.011	0.987

At all moisture contents, the static coefficient of friction was greatest against mild steel (0.81 to 0.87), followed by plywood (0.74 to 0.83) and least for glass (0.59 to 0.73). The linear equations for static coefficient of friction (μ) on all test surfaces can be represented as:

$$\mu = A + B \times M_C \quad (18)$$

where:
μ – coefficient of friction
A, B – intercept and regression coefficient, respectively

These values are given in Table 2.

CONCLUSION

The following conclusions can be drawn from this work:

One thousand seed mass increased from 434.7 to 501.7 g and the sphericity increased from 59.75 to 62.40% with an increase in moisture content from 7.35 to 25.79% d.b. The volume, arithmetic mean diameter and geometric mean diameter increased linearly from 624.46 to 801.22 mm^3, 11.23 to 12.12 mm and 10.19 to 11.21 mm, respectively. The surface area increased from 277.29 to 333.30 mm^2 and the porosity decreased from 60.66 to 56.83%. The bulk density increased linearly from 345.66 to 396.05 kg/m, whereas the true density increased from 878.69 to 917.36 kg/m^3.

The terminal velocity and angle of repose increased from 4.30 to 6.73 m/s and 32.05 to 42.27°, respectively. The static coefficient of friction increased on three structural surfaces: glass (0.59 to 0.73), plywood (0.74 to 0.83) and mild steel (0.81 to 0.87) in the moisture range from 7.35 to 25.79% d.b.

The physical parameters of kokum seeds are expressed in the form of regression equations as a function of moisture content. Once the moisture content is known, the physical parameters can be obtained from these equations. As moisture content depends on weather conditions, these equations can be used for other environmental conditions than those of India. These data can also be used for designing machines and storage facilities in India as well as other countries.

References

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

Amin M.N., Hossain M.A., Roy K.C., 2004. Effect of moisture content on some physical properties of lentil seeds. Journal of Food Engineering, *65*: 83–87.

ASAE, 1994. Moisture measurement-ungrounded grains and seeds. In: ASAE Standards 1994. St. Joseph, USA.

Balasubramanian D., 2001. Physical properties of raw cashew nut. Journal of Agricultural Engineering Research, *78*: 291–297.

Baryeh E.A., 2002. Physical properties of millet. Journal of Food Engineering, *51*: 39–46.

Carman K., 1996. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, *63*: 87–92.

Deshpande S.D., Bal S., Ojha T.P., 1993. Physical properties of soybean. Journal of Agricultural Engineering Research, *56*: 89–98.

Dutta S.K., Nema V.K., Bhardwaj R.K., 1988. Physical properties of gram. Journal of Agricultural Engineering Research, *39*: 259–268.

Gharibzahedi S.M.T., Mousavi S.M., Moayedi A., Taheri Gara V., Alizadeh S.M., 2010. Moisture-dependent engineering properties of black cumin (*Nigella sativa* L.) seed. Agricultural Engineering International: CIGR Journal, *12*: 194–202.

Gupta R.K., Das S.K., 1997. Physical properties of sunflower seeds. Journal of Agricultural Engineering Research, *661*: 1–8.

Hsu M.M., Mannapperuma J.D., Singh R.P., 1991. Physical and thermal properties of pistachios. Journal of Agricultural Engineering Research, *49*: 311–21.

Isik E., Izli N., 2007. Physical properties of sunflower seeds. International Journal Agricultural Research, *2*: 677–686.

Jain R.K., Bal S., 1997. Properties of pearl millet. Journal of Agricultural Engineering Research, *66*: 85–91.

Joshi D.C., Das S.K., Mukherjee R.K., 1993. Physical properties of pumpkin seeds. Journal of Agricultural Engineering Research, *54*: 219–229.

Kabas O., Yilmaz E., Ozmerzi A., Akinci I., 2007. Some physical and nutritional properties of cowpea seed (*Vigna sinensis* L.). Journal of Food Engineering, *79*: 1405–1409.

Konak M., Carman K., Aydin C., 2002. Physical properties of chick pea seeds. Biosystem Engineering, *82*: 73–78.

Krishnamurthy N., Lewis Y.S., Ravindranath B., 1982. Chemical constituents of kokum fruit rind. Journal of Food Science and Technology, *19*: 97–100.

Mirzaee E., Rafiee S., Keyhani A., Emam Djom-Eh Z., 2009. Physical properties of apricot to characterize best post harvesting options. Australian Journal of Crop Science, *3*: 95–100.

Mohsenin N.N., 1986. Physical Properties of Plant and Animal Materials. 2nd Ed.. New York, Gordon and Breach Science Publications.

Nimkar P.M., Chattopadhyay P.K., 2001. Some physical properties of green gram. Journal of Agricultural Engineering Research, *80*: 183–189.

Patil B.P., 2005. The world of Kokum and kokam in globalised world: facts on kokum, In: Proceeding of Second National Seminar on Kokum, University of Goa, India.

Perez E.E., Crapiste G.H., Carelli A.A., 2007. Some physical and morphological properties of wild sunflower seeds. Biosystem Engineering, *96*: 41–45.

Peter K.V., 2001. Handbook of Herbs and Spices. Boca Raton, CRC Press.

Razavi S., Milani E., 2006. Some physical properties of the watermelon seeds. African Journal Agricultural Research, *13*: 65–69.

Sahoo P.K., Srivastava A.P., 2002. Physical properties of okra seed. Biosystem Engineering, *83*: 441–448.

Sampathu S.R., Krisnamurthy N., 1982. Processing and utilization of kokum (*Garcinia indica*). Indian Spices, *19*: 15–16.

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

Singh K.K., Goswami T.K., 1996. Physical properties of Cumin seed. Journal of Agricultural Engineering Research, *64*: 93–98.

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

Teotia M.S., Ramakrishna P., 1989. Densities of melon seeds, kernels and hulls. Journal of Food Engineering, *9*: 231–236.

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