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Research paper

Moisture Dependent Physical Properties of Jackfruit Seed

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ABSTRACT

Effect of moisture content (9.43 to 101.7 and 11.37 to 130.68 % db) on physical properties (geometric, gravimetric and frictional properties of jackfruit seed i.e., firm flesh (*Kapa)* and soft flesh (*Barka*) were determined. The geometric properties (linear dimensions, sphericity, geometric mean diameter and surface area), gravimetric properties (bulk density, true density and porosity) and frictional property (angle of repose) were determined at moisture content 9.4, 19.9, 35.9 65.8, 101.7 (% db) for firm flesh (*Kapa)* and at 11.3, 37.3, 52, 89.5 and 130.6 for soft flesh (*Barka*). The geometric properties increase with increase in moisture content for both the types of jackfruit seeds. Bulk density, true density increases with increase moisture content while porosity decreases with decrease in moisture content in both types of jackfruit seeds. Bulk density was 626.2-383.7 kg/m^3 for firm flesh *(Kapa)* and 657.6-362.9 kg /m^3 soft flesh (*Barka*). The angle of repose was in range of 57.34-66.71° and 58.39-66.36° for firm flesh (*Kapa)* and soft flesh (*Barka*) respectively and it increases at moisture content (9.4 to 101.7 % db) and (11.3 to 130.6 % db) respectively.

Keywords: Firm flesh (*Kapa*), soft flesh (*Barka*), linear dimensions, sphericity, geometric mean diameter and surface area bulk density, truedensity, porosity, angle of repose

Jackfruit (*Artocarpus heterophyllus Lam.)* is one of the evergreen trees of family *moraceae* in tropical areas and widely grown in Asia including India. It produces heavier yield than any other tree and bear the largest known edible fruit (up to 35 kg in weight). Many parts of this plant, including the bark, roots, leaves, fruits and seeds have the medicinal use (Theivasanthi *et al.* 2001). The ripe fruit contains flavorful yellow sweet bulbs and seeds make-up around 10 to 15% of the fruit weight seeds. The seed is 2-3 cm in long and 1-2 cm in diameter. Up to 500 seeds can be found in a single fruit (Menka *et al.* 2011).

Jackfruit occurs naturally in two textural forms; soft flesh (*Barka)* with soft and pulpy perianth while firm flesh (*Kapa*) with firm perianth when ripe (Odoemelam, 2005). The edible bulbs of ripe jackfruit are consumed fresh or processed dehydrated bulbs, bulb powder into canned products. Seeds make-up around 10 to 15% of the total fruit weight and have high carbohydrate and protein contents (Tulyathan *et al.* 2002). Fig. 1 (a) shows the firm flesh (*Kapa*) jackfruit seed and Fig. 1 (b) shows the soft flesh (*Barka*) jackfruit seeds. The nutritional content of jackfruit seed is moisture content 61.8%, protein content (11.85%), fibre content (3.19 %) and carbohydrate content is (26.20 %). The calorific value is 382.79 kcal/100g. The

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(a) (b)

Fig. 1: Jackfruit Seed **(a)** Firm Flesh (*Kapa*); **(b)** Soft Flesh (*Barka*)

ash and fat contents (dry matter basis) is 0.15 % and 1.006 % respectively (Gupta *et al.* 2011). The Jackfruit seed flour contains an appreciable value of calcium (3087 mg/kg), Iron (130.74 mg/kg), potassium (14781 mg/kg), sodium (60.66 mg/kg), copper (10.45 mg/kg) and manganese (1.12 mg/kg). The jackfruit seed flour contains high water absorption capacity (25 %), fat absorption capacity (17.0 %) and bulk density (0.80 g/cm^3) is recorded (Ocloo *et al.* 2010).

The physical properties of jackfruit seed, which are important in the design and selection of storage structures, storage and processing equipment. The physical properties of jackfruit seeds are to be known; for design and improvement of relevant machines and facilities, storing, handling and processing. The information on seeds bulk density, true density, porosity and angle of repose can be useful for sizing seed hoppers and storage facilities: they can affect the rate of heat and mass transfer of moisture during the aeration and drying processes. The size and shape of seeds are important in designing of separating, harvesting, sizing and grinding machines. The physical properties depend, on seed moisture content.

The physical properties of various seeds, grains and nuts etc have been studied by various researchers. Altuntas *et al.* (2004); Milani *et al.* (2007); Aydin, 2003; Altuntas *et al.* (2007); Tavakoli *et al.* (2009); Ojediran *et al*. (2009); (Paksoy *et al.* 2010) for fenugreek seeds, cucurbit seeds, almond nut, faba bean, Soyabean grains, Pearl millet and watermelon seeds.

No detailed study concerning the physical properties of common types of jackfruit seeds have been reported in the literature. In the present study moisture dependent important physical properties (principal dimensions, geometric mean diameter, sphericity, bulk density, true density, porosity, angle of repose) were determined for two types of jackfruit seeds i. e.firm flesh (*Kapa)* and soft flesh (*Barka*) atmoisture contents 9.43 to 101.7 and 11.37 to 130.68 % db respectively. These data will useful to design of equipment for post harvest handling, drying and storage of the jackfruit seeds during processing.

MATERIALS AND METHODS

Raw material

The material required for experimentation was procured from the university farm (Central Experimental Station, Wakwali), Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. Jackfruits are available in two-types namely- firm flesh (*Kapa*) and soft flesh (*Barka*). Both types were collected at its maturity stage and kept at room temperature for

2-3 days for ripening. Fully ripe jackfruits of two types were cut with power operated jackfruit cutter developed in NAIP - Kokum, Karonda Jamun and Jackfruit laboratory; the seeds were removed from the perianths. The fruit outer layer was separated manually and the bulbs and seeds were separated. The seeds were washed with water. The surface moisture of the seeds were removed with the help of blotting paper.

Sample preparation

Physical properties determination

The collected seed of firm flesh *(Kapa)* and soft flesh (*Barka*) seeds were dried from initial moisture content 101.7 (% db) at 60 °C in convective hot air tray dryer for varied time interval i.e. 0, 3, 7.3, 12.1, 21.5 hours for firm flesh (*Kapa*) up to the final moisture content of 101.7, 65.86, 35.96, 19.9 and 9.433 (% db) and for soft flesh (*Barka)* seed was dried from initial moisture content 130.68 at 60 °C up to 130.6, 89.5, 52, 37.3 and 11.37 (% db) for 0, 3, 8.1, 12.2, 23.1 hours. The average moisture content achieved for firm flesh (*Kapa*) was 101.77, 65.86, 35.96, 19.93 and 9.433 (% db) and for soft flesh (*Barka*) was 130.68, 89.57, 52.06, 37.38 and 11.37 (% db) were taken for determination of physical properties of jackfruit seeds.

All physical properties were determined at all five moisture content i.e. 101.77, 65.86, 35.96, 19.93 and 9.433 (% db) for firm flesh (*Kapa*) and 130.68, 89.57, 52.06, 37.38 and 11.37 (% db) for soft flesh (*Barka*). Three replications of each test were carried out at each moisture level.

1. Linear dimensions (L, W, T)

The linear dimensions like length L (mm), width W (mm) and thickness T (mm) were measured from each set of moisture content, using vernier caliper of least count 0.01 cm. Length (mm), width (mm) and thickness (mm) was determined for jackfruit seed of firm flesh (*Kapa*) at 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and soft flesh (*Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. The experiment was replicated for hundred times for its replication.

2. Geometric mean diameter (D_p)

Geometric mean diameter of the jackfruit seeds were determined by using three linear dimensions namely length L (mm), width W (mm) and thickness T (mm) of seeds from each set of moisture content. The geometric diameter was determined for jackfruit seed of firm flesh (*Kapa*) at 101.77, 65.56, 35.96, 19.93 and 9.433 (db) and soft flesh (*Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. D_p of grain was calculated using the following equation (Milani *et al*. 2007).

$$D_p = (LWT)^{1/3} \qquad \ldots(1)$$

Where, L = length of seed, *mm*

W = width of seed, *mm*

T = thickness of seed, *mm*

3. Sphericity (Φ)

For obtaining sphericity the ratio of the surface area of the sphere having the same volume as that of seed to the surface area of grain was determined using the following formula (Seifi, 2010). The sphericity was determined for jackfruit seeds of firm flesh (*Kapa*) at 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and soft flesh (*Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. The degree of sphericity is calculated as,

$$\Phi = \frac{(LWT)^{1/3}}{L} \qquad \ldots(2)$$

This equation was used to calculate the sphericity of the jackfruit seeds in present investigation.

4. Surface area (S)

The surface area 'S' of the jackfruit seed was determined by the analogy with a sphere of same D_p, using Eq. (3) (Ampah *et al.* 2012; Tavakoli *et al*. 2009: Altuntas *et al*. 2005). The surface area was determined for jackfruit seeds of firm flesh (*Kapa)* at 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and soft flesh *(Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content.

$$S = \pi \left(D_p \right)^2 \qquad \ldots(3)$$

Where, D_p = geometric mean diameter of seed (mm).

5. True density (ϱ_t)

The true density of a seed is defined as the ratio of the mass of a sample of a seed to the solid volume occupied by the sample (Altuntas *et al*. 2005). The jackfruit seed volume and its density were determined using the liquid displacement method. Toluene was used in place of water because it absorbed in lesser extent. Also, its surface tension is low, so that it fills even shallow dips in a seed and its low dissolution power (Altuntas *et al*. 2005). The true density was determined for jackfruit seed of firm flesh (*Kapa*) at 101.77, 65.56, 35.96, 19.93 and 9.433 (db) and soft flesh (*Barka)* at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. The experiment was repeated for three times for replication.

6. Bulk density (ϱ_b)

The bulk density was determined with a weight per hectoliter tester which was calibrated in kg per hectoliter (Milani *et al*. 2007). The jackfruit seeds at each moisture level were poured in the calibrated cylinder up to its brim from a height of about 15 cm and excess jackfruit seeds were removed by strike off sticks. The jackfruit seeds were not compacted in any way and then the weight (W) of 1000 ml seeds of all samples were recorded. The bulk density was assessed using Eq. (3). The bulk density was determined for jackfruit seed of firm flesh (*Kapa*) at 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and soft flesh (*Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. The experiment was repeated for three times for its replication.

$$\rho b = \frac{W}{1000} \times 10^6 \qquad \ldots(4)$$

Where, W = sample weight (g).

7. Porosity (P)

The porosity was calculated for jackfruit seed of firm flesh (*Kapa)* at 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and soft flesh (*Barka*) at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content. The porosity P of bulk jackfruit seeds were computed from the values of true density and bulk density using the relationship given by (Milani *et al*. 2007) as follows,

$$P(\%) = \left(1 - \frac{\rho b}{\rho t} \right) \times 100 \qquad \ldots(5)$$

8. Angle of repose (θ)

The angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using a topless and bottomless cylinder of 300 mm diameter and 500 mm height. The cylinder was placed at the center of a raised circular plate and was filled with jackfruit seeds. The cylinder was raised slowly until it formed a cone on a circular plate. The angle of repose was calculated from the measurement of the height of the cone and the diameter of cone (Altuntas *et al*. 2004). The experiment was performed at moisture content 101.77, 65.56, 35.96, 19.93 and 9.433 (% db) for firm flesh (*Kapa*) and soft flesh *(Barka)* at 130.68, 89.57, 52.06 37.38 and 11.37 (% db). The experiment was replicated for three times for its replication.

$$\theta = \tan^{-1} \left(2H / D \right) \qquad \ldots(6)$$

Where, H = Height of the heap, mm

D = Diameter of the heap, mm

RESULTS AND DISCUSSION

Linear dimensions

Fig. 2- 4 shows the effect of moisture content on the linear dimensions i.e. L, W, and T of jackfruit seeds i.e. firm flesh (*Kapa*) and soft flesh (*Barka*) types. The linear dimensions length (L), width (W) and thickness (T) of jackfruit seed at 9.43 to 101.7 and 11.37 to 130.68 (% db) moisture contents indicated the average values of length (L) increases from 23.13 to 26.99 mm and from

23.85 to 27.99 mm; the width increases from 13.10 to 17.94 mm and from 13.84 to 18.64 mm; whereas the thickness increases from 9.857 to 12.94 mm and from 10.05 to 14.26 mm for the firm flesh (*Kapa*) and soft flesh (*Barka*) types jackfruit seeds.

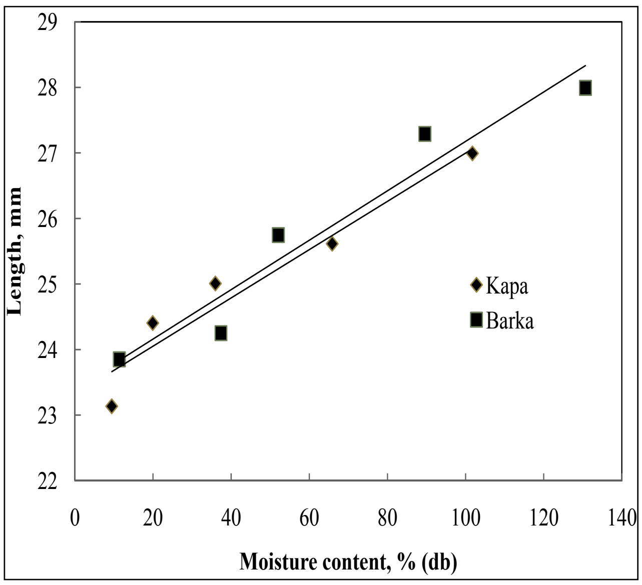

Fig. 2: Effect of moisture content (% db) on length (L) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

These linear behaviors are in accordance with results reported in literature for almond, cucurbit seeds, Pearl millet and watermelon seeds, Aydin, 2003; Milani *et al.* 2004; Ojediran *et al*. 2009; and Paksoy *et al.* 2010. The relationships between axial dimensions (L, W, T) and moisture content (% db) for jackfruit seed i.e. firm flesh (*Kapa*) and soft flesh (*Barka)* were found to be linear and can be expressed as in Eq. (7, 8, 9, 10, 11, and 12) and presented in Table 1.

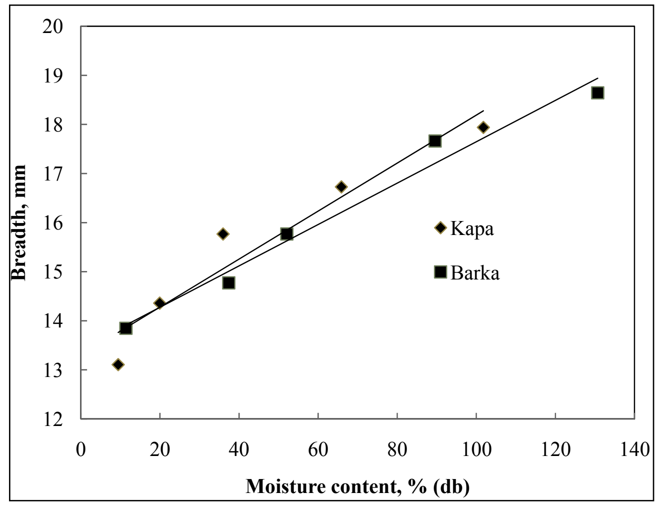

Fig. 3: Effect of moisture content (% db) on width (W) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

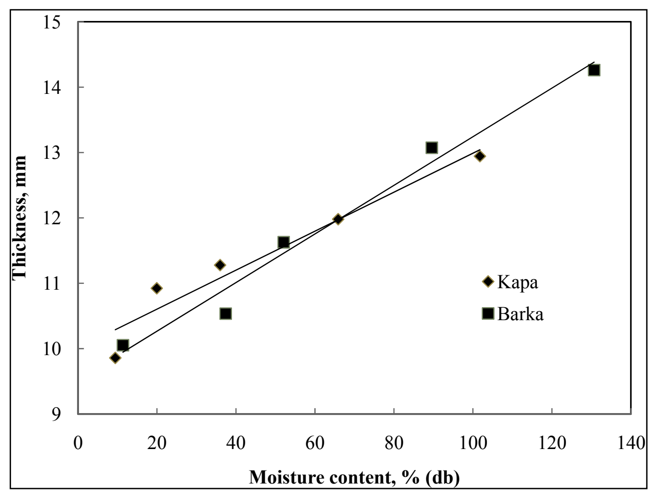

Fig. 4: Effect of moisture content (% db) on thickness (T) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

Table 1: Relationship between the linear dimensions (L, W, T) of jackfruit seeds at varied moisture content

Type of seed	Linear dimensions	Equation	Correlation Coefficient (R^2)	Eq. no.
Firm flesh (*Kapa)*	Length (L)	L= 0.036x + 23.31	0.931	…(7)
	Width (W)	W = 0.048x + 13.30,	0.976	…(8)
	Thickness (T)	T = 0.029x + 10.00,	0.936	…(9)
Soft flesh *(Barka*)	Length (L)	L = 0.037x + 23.40,	0.936	…(10)
	Width (W)	W = 0.042x + 13.43,	0.976	…(11)
	Thickness (T)	T = 0.037x + 9.522,	0.980	…(12)

Geometric mean diameter (D_p)

The variation of mean geometric diameter of the jackfruit seed at increase in moisture content is shown in Fig. 5.

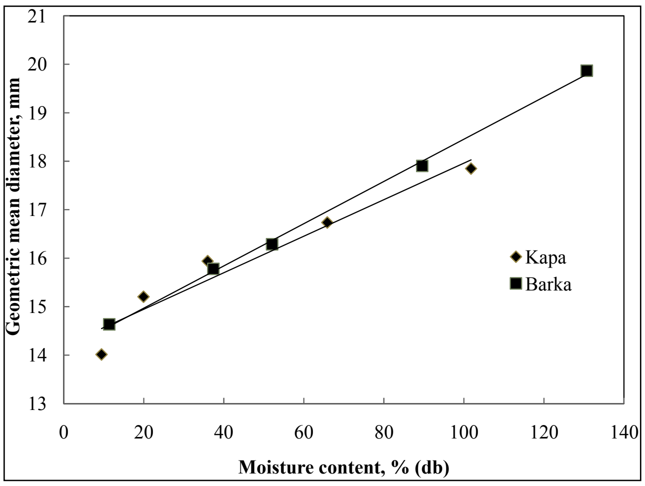

Fig. 5: Effect of moisture content (% db) on geometric mean diameter (D_p), (mm) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

It is evident from the figure that geometric mean diameter of seeds increases with increase in moisture content. Mean values of geometric mean diameter were increases from 14.01 to 17.84 mm and from 14.63 to 19.86 mm at 9.43 to 101.7 (% db) moisture content for firm flesh (*Kapa*) and 11.37 to 130.68 (% db) moisture content for soft flesh (*Barka)* seed respectively. The geometric mean diameter increases with increase in moisture content for both the type of seeds. Eq. 13 and 14 represented relationship between the geometric mean diameters with the moisture content. These linear behaviors are in accordance with similar kind of results reported in literature for Cucurbit seeds, Tigernut and Pistachio nuts (Milani *et al.* 2007; Oyerinde and Olalusi, 2013; Peyman *et al.* 2013) respectively.

$$D_{pk} = 0.037x + 14.19 \ R^2 = 0.936 \quad \ldots(13)$$

$$D_{pb} = 0.043x + 14.09 \ R^2 = 0.998 \quad \ldots(14)$$

Sphericity (Φ)

The sphericity of jackfruit seed were calculated using Eq. (2). The sphericity of jackfruit seed increases with increase in moisture content for both firm flesh (*Kapa*) and soft flesh (*Barka*) type jackfruit seeds. The sphericity of jackfruit seeds increases from 0.606 to 0.664 with increase in moisture content from 9.433 to 101.77 (% db) and from 0.608 to 0.673 with moisture content from 11.37 to 130.68 (% db) for firm flesh (*Kapa*) and soft flesh (*Barka)* seeds respectively.

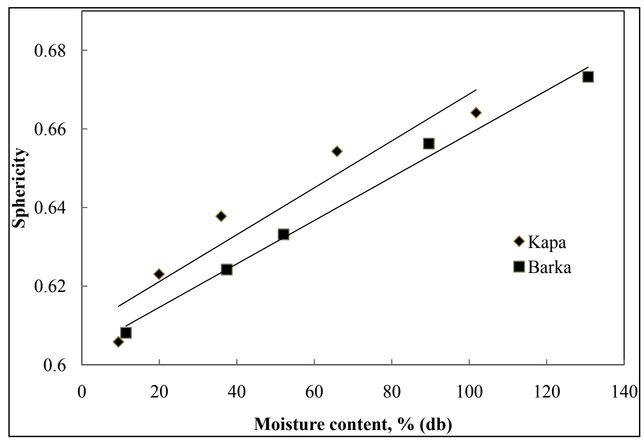

Fig. 6: Effect of moisture content on sphericity of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

Fig. 6 shows the sphericity of jackfruit seed for firm flesh (*Kapa*) and soft flesh (*Barka*) seeds at varied moisture contents 9.43 to 101.7 and 11.37 to 130.68 (% db) for firm flesh (*Kapa)* and soft flesh (*Barka*) respectively. Equation 15 and 16 shows the relationship between sphericity of jackfruit seeds at varied moisture content for firm flesh (*Kapa)* and soft flesh (*Barka*) type jackfruit seeds. The increase in sphericity with increase in moisture has been reported for watermelon seeds, Pistachio nuts and Sunflower seeds (Paksoy *et al.* 2010; Peyman *et al.* 2013 and Seifi, 2010) respectively.

$$\Phi_k = 0.001x + 0.609 \ R^2 = 0.907 \quad \ldots(15)$$

$$\Phi_b = 0.001x + 0.603 \ R^2 = 0.992 \ . \quad ..(16)$$

Surface area (S)

The surface area obtained for jackfruit seeds of firm flesh (*Kapa*) and soft flesh (*Barka)* types is graphically represented in Fig 7. The surface area increases linearly from 620.00 to 1014.17 mm^2 and 662.28 to 1140.82 mm^2 with increase in moisture content from 9.433 to 101.77 (% db)and 11.37 to 130.68 (% db) for firm flesh (*Kapa)* and soft flesh (*Barka*) seeds respectively.

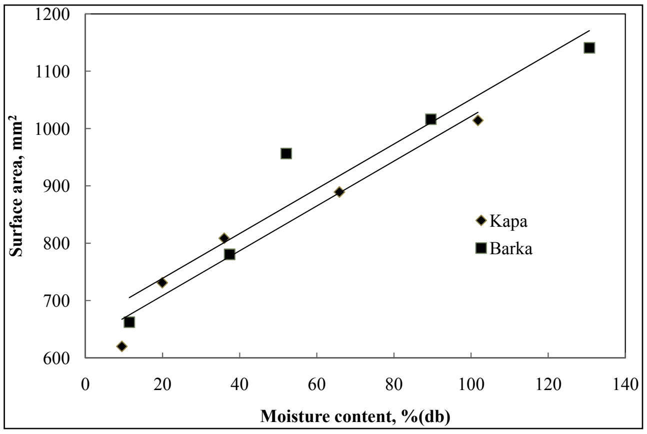

Fig. 7: Effect of moisture content (% db) on surface area (*S*) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

This linear relationship of surface area for firm flesh (*Kapa*) and soft flesh (*Barka*) is presented in Eq. 17 and 18. This increase in surface area was observed due to increase in dimensions of jackfruit seeds with respect to increase in moisture content of jackfruit seeds. Similar trend of increase in surface area has been reported for Fenugreek seed, cowpea and Soyabean grains (Altuntas *et al.* 2004; Ampah *et al*. 2012 and Tavakoli *et al*. 2009) respectively.

$$S_k = 0.3909\,x + 630.40 \quad R^2 = 0.951 \qquad ...(17)$$

$$S_b = 0.3902\,x + 460.07 \quad R^2 = 0.917 \qquad ...(18)$$

Bulk density (ϱ_b)

Fig. 8 shows the effect of moisture content on bulk density of jackfruit seeds. As it can be seen, that firm flesh (*Kapa)* and soft flesh (*Barka*) jackfruit seeds shows linear increase in bulk density with increase in moisture content from 9.433 to 101.77 (% db)and 11.37 to 130.68 (% db) respectively. The increase in bulk density was due to an increase in mass due to moisture gain in the sample which was higher than the volumetric expansion of the bulk. It was observed that the bulk density at 9.433 to 101.77 (% db)and 11.37 to 130.68 (% db) moisture content for firm flesh (*Kapa*) and soft flesh (*Barka*) seeds was increases from 383.7 to 626.2 kg/m^3 and from 362.9 to 657.6 kg/m^3 respectively.

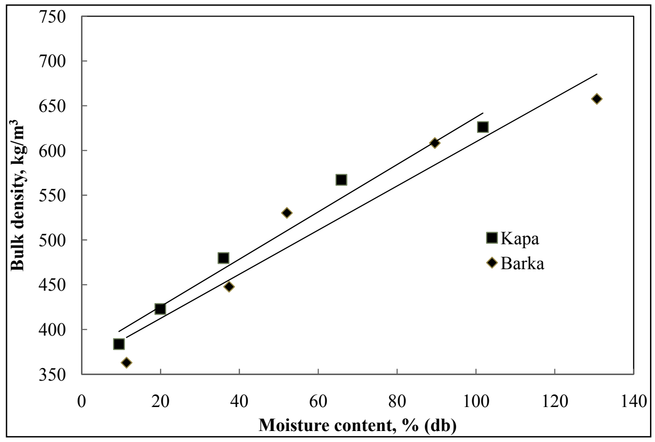

Fig. 8: Effect of moisture content (% db) on bulk density (ρb) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

The bulk density in seed increases linearly with increase in moisture content as represented in Eq. 19 and 20 for firm flesh (*Kapa*) and soft flesh (*Barka*) jackfruit seeds. Similar trends were observed for Pistachio nut, Tigernut and Barley (Peyman *et al.* 2013; Oyerinde and Olalusi, 2013 and Aghajani *et al*. 2012) respectively.

$$\rho_{kb} = 0.002x + 0.372 \quad R^2 = 0.975 \qquad \ldots(19)$$

$$\rho_{bb} = 0.003x + 0.380 \quad R^2 = 0.900 \qquad \ldots(20)$$

True density (ϱ_t)

Fig. 9 shows the increase of true density of jackfruit seeds at 9.433 to 101.77 (db) and 11.37 to 130.68 (db) for firm flesh (*Kapa)* and soft flesh (*Barka*) seeds. It was observed that the true density for firm flesh (*Kapa*) was 829 to 1054.54 kg/m^3, and for soft flesh (*Barka*) was 844 to 1088 kg/m^3 as moisture contents increases from 9.433 to 101.77 (% d.b.) and 11.37 to 130.66 (% d.b.) respectively. The true density of jackfruit seeds shows linear increase with increase in moisture content is shown in Eq. 21 and 22. Similar trends were observed for Groundnut kernel, Barley and Pistachio nut (Firouzi *et al.* 2009; Aghajani *et al.* 2012 and Peyman *et al.* 2013) respectively.

$$\rho_{tk} = 0.002x + 0.831 \; R^2 = 0.933 \qquad \ldots(21)$$

$$\rho_{tb} = 0.002x + 0.839 \; R^2 = 0.963 \qquad \ldots(22)$$

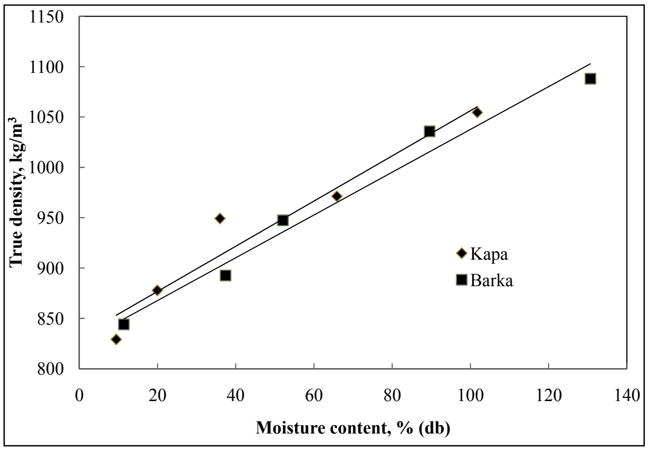

Fig. 9: Effect of moisture content (% db) on true density (ρ_t) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

Porosity (P)

Fig. 10 shows the effect of moisture content on porosity of jackfruit seed, firm flesh (*Kapa*) and soft flesh (*Barka*).

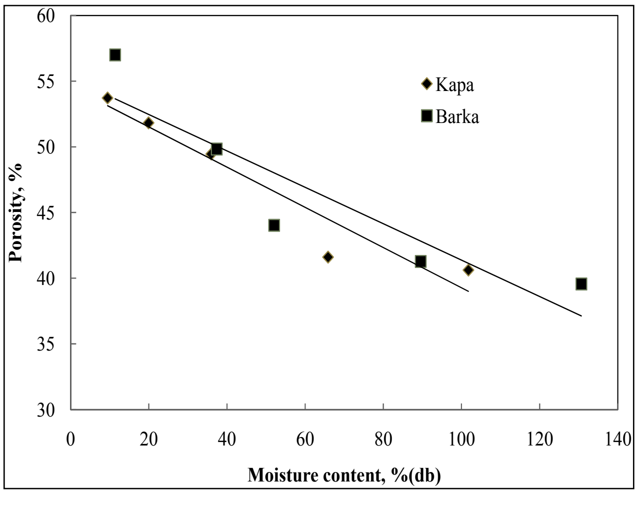

Fig. 10: Effect of moisture content (% db) on porosity (*P*) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

The porosity of jackfruit seed for firm flesh (*Kapa)* and soft flesh (*Barka*) decreases from 53.71 to 40.61 % and from 57.00 to 39.55 % as moisture content increases from 9.433 to 101.77 (% d.b.) and from 11.37 to 130.66 (% d.b.) moisture content respectively. The effect of porosity on moisture content of jackfruit seeds follows linear relationship with increase in moisture content which is represented by Eq. 23 and 24. The nature is similar to that for Pistachio nut (Peyman *et al.* 2013).

$$P_k = -0.138x + 55.23 \; R^2 = 0.825 \qquad \ldots(23)$$

$$P_b = -0.153x + 54.57 \; R^2 = 0.919 \qquad \ldots(24)$$

Angle of repose (θ)

The angle of repose of jackfruit seed increases from 57.34 to 66.31° and 58.39 to 66.36° for firm flesh (*Kapa*) and soft flesh (*Barka*) jackfruit seeds respectively at moisture content increases from 9.433 to 101.77 (% d.b.) and from 11.37 to 130.66 (% d.b.), respectively.

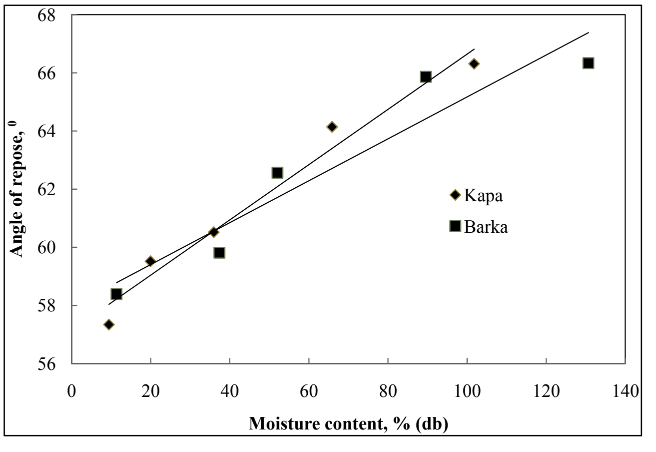

Fig. 11: Effect of moisture content (% db) on angle of repose (θ) of jackfruit seed **(a)** firm flesh (*Kapa*); **(b)** soft flesh (*Barka*)

Fig. 11 shows the effect of moisture content on angle of repose of firm flesh (*Kapa*) and soft flesh (*Barka*) seed. The increase of angle of repose may be due to increase of internal friction with increase of contact surface area among the seed. It is fact that if internal friction among the grain increases the angle of repose will also be increased. The values of angle of repose for two types of jackfruit seed firm flesh (*Kapa*) and soft flesh (*Barka*) shows linear relationship with increase in moisture content. Eq. (25) and (26) represents the relationship between angle of repose and moisture content of firm flesh (*Kapa*) and soft flesh (*Barka*) jackfruit seed. Similar trend were observed for Fenugreek seeds, Groundnut kernel and Pearlmillet (Altuntas *et al.* 2004; Firouzi *et al.* 2009 and Ojediran *et al.* 2010).

$$\theta_k = 0.095 + 57.13\ R^2 = 0.970\ . \quad ..(25)$$

$$\theta_b = 0.072x + 57.96\ R^2 = 0.904 \quad \dots(26)$$

CONCLUSION

The following conclusions were drawn from the experiment on physical properties of jackfruit seed at five moisture content at101.77, 65.56, 35.96, 19.93 and 9.433 (% db) and at 130.68, 89.57, 52.06 37.38 and 11.37 (% db) moisture content for firm flesh (*Kapa*) and soft flesh (*Barka*) seeds respectively.

1. The linear dimensions length (L), width (W) and thickness (T) of jackfruit seed at different moisture contents, length (L) were increases from 23.13 to 26.99 mm and from 23.85 to 27.99 mm; the width varied from 13.10 to 17.94 mm and 13.84 to 18.64 mm, whereas the thickness between 9.857 to 12.94mm and 10.05 to 14.26 mm for the firm flesh (*Kapa)* and soft flesh *(Barka)* types jackfruit seeds respectively with increase in moisture content from 9.433 to 101.77 (% db) and 11.37 to 130.68 (% db).
2. The bulk density at 9.433 to 101.77 (db)and 11.37 to 130.68 (db) moisture content for firm flesh (*Kapa*) and soft flesh (*Barka*) was 626.2 to 383.7 kg/m^3 and 657.6 to 362.9 kg/m^{3}whereas the true density for firm flesh (*Kapa*) was 1054.54-829 kg/m^3, and for soft flesh (*Barka*) 1088 to 844 kg/m^3 as moisture content increases from 9.433 to 101.77 (% d.b.) and 11.37 to 130.66 (% d.b.) respectively.
3. The porosity of jackfruit seed for firm flesh (*Kapa*) and soft flesh (*Barka)* were decreases from 40.61% to 53.71 and 39.55 to 57.00 % at 9.433 to 101.77 (% d.b.) and 11.37 to 130.66 (% d.b.) moisture content respectively.
4. The angle of repose of jackfruit seed were increases from 57.34 to 66.31^o and 58.39 to 66.36^o for firm flesh (*Kapa*) and for soft flesh (*Barka*) jackfruit seeds from moisture content 9.433 to 101.77 (% d.b.) and 11.37 to 130.66 (% d.b.), respectively.

Nomenclature

L - Length, mm

W - Width, mm

T - Thickness, mm

D_p - Geometric mean diameter, mm

D_{pk} - Geometric mean diameter of Kapa, mm

D_{pb} - Geometric mean diameter of Barka, mm

Φ - Sphericity, %

Φ_k - Sphericity of Kapa, %

Φ_k - Sphericity of Barka, %

S - Surface area, mm^2

S_k - Surface area of Kapa, mm^2

S_b - Surface area of Barka, mm^2

ϱ_t - Truedensity, g/cm^3

ϱ_{tk} - Truedensity of Kapa, kg/m^3

ϱ_{tb} - Truedensity of Barka, kg/m^3

ϱ_b - Bulk density, kg/m^3

ϱ_{bk} - Bulk density of Kapa, kg/m^3

ϱ_{bb} - Bulk density, Barka kg/m^3

P - Porosity, %

P_k - Porosity of Kapa, %

P_b - Porosity of Barka, %

θ - Angle of repose, ^{0}

θ_k - Angle of repose of Kapa, ^{0}

θ_b - Angle of repose of Barka, ^{0}

R^2 - Coefficient of determination

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