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Studies on physical, morphological and rheological properties of custard apple (*Annona squamosa* L)

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Abstract

A knowledge of physical and morphological properties of custard apple fruit and seeds as well as rheological properties of pulp-flakes are important for determining the unit operations during processing of custard apple pulp and for design of pulp-flakes extractor. In the present investigation, physical and morphological properties of custard apple fruit such as peel, carpellary pulp, gritty pulp and weight of seeds per fruit were found to be 46.77, 35.36, 11.63 and 6.24 %, respectively. Size, sphericity, and angle of repose were found to be increased with increase in moisture content while bulk density, true density and porosity decreased with increase in moisture content of custard apple seeds. It is of vital importance to study the separation of flakes of custard apple from seeds and to find out the force required for the separation. Rheological properties of custard apple pulp-flakes such as stickiness (184.34 g), hardness (596.67 g), cohesiveness (0.31) and viscosity (50.9 cP) were observed along with the shear force (1.84 N) required to separate the pulp-flakes from seeds.

Keywords : Custard apple, pulp-flakes, seeds, physical and rheological properties.

I. INTRODUCTION

Annona squamosa L. (Custard apple, *Sitaphal, Seethaphal, Shareefa*, Sugar apple, Sweetsop) is the most important tropical fruit and widely distributed among the annonaceous fruits. It is hardy and thrives well under adverse climatic conditions. In India, it is most commonly found in Andhra Pradesh, Maharashtra, Tamil Nadu, Orissa, Assam, Uttar Pradesh, Bihar and Rajasthan. In Maharashtra, the custard apple crop is mainly concentrated in the districts of Beed, Dhule, Pune, Aurangabad, Nagpur and Bhandara with a production of 2, 31,550 MT over an area of 45,000 ha (Shete et al., 2009).

It is usually eaten as a dessert fruit and finds immense applications in the preparations of beverages and ice creams (Chikhalikar et al., 2000). Fruit has gained considerable importance because of its sweet pulp being medicinally valuable and it is good source of carbohydrates (23.5 %), minerals (0.9 %) and proteins (1.6 %) as reported by Gopalan et al. (1991). Processed products of custard apple such as jam, jelly, crush etc. has more demand in the market if they have flakes along with pulp. Custard apple pulp has also great demand in ice-cream industry. However retention of flakes is more important during pulp extraction to have good organoleptic properties of processed products. Custard apple is considered as a critical fruit for separating the seeds from pulp-flakes with minimum damage to the flakes. A manual separation of pulp-flakes is very cumbersome, time consuming and unhygienic. It also leads to crushing of flakes to some extent. Further, manual separation has constraints in separation of pulp-flakes on large scale.

Physical and morphological properties of custard apple fruit and seeds and rheological properties of custard apple pulp-flakes are important for designing of custard apple pulp-flakes extractor machine and for determining the different processing conditions and unit operations related to separation of seeds from pulp-flakes. Therefore, there is a vital need to study the various properties of fruit, seeds, pulp and to find out the force required for the separation of flakes of custard apple from seeds. In the present investigation, physical and morphological properties such as per cent peel, per cent pulp, per cent seeds, number of seeds per fruit; physical properties such as size, sphericity and rheological properties *viz*., stickiness, cohesiveness, viscosity were determined along with the shear force required to separate the pulp-flakes from seeds.

II. MATERIALS AND METHODS

Custard apple fruits

Uniform size and healthy fruits of custard apple Cv. Local were procured from All India Co-ordinated Research Project on Arid Zone Fruits (Fig and Custard Apple), Jadhavwadi, Tahasil-Purandhar, District- Pune for the experiments during the year 2014.

Physical and morphological properties custard apple fruit

Physical and morphological properties of custard apple fruit such as weight of fruit, percentage of peel, carpellary pulp, gritty pulp and seed as well as weight per seed were measured by recording weight of each sample on a weighing balance (German Make) with 0.001 g least count and percentage value of each of the parameter were reported. Also, number of seeds per fruit, fruit to pulp ratio and pulp to seed ratio were also determined.

Physical properties of custard apple fruit

Physical properties of custard apple fruit such as length (along major axis), width (along intermediate axis) and breadth (along minor axis) were measured using digital Vernier Caliper (Mitutoya, Japan Make) having a least count of 0.01 mm. One hundred fruits were randomly selected and values for each parameter were recorded. Fruit size and sphericity were calculated following Mohsenin (1986).

Physical properties of custard apple seeds

Custard apple seeds immediately after separation from pulp were evaluated for seed size, sphericity, bulk and true density, porosity and angle of repose at initial moisture content of (15.40 % d.b.) seed and also after shade drying of seed to 12.50 and 10.25 % (d.b.). Spatial dimensions of seeds were measured using micrometer screw gauge (Mitutoya, Japan make) having least count of 0.01 mm and moisture content of the custard apple seed was determined by using hot air oven method (A.O.A.C., 1990).

Seed size

Seed size of 100 randomly selected sound seeds was calculated by using equation (1).

$$\text{Seed size} = (\text{abc})^{1/3} \quad \ldots(1)$$

Sphericity

Sphericity of custard apple seeds for100 fruits was determined by using equation (2).

$$\text{Spericity} = \frac{(\text{abc})^{1/3}}{\text{a}} \quad \ldots(2)$$

where, a = length (major axis), mm
b = width (intermediate axis), mm
c = breadth (minor axis), mm

Bulk density

Bulk density is defined as the ratio of total weight of sample to its total volume. Bulk density of 100 samples was determined as follows.

$$\text{Bulk density} = \frac{\text{Mass of seeds (g)}}{\text{Volume of seeds (mL)}} \quad \ldots(3)$$

True density

The ratio of sample mass to the true volume is termed as true density of the sample. It was determined by toluene liquid displacement method for 100 seed samples.

$$\text{True density} = \frac{\text{Mass of seeds (g)}}{\text{Volume of toluene displaced by seeds (mL)}} \quad \ldots(4)$$

Porosity

Porosity of custard apple seeds was calculated by using the formula :

$$\text{Porosity (\%)} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \text{x}100 \quad \ldots(5)$$

Angle of repose

Angle, with which the side of pile makes with the horizontal plane, is called as angle of repose. Angle of repose was calculated by using following formula.

$$\theta = \tan^{-1}(h/L) \quad \ldots(6)$$

where, θ = Angle of repose in degree
h = Height of inclined plate from base, mm
L = Length of plate, mm

Rheological properties custard apple pulp flakes

Rheological properties (*viz.,* shear force, viscosity, torque, hardness, cohesiveness and stickiness) of 15 fresh custard apple pulp flake samples were recorded.

Shear force required to separate the seeds from flakes

It is the force required to produce a major break/rupture in a sample to separate the seeds from the pulp-flakes and it was measured with the help of texture analyzer (M/s. Brookfield Engineering Labs, Inc., USA). Texture analyzer was equipped with a 50 N load cell and TA3/100 probe operated at a test speed of 1 mm/s transversally.

Pulp stickiness

Stickiness/adhesiveness is the work/force necessary to overcome the attractive forces between the surface of the product and the surface of the probe with which the product comes in contact. It is common textural property measured by texture analyzer and is multiplication of hardness and cohesiveness (which is Area2/Area1) (Peleg, 1996 and Breene, 2007). Hardness is the force required to compress a substance between the molar teeth or between tongue and plate to a given deformation or penetration and designated as soft, firm or hard.

Viscosity of pulp

Viscosity of custard apple pulp is a measure of its resistance to gradual deformation by shear stress or tensile stress. Viscosity of fresh custard apple pulp samples is measured with the help of Brookfield Viscometer DV-II+Pro. The spindle (probe) no. 64 was used for measurement of viscosity at 200 rpm with constant sample temperature 23.4°C.

III. RESULTS AND DISCUSSION

Physical and morphological properties of custard apple fruits

Physical and morphological properties of custard apple fruits are presented in Table 1. Weight of fruit and seed were found to be 238.68 and 0.30 g, respectively. Peel, carpellary pulp, gritty pulp and seeds were found to be 46.77, 35.36, 11.63 and 6.24 per cent, respectively. Number of seeds, total weight of pulp, fruit to pulp ratio and pulp to seed ratio recorded were 49.50, 113.29 g, 2.14 and 8.18, respectively. These results are in agreement with Beerh et al. (1983), Pal and Sampath Kumar, (1995), Rao and Subramanyam (2011) and Pawar (2012) for physical and morphological properties of custard apple fruits.

Table 1. Physical and morphological properties of custard apple fruit.

Parameter /property	Mean*± SE
Weight of fruit (g)	238.68 ± 14.97
Peel (g)	110.48 ± 6.23
Peel (%)	46.77 ± 0.82
Carpillary pulp (g)	85.42 ± 6.3
Carpillary pulp (%)	35.36 ± 0.73
Gritty pulp (g)	27.78 ± 2.37
Gritty pulp (%)	11.63 ± 0.54
Number of seeds per fruit	49.5 ± 3.85
Seeds per fruit (g)	15 ± 1.26
Seeds per fruit (%)	6.24 ± 0.31
Weight per seed (g)	0.30 ± 0.01
Total weight of pulp (g)	113.29 ± 8.19
Fruit to pulp ratio	2.14 ± 0.04
Pulp to seed ratio	8.18 ± 0.6
Major axis (mm)	84.00 ± 1.69
Intermediate axis (mm)	74.25 ± 1.76
Minor axis (mm)	65.15 ± 1.7
Size (mm)	74.04 ± 1.67
Sphericity (fraction)	0.88 ± 0.01

* Mean of 100 samples

Physical properties of custard apple fruits

Linear dimensions of 100 randomly selected fruits *viz.*, length, breadth and thickness of were 84.00, 74.25 and 65.15 mm, respectively. Size and sphericity of custard apple fruit were found to be 74.04 mm and 0.88, respectively (Table 1). These results are in accordance with Beerh et al. (1983), Dhumal (1994), Pal and Sampath Kumar (1995) and Pawar (2012) for the length, width, thickness, size and sphericity of custard apple fruits.

Physical properties of custard apple seeds

Linear dimensions *viz.*, length, breadth and thickness of custard apple seeds recorded were 13.698, 8.29 and 6.10 mm respectively at an initial moisture content (15.40 % d.b.) and same were decreased with decrease in moisture content to 12.50 and 10.25 % (d.b.), respectively. Similarly, seed size (8.83 mm), sphericity (0.65) and angle of repose (29.47^0) also decreased to 8.09 mm, 0.62 and 25.84^0, respectively with decrease in moisture content from 15.40 to 10.25 % (d.b.) However, bulk density (642.42 kg m^{-3}) true density (898.22 kg m^{-3}) porosity (28.46 %) were increased to 684.03 kg m^{-3}, 1002.73 kg m^{-3} and 31.74 per cent , respectively as initial moisture content was decreased from 15.40 to 10.25 % (d.b.), which exhibited the dependence of these physical properties on moisture content (Table 2 and Fig. 1 to 4). Similar findings were reported by Mishra et al. (2009) and Pawar (2012) for physical properties of custard apple seeds.

Table 2. Physical properties of custard apple seed at different moisture levels.

Parameter /property*	Moisture content (% d.b.)		
	15.4	12.5	10.25
Length (mm)	13.69 ± 0.26	13.04 ± 0.23	12.98 ± 0.19
Breath (mm)	8.29± 0.12	7.72 ± 0.14	7.49 ± 0.14
Thickness (mm)	6.10 ± 0.11	5.61 ± 0.12	5.49 ± 0.13
Seed size (mm)	8.83 ± 0.11	8.25 ± 0.12	8.09 ± 0.11
Sphericity	0.65 ± 0.01	0.63 ± 0.01	0.62 ± 0.01
Bulk density (kg m^{-3})	642.42 ± 3.47	661.35 ± 2.76	684.03 ± 1.92
True density (kg m^{-3})	898.22 ± 2.34	950.46 ± 2.24	1002.73 ± 5.43
Porosity (%)	28.46 ± 0.49	30.41 ± 0.32	31.74 ± 0.39
Angle of repose (^{0})	29.47 ± 0.24	27.85 ± 0.2	25.84 ± 0.35

* Mean of 100 samples

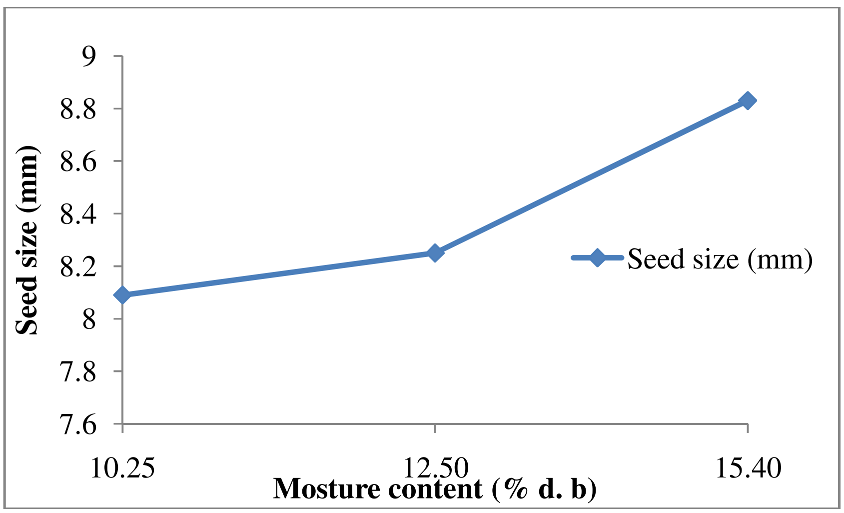

Figure 1. Effect of moisture content on size of custard apple seed

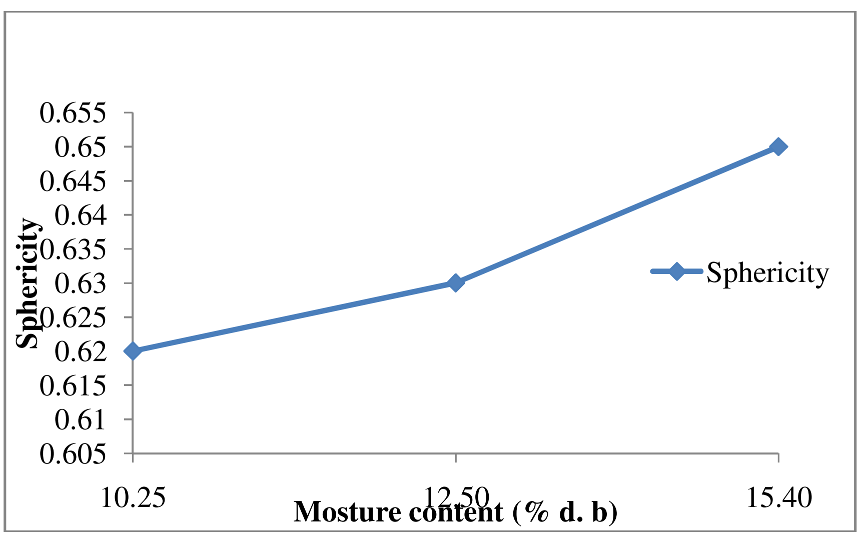

Figure 2. Effect of moisture content on sphericity of custard apple seed

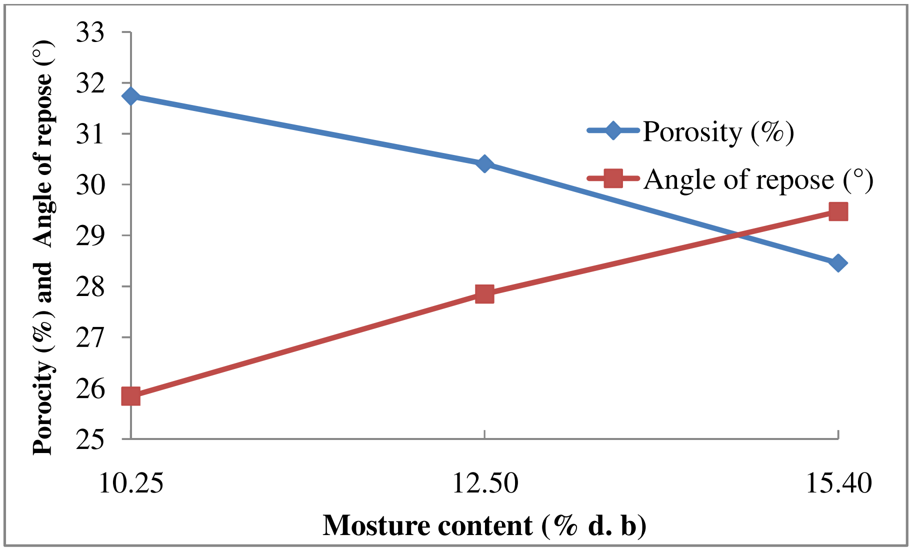

Figure 3. Effect of moisture content on porosity and angle of repose of custard apple seed

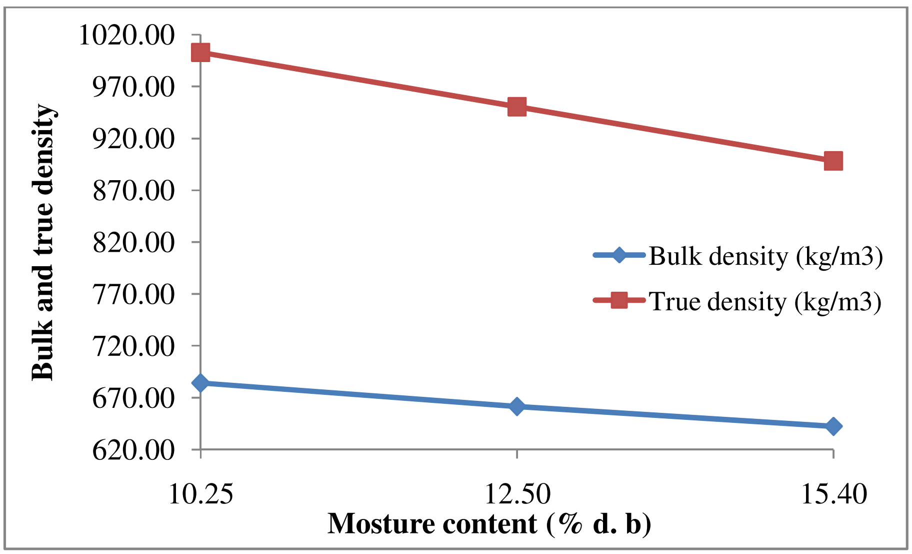

Figure 4. Effect of moisture content on bulk and true density of custard apple seed

Rheological properties

Knowledge of rheological properties *viz*., shear force, viscosity, torque, hardness, cohesiveness and stickiness are of vital importance for design of pulp-flake extractor equipment and to determine unit operations in processing of pulp.

Shear force required for separating flakes from the seeds is reported in Table 3. Shear force required to separate seeds from flakes was found to be 1.84 N. Similar results were reported by Soliva et al. (2002) for fresh cut pears, Costell et al. (1995) for sweet orange and Kokini and Carrilo (1989) for tomato paste.

Hardness and cohesiveness of custard apple pulp was recorded was 596. 67 g and 0.31, respectively. Stickiness, which is the product of hardness and cohesiveness was found to be 184.34 g. These findings are corroborated with Sigita et al. (2013) for apple pulp, Ahmad et al. (2005) for fruit bar made from papaya and tomato and Costell et al. (1995) for sweet orange.

Viscosity determines the flow characteristics of the pulp. Viscosity is required for determination of angle of outer casing and pulp-flakes outlet of the pulp-flakes extractor. Viscosity and torque of custard apple pulp is presented in Table 3. Values of viscosity and torque recorded were 50.9 cP and 33.07 Nm, respectively. These results are in agreement with the values as reported by Sigita et al. (2013) for apple pulp and Shahnawaz and Shiekh (2011) for jamun fruit juice, squash and jam.

Table 3. Rheological properties of custard apple pulp

Property	Mean*± SE
Shear force (N)	1.84 ± 0.14
Viscosity (cP)	50.90 ± 0.33
Torque (Nm)	33.07 ± 0.39
Hardness (g)	596.67 ± 98.05
Cohesiveness	0.31 ± 0.03
Stickiness (g)	184.34 ± 32.83

* Mean of 15 samples

IV. CONCLUSION

Peel, carpellary pulp, gritty pulp and seeds in custard apple fruit were found to be 46.77, 35.36, 11.63 and 6.24 %, respectively. Weight of fruit and seed recorded were 238.68 and 0.300 g, respectively. Linear dimensions, size, sphericity and angle of repose were decreased, while bulk density, true density and porosity were increased with decrease in moisture content showing their moisture dependence. Physical and rheological properties are very much useful for design of custard apple pulp-flakes extractor machine.

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