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Physico-Chemical Properties of Custard Apple

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Authors' contributions

This work was carried out in collaboration between both authors. Author SK designed the study, supervised the work, managed the analyses of the study, wrote the protocol and the first draft of the manuscript. Author KRJ observation the experiment and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Custard apple is a climacteric fruit with less storage life as compared to other fruits. Custard apple contain anti-oxidants like Vitamin-C and good source of potassium, magnesium, Vitamin-A. For development of processing technology (preparation of custard apple pulp and other value-added products) and equipment some basic data of physical and chemical properties are necessary. Hence, physico-chemical properties play important role in design or development of pre and post-harvest equipment and value added product. The observations on tree for percentage increase in dimensions of fruits (Horizontal and vertical diameter) on tree was more rapidly in early stage of fruit setting (0 to 25 days). After 25 days of fruit setting, the percentage increase in dimensions of fruit was increased gradually (30-40 days) and at the time of harvesting of fruit the percentage change in dimensions was negligible or became constant (45-55 days). The average weight, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, volume, hardness for ripe and unripe fruits were 103.04 g, 57.63 mm, 60.52 mm, 0.88, 10579.27 mm^2, 118.38 cm^3, 1.27 kgf; 143.57 g, 62.39 mm, 65.60 mm, 0.85, 12283.54 mm^2, 144.09 cm^3, 3.66 kgf, respectively. The pulp content, seeded pulp content, seed content, peel content for ripe and unripe fruits were 35.08%, 47.63%,

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11.38%, 51.50%; 31.98%, 40.20%, 7.52%, 59.29% respectively. The average moisture content, pH, total soluble solids, acidity, reducing sugar, total sugar, ascorbic acid for ripe and unripe fruit pulps were 68.42%, 6.1, 30.7 °brix, 0.3%, 8.5 g/100 g, 15.6 g/100 g, 13.65 mg; 64.75%, 5.8, 37.7 °brix, 0.3%, 5 g/100 g, 12.07 g/100g, 12.35 mg, respectively.

Keywords: Custard apple; physical properties; chemical properties.

1. INTRODUCTION

The custard apple (*Annona squamosa*) is a semi-deciduous, sub-tropical and climacteric fruit with less storage life as compare to other (George and Nissen [1]). Physico-chemical properties gives an idea for design efficient machine for pre and post harvest. These properties include the mass, size, volume, aerthmetic mean diameter, sphericity, bulk density, true density, porosity, surface area etc. some of the properties such as physicalogical increment in volume and weight of fruit on tree.

Custard apple tree is about 3-6 m (10 to 20 ft) in height with open crown of irregular branches and some-what zigzag twigs. Bark is thin and grey. Leaves are simple and alternate having dimensions 3.5-8 × 1.5-4 cm, oblong–lanceolate or elliptic, obtuse or sub-acute in shape, glabrous above, glucose and pubescent beneath when young; lateral nerves 8-11 pairs, petiole up to 2 cm long. Its flower is bisexual, drooping, green, solitary, leaf opposed or 2-4 on short extra auxiliary branch lets. They are oblong, 2.5-3.8 cm long, never fully open; with 2.5 cm long, drooping stalks, and 3 fleshy outer petals, yellow-green on the outside and pale-yellow inside with a purple or dark-red spot at the base. The 3-inner petals are merely tiny scales. The compound fruit is nearly round, ovoid, or conical; 6-10 cm long, 8-16 cm in diameter; may be symmetrically heart-shaped, lopsided, or irregular; or nearly round, or oblate, with a deep or shallow depression at the base. Its thick rind composed of knobby segments, pale-green, gray-green, bluish-green or in one form, dull, deep-pink externally (nearly always with a bloom); separating when the fruit is ripe and revealing the mass of conically segmented, creamy-white, glistening, delightfully fragrant, juicy, sweet, delicious flesh. The areoles are well marked and its pulp is white and sweet. Many of the segments enclose a single oblong-cylindrical, black or dark-brown seed about 1.25 cm long. There may be a total of 50 to 75, or perhaps more, seeds in the average fruit. Some trees, however, bear seedless fruits. Flowering time is March – July and the fruiting time is August - January (Pathak and Zaman [2]).

2. MATERIALS AND METHODS

2.1 Determination of Variations in Size of Fruits on Tree

To determine the changes in size of fruits on trees different locations around the college campus (College of Agricultural Engineering & Technology, Anand Agricultural University, Godhra, Gujarat, India) were identified. Among them four trees were selected for the study and randomLy three fruits have been selected in each tree for the monitoring of size variations. Daily monitoring of horizontal and vertical dimensions of fruits were measured using digital caliper (Fruit horizontal and vertical dimensions are helped to find out the fruit volume and using of true density to find out fruit mass).

2.2 Physical Properties

For determining the physical properties of custard apple, the standard procedure suggest by Mohsenin [3] were followed.

2.2.1 Weight

A digital balance (Osaw Industrial Product Pvt. Ltd., Haryana) with measurement precision of ±0.1g was used for weighing sample.

2.2.2 Geometric mean diameter (D_g)

Three principal axes (length, width and thickness) of the fruit and seed was measured with the help of Vernier-caliper (Mitutoyo Measuring Instruments (Suzhou) Co. Ltd., China) having a least count of 0.02 mm. The size of fruit and seed was calculated by using following formula (Sreenarayanan et al. [4] and Sharma et al. [5].

$$D_g = (L \times B \times T)^{1/3} \quad (1)$$

Where,

L= Major axial dimension (mm)
B= Intermediate axial dimension (mm)
T= Minor axial dimension (mm)

2.2.3 Arithmetic mean diameter (D_a)

Arithmetic mean diameter (D_a) for each custard apple fruit was calculated by using following equation (Mohsenin [3]).

$$D_a = \frac{(L+B+T)}{3} \quad (2)$$

Where,

D_a = Arithmetic mean diameter (mm)
L = length of fruit (mm)
B = width of fruit (mm)
T= thickness of fruit (cm)

2.2.4 Sphericity (Φ)

The sphericity of fruits and seeds was calculated by using following formula (Mohsenin [3]).

$$\Phi = \frac{(L \times B \times T)^{1/3}}{L} \quad (3)$$

Where,

Φ= Sphericity
L= Major axial dimension (mm)
B= Intermediate axial dimension (mm)
T= Minor axial dimension (mm)

2.2.5 Surface area (S)

The surface area of custard apple fruit was calculated by using below given formula (McCabe [6]).

$$S = \pi \times D_g^2 \quad (4)$$

Where,

S= Surface area, (mm^2)
D_g = Geometric mean diameter (mm)

2.2.6 Volume of fruit (V)

The volume was calculated by considering the geometry of the object similar to the oblate spheroid shape. The volume was calculated by using following formulas (Mohsenin [3]).

$$\text{and } v = \frac{4}{3}\pi\left(\frac{L}{2}\right)\left(\frac{B}{2}\right)\left(\frac{T}{2}\right) \quad (5)$$

Where,

V = volume of fruit (cm^3)
L = length of fruit (cm)
B = width of fruit (cm)
T = thickness of fruit (cm)

2.2.7 Hardness

A fruit Penetrometer (EFFEGI, Italy; accuracy ±0.2 lbs) was used to check the hardness of the outer peel of the custard apple for determination of load bearing capacity during storage and quality control aspect. About 10 samples of fruits were punctured at the middle portion of ripe and unripe fruits.

2.2.8 Pulp content of fruit

Pulp of custard apple fruit was separated from the peel and seeds. The Pulp content was calculated by using following formula (Kolekar and Tagad [7]).

$$\text{Pulp content, \%} = \frac{C}{I} \times 100 \quad (6)$$

Where,

C= Weight of pulp (g)
I= Weight of fruit (g)

2.2.9 Seeded pulp content of fruit

Seeded pulp content of fruit was calculated by using following formula;

$$\text{Seeded pulp content, \%} = \frac{A}{I} \times 100 \quad (7)$$

Where,

A= Seeded pulp weight (g)
I= Weight of fruit (g)

2.2.10 Seed content of fruit

Seed content of fruit was calculated by using following formula (Kolekar and Tagad [7]).

$$\text{Seed content, \%} = \frac{K}{I} \times 100 \quad (8)$$

Where,

K= Weight of seeds (g)
I= Weight of fruit (g)

2.2.11 Peel content of fruit

Peel content of fruit was calculated by using following formula;

$$\text{Peel content, \%} = \frac{B}{I} \times 100 \quad (9)$$

Where,

B= Peel weight, (g)
I= Weight of fruit, (g)

2.3 Biochemical Properties

2.3.1 Moisture content

The sample was kept in oven at 100℃ in uncover pre-weighed petri dishes (Ranganna [8]). After drying, petri dishes were covered with lid and cooled in desiccators containing silica gel for 1 h before weighing.

$$\text{M. C., \%w. b.} = \frac{\text{initial weight of sample} - \text{final weight of sample}}{\text{initial weight of sample}} \quad (10)$$

$$\text{M. C., \%d. b.} = \frac{\text{initial weight of sample} - \text{final weight of sample}}{\text{dry weight of sample}} \quad (11)$$

2.3.2 pH

The pH of the products was determined by using a digital pH meter.

2.3.3 Total soluble solids (^{O} Brix)

Small samples of the fruit pulp were filtered through muslin cloth and a drop of filtrate was taken to determine the total soluble solids (TSS) using a hand held refractometer (Erma Tokyo A) and TSS was expressed as °Brix (Ranganna [8]).

2.3.4 Acidity

The acidity of the custard apple pulp was determined by diluting an aliquot of the sample with distilled water and titrating with 0.1N NaOH using phenolphthalein as indicator. The calculated acidity was expressed as percent anhydrous citric acid (Sravanthi [9]).

2.3.5 Reducing sugars

To 25 g of the sample in a volumetric flask 100 mL of water was added and neutralized with 1N NaOH. 2 mL of 66% lead acetate solution was added and kept for 10 minutes. Excess lead acetate was precipitated by necessary amount of 20% potassium oxalate, made up to the volume with water, filtered and taken in burette. 10 mL of mixed Fehling's solution was taken in 250 mL conical flask. Little quantity of the sample was run into flask and heated to boil moderately for 2 minutes. 3 drops of methylene blue solution was added and completed the titration until the indicator was completely decolourized. Brick red colour of the solution indicates the end point (Lane & Eynon [10]).

2.3.6 Total sugars

For total sugars 50 mL of filtered sample was taken in a 200 mL conical flask to which 50 mL water and 5 g of citric acid was added, boiled gently for 10 minutes to complete the inversion of sucrose, transferred to 250 mL volumetric flask and neutralized with 1N NaOH. The volume was made up to the mark and determined the total sugars as invert sugars (Lane & Eynon [10]).

2.3.7 Ascorbic acid (mg/100 mL or mg/100 g sample)

Ascorbic acid was estimated by visual titration method [9]. 10 mL of the sample was made up to 100 mL with 3% metaphosphoric acid and filtered. To estimate the interference of sulphur dioxide in the sample, 10 mL of the filtrate was taken and added with 1 mL of 40% formaldehyde and 0.1 mL of HCl and kept for 10 minutes. The sample was titrated with the standard 2.6-dichlorophenol-indophenol dye to a pink end-point that should persist for at least 15 seconds.

3. RESULTS AND DISCUSSION

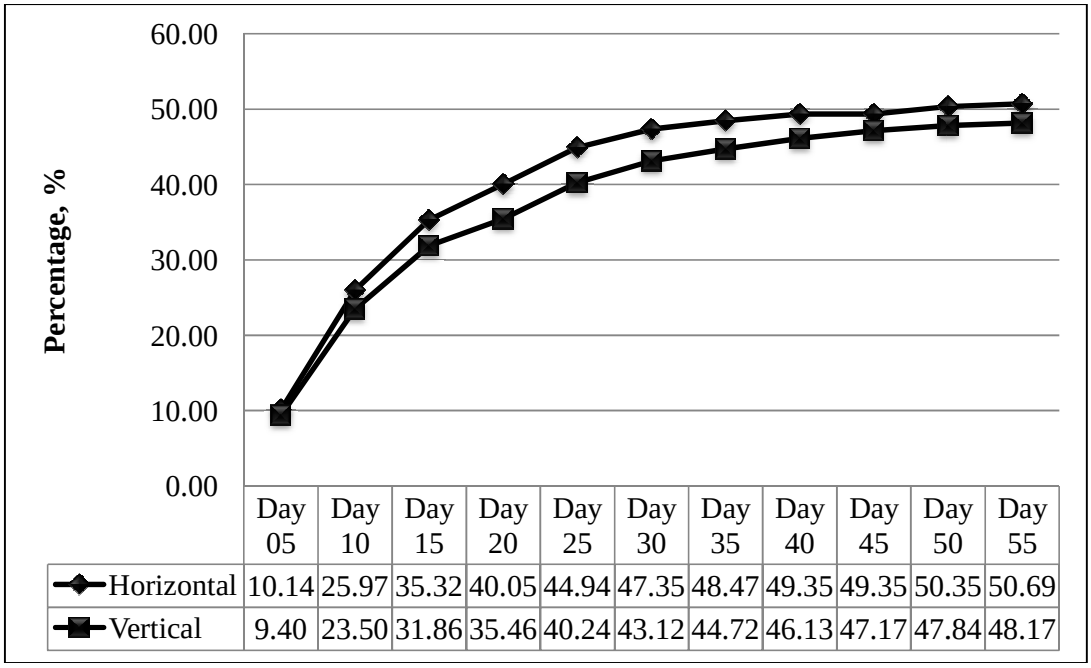
3.1 Determination of Variations in Size of Fruits on Tree

It can be observed from the chart (Fig. 1) that percentage of increase in dimensions of fruits (Horizontal and vertical diameter) on tree was more rapidly in early stage of fruit setting (0 to 25 days). After 25 days of fruit setting, the percentage of increase in dimensions of fruit was decreased gradually (30-40 days) and at the time of harvesting of fruit the percentage of increase in dimensions was negligible or became constant (45-55 days). After 60 days, the fruit became ripen on tree and ready to eat.

Similar type of results has been obtained for percentage increase in volume as well as mass of fruit on tree (Fig. 2).

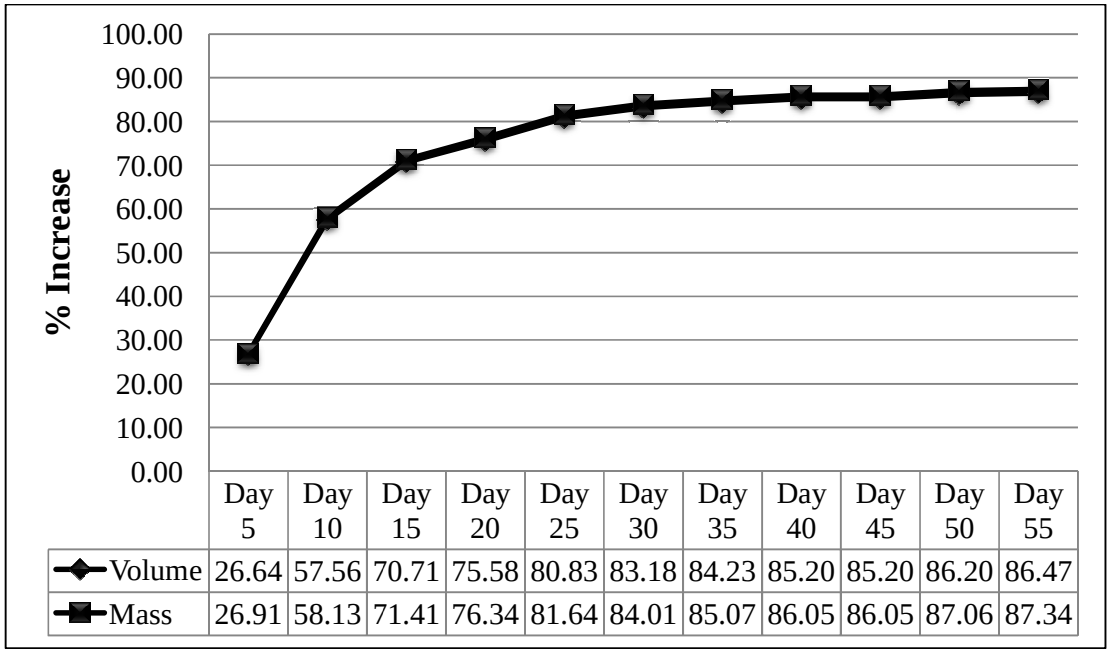
3.2 Physical Properties of Custard Apple Fruit

The samples were separated in two lots based on conduction for ripe and unripe. These were analyzed for physical properties.



	Day 05	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40	Day 45	Day 50	Day 55
Horizontal	10.14	25.97	35.32	40.05	44.94	47.35	48.47	49.35	49.35	50.35	50.69
Vertical	9.40	23.50	31.86	35.46	40.24	43.12	44.72	46.13	47.17	47.84	48.17

Fig. 1. % Increase in dimensions of fruit on tree



	Day 5	Day 10	Day 15	Day 20	Day 25	Day 30	Day 35	Day 40	Day 45	Day 50	Day 55
Volume	26.64	57.56	70.71	75.58	80.83	83.18	84.23	85.20	85.20	86.20	86.47
Mass	26.91	58.13	71.41	76.34	81.64	84.01	85.07	86.05	86.05	87.06	87.34

Fig. 2. % Increase in volume and mass on tree

3.3 Weight of Custard Apple

It is the maximum weight of a custard apple. It can be observed from Tables 1 to 2 that the weight for ripe and unripe samples varied from 76.85 to 143.25 g and 119.95 to 180.05 g, with an average value of 103.04±18.51 g and 143.57±18.40 g, respectively.

It can be observed from Table 3 that f value for the variation is 24.11 against F(critical) value of 4.41, indicating signification in weight of two lots.

Therefore, storing on the basis of weight can be performed for their further processing and market value.

3.4 Length of Custard Apple

It is the maximum dimension of a custard apple. It can be observed from Tables 1 to 2 that the length for ripe and unripe samples varied from 44.05 to 98.24 mm and 49.95 to 98.51 mm, with an average value of 59.96±14.30 mm and 62.97±13.41 mm respectively.

It can be observed from Table 4 that f value for the variation is 0.23 against F(critical) value of 4.41, indicating no signification in length of two lots. Therefore, storing on the basis of length can't be performed for their further processing and market value.

3.5 Width of Custard Apple

Width of custard apple represents the approximate cross-section of the custard apple. It can be observed from Tables 1 to 2 that the width for ripe and unripe samples varied from 58.76 to 98.50 mm and 64.04 to 73.57 mm with an average value of 66.06±12.20 mm and 70.03±2.71 mm, respectively.

It can be observed from Table 5 that f value for the variation is 1.011 against F(critical) value of 4.41, indicating no signification in width of two lots. Therefore, storing on the basis of width can't be performed for their further processing and market value.

3.6 Thickness of Custard Apple

Thickness of custard apple represents the approximate cross-section of the custard apple. It can be observed from Tables 1 to 2 that the width for ripe and unripe samples varied from 48.47 to 63.50 mm and 51.37 to 70.29 mm with an average value of 55.55±4.83 mm and 62.77±6.06 mm, respectively.

It can be observed from Table 6 that f value for the variation is 8.68 against F(critical) value of 4.41, indicating no signification in thickness of two lots. Therefore, storing on the basis of thickness can't be performed for their further processing and market value.

3.7 Geometric Mean Diameter of Custard Apple

It is the represents length, width and thickness of custard apple. It can be observed from Tables 1 to 2 that the Size for ripe and unripe samples varied from 48.20 to 75.21 mm and 57.10 to 69.77 mm, with an average value of 57.63±7.29 mm and 62.39±4.10 mm, respectively.

It can be observed from Table 7 that f value for the variation is 2.95 against F(critical) value of 4.41, indicating no signification in size of two lots. Therefore, storing on the basis of size can't be performed for their further processing and market value.

3.8 Arithmetic Mean Diameter of Custard Apple

It is calculated with the help of the mathematical formula. It can be observed from Tables 1 to 2 that the arithmetic mean diameter for ripe and unripe samples varied from 50.50 to 82.28 mm and 59.98 to 74.60 mm, with an average value of 60.52±8.65 mm and 65.60±4.54 mm respectively.

It can be observed from Table 8 that f value for the variation is 2.35 against F(critical) value of 4.41, indicating no signification in arithmetic mean diameter of two lots. Therefore, storing on the basis of arithmetic mean diameter can't be performed for their further processing and market value.

3.9 Sphericity of Custard Apple

It is the represents length, width and thickness of custard apple. It can be observed from Tables 1 to 2 that the Sphericity for ripe and unripe samples varied from 0.76 to 0.94 mm and 0.71 to 0.92 mm, with an average value of 0.88±0.6 mm and 0.85±0.06 mm respectively.

It can be observed from Table 9 that f value for the variation is 1.01 against F(critical) value of 4.41, indicating signification in sphericity of two lots. Therefore, storing on the basis of sphericity can be performed for their further processing and market value.

3.10 Surface Area of Custard Apple

It is calculated with the help of the mathematical formula. It can be observed from Tables 1 to 2

Table 1. Physical properties of ripe custard apple

Ripe custard apple									
No. of sample	**Total weight (g)**	**L (mm)**	**B (mm)**	**T (mm)**	**Size (mm)**	**Sphericity (mm^2)**	**Surface area (mm^2)**	**Arithmetic mean dia. (mm)**	**Volume of fruit (cm^3)**
1	143.25	61.15	71.51	60.51	61.58	0.86	11908.01	64.39	138.25
2	93.10	98.24	98.50	50.11	75.21	0.76	17760.61	82.28	253.36
3	103.35	55.85	60.24	59.65	56.21	0.93	9921.83	58.58	104.86
4	118.50	59.98	67.60	63.50	61.03	0.90	11695.25	63.69	134.53
5	114.95	56.48	65.50	53.30	55.89	0.85	9807.07	58.43	103.03
6	95.35	55.81	59.46	52.67	53.71	0.90	9056.90	55.98	91.32
7	100.60	59.65	60.74	58.61	57.27	0.94	10298.81	59.67	110.95
8	91.80	56.06	58.76	54.61	54.22	0.92	9230.69	56.48	93.99
9	92.60	52.36	59.28	54.09	53.00	0.89	8819.54	55.24	87.72
10	76.85	44.05	58.97	48.47	48.20	0.82	7293.95	50.50	65.79

Table 2. Physical properties of unripe custard apple

Unripe custard apple									
No. of sample	**Total weight (g)**	**L (mm)**	**B (mm)**	**T (mm)**	**Size (mm)**	**Sphericity (mm^2)**	**Surface area (mm^2)**	**Arithmetic mean dia. (mm)**	**Volume of fruit (cm^3)**
1	126.60	49.95	69.07	65.17	58.36	0.84	10694.63	61.40	117.48
2	135.70	58.32	70.26	51.37	57.10	0.81	10239.17	59.98	109.98
3	149.80	59.33	70.20	54.29	58.47	0.83	10734.66	61.27	118.15
4	180.05	65.59	70.99	68.56	65.52	0.92	13478.43	68.38	166.80
5	161.80	65.35	73.15	67.08	65.61	0.90	13518.38	68.53	167.55
6	126.70	53.91	68.47	63.94	59.30	0.87	11042.61	62.11	123.32
7	138.15	59.22	68.98	60.63	60.25	0.87	11399.61	62.94	129.41
8	142.25	56.55	73.57	70.29	63.65	0.87	12720.59	66.80	152.80
9	154.65	63.00	71.59	65.15	63.75	0.89	12760.88	66.58	153.53
10	119.95	98.51	64.04	61.24	69.77	0.71	15287.19	74.60	201.86

that the Surface area for ripe and unripe samples varied from 7293.95 to 17760.61 mm^2 and 10239.17 to 15287.19 mm^2, with an average value of 10579.27±2861.94 mm^2 and 12283.54±1623.64 mm^2 respectively.

It can be observed from Table 10 that f value for the variation is 2.95 against F(critical) value of 4.41, indicating no signification in surface area of two lots. Therefore, storing on the basis of surface area can't be performed for their further processing and market value.

3.11 Volume of Custard Apple

It is calculated with the help of the mathematical formula. It can be observed from Tables 1 to 2 that the volume for ripe and unripe samples varied from 65.79 to 253.36 cm^3 and 109.98 to 201.86 cm^3, with an average value of 118.38±52.05 cm^3, and 144.09±29.36 cm^3 respectively.

It can be observed from Table 11 that f value for the variation is 1.85 against F(critical) value of 4.41, indicating no signification in volume of two lots. Therefore, storing on the basis of Volume can't be performed for their further processing and market value.

3.12 Hardness of Custard Apple

Puncture test represents hardness of the custard apple. It is measurement of puncture pressure at the middle of the fruit. It can be observed from Tables 13 and 14 that the pressure requires for ripe and unripe samples varied from 1.00 to 2.10 Kgf and 1.60 to 6.50 Kgf, with an average value of 1.27±0.41 Kgf and 3.66±1.64 Kgf, respectively.

Table 3. Analysis of variance for custard apple sample weight

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	8213.405	1	8213.405	24.11302	0.000113	4.413873
Within groups	6131.181	18	340.6211			
Total	14344.59	19				

Table 4. Analysis of variance for custard apple sample length

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	45.3005	1	45.3005	0.235901	0.633042	4.413873
Within groups	3456.57	18	192.0317			
Total	3501.871	19				

Table 5. Analysis of variance for custard apple sample width

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	79.04288	1	79.04288	1.011898	0.327781	4.413873
Within groups	1406.043	18	78.11351			
Total	1485.086	19				

Table 6. Analysis of variance for custard apple sample thickness

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	260.642	1	260.642	8.68317	0.008628	4.413873
Within groups	540.3045	18	30.01692			
Total	800.9465	19				

Table 7. Analysis of variance for custard apple sample geometric mean diameter

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	103.4453	1	103.4453	2.954803	0.102773	4.413873
Within groups	630.1659	18	35.00922			
Total	733.6112	19				

Table 8. Analysis of variance for custard apple sample Arithmetic mean diameter

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	112.1169	1	112.1169	2.350707	0.142614	4.413873
Within groups	858.5095	18	47.69497			
Total	970.6264	19				

Table 9. Analysis of variance for custard apple sample sphericity

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	0.00338	1	0.00338	1.01909	0.32611	4.413873
Within groups	0.0597	18	0.003316667			
Total	0.06308	19				

Table 10. Analysis of variance for custard apple sample surface area

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	1019.93	1	1019.93	2.954803	0.102773	4.413873
Within groups	6213.184	18	345.1769			
Total	7233.113	19				

Table 11. Analysis of variance for custard apple sample volume

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	275.9255	1	275.9255	5.187446	0.035185	4.413873
Within groups	957.4381	18	53.19101			
Total	1233.364	19				

Table 12. Analysis of variance for Hardness in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	26.6805	1	26.6805	18.64538	0.000414	4.413873
Within groups	25.757	18	1.430944			
Total	52.4375	19				

It can be observed from Table 12 that f value for the variation is 18.64 against F(critical) value of 4.41, indicating signification in hardness of two lots. Therefore, storing on the basis of hardness can be performed for their further processing and market value.

3.13 Pulp Content of Custard Apple

It is calculated percentage with the help of the ratio between weight of pulp and weight of fruit. It can be observed from Tables 13 and 14 that the pulp content for ripe and unripe samples varied from 20.76 to 45.90% and 21.93 to 40.54%, with an average value of 35.08±7.91%, and 31.98±6.69% respectively.

It can be observed from Table 15 that f value for the variation is 0.81 against F(critical) value of 4.41, indicating no signification in pulp content of two lots. Therefore, storing on the basis of pulp content can't be performed for their further processing and market value.

3.14 Seeded Pulp Content of Custard Apple

It is calculated percentage with the help of the ratio between weight of seeded pulp and weight of fruit. It can be observed from Tables 13 and 14 that the seeded pulp for ripe and unripe samples varied from 37.38 to 56.99% 27.17 to 50.24%, with an average value 47.63±6.71%, and 40.20±7.83% respectively.

It can be observed from Table 16 that f value for the variation is 5.18 against F(critical) value of 4.41, indicating no signification in seeded pulp content of two lots. Therefore, storing on the basis of seeded pulp content can't be performed for their further processing and market value.

Table 13. Physical properties of ripe custard apple

Ripe									
No. of sample	**Total Weight (g)**	**Skin (g)**	**Seeded pulp (g)**	**Pulp (g)**	**Seed (g)**	**Pulp content %**	**Seed content %**	**Seeded pulp %**	**Hardnesss (Kgf)**
1	143.25	74.75	66.65	49.60	14.95	34.62	10.44	46.53	1.00
2	93.10	57.90	34.80	26.20	6.90	28.14	7.41	37.38	2.10
3	103.35	57.25	44.65	28.30	14.50	27.38	14.03	43.20	1.90
4	118.50	72.20	46.15	24.60	18.50	20.76	15.61	38.95	1.00
5	114.95	59.85	54.00	38.75	14.50	33.71	12.61	46.98	1.20
6	95.35	45.85	49.25	37.65	10.50	39.49	11.01	51.65	1.40
7	100.60	51.60	46.20	36.20	9.55	35.98	9.49	45.92	1.00
8	91.80	42.85	48.20	37.50	10.50	40.85	11.44	52.51	1.10
9	92.60	40.50	52.00	42.50	9.15	45.90	9.88	56.16	1.00
10	76.85	32.60	43.80	33.75	9.10	43.92	11.84	56.99	1.00

Table 14. Physical properties of unripe custard apple

Unripe									
No. of sample	**Total Weight (g)**	**Skin (g)**	**Seeded pulp (g)**	**Pulp (g)**	**Seed (g)**	**Pulp content %**	**Seed content %**	**Seeded pulp %**	**Hardnesss (Kgf)**
1	126.60	61.65	63.60	47.15	14.85	37.24	11.73	50.24	2.10
2	135.70	89.40	45.60	35.45	9.20	26.12	6.78	33.60	2.80
3	149.80	102.50	46.80	35.60	10.65	23.77	7.11	31.24	5.00
4	180.05	88.80	90.35	73.00	16.60	40.54	9.22	50.18	3.80
5	161.80	93.60	67.70	55.20	11.50	34.12	7.11	41.84	4.60
6	126.70	73.55	52.50	40.90	10.40	32.28	8.21	41.44	2.40
7	138.15	87.35	50.70	39.85	10.65	28.85	7.71	36.70	5.00
8	142.25	102.90	38.65	31.20	7.25	21.93	5.10	27.17	6.50
9	154.65	84.55	69.60	62.00	7.45	40.09	4.82	45.00	2.00
10	119.95	65.30	53.45	43.55	8.85	36.31	7.38	44.56	1.60

Table 15. Analysis of variance for pulp content in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	43.51958	1	43.51958	0.811186	0.379663	4.413873
Within groups	965.6874	18	53.6493			
Total	1009.207	19				

Table 16. Analysis of variance for seeded pulp content in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	275.9255	1	275.9255	5.187446	0.035185	4.413873
Within groups	957.4381	18	53.19101			
Total	1233.364	19				

3.15 Seed Content of Custard Apple

It is calculated percentage with the help of the ratio between weight of seed and weight of fruit. It can be observed from Tables 13 and 14 that the seed content for ripe and unripe samples varied from 7.41 to 15.61% and 4.82 to 11.73%, with an average value of 11.38±2.34% and 7.52±1.98% respectively.

It can be observed from Table 17 that f value for the variation is 15.88 against F(critical) value of 4.41, indicating signification in seed content of two lots. Therefore, storing on the basis of seed content can be performed for their further processing and market value.

3.16 Peel Content in Custard Apple

It is calculated percentage with the help of the ratio between weight of peel and weight of fruit. It can be observed from Tables 13 and 14 that the seed content for ripe and unripe samples varied from 42.42 to 62.19% and 48.70 to 72.34%, with an average value of 51.50±6.64% and 59.29±7.98% respectively.

It can be observed from Table 18 that f value for the variation is 5.63 against F(critical) value of 4.41, indicating no signification in seed content of two lots. Therefore, storing on the basis of peel content can't be performed for their further processing and market value.

3.17 Chemical Properties of Custard Apple Pulp

The samples were separated in two lots based on conduction for ripe and unripe. These were analyzed for various chemical properties.

3.17.1 Moisture content

It is calculated by standard hot air oven methods and represented in percentage. Wet bases moisture content for ripe and unripe samples varied from 67.25 to 69.75% and 65.5 to 64.0%, with an average value of 68.42±1.1% and 64.75±1.0%, respectively. Dry bases moisture content for ripe and unripe samples varied from 205.34 to 230.58% and 189.86 to 177.78%, with an average value of 216.99±11.19% and 183.82±8.5%, respectively.

It can be observed from Tables 19 and 20 that f value for the variation is 7.70 (w.b. & d.b.) against F (critical) value of 14.56 for wet basis and 12.68 for dry basis, indicating signification changes in moisture content of two lots. Therefore, storing on the basis of moisture content can be performed for their further processing and market value.

3.17.2 pH

The pH samples were determined by pH meter. The pH of ripe and unripe samples was 6.1 and 5.8, respectively.

3.17.3 Total soluble solid

The result obtained from the test that the TSS of ripe and unripe custard apple pulp ranges between 30.7 and 37.7°brix.

3.17.4 Acidity

Acidity of custard apple pulp was found by titration method. The acidity of ripe and unripe samples was 0.3 and 0.3%, respectively.

Table 17. Analysis of variance for seed content in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	74.55013	1	74.55013	15.88844	0.000866	4.413873
Within groups	84.45779	18	4.6921			
Total	159.0079	19				

Table 18. Analysis of variance for peel content in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	303.6093	1	303.6093	5.636721	0.028917	4.413873
Within groups	969.5295	18	53.86275			
Total	1273.139	19				

Table 19. Analysis of variance for moisture content (w.b.) in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	17.52083	1	17.52083	14.56277	0.018841	7.708647
Within groups	4.8125	4	1.203125			
Total	22.33333	5				

Table 20. Analysis of variance for moisture content (d.b.) in custard apple sample

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	1424.278	1	1424.278	12.68561	0.02355	7.708647
Within groups	449.1005	4	112.2751			
Total	1873.379	5				

3.17.5 Reducing sugar

Reducing sugar was found by Lane and Eynon Method. The reducing sugar of ripe and unripe samples was 8.5 and 5.0 g/100 g, respectively.

3.17.6 Total sugar

Total sugar of pulp was found by Lane and Eynon Method. The total sugar of ripe and unripe samples was 15.60 and 12.07 g/100 g, respectively.

3.17.7 Ascorbic acid

Ascorbic acid was found by 2,6-Dichlorophenol-indophenol visual titration method. The ascorbic acid of ripe and unripe was 13.65 to 12.35 mg, respectively.

4. CONCLUSION

The observations on tree for percentage increase in dimensions of fruits (Horizontal and vertical diameter) on tree was more rapidly in early stage of fruit setting (0 to 25 days). After 25 days of fruit setting, the percentage increase in dimensions of fruit was increase gradually (30-40 days) and at the time of harvesting of fruit the percentage change in dimensions was negligible or became constant (45-55 days). The average weight, geometric mean diameter, arithmetic mean diameter, sphericity, surface area, volume, hardness for ripe and unripe fruits were 103.04 g, 57.63 mm, 60.52 mm, 0.88, 10579.27 mm^2, 118.38 cm^3, 1.27 kgf; 143.57 g, 62.39 mm, 65.60 mm, 0.85, 12283.54 mm^2, 144.09 cm^3, 3.66 kgf, respectively. The pulp content, seeded pulp content, seed content, peel content for ripe and unripe fruits were 35.08%, 47.63%, 11.38%, 51.50%; 31.98%, 40.20%, 7.52%, 59.29%, respectively. The average moisture content, pH, total soluble solids, acidity, reducing sugar, total sugar, ascorbic acid for ripe and unripe fruits pulp were 68.42%, 6.1, 30.7 °Brix, 0.3%, 8.5 g/100 g, 15.6 g/100 g, 13.65 mg; 64.75 %, 5.8, 37.7 °Brix, 0.3%, 5 g/100 g, 12.07 g/100 g, 12.35 mg, respectively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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