International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 1945-1952

Received: 04-09-2018
Accepted: 08-10-2018

RM Kher
Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Navsari Agricultural University, Dediapada, Gujarat, India

FM Sahu
Centre of excellence on Post Harvest Technology, Navsari Agricultural University, Navsari, Gujarat, India

Correspondence
RM Kher
Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Navsari Agricultural University, Dediapada, Gujarat, India

Engineering physical properties of papaya (*Carica papaya* L) at different ripening stages

RM Kher and FM Sahu

Abstract
The present investigation was carried out with a view to determine applicable engineering, physico-chemical and sensory properties of two most common cultivars of papaya (*Carica papaya* L.) cv. Red lady and cv. Local from Gujarat, at different ripening stages which could be useful in designing and fabrication of appropriate post harvest handling and processing equipments. The papaya cultivars Red lady (C_1) and Local (C_2) were harvested at five different maturity stages *viz.* Green (S_1), Colour break (S_2), Quarter Ripe: 5 − 25% yellow skin (S_3), Half Ripe: 26 − 50 % yellow skin (S_4) and Three Quarter Ripe: 51 − 75 % yellow skin (S_5).Based on the results, it was observed that papaya cv. Red lady was having significantly larger fruit weight, fruit size, density and surface area than cv. Local at all stages of ripening on the day of harvesting. Shapes of both cultivars were similar and correspond to near round to oval and can be called as obovate shape with a sphericity of 0.77 and 0.83 for cv. Red lady and cv. Local, respectively. Coefficient of friction was in the range of 0.20 – 0.22 at different ripening stage for both cultivars. The maximum PLW of 9.9 % was noted in ripening stages 1 in cv. Red lady while it was 10.32% in cv. Local at the same stage. Fruit firmness showed a decreasing trend with respect to ripening stage as well as days of storage for both cultivars. Fruit firmness was highest at green stage $S_1$for cv. Red lady and cv. Local with values 9.6 kgf and 9.0 kgf, respectively and lowest at three quarter ripe $S_5$for cv. Red lady and cv. Local with values 1.6 kgf and 1.5 kgf, respectively.

Keywords: papaya cv. red lady and cv. local., weight, length, volume, coefficient of friction and P.L.W.

Introduction
Maturity at harvest is a very important determinant of storage life and final fruit quality. For commercial trade papayas are harvested when the peel color is between color break and one-quarter yellow, depending on the distance to markets. At this stage the flesh is hard but will continue to ripen after harvest, and the fruit will withstand the rigors of postharvest handling and transport. Skin and flesh color development, textural and compositional (organic acids) changes, and synthesis of volatile aroma compounds occur during ripening after harvest, concomitant with the climacteric period. Fruit harvested before color break will fail to complete ripening, will have lower total soluble solids content, and will not reach a desirable taste. Fruit harvested at an advanced yellow stage are highly susceptible to bruising, decay, and water loss, resulting in quality deterioration. Therefore, suitable maturity indices for harvesting are very important to minimize quantitative and qualitative losses (Shivkumar and Wall, 2013). Consumers are more likely to purchase bright, colorful papayas. During ripening, the external yellow skin color develops from the blossom end, whereas the internal flesh coloring and softening develops from the endocarp outward.

Fruit texture is commercially important, as it directly dictates papaya shelf life, quality and consumer acceptance. High-quality papayas are firm and fresh in appearance and will soften and ripen uniformly before consumption. Therefore, mechanical damage during harvesting, storage and transportation needs to be avoided to maintain papaya quality. Fruit softening is due to depolymerization of pectin in the cell wall. During ripening, ethylene (C_2H_4) initiates the carotenoid content in the skin and flesh and many of the biochemical changes associated with fruit flavor, aroma and texture. Production practices adopted during the farm to fork chain such as harvesting, field handling, sorting, grading, postharvest treatments, packing, storage, and transportation have a great impact on maintaining the optimum organoleptic, nutritional, and functional quality attributes of the papaya fruit. Determination and application of physical and mechanical properties of fruits and vegetables in design and fabrication of processing equipment such as sorters can significantly improve the results of sorting and grading of produce.

The attempts to find any published work about the engineering and physicochemical properties of different variety of papaya lead to only few documented research on Red lady variety. Therefore, this research was taken with a view to determine some applicable engineering, physico-chemical and sensory properties of two most common cultivar of papaya (*Carica papaya)* cv. Red lady and Local from Gujarat, which could be useful in design, development and fabrication of appropriate processing equipment. Looking into the need and keeping the above factors in view, the present investigation was Engineering Physical Properties of Papaya (Carica Papaya L) At Different Ripening Stages"

Materials and Methods

Selection and procurement of papaya fruits

Papaya fruit cv. Taiwan Red Lady was procured from organic farm, Navsari Agricultural University and cv. Local was procured from a local farmer near Navsari. Mature green fruits as well as tree ripen fruit at different ripening stage were selected for the experiment. The harvesting was done manually, by twisting the fruits clock wise, in the morning hours (8:00 to 9:00 AM). The fruits were then transported in the plastic crates, cushioned with newspaper, to the laboratory immediately. Treatments details ware given ahead.

Treatment details

Factor 1: Cultivars (*Carica Papaya*) = 2
C_1 = Taiwan Red lady and C_2 = Local
Factor 2: Ripening stages = 5
S_1 = Matured Green, S_2 = Colour Break, S_3 = Quarter Ripe 5 −25% yellow skin
S_4 = Half Ripe 26 − 50 % yellow skin, S_5 = Three Quarter Ripe 51 − 75 % yellow skin

Table 1: Treatment combinations

Cultivars	Ripening stages				
	S_1	**S_2**	**S_3**	**S_4**	**S_5**
C_1	$T_1(C_1S_1)$	$T_2(C_1S_2)$	$T_3(C_1S_3)$	$T_4(C_1S_4)$	$T_5(C_1S_5)$
C_2	$T_6(C_2S_1)$	$T_7(C_2S_2)$	$T_8(C_2S_3)$	$T_9(C_2S_4)$	$T_{10}(C_2S_5)$

Measurement of Physical properties of papaya fruits

Fruit weight

From each treatment, five uniformly sized fruits were weighed on electronic balance and the average value was computed in grams. (Scale Tech. Capacity – 6kg, Least count: 1g)

Length, width and thickness

Size is an important physical attributes of papaya fruits used in grading and sorting, determination of fruit surface area and correlated to volume and weight. Three linear dimensions namely length (a) in mm, width (b) in mm and thickness (c) in mm of each fruit was measured with a digital Vernier calliper with 0.01 mm least count. The geometric mean dimension, D_p of the fruit was calculated by using the relationship given by Mohsenin (1986) [3].

$D_p = (abc)^{1/3}$

Where,
D_p = geometric mean dimension;
a = Length of the fruit (longest intercept)
b = Width of the fruit (intercept perpendicular to a)
c = Thickness of the fruit (intercept perpendicular to a and b)

When papaya was placed vertically, longest dimension/intercept is considered as length of the papaya fruits and other two dimensions taken perpendicular to each other at a point of average diameters are width and breadth.

Shape of fruit

Shape describes the object in terms of a geometrical body and was measured by combining the size measurements. In identification of shape of papaya fruit, the tracing of the longitudinal and lateral cross sections of the fruits are compared with the shapes listed on standard chart. Using standard charts, the shape of papaya was defined either by a number on chart or by descriptive terms as specified for fruits and vegetables by Mohsenin (1986) [3]. Shape of papaya cv. Red lady was mostly resembles near round to obovate.

Sphericity

Sphericity (S_p) is the degree to which an object resembles a sphere. The geometric foundation of the concept of sphericity rests upon the isoperimetric property of a sphere. The intercepts need not intersect each other at a common point. The sphericity was estimated by following equation given by Mohsenin (1986) [3].

$$\text{Sphericity (Sp)} = \frac{(abc)^{\frac{1}{3}}}{a} = \frac{\text{Geometric mean Dimension } (D_p)}{\text{Longest intercept (a)}}$$

True density

The true density (ρ_t) of the tropical fruits, were determined dividing the individual fruit weight taken in precision weighing balance and volume obtained from liquid displacement method.

$$\text{True density } (\rho_t) = \frac{\text{weight of fruit (kg)}}{\text{volume of the fruit } (m^3)}$$

Where, ρ_t = True density, kg /m^3

Coefficient of friction

Coefficient of static friction (μ_s) was measured by a friction device having stainless steel surface. For this measurement, the material was placed on the surface, and then gradually raised by the screw. Vertical and horizontal height values were read from the ruler when the material started sliding over the surface, and then using the tangent value of the angle, the coefficient of friction was found.

Physiological loss in weight

Individual weight of fruits was recorded using electronic balanced at periodic intervals for determining physiological loss in weight (PLW). The PLW was computed from the difference in fruit weight from the first day to the subsequent day up to 5 days after harvesting of fruit at different ripening stages. The PLW was expressed in percent.

Fruit firmness

Firmness of papaya fruit was measured by a fruit penetrometer as well as by a texture analyser. Firmness of the papaya fruit was measured by measuring the penetrating force a fruit pressure tester (Penetrometer, Make: Wagner, Model FT 327, Italy) and it was expressed as kgf. For measurement, a circular thin patch of skin about one cm in diameter was removed from the fruit surface with the help of a sharp knife and the penetrometer (adjusted to zero) was pierced into the

fruit up to the knob. The fruit was hold against a hard surface using the Wagner FTK test stand for better fruit testing control. The pressure required to penetrate flesh penetrometer was recorded in kgf provided on the circular disk of the penetrometer. Firmness was tested from two opposite sides of a fruit and average values were worked out.
Firmness of papaya was also determined by Texture analyser using standard method. It was expressed as N. To convert kgf to N, a multiplication of 9.81 was used. (1 kgf = 9.81 N)

Result and Discussion

Fruit weight

The data of fruit weight are presented in Table 2 and depicted in Figure 1. The mean fruit weight of papaya cv. Red Lady at stages 1 (C_1S_1), was 1150 g with a minimum weight of 1146 g and maximum weight of 1153. Similarly, mean fruit weight at stages 2 (C_1S_2), 3 (C_1S_3), 4 (C_1S_4) and 5 (C_1S_5) were 1203 g, 1211g, 1292 g and 1007g, respectively. For cv. Local, The mean fruit weight at stages 1 was 576.5 g with a minimum weight of 570.6 g and maximum weight of 581.8. Similarly, mean fruit weight at stages 2 (C_2S_2), 3 (C_2S_3), 4 (C_2S_4) and 5 (C_2S_5) were 620g, 508g, 525g and 494g, respectively. It was evident from data that individual weights of papaya at different ripening stages were significantly higher in cv. Red lady as compared to cv. Local.

Table 2: Fruit weight (g) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	1150	1146	1153
C_1S_2	1203	1198	1207
C_1S_3	1211	1203	1222
C_1S_4	1292	1281	1302
C_1S_5	1007	998	1013
C_2S_1	576.5	570.6	581.8
C_2S_2	620	609	637
C_2S_3	508	493	532
C_2S_4	525	490	548
C_2S_5	494	460	518
Mean	858.65	844.86	871.38
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	4.37	12.89	1.97
S	6.91	20.38	
C× S	9.7	28.83	

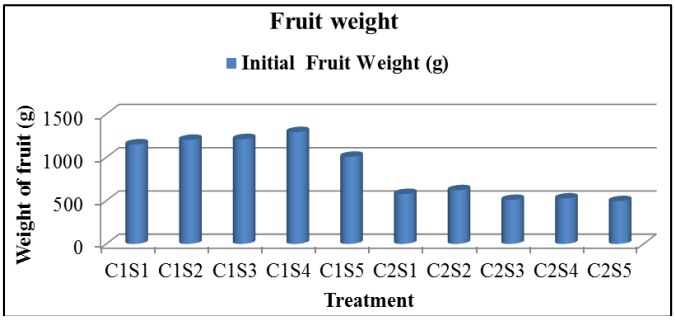

Fig 1: Fruit weight (g) of papaya at different ripening stages

Length

The data of fruit length are presented in Table 3 and depicted in Figure 2. The mean length of papaya fruit cv. Red Lady at stages 1 (C_1S_1) was 18.42 cm with a minimum value of 17.8 cm and maximum value of 19.42 cm. Similarly, mean fruit length at stages 2 (C_1S_2), 3 (C_1S_3), 4 (C_1S_4) and 5 (C_1S_5) were 16.99cm, 18.04 cm, 18.95 cm and 16.24 cm, respectively. For cv. Local, The mean fruit length at stages 1(C_2S_1) was 13.15cm with a minimum value of 12.85cm and maximum value of 13.33 cm. Similarly, mean fruit length at stages 2 (C_2S_2), 3 (C_2S_3), 4 (C_2S_4) and 5 (C_2S_5) were 13.79 cm, 12.96 cm, 12.36 cm and 12.68 cm, respectively. The lengths of papaya are shorter for fruit with less weight and vice versa in both the cultivar. Mean lengths of cv. Red Lady were significantly higher than cv. Local for all ripening stages. This was due a small fruit size in local cultivar.

Table 3: Fruit Length (cm) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	18.42	17.80	19.42
C_1S_2	16.99	16.10	17.57
C_1S_3	18.04	17.44	18.44
C_1S_4	18.95	18.60	19.23
C_1S_5	16.24	15.88	16.76
C_2S_1	13.15	12.85	13.33
C_2S_2	13.79	13.19	14.53
C_2S_3	12.96	12.59	13.54
C_2S_4	12.36	11.97	12.94
C_2S_5	12.68	12.08	13.07
Mean	15.36	14.85	15.88
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	1.485	4.380	3.74
S	2.348	6.926	
C× S	3.320	9.795	

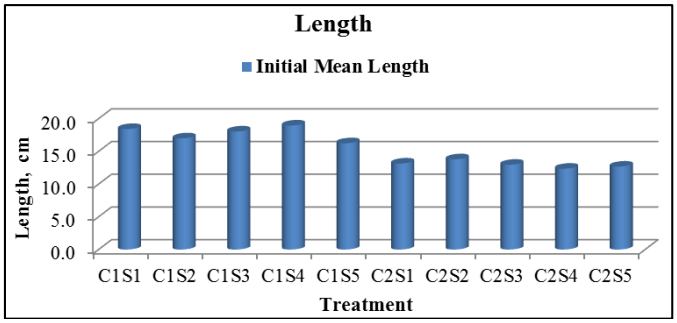

Fig 2: Fruit Length (cm) of papaya at different ripening stages

Width

The data of fruit width are presented in Table 4 and depicted in Figure 3. The mean width of papaya fruit cv. Red Lady at stages 1 (C_1S_1) was 11.79 cm with a minimum value of 11.47 cm and maximum value of 12.26 cm. Similarly, mean fruit width at stages 2 (C_1S_2), 3 (C_1S_3), 4 (C_1S_4) and 5 (C_1S_5) were 13.16cm, 12.56 cm, 13.05 cm and 11.03 cm, respectively. For cv. Local, The mean fruit width at stages 1(C_2S_1) was 10.07cm with a minimum value of 9.17cm and maximum value of 10.87 cm. Similarly, mean fruit width at stages 2 (C_2S_2), 3 (C_2S_3), 4 (C_2S_4) and 5 (C_2S_5) were 10.24 cm, 9.94 cm, 10.03 cm and 9.22 cm, respectively. The widths of papaya in both the cultivar did not vary significantly with ripening stages. Mean widths of cv. Red Lady were significantly higher than cv. Local for all ripening stages.

Table 4: Fruit width (cm) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	11.79	11.47	12.26
C_1S_2	13.16	12.84	13.53

C_1S_3	12.56	12.04	13.56
C_1S_4	13.05	12.41	13.95
C_1S_5	11.03	10.82	11.24
C_2S_1	10.07	9.17	10.87
C_2S_2	10.24	9.97	10.62
C_2S_3	9.94	9.75	10.13
C_2S_4	10.03	9.89	10.10
C_2S_5	9.22	8.79	9.62
Mean	11.11	10.71	11.59
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	5.008	NS	17.4
S	7.918	NS	
C× S	11.197	33.143	

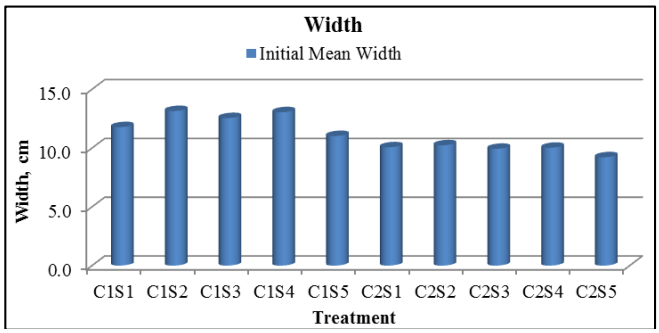

Fig 3: Fruit width (cm) of papaya at different ripening stages

Thickness

The data of fruit thickness are presented in Table 5 and depicted in Figure 4. The mean thickness of papaya fruit cv. Red Lady at stages 1 (C_1S_1) was 11.52 cm with a minimum value of 10.79 cm and maximum value of 11.93 cm. Similarly, mean fruit thickness at stages 2 (C_1S_2), 3 (C_1S_3), 4 (C_1S_4) and 5 (C_1S_5) were 12.47cm, 12.37 cm, 11.71 cm and 10.73 cm, respectively. For cv. Local, The mean fruit thickness at stages 1(C_2S_1) was 9.86cm with a minimum value of 9.39cm and maximum value of 10.67 cm. Similarly, mean fruit thickness at stages 2 (C_2S_2), 3 (C_2S_3), 4 (C_2S_4) and 5 (C_2S_5) were 10.14 cm, 10.13 cm, 9.96 cm and 8.95 cm, respectively. The thickness of papaya in both the cultivar did not vary significantly with ripening stages but thickness of cv. Red Lady were significantly higher than cv. Local for all ripening stages. Mohsenin (1986) [3] has effectively highlighted the imperativeness of the axial dimensions in machine design.

Table 5: Fruit thickness (cm) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	11.52	10.79	11.93
C_1S_2	12.47	12.27	12.69
C_1S_3	12.37	12.08	12.85
C_1S_4	11.71	11.53	11.91
C_1S_5	10.73	10.42	10.93
C_2S_1	9.86	9.39	10.67
C_2S_2	10.14	9.28	10.62
C_2S_3	10.13	9.34	10.64
C_2S_4	9.96	9.49	10.77
C_2S_5	8.95	8.46	9.77
Mean	10.79	10.30	11.28
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	1.477	4.357	5.3
S	2.335	6.889	
C× S	3.303	NS	

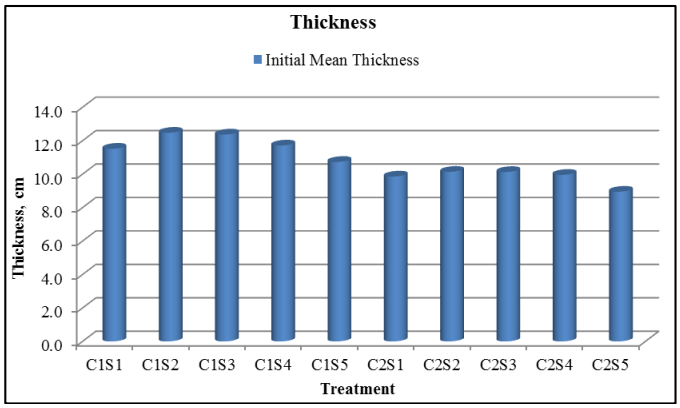

Fig 4: Fruit thickness (cm) of papaya at different ripening stages

Shape of the fruit

In identification of shape of papaya fruit, the tracing of the longitudinal and lateral cross sections of the fruits were compared with the shapes listed on standard chart. Using standard charts, the shape of papaya was defined either by a number on chart or by descriptive terms as specified for fruits and vegetables by Mohsenin (1986) [3].

Table 6: Fruit thickness (cm) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	11.52	10.79	11.93
C_1S_2	12.47	12.27	12.69
C_1S_3	12.37	12.08	12.85
C_1S_4	11.71	11.53	11.91
C_1S_5	10.73	10.42	10.93
C_2S_1	9.86	9.39	10.67
C_2S_2	10.14	9.28	10.62
C_2S_3	10.13	9.34	10.64
C_2S_4	9.96	9.49	10.77
C_2S_5	8.95	8.46	9.77
Mean	10.79	10.30	11.28
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	1.477	4.357	5.3
S	2.335	6.889	
C× S	3.303	NS	

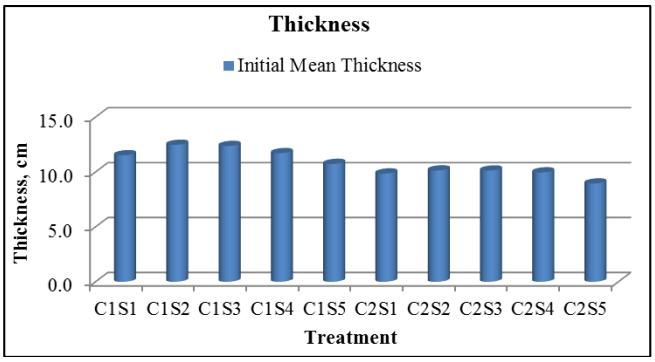

Fig. 4: Fruit thickness (cm) of papaya at different ripening stages

Using standard charts, the shape of papaya was defined either by a number on chart or by descriptive terms as specified for fruits and vegetables by Mohsenin (1986) [3]. The shape of the papaya fruit for both cultivar, cv. Red lady and cv. Local were mostly resembles to obovate (Inverted ovate- broad at apex)

True density (kg/m^3)

The data of true density of papaya are presented in Table 7 and depicted in Figure 5. The mean true density of papaya fruit cv. Red Lady at stages 1 (C_1S_1) was 1024.95 kg/m^3 with a minimum value of 1022 kg/m^3 and maximum value of 1027 kg/m^3. Similarly, mean fruit true density at stages 2 (C_1S_2), 3 (C_1S_3), 4 (C_1S_4) and 5 (C_1S_5) were 1178.25, 1053.04, 1076.66 and 1184.71 kg/m^3, respectively. For cv. Local, The mean fruit true density at stages 1(C_2S_1) was 847.79kg/m^3 with a minimum value of 846kg/m^3 and maximum value of 850 kg/m^3. Similarly, mean fruit true density at stages 2 (C_2S_2), 3 (C_2S_3), 4 (C_2S_4) and 5 (C_2S_5) were 784.81, 747.06, 760.87 and 784.13kg/m^3, respectively. The true density of papaya in both the cultivar did not vary significantly with ripening stages but true density of cv. Red Lady were significantly higher than cv. Local for all ripening stages.

Table 7: True density (kg/m^3) of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	1024.95	1022.00	1027.00
C_1S_2	1178.25	1176.00	1180.00
C_1S_3	1053.04	1049.00	1058.00
C_1S_4	1076.66	1075.00	1078.00
C_1S_5	1184.71	1182.00	1187.00
C_2S_1	847.79	846.00	850.00
C_2S_2	784.81	782.00	790.00
C_2S_3	747.06	744.00	749.00
C_2S_4	760.87	753.00	770.00
C_2S_5	784.13	782.00	786.00
Mean	944.23	941.10	947.50
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	0.983	2.9	0.4
S	1.555	4.58	
C× S	2.19	6.48	

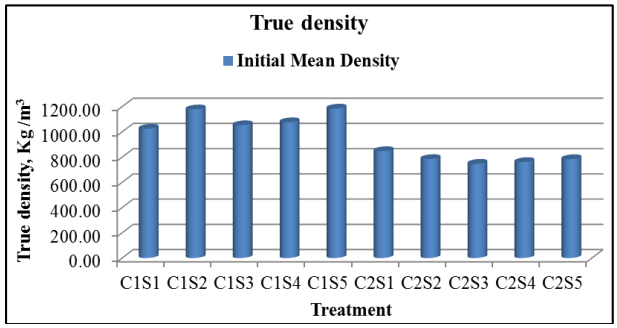

Fig 5: True density (kg/m^3) of papaya at different ripening stages

Sphericity

The data pertaining to sphericity of papaya are presented in Table 8 and depicted in Figure 6. The mean sphericity of papaya fruit cv. Red Lady at stages 1 (C_1S_1) was 0.74 with a minimum value of 0.70 and maximum value of 0.81. Similarly, mean fruit true density at stages 2(C_1S_2), 3(C_1S_3), 4(C_1S_4) and 5(C_1S_5) were 0.83, 0.78, 0.75 and 0.77, respectively. For cv. Local, the mean sphericity at stages 1(C_2S_1) was 0.83 with a minimum value of 0.75 and maximum value of 0.90. Similarly, mean fruit true density at stages 2(C_2S_2), 3(C_2S_3), 4(C_2S_4) and 5(C_2S_5) were 0.82, 0.83, 0.87 and 0.80, respectively. The sphericity papaya in both the cultivar did not vary significantly with ripening stages but sphericity of cv. Local were significantly higher than cv. Red Lady for all ripening stages. Sphericity of both cultivars suggests that papaya shape is in the category of round shape with an obovate structure as assumed in the methodology. Local cultivar was more round than cv. Red Lady.

Table 8: Sphericity of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	0.74	0.70	0.81
C_1S_2	0.83	0.80	0.85
C_1S_3	0.78	0.74	0.80
C_1S_4	0.75	0.70	0.80
C_1S_5	0.77	0.77	0.78
C_2S_1	0.83	0.75	0.90

C_2S_2	0.82	0.78	0.86
C_2S_3	0.83	0.75	0.90
C_2S_4	0.87	0.85	0.90
C_2S_5	0.80	0.77	0.87
Mean	0.80	0.76	0.85
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C*	0.013	0.037	6.04
S	0.02	NS	
C× S	0.028	NS	

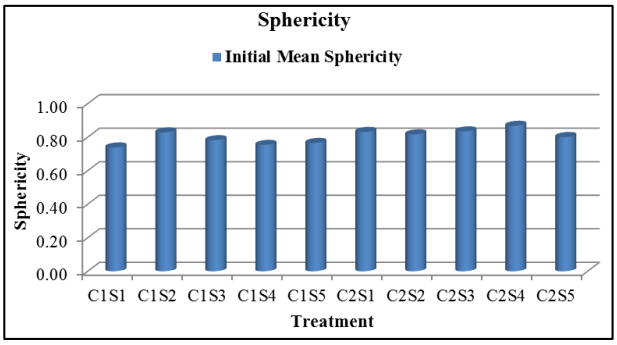

Fig 6: Sphericity of papaya at different ripening stages surface area volume ratio

The data pertaining to surface area volume ratio (SAVR) of papaya are presented in Table 9 and depicted in Figure 7. The Mean SAVR of papaya fruit at stages 1 (C_1S_1) was 0.61 with a minimum value of 0.60 and maximum value of 0.61. Similarly, mean SAVR at stages 2(C_1S_2), 3(C_1S_3), 4(C_1S_4) and 5(C_1S_5) were 0.64, 0.52, 0.56 and 0.60, respectively. For cv. Local, the mean SAVR at stages 1(C_2S_1) was 0.54 with a minimum value of 0.46 and maximum value of 0.58. Similarly, mean SAVR at stages 2(C_2S_2), 3(C_2S_3), 4(C_2S_4) and 5(C_2S_5) were 0.53, 0.60, 0.55 and 0.54, respectively. The SAVR of papaya in both the cultivar did not vary significantly with ripening stages but SAVR of cv. Red lady were significantly higher than cv. local for all ripening stages.

Coefficient of friction

The data pertaining to coefficient of friction of papaya are presented in Table 10 and depicted in Figure 8. The overall mean coefficient of friction of papaya fruit for both cv. Red Lady as well as cv. Local ranges from 0.20-22 in a stainless steel surface for all ripening stages and didn't vary significantly with the period of study. Papaya fruit at ripening stages S_3, S_4 and S_5 spoiled after 4, 3 and 2 days of study period; hence their data were not recorded. A similar result was also reported by Athmaselvi *et al*., (2013) [1] for papaya.These properties are the key elements for calculation of compressibility and flow behavior of materials used for designing storage structures.

Table 9: Surface area volume ratio of papaya at different ripening stages

Treatment	Mean	Min	Max
C_1S_1	0.61	0.60	0.61
C_1S_2	0.64	0.50	0.72
C_1S_3	0.52	0.48	0.54
C_1S_4	0.56	0.50	0.60
C_1S_5	0.60	0.53	0.63
C_2S_1	0.54	0.46	0.58
C_2S_2	0.53	0.38	0.63
C_2S_3	0.60	0.53	0.63
C_2S_4	0.55	0.46	0.65
C_2S_5	0.54	0.47	0.58
Mean	0.57	0.49	0.62
ANOVA Table			
Source	**S.Em. ±**	**CD at 5%**	**CV %**
C	0.013	0.037	6.04
S	0.02	NS	
C× S	0.028	NS	

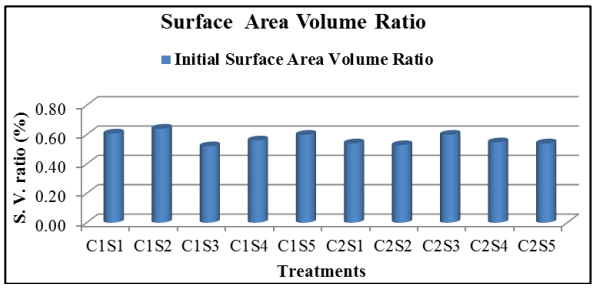

Fig 7: Surface area volume ratio of papaya at different ripening stages

Table 10: Coefficient of friction of papaya at different ripening stages

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
C_1S_1	0.22	0.21	0.21	0.22	0.22	0.21
C_1S_2	0.22	0.21	0.21	0.21	0.21	0.22
C_1S_3	0.21	0.22	0.21	0.22	0.21	-
C_1S_4	0.21	0.21	0.20	0.21	-	-
C_1S_5	0.21	0.22	0.21	-	-	-
C_2S_1	0.21	0.21	0.22	0.21	0.21	0.21
C_2S_2	0.21	0.21	0.21	0.21	0.20	0.21
C_2S_3	0.20	0.21	0.22	0.21	0.21	-
C_2S_4	0.21	0.21	0.21	0.20	-	-
C_2S_5	0.21	0.21	0.22	-	-	-
Mean	0.21	0.21	0.21	0.21	0.21	0.17
	ANOVA Table					
S.Em. ± (C)	0.003	0.002	0.003	0.002	0.002	0.002
S.Em. ± (S)	0.005	0.004	0.004	0.003	0.002	0.003
S.Em. ± C×S	0.007	0.005	0.006	0.005	0.003	0.004

CD % (C)	NS	0.007	NS	NS	NS	NS
CD % (S)	NS	0.011	NS	0.01	0.007	0.009
CD % C × S	NS	0.015	NS	NS	NS	NS
CV %	5.5	4.5	4.7	5.1	4.7	8.9

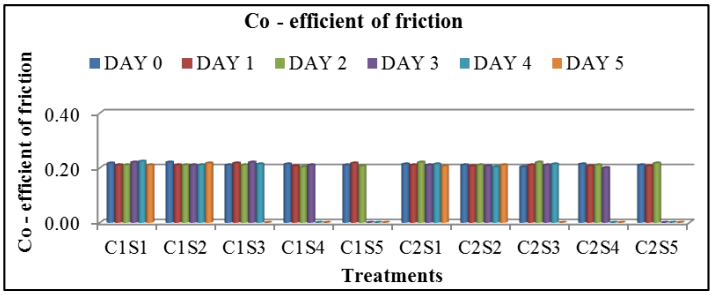

Fig 8: Coefficient of friction of papaya at different ripening stages

Physiological loss in weight (PLW)

The data pertaining to PLW of papaya are presented in Table 11 and depicted in Figure 9. The mean PLW of papaya fruit for cv. Red Lady for stages 1(C_1S_1) and 2(C_1S_2) were 9.9% and 9.82%, respectively over a period of 5 days of harvesting at ambient condition (30°C, 70% RH).PLW for at stages 3(C_1S_3) was 8.9% after 4 days of harvesting as fruit spoiled due to fungus development. PLW for at stages 4 (C_1S_4) was 5.14% after 3 days of harvesting as fruit spoiled due to fungus development. PLW for at stages 5(C_1S_5) was 5.07% after 2 days of harvesting as fruit spoiled due to fungus development. For cv. Local, the mean PLW at stages 1 (C_2S_1) and 2(C_2S_2) were 10.32% and 9.17%respectivelyover a period of 5 days of harvesting at ambient condition. Similarly, PLW at stages 3(C_2S_3), 4(C_2S_4) and 5(C_2S_5) were 7.18%, 5.64% and 5.20% after 4th, 3rd and 2nd day of harvesting, respectively. The physiological loss in weight of fruits resulted in wilting and shrivelling of fruits and ultimately losing the freshness and appearance of the fruit. The loss in weight is a direct loss of saleable produce in economic terms coupled with the reduced acceptability of the produce. From the result, it was evident that shelf life of tree ripened papaya at stages S_5 was maximum of 2 days, stages S_4 was 3 days, stages S_3 was 4 days respectively. Stages S_2 and S_1 have shelf life of 5-6 days after harvesting at ambient condition of storage. Similar results were also observed for cv. Local.

Table 11: Physiological loss in weight (PLW, %) of papaya at different ripening stages

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
C_1S_1	0	3.20	4.68	7.64	9.03	9.90
C_1S_2	0	2.48	5.45	7.77	9.00	9.82
C_1S_3	0	3.35	5.31	7.60	8.90	-
C_1S_4	0	1.30	3.05	5.14	-	-
C_1S_5	0	3.05	5.07	-	-	-
C_2S_1	0	2.54	5.66	8.20	9.35	10.32
C_2S_2	0	2.29	4.01	6.16	8.17	9.17
C_2S_3	0	1.54	2.74	5.30	7.18	-
C_2S_4	0	1.57	3.29	5.64	-	-
C_2S_5	0	3.57	5.20	-	-	-
Mean	0.00	2.49	4.45	6.68	8.61	9.80

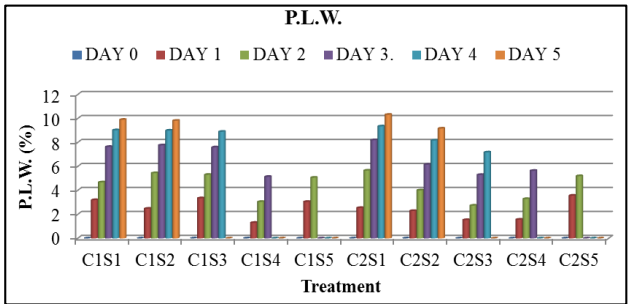

Fig 9: Physiological loss in weight (PLW, %) of papaya at different ripening stages

Fruit firmness (kgf)

The data pertaining to firmness of papaya are presented in Table 12 and depicted in Figure 10. The mean firmness of papaya fruit cv. Red Lady at stages 1(C_1S_1), 2(C_1S_2), 3(C_1S_3), 4(C_1S_5) and 5(C_1S_4) were 9.6kgf, 8.1kgf, 6.1kgf, 4.9kgfand 1.6kgf, respectively. Whereas for cv. Local mean firmness of papaya fruit at stages 1(C_2S_1), 2(C_2S_2), 3(C_2S_3), 4(C_2S_4) and 5(C_2S_5) were 9.5 kgf, 8.8kgf, 7.9kgf, 5.2kgfand 1.5 kgf, respectively. The data on firmness showed a decreasing trend from stages S_1 (Green) to stages S_5 (Three quarter ripe) for both the cultivar suggesting a firm texture at green mature stages and soft texture at three quarter ripe. Firmness also showed a decreasing trend from day 0 to day 5 after harvesting of fruit at all ripening stages in both cultivars.

Softening of papaya fruit was characterized by an increase in solubility of cell wall pectin. The storage under condition resulted in accelerated softening (Bron and Jacomino, 2006) [2]. Papaya at Stages S_5 in both cultivar are suitable for processing and juice making while stages S_3 and S_4 are best suited for table fruit as dessert. Stages S_1 and S_2 were suitable for table purpose as dessert fruit and processing only after 5-4 days after harvesting and storage. The stage S_2 was best for distance market while S_1 was suitable for cooking as vegetable and preparation of Tutti-Frutti.

Table 12: Firmness (kgf) of papaya at different ripening stages

Treatment	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
C_1S_1	9.6	9.4	9.1	8.3	5.4	3.1
C_1S_2	8.1	7.6	7.2	5.5	4.0	1.0
C_1S_3	6.1	6.0	5.8	4.0	1.0	-
C_1S_4	4.9	4.0	3.5	1.0	-	-
C_1S_5	1.6	1.0	1.0	-	-	-
C_2S_1	9.5	9.2	8.7	8.2	5.1	1.2
C_2S_2	8.8	8.2	8.0	4.8	2.3	1.2
C_2S_3	7.9	6.1	4.1	3.0	1.2	-
C_2S_4	5.2	4.8	2.1	1.0	-	-
C_2S_5	1.5	1.4	1.3	-	-	-
Mean	6.3	5.8	5.1	4.5	3.1	1.6
	ANOVA Table					
S.Em. ± (C)	0.064	0.057	0.126	0.063	0.058	0.028
S.Em. ± (S)	0.101	0.09	0.199	0.1	0.091	0.043
S.Em. ± C×S	0.143	0.127	0.282	0.142	0.129	0.063
CD % (C)	0.189	0.168	0.372	0.187	0.17	0.084
CD % (S)	0.299	0.266	0.588	0.296	0.268	0.132
CD % (C×S)	0.423	0.376	0.832	0.418	0.38	0.187
CV %	3.94	3.82	9.62	6.9	11.8	16.9

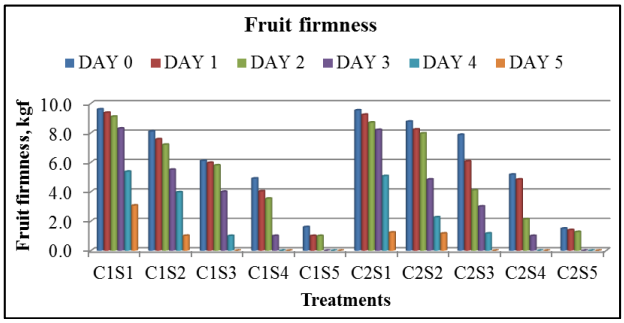

Fig 10: Firmness (kgf) of papaya at different ripening stages

Conclusion

Average fruit weight, fruit size (length, breadth and thickness), true density of papaya cv. Red lady were significantly higher than cv. Local at all stages of ripening on the day of harvesting. Shape of papaya fruit cv. Red Lady and cv. Local resembles to obovate. Average sphericity of papaya fruit for cv. Red Lady and cv. Local were 0.77 and 0.83, respectively indicating a near spherical shape. Coefficient of friction being in the range of 0.20-22 on stainless steel surface suggests a low flow ability of papaya fruit during bulk handling. Decreasing trend in firmness of papaya from stage $S_1$to stage S_5 indicating a loss in firmness due to ripening.

References

1. Athmaselvi KA, Jenney P, Pavithra C and Roy I. Physical and biochemical properties of selected tropical fruits. Int. Agrophys. 2013; 28:383-388.
2. Bron UI and Jacomino AP. Ripening and quality of 'Golden' papaya fruit harvested at different maturity stage. Braz. J. Plant Physiol. 2006; 18(3):389-396.
3. Mohsenin NN. Physical properties of plant and animal materials.2nd Eds. Gordon and Breach Press, New York, USA, 1986.
4. NHB. Indian Horticulture Database-2014, Nation Horticulture Board, Ministry of Agriculture, Government of India, 2014, 100-105.
5. Sivakumar D. and Wall MM. Papaya Fruit Quality Management during the Postharvest Supply Chain, Food Reviews International. 2013; 29(1):24-48, DOI:10.1080 /87559129.2012.692138.