International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2381-2387

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

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Engineering, physico-chemical properties of papaya (*Carica papaya*) at different ripening stages

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Abstract
Papaya (*Carica papaya*) is the tropical fruit crop, and have second highest productivity in India. To analyse the development and physiological and engineering characteristic of papaya it is a most important to study physico - chemical and sensory quality of papaya at a ripening or maturity stages of papaya. The red lady Taiwan papaya at five different Ripening stages. Total green, Colour break, Quarter ripe = 5to 25% yellow, Half ripe = 26to 50% yellow, Three Quarter ripe = 51to 75% yellow colour skin. Result indicated a significant impact of maturity levels on all parameters included in the study when consider individually. Study was laid by considering the physical and chemical property of red lady and local variety Of papaya on the basis of weight, length, breadth, surface area, surface volume ratio, sphericity, Co- efficient of friction, firmness, physiological loss in weight, true density, and in chemical property in Total soluble solid, pH, Titratable acidity, Ascorbic acid, Total sugar and also sensory or organoleptic property. The best quality in reference to colour, flavour, texture analysis in 5th stage was observed in papaya CV. Red lady Taiwan. When harvested at three quarter ripe 51-75 % yellow skin change in skin colour and its physico-chemical properties at different ripening stages. The above investigations through light on possibility of extend self life and good quality of papaya at the different ripening sages.

Keywords: engineering, physico-chemical, papaya, *Carica papaya*

Introduction
Papaya (*Carica papaya* L) is an evergreen tropical fruit crop, tree-like herb, 2-10 m tall, usually unbranched although sometimes branched due to injury, containing white latex in all parts. The stems are cylindrical, 10-30 cm in diameter, hollow with prominent leaf scars and spongy-fibrous tissue having an extensive rooting system.Generally, the papaya fruit is melon-like, oval to nearly round, varying in size from15 to 50 cm in length and from 10 to 20 cm in width and weighing up to 9 kg. The skin is waxy and thin but fairly tough. When the fruit is green and hard it is rich in white latex. As it ripens, it becomes light- or deep-yellow externally and the thick wall of succulent flesh becomes aromatic, yellow, orange or various shades of salmon or red. It is then juicy, sweetish and somewhat like a cantaloupe in flavor; in some types quite musky. Mature fruit contain numerous grayish black, ovoid corrugated, peppery seeds about 5 mm long, each coated with a transparent, gelatinous aril enclosed in a sarcotesta, and attached to the flesh by soft, white, fibrous placental tissue (Morton, 1987) [27].

Papaya is grown both commercially as well as in the kitchen garden of many households all over India because of its high nutritive and medicinal value. The early and continuous bearing habit makes papaya a popular fruit crop. Ripe papaya is not only eaten fresh all over India but also used to make fruit salads, refreshing drinks, nectars, jam, jelly, candies and dried fruit. Green papayas prepared as salad, cooked vegetables or as chutneys and preserve. They are also used in the preparation of tutti-frutti. It is rich in a number of nutrients (Table 1) and antioxidants and has a high medicinal value. Papain is tapped from green fruits which has industrial use.

Table 1: Nutritional composition of papaya pulp per 100 g of pulp

Composition	Unripe	Hard Ripe	Very Ripe
	Percent/ per 100 mg		
Moisture content	81.39	86.68	89.21
Carbohydrate	18.47	14.63	9.65
Fat	0.55	0.45	0.35
Crude Protein	1.46	0.64	0.29
Crude Fibre	11.62	8.29	6.18
Ash	4.84	5.24	2.83
Calcium	58.78 mg	46.76 mg	14.69 mg
Sodium	25.68 mg	25.76 mg	27.25 mg
Potassium	58.67 mg	56.27mg	36.0mg
Phosphorus	9.48 mg	8.8mg	3.1 mg
Magnesium	12.8 mg	10.40 mg	6.4 mg
Vitamin A	1354.87 IU	2308.12IU	2085.13IU
Vitamin C	150.12 mg	149.0 mg	112.0 mg

Source: Chukwuka *et al*., 2013) [13]

Giri *et al.* (1980) [17] reported that climatic conditions of India are suitable for the growth of papaya. Papaya is a rich source of vitamin A (carotene), vitamin C and riboflavin, besides minerals.
Pal *et al.* (1980a) [31] reported that the papaya is mostly used for fresh consumption because of richness in vitamin A, C and minerals. The study described the analysis on physico-chemical parameters of tree and room ripened fruits. The tree ripened fruits were found superior over room ripened fruits with regard to increased pulp proportion, pulp / peel ratio, dry matter, alcohol insoluble acids, total soluble acids, soluble acids, soluble amino acids, total sugars, glucose, vitamin A and soluble amino acids content.

2. Post-harvest factors affecting the quality and storage life of fruit

Quality of a horticultural product in short is defined as the degree of excellence or superiority, is a combination of attributes, properties, or characteristics that give each commodity value, in terms of its intended use. The relative importance given to a specific quality attribute varies in accordance with the commodity concerned and with the individual (producer, consumer, and handler) or market concerned with quality assessment. High yields, good appearance, ease of harvest, and the ability to withstand long-distance shipping to markets are important quality attributes to producers, from the point of view of wholesale and retail marketers, appearance, firmness, and shelf-life are important. Consumers, on the other hand, judge the quality of fresh fruits, ornamentals, and vegetables on the basis of appearance (including 'freshness') at the time of initial purchase. Subsequent purchases depend upon the consumer's satisfaction in terms of flavor (eating) quality of the edible part of produce (Kader and Rolle, 2004) [25].
Kader *et al*., (1989) [24] reported that it is not possible to improve the quality of produce after harvest, but it is possible to maintain it by slowing down the rate of deteriorative changes. The rate at which these changes occurred in harvested fruit may be influenced by a number of factors like harvest maturity, temperature and relative humidity, atmospheric composition during storage and transportation, mechanical injuries, disease and pest incidence. The objectives of post-harvest management and handling system must ensure that the fruit reaches the market in exact condition desired by the consumer.

3. Harvest maturity of papaya

Papaya normally require three month from flowering until fruit maturity. Maturity at harvest is a very important determinant of storage life and final fruit quality as harvesting fruit at improper maturity can lead to uneven ripening and overripe fruit (Chan *et al.,* 1979) [11]. One of the major problems faced by papaya fruit marketing was the identification of optimum harvest maturity to ensure adequate fruit ripening to excellent eating quality. Maturity include internal pulp colour and % soluble solids content (sugar content). These indices are used to test randomly selected fruits in order to correlate fruit size with maturity. The internal pulp colour of mature papaya fruit changes from cream to yellow orange as the external skin colour changes from green to yellow-orange during ripening. The soluble solids content of mature fruits should be at least 11.5%, and can be determined by placing several drops of juice on a hand-held refract meter.
Papayas are harvested after the skin color changes from dark green to light green, because the fruit accumulate sugars during the final stage of development. However, the sugar content does not increase after picking and this will affect fruit flavor. Papayas for commercial trade are harvested when the peel color is between color break and one-quarter yellow, depending on the distance to markets (Nakasone and Paull, 1998) [29]. 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.
Consumer acceptance is higher for papayas free from external damage and decay, and uniform in size, shape, and color. Usually small- or medium-sized papaya fruit with yellow or red flesh color are exported. Generally, hermaphrodite (pear-shaped) or female (round) fruit are accepted by consumers. Internal quality attributes of papaya include uniform and intense flesh color, freedom from damage, and adequate soluble solids contents (SSC), depending on cultivar and consumer preferences. Papaya fruit flavor quality also depends on variety, maturity stage at harvest, postharvest handling methods and treatments, and the incidence of mechanical damage or chilling injury, which can affect fruit flavor as observed in other tropical and subtropical fruits (Wall, 2006; Shivkumar and Wall, 2013) [42, 39]. Harvest and postharvest 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.
Akamine and Goo (1971) [1] reported that the sugar content of papaya fruit does not increase after picking and thus affecting fruit flavour. An important criterion to determine suitable harvest maturity is the development of a yellow tinge or streak at the blossom end (color break). Papaya fruits accumulated sugars in the final stage of development and the fruits were, therefore, not harvested till it attained a minimum total soluble solid of 11.5 per cent and at least six per cent surface colouration at the blossom end region.
Pal *et al.,* (1980a) [31] indicated that the tree ripened fruits were superior in quality to those harvested at maturity and ripened under ambient conditions with regard to pulp contents, pulp to peel ratio, dry matter, total sugars, vitamin A and soluble amino acids.
Selvaraj *et al.,* (1982) [37] recommended papaya the fruits were picked when either the green colour was changed half way to yellow for local market or after the blossom end had

turned yellow for export purpose. Thus, the change of fruit surface colour was an index of harvest maturity in papaya.
Paull (1993) [24] reported that papaya harvested before colour 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. Papaya fruit are climacteric, with respiration rates at 20°C for fruit at the colour break and ripe stages of 9 -18 and 70 - 90 mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$, respectively. Ethylene rates ranged from 7 to 10 $\mu g \cdot kg^{-1} \cdot h^{-1}$, in ripening fruit.
Nakasone and Paull (1998) [29] reported that papayas for commercial trade are harvested when the peel colour is between colour 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 colour development, textural and compositional (organic acids) changes, and synthesis of volatile aroma compounds occur during ripening after harvest, concomitant with the climacteric period (Paull, 1996) [25].
Anon. (2003) [4] assessed the effect of maturity stages on storage life of papaya. They observed that fruits harvested at colour break stage and held at 25-28ºC ripened to 60-70% yellow skin colour within 4-6 days. Fruits could be stored for 14-21 days at 10ºC with adequate postharvest disease controlling measures. Market life was very short at advanced stages of maturity (5-6 days for three quarters ripe fruit).
Bron and Jacomino (2006) [10] studied the ripening physiology and quality of "Golden" papaya at four different maturity stages (Stage 0: totally green; Stage 1: upto 15% of yellow skin; Stage 2: 16-25% of yellow skin and Stage 3: 26-50% of yellow skin) at 23ºC**.** Results revealed that regardless of maturity stages, fruit showed similar variation in respiration rate, exhibiting constant values after the 2nd day of storage at 23ºC (~31 ml CO_2 kg^{-1} h^{-1} for stages 0, 1, and 2, and ~37 ml CO_2 kg^{-1} h^{-1} for stage 3). Fruit harvested at stage 0 and 1 showed a well-defined ethylene production peak of 2.1 µL C_2H_4 kg^{-1} h^{-1} after 7 d of storage and 1.3 µl C_2H_4 kg^{-1} h^{-1} after 6 d, respectively and typical climacteric behaviour was not observed for any maturity stages. The ascorbic acid concentration increased 20-30% during ripening, while skin hue angle and titratable acidity was reduced. It was reported that soluble solid did not alter during ripening and fruit harvested at stage 2 (16 to 25% of yellow skin) and stage 3 (26 to 50% of yellow skin) had superior scores for sensorial evaluation mainly for flavor and appearance.
Naglaa (2011) [28] studied the importance of harvesting papaya fruits at the proper maturity stage, because sugar content does not increase after harvest. Non-destructive indices such the number of days from flowering, fruit size and external colour and destructive indices such as percentage of internal pulp colour and soluble solids content were used to determine harvestable maturity of papaya. It was reported that internal pulp colour changes from cream to yellow- orange whereas the external skin colour changes from green to yellow-orange during ripening. Similarly, soluble solid content of matured papaya fruit was found to be 11.5 % and at a stage of 50 % yellow skin of papaya, a shelf life of 5-7 days was found. It was also found that cold storage is a likely solution for slowing the loss of firmness and short term storage, for the purpose of long distance only, not for order.
Serry (2011) [38] harvested papaya fruits of cultivar 'Solo' at three different maturity stages (25% yellow, 50% yellow and fully yellow) and evaluated them under ambient conditions (20 ± 2° C temperature and 80-85% relative humidity) for 4 days and in cold storage (6°C temperature and 90-95% relative humidity) for 20 days. They concluded that papaya fruits harvested at 50% yellowing and kept at 6ºC for 20 days followed by 3 days at 20ºC had superior scores for sensory evaluation.

4. Low temperature storage of papaya fruit
A range of storage temperatures, kept under refrigeration had been reported for different cultivar of papaya, usually for fruit harvested at colour break stage. Papaya could be stored for 16 days at the temperatures between 10 to 15ºC, while 12ºC was recommended as optimum storage temperature for two weeks (de-Arriola *et al.*, 1980) [6] and fruit under ambient tropical conditions (30ºC) has a maximum storage life of seven days (Maharaja, 1988).
Paull *et al.*, (1997) [35] reported that mature green fruit with tinge of yellow colour on peel could be stored at 10ºC for less than 14 days whereas quarter ripe and three-fourth ripe could be stored for 21 days at 7ºC.

5. Chilling injury
Chilling injury is a major physiological disorder induced by low but non-freezing temperatures which is attributed to the lipophilic nature of proteins and the phase transition of lipids. The common symptoms of chilling injury in papayas, which became more apparent upon returning the fruit to ripening temperature, were pitting of skin, discoloration of flesh, development of hard areas in the pulp and around the vascular bundles, water soaking of tissues, increase in electrolyte leakage, abnormal ripening, production of off-flavours and increased susceptibility to decay (Chen and Paull, 1986) [12].
Chen and Paull, (1986) [12] reported that mature green papayas were found to be the most sensitive to chilling while ripening fruits were less susceptible. They opined that the decrease in chilling sensitivity with preconditioning was associated with partial fruit ripening and thus a reduced postharvest life.
Ali *et al.*, (1993) [2] reported that chilling injury could be prevented by determining the critical temperature or storage time relationships for its development and not exposing the fruit to temperature or time below the allowable limits. The Pre-conditioning of the fruit, where the temperature was lowered in stages, alsoreduces chilling injury in papaya.

6. Ripening conditions and physiological loss in weight (PLW)
Paull and Chen, (1989) [25] reported that the optimum temperature for papaya fruit ripening was between 22.5 and 27.5°C with fruit taking 10 to 16 days to reach full skin yellowing from colour break stage. Severe mass loss and external abnormalities become significant at temperature higher than 27.5°C and fruits ripened at 32.5°C have poor flesh colour development. The loss of around eight per cent of initial mass from mature green papayas produced 'rubbery', low gloss and unsaleable fruits.
The mature climacteric fruit once detached from tree, can maintain an independent existence for days or even weeks. During this period, the fruit undergoes a series of metabolic processes which eventually lead the fruit towards ripening. The tissues continue to respire and transpire during these metabolic processes and lose a significant quantity of their

moisture and other chemical ingredients, which ultimately results in the loss of weight (Biale, 1975) [8].

Paull and Chen (1989) [36] reported that the major mode of weight loss was the skin because of its larger surface area. Weight loss in surface shipped papaya was a major problem. Fruit waxing reduced weight loss by 14% to 40%, while plastic shrink wrap reduced by nearly 90%. Similarly, also found that weight loss was the lowest in polyethylene wrapped fruits, intermediate in waxed fruits and highest in controls.

7. Postharvest losses in papaya fruit

Nanda *et al.* (2012) [30] reported that overall total harvest and post-harvest loss of papaya fruit in India stood at 7.4 % which includes a total loss of 5.1% in farm operations at various stages such as harvesting (1.4%), collection (0.3%), sorting and grading (2%), packing (0.2%) and transportation (1.1%) and a total loss in storage of 2.3%.

Nunes *et al.* (2006) [31] reported that the major causes for postharvest quality losses in papaya along the marketing chain was due to mechanical injury that occur during harvesting, field handling or transportation, over ripe fruit, desiccated fruit, postharvest diseases (anthracnose, stem-end rots, Rhizopus rot), chilling injury from improper storage temperature, pest damage, and physiological disorders. These factors affect the appearance, texture, flavour, and nutritional value of papaya. Loss of firmness and chilling injury were the main limitations to retail quality for "Red Lady" papayas subjected to fluctuating temperatures (too cold or warm) during simulated shipping and handling.

Haydar *et al.* (2007) [19] reported that in currently used system, while designing equipment for harvesting tropical fruits, their physical properties are not taken into considerations there by the resulting design leading to inadequate applications. Therefore, determination of physical properties of tropical fruit have an important role in designing harvesting as well as post-harvest equipments used in transporting, storing, cleaning, separating, sorting, sizing, packaging, and processing it into different food.

8. Physiological and biochemical changes during storage and ripening stages of papaya fruit

8.1 Physiological changes

Eskin *et al*. (1971) [16] reported that senescence start with the process of ripening of fruit and progress is accompanied significant loss of green colour (chlorophylls), followed by the development of other characteristic colour which reach their full expression at the climacteric peak and are accompanied by changes in fruit texture.

Pal *et al*. (1980b) [32] studied on 12 varieties of papaya for physical parameters such as size, pulp colour, texture and density, fruit and seed cavity dimensions as well as chemical composition like, total soluble solids, acidity, dry matter, insoluble solids, starch, sucrose, glucose, fructose, minerals and vitamins. Results revealed the values for important constituents like, fruit weight, pulp percentage, acidity, vitamin A, vitamin C, sucrose, glucose and fructose with range 0.48 - 1.92kg, 73.0 - 88.75%, 0.058-0.116 (% citric acid / 100 g pulp), 1599-6347 IU, 46.3 -125.9 mg/100g, 0.48-2.47 %, 2.91-5.24% and 2.34-4.19%, respectively.

Tucker (1993) reported that fruit texture is commercially important, as it directly dictates papaya shelf life, quality, and consumer acceptance. It was found that bruised papayas soften and deteriorate quickly because bruising cause compression of cell layers and the loss of elasticity of the cell wall, leading to the rupture and release of cell contents into the intercellular spaces. Results revealed that mechanical wounding has been shown to induce the activity of 1-aminocyclopropane-1-carboxylic acid synthase, which catalyses production of 1-aminocyclopropane-1-carboxylic acid, the immediate precursor for C_2H_4. Therefore, mechanical damage during harvesting, storage, and transportation needs to be avoided to maintain papaya quality. High-quality papayas are firm and fresh in appearance, and will soften and ripen uniformly before consumption.

8.2 Biochemical changes in papaya during ripening

Hulme (1971) [20] reported that there are two main types of carbohydrates in papaya fruit, cell wall polysaccharides and soluble sugars. Best quality fruit is determined largely by sugar content. During early stage of fruit development, glucose is the main sugar. The sucrose content increases during the ripening process.

Desai and Wagh (1995) [15] reported that sugar is major components of papaya and its content varies widely depending on the cultivar. They reported that during extraction of sugar from papaya, the action of enzyme invertase decreases the amount of non-reducing sugar and increases reducing sugar. After inactivation of invertase by microwave heating, sugar extraction of ripe papaya yielded 48.3% sucrose, 29.8% glucose and 21.9% fructose.

Gomez *et al.* (2002) [18] reported that sweet taste is an important quality parameter for fruit. Taste is generally associated with sucrose, glucose, and fructose contents, which are used as a ripening index to determine the stage of ripeness and for quality standards of papaya. It was suggested that the sweet taste in papaya is related to a loss of fruit firmness and textural changes.

Anon. (2005) [4] reported that the soluble solids content of papaya tends to increase during ripening and softening, and varies from 6% to 19% depending on cultivar. However, the soluble solids content of mature fruit should be at least 11.5% to meet market grade.

Zaman *et al.* (2006) [44] carried out varietal study of four varieties of papaya mainly Bombai, Deshi, Shahi (Yellow) and Shahi (Red) to access their suitable for processed product.Result revealed that Shahi (yellow) has highest suitability percentages i.e. 87.4% along with 12% total soluble solids. They reported that except Shahi (Red), all other varieties are suitable for table purpose, canning and preparation of drinks and product making.

Jain *et al.* (2011) [11] carried out a study on quality of guava and papaya fruit pulp as influenced by blending ratio and storage period. They analyzed the organoleptic characteristic and qualitative characters (i.e., TSS, pH, acidity, ascorbic acid content) of papaya (cv. Taiwan) and observed that pH of papaya pulp was 4.39 with 12.40°brix TSS, 69.44mg/100g ascorbic acid and 0.316 percent acidity. Results revealed a 70% recovery of pulp and up to 40% papaya pulp blending with guava was acceptable.

Chukwuka *et al.* (2013) [13] compared the nutritive value of *Carica papaya* L. fruit at different ripening stages for advising consumers about the best stage of consumption. They reported that unripe papaya is a good source of carbohydrate, protein as well as vitamin C than ripe papaya. Similarly, the unripe papaya contained highest amount of all the non- nutritive elements such as saponin, alkaloids, tannin, flavonoid and phenol. Based on their study, they recommended unripe papaya over ripe papaya even though latter is sweet and tasty.

Jayathunge *et al.* (2014) studied on the physico-chemical and sensory quality of fresh fruit cut papaya (*Carica Papaya*) packaged in micro–perforated polyvinyl chloride containers. Papaya cubes at maturity stages, 5-45% yellow (more green then yellow) and 55-80 % yellow (more yellow then green) were washed with 5 % H_2O_2, drained and packaged in PVC trays having five, seven and ten micro perforations and stored for 19 days. Based on physico-chemical properties, optimum maturity for papaya and micro-perforation level of PVC trays were determined.Firmness and TSS change significantly, while titratable acidity did not change significantly throughout the storage. The result revealed that fruit firmness is a direct indicator for determining the fruit ripening with initial firmness of papaya at maturity stage more green than yellow was 8.00 ± 0.20 kg $cm^{-2}$the firmness did not change towards table ripe level throughout the storage period regardless of micro perforation level and storage period. Whereas firmness of papaya cubes at maturity stage more yellow than green having an initial firmness of 5.00 ± 0.20 $kgcm^{-2}$ gradually reduced towards the firmness of table ripe stage which is 0.45 ± 0.05 $kgcm^{-2}$. They found that optimum maturity stage for minimal processing of papaya was more yellow than green with firmness of 5.00 ±0.20 $kgcm^{-2}$.

Dasu *et al.* (2016) examined the efficacy of concentration of $CaCl_2$, Ca (NO_3) on post-harvest behaviour of papaya fruits and reported that the fruits treated with 4% $CaCl_2$ resulted in significantly lowest physiological loss in weight PLW of 9.61%, lowest percentage of ripening of 41.52%, highest fruit firmness of 6.36 $kgcm^{-2}$, highest organoleptic scoring, acidity, ascorbic acid, highest shelf life and lowest TSS, total sugar, reducing sugar and brix acid ratio. Application of 4% $CaCl_2$ has improved the shelf life of papaya fruit from normal 4 days at room temperature to 10.67 days without any losses in physical and chemical properties.

Tandel *et al.* (2017) [40] conducted an experiment on effect of integrate nutrient management on yield and quality of papaya. Result reveals that fruit quality having highest fruit firmness (7.38 kg/cm^2), shelf life (7.54 days), total soluble solid (8.12 %), total sugar (9.80 %) reducing sugar (8.45%) and ascorbic acid (23.90 mg/100g pulp) and also lowering physiological loss in weight (11.20 %) and Titratable acidity (0.016 %) were recorded in plants treated with 25 % RDN through bio mass compost + 25 % RDN through castor cake +50 % RDN through inorganic fertilizer.

9. Physical and mechanical properties of papaya at different level of ripeness

Ripening is a process in fruits that cause them to become more palatable. In general, a fruit become sweeter, less green and softer as it ripens even though the acidity of fruit may increases. Ripening of climacteric fruit such as papaya depends on ethylene action which later accompanied by softening process that can influence postharvest quality and storability of the fruit. All physical and mechanical properties of papaya except deformation have high correlation with stage of ripeness.

Mohsenin (1986) [26] reported that shape describes the object in terms of a geometrical body. It is important in heat and mass transfer calculations, screening solids to separate foreign materials, grading of fruits and vegetables, and evaluating the quality of food materials. The shape of a food material is usually expressed in terms of its sphericity, aspect ratio, ellipsoid ratio and slenderness ratio.

Amarasinghe and Sonnadara (2009) [3] investigated the surface colour variation of papaya fruits with maturity and surface colour which is considered as a quality parameter change with the maturity of papaya fruits. The result revealed that change of surface colour of a fruit with the maturity can be used as a parameter to measure the ripeness, Often, unripe fruits show greenish surface colour which changes to yellowish colour when they ripen gradually these colour patterns were similar within fruit categories.

Athmaselvi *et al.* (2013) [7] studied the physical and biochemical properties of guava, sapota and papaya. They reported the moisture content of papaya as 90.43 % (w.b.) and average mass, length, breadth and width of papaya to be 1022 g, 17.67 cm, 12.03 cm and 12.43 cm, respectively. Sphericity and aspect ratio of papaya were found to be 81.2% and 71.9%, respectively. The roundness of papaya was found to be 69.44 indicating oval- shaped. The papaya fruit has higher surface areas compared to guava and sapota and lower packing coefficient of 0.36. The true density, bulk density and porosity of papaya were 1127kg/m^3, 449 $kg/m^3$and 47%, respectively.

Bhosale and Sundaram (2015) [9] studied the non-destructive method for ripening prediction of papaya and found that firmness shows a linear correlation up to 99% to capacitive method at a resonant frequency of 250 kHz. The firmness of papaya varies from 23.5 N (firm) to 4.35 N (soft) in 5 days of ripening period.

Conclusion

It is observed that ripeness stages can be accounted physico-chemical and sensory property at different ripening stages with different engineering property. In physical properties are included that, size, shape, colour, textural, surface area, etc. And also include in chemical property in pH, TSS, Ascorbic acid, Titratable acidity, Total sugar.

In the 4th stage of three Quarter ripe = 51to 75% yellow colour skin papaya is good condition for use other purpose like, eating, pulping etc. In the chemical property change with the different ripening stages. The fruit firmness is a direct indicate for determine the fruit ripening. The initial firmness of papaya at the maturity stage more green than yellow colour was 11 to 1 kgf and the firmness change toward at the different ripening stages.

It is important for papaya fruit at the proper maturity stage because the sugar content does not increase after harvesting. At the ripening stage including the fruit size, external colour, and fruit ripening internal pulp colour % and soluble solid content.

The internal pulp colour of mature (Ripening papaya) fruit changes from cream to yellow or red, orange at the same part of outside of the papaya, but the colour is green to yellow or orange.

At the 1st stage (total green colour) papaya fruit's self-life 7-9 days after harvesting. Than 2nd stage (Colour break) papaya fruit‘s self-life is 5-7 days after harvesting of papaya. Then 3rd stage (Half ripe 5 to 25% yellow) 5to 6 days storage life after harvest. Then 4th stage (Half ripe = 26to 50% yellow) 3 to 5 days storage self after harvest. Then 5th stage (Three Quarter ripe = 51to 75 % yellow) 3 days storage self after harvest.

In the chemical property the range between 11% to 13 %, and ascorbic acid of red lady taiwan papaya range between 70-90 (mg/100mg) and pH was 6 to 6.7

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