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Shelf life extension of carica papaya by shrink wrapping

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Abstract
Papaya (*Carica papaya*) is a popular and economically important fruit of tropical and subtropical countries. Papaya ranks first among 13 to 17 fresh fruits for vitamin C content per 100 grams edible tissue. One serving of papaya will meet about 20% of an adult's daily folate needs and provides about 75% of an adult's daily vitamin C needs. Marketing of fresh papaya is a great problem because of its short post-harvest life, which leads to high post-harvest losses. Papaya fruits soften rapidly at room temperature after harvest with a very short shelf life. Considering the heavy post-harvest losses the technology of shrink wrapping has been standardized. This technique involves over wrapping of the produce with heat-shrinkable films of the desirable thickness with the help of a machine. Shrink film or Shrink wrap is a material made up of polymer plastic film. When heat is applied, it shrinks tightly over the material it is covering. The focus of this research was to study the effect of shrink wrapping on physico-chemical properties and shelf life extension of papaya. Two sets of fruits (wrapped and unwrapped) were held at ambient (32-39 ºC, 72-83% RH) and refrigerated (10-12 ºC, 90-95% RH) conditions throughout the storage period. Weight loss, pH, Moisture content, TSS, vitamin C, vitamin A, proteins, carbohydrates were evaluated at an interval of 4 days. Changes in moisture content, protein, vitamin C, carbohydrates of the shrink-wrapped fruits were lower than that of non-wrapped fruits during storage. Papaya fruits stored at room temperature, refrigeration, shrink wrapped and shrink wrap + refrigeration had a shelf life of 9, 14, 13, and 16 days respectively. By the observed results it was proved that shrink wrapped fruits at refrigerated conditions had longer storage period compared to other storage conditions.

Keywords: Carica papaya, shrink wrapping, shelf life

1. Introduction
Papaya (*Carica papaya* L.) is a large-leafed, unlignified and perennial herbaceous plant (Saeed *et al.*, 2014) [5]. The shape of fruit is elongated oval round. (Emma Dawson, 1998) [4]. *Carica papaya* is a species of the genus *Carica* from the plant family *Caricaceae*. Though its origin is rather obscure, papaya may represent the fusion of two or more species of *Carica*, native to Mexico and Central America (Workneh, 2012, Saeed *et al*., 2014) [31,5]. Papaya is rich in vitamin A, vitamin C, vitamin B, folates, minerals and fiber. It is also rich in antioxidants, low in sodium and calories, high in potassium and no cholesterol (Osato *et al.*, 1993; Lim *et al*., 2007; Krishna *et al*., 2008 and Aravind *et al*., 2013) [9,13,11,2]. Papaya skin and seeds contain numerous phytochemicals including polyphenols. Papaya fruit and other parts of the tree contain papain, a protein digesting enzyme (Pendzhiev 2002; Saeed *et al*., 2014) [19,5]. The ripe fruit is directly eaten raw while the unripe fruit is cooked before eating. The stem and bark is used to make ropes. The pectin in papaya is used to make jellies. The black seeds are sometimes used to substitute black pepper when ground. Papaya extracts are used in soaps and other skin care products. Papain is used as one of the ingredients in some chewing gums. Because of the high content of papain in the raw papaya it is used in meat tendering agents. Today it is cultivated throughout the tropics and in the warmest parts of the subtropics (Osato *et al*., 1993; Pendzhiev 2002; Paull and Duarte, 2011; Workneh, 2012, Saeed *et al*., 2014) [9,19,23,31,5]. India is the largest producer of papaya in the world while Andhra Pradesh is the largest producer in India (Mohan and Reddy, 2017) [22]. Papaya is a climacteric fruit. Climacteric fruits are defined as fruits that enter 'climacteric phase' after harvest *i.e.* they continue to ripen (Paull and Duarte, 2011) [23]. During the ripening process the fruits emit ethylene.

Ripe fruits are soft and delicate and generally cannot withstand Rigours of transport and repeated handling (Srinu *et al*., 2017) [28]. These fruits are harvested hard and green, but fully mature and are ripened near consumption areas.

Exporting papaya is limited due to difficulties in storing them and their susceptibility to bruising. The export market concentrates on processed papaya products like papaya pulp and dried papaya. Only 0.08% of domestic production is exported and the rest is consumed within the country. Delhi and Mumbai are the two principal markets. The crop arrives in the market around the year in the major States *viz*. Andhra Pradesh, Assam, Gujarat, Karnataka, Kerala, Maharashtra, Orissa and West Bengal (Mohan and Reddy, 2017) [22]. The perishable nature of papaya is a major drawback for transport of fruits to distant places and storage during glut in the market (Srinu *et al*., 2017) [28]. So the processing of papaya has attained greater significance. Post-harvest losses of tropical fruits is a serious problem because of rapid deterioration during handling, transport and storage (Yahia, 1998) [33]. Papaya fruits soften rapidly at room temperature (Srinu *et al*., 2017) [28]. Fruits face tremendous loss due to old-fashioned preservation practice and ignorance about preservation strategies. Different storage methods used to preserve papaya include low temperature storage, controlled atmospheric storage, chemical preservatives, wax coatings and plastic film wraps. But there are many reports that papaya in refrigerated storage is susceptible to fungal decay. Gamma irradiation has also been used to increase the shelf life. However, higher doses caused excessive softening of flesh, and low dose gamma radiation though increased the shelf life but reduced the levels of ascorbic acid. Chemical preservatives can have dangerous effects on health such as kidney and liver damages, various types of cancers etc. Hence there is a need to develop suitable cheaper storage techniques. Considering the heavy post-harvest losses the technology of shrink wrapping has been adopted. This technique involves over wrapping of the produce with heat-shrinkable films of the desirable thickness with the help of a machine. Shrink film or Shrink wrap is a material made up of polymer plastic film. When heat is applied, it shrinks tightly over the material it is covering. Commonly used shrink films include polyethylene, polypropylene and Polyolefin. Polyolefin films extend the shelf life of individual and tray wrapped fruits at ambient conditions and minimizes water loss during long term cold storage. The greatest advantage of individual shrink wrapping is its ability to control moisture loss to a great extent (Abd-elghany *et al*., 2012, Singh *et al*., 2014 and Thakur *et al*., 2017) [15,1]. Unlike waxing, the film forms a barrier that markedly increases the resistance to water vapor. The transpiration rate can be reduced 5 to 20 times by individual seal packing of fruit using selectively permeable films. Merits of shrink wrapping also includes easy and user friendly technique which can be very well adopted by marginal farmers and entrepreneurs, wrapped produce looks attractive, hygienic and free from dust and dirt, easy to handle shrink-wrapped fruits and vegetables during storage or transportation, avoids secondary infection, which is important for long term storage

Based on the above background, the present project was undertaken to study the process parameters for shelf life extension of papaya with the following objectives

1. To study the effect of shrink wrapping on papaya to extend shelf life.
2. To study the effect of shrink wrapping on physico-chemical, organoleptic properties quality of stored Papaya.

2. Materials and Methods

2.1 Experimentation Place

The experimental work was carried out at the process engineering laboratory, Department of agricultural process and food engineering, College of agricultural engineering, Bapatla and Microbiology laboratory, Post-harvest technology center, Bapatla.

2.2 Raw Materials

Freshly harvested papaya fruits (Variety: Taiwan Red Lady) used for the study were obtained from papaya farm, Pedda Ogirala, Krishna district. Healthy and matured fruits which were harvested on the same day were selected for the study.

2.3 Mini shrink wrap machine

It is used to shrink wrap the papaya fruits. Mini shrink wrap machine consists of a heat shrink tunnel (22” × 9” × 9”) through which the products were passed on a moving belt conveyor. The heat shrink tunnel is equipped with pair of electric heaters arranged one on either side of the shrink tunnel and a blower fan attached to the roof of tunnel. The blower and conveyor are operated by individual motors. A control panel present above the tunnel consists of various controls for varying conveyor speed, temperature setting, and Power knobs for conveyor, heaters and blower. Fruits sealed with shrink film were placed over the moving belt. Shrink wrapping of individual fruits was achieved by hot air circulation inside the tunnel which causes shrinkage of the film due to high temperature. Wrapped fruits were collected on the other end of the conveyor belt.

2.4 Determination of size and shape of papaya

Three axial dimensions namely as length, width and cross length were measured using a digital calipers with sensitivity of 0.01 mm. Dimension ‘L’ is the main (length) diameter, ‘*W*’ (width) is the longest dimension perpendicular to ‘*L*’ (Kheiralipour *et al*., 2008) [10].

2.5 Shrink Wrapping of papaya fruits

Individual papaya fruits were enclosed in heat shrinkable film (Polyolefin shrink film, 15 µ). A sealer was used to loosely pack the films around the fruits before wrapping in heat shrink tunnel. The fruits sealed in the film were then passed through a heat shrink tunnel on a moving belt at 220ºC for 10 seconds with belt speed of 6 cm/s to form a tight wrap on the fruit surface. Shrink wrapped fruits were collected on the other end of the belt. After packaging, samples were studied for storage life under two different conditions. One sample at ambient condition **(**Temp: 32-39 ºC; RH: 72-83%) and another sample of fruits were stored under refrigeration condition (Temp: 12-15°C; RH: 90-95%).

2.6 Chemical analysis of papaya fruits

Chemical analyses were conducted during at microbiology laboratory, Post-harvest technology centre, Bapatla. Fruits were washed with fresh water and stored under ambient condition (Temp: 32-39 ºC; RH: 72-83%) and another sample of fruits were stored under refrigeration condition (Temp: 12-15 °C; RH: 90-95%). Data on weight loss, pH, TSS, carbohydrates, ascorbic acid content, protein and vitamin A were recorded at an interval of 4 days for 20 days. The temperature and relative humidity of the ambient storage were noted on daily basis.

2.6.1 Estimation of proteins
Protein is estimated by Lowry's method (Thimmaiah, 1999) [32]. Protein reacts with the Folin-ciocalteu reagent (FCR) to give a blue-colored complex. The color so formed is due to the reaction of the alkaline copper with the protein as in the biuret test and the reduction of phosphomolybdic-phospotungstic components in the FCR by the amino acids tyrosine and tryptophan present in the protein. The intensity of the blue color is measured at 600nm. The intensity of the color depends on the amount of these aromatic amino acids present and will thus vary for different proteins.

2.6.2 Estimation of carbohydrates
The amount of total soluble sugars can be estimated using anthrone method (Thimmaiah, 1999) [32]. The carbohydrate content can be measured by hydrolyzing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides. The anthrone reaction is the basis of a rapid and convenient method for the determination of hexoses, aldopentoses and hexuronic acids either free or present in polysaccharides. Carbohydrates are dehydrated by concentrated H_2SO_4 to form furfural. Furfural condenses with anthrone (10-keto- 9, 10-dihydro-anthracene) to form a blue-green colored complex which is measured calorimetrically at 630nm.

$$\text{Amountofcarbohydrates} = \frac{\text{sugarvaluefromgraph}}{\text{amountofcentrifusedsample}} \times \frac{\text{totalvolumeextract}}{\text{weightofsample}} \times 100$$

2.6.3 Estimation of Vitamin A
Acetone, anhydrous sodium sulphate, petroleum ether were used as reagents. 5g of fresh sample was taken and crushed in 10-15ml acetone, adding a few crystals of anhydrous sodium sulphate with the help of pestle and mortar. Decent the supernatant into a beaker and the process was repeated twice and the combined supernatant transferred to a separatory funnel at 10 to 15 ml petroleum ether and mixed thoroughly, two layers will separate out on standing. The lower layer was discarded and the upper layer was collected into a 100ml volumetric flask, to make up the volume to 100ml with petroleum ether and the optical density at 452nm using petroleum ether was recorded as blank. (Srivastava and Sanjeev Kumar, 2012)

$$\beta\text{-Carotene } (\mu g/100g) = \frac{\text{O.D X 13.9 X 1000}}{\text{Wt.of sample X 560}}$$

$$\text{Vitamin A (I.U)} = \frac{\text{beta carotene}(\mu g/100)}{0.6}$$

2.6.4 Estimation of ascorbic acid (Vitamin-C)
Ascorbic acid is estimated by volumetric and colorimetric methods. Ascorbic acid reduces the 2, 6-dichlorophenol indophenol dye to a colorless leuco-base. The ascorbic acid gets oxidized to dehydroascorbic acid. Though the dye is a blue colored compound, the end product is the appearance of pink color. The dye is pink colored in acid medium. Oxalic acid is used as the titrating medium.

$$\text{The amount of ascorbic acid (mg/100g)} = \frac{0.1\text{mg} \times V2 \times 100}{V1 \times 5\text{ml} \times \text{wt of the sample}} \times 100$$

Where
V_1 = Standard titrate value
V_2 = Volume of oxalic acid consumed

2.6.5 Estimation of Total Soluble Solids
Total soluble solids of juice samples was measured by placing a drop of the juice sample on the prism of the Hand refractrometer and expressed in terms of % Brix. (Srivastava and Sanjeev Kumar, 1994) [29]. Correction at 20^0C was applied for the observed reading.

2.6.6 Estimation of p^H
The pH measurement was performed using a p^H meter. (Srivastava and Sanjeev Kumar, 1994) [29]. The device having the glass electrode was placed inside the homogenized sample of papaya juice and the value was registered once it had stabilized.

2.6.7 Estimation of Moisture Content
Moisture content (% w.b) of the papaya was determined by hot air-oven method (AOAC, 1984). 5 g of sample was accurately weighed into a clean dish and dried in an oven at 105^0C for 5 hr. It was then cooled in desiccators and weighed. This was repeated till a constant weight was obtained. The moisture content was expressed as % of sample.

$$\% \text{ Moisture (w.b.)} = \frac{(W2-W3)}{(W2-W1)} \times 100$$

Where
W_1 = Weight of petri dish (g),
W_2 = Weight of petri dish + sample (g),
W_3 = Weight of petri dish + dried sample (g).

2.6.8 Sensory analysis of papaya fruit
Sensory evaluation for the prepared shrink wrapped sample was carried out by comparing with control samples. The hedonic rating was used to measure the consumer acceptability of food products. From 1 to 16 samples were served to panelist at one session and was asked to rate the acceptability of product on a scale, usually of on points, rating from “like extremely” to “dislike extremely”. The results were analyzed for preference with data from panelists. Organoleptic quality of papaya fruit was determined with the help of a 10 member consumer panel using 9-point hedonic scale. The samples were evaluated for peel color, taste, aroma, overall acceptability. The sensory evaluation score card is described in table.1

Table 1: Sensory Evaluation Score card

S. No	Scale	Characteristics
1	9	Like extremely
2	8	Like very much
3	7	Like moderately
4	6	Like slightly
5	5	Neither like nor dislike
6	4	Dislike slightly
7	3	Dislike moderately
8	2	Dislike very much
9	1	Dislike extremely

3. Results and Discussion

From the observations it was found that unwrapped papaya fruits stored at room temperature, refrigeration had a shelf life of 10, 14 days respectively. Whereas shrink wrapped papaya fruits stored at room temperature, refrigeration had a shelf life of 12, 19 days respectively.

3.1 Effect of Shrink wrapping on Weight Loss

The weight loss of unwrapped, and shrink wrapped fruits at ambient temperature was gradually increased to 29.8%, 10.21% respectively by 12th day. Whereas at refrigeration temperature the weight loss of unwrapped, shrink wrapped fruits was increased to 16.73% (16th day), 2.5% (20th day) respectively. From fig.1 it was evident that the weight loss in wrapped fruit at refrigeration was minute. The reduction in weight loss in fruits may be attributed to higher respiration rates due to metabolic activities.

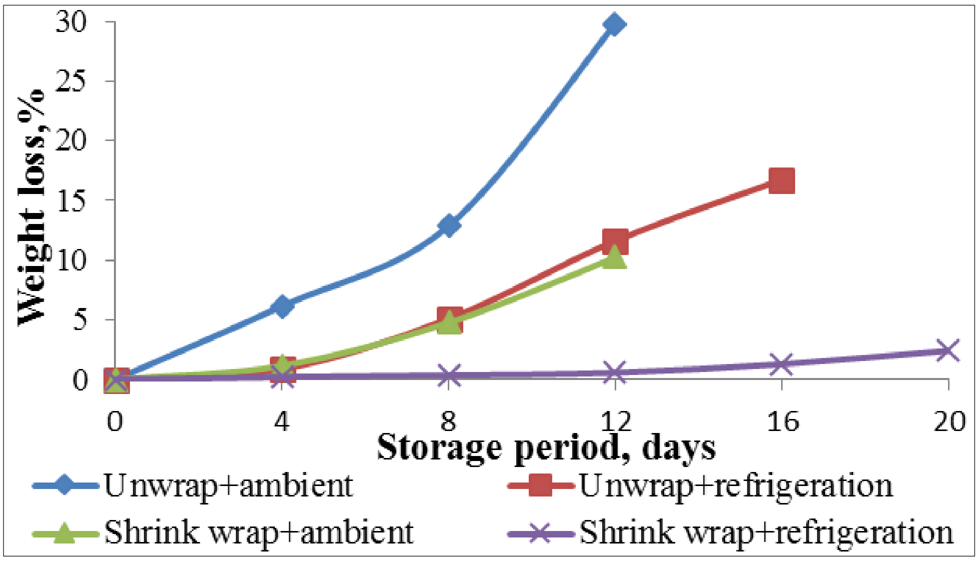

Fig 1: Effect of shrink wrapping on weight loss

3.2 Effect of Shrink Wrapping On p^H

The p^H of freshly harvested fruit was 4.79 and was increased by 5.91, 5.29 in unwrapped, shrink wrapped fruits at ambient temperature respectively by 12th day. Whereas at refrigeration temperature in unwrapped, shrink wrapped fruits it was increased by 5.61 (16th day), 5.36 (20th day) respectively. Shrink wrapping lowered the changes in p^H, effectively delaying fruit ripening was showed in fig. 4.2. This is due to the modification in internal atmosphere. The organic acids present in papaya are largely citric and malic acids. The increase in p^H during storage was due to metabolic processes of the fruit that resulted in a decrease of organic acids.

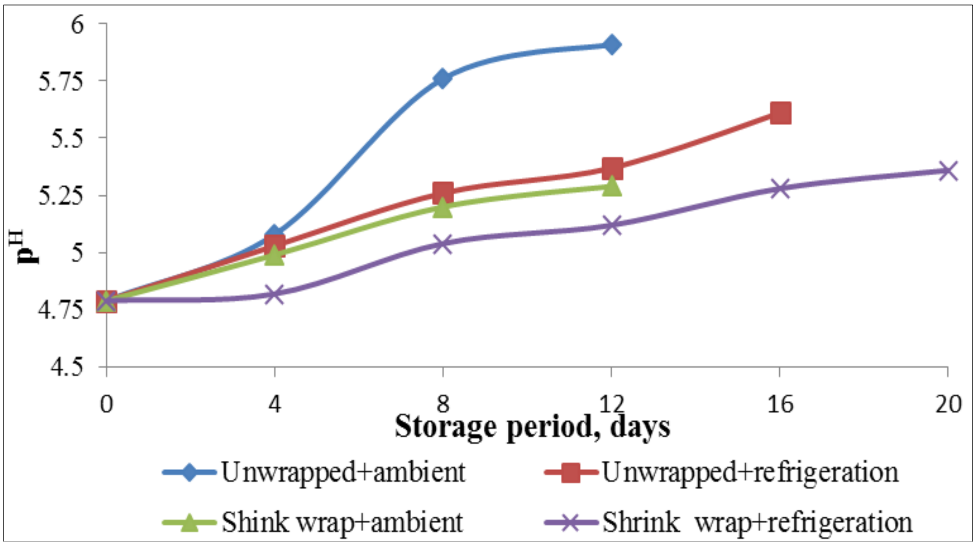

Fig 2: Variation in p^H of stored papaya

3.3 Effect of shrink wrapping on total soluble solids (TSS)

Freshly harvested fruits had TSS of 5.4ºBrix. It was increased to 9.3, 8.1°Brix at ambient temperature in unwrapped and shrink wrapped fruits respectively by 12th day. At refrigeration temperature TSS of unwrapped fruits was increased by 8.2°Brix (16th day) and to 7.9˚Brix (20th day) for shrink wrapped fruits. The increase in TSS of papaya fruits was mainly due to the progressive boost in free sugars of fruit during storage periods was showed in fig.3. Shrink wrapped fruits retarded TSS development because wrapping decreases the respiration and eventually catabolism of sugars.

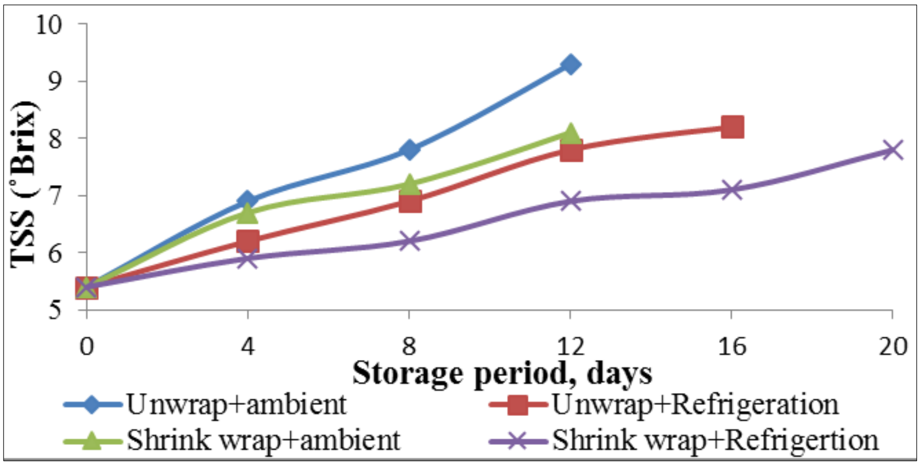

Fig 3: Variation in TSS during papaya storage

3.4 Effect of shrink wrapping on moisture content

The moisture content of freshly harvested papaya fruit was 85.67%. The moisture content increased significantly to 90.08%, 89.66% by 12th day for unwrapped, shrink wrapped fruits at ambient temperature respectively. At refrigeration temperature unwrapped, shrink wrapped fruits increased to 91.05% (16th day), 91.25% (20th day) respectively. So it was concluded that moisture content in shrink wrapped fruit varies slowly as shown in fig.4. At low temperatures, invert sugars are cause for increase in moisture content of papaya fruits.

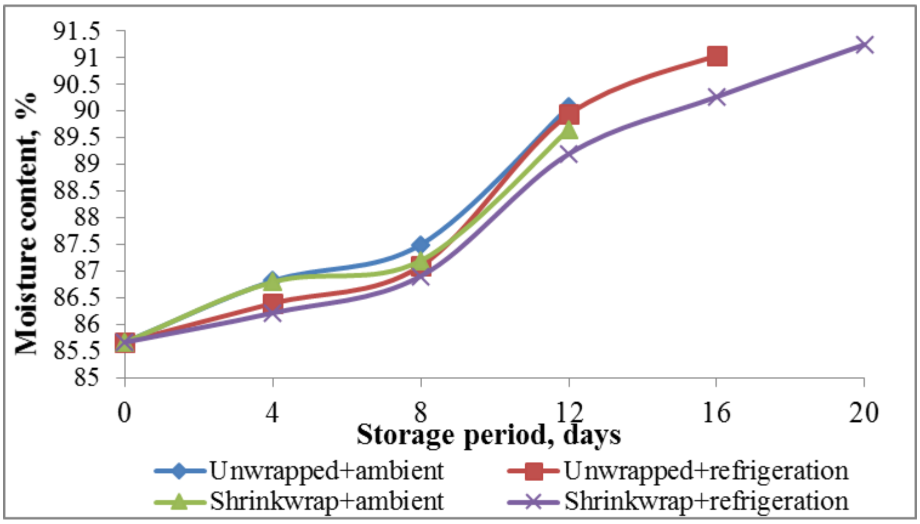

Fig 4: Variation in moisture content of stored papaya

3.5 Effect of shrink wrapping on vitamin-C

Freshly harvested papaya fruits had the highest content of ascorbic acid (76 mg/100g). At ambient temperature it was decreased to 48 mg/100g, 52.6 mg/100g for unwrapped, shrink wrapped fruits respectively by 12th day. Whereas the unwrapped, shrink wrapped fruits at refrigeration temperature, vitamin-C content was decreased to 62.1mg/100g (16th day), 54.3mg/100g (20th day) respectively. The ascorbic acid content in the fruits decrease may be due to the utilization of organic acids in respiration process. Retention of vitamin-C content during extended storage of papaya fruits was of prime importance in post-harvest handling as it would be rapidly lost during storage was shown in fig.5.

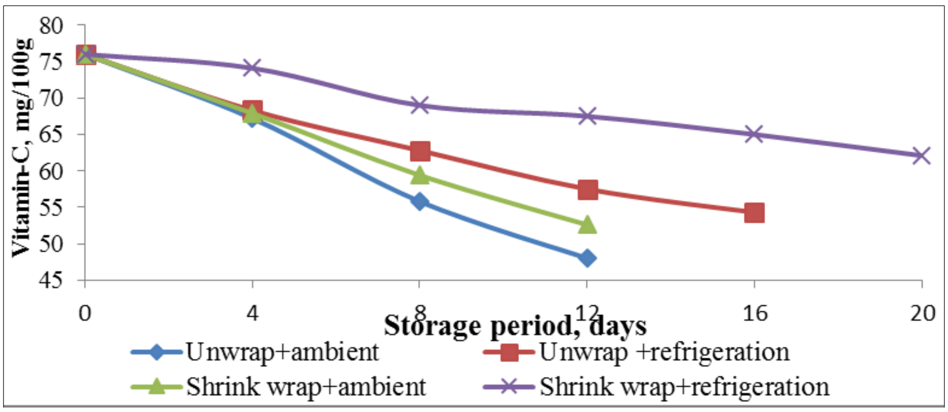

Fig 5: Variation in Vitamin C with shrink wrapping

3.6 Effect of Shrink Wrapping on Vitamin-A

Vitamin A content of freshly harvested fruit was 0.223mg/100g. Vitamin A content increased significantly to 0.529mg/100g, 0.369mg/100g by 12th day for unwrapped, shrink wrapped fruits at ambient temperature respectively. For unwrapped, shrink wrapped fruits at refrigeration temperature it was increased to 0.439mg/100g (16th day), 0.297mg/100g (20th day) respectively. Unwrapped fruits at ambient temperature had the highest vitamin A while freshly harvested fruits had the lowest from fig.6. As the fruit ripened slowly vitamin A content also increased slowly. Carotenoid content is increased with maturation and ripeness (Lee and Kader, 2000) [12]

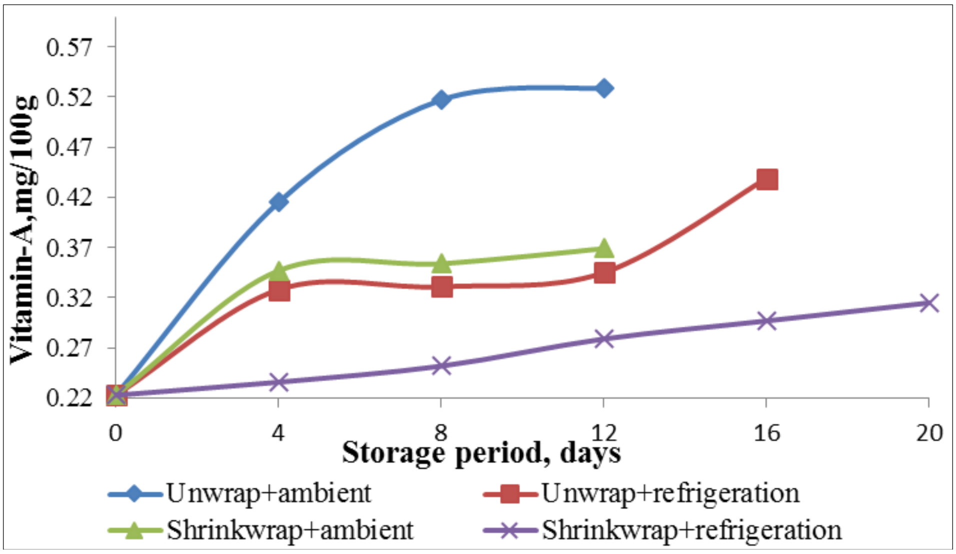

Fig 6: Variation in vitamin A during papaya storage

3.7 Effect of shrink wrapping on carbohydrates

Freshly harvested papaya fruit had the carbohydrates content of 8.59g/100g. Unwrapped fruits at ambient temperature increased to 10.4g/100g upto 8th day and then decreased to 9.86g/100g by 12th day, whereas the unwrapped fruit at refrigeration increased to 10.365g/100g upto 12th day and then decreased to 10.02g/100g by 16th day. The shrink wrap fruits at ambient increased to 10.5g/100g by 12th day and the shrink wrap fruit at refrigeration temperature increased to 10.7g/100g till 16th day and then decreased to 9.81 by 20th day. From the fig.7, the carbohydrates reached to a peak stage when it was fully ripened and decreased as it degrades. During ripening, starch and sucrose are converted into glucose, which is the main substrate utilize in the respiration.

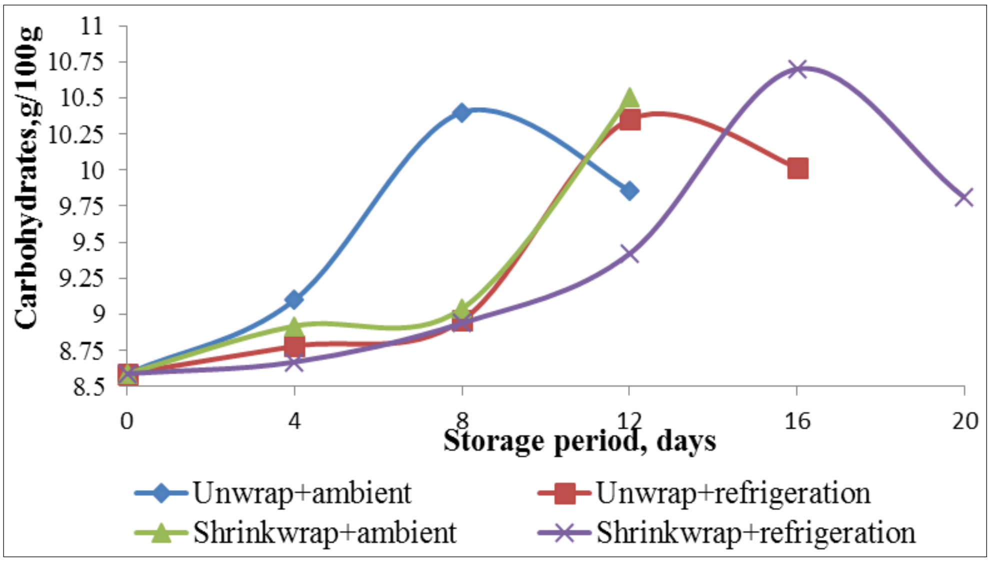

Fig 7: Variation in Carbohydrate content of stored papaya

3.8 Effect of shrink wrapping on protein

The protein content of freshly harvested fruit was 0.49g/100g. From fig.8, it was observed that the protein content in the unwrapped fruits at refrigeration temperature was increased to 0.631g/100 g upto 8th day and then decreased to 0.496g/100g by 12th day, whereas the shrink wrapped fruits at ambient temperature increased to 0.629g/100 g by 12th day. Wrapped fruits at refrigeration increased to 0.605g /100g upto 12th day and then decreased to 0.576g/100g, whereas the shrink wrapped fruit at refrigeration temperature increased to 0.597g/100g upto 16th day and then decreased to 0.574g/100g by 20th day. During the climacteric phase of respiration, there is a decrease in free amino acids which reflects an increase in protein synthesis, while during senescence, the level of free amino acids increases reflecting, breakdown of enzymes and decrease in metabolic activity.

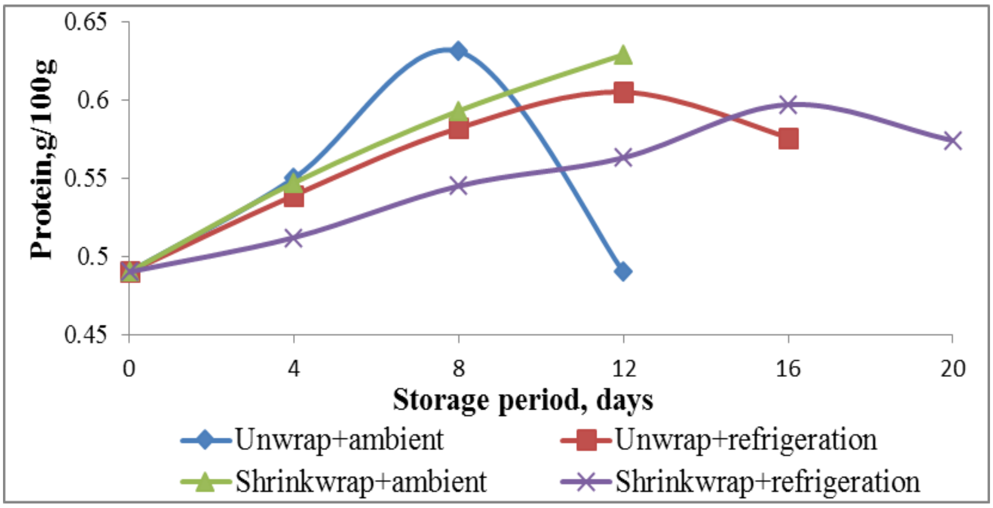

Fig 8: Variation in Protein content of stored papaya

3.9. Sensory evaluation

Color is one of the most important visual attributes of papaya. The bright green color papaya fruits changed to yellow color after storage period. Complete yellowness was found after 10, 12 days storage of unwrapped, shrink wrapped fruits respectively at ambient temperature, whereas green skin with well-defined yellow stripe was found at 10, 13 days storage period of unwrapped, shrink wrapped fruits respectively at refrigeration temperature. Visual assessment is the first impression and a key feature in the choice of the fruit. Surface color of papaya is one of the most important criteria in determining ripening of papaya. Color retention of shrink wrapped fruits was due to the delay in ripening of fruits. The modified atmosphere created by the shrink film retarded the ethylene production rate therefore, delaying ripening, chlorophyll degradation and caratenoids synthesis thus ultimately delaying color change of fruits was shown in fig. 9, fig. 10, fig.11.

Regarding taste shrink wrapped fruits had some bitter taste compared to ambient until 8th day. After 8th day the fruits at ambient condition were degraded slowly and by the 12th day it degraded completely and cannot be used for eating. Aroma was relatively similar to fruits at all conditions. Overall acceptance was good for shrink wrapped fruit even on the 20th day.

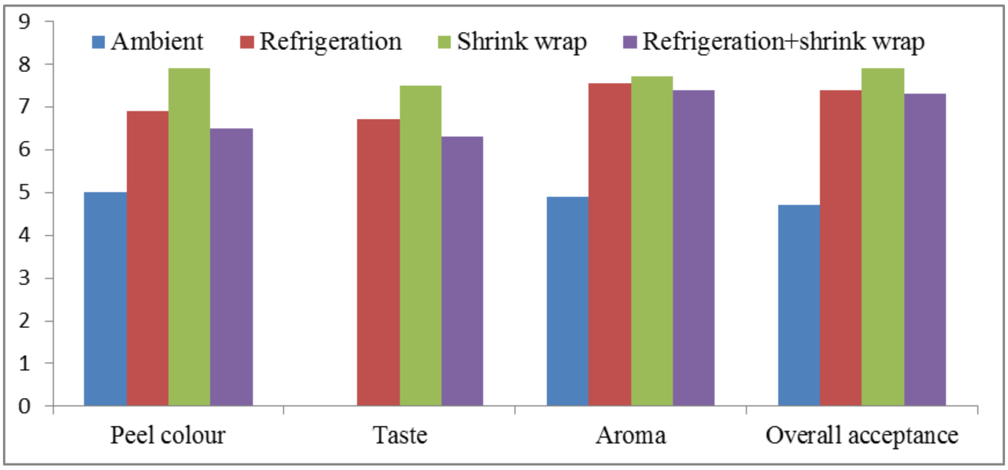

Fig 9: Sensory evaluation on 12th day

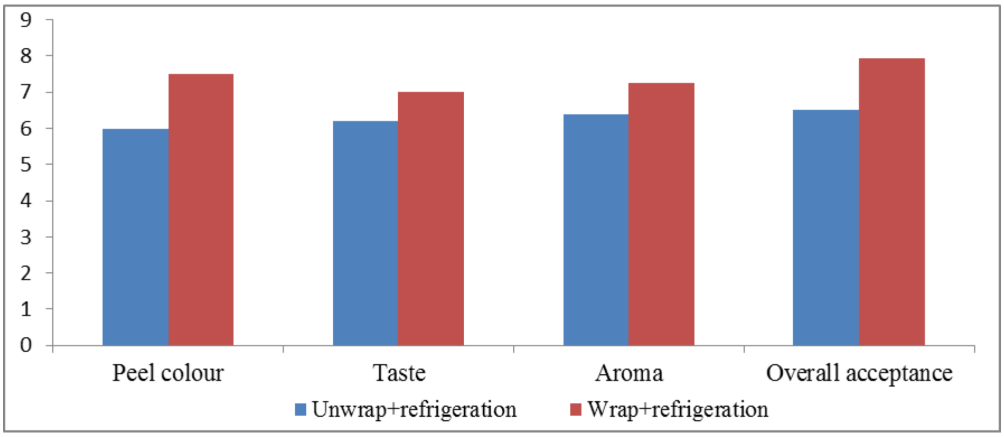

Fig 10: Sensory evaluation on 16th day

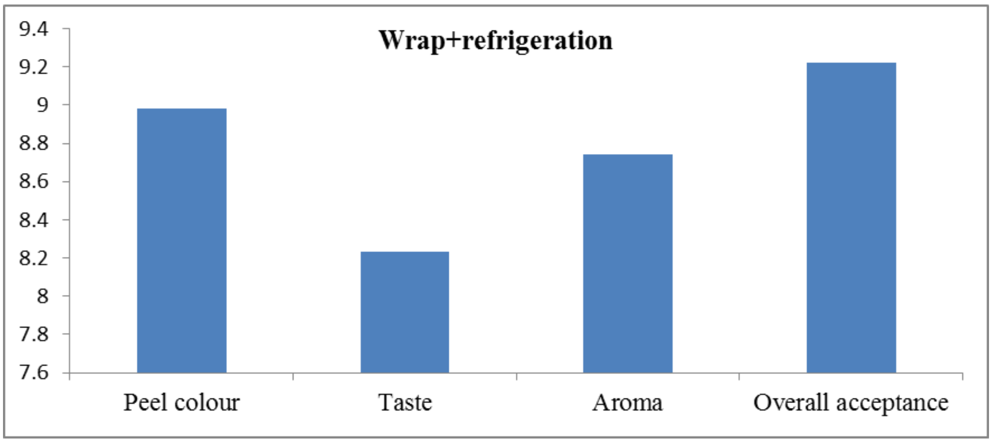

Fig 11: Sensory evaluation on 20th day

4. Summary and Conclusion
Freshly harvested papaya were stored at ambient condition (Temp: 32-39 ^{0}C; RH:72-83%) without wrapping and different Physico-chemical attributes were studied at 4 days interval until quality deterioration was observed. Effect of shrink wrapping on shelf life extension of papaya stored under ambient and refrigerated condition was studied.

1. Findings indicated that papaya fruits can be stored at ambient condition (Temp: 32-39 ºC; R.H: 72-83%), refrigerated conditions (10-12ºC, 90-95% RH) without wrapping upto 10, 13 days with a minor loss of quality.
2. Of all the conditions, polyolefin shrink wrapped fruits retained higher values for various physico-chemical parameters studied and was rated best under both the storage conditions. Shelf life of papaya was extended to 12 days under ambient storage condition (75-83% RH, 32-39 ˚C) and it was enhanced up to 19 days under refrigerated conditions (10-12ºC, 90-95% RH).
3. Moisture content, vitamin C of the shrink-wrapped fruits decreased at a minute rate compared to unwrapped fruits.
4. Vitamin A, protein, p^H, carbohydrates, TSS increased as the fruit ripens in both shrink wrapped and unwrapped fruits at different rates during storage.
5. Shrink wrapped fruits retained higher scores for various organoleptic attributes under both ambient and refrigerated storage conditions.

5. Suggestions for future work
Based on the experience gained during the present study carried out and as per the results discussed, the research can be advanced on the following aspects:

- The experiment can be done by using different films of variable thickness.
- Studies can be done on shrink wrapping in combination with bio preservatives.
- Shelf life at different storage temperatures can be studied.

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