Indian Journal of Agricultural Sciences **87** (8): 1077–83, August 2017/Article
https://doi.org/10.56093/ijas.v87i8.73271

Influence of edible coatings on physico-chemical characteristics and shelf-life of papaya (*Carica papaya*) fruits during ambient storage

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Received: 15 February 2017; Accepted: 09 May 2017

ABSTRACT

Papaya (*Carica papaya* L.) is one of the commercial fruit crops of tropical and sub-tropical region of the world. Papaya fruits have very high respiration and softening rates, making the storage and marketing of fruits challenging in domestic and international market. The fruits deteriorate rapidly after harvest. The main reasons of deterioration are weight loss, colour changes, softening, surface pitting, stem browning and loss of acidity and TSS. Among the different methods used to extend the shelf-life, application of edible coating have received attention world wide. In order to extend the shelf-life of papaya fruits at ambient storage, an experiment was conducted with the following edible coatings, T_1= carboxy methyl cellulose (CMC) (1% w/v), T_2= chitosan (1% w/v), T_3= *Aloe vera* gel, T_4= liquid paraffin wax 100%, T_5= sodium caseinate (1% w/v), T_6= kaolene (1% w/v), T_7= control (Water spray). Among all treatments, the highest effect on extending the shelf-life and delaying the ripening was recorded in paraffin wax coated fruits. Treatments were compared within 16 days where paraffin wax showed superiority in different cases attributing characters like physiological loss in weight (PLW) percentage (7.83%), fruit firmness (3.84), spoilage per cent (18.47%), total soluble solids (TSS) (9.58 %), ascorbic acid (63.36 mg/100 g), titratable acidity (0.147%), total sugars (8.35%), reducing sugar (5.30%), TSS: acid ratio (63.37), peel colour (3.68), taste (7.21) and appearance (5.73). The overall assessment of the present study concluded that paraffin wax was the most efficient edible coatings for extending the shelf-life and delaying the ripening of Red Lady papaya fruit.

Key words: Edible coatings, Papaya, Physico-chemical characteristics, Shelf-life

Under ordinary conditions, papaya (*Carica papaya* L.) fruits can keep well only for 3-4 days after harvest. Papaya fruits are liable for rapid deterioration immediately after harvest and loose consumer's appeal within a short span of storage period. Because of enhanced respiration and ethylene release it ripens very fast at ambient conditions and consequently affected by diseases which in turn reduce the shelf-life and hinder fresh fruit export and reduce the value in domestic market. The physiological changes in fruits occur immediately after harvest. Fruits begin to lose moisture very soon as when harvested and quickly lose market value if held under hot, dry conditions. In developing countries like India, the infrastructure facilities for processing are not optimum for majority of the growers and thus indulging them to have low market return because of glut in market. Due to poor keeping quality of papaya and difficulties of long distance transportation and preservation facilities, a large amount of this nutritious fruits have been wasted and spoiled. Reports claim that about 30-50% of the harvested papaya never reach the consumers mainly because of post-harvest spoilage (Mondal and Bose 2007).

This necessitates the development of suitable technology for extension of their post-harvest life and quality. Extension of shelf-life may be possible by checking the transpiration rate, respiration rate and microbial infection. By protecting against moisture loss, bruising, mould growth and contamination, different coatings help in longer freshness of fruits. Number of skin coatings, viz. liquid paraffin, paraffin solid wax, castor oil and shellac of light orange colour were used to enhance the shelf-life of different fruits, although promising results were obtained with waxes and have been accepted commercially (Sindhu *et al.* 2009, Meena *et al.* 2009).

The application of edible coatings is increasingly demonstrating to be a relatively new and simple technology effective in preventing the appearance and textural deterioration of several products. The use of different types of films based on a variety of single biopolymers, or on their combinations, results to be extremely advantageous even though all data obtained so far indicate that the coatings need to be tailored and optimized for each kind of foods (Porta *et al.* 2011, Rojas-Graü *et al.* 2012). Edible coatings based on cellulose gums effectively delay ripening in some climacteric fruits like mangoes, papayas, and bananas and significantly reduce enzymatic browning on sliced mushrooms (Nisperos-

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Carriedo *et al.* 1991). Several polysaccharides (chitosan, alginate, methylcellulose or pectin) and proteins (casein, collagen, gelatin, phaseolin, zein, soy or whey proteins), or mixtures of them, were shown to give rise to edible films effective as water vapor and gas barriers for a wide range of food products and as carriers for antimicrobials (Porta *et al.* 2011).

Edible coatings are traditionally used to improve food appearance and maintenance of quality. They have many advantages in comparison with other techniques but, only when the coated products are stored at proper temperatures, which depend on the commodity. These act as moisture and gas barriers, control microbial growth, preserve the colour, texture and moisture of the product and effectively extend the shelf-life of the treated products (Sehat 2012). These do not only retard food deterioration and enhance its quality but are also safe due to natural biocide activity or incorporation of the anti-microbial compounds (Peterson *et al.* 1999). Different compounds have mainly been used as edible coatings to prevent commodity weight loss including wax, milk protein, celluloses, lipids, starch, zein, and aliquate (Cha and Chinan 2004). Chitosan based coatings are generally used to increase the shelf-life of strawberries (Vargas *et al.* 2006). Coating with *Aloe vera* gel reduces stem browning and dehydration of fruits during storage without loss of taste, aroma and flavours (Martýnez-Romero *et al.* 2006). Sodium carboxymethyl cellulose-based edible coatings strongly decreased water loss and increased concentration of internal carbon dioxide of zucchini fruits (Avena-Bustillos *et al.*1994), and reduced changes of color, retained acid, maintained the keeping quality and increased shelf-life of tomato and banana fruits (Tasdelen and Bayindirli 1998, Malmiri *et al.* 2012).

Keeping in view the above points, the present study was laid out to find out suitable edible skin coating in increasing the shelf-life of papaya cv. Red Lady in Mizoram condition.

MATERIALS AND METHODS

Fresh, good looking, uniform size and shape papaya fruits of cultivar Red Lady were harvested at the pre-climacteric stage (nearly ripe), with green color, firm, although physiologically maturated with average TSS and acidity of 6.70 and 1.70. The fruits were obtained from a commercial papaya orchard of Baktawng village, Serchhip district of Mizoram. Geographically the village is situated at 23º 32’11’’ N latitide and 92º 50’47’’ E longitude and 1164 m above mean sea level. Only firm and healthy fruits of uniform size and maturity, were selected for the experiment. Visually blemished, diseased, damaged, injured and bruised papayas were discarded to minimize biological variability.

The fruits were washed to remove all foreign matters such as dust and dirt and treated with chlorinated water (0.25 g/L) according to Garcia *et al.* (1998a, 1998b) and dried using tissue paper. The fruits were graded by density gradation method to select fruits having uniform maturity. The fruits were treated with edible coatings, i.e. T_1: carboxy methyl cellulose (CMC) (1% w/v), T_2 : chitosan (1% w/v), T_3 : *Aloe vera* gel, T_4 : liquid paraffin wax 100%, T_5 : sodium caseinate (1% w/v), T_6 : kaolene (1% w/v) and T_7 : control (water spray).

For chitosan treatment, fruits were dipped for 2 min in solution of 1 and 2% (w/v) chitosan with 1 % acetic acid (v/v), which was prepared according to the method described by Jiang *et al.* (2005). Formulations of carboxy methyl cellulose were obtained through dispersion of the carboxy methyl starch of high viscosity in distilled water with constant stirring at room temperature. The solutions were left to rest for approximately 12 hr for the withdrawal of bubbles before the application of the coating treatment. Then, glycerol was added as plasticizer, and the solutions were emulsified using a homogenizer. Sodium caseinate powder was dissolved in 100 ml of distilled water. Then, glycerol was added as plasticizer (between 0 and 2%, w/w) and the solutions were emulsified using a homogenizer at 21 500 rpm for 3 min. The coating treatment of paraffin waxes was manually applied by brush at ambient temperature depending on the size of the fruits. Dipping fruits in distilled water was used as a control. The fruit were washed with 0.05 % sodium hypochlorite, prior to coating treatments. The fruit were allowed to air dry, after which they were randomly divided into seven different sets with three replicates. Each set contained fifteen fruits.

The various observations on various physico-chemical attributes and organoleptic values of papaya fruits were taken on same day of harvest and after 4, 8, 12 and 16 days of ambient storage with 20±5°C temperature and 70±5% relative humidity. The physiological loss in weight (PLW) of the fruits was calculated on initial weight basis and expressed in percent. The TSS of fruit was measured with the help of Zeiss Hand Refractometer of 0–32° Brix range. The acidity, sugar and vitamin C contents were determined as per the method of AOAC (1995). Subjective (non-destructive) fruit firmness was recorded by finger pressure by employing a panel of 10 members as tester by following the methods of Shahnawaz and Sheikh (2011) using a score of 0-6. Peel color was measured visually based on skin color change initially and during storage intervals. Color was assessed visually by matching sample fruits with `Maturity stages of Maradol papaya' (Basulto *et al.* 2009) with some modification. The sensory quality parameters such as appearance, taste, flavour and texture of each sample was evaluated by a semi trained panel of 5 judges using the 9-point Hedonic rating scale (Amerrine *et al.* 1965).

The treatments were replicated 3 times and twenty fruits were taken for each treatment in each replication. The data obtained from laboratory analysis were subjected to Fisher’s method of analysis of variance (ANOVA) by following completely randomized design. Significance and non-significance of the variance due to different treatments were determined by calculating the respective ‘F’ value and comparing with the appropriate value of ‘F’ at 5 % probability level by following the methods of Panse and Sukhatme (1985). By comparing different treatments among themselves critical difference was calculated at 5% probability level.

RESULTS AND DISCUSSION

Physiological loss in weight (PLW)

The different edible coatings have significant effect in reducing the physiological loss in weight of the papaya fruits at various day after storage (Table 1). The PLW of fruit, in general, increased with the advancement in storage period, rather slowly in the beginning, but at a faster pace as the storage period advanced. Increase in PLW with the storage period might be due to loss of moisture from the fruits by way of transpiration or evaporation. Among the various treatments, the significantly lowest PLW of 3.91, 6.24, 6.78 and 7.83 % after 4, 8, 12 and 16 days of storage, respectively, were recorded when fruits were coated with paraffin wax followed by chitosan coating. Similarly, the highest PLW of 8.70, 12.43, 14.77 and 17.92 % was recorded in control. The loss in weight is a direct loss of saleable produce in economic terms coupled with the reduced acceptability of the produce. The paraffin wax emulsion served as a physical barrier around the fruit which partially close the stomatal openings and lenticels thereby reduces the rates of transpiration and respiration (Jain and Mukherjee 2011). The highest rate of PLW in control might be due to higher moisture loss and increased respiration through uninterrupted atmospheric column and lower relative humidity as compared to coated fruits (Pongener *et al.* 2011). Similar findings on effect of wax coating on PLW was also reported by Yadav *et al.* (2010) in kinnow mandarin and Singh *et al.* (2011) in passion fruit.

Fruit firmness

The fruit firmness, in general followed a declining trend commensurate with advancement in storage period (Table 1). It decreased sharply with the increase in storage period from 4th day till 16th day of storage. The decrease in fruit firmness with advancement of storage period might be attributed due to change in the turgour of the cell and changes in the composition of cell wall pectins and lipo-protein membrane bordering the cells (Chen *et al.* 1983). Among the various treatments, fruits coated with paraffin wax maintained the highest firmness 5.62, 5.23, 4.67, 3.84 at 4, 8, 12 and 16 days after storage closely followed by chitosan coatings 5.48, 4.81, 4.41 and 3.48 respectively. The controlled fruits registered the lowest firmness 5.11, 3.38, 3.15 and 2.21 respectively at 4, 8, 12 and 16 days after storage. The softening of fruits is caused either by breakdown of insoluble proto pectins into soluble pectin or by hydrolysis of starch or by cellular disintegration leading to membrane permeability (Sindhu *et al.* 2009, Mahajan *et al.* 2013). According Goulao and Oliveira (2008), this may be attributed to several physiological and biochemical changes that include the conversion of starch into sugars, biosynthesis of volatile flavor and aroma and changes in the metabolism and structure of cell wall, resulting in the loss of fruit firmness. The paraffin wax coatings of fruits resulted in higher fruit firmness, which might be due to reduced transpiration and respiration activity along with delayed ethylene production and thus retained more turgidity of the cells of the fruits (Nanda *et al.* 2001). Our study is in close conformity with the findings of Sindhu *et al.* (2009) in pear and Singh *et al.* (2011) in passion fruit.

Spoilage percentage

It has been observed from the data presented in Table 1 that the spoilage percentage increased significantly with the increase in storage period from 4th to 16th day. On 16th day of storage, the significantly lowest spoilage (23.81%) was recorded in paraffin wax coated fruits followed by chitosan (26.72%) and *Aloe vera* (31.63%) as compared to maximum in control (43.26%). The less spoilage in wax coated fruits might be due to the fact the waxing filled the lenticels and left no places for entry of pathogens like fungi and bacteria, which reduce parenchymatous tissue to watery mass and hence less spoilage percentage. Similar findings in different fruit crops have also been observed by Sindhu *et al.* (2009), Patel *et al.* (2011) and Singh *et al.* (2011).

Total soluble solids (TSS)

It is evident from the data presented in Fig 1 that TSS of the fruits increased with the increase in storage period from 4th day to 12th day of storage and thereafter it

Table 1 Effect of different edible coatings on physiological loss in weight, firmness and spoilage percentage of papaya fruit

Treatment	Physiological loss in weight PLW (%)				Firmness				Spoilage (%)			
	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day
T_1	5.83	7.83	10.50	12.92	5.30	4.64	3.97	3.26	5.42	7.09	17.99	24.41
T_2	4.62	7.10	9.43	11.48	5.48	4.81	4.14	3.48	4.38	5.71	14.70	19.72
T_3	5.50	7.50	10.20	12.19	5.38	4.72	4.05	3.40	4.94	7.28	17.14	21.96
T_4	3.91	6.24	6.78	7.83	5.62	5.29	4.67	3.84	3.14	4.21	12.45	18.47
T_5	7.10	9.77	12.10	13.39	5.25	4.58	3.91	3.03	6.59	9.26	19.43	26.53
T_6	7.40	10.73	12.50	16.20	5.17	4.50	3.50	2.83	7.53	9.43	21.24	27.74
T_7	8.70	12.43	14.77	17.92	5.11	3.38	3.05	2.21	8.21	10.13	22.34	29.93
SEm ±	0.61	0.80	0.75	0.64	0.07	0.27	0.44	0.23	0.59	0.94	1.25	1.37
CD (P=0.05)	1.27	1.66	1.56	1.34	0.15	0.56	0.91	0.48	1.22	1.97	2.62	2.85

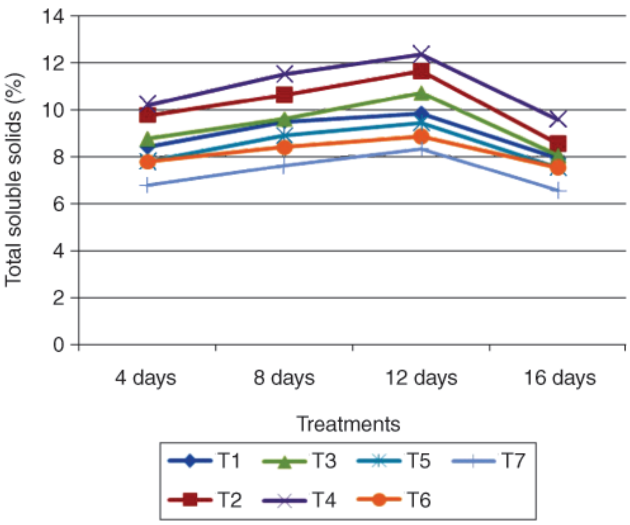

Fig 1 Effect of different edible coatings on total soluble solids of papaya fruit.

decreased indicating rapid metabolic breakdown in those fruits. There was great difference in fruits coated with different coatings than with the uncoated control at various day of storage and at the end of 16th day, fruits in control had lowest TSS (6.53%) and those coated with paraffin wax had the highest TSS (9.58%). The increase in TSS during storage may possibly due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into sugars. On complete hydrolysis of starch no further increase in sugars occurs and subsequently a decline in these parameters is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al.* 1980). The increase in TSS in wax coated fruits till 12th day and then gradual decrease as compared to control fruits indicating the possible role in delaying metabolic activities of fruits during ripening and storage (Fan *et al.* 1999).

Ascorbic acid

With respect to ascorbic acid, it is clear from the Fig 2 that it decreased with the advancement of storage period, irrespective of treatments. The data also revealed that the decrease in ascorbic acid was significantly higher throughout the storage period in the treated fruits as compared to untreated ones. However at the end of storage period, the significantly highest ascorbic acid was observed in T_4 (63.36 mg/100 g) which was higher than all other treatments. This could possibly be due to retardation of oxidation process and consequently slow rate of conversion of L-ascorbic acid into dehydroascorbic acid by ascorbic acid oxidase. The retention of higher ascorbic acid in coated fruits might be due to the ripening retarding effect and slow rate of biological activities during storage. Similar observations have also been recorded in mango (Jain and Mukherjee 2011) and mandarin orange (Yadav *et al.* 2010).

Total sugars

The total sugars of the fruits increased with the increase in storage period from 4th day to 12th day of storage and thereafter it declined irrespective of treatments as shown in the Fig 3. The initial increase in total sugars of fruits under different packages might be due to loss of water from the fruits and conversion of polysaccharides and pectic substances into sugars. The increase in total sugars with the storage interval up to 12 day might be due to the hydrolysis of starch, yielding mono and disaccharides. Thereafter, decline can be attributed to metabolic breakdown and senescence of fruit as a result of moisture and firmness loss during storage (Ryall and Pentzer 1982). Similar findings have also been reported by Jain and Mukherjee (2011) in mango. Among all the treatments, wax coating significantly increased the total sugars.

Reducing sugars

The reducing sugar of the fruits increased up to 12th day of storage and then followed by slight decline at 16th

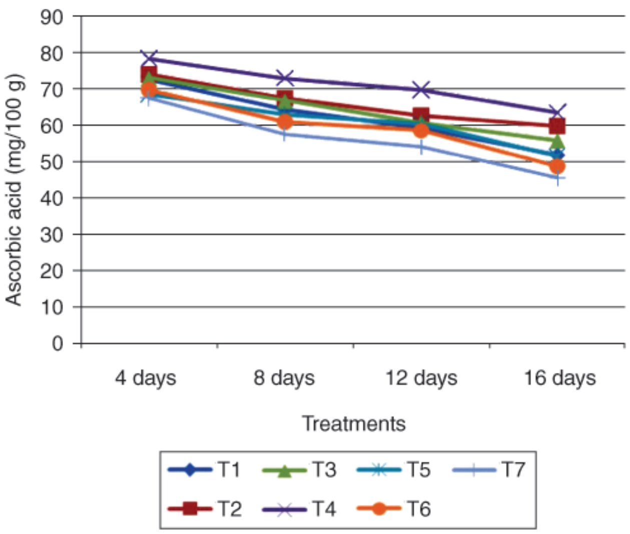

Fig 2 Effect of different edible coatings on ascorbic acid of papaya fruit.

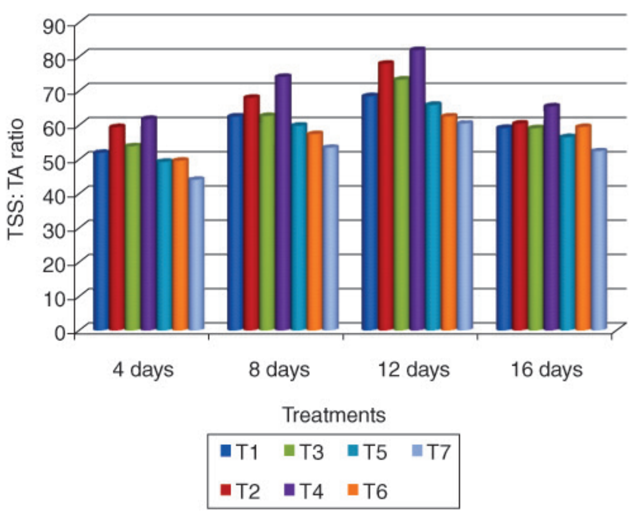

Fig 3 Effect of different edible coatings on TSS: TA ratio of papaya fruit.

Table 2 Effect of different edible coatings on titratable acidity and sugars of papaya fruit.

Treatment	Titratable acidity (%)				Reducing sugars (%)				Total sugars (%)			
	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day
T_1	0.161	0.152	0.144	0.132	5.27	5.42	5.44	5.24	8.13	8.26	8.31	8.16
T_2	0.164	0.156	0.150	0.141	5.38	5.57	5.59	5.29	8.25	8.43	8.53	8.26
T_3	0.163	0.154	0.147	0.134	5.37	5.52	5.58	5.28	8.21	8.36	8.42	8.23
T_4	0.166	0.157	0.151	0.147	5.52	5.81	5.90	5.30	8.48	8.63	8.76	8.35
T_5	0.158	0.149	0.143	0.131	5.19	5.41	5.42	5.11	8.05	8.21	8.27	8.05
T_6	0.155	0.147	0.142	0.127	5.03	5.31	5.37	5.01	7.86	8.19	8.24	7.96
T_7	0.154	0.143	0.138	0.125	4.97	5.27	5.26	4.89	7.77	8.16	8.21	7.79
SEm ±	0.001	0.002	0.002	0.002	0.14	0.08	0.12	0.06	0.16	0.14	0.17	0.14
CD (P=0.05)	0.003	0.004	0.003	0.005	0.30	0.17	0.26	0.12	0.34	0.29	0.36	0.28

day of storage (Table 2). Various coatings had significant effect irrespective of storage period on reducing sugar. Fruits treated with paraffin wax have the maximum reducing sugars (5.30 %) while the control have the lowest reducing sugars (4.89 %) at 16^{th} day of storage. The progressive increase in sugars during storage period up to 12 day and a gradual decline thereafter might be due to metabolic transformation in soluble compounds and more conversion of organic acid into sugars (Baviskar *et al.* 1995), which declined later on during storage, might be due to their rate of consumption for metabolic activities like respiration and other energy sources of fruits resulting in breakdown of starch into sugars. Our result is in agreement with the findings of Yadav *et al.* (2010) and Singh *et al.* (2011).

Titratable acidity

The titratable acidity of the fruits decreased with the storage period irrespective of the treatments (Table 2). Among all the treatments, at the end of storage period, maximum retention of titratable acidity was found in the fruits treated with wax emulsion (0.147%), followed by chitosan (0.141%) and *Aloe vera* gel (0.137%). The decrease in TA with the increase in storage period could possibly be attributed due to the decreased hydrolysis of organic acids in pyruvate decarboxylation reaction occurring during the ripening process and subsequent accumulation of organic acids which were oxidised at a slow rate because of decreased respiration. Similar findings have also been reported by Jain and Mukherjee (2011) and Sarkar *et al.* (1995).

TSS: TA ratio

It was observed from the data presented in Fig 3 that the TSS: TA ratio is increased with the storage period till 12^{th} day of storage and thereafter it gradually declined irrespective of all the treatments. Among all the treatments, the fruits coated with paraffin wax have significantly highest TSS: TA ratio as compared to other treatments. It might be due to more moisture loss from the fruits in paraffin wax coated fruits leading to more concentration of juice resulting in higher sugar content, whereas maximum decrease in acidity of fruits coated with paraffin wax may be ascribed due to increased respiration rate and more utilization of acids in biochemical activities leading to depletion of organic acids.

Peel colour

As depicted in Table 3, the different coatings delayed the loss of green colour in papaya fruits. In all the treatments, the colour of the fruits changed from green to yellow from the first day of storage (4 day) till the end of storage

Table 3 Effect of different edible coatings on peel colour, taste, appearance, overall acceptability and shelf life of papaya fruits

Treatment	Peel colour				Taste				Appearance				Overall acceptability				Shelf life
	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day	4 day	8 day	12 day	16 day	
T_1	1.70	2.67	3.61	4.88	7.17	7.50	7.57	6.67	6.90	6.23	5.87	5.13	6.83	6.47	6.33	6.07	11.40
T_2	1.45	2.50	3.27	4.44	7.24	7.70	8.07	6.91	7.07	6.40	5.99	5.20	7.30	7.07	6.93	6.57	14.23
T_3	1.61	2.74	3.33	4.67	7.10	7.43	7.68	6.77	7.02	6.35	5.95	5.27	6.92	6.67	6.53	6.10	13.10
T_4	1.07	2.18	2.82	3.68	7.54	7.77	8.57	7.21	7.57	6.90	6.38	5.73	7.70	7.43	7.23	6.83	15.33
T_5	1.75	2.72	3.63	5.14	6.17	6.83	7.03	5.93	6.83	6.17	5.73	4.97	6.70	6.37	6.00	5.60	11.27
T_6	1.88	2.77	3.80	5.25	6.03	6.50	6.83	5.70	6.60	5.93	5.50	4.67	6.47	6.13	5.67	5.33	10.33
T_7	2.05	3.57	4.63	5.78	5.53	5.87	6.33	5.20	6.50	5.83	4.78	4.37	6.37	5.87	5.50	4.73	6.77
SEm ±	0.19	0.21	0.11	0.18	0.34	0.20	0.43	0.30	0.23	0.27	0.24	0.18	0.38	0.31	0.26	0.26	0.49
CD (P=0.05)	0.40	0.33	0.22	0.38	0.71	0.42	0.89	0.63	0.48	0.55	0.50	0.37	0.78	0.64	0.55	0.53	1.01

period (16 day). In wax coated fruits, the development of yellow colour was at a slow and steady rate indicating more consumers preferred peel colour till the end of storage period. Among all the treatments, the lowest value with respect to colour score was obtained in wax coated fruits followed by chitosan and *Aloe vera* gel coatings. In wax coated fruits, the development of yellow colour increased at a slower rate till 16th day of storage resulting in development of uniform coloured fruit surface. The improvement in colour during storage might be due to degradation of the chlorophyll pigments of the fruits and increased synthesis of carotenoids pigments. Our study is in close conformity with the findings of Petracek and Montalvo (1997), who reported that lower oxygen level and increased CO_2 inside the fruits have been reported to slow down degreening in waxed Pallglo tangerine *(Citrus* hybrid).

Taste

The papaya fruits showed a gradual and steady increase in the taste of the fruits up to 12th day of storage and after that a sharp decline was observed (Table 3). The wax coated fruits were rated as extremely desirable after 12 day and thereafter taste declined. The gradual increase in the taste of papaya fruits during storage has been attributed to the increase in the concentration of total sugars and TSS contributing to the typical papaya taste.

Appearance

The fruits treated with paraffin wax had gloss, shiny appearance and no wrinkles and browning, therefore scoring maximum value with respect to appearance (5.90) followed by chitosan (5.40) and *Aloe vera* gel coatings (5.35) at 16 day of storage (Table 3). On the other hand, control fruits registered the minimum appearance value (4.50). The wax coated fruits were rated as very much desirable to moderately desirable appearance at 12th and 16th day of storage as compared to control which were found acceptable till 8th day of storage. The development of better appearance in the wax coated fruits could be possibly due to creation of favourable gaseous atmosphere under congenial temperature. Our study is in close conformity with the findings of Ladaniya (2001) in Mosambi sweet orange where the wax coated fruits had better appearance as compared other fruits.

Overall acceptability

The papaya fruits showed a gradual and steady decline in the overall acceptability of the fruits with the increase in storage period (Table 3). The wax coated fruits were rated as extremely desirable after 12th day and thereafter taste declined. At the end of the storage period, the highest score for overall acceptability was observed in paraffin wax coating (6.83) while, the lowest was observed in control (4.77). The overall acceptability of papaya fruits depends on a delicate balance of sugars, acids, phenolics and aromatic compounds with a number of additional factors such as pulp texture and visual appearance also influence the perceived quality and consumer acceptance and appreciation. Our study is in close conformity with the findings of Predieri *et al.* (2006), in peach.

Shelf-life

The shelf-life of papaya fruits varied significantly among different treatments (Table 3). Among all the treatments, fruits coated with paraffin wax have maximum shelf-life of 15.33 day followed by chitosan and *Aloe vera* gel coatings, while control recorded the lowest shelf-life of 6.77 day. The probable reason for paraffin wax coated fruits having maximum shelf-life might be due to its ability to serve as a physical barrier around the fruit which reduce transpiration and respiration activity along with delayed ethylene production. In addition, waxing filled the lenticels and left no places for entry of pathogens like fungi and bacteria so ultimately it increases the shelf life of the papaya fruits. The positive effect of wax coating on storage life could probably due to the modifying the atmosphere. The modified atmosphere created could, therefore, delay the ripening by delaying ethylene production and by reducing the level of internal oxygen and consequently prolonging the storage life of fruit (Gol and Rao 2011).

Chemical preservatives which are now used widely can have dangerous effects on health such as various types of cancers, kidney and liver damage, etc. To effectively extend the shelf-life of fruits, edible coatings are relatively convenient and safe. Another advantage of this coating is totally harmless to the human health as well as environment. In fact it can be considered as a green alternative to synthetic coatings.

The results of the present investigation revealed that edible coatings proved to be highly effective in extending the shelf-life of papaya. Among all the edible coatings, paraffin wax was the most efficient for extending the shelf-life as well as for maintaining the best quality parameters for maximum duration of papaya cv. Red Lady. The growers as well as the exporters should use the coatings with paraffin wax for increasing the shelf-life as well as delaying the ripening of papaya fruits in order to fetch premier price in the domestic and international market.

REFERENCES

Amerine M A, Pangborn R H and Roessler E B. 1965. *Principles of Sensory Evaluation of Food*. Academic Press, London.

AOAC. 1995. *Official Methods of Analysis,* 16th Edn. Association of Official Analytical Chemists, Washington DC.

Avena-Bustillos R J, Krochta J M, Saltveit M E, Rojas-Villegas R J and Sauceda-Perez J A. 1994. Optimization of edible coating formulations on zucchini to reduce water loss. *Journal of Food Engineering* **21:** 197–14.

Basulto F, Duch E, Gil F, Plaza R, Saavedra A and Santamar A J. 2009. Post-harvest ripening and maturity indices for maradol papaya. *Interciencia* **34:** 583–8.

Baviskar M R, Waskar D P and Kaulgad S N. 1995. Effect of various post-harvest treatments on shelf-life and quality of ber fruits. *Indian Journal of Horticulture* **52:** 37–45.

Cha D S and Chinnan M 2004. Biopolymer-based antimicrobial packaging: a review. *Critical Reviews in Food Science and*

Nutrition **44:** 223–37.

Chen P M, Mellenthin W M and Borgic DM 1983. Changes in ripening behavior of 'd'Anjou' pears (*Pyrus communis* L.) after cold storage. *Scientia Horticulturae* **21:** 137– 46.

Drew P, Beniwal V S and Singh P. 1998. *Papaya,* pp 66-8. Corn Publication 59.

Fan X, Blankenship S M and Mattheis J P. 1999. 1-MCP inhibits apple ripening. *Journal of American Society for Horticultural Science* **124:** 690–5.

Gol N B and Rao T V R. 2011. Banana fruit ripening as influenced by edible coatings. *International Journal of Fruit Science* **11:** 119–35.

Goulao L F and Oliveira C M. 2008. Cell wall modifications during fruit ripening: when a fruit is not the fruit- a review. *Trends in Food Science and Technology* **19:** 4–25.

Jain S K and Mukherjee S. 2011. Enhancing keeping quality of fruits in mango cv. Langra. *Indian Journal of Horticulture* **68:** 142–4.

Jiang Y, Li J and Jiang W. 2005. Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. *LWT-Food Science and Technology* **38:** 757–61.

Ladaniya M S. 2001. Response of 'Mosambi' sweet orange (*Citrus sinensis*) to degreening, mechanical waxing, packaging and ambient storage conditions. *Indian Journal of Agricultural Sciences* **71:** 234–9.

Mahajan B V C, Kumar D and Dhillon W S. 2013. Effect of different polymeric films on the shelf life and quality of pear fruits under supermarket conditions. *Indian Journal of Horticulture* **70:** 309–12.

Malmiri H J, Osman A, Tan C P and Rahman R A. 2012. Effects of edible surface coatings (Sodium carboxymethyl cellulose, sodium caseinate and glycerol) on storage quality of berangan banana (*Musa sapientum* cv. Berangan) using response surface methodology. *Journal of Food Processing and Preservation* **36:** 252–61.

Martiýnez-Romero D, Alburquerque N, Valverde J M, Guill´en F, Castillo S, Valero D and Serrano M. 2006. Postharvest sweet cherry quality and safety maintenance by *Aloe vera* treatment: A new edible coating. *Postharvest Biology and Technology* **39:** 93–100.

Meena H R, Kingsly A R P and Jain R K. 2009. Effect of post-harvest treatments on shelf life of ber fruits. *Indian Journal of Horticulture* **66:** 58–1.

Mondal M F and Bose S K. 2007. Physico-chemical changes in papaya fruits during storage. *Journal of Bangladesh Society of Agricultural Science and Technology* **4:** 145–8.

Nanda S, Rao D V S and Krishnamurthy S. 2001. Effect of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits cv Ganesh. *Postharvest Biology and Technology* **22:** 61–9.

Nisperos-Carriedo M O, Baldwin E A and Shaw P E. 1991. Development of an edible coating for extending postharvest life of selected fruits and vegetables. *Proceedings of Florida State Horticultural Society* **104:** 122–5.

Panse V G and Sukhatme P V. 1985. *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.

Patel N, Naik A G, Arbat S S. 2011. Response of post-harvest chemical treatments on shelf-life and quality of custard apple cv. Balanagar. *Indian Journal of Horticulture* **68:** 547-50.

Predieri S, Ragazzini P and Rondelli R. 2006. Sensory evaluation and peach fruit quality. *Acta Horticulturae* **713:** 429–34.

Petersen K, Nielsen P V, Lawther M, Olsen M B, Nilson N H, Mortensen G. 1999 Potential of biobased materials for food packaging. *Trends in Food Science and Technology* **10:** 52–68.

Petracek P D and Montalvo L. 1997. The degreening of 'Fallglo' tangerine. *Journal of American Society of Horticultural Science* **122:** 547–52.

Pongener A, Mahajan B V C and Singh H. 2011. Effect of different packaging films on storage life and quality of peach fruits under cold storage conditions. *Indian Journal of Horticulture* **68:** 240–5.

Porta R, Mariniello L, Di PierroP, Sorrentino A and Giosafatto C V. 2011. Transglutaminase crosslinked pectin- and chitosan-based edible films: a review. *Critical Reviews in Food Science and Nutrition* **51:** 223–38.

Rojas-Graü M A, Salvia-Trujillo L, Soliva-Fortuny R and Martín-Belloso. 2012. Edible films and coatings. *(In) Decontamination of Fresh and Minimally Processed Produce.* John Wiley and Sons Inc, USA.

Ryall A L and Pentzer W T. 1982. *Handling, Transportation and Storage of fruits and Vegetables*. AVI Pub. Co. Inc, Westport.

Sarkar H N, Hasan M A and Chattopadhyay P K. 1995. Effect of packaging and chemicals on the storage behavior of sapota. *Horticulture Journal* **8:** 17–24.

Sehat N N B M. 2012. 'Effect of dipping treatment and cassavastarch coating on keeping quality of fresh-cut pineapple (*Ananas comosus*)'. Project Report, Faculty of Applied Sciences, University of Technology, MARA, Malaysia.

Shahnawaz M and Sheikh S A. 2011. Physicochemical characteristics of jamun fruit. *Journal of Horticulture and Forestry* **3:** 301–6.

Sindhu G S, Dhillon W S and Mahajan B V C. 2009. Effect of waxing and packging on storage of pear cv. Punjab Beauty. *Indian Journal of Horticulture* **66:** 239–44.

Singh A, Yadav D S, Patel R K, Nath A and Bhuyan M. 2011. Wax coating and padding materials influence quality and shelf-life of purple passion fruit during storage. *Indian Journal of Horticulture* **68:** 246–9.

Tasdelen O and Bayindirli L. 1998. Controlled atmosphere storage and edible coating effects on storage life and quality of tomatoes. *Journal of Food Processing and Preservation* **22:** 303–20.

Vargas M, Albors A, Chiralt A and Gonz´alez-Mart´1nez C. 2006. Quality of cold-stored strawberries as affected by chitosan-oleic acid edible coatings. *Postharvest Biology and Technology* **41:** 164–71.

Wills R B H, Bembridge P A and Scott K J. 1980. Use of flesh firmness and other objective tests to determine consumer acceptability of Delicious apples. *Australian Journal of Experimental Agriculture and Animal Husbandry* **20:** 252–6.

Yadav M, Kumar N, Singh D B and Singh G K. 2010. Effect of post-harvest treatments on shelf-life and quality of Kinnow mandarin. *Indian Journal of Horticulture* **67:** 243–8.