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Enhancement of quality parameters and shelf-life of papaya fruit (*Carica papaya* L.) by edible coating during storage and transportation

Mudavath Raju, Radhajogita Mondal*, Akash Sanjay Valliath, Swarna Tejaswi & Piu Das

Department of Horticulture, School of Agriculture, Lovely Professional University, Punjab 144 411, India

*Email: radhajogita.26812@lpu.co.in

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Abstract

The postharvest losses of papaya fruits are important concerns during storage, shipping and marketing; the causes of these postharvest losses include microbial infestation, temperature, inappropriate handling and other factors. Which can be decreased by using edible coatings that have enhanced quality and have a longer shelf life. The effects of three different coating materials-aloe vera gel, ascorbic acid and chitosan on the shelf life and qualitative parameters of papaya fruits that were maintained at room temperature for a period of 15 days were investigated. When compared to fruits that have not been coated, fruits that have been coated with aloe vera gel, ascorbic acid and chitosan retain the original values for all of the qualitative parameters, including total soluble solids (9.9), titratable acidity (0.670 %), ascorbic acid (67.125 100 g/mg), TSS: acid ratio (23.116 percent), total sugar (0.119 %), reducing sugar (24.570 %) and non-reducing. According to the findings of this investigation, the combination of aloe vera gel (50%), chitosan (1%) and ascorbic acid (1%) has the potential to lengthen the shelf life of papaya fruits while maintaining their nutritional qualities, which is significant for the purposes of commercial storage, transportation and sales.

Keywords

Aloe vera gel, ascorbic acid, chitosan, papaya, quality

Introduction

The world's most major tropical and subtropical fruit in terms of fresh and processed goods is the papaya (*Carica papaya* L.) (1), belongs to the family Caricaceae and chromosome number is 2n=18. This plant is semi-woody, single stemmed and located in the eastern lowlands of Mexico, Panama, and Central America (2). They are more nutritious and have a longer fruiting season (3). Papaya is a fruit that is rich in the vitamins C, A, B, E and K. Ripe papaya has 32 calories, 0.6 g of protein, 0.1 g of fat, 7.2 g of carbs and 2.6 g of fibre per 100 g.

The annual productivity and average loss of Papaya fruit in India are 5988.8 MT/ha 6.70% (4). Being a climacteric fruit, papayas produce more ethylene as their rate of respiration increases. Due to poor post-harvest handling and a shorter shelf life, 40-100% of papaya fruits decompose. If fruits are kept at the ideal temperature (10-13 ^{0}C) and relative humidity (85-90%), they can be kept for extended lengths of time (1-3 weeks) (5). When kept at a low temperature, fruits can last for a few weeks. Senescence and respiration will occur more slowly at low temperatures (7 ^{0}C), and water loss will be minimised without accelerating decay when relative humidity is at its ideal level (6). When chemical preservatives are added, physiological and microbiological losses are reduced, and respiration and senescence are slowed down by maintaining the ideal gaseous environment (7). Quality decrease brought on by microorganisms leads to a range of commercially undesirable types of spoiling (8). A covering of edible material is helpful for safeguarding postharvest quality and extending shelf life for highly perishable fruits, such as papaya, by preserving volatile flavour and lowering dehydration, respiration and microbial development (9, 10).

Fruits coated with *aloe vera* gel offer several positive advantages, such as a glossy look and better colour, prevention of microbiological deterioration and increased shelf life (11). Chitosan forms a coating on fruit peels that actually reduces water retention and weight loss. The usage of 1.5% and 2.0% chitosan coatings prevented weight loss by as much as 6% in comparison to the control, which is sufficient to maintain papaya quality and appearance (12). Ascorbic acid prevents the enzymatic browning, as a organic acid it regulates the microbial level of fresh fruit (13). Ascorbic acid maintains the vitamin-A content of papaya fruit (14), high phenol content, high antioxidant enzyme activity and low decay of fruit (15). The involvement of Ascorbic acid in the preservation of strawberry (16), apple (17) and kiwifruit (18) has been documented. The purpose of the present experiment was to improve the marketability and shelf life of papaya fruits by investigating the impact of edible coating on their qualitative characteristics.

Materials and Methods

The present experiment was carried out in a Laboratory of Lovely Professional University, Punjab, India during 2021-2022. Present experiment consists of seven treatments with two replications and Completely Randomized Design (CRD) was followed. Seven treatments of edible coatings were given in Table 1: (i) Aloe vera gel 50% (T1), (ii) Aloe vera gel + Ascorbic acid (T2), (iii) Chitosan (T3), (iv) Aloe vera gel + Chitosan (T4), (v) Chitosan + Ascorbic acid (T5), (vi) Aloe vera gel + Chitosan + Ascorbic acid (T6), and (vii) Control (T7).

Table 1. Details of the treatments

Treatment	Treatment Details	Concentration
T1	Aloe vera	50%
T2	Aloe vera + Ascorbic acid	50% + 1%
T3	Chitosan	1%
T4	Aloe vera + Chitosan	50% + 1%
T5	Chitosan + Ascorbic acid	1% + 1%
T6	Aloe vera + Chitosan + Ascorbic	50% + 1% + 1%
T7	Control	-

Total soluble solids (°Brix)

All papaya fruits from all treatments were tested for total soluble solid (TSS) content using a hand refractometer and the °Brix values were recorded (19).

Titratable acidity (%)

The volumetric method was used to measure titratable acidity. 100 ml of distilled water and 2 grammes of papaya fruit macerated in a mortar and pestle were used. It was then mixed with 10 millilitres of the sample and 2-3 drops of the phenolphthalein indicator. The aliquot was then titrated with a 0.1 N solution of NaOH in the burette. We stopped burette and recorded our results when the aliquot in the test beaker turned light pink (19). In order to determine the titratable acidity, the following formula was used:

$$\frac{\text{Titre value x Normality of alkali x Volume made up x 64.04 x100}}{\text{Weight of sample x volume of aliquot taken x 1000}} \text{x 100}$$

$$\text{Ascorbic Acid}\left(\frac{\text{mg}}{\text{100g}}\right) = \frac{\text{Titre value x dye factor x volume made x 100}}{\text{Volume of filtrate taken x weight of sample}}$$

Ascorbic acid (mg/100 g)

A mortar and pestle were used to grind up 2 g of papaya fruit and 100 mL of metaphosphoric acid. For 15 seconds, the sample was filtered with 2,6-Dichollorophenol-Indophenol dye until it turned pink, at which point it was discarded. mg 100 g^{-1} was used to express the results, which were noted down (20, 21).

TSS: acid ratio (%)

TSS: Acid ratio was computed by subtracting the total titrable acidity percentage from the TSS measurement, and mean values are shown (22). TSS: The following formula was used to obtain the acid ratio:

$$\text{TSS: Acid ratio} = \frac{\text{Total soluble solids}}{\text{Titratable acidity}}$$

Total sugar (%)

The anthrone reagent was utilised to calculate the overall sugar content (22). To make the anthrone reagent, 0.05 % anthrone was dissolved in highly concentrated sulphuric acid. The sample was prepared by macerating 2 g of fruit pulp with 100 mL of distilled water. After collecting 1 mL of fruit sample, 1 mL of distilled water, and 3 mL of anthrone reagent were added to the test tube. The test tube was then heated to 100 ^{0}C in a water bath for 15 min (23, 24). After absorbance,

$$\text{Total sugar (\%)} = \frac{\text{Factor for Fehling solution x Dilution x 100}}{\text{Titre x Weight or volume of sample for estimation}}$$

Reducing sugar (%)

The extract was taken and titrated against 10 mL of mixed Fehling solution using methylene blue as indicator. Sufficient amount of the extract was run to reduce Fehling solution treated and boiled for two minutes. The end point was

$$\text{Reducing sugar \%} = \frac{\text{Dilution} \times \text{Factor of Fehling (gm)}}{\text{Weight of sample} \times \text{Titre value}} \text{x100}$$

identified when the discolouration of indicator takes place to reduce Fehling solution, treated and boiled for 2 min (22).

Non- reducing sugars (%)

The content of non-reducing sugars was calculated by the formula given below:

$$\text{Non reducing sugars (\%)} = \text{Total sugars (\%)} - \text{Reducing sugars (\%)}$$

Statistical analysis

Collected data were subjected to statistical analysis of variance by Panse and Sukhatme (25) and mean data were analysed by OPSTAT throughout this course of investigation.

Results and Discussion

According to the data given in the Table 2, the treatment T6 (*Aloe vera* gel 50% + Chitosan 1% + Ascorbic acid 1%) showed the highest TSS (9.90, 9.75 and 9.60 °Brix) followed by T1 (*Aloe vera* gel 50%) with 9.65, 9.5 and 9.25 °Brix at the 5th, 10th and 15th days after coating as compared to the control, which had the lowest TSS (8.70, 8.20 and 8.05 °Brix). Similar result was obtained stating that the TSS of coated papaya fruits were 12.7, 12.1 and 11.50 Brix after 8, 25 and 32 days of coating (26). This fact is due to the formation of thin layer over the fruit surface, which reduced the rate of respiration, evaporation and delayed degradation process and metabolism of sugar (27).

Table 2. Effect of the different edible coating on total soluble solids (°Brix)

Treatment	5 DAC	10 DAC	15 DAC
T1	9.650	9.500	9.250
T2	9.200	9.100	8.950
T3	8.900	9.050	8.500
T4	9.500	9.450	9.100
T5	9.000	8.650	8.150
T6	9.900	9.750	9.600
T7	8.700	8.200	8.050
C.D.	0.391	0.315	0.589
SE(m)	0.115	0.093	0.173

DAC: days after coating

According to the data analysis given in the Table 3, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 15%) had the highest titratable acidity (0.670, 0.655 and 0.640 %) followed by T1 (Aloe vera gel 50%) with 0.64, 0.62 and 0.60 % at 5th, 10th, and 15th days after coating, while the control had the lowest titratable acidity (0.419, 0.405 and 0.391 %). Experimental result showed that the titratable acidity content of coated fruits were 49% more than uncoated fruits, which is similar to this present experiment and rapid decrease of TA in uncoated fruits (28). It was reported that there was less reduction of TA content after 10 days of coating in storage, where there was more reduction of TA content in uncoated fruits (29). This retention of titratable acidity in coated papaya fruits is due to coating materials as protective barrier against atmospheric oxygen and respiration rate reduction (30).

Table 3. Effect of the different edible coating on Titratable acidity (%)

Treatment	5 DAC	10 DAC	15 DAC
T1	0.640	0.625	0.605
T2	0.425	0.419	0.413
T3	0.525	0.505	0.473
T4	0.570	0.540	0.510
T5	0.530	0.500	0.470
T6	0.670	0.655	0.640
T7	0.419	0.405	0.391
C.D.	0.01413	0.01548	0.01264
SE(m)	0.00423	0.00463	0.00378

DAC: days after coating

According to the data given in the Table 4, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 15%) had the highest Ascorbic acid (67.215, 65.790 and 64.365 mg/100 g) content followed by T1 (Aloe vera gel 50%) with 66.93, 65.42 and 63.91 mg/100 g at the 5th, 10th and 15th days after coating, while the control had the lowest Ascorbic acid (59.905, 57.020 and 54.135 mg/100g). Same results were reported earlier (31, 32). Papaya fruits showed reduced ascorbic acid content in storage due to oxidation of ascorbic acid into dehydro ascorbic acid by the enzyme ascorbic acid oxidase. Coating materials prevent the oxidation process of ascorbic acid oxidase, which maintain the ascorbic acid content in Papaya fruits (29).

Table 4. Effect of the different edible coating on Ascorbic acid (mg/100 g)

Treatment	5 DAC	10 DAC	15 DAC
T1	66.935	65.425	63.9155
T2	63.100	60.120	57.140
T3	61.715	59.945	58.175
T4	63.925	61.375	58.825
T5	62.855	60.615	58.375
T6	67.215	65.790	64.365
T7	59.905	57.020	54.135
C.D.	2.90341	4.02681	1.97316
SE(m)	0.86822	1.20416	0.59005

DAC: days after coating

According to the data presented in the Table 5, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 15%) shows the highest TSS: acid ratio (23.116, 22.110 and 21.094 %) followed by T1 (Aloe vera gel 50%) with 22.54, 20.46 and 18.38 % at the 5th, 10th and 15th days after coating, while the control had the lowest TSS: acid ratio (15.360, 14.436 and 13.512 %). It was observed that TSS:acid ratio (63.37) was higher in coated (paraffin wax) fruits as compared to uncoated fruits (22). Coated fruits show more TSS:acid ratio due to more moisture loss, con-

Table 5. Effect of the different edible coating on TSS: acid ratio (%)

Treatment	5 DAC	10 DAC	15 DAC
T1	22.540	20.464	18.388
T2	16.820	15.818	14.816
T3	15.817	14.816	13.815
T4	18.416	17.413	16.410
T5	17.571	16.554	15.537
T6	23.116	22.110	21.094
T7	15.360	14.436	13.512
C.D.	0.8532	0.69892	0.89869
SE(m)	0.2551	0.209	0.26874

DAC: days after coating

centrated fruit juice and more TSS. Decrease in acidity is due to more respiration rate and depletion of organic acids by biochemical activities.

According to the data analysis given in the Table 6, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 1%) exhibits the highest total sugar content (0.119, 0.117 and 0.115 %) followed by T1 (Aloe vera gel 50%) with 0.117, 0.115 and 0.113 % at the 5th, 10th and 15th days after coating, while the control had the lowest Total sugar (0.111, 0.108 and 0.105 %). It was observed that fruits coated with paraffin wax have higher total sugar (8.35%) than

Table 6. Effect of the different edible coating on Total sugar (%)

Treatment	5 DAC	10 DAC	15 DAC
T1	0.117	0.115	0.113
T2	0.114	0.112	0.110
T3	0.115	0.113	0.111
T4	0.116	0.114	0.112
T5	0.113	0.111	0.109
T6	0.119	0.117	0.115
T7	0.111	0.108	0.105
C.D.	0.04469	0.01264	0.01548
SE(m)	0.01336	0.00378	0.00463

DAC: days after coating

uncoated papaya fruits (22). Detention of total sugar in uncoated fruits are attributed to hydrolysis of starch, metabolic breakdown, senescence of fruits, loss of moisture and firmness. Similar result was also observed (37).

According to the data analysis given in the Table 7, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 15%) reveals the highest reducing sugar content (24.570, 22.065 and 20 %) followed by T1 (Aloe vera gel 50%) with 23.91, 21 and 18 % at the 5th, 10th and 15th days after coating, while the control had the lowest reducing sugar (20.035, 17.180 and 14.450 %). Similar results were also observed earlier (22). Reducing sugar content of coated papaya fruit was higher as compared to uncoated

Table 7. Effect of the different edible coating on Reducing sugar (%)

Treatment	5 DAC	10 DAC	15 DAC
T1	23.910	21.000	18.665
T2	20.530	19.045	17.150
T3	21.800	19.290	16.850
T4	22.370	20.585	17.180
T5	20.100	18.455	16.235
T6	24.570	22.065	20.000
T7	20.035	17.180	14.450
C.D.	0.999	1.372	1.464
SE(m)	0.294	0.403	0.430

DAC: days after coating

fruits, because with increasing days after coating, reducing sugar content decreases. This is due to more conversion of organic acid into sugars, which increases the rate of consumption by respiration and enzyme activities.

According to the data presented in the Table 8, the treatment T6 (Aloe vera gel 50% + Chitosan 1% + Ascorbic acid 1%) had the highest non-reducing sugar % (14.080, 12.805 and 11.630 %) followed by T1 (Aloe vera gel 50%) with 12.18, 10.85 and 9.8 % at the 5th, 10th and 15th days after coating, while the control had the lowest non-reducing sugar (8.935, 7.095 and 4.965 %). Similar results were also reported earlier stated that coated papaya fruit contains more non-reducing sugar as compared to uncoated fruits and this is due to acid hydrolysis and inversion of non-reducing sugar into reducing sugar (22, 33).

Table 8. Effect of the different edible coating on non-reducing sugars (%)

Treatment	5 DAC	10 DAC	15 DAC
T1	12.185	10.850	9.805
T2	12.020	10.750	8.170
T3	10.370	9.030	7.935
T4	11.990	10.080	9.425
T5	9.220	8.230	6.985
T6	14.080	12.805	11.630
T7	8.935	7.095	4.965
C.D.	0.690	0.508	0.619
SE(m)	0.203	0.149	0.182

DAC: days after coating

Conclusion

In comparison to the compositional changes and maximum quality loss showed by uncoated fruits in storage under room temperature, the application of edible surface coatings on papaya fruit results a significant delay in ripening and minimal loss in quality. The coating material acts as a physical barrier between the fruit and the surrounding environment, preventing gas exchange. Treatment T6 with

Aloe vera gel (50%) + Chitosan (1%) + Ascorbic acid (1%), was most effective for maintaining better qualitative parameters like, TSS, titrable acidity, ascorbic acid, total sugar, reducing and non-reducing sugar, TSS:acid ratio during storage and transportation as compared to control. With the consideration of above presented findings, unhealthy chemical coating can be replaceable by Aloe vera gel + Chitosan + Ascorbic acid coating for commercial application during storage, shipping and marketing (long distance) of papaya fruit for better quality maintenance and shelf-life extension.

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Authors contributions

RM designed the experimental details and guided to perform the whole experiment. MR carried out the experiment in the laboratory and analysed the data. ASV, ST and PD participated in its experiment and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare

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