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Physiological, biochemical and microbial changes associated with ripening and shelf life extension of Surya papaya as influenced by postharvest treatments

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Abstract

Papaya fruits' popularity and widespread consumption are due to their peculiar flavour and nutritional characteristics. However, rapid deterioration and high incidence of rots during handling and storage limits its shelf life. Traditionally, people resort to applying synthetic chemical fungicides to control the anthracnose caused by the fungus *Colletotrichum gloeosporioides* on fruits. However, their repeated use has caused resistance in microorganisms and toxicity in humans. Hence, there is increasing interest in using natural alternatives instead of chemical treatment. Papaya variety Surya fruits collected at the fully mature green stage were subjected to different postharvest management practices and were packaged in corrugated fibre board boxes and stored till the end of shelf life under ambient conditions. Papaya fruits harvested at a fully mature green stage and subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (T_7) recorded the longest shelf life of 9.67 days. The same treatment also registered the lowest physiological loss in weight (5.64 %), least ion leakage (93.41 %), maximum total carotenoids, total soluble solids, total sugar, reducing sugar and minimum acidity after nine days of storage. No fungal spoilage and fruit rot were recorded in T_7 after three days of storage, with zero percent disease index. After six and nine days of storage, the lowest disease index (16.67 % and 27.78 % each) was noticed in T_7.

Key words: Anthracnose, chitosan, papaya, postharvest treatments, precooling

Introduction

Papaya (*Carica papaya* L.), a member of the Caricaceae family, has long been esteemed as a tropical marvel, primarily cultivated for its delightful flavour and the extraction of its digestive constituent, papain. Spanning 97.7 thousand hectares, with an annual production of 6.09 million MT (NHB, 2020), this climacteric fruit faces challenges due to its rapid ripening, softening, and susceptibility to various stresses, leading to substantial postharvest losses. A significant contributor to this loss is anthracnose, induced by the fungus *Colletotrichum gloeosporioides*, manifesting as round, watery, sunken stains on mature fruits.

Traditionally, the control of this disease involves the application of synthetic chemical fungicides both on the crop and during storage. However, their repeated use has led to microbial resistance and human toxicity. Consequently, there is a growing interest in exploring alternative postharvest practices such as precooling, surface sanitization, hot water treatment, and adopting natural alternatives like waxing and packaging with ethylene scrubbers. Research indicates that while postharvest changes in fresh fruits cannot be entirely halted, these practices can effectively slow down such alterations within certain limits.

In Eksotika II papaya, Ali *et al.* (2011) reported that chitosan is effective in weight loss reduction, maintaining firmness, and delaying the peel colour changes during five weeks of storage. Jayasheela (2014) reported that fruits of papaya var. Coorg Honeydew treated with hot water at 50°C for 20 minutes with waxing and ethylene absorbent ($KMnO_4$) recorded highest shelf life (11 days), lowest physiological loss in weight (2.98 percent) as against 4 days shelf life and highest physiological loss in weight (6.85 percent) noticed in control fruits. Waskar and Dhemre (2023) reported that precooling and waxing significantly improved the shelf life of kesar mango fruits. Aglar *et al.* (2017) opined that both pre and postharvest treatments have an inevitable role in improving the quality and storage life of produce and hence this study was conducted to standardize the postharvest treatments for delayed ripening and to extend the shelf life of papaya variety Surya with minimum nutritional loss.

Materials and methods

Papaya variety Surya was raised at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, according to the Kerala Agricultural University package of practices for studying the extension of shelf life of fruits during 2019-2020. Fruits were collected at the fully mature green stage, subjected to different postharvest management practices, packaged in Corrugated Fibre Board (CFB) boxes, and stored under ambient conditions till the end of shelf life.

Different postharvest treatments adopted in the study included: T_1: Precooling (hydro cooling), T_2: Surface sanitization with sodium hypochlorite (150 ppm), T_3: External coating with chitosan (1%), T_4: Precooling followed by external coating with 1% chitosan, T_5: Packaging with ethylene scrubber $KMnO_4$ (8 g per kg of fruit weight), T_6: Precooling followed by packaging with ethylene scrubber $KMnO_4$, T_7: Precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$, T_8: Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$, T_9: Control

The study followed a Completely Radomized Block design (CRD). Observations on changes in physiological quality, biochemical quality and microbial quality were recorded at three days interval till the end of shelf life.

Shelf life: As influenced by different postharvest treatments, the life of papaya fruits was calculated by counting the days required to ripe fully to retain optimum marketing and eating qualities.

Physiological loss in weight (PLW): PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) at three days interval and expressed as percentage.

$$\text{PLW} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Ion leakage (%): The uniform sized fruit pieces were made into thin slices, immersed in 100 mL distilled water for three hours and absorbance was read in UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100° C for 20 minutes, filtered, filtrate was made upto 100 mL and the absorbance was read in UV spectrophotometer at 273 nm. The loss of membrane integrity was expressed in percent ion leakage. Percent leakage was calculated using the formula given below and expressed as percentage (Amith, 2012):

$$\text{Percent leakage} = \frac{\text{IABM x Dilution factor}}{\text{Final absorbance of bathing medium}}$$

Where, IABM= Initial absorbance of bathing medium

Total soluble solids (TSS): TSS of the fruit pulp was measured using a hand refractometer (Erma) (range 0-32°Brix) and expressed in degree brix (A.O.A.C, 1980).

Titratable acidity: The titrable acidity was estimated by titrating with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed as percent of citric acid. A known weight of fruit was ground using distilled water and made upto 100 mL in a standard flask. An aliquot of 10 mL from this was titrated against 0.1 N NaOH (Ranganna, 1997).

$$\text{Acidity} = \frac{\dfrac{\text{Normality x Titre value x Equivalent weight x}}{\text{Volume made up x 100}}}{\text{Weight of sample x Aliquot of sample x 1000}} \times 100$$

Total carotenoids: Determination of total carotenoids was done by extraction with acetone and petroleum ether. The colour was measured at 452 nm using petroleum ether as blank in spectrophotometer. Total carotenoids were expressed as μg $100g^{-1}$ of material (Ranganna, 1997).

$$\text{Total carotenoids } (\mu g\ 100g^{-1}) = \frac{\dfrac{\text{3.857 x Optical density x}}{\text{Volume made up}}}{\text{Weight of the sample}} \times 100$$

Total sugars: Total sugars was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp.

Reducing sugars: Reducing sugars was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp.

Percentage disease index: Papaya fruits subjected to different postharvest management practices were visually observed for fungal spoilage and fruit rots. The number of fruits infected or spoiled was recorded periodically to assess the effect of treatments on retarding fruit spoilage. It was reported as percentage disease index and was calculated by the following formula (Marpudi *et al.*, 2011).

$$\text{Disease index} = \frac{(0xa + 1\ xb + 2xc + 3xd + 4xe + 5xf)}{a+b+c+d+e} \times 100$$

0= no lesions (no disease symptoms); 1= 5 to ≤ 15 percent disease symptoms (spot first appearing); 2 = ≥ 16 to ≤ 25 percent disease symptoms (spots increasing in size and number); 3= ≥ 26 to ≤ 50 percent disease symptoms (small to large brownish sunken spots with slight to moderate mycelium growth); 4 = ≥ 51 to ≤ 75 percent disease symptoms (large spots with wide spread mycelium growth, fruit is partially or completely rotten); 5=≥ 75 percent disease symptoms.

a, b, c, d, e and f are number of fruits that fall into the infection categories

X = maximum number of infection categories

Microbial load: The enumeration of microbial load in pre and post treated sample was carried out by serial dilution technique. Nutrient agar and Martin's Rose Bengal agar medium were used for enumeration of bacterial and fungal population of the fruit surfaces, respectively.

$$\text{No. of colony forming units (cfu) / mL of the sample} = \frac{\text{Total number of colony formed x DF}}{\text{Aliquot plated}}$$

DF = Dilution factor

Statistical analysis: The data was analyzed statistically by applying the variance analysis techniques (Panse and Sukhatme, 1985).

Results and discussion

Shelf life: The effect of different postharvest treatments on the shelf life of papaya variety Surya fruits packaged in CFB boxes and stored under ambient conditions is depicted in Table 1. Significantly higher shelf life of 9.67 days was observed in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (T_7), which was on par with T_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) with a shelf life of 9.00 days. Significantly lowest shelf life of 4.33 days was observed in control (T_9). A rapid removal of field heat from the freshly harvested papaya by precooling and the ability of potassium permanganate to absorb ethylene produced by the fruit during the ripening process aids in retarding respiration, ripening, senescence, water loss and decay in treatment T_7. In addition to this, external coating with 1% chitosan helped in forming an excellent film over the produce which retards the respiration rate and also helped in maintaining the optimum quality and prolonged shelf life of fruits in T_7. Brosnan and Sun (2001) depicted precooling as the first and most crucial line of defense in reducing the field heat of horticultural produce, thereby reducing its metabolic activity and, entering a low energy consumption state and prolongs its shelf life. Ali *et al.* (2011) identified the commercial application of chitosan as a promising edible coating for extending the storage life of the papaya cv. Eksotika. The use of ethylene absorbents to delay ripening was recorded by Razali *et al.* (2013) in papaya.

Physiological loss in weight (PLW): Physiological loss in weight of papaya variety Surya fruits increased in all the treatments during storage under ambient conditions (Table 1). T_7 had significantly lowest physiological loss in weight after three, six and nine days of storage (1.49, 3.63 and 5.64 %, respectively). In control (T_9) the weight loss reached 7.54 percent after three days of storage and was significantly higher. Physiological loss in weight depicts the total moisture lost during storage and ripening, ultimately resulting in desiccation and shriveled appearance of fruit (Davies and Hobson, 1981). This physiological loss in weight is essentially due to transpiration and respiration (Krishnamurthy and Subramanyam, 1970). The combined effect of precooling, external coating with 1% chitosan and packaging with ethylene scrubber might have contributed to the reduced physiological loss in weight of T_7 treatment at three, six and nine days after storage. Jawandha *et al.* (2016) reported that precooled fruits of peach cv. Shan-i-Punjab exhibited a relatively slower loss in weight at all the storage intervals as compared to the non-precooled (control) fruits. Paull and Chen (1989) observed that chitosan coating can develop a film on fruit surfaces and thereby provide a barrier against moisture diffusion through stomata, contributing to reduced weight loss.

Ion leakage (%): Initial analysis (0 DAS) of papaya fruits revealed no significant difference in ion leakage (%) of fruits among treatments (Table 1). However, after three, six and nine days of storage, fruits treated with various postharvest treatments, packaged in CFB box and stored under ambient condition witnessed significant differences in ion leakage of papaya fruits. T_7 had least ion leakage after three, six and nine days of storage (34.63, 63.14 and 93.41 %, respectively). It was on par with T_8. The lower ion leakage observed in T_7 and T_8 might be due to the intact membrane which resulted from the better treatments like precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber in T_7 and hot water treatment coupled with waxing and ethylene absorbent application in T_8. Jayasheela *et al.* (2016) supported the findings of the present study. They concluded that fruits of papaya cv. Coorg Honeydew subjected to HWT at 50° C for 20 minutes with waxing and with ethylene absorbent had least percent leakage. According to Parker and Maalekuu (2013), membrane ion leakage and a high water loss rate have a very high and positive correlation. The higher percent ion leakage in control might be due to the loss of physical integrity of the cellular membrane, leading to the loss of ions and unrestricted travel of fluids within cellular compartments, a condition deleterious to fruits (Maalekuu *et al.*, 2004).

Total soluble solids (TSS)*:* TSS content of papaya fruits increased in all the treatments during storage, and varied significantly among each treatment after three, six and nine days of storage in the present study. The highest TSS of 13.23 °Brix, 14.33 °Brix and 13.97°Brix was observed in T_9, T_3 and T_8, respectively after three, six and nine days of storage (Table 1). Lowest TSS (10.20, 11.20 and 13.50 °Brix) was found in T_7 after three, six and nine days of storage. Breakdown of starch and polysaccharides into simple sugars during ripening contributes to the increment in the TSS during storage. Therefore, the higher TSS observed in T_9 after three days of storage indicates that ripening was hastened in untreated fruits. In contrast, the cumulative effect of precooling, external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ delayed the ripening in T_7, which the lowest TSS proves after three, six and nine days of storage. Jawandha *et al.* (2016) opined that slower increment in TSS under precooling treatments might be due to the immediate removal of field heat after the harvest from the fruit, which limits the respiratory activities and reduced the moisture loss and hydrolysis of starch into simple sugars.

Titratable acidity*:* The present study found that titratable acidity of papaya fruits decreases with increasing storage time in all the treatments (Table 2). The decrease in acidity during storage is attributed to the use of acids in respiration and conversion to sugars, demonstrating the fruit ripening. The lowest acidity (0.16 %) was noticed in T_9 (control) after three days of storage, whereas T_7 recorded the highest acidity after three, six and nine days of storage (0.27, 0.22 and 0.16 %, respectively). Slow ripening of papaya fruits in all treatments except that of control (T_9) resulted in the delayed breakdown of organic acid and higher titratable acidity after three days of storage. According to Jawandha *et al.* (2016), precooling (hydrocooling) retained maximum acid content than control in peach cv. Shan-I Punjab fruits after 35 days of storage. Slower conversion of acids into sugars after precooling and utilization of acids during respiration might have contributed to this. Sanches *et al.* (2019) reported higher titratable acidity in

Table 1. Effect of postharvest management practices on shelf life, physiological loss in weight, ion leakage and TSS of papaya fruit var. Surya

Treatments	Shelf life (days)	Physiological loss in weight (%)				Ion leakage (%)				TSS (°Brix)			
		Initial (0 DAS)	3 DAS	6 DAS	9 DAS	Initial (0 DAS)	3 DAS	6 DAS	9 DAS	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
T_1	5.67	0.00	4.48(2.12)	-	-	11.37	64.39	-	-	8.07	11.80	-	-
T_2	5.00		5.75 (2.40)	-	-	11.04	81.07	-	-	8.37	12.70	-	-
T_3	6.33		3.51 (1.87)	6.80 (2.61)	-	11.21	60.47	92.24	-	7.83	12.13	14.33	-
T_4	7.67		2.77 (1.66)	5.83 (2.41)	-	10.64	51.43	84.33	-	8.17	10.73	13.67	-
T_5	6.33		3.16 (1.78)	6.47 (2.54)	-	10.63	57.80	91.85	-	7.97	12.03	14.03	-
T_6	7.33		2.47 (1.57)	5.64 (2.37)	-	10.60	46.50	80.07	-	8.13	10.93	13.40	-
T_7	9.67		1.49 (1.21)	3.63 (1.90)	5.64	10.70	34.63	63.14	93.41	8.17	10.20	11.20	13.50
T_8	9.00		1.59 (1.26)	3.96 (1.99)	6.50	10.74	37.02	64.23	95.78	8.03	10.33	11.70	13.97
T_9	4.33		7.54 (2.74)	-	-	11.37	90.25	-	-	8.03	13.23	-	-
SEm (±)	0.29	-	0.18 (0.05)	0.18 (0.04)	0.17	0.29	0.98	0.97	-	0.14	0.22	0.30	-
CD (0.05)	0.87	-	0.52 (0.15)	0.56 (0.12)	4.64*	NS	2.91	3.01	6.09*	NS	0.65	0.91	3.45*

DAS: Days after storage. Values in bracket are square root transformed values.

Table 2. Effect of postharvest management practices on titratable acidity, total carotenoids, total sugars and reducing sugars of papaya var. Surya fruit

Treatments	Titratable acidity (%)				Total carotenoids (mg $100g^{-1}$)				Total sugars (%)				Reducing sugars (%)			
	0 DAS	3 DAS	6 DAS	9 DAS	0 DAS	3 DAS	6 DAS	9 DAS	0 DAS	3 DAS	6 DAS	9 DAS	0 DAS	3 DAS	6 DAS	9 DAS
T_1	0.29	0.19	-	-	0.98	2.50	-	-	5.03	8.58	-	-	4.14	7.52	-	-
T_2	0.30	0.19	-	-	1.15	2.55	-	-	5.08	8.94	-	-	4.53	7.59	-	-
T_3	0.29	0.22	0.14	-	1.29	2.34	2.77	-	4.75	7.26	9.87	-	4.16	6.34	8.63	-
T_4	0.30	0.23	0.16	-	1.05	1.83	2.61	-	4.99	6.54	9.49	-	4.45	5.71	8.07	-
T_5	0.29	0.21	0.14	-	1.01	2.20	2.69	-	5.10	7.53	9.70	-	4.26	6.43	8.43	-
T_6	0.29	0.23	0.15	-	1.11	2.11	2.67	-	5.01	6.35	9.20	-	4.28	5.77	8.35	-
T_7	0.30	0.27	0.22	0.16	1.02	1.40	1.89	2.50	5.00	5.73	7.75	8.58	4.41	5.36	6.59	8.00
T_8	0.29	0.25	0.21	0.15	1.01	1.45	2.11	2.64	4.92	5.90	8.14	9.17	4.41	5.52	6.89	8.43
T_9	0.30	0.16	-	-	1.12	2.70	-	-	4.99	9.40	-	-	4.48	8.16	-	-
SEm (±)	0.00	0.00	0.00	-	0.07	0.04	0.07	-	0.07	0.24	0.30	-	0.06	0.23	0.31	-
CD (0.05)	NS	0.02	0.03	1.47* (NS)	NS	0.13	0.22	8.25*	NS	0.72	0.94	4.82*	NS	0.68	0.95	3.11*

DAS: Days after storage. *T statistic value. T- Table (0.05): 2.048

pinha (*Anonna squamosa* L.) fruits packed with $KMnO_4$ sachets with the control, indicating a less advancement of ripening in $KMnO_4$ supplied packs due to the slower consumption of organic acids. Delayed drop in titratable acidity during storage in mango cv. Kitchner was reported by Elzubeir *et al.* (2018) upon waxing and $KMnO_4$ treatment.

Total carotenoid content*:* There was significant variation in total carotenoid content in papaya cv. Surya fruits subjected to different postharvest treatments after three days of storage (Table 2). Highest total carotenoid content (2.70 mg $100g^{-1}$) was recorded in T_9 after three days of storage. The lowest total carotenoid content of 1.40 mg $100g^{-1}$, 1.89 mg $100g^{-1}$ and 2.50 mg $100g^{-1}$, respectively was found in T_7 after three, six and nine days of storage. Petriccione *et al.* (2015) noticed that chitosan treatment delayed the senescence rate and consequently there was a delay in the increase in carotenoid content throughout the storage in loquat (*Eriobotrya japonica* Lindl.) fruits compared to control. This may be achieved due to meagre activity of pectin methyl esterase enzyme and delayed chlorophyll degradation in conjunction with enzymatic action.

Total sugars*:* Papaya fruits registered an increasing trend in total sugars during storage (Table 2). Control (T_9) recorded a significantly higher percent of total sugars (9.40 %) at 3 days after storage. Lowest total sugars content (5.73 %) was recorded in T_7 after three days of storage. Higher percent of total sugars in untreated fruits (control) seems to be due to rapid increase in respiration rate. The increase of total sugar was normal in all other treatments due to slow degradation of polysaccharides to sugars and the gradual buildup of sugars concomitant with reduced utilization of sugars as substrates during respiration. The slow buildup of sugars in T_7 treated fruits after three days of storage is attributed to more shelf life. In papaya cv. Coorg Honeydew, similar findings have been documented by Jayasheela (2014).

Reducing sugars: The amount of reducing sugars showed an upward trend with the advancement of storage period (Table 2). After three days of storage, the highest reducing sugars content (8.16 %) was noticed in T9 (control). The lowest reducing sugars content (5.36, 6.59 and 8.00%, respectively) was noticed in T7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber KMnO4) after three, six and nine days of storage. A low respiration rate coupled with lower enzymatic activity is contribed to a low reducing sugar content in T_7. This slow buildup of reducing sugar was achieved by reducing sugars' utilization in respiration. Kaur and Kaur (2018) reported that banana cv. Grand Naine fruits stored in unperforated polythene bags with $KMnO_4$ witnessed minimum reducing sugar after eight days of storage compared to control and opined that it is due to ripening inhibiting effect of $KMnO_4$. They further registered an increment in reducing sugars as ripening progresses.

Percentage disease index: Anthracnose and stem end rot are the major postharvest fungal diseases affecting papaya during storage. The number of fruits infected with anthracnose showed significant differences among treatments in the present study (Table 3). Lowest disease incidence of zero percent was witnessed in T_7 and T_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) after three days of storage. However, higher sign of lesions (38.89 %) was observed in control after three days of storage. Packaging with ethylene scrubber $KMnO_4$ (T_5) recorded highest disease index (33.33 %) after six days of storage. However, after six days and nine days of storage, lowest disease index was noticed in both T_7 and T_8 (16.67 and 27.78 %, respectively). The combined application of three postharvest management measures in T_7 and T_8 might have contributed to the reduced disease incidence. Jawandha *et al.* (2016) opined that precooling (hydrocooling) effectively reduced the spoilage of peach cv. Shan-i-Punjab fruits. Precooling reduced fruit spoilage by reducing metabolic, respiration and ripening rate and prolonging keeping quality. Eryani-Raqeeb *et al.* (2009) reported that chitosan controlled the disease incidence in papaya cv. Eksotika. Shiekh *et al.* (2013) attributed the natural antimicrobial activity of chitosan to delayed fruit deterioration in commodities by inhibiting the growth of microorganisms. Mango fruits coated with carnauba wax exhibited reduced fruit decay during storage (Baldwin *et al.*, 1999). According to Issar *et al.* (2010), the reduced spoilage in waxed fruits was probably due to the covering of bruised points with wax and restricting the entry of microorganisms into the fruit.

Microbial load: Lowest bacterial and fungal count was witnessed in T_7 after three, six and nine days of storage (4.67 cfU/mL x 10^6, 16.00 cfU/mL x 10^6 and 24.33 cfU/mL x 10^6 of bacteria and 1.67 cfU/mL x 10^3, 4.67 cfU/mL x 10^3 and 13.33 cfU/mL x 10^3 of fungi respectively) (Table 3). Minh *et al.* (2019) documented that chitosan coating effectively inhibited the growth

Table 3. Effect of postharvest management practices on percentage disease index and microbial load (bacterial and fungal count) of papaya var. Surya fruit

Treat-ments	Disease index (%)				Bacterial count (cfU/mL x 10^6)				Fungal count (cfU/mL x 10^3)			
	0 DAS	3 DAS	6 DAS	9 DAS	0 DAS	3 DAS	6 DAS	9 DAS	0 DAS	3 DAS	6 DAS	9 DAS
T_1		33.33 (35.26)	-	-	2.67	43.33	-	-	0.67	13.67	-	-
T_2		27.78 (31.75)	-	-	3.33	54.00	-	-	0.33	14.67	-	-
T_3		16.67 (24.10)	30.55 (33.51)	-	2.67	22.33	46.33	-	0.67	7.33	9.33	-
T_4		11.11 (16.45)	27.78 (31.75)	-	3.33	14.33	36.00	-	0.67	6.00	8.67	-
T_5	0.00	16.67 (24.10)	33.33 (35.16)	-	2.67	19.33	51.67	-	1.00	6.67	9.33	-
T_6		5.56 (8.81)	22.22 (28.03)	-	2.67	14.00	31.67	-	0.67	5.00	8.33	-
T_7		0.00 (1.17)	16.67 (24.10)	27.78	2.67	4.67	16.00	24.33	0.33	1.67	4.67	13.33
T_8		0.00 (1.17)	16.67 (24.10)	27.78	2.67	5.67	16.33	25.67	0.33	2.00	5.33	14.00
T_9		38.89 (38.56)	-	-	3.67	89.33	-	-	1.33	22.33	-	-
SEm (±)	-	3.05 (3.69)	2.78 (1.76)	-	0.38	0.91	0.64	-	0.31	0.40	0.41	-
CD (0.05)	-	9.16 (10.97)	8.56 (5.44)	0.00* (NS)	NS	2.74	1.97	2.83*	NS	1.20	1.26	2.65*

Values in bracket are angular transformed values. DAS: Days after storage. *T statistic value. T- Table (0.05) : 2.048

of microorganisms in soursop. Martins *et al.* (2010) believed that papaya fruit treated with hot water at 48-50°C for 20 minutes controlled the anthracnose disease in papaya. Jayasheela (2014) reported that papaya fruits sanitized with hot water treatment at 50°C for 20 minutes with waxing and ethylene absorbent had the lowest bacterial and fungal populations. Edible films and coatings can act as a barrier against microbial invasion (Kester and Fennema, 1986).

From the study, it is concluded that papaya var. Surya fruits harvested at the fully mature green stage and subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ gave the most extended shelf life of 9.67 days with maximum fruit quality parameters and minimum microbial load.

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