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Physiological, physical and biochemical changes associated with ripening and shelf life extension of Red Lady papaya as influenced by post harvest treatments

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Abstract

Papaya is one of the important fruit crops grown commercially in India and area under the cultivar Red lady is expanding due to its consumer acceptance. Papaya is a climacteric fruit, and changes associated with ripening occur faster, leading to high perishability and short shelf life. In the present study, different post harvest treatments were evaluated for the shelf life extension of papaya cv. Red Lady so that fruits can be marketed with good quality and reduce post harvest loss. The harvested Red lady papaya fruits of optimum maturity (colour break stage) after sanitisation (ozonation 2 ppm) followed by hot water treatment (50^0 C for 20 minutes) were subjected to various postharvest treatments, *viz.,* Naphthalene acetic acid (250 ppm), Edible coating (Papaya leaf extract + Aloe gel 1:1), Gibberellic Acid (100 ppm), Calcium chloride (2%) and Salicylic Acid (2 mM). The treated fruits were stored in Corrugated fibre board boxes with 5% ventilation at room temperature and were analysed for physiological, physical, and biochemical parameters periodically till the end of shelf life. Among the treatments, Salicylic acid (2 mM) application of papaya effectively reduced the respiration rate (94.83 mL CO_2 kg^{-1} h^{-1}), physiological loss in weight (13.10%), titratable acidity and recorded the highest values for total soluble solids (11.52 %), sugars, and carotenoid content (2.55 mg $100g^{-1}$) at the end of shelf life. The study revealed that post harvest treatment of Red Lady papaya with 2 mM Salicylic acid delayed the ripening and extended the shelf life upto14.56 days at room temperature storage, with minimum nutritional loss.

Keywords: Delayed ripening, Edible coating, Papaya, Postharvest treatments, Salicylic acid, Shelf life.

Introduction

Papaya (*Carica papaya* L.) is extensively cultivated as a cash crop in tropical and subtropical regions. India is one of the major papaya producing countries and the fourth most traded crop. It is cultivated on 97.7 thousand hectares with an annual production of 6.09 million MT (NHB, 2020). The fruit is a rich source of sugars, ascorbic acid, carotenoids, and potassium and is highly valued for its nutraceutical properties (Parker et al., 2010). High water content, rapid flesh softening, mechanical damages and postharvest diseases contributed to a substantial increase in qualitative and quantitative postharvest losses in papaya. Lack of infrastructure facilities and poor postharvest handling practices in papaya accounted for 75 and 90% of postharvest losses, respectively (Ramesh et al., 2016).

Postharvest treatments have been reported to enhance the quality and improve firmness by maintaining cell integrity that prolongs the shelf life of papaya with minimum losses. They extend the green life through delayed ripening and senescence of fruits by retardation of biosynthesis of ethylene or its action (Asghari and Aghdam, 2010). As a climacteric fruit, papaya shows a'climacteric peak' at the onset of ripening and undergoes biochemical

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changes associated with respiration and senescence, causing catabolic destruction of biochemical substances at a faster rate. Hence, adopting adequate postharvest treatments can combat the deterioration by reducing respiration rate and thus extending the shelf life (Dasu et al., 2016). In papaya, postharvest losses during farm operations, storage and transportation are reported as 7.36% (Bhanushree et al., 2018) and different varieties of the same species respond differently to postharvest chemical treatments in delaying the ripening process and extending shelf life. Postharvest treatments with different materials for extending shelf life of fruits were found promising and hence this study was conducted to standardize the postharvest treatments for delayed ripening and to extend the shelf life of papaya cv. Red Lady with minimum nutritional loss.

Materials and Methods

Good quality Red Lady papaya fruits of uniform size, shape and maturity at colour break stage were harvested from the commercially grown field of progressive farmers of Farmer Producer Organisation at Thiruvananthapuram. The fruits were harvested in the early morning and brought to the research lab without delay and were subjected to different postharvest treatments in order to assess the effectiveness of treatments for delayed ripening and to extend the shelf life by analysing its physical, physiological and biochemical changes periodically. The selected Red Lady papaya fruits after sanitization (Ozonisaton 2 ppm) followed by hot water treatment (50^0C for 20 minutes) were subjected to postharvest treatments by dipping for 5 minutes. The postharvest treatments were T_1- Ozonation + Hot water treatment + Naphthalene Acetic acid (250 ppm), T_2- Ozonation + Hot water treatment + Edible coating (Papaya leaf extract and Aloe gel in 1:1), T_3- Ozonation + Hot water treatment + GA_3 (100ppm), T_4- Ozonation + Hot water treatment + $CaCl_2$ (2%), T_5- Ozonation + Hot water treatment + Salicylic acid (2 mM), T_6- Ozonation + Hot water treatment and T_7- Control (ozonation alone). The pre-treated fruits after removal of surface moisture were stored in Corrugated fibre board (CFB) boxes with 5% ventilation at room temperature (30 ± 2^0 C; 80-85% RH). Experiment was laid out in Completely Randomised Design with three replications.

Naphthalene acetic acid (NAA) of 250 ppm was prepared by adding 250 mg in 3mL of 1 N NaOH before being mixed with 1 L distilled water and 0.1% Tween 80 was added to it as a wetting agent. For the preparation of edible coating (Papaya leaf extract + Aloe gel), gel matrix (colourless hydro parenchyma) underneath the leaf rind extracted from fresh *Aloe vera* leaves was pulped using a blender, filtered and 1% sodium alginate was added as a stabiliser to facilitate uniform coating. The pure aloe gel (AG; 100%) obtained was pasteurized at 70^0 C for 45 minutes. To prepare Papaya leaf extract + Aloe gel (1:1), 500 g of fresh papaya leaves washed in running water were sterilised using 0.1% sodium hypochlorite for l0 minutes and washed thoroughly with distilled water to remove the residues of chemicals. Papaya leaves were then crushed with aloe gel in 1:1, filtered and Tween 80 @ 0.1% was added to the solution as a wetting agent as per the procedure described by Brishti et al. (2013). The GA_3 @ 100 ppm concentration was prepared by taking 100 mg in 3 ml of 95% ethanol which was further dissolved in distilled water (1 l). The 2% concentration of calcium chloride solution was made up by dissolving 2 g in 100 ml of distilled water and Salicylic Acid solution of 2 mM was made up by adding 276 mg in 1 l of distilled water after being dissolved in 3 ml of 95% ethyl alcohol and in all treatments Tween 80 @ 0.1% was added as a wetting agent.

Physiological, physical, and biochemical parameters of fruits during storage were recorded at an interval of three days till the end of shelf life.

Physiological loss in fruit weight (PLW) was determined as cumulative weight loss by noting the weight of fruits at 3 days intervals and deducted from the initial weight recorded at the time of storage and expressed in percentage. Checkpoint Portable Gas Analyser was used to record the amount of CO_2 expelled during respiration and expressed in mL CO_2 kg^{-1} h^{-1}.

Textural properties of treated papaya fruits were evaluated using a texture analyzer TA–HD® (Stable Micro systems, Surrey, England) equipped with a 50kg load cell. The analyzer was linked up to a computer that recorded data via a software program called Texture Expert (version 1.22, Stable Micro Systems, UK). Textural evaluation was carried out by placing the whole fruit with skin on the platform of the texture analyzer and penetrating it with a 2 mm diameter cylindrical stainless steel probe (P/2 diameter cylinder stainless steel) at a speed of 0.5mms^{-1} with automatic return to plot a corresponding deformation curve. The penetration was taken at three different positions on same vertical axis. The downward distance (penetration distance into the fruit) was set at 20 mm and pre-test speed, test speed and post-test speed were 5 mms^{-1}, 2 mms^{-1} and 10 mms^{-1} respectively. The trigger force and data acquisition rate were set as 0.049 N and 200 pps respectively. The maximum distance covered by the probe was considered as a measure of fruit texture and expressed in newton (N). Papaya fruits after postharvest treatment were visually observed during storage and scored relying on the standard colour index scaling from 0 to 6 as developed by Mandal et al. (2017) as Score 0 : Green skin without yellow stripe; Score 1 : Green skin with light yellow stripe; Score 2 : Green skin with well-defined yellow stripe; Score 3 : One or more orange-coloured stripes in skin; Score 4 : Clearly orange-coloured skin with some light green areas; Score 5 : Characteristic orange-coloured skin of papaya; and Score 6 : Fruit colour similar to stage 5, but more intense.

To record the moisture content, one gram of fruit pulp was kept in moisture analyser (Essae, AND MAX 50) based on principle of thermo gravimetric analysis and expressed in terms of percentage. Total Soluble Solids (TSS) was determined with Atago - 0 to 85% digital refractometer and Sugars (%), titratable acidity (%), and carotenoid content were analyzed based on the methods prescribed by Ranganna (1986). Shelf life of treated papaya fruits was recorded as the number of days for 10% spoilage of fruits during storage and expressed in days. Each treatment was conducted in triplicate and the experiment was statistically laid out in Completely Randomised Design and the data generated were analysed in SPSS 21.0 with $P \leq 0.05$.

Results and Discussion

Physiological parameters

Physiological loss in weight determines the saleable weight of fruits and is an indicator for shelf life and it showed an increasing trend during the storage of Red Lady papaya fruits irrespective of the treatments. Salicylic acid (2 mM) treatment recorded the lowest weight loss of 13.10% after 14 days of storage at room temperature (Table 1). The reduction in weight loss during storage and ripening might be due to stomatal closure which led to decrease in transpiration rate (Mandal et al., 2017 and Lata et al., 2018). The respiration and ethylene production increase during ripening of climacteric fruits leading to shorter shelf life. In the present experiment, Red Lady papaya treated with Salicylic Acid at 2 mM recorded the lowest respiration rate of 94.83 ml CO_2 kg^{-1} h^{-1} after 14 days of storage (Table 2) where Salicylic acid acts as an electron donor and scavenge free radicals, therefore reduced the rate of respiration rate and weight loss as reported by Zheng and Zhang (2004).

Physical parameters

The moisture content of papaya fruits increased during ripening. Red Lady papaya fruits treated with Salicylic acid 2 mM recorded the lowest moisture content of 95.27% after 14 days of room temperature storage (Table 3) which indicated the acceptable ripening and firmness. Papaya fruits subjected to postharvest treatments reduced the loss of moisture content by reducing transpiration associated with ripening and senescence. Bal and

Table 1. Effect of postharvest treatments on Physiological loss in weight (%) of papaya cv. Red Lady during storage

Postharvest Treatments (T)	Days after storage (D)				
	3	6	9	12	14
T_1 (NAA 250 ppm)	2.94 (1.98)	5.84 (2.62)	7.49 (2.91)	10.84 (3.44)	13.95 (3.87)
T_2 (Edible coating)	3.47 (2.11)	7.88 (2.98)	9.31 (3.21)	14.56 (3.94)	16.49 (4.18)
T_3 (GA_3 100 ppm)	3.29 (2.07)	6.83 (2.80)	8.55 (3.09)	12.46 (3.67)	14.27 (3.91)
T_4 ($CaCl_2$ 2%)	4.63 (2.37)	8.92 (3.15)	11.63 (3.55)	16.82 (4.22)*	-
T_5 (Salicylic acid 2 mM)	2.60 (1.90)	4.45 (2.34)	6.55 (2.75)	9.34 (3.22)	13.10 (3.76)
T_6 (Hot water treatment)	5.83 (2.61)	10.84 (3.44)	15.47 (4.06)*	-	-
T_7 (Control)	5.93 (2.63)	11.78 (3.57)	16.65 (4.20)*	-	-
	SE± (m)	CD (0.05)	SE±(m)		SE±(m)
Treatments (T) × Days (D)	0.012	0.034	0.015		0.013
			CD (0.05)		CD (0.05)
			0.046		0.041

(Square root transformed values are provided in parenthesis) *P apaya fruits were discarded due to spoilage

Table 2. Effect of postharvest treatments on respiration rate (mL CO_2 kg^{-1} h^{-1}) of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	29.82	41.01	57.88	77.45	89.62	95.65
T_2 (Edible coating)	30.81	43.60	68.99	86.85	93.58	98.56
T_3 (GA_3 100 ppm)	30.40	42.45	61.68	81.34	91.45	97.63
T_4 ($CaCl_2$ 2%)	31.34	45.98	71.85	92.32	94.65	-
T_5 (Salicylic acid 2 mM)	29.30	40.21	54.57	75.99	88.55	94.83
T_6 (Hot water treatment)	31.54	48.91	75.41	92.90	-	-
T_7 (Control)	32.30	51.97	78.78	98.92	-	-
Treatments (T) × Days (D)		SE± (m)	CD (0.05)	SE± (m)		SE± (m)
		0.526	1.493	0.126		0.249
				CD (0.05)		CD (0.05)
				0.402		0.08

Table 3. Effect of postharvest treatments on moisture content (%) of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	83.24	86.25	89.90	92.84	94.93	96.29
T_2 (Edible coating)	82.84	88.76	91.92	94.71	96.77	97.85
T_3 (GA_3 100 ppm)	83.11	87.97	90.78	93.81	95.62	96.96
T_4 ($CaCl_2$ 2%)	82.74	88.47	92.93	93.71	97.42	-
T_5 (Salicylic acid 2 mM)	83.02	85.86	88.65	91.69	93.77	95.27
T_6 (Hot water treatment)	82.87	90.04	94.12	95.53	-	-
T_7 (Control)	82.76	91.78	95.01	97.31	-	-
		SE± (m)	CD (0.05)	SE± (m)		SE± (m)
Treatments (T) × Days (D)		0.243	0.69	0.138		0.271
				CD (0.05)		CD (0.05)
				0.439		0.844

Celik (2010) proved that the SA application of fruits inhibited the activity of two key enzymes (ACC synthase and ACC oxidase) involved in ethylene biosynthesis which in turn reduced the ethylene production and moisture loss. The increase in moisture content of fruits with ripening might be due to the complete metabolism of starch to carbon dioxide and water during storage along with osmotic absorption of water from peel to pulp as explained by Hakim et al.(2013).

Fruit firmness is the key factor indicating the ripeness as well as consumer acceptability of papaya fruits. Salicylic Acid at 2 mM treated papaya fruits

Table 4. Effect of postharvest treatments on texture (fruit firmness) (N) of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	95.46	82.65	66.63	43.82	26.64	17.65
T_2 (Edible coating)	94.38	77.81	62.11	41.98	22.73	15.23
T_3 (GA_3 100 ppm)	94.62	80.87	64.25	42.29	25.09	15.93
T_4 ($CaCl_2$ 2%)	94.84	89.73	69.18	44.88	23.72	-
T_5 (Salicylic acid 2 mM)	94.91	85.66	68.99	45.12	27.43	19.89
T_6 (Hot water treatment)	95.39	66.68	20.25	16.15	-	-
T_7 (Control)	94.15	59.35	19.94	15.87	-	-
	SE± (m)		CD (0.05)	SE± (m)		SE± (m)
Treatments (T) × Days (D)	0.551		1.565	0.541		0.667
				CD (0.05)		CD (0.05)
				1.725		2.208

retained the maximum firmness of 19.89 N on 14th day of storage as compared to untreated fruits (Table 4). This might be due to the reduced breakdown of cell wall polysaccharides by the activity of β-galactosidase and polygalacturonase and improved cell membrane integrity which in turn delayed the ripening and fruit softening (Maqbool et al., 2011). This was supported by Hong et al. (2014) in mango, Mandal et al. (2017) in Red Lady papaya.

Colour development is an indication of ripening and an important visual sensory attribute contributing to better marketability and consumer acceptability. The increased rate of respiration and ethylene production in papaya fruits through the ripening process changed its colour from green to yellow owing to chlorophyll degradation and carotenoid biosynthesis. Papaya fruits with 2 m M SA treatment recorded a colour score of 5.4 similar to stage 5, but more intense colour development (6) was reported by the other treatments after 14 days of storage (Table 5). Brishti et al. *(*2013) observed that postharvest treated papaya fruits inhibited ethylene production which in turn helped in delayed ripening, chlorophyll break down, carotenoid biosynthesis and ultimately the colour development than the untreated fruits. The results are in conformity with the findings of Singh et al. (2012) in papaya cv. Pusa Delicious, Hakim et al. (2013) in banana and Lata et al. (2018) in papaya cv. Red Lady. The anti-senescent nature of SA which delayed the ripening and carotenoid production in postharvest treated papaya in the present study was also supported by Mandal et al. (2017).

Biochemical parameters

Total soluble solids is associated with palatable quality and confer to the sweetness of fruits which increases during the ripening of fruits. The influence of postharvest treatments on TSS is given in Table 6. The slow increment in TSS of SA treated fruits from 4.49 to 11.52% might be due to slower biochemical and enzymatic reactions that lead to delayed ripening as compared to control. The increase in TSS with enhanced ripeness in papaya was also reported by Mandal et al. (2017). Reducing

Table 5. Effect of postharvest treatments on skin colour of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	0	0	1.8	3.2	4.4	5.6
T_2 (Edible coating)	0	1.4	2.8	4.4	5.4	6
T_3 (GA_3 100 ppm)	0	1.2	2.2	4.2	5.2	6
T_4 ($CaCl_2$ 2%)	0	1.6	3.4	4.8	6	-
T_5 (Salicylic acid 2 mM)	0	0	1.2	2.2	4	5.4
T_6 (Hot water treatment)	0	2.2	4.6	6	-	-
T_7 (Control)	0	2.4	5.2	6	-	-

Table 6. Effect of postharvest treatments on total soluble solids (%)of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	4.50	5.47	6.85	8.21	10.34	11.93
T_2 (Edible coating)	4.66	6.93	8.24	9.58	12.02	13.48
T_3 (GA_3 100 ppm)	4.53	6.27	7.19	8.97	11.58	12.64
T_4 ($CaCl_2$ 2%)	4.53	7.33	9.30	10.61	13.20	-
T_5 (Salicylic acid 2 mM)	4.49	5.17	6.32	7.66	9.74	11.52
T_6 (Hot water treatment)	4.53	7.16	10.02	12.03	-	-
T_7 (Control)	4.61	8.47	12.30	13.24	-	-
	SE± (m)		CD (0.05)	SE± (m)	SE± (m)	
Treatments (T) × Days (D)	0.079		0.223	0.119	0.066	
				CD (0.05)	CD (0.05)	
				0.38	0.207	

Table 7. Effect of postharvest treatments on reducing sugar (%)of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	3.66	4.28	5.90	6.95	8.61	8.84
T_2 (Edible coating)	3.42	4.49	6.62	7.68	8.95	9.28
T_3 (GA_3 100 ppm)	3.53	4.40	6.20	7.33	8.51	9.05
T_4 ($CaCl_2$ 2%)	3.57	4.81	6.93	9.23	9.15	-
T_5 (Salicylic acid 2 mM)	3.42	4.15	5.64	6.69	8.01	8.26
T_6 (Hot water treatment)	3.50	6.10	8.78	8.65	-	-
T_7 (Control)	3.41	6.30	9.46	9.37	-	-
	SE± (m)		CD (0.05)	SE± (m)	SE±(m)	
Treatments (T) × Days (D)	0.093		0.263	0.056	0.025	
				CD (0.05)	CD (0.05)	
				0.180	0.079	

sugar content of papaya increased in all the treatments with the advancement of the storage period and SA treatment noticed a reducing sugar of 8.26% after 14 days of storage (Table 7). In similar vein, total sugar content increased during storage (Fig. 1) that could be accomplished by hydrolysis of polysaccharides in the cell wall (Bhooriya et al., 2018). During storage, the hydrolysis of complex metabolites into simple molecules or breakdown of starch into simple soluble sugars by amylase resulted in accumulation of glucose and fructose. This might be the reason

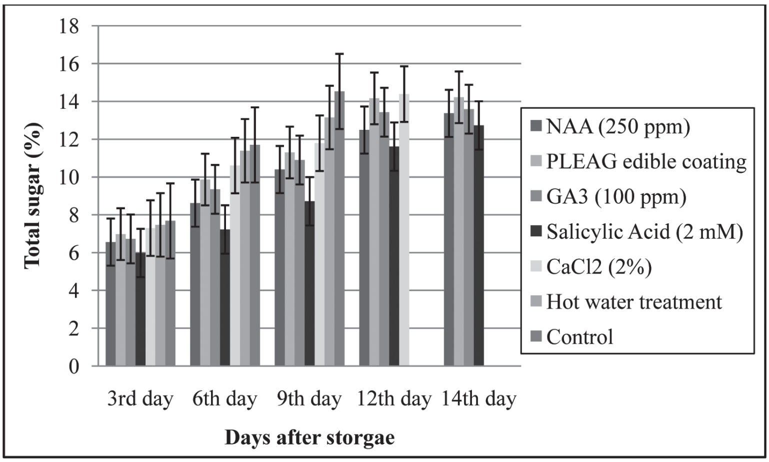

Figure 1. Effect of postharvest treatments on total sugar (%) of papaya cv. Red Lady during storage

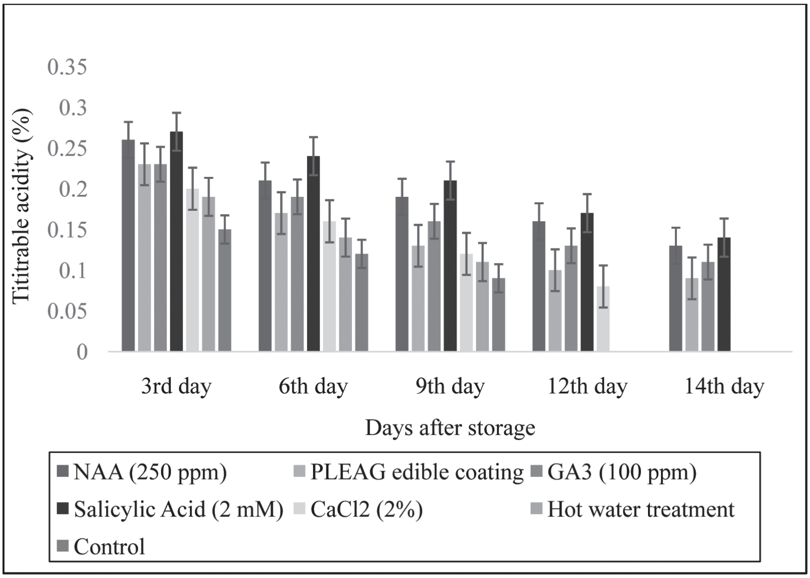

Figure 2. Effect of postharvest treatments on titratable acidity (%) of papaya cv. Red Lady during storage

for the increment in sugars during storage of the fruits (Jaishankar and Kukanoor, 2016) and parallel findings were reported by Lata (2017) and Devarakonda et al. (2020) in papaya. Titratable acidity is associated with organic acids present in fruits and is responsible for flavour and quality. In the present study, the titratable acidity exhibited a declining trend in both treated and untreated papaya fruits during storage but the decrease was the lowest in SA treated fruits indicating the slow ripening process. The Red Lady papaya fruits treated with 2 m M SA recorded the highest titratable acidity of 0.14% after storage for 14 days over the control (Fig. 2). The reduction in titratable acidity with the onset of ripening might be due to the catabolism of organic acids into simple sugars and their derivatives during respiration as reported by Hong et al. (2016). Carotenoid content increased during storage and recorded as 2.55 mg $100g^{-1}$ in fruits treated with SA 2 mM (Table 8). The treatment, SA delayed the rapid increase in carotenoid content by reducing chlorophyll metabolism and delayed ripening during storage with maximum fruit quality as supported by Barman and Asrey (2014).

Shelf life

The postharvest application of SA at 2 mM concentration significantly recorded the highest

Table 8. Effect of postharvest treatments on carotenoid content (mg $100g^{-1}$) of papaya cv. Red Lady during storage

PostharvestTreatments (T)		Days after storage (D)				
	At storage	3	6	9	12	14
T_1 (NAA 250 ppm)	0.65	1.09	1.47	2.15	2.45	2.63
T_2 (Edible coating)	0.65	1.27	1.58	2.27	2.50	2.89
T_3 (GA_3 100 ppm)	0.67	1.13	1.68	2.23	2.53	2.77
T_4 ($CaCl_2$ 2%)	0.68	1.41	1.77	2.56	2.71	-
T_5 (Salicylic acid 2 mM)	0.65	1.04	1.25	2.09	2.41	2.55
T_6 (Hot water treatment)	0.66	1.42	2.33	2.66	-	-
T_7 (Control)	0.67	1.51	2.44	2.92	-	-
	SE± (m)	CD (0.05)		SE±(m)		SE±(m)
Treatments (T) × Days (D)	0.030	0.086		0.029		0.005
				CD (0.05)		CD (0.05)
				0.092		0.015

Table 9. Effect of postharvest treatments on shelf life (days) of papaya cv. Red Lady

Postharvest Treatments		Shelf life (days)
T_1 (NAA 250 ppm)		13.01
T_2 (Edible coating)		11.37
T_3 (GA_3 100 ppm)		12.32
T_4 ($CaCl_2$ 2%)		9.75
T_5 (Salicylic acid 2 mM)		14.56
T_6 (Hot water treatment)		8.33
T_7 (Control)		7.38
SE± (m)	0.139	
CD (0.05)	0.427	

shelf life of 14.56 days in Red Lady papaya at room temperature storage (Table 9) where SA act as anti-senescent phytohormone by minimizing changes in physiological, biochemical, physical and sensory attributes. The increase in shelf life with salicylic acid application is attributed to increased fruit firmness by potentially suppressing the activity of cell wall degrading enzymes like pectin methyl esterase, cellulase, polygalacturonase, xylanase, and β-1-3 glucanase (Ali et al*.,* 2004) and delayed ripening and adjoining biochemical changes as a result of reduced respiration rate and ethylene production (Mandal et al., 2017). Similar results were also reported in papaya by Bhanushree et al. (2018) and Devarakonda et al. (2020). The present study reported the efficiency of salicylic acid in extending the shelf life of papaya cv Red Lady by delaying the climacteric phase of ripening that was evident from the data of respiration rate, physical, and biochemical changes during the storage of the fruits at room temperature.

Based on the physiological, physical and biochemical analysis, it can be concluded that Red Lady papaya harvested at colour break stage, subjected to the postharvest treatments of ozonation (2ppm), hot water treatment (50^0 C for 20 minutes) followed by dipping in Salicylic Acid at 2 mM solution for 5 minutes was effective in delaying the ripening process and recorded the highest shelf life of 14.56 days at room temperature storage. The developed protocol can increase the marketability of papaya with prolonged shelf life by slowing down the ripening and senescence associated changes for better farm income and reduction in postharvest losses.

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