www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 538-544

www.thepharmajournal.com
Received: 06-01-2022
Accepted: 12-02-2022

Maruti Shankhu
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Mallikarjun G Awati
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Kavya K
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Jagadish SL
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Bhuvaneshwari G
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Corresponding Author:
Maruti Shankhu
Department of Post-Harvest Technology, College of Horticulture, Bagalkot, Karnataka, India

Role of post-harvest treatment of polyamines on biochemical characteristics and shelf life of papaya (*Carica papaya* L.) var. red lady fruits during ambient storage

Maruti Shankhu, Mallikarjun G Awati, Kavya K, Jagadish SL and Bhuvaneshwari G

Abstract
Polyamines are the natural compound that plays a pivotal role in postharvest life of fruits and vegetables. The study was conducted with an objective to investigate the effect of post-harvest application of polyamines in different concentration on biochemical quality parameters and shelf life of papaya fruits during ambient storage (33-36 ºC). Papaya fruits are treated with different concentration of polyamines i.e., T_2-0.50mM Spermine, T_3- 1.0mM Spermine, T_4- 1.5mM Spermine, T_5- 0.50 mM Spermidine, T_6- 1 mM Spermidine, T_7- 1.5mM Spermidine, T_8- 2 mM Putrescine, T_9- 3 mM Putrescine, T_{10}- 4 mM Putrescine and T_1-Control. Among the treatments, papaya fruits treated with 4 mM of Putrescine (T_{10}) recorded significantly minimum total soluble solids (10.90 ºB), ß-carotene (0.76mg/100g) and maximum titratable acidity (0.34%), total phenols (180.92mg GAE/g) and shelf life (9 days) and sensory scores (overall acceptability- 8.46). Hence, it is confirmed from the study that the Putrescine at 4 mM (T_{10}) was found to be effective in delaying the biochemical and ripening of papaya fruits and maintaining the organoleptic qualities for long time.

Keywords: Polyamine, TSS, titratable acidity, careteniod, total phenols, shelf life, sensory evaluation

Introduction
Papaya (*Carica papaya* L.) is also known as pawpaw belongs to the family Caricaceae. It is considered as one of the most popular fruits among the millions of people due to it taste, nutrition value and medicinal use. It is regarded as the wonder fruit of the tropical and sub-tropical regions. It is originated in Mexico and it was introduced to India during 16th century from Malaca (Kumar and Abraham, 1943) [27]. India is the main producer of papaya, while Mexico ranks sixth and accounts for about 45.01 per cent and 6.13 per cent of total production, respectively (Anonymous, 2018) [2]. India has approximately 1.38 lakh hectares of land under papaya cultivation and produces around 59.89 million metric tons per year (Anonymous, 2018) [2]. Andhra Pradesh is the leader in papaya production among the Indian states followed by Karnataka, Gujarat and Maharashtra.

It is one of the richest source of vitamin A and a good source of vitamin C besides rich in sugars and pectin content. The red-fleshed varieties contain lycopene as a major pigment (Yamamoto, 1964; Kimura *et al*., 1991) [55, 26]. Lycopene is vitamin A inactive but is a more efficient antioxidant than β-carotene (Di-mascio *et al*., 1989) [12] and it has been linked with reduction of risk of cancer especially lung, stomach and prostate cancer (Giovannucci, 1999) [16]. All these aspects have made papaya an ideal dessert fruit. The milky latex of unripe papaya fruits contains papain, a proteolytic enzyme that digests proteins. Papain is used as a meat tenderizer and for medical and industrial purposes (Sankat and Maharaj, 1997) [45].

It is a common observation that, because of the extremely delicate nature of papaya fruits, heavy spoilage is of frequent occurrence before they reach the consumers. In India, the estimated loss is 10 to 25 per cent in ripe and 5 to 10 per cent in green fruits (Anonymous, 2018) [2]. The major polyamines found in every plant cell are spermidine, spermine and putrescine (Galston and Kaur-Sawhney, 1990) [14]. Polyamines are the natural compounds that have a specific role in fruits and vegetables in post-harvest life. Earlier research suggests that, polyamines in their free forms act as anti-senescent agents (Valero *et al.,* 1998) [52]. Polyamines are known to inhibit the ethylene production as it exerts a competition during its synthesis for a common precursor, S-adenosyl methionine and also provide alternative to use of chemicals to extend the shelf life of many fruits.

Materials and Methods

Experimental details: An experiment was carried out at Department of Post-harvest Technology, College of Horticulture, University of Horticultural Sciences, Bagalkot, Karnataka state during the year 2018-2019 with 10 treatments and 3 replications. The statistical design applied was completely randomized design (CRD). The treatment Details are T_1-Control, T_2-0.50mM L^{-1} Spermine, T_3- 1.0mM L^{-1} Spermine, T_4- 1.5mM L^{-1} Spermine, T_5- 0.50 mM L^{-1} Spermidine,T_6- 1 mM L^{-1}Spermidine,T_7- 1.5mM L^{-1} Spermidine, T_8- 2 mM L^{-1} Putrescine, T_9- 3 mM L^{-1} Putrescine, T_{10}- 4 mM L^{-1} Putrescine.

Papaya fruits required for the experiment were procured from the papaya orchard located in the out skirts of Bagalkot situated at 15 km away from the experimental department. The fruits were carefully chosen from the orchard and manually harvested and gathered in the field. The fruits were selected based on the appearance of one or two yellow streaks on the surface of the fruits. After selection, individual fruits were wrapped with paper and placed in plastic crate and brought to laboratory in a small vehicle. In laboratory, fruits were uncovered with papers and immediately, washed with water containing 0.2 percent sodium hypochlorite and air dried under electrical fan. The air dried fruits were dipped in the putrescine at 2, 3, 4 milli molar of spermine and spermidine at 0.5, 1, 1.5 milli molar and one with distilled water which was served as control. The fruits were dipped in putrescine, spermine and spermidine for 5 min, fruits were taken out from the solutions and air dried for 5 min under electrical fan. Then the individual fruits were placed in plastic crates by maintaining 10 fruits per replication. The crates were placed in ambient and cold storage for further studies.

Total soluble solids (°B): The juice extracted by crushing the pulp of the papaya and strained through muslin cloth was used for measuring total soluble solids. Total soluble solids estimated using Digital Refractrometer. The results were expressed as degree brix.

Titratable acidity (%): The titratable acidity of papaya pulp sample was determined by titration method (Ranganna, 1986) [42]. The acidity was calculated as follows.

$$\text{Acidity (\%)} = \frac{\text{TV x 0.1 N NaOH x Volume made-up x Equivalent weight of citric acid}}{\text{Volume of sample taken for titration x Weight of sample x1000}} \text{ x } 100$$

Beta carotene content (mg 100 gm^{-1})

B-carotene content in papaya pulp samples was determined by a modified method of the one described by Ranganna (1986) [42]. Absorbance was measured at 452 nm using petroleum ether as a blank in spectrophotometer.

$$\beta - \text{Carotene (mg/100 g)} = \frac{\text{3.2 x OD value x Dilution factor}}{\text{Weight of the sample (g) x1000}} \times 100$$

Total phenol content (mg GAE /100g)

The concentration of total phenol content was estimated by the Folin-ciocalteau colorimetric method proposed by Singleton *et al*. (1999). The absorbance was recorded at 725nm (A_{725}) against a reagent blank. The total phenol content was expressed as gallic acid equivalents (GAE) in mg/100 g fresh fruit material. The concentration of phenol compound was calculated according to the following equation that was obtained from the standard gallic acid graph.

$$\text{Total phenol (mg/100g)} = \frac{\text{A} \times \text{volume made up (mL)} \times \text{Dilution} \times 100}{\text{aliquot (mL)} \times \text{Weight of the sample (g) x1000}}$$

Sensory evaluation (9 point hedonic rating scale)

Organoleptic evaluation of papaya fruits were conducted on the basis of colour, flavour, taste, texture and overall acceptability by a panel of ten judges consisting of teachers and post-graduate students of College of Horticulture, Bagalkot using nine point hedonic scale i.e., 9 - like extremely, 8-like very much 7-like moderately, 6- like slightly, 5- neither like nor dislike, 4-dislike slightly, 3-dislike moderately, 2-dislike very much, 1-dislike extremely.

Shelf life

The number of days of the ripe fruits were in edible condition was taken as the shelf-life or keeping quality of ripe fruits.

Statistical analysis

The data of experiment was analyzed as applicable to completely randomized design (CRD). Statistical analyses of experiments were performed using Web Agri Stat Package (WASP) Version 2 (Jangan and Thali, 2010) [18]. The level of significance used in 'F' and't' was p=0.01 and p=0.05 for some parameters. Critical difference values were calculated whenever F-test was found significant.

Table 1: Effect of different concentrations of polyamines on total soluble solids (^{0}B), titratable acidity (%) and Carotenoids (mg 100 g^{-1}) of papaya cv. red lady fruits under ambient storage

Treatments	Total soluble solids (^{0}B)					Titratable acidity (%)					Carotenoids (mg 100 g^{-1})				
	Days of storage					Days of storage					Days of storage				
	3	6	8	9	Mean	3	6	8	9	Mean	3	6	8	9	Mean
T_1 – Control	10.84	12.64	14.15	16.72	13.59	0.24	0.21	0.14	0.12	0.18	0.83	0.93	0.98	1.18	0.98
T_2 - Spermine @ 0.50 mM L^{-1}	9.77	12.22	13.12	15.24	12.59	0.28	0.24	0.17	0.15	0.21	0.80	0.85	0.93	1.05	0.91
T_3 -Spermine @ 1 mM L^{-1}	9.69	12.03	12.93	15.38	12.51	0.30	0.25	0.18	0.17	0.23	0.78	0.83	0.91	0.99	0.88
T_4 - Spermine @ 1.5 mM L^{-1}	9.27	11.73	12.49	14.63	12.03	0.35	0.29	0.23	0.21	0.27	0.72	0.77	0.84	0.94	0.82
T_5 - Spermidine @ 0.50 mM L^{-1}	10.00	12.32	13.43	15.70	12.86	0.24	0.2	0.15	0.13	0.18	0.82	0.89	0.96	1.09	0.94
T_6 -Spermidine @ 1 mM L^{-1}	9.90	12.22	13.24	15.36	12.68	0.27	0.23	0.16	0.14	0.20	0.81	0.87	0.95	1.06	0.92
T_7 - Spermidine @ 1.5 mM L^{-1}	9.19	11.17	12.23	14.56	11.79	0.38	0.35	0.25	0.23	0.30	0.68	0.74	0.81	0.92	0.79
T_8 - Putrescine @ 2 mM L^{-1}	9.62	12.17	12.90	14.99	12.42	0.32	0.28	0.19	0.17	0.24	0.76	0.81	0.89	0.97	0.86
T_9 -Putrescine @ 3 mM L^{-1}	9.51	12.01	12.74	14.84	12.28	0.34	0.31	0.22	0.20	0.27	0.74	0.79	0.87	0.96	0.84
T_{10} - Putrescine @ 4 mM L^{-1}	8.62	10.19	11.15	13.65	10.90	0.42	0.39	0.29	0.27	0.34	0.66	0.72	0.78	0.89	0.76
Mean	9.64	11.87	12.84	15.11		0.31	0.28	0.20	0.18		0.76	0.82	0.89	1.01	
S.Em±	0.17	0.25	0.22	0.25		0.05	0.03	0.02	0.03		0.03	0.01	0.02	0.04	
CD @ 1%	0.72	1.01	0.88	1.02		0.07	0.04	0.03	0.04		0.11	0.12	0.13	0.15	

Table 2: Effect of different concentrations of polyamines on sensory evaluation (flesh colour, visual appearence, flavour and taste) of papaya cv. red lady fruits under ambient storage

Treatments	Sensory evaluation														
	Flesh colour					Visual appearance					Flavour and Taste				
	Days of storage					Days of storage					Days of storage				
	3	6	8	9	Mean	3	6	8	9	Mean	3	6	8	9	Mean
T_1 – Control	8.01	5.23	3.09	--	4.08	7.91	5.06	3.05	--	4.00	8.19	6.05	3.13	--	4.34
T_2 - Spermine @ 0.50 mM L^{-1}	8.40	7.86	7.19	6.14	7.39	8.27	7.71	7.02	5.62	7.15	8.56	8.14	7.05	6.07	7.45
T_3 -Spermine @ 1 mM L^{-1}	8.49	8.03	7.36	6.39	7.56	8.34	7.94	7.10	5.97	7.33	8.65	8.34	7.27	6.39	7.66
T_4 - Spermine @ 1.5 mM L^{-1}	8.75	8.47	7.64	7.11	7.99	8.81	8.47	7.69	7.04	8.00	9.00	8.52	7.74	7.09	8.08
T_5 - Spermidine @ 0.50 mM L^{-1}	8.19	6.87	5.84	4.95	6.46	8.07	6.64	6.64	5.28	6.65	8.37	6.56	5.67	4.21	6.20
T_6 -Spermidine @ 1 mM L^{-1}	8.22	7.01	6.02	5.61	6.71	8.14	7.58	5.44	4.07	6.30	8.40	6.87	5.86	4.59	6.43
T_7 - Spermidine @ 1.5 mM L^{-1}	9.00	8.64	7.87	7.41	8.23	9.00	8.54	7.81	7.58	8.23	9.00	8.61	7.81	7.28	8.17
T_8 - Putrescine @ 2 mM L^{-1}	8.57	8.18	7.39	6.51	7.66	8.54	8.07	7.38	6.39	7.59	8.86	8.29	7.43	6.64	7.80
T_9 -Putrescine @ 3 mM L^{-1}	8.64	8.36	7.58	6.78	7.84	8.75	8.29	7.54	6.78	7.84	9.00	8.47	7.59	6.94	8.00
T_{10} - Putrescine @ 4 mM L^{-1}	9.00	8.89	8.17	7.86	8.48	9.00	8.81	8.05	7.77	8.40	9.00	8.87	8.09	7.62	8.39
Mean	8.52	7.75	6.81	5.87		8.48	7.71	6.77	5.65		8.70	7.87	6.76	5.68	
S.Em±	0.98	0.88	0.79	0.68		0.98	0.92	0.80	0.71		0.99	0.83	0.78	0.70	
CD @ 1%	NS	NS	3.20	2.78		NS	NS	2.38	2.88		NS	NS	3.18	2.84	

Table 3: Effect of different concentrations of polyamines on sensory evaluation (texture, overall acceptability), shelf life (days) and total phenols (mg GAE/100g) of papaya cv. red lady fruits under ambient storage

Treatments	Sensory evaluation										Shelf life (days)	Total phenols (mg GAE/100g)				
	Texture					Overall Acceptability										
	Days of storage					Days of storage						Days of storage				
	3	6	8	9	Mean	3	6	8	9	Mean		3	6	8	9	Mean
T_1 – Control	7.64	5.04	3.80	--	4.12	7.93	5.34	3.99	--	4.31	4.66	138.07	92.09	71.18	29.37	82.68
T_2 - Spermine @ 0.50 mM L^{-1}	8.12	7.74	6.82	5.56	7.06	8.33	7.86	7.29	5.84	7.33	6.00	167.34	121.35	100.44	54.46	110.90
T_3 -Spermine @ 1 mM L^{-1}	8.23	7.91	7.01	5.89	7.26	8.42	8.05	7.45	6.16	7.52	6.33	175.69	133.89	108.81	62.82	120.30
T_4 - Spermine @ 1.5 mM L^{-1}	8.89	8.47	7.76	6.94	8.01	8.86	8.48	7.90	7.04	8.07	6.66	200.78	171.52	133.89	100.44	151.66
T_5 - Spermidine @ 0.50 mM L^{-1}	7.89	6.56	5.12	4.06	5.90	8.13	6.65	6.04	4.62	6.36	5.33	150.61	104.63	83.72	37.73	94.17
T_6 -Spermidine @ 1 mM L^{-1}	8.01	6.67	5.34	4.86	6.22	8.19	7.03	5.91	4.78	6.47	5.66	158.97	112.99	92.09	46.10	102.54
T_7 - Spermidine @ 1.5 mM L^{-1}	9.00	8.67	7.98	7.45	8.27	9.00	8.61	8.06	7.43	8.27	8.66	209.14	179.88	146.43	112.98	162.11
T_8 - Putrescine @ 2 mM L^{-1}	8.45	8.07	7.38	6.29	7.54	8.60	8.15	7.61	6.45	7.70	7.33	184.06	146.43	117.17	75.36	130.76
T_9 -Putrescine @ 3 mM L^{-1}	8.75	8.24	7.44	6.67	7.77	8.78	8.34	7.75	6.79	7.90	7.66	192.42	158.97	125.53	87.90	141.21
T_{10} - Putrescine @ 4 mM L^{-1}	9.00	8.80	8.10	7.67	8.39	9.00	8.84	8.29	7.73	8.46	9.00	230.04	200.78	171.52	121.35	180.92
Mean	8.39	7.61	6.67	5.53		8.52	7.73	7.02	5.68		6.72	180.71	142.25	115.08	72.85	
S.Em±	0.95	0.85	0.74	0.64		0.96	0.88	0.80	0.66		0.25	8.45	7.00	5.92	4.32	
CD @ 1%	NS	NS	3.00	2.60		NS	NS	2.39	2.68		0.99	34.01	28.17	23.82	17.41	

Results and Discussion

Total soluble solids (^{0}Brix)

The total soluble solids acts as a rough index of the amount of sugars present in fruits, as sugar constitute about 80-85 per cent of total soluble solids. Hydrolysis of starch and accumulation of sugars are the most striking chemical changes that occur during the post-harvest ripening of banana fruit (Archana and Suresh, 2018) [3].

In the present study, under ambient condition the fruits treated with putrescine @ 4mM showed minimum total soluble solids of 13.65°B. The control fruits expressed highest value for total soluble solids (16.72°B) (Table 1). The results indicated that the conversion of starch into sugars was rapid in control fruits than treated fruits. Higher TSS and sugars in control fruits may be due to increased water loss and hydrolysis of starch in to the simple sugars, and such conversion might have taken place at a slower rate in polyamines treated fruits in comparison to untreated fruits (Bregoli *et al*., 2002) [8]. Total soluble solids of papaya fruits was found to be increased considerably during the storage in all the treatments. Increase in TSS content of fruits might be attributed to increase in soluble solids, soluble pectin, soluble organic acids, *etc.*

The postulate of effect of putrescine on minimum per cent of sugar content is could be due to slow hydrolysis of starch into sugars, delayed ripening and senescence processes. An increase in amylase and phosphorylase activities is strongly correlated with starch degradation during papaya ripening. The polyamines may affect the activities of such enzymes involved in starch metabolism (Archana and Suresh, 2018) [3]. Apart from that in general, the effect of polyamines in reducing the TSS of papaya fruit was probably due to the slowing down of respiration and metabolic activity, hence retarding the ripening process. It is well documented that the filmogenic property of polyamine results in an excellent semi-permeable film around the fruit, modifying the internal atmosphere by reducing O_2 and/or elevating CO_2 and suppressing the ethylene evolution. A suppressed respiration rate also slows down the synthesis and the use of metabolites, resulting in lower TSS due to the slower hydrolysis of carbohydrates to sugar. Similar results have been reported in papaya (Ali *et al.*, 2011; Asgar *et al.*, 2011) [1, 4] and bell pepper (Gholamipour *et al.*, 2010; Mustafa and Kenan, 2010) [15, 37]. The delayed changes in putrescine treated fruits might be mediated through the slower conversion of starch to sugar, reduction or delay in ethylene production and in turn the delay in ripening. These results are in accordance with findings by Khan *et al.* (2008) [24] and Bal (2012) [5]. The effect of putrescine on gradual variation in TSS has also been reported in pomegranate (Burman *et al.,* 2011 and Mirdehghan *et al.,* 2007) [6, 35] and in mango (Malik *et al.,* 2006) [32].

Titratable acidity (%)

In the present study, titratable acidity (TA) was higher during initial stage and then decreased by the end of storage. The fruits treated with T_{10} (putrescine @ 4mM) recorded highest TA during storage. The treatment, T_{10} showed highest titratable acidity of 0.27% followed by T_7 (0.23%) at 9 days of storage (Table 1). This might be due to the reason that, as the ripening advances, increase in acidity could be justified by the formation of organic acids produced by enzymes, such as pectinmethylesterase and polygalacturonase that degrade the cell wall during the ripening of papaya with a drop in pH. Similar results were reported by Oliveira *et al.* (2004) [39]; Lodh *et al.* (1971) [30] and Madamba *et al.* (1977) [31]. These results are similar to the findings of Wills *et al.* (1984) [53] who reported that, the titratable acidity per cent of the fruit increased during ripening of the fruit and then decreased due to the apparent stability observed as an indicator of metabolic stability, because the same serve as substrate for such reactions as respiration and production of volatiles during ripening (Reboucas *et al.,* 2013; Jayathunge *et al.,* 2011) [43, 20]. It also confirms the earlier findings by Pinto *et al.* (2006) [41] who reported a similar fact while storing papayas "Golden" and assigned this lower tendency to acidification to a reduced accumulation of CO_2, caused by lower metabolic activity.

This was mainly due to papaya fruits treated with putrescine @ 4mM which reduced the respiration and transpiration rate that might have slowly decreased the acid content. It was also reported that, acidity decreases with ripening and senescence. Similar results have been reported in papaya (Ali *et al.,* 2011 and Asgar *et al.,* 2011) [1, 4], tomato (Padmini, 2006) [40].

Carotenoid (mg 100 g^{-1})

The total carotenoid content of papaya fruits increased with increasing ripening. The disappearance of chlorophyll is often associated with the synthesis and/or the revelation of pigments ranging from yellow to red. Many of these pigments are carotenoids, which are unsaturated hydrocarbons with generally 40 carbon atoms and sometimes one or more oxygen atoms in the molecule. Carotenoids are stable compounds and remain intact in the tissue even when extensive senescence has occurred (Wills *et al.,* 2007) [54].

The total caroteniod content of papaya fruits increased with increasing ripening. There were significant changes in caroteniod content of papaya fruits, as influenced by post harvest application with polyamines. In ambient storage conditions, T_1 (control) papaya fruits recorded maximum amount of caroteniod of 1.18 mg/100 g at 9 days of storage. While, papaya fruits treated with T_{10} (putrescine @ 4mM) registered minimum amount of carotenoids of 0.89 mg/100 g at 9 days of storage (Table 1.).

The putrescine @ 4mM treated fruits, beta carotenoids content was lowest compared to control. However, in polyamines treated fruits, beta carotene content increased rapidly due to the carotenoids pigments expressed concurrently with chlorophyll degradation. Whereas, beta carotene content of putrescine @ 4mM treated fruits recorded the lesser chlorophyll degradation of fruits during storage. In addition, the temperature during storage condition affect the pathways involved in biosynthesis of carotenoids, lead to lower carotene content of papaya fruit. Similar results have been reported in papaya (Barrera *et al.,* 2015) [7].

Total phenol content (mg GAE /100g)

Phenolic-related compounds, phenols and flavonoids are of great interest as their qualitative and quantitative differences appear to be functions of fruit quality (Fernandez *et al*., 1992) [13]. Also, phenolics play an important role in sensory qualities such as colour and flavour (Herrmann, 1990) [17]. Moreover, the enhancement of phenols and flavonoids is a defence system against biotic and abiotic stresses (Katoh *et al.,* 2009) [22]. The contents of phenolics were influenced by the degree of maturity at and after harvest, genetic differences (cultivar), pre harvest storage conditions and processing (Zadernowski *et al.,* 2005) [56].

In this study, total phenols decreased with the increase in storage period irrespective of the treatments. Decline in phenolics with advancement of the storage period may be attributed to the activity of poly phenol oxidase. The loss in astringency, which occurs during ripening is probably connected with increased polymerization of tannins, as reported by Mellentehin and Wang (1977) [34]. In ambient storage conditions, T_1(control) papaya fruits recorded minimum total phenol content of 29.37 mg GAE /100 g at 9 days of storage. While, papaya fruits treated with T_{10} (putrescine @ 4mM) registered maximum total phenol content of 121.35 mg GAE/100 g at 9 days of storage (Table 3). The slower rate of degradation of phenolics in polyamine treated fruits apparently indicates that they play an important role in delaying the activity of polyphenoloxidase enzymes due to delay the respiratory activity of the fruits (Jhalegar *et al.,* 2011) [21]. Seiler and Raul (2005) [46] and Kusano *et al.* (2007) [28] have reviewed the role of polyamines in plants and reported that they help to maintain or increases the content of phenolic compounds in fruits.

Shelf life (days)

Shelf life of papaya fruits is interconnected with fruit disease index parameter. The changes were observed in shelf life of papaya cv. Red Lady fruits, which was influenced by postharvest application of polyamines under ambient storage condition.

Significantly maximum shelf-life was observed in the fruits treated with putrescine @ 4Mm (9 days) and minimum shelf-life was recorded in the control fruits (4.66 days) under ambient storage (Table 3). The maximum shelf-life of papaya is obtained by slow ripening (Marriott and Lancaster, 1983) [33]. The shelf-life of papaya increased with the exogenous application of polyamines by retarding fruit softening, weight loss, inhibiting in respiration rate, colour development and delaying ripening process without affecting organoleptic properties of the fruit. In many plant system, leaf and fruit ageing and senescence is correlated with a decrease in polyamine levels. The exogenous application of polyamines often delays or prevents progression of senescence (Kaur *et al.,* 1982) [23]. The honey dew melon fruits treated with exogenous putrescine reduced membrane peroxidation indicated by lower production of malondialdehyde, decreased lipoxygenase and phospholipase-D activities and decreased petrubation of plasma membrane (Lester, 2000) [29]. This anti-senescence property of polyamines is the main reason to improve the shelf-life of fruits under storage. Since, these compounds affect ethylene production and expression of genes involved in ethylene bio-synthesis, this hormone is likely to influence the mode of action by which these polyamines affect shelf-life (Torrigiani *et al.*, 2004) [51].

The polyamines has been reported to improve the shelf-life of fruits as reported by Dibble *et al.* (1988) [11] in tomato, Mirdehghan *et al.* (2007) [35] in pomegranate, Khoshroshahi *et al.* (2007) [25] in strawberry, Jawandha *et al.* (2012) [19] in mango, Shiri *et al.* (2013) [48] in grapes and in papaya (Novita and Purwoko, 2004) [38].

Sensory evaluation (9 point hedonic scale)

There were significant changes in sensory evaluation of papaya fruits, as influenced by postharvest application of polyamines. Control papaya fruits were recorded lesser sensory score. While, putrescine @ 4mM (T_{10}) treated fruits recorded higher score for overall acceptability of 7.73 during 9 days under ambient storage.

In general, colour increases the attractiveness of fruits. Surface colour is important for choosing fruits in the market and internal colour is also important to influence overall acceptability during consumption. Maximum score for texture, visual attractiveness, flavour and overall acceptability was noted in the treatment T_{10} (putrescine @ 4mM) (Table 2 & 3) and this could be due to treatment with polyamines as it maintained greater firmness and delayed membrane lipid peroxidation in fruits. Exogenous application of polyamines may also induce the expression of many defense genes during fruit storage.

Colour changes in papaya during ripening have been used as rough guide to the stage of ripeness in many papaya cultivars (Thompson, 1996) [50]. The change in papaya peel and pulp colour during ripening in papaya is associated with the breakdown of chlorophylls, with carotenoid levels remaining relatively constant (Seymour, 1985) [47]. The maximum score for flesh colour (8.48) and visual appearance (8.40) was noticed in the fruits treated with putrescine @ 4 mM in comparison to control (Table 2). The poor skin colour is attributed to over ripe fruit in control and the maximum score for skin colour in putrescine treated fruits are attributed to greenness of peel due to delayed ripening. During ripening of papaya, the flesh colour changes from the typical opaque white of a product with high starch content to a very soft yellow as the skin intensifies (Salvador *et al.*, 2007) [44]. As polyamines treated fruits add maximum per cent of starch in comparison to the control the fruits showed opaque white colour and scored maximum in comparison to control fruits.

The very good score for texture (8.39) was noticed in putrescine @ 4mM treated fruits. It is important to ascertain pulp texture during maturation. The crisp hard and green fruit turns into a yellow fruit with tender and soft internal pulp at a optimal ripening stage and become mushy as it advance towards senescence. The low texture during ripening leads to lower quality and higher incidences of mechanical damage during handling and transportation (Dadzie and Orchard, 1977) [10]. The loss of texture is associated with two or three processes. The first is the breakdown of starch to form sugar. The second is the breakdown of the cell walls or reduction in the middle lamella cohesion due to solubilisation of pectin substances (Smith, 1989) [49]. The lower for control fruits might be due to mushy of soft texture due to over ripening. While, the maximum score for putrescine treated fruits is due to maximum firmness of the fruits as polyamines link to carboxylic group of pectic substance in the cell wall, resulting in rigidification in turn inhibits loss of texture (Archana and Suresh, 2018) [3].

The taste and flavour of any fruit is influenced by the proportion of sugars, acids, voltailes and firmness factors influencing the mouth feel. The taste and flavour (8.39) is maintained by putrescine treated fruits due to delayed ripening while it reduced in control fruits as fruits were in scenscence stage at the end of the storage period. The maximum overall acceptability (8.46) was recorded in putrescine @ 4 mM treated fruits and minimum for control fruits (Table 3). This may be due to good appearance, better texture and skin colour. The postharvest dip treatment of polyamines resulted in better organoleptic quality, especially in terms of flesh texture, colour and appearance and taste. The similar findings were reported in grapes (Champa *et al.*, 2014 and Shiri *et al.*, 2013) [9, 48], mango (Jawandha *et al.*, 2012) [19] and in strawberry (Khosroshahi *et al.*, 2007) [25].

Conclusion

Results of the study revealed that, post-harvest application of polyamines influence on biochemical quality characteristics and shelf life of papaya fruit and thereby overall quality improvement was observed during ambient storage. The fruits treated with putrescine @ 4mM (T_{10}) recorded significantly minimum total soluble solids, ß-carotene and maximum titratable acidity, total phenols and shelf life and sensory scores. Hence, it is confirmed from the study that the Putrescine at 4 mM was found to be effective in delaying the biochemicals and ripening of papaya fruits and maintaining the organoleptic qualities of papaya fruits.

References

1. Ali A, Muhammad MTM, Sijam K, Siddiqui Y. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food Chem. 2011;124:620-26.
2. Anonymous. Papaya area, production, gov.in/statistics/area-production-statistics.html. 2018.
3. Archana TJ, Suresh GJ. Putrescine and spermine affects the postharvest storage potential of banana cv. Grand Naine. Int. J Curr. Microbiol. App. Sci. 2018;8(1):3127-3137.
4. Asgar A, Mahmud TMM, Kamaruzaman S, Yasmeen S. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya* L.) fruit during cold storage. Food Chem. 2011;124:620-626.
5. Bal E. Effect of postharvest putrescine and salicylic acid treatments on cold storage duration and quality of sweet cherries. J Fac. Agric. 2012;7:23-31.
6. Burman K, Asrey R, Pal RK. Influence of putrescine and carnauba wax on functional and sensory quality of pomegranate (*Punica granatum* L.) fruits during storage. Sci. Hort. 2011;130:795-800.
7. Barrera E, Gil J, Restrepo A, Mosquera K, Durango D. A coating of chitosan and propolis extract for the postharvest treatment of papaya (*Carica papaya* L. cv. Hawaiiana). Nat. Agric. 2015;68:7667-7678.
8. Bregoli A, Scaramagli S, Costa G, Sabatini E, Ziosi V, Biondi S, *et al*. Peach (*Prunus persica*) fruit ripening: Aminoethoxyvinylglycine (AVG) and exogenous polyamines affect ethylene emission and flesh firmness. Physiol. Plant. 2002;114:472-481.
9. Champa HWA, Gill MIS, Mahajan BVC, Arora NK.

Postharvest treatment of polyamines maintains quality and extends shelf-life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. Postharvest Biol. Tech. 2014;91:57-63.
10. Dadzie BK, Orchard JE. Postharvest screening of banana/plantain hybrids: Criteria and methods. International network for the improvement of tomato, Montpellier, France. 1977, pp. 47.
11. Dibble ARG, Davies PJ, Mutschler MA. Polyamine content of long keeping alcobacca tomato fruit. Pl. Physiol. 1988;86:338-340.
12. Di-mascio P, Kaiser S, Sies H. Lycopene as the most effective biological carotenoid singlet oxygen quencher. Arch. Biochem. Biophys. 1989;274:532-538.
13. Fernandez B, Perez J, Herna T, Cordove C, Estrella I. Importance of phenolic compounds for the characterization of fruit juices. J Agric. Food Chem. 1992;40:1531–1535.
14. Galston AW, Kaur-Sawhney R. Polyamines in plant physiology. Plant Physiol. 1990;94:406-410.
15. Gholamipour F, Kamari S, Ghasemnezhad M, Ghazvini RF. Effect of chitosan coating on weight loss and postharvest quality of green pepper (*Capsicum annum* L.) fruits. Acta Hort. 2010;8(5):869-877.
16. Giovannucci E. Tomatoes, tomato based products, lycopene and cancer: Review of the epidemiological literature. J Nat. Cancer Res. Inst. 1999;91:317-331.
17. Herrmann K. Significance of hydroxycinnamic acid compounds in food I. Antioxidant activity-effects on the use, digestibility and microbial spoilage of food. Chem. Microbiol. Technol. Lebensm. 1990;12:137–144.
18. Jangam AK, Thali P. ICAR Research Complex, Goa, Old Goa, Goa (India), 2010, pp. 402-403.
19. Jawandha SK, Gill MS, Gill PP, Singh N. Effect of postharvest of putrescine on storage of mango cv. Langra. African J. Agri. Res. 2012;7(48):6432-6436.
20. Jayathunge KGLR, Prasad HUKC, Fernando MD, Palipane KB. Prolonging the postharvest life of papaya using modified atmosphere packaging. J Agric. Technol. 2011;7(2):507-518.
21. Jhalegar MJ, Sharma RR, Pal RR, Rana V. Effect of postharvest treatments with polyamines on physiological and biochemical attributes of kiwifruit (*Actinidia deliciosa*) cv. Allison. Fruits. 2011;67:13–22.
22. Katoh H, Suzuki S, Saitoh T, Takayanagi T. Cloning and characterization of VIGG, a novel virus-induced grapevine protein, correlated with fruit quality. Plant Physiol. Biochem. 2009;47:291–299.
23. Kaur A, Shih R, Cegielska T, Galston AW. Inhibition of protease activity by polyamines-relevance for control of leaf senescence. FEBS Lett.1982;145:345-349.
24. Khan AS, Singh Z, Abbasi NA, Swinny EE. Pre or post harvest applications of putrescine and low temperature storage affect fruit ripening and quality of 'Angelino' plum. J. Sci. Food and Agric. 2008;88:1686-1695.
25. Khosroshahi M, Ashari M, Ershadi A. Effect of exogenous putrescine on post-harvest life of strawberry fruit, cv. Selva. Sci. Hort. 2007;114:27-32.
26. Kimura M, Rodriguez S, Amaya DB, Yokoyama SM. Cultivar differences and geographical effects on the carotenoid composition and vitamin A value of papaya. Lebens. Wissen. Technol. 1991;24:415-418.
27. Kumar LSS, Abraham NS. The papaya, its botany, culture and uses. J Bombay Nat. His. Soc. 1943;5(7):45-49.
28. Kusano T, Yamaguchi K, Berberich T, Taka-hashi Y. Advances in polyamine research. Curr. Topics Plant Res. 2007;120:345-350.
29. Lester GE. Polyamines and their cellular anti-senescence properties in honey dew muskmelon fruit. Plant Sci. 2000;160:105-112.
30. Lodh SB, Ravel P, Selvaraj Y, Kohli RR. Biochemical changes associated with growth and development of papaya. Indian J Hort. 1971;28:38-43.
31. Madamba LS, Baes AU, Mendoza DB. Effect of maturity on some bio-chemical changes during ripening of banana. J Food Chem. 1977;2(3):162-166.
32. Malik AU, Singh Z, Tan SC. Exogenous application of polyamines improves shelf life and fruit quality in mango. Acta Hort. 2006;699:291-296.
33. Marriott J, Lancaster PA. Banana and plantains *In*: Handbook of Tropical Food Chan, Inc. 1983, New York.
34. Mellentehin WM, Wang CY. The relationship of premature ripening of Bartlett pears to preharvest temperatures. Acta Hort. 1977;69:281-286.
35. Mirdehghan H, Rahem M, Castillo S, Martinez D, Serrano M, Valero D. Pre-storage application of polyamines by pressure or immersion improves shelf-life of pomegranate stored at chilling temperature by increasing endogenous polyamine levels. Postharvest Biol. Technol. 2007;44:26–33.
36. Mirdehghan SH, Rahimi S, Esmaeilizadeh M. Improving the postharvest characteristics of table grape by pre harvest application of polyamines. Acta Hort. 2013;1012:293-298.
37. Mustafa S, Kenan K. Biochemical and quality parameters changes of green sweet bell peppers as affected by different postharvest treatments. African J Biotech. 2010;9(4):8174-8181.
38. Novita T, Purwoko BS. Role of polyamine in ripening of solo papaya fruits (*Carica papaya* L.). J Hort. Sci. 2004;72: 371-377.
39. Oliveira LFG, Coelho ME, Berbet PA, Coelho FC. Evaluation of cultivar golden in storage in modified atmosphere package. Rev. Brasileira Amazon. 2004;29:137-142.
40. Padmini T. Studies behavior of tomatoes coated with chitosan-lysozyme films. M.Sc. (Hort.) Thesis, McGill Univ., Montreal, Quebec (Canada), 2006.
41. Pinto LKA, Martins MLL, Resende ED, Almeida RF, Vitorzi L, Pereira SMF. Influence of modified atmospheric film with potassium permanganate on quality of papaya in low temperature storage. Cienc. Technol. Amentos. 2006;26:744-748.
42. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products, 2nd Edition, Tata McGraw-Hill Pub. Co. 1986; New Delhi, India.
43. Reboucas JL, Machado FLC, Afonso MRM, Costa JMC. Postharvest conservation of papaya formosatainung 01 conditioned under different packaging systems. Int. J Sci. 2013;2:57-65.
44. Salvador AT, Sanz, Fiszman SM. Changes in colour and texture and their relationship with eating quality during storage of two different dessert bananas. Postharvest Biol. Technol. 2007;43:319-325.
45. Sankat CK, Maharaj R. Papaya. In: postharvest

physiology and storage of tropical and subtropical fruits, CAB International, London, 1997, pp. 167-189.
46. Seiler N, Raul F. Polyamines and apoptosis. J Cell Mol. Med. 2005;9:623-642.
47. Seymour GB. The effects of gases and temperature on banana ripening. Ph.D Thesis, University of California, USA, 1985.
48. Shiri MA, Ghasemnezhad M, Bakhshi D, Sarikhnai H. Effect of postharvest putrescine application and chitosan coating on maintaining quality of table grape cv. Shahroudi during long-term storage. J Food Process. Preserv. 2013;37:999-1007.
49. Smith NJ. Textural and biochemical changes during ripening of bananas. Ph.D. Thesis, Univ. Nottingham (England), 1989.
50. Thompson AK. Fruit ripening conditions. *In*: postharvest technology of fruits and vegetables. Blackwell Science Ltd., New York, 1996, pp. 186.
51. Torrigiani P, Bregoli AM, Ziosi V, Scaramagli S, Ciriaci T, Rasori A, *et al*. Pre-harvest polyamine and Aminoethoxy Vinyl Glycine (AVG) applications modulate fruit ripening in stark Red Gold nectarines (*Prunus persica* L. Batsch). Postharvest Biol. Technol. 2004;33:293-308.
52. Valero D, Romero M, Serrano M, Riquelme F. Influence of postharvest treatment with putrescine and calcium on endogenous polyamines, firmness, and abscisic acid in lemon (*Citrus limon* L Burm cv. Verna). J Agric. Food Chem. 1998;46:2102-2109.
53. Wills RB, Lim JS, Greenfield H. Changes in chemical composition of papaya (*Carica papaya* L.) during ripening. J Food Bio. Chem. 1984;8:69-77.
54. Wills RB, Mcglasson WB, Graham D, Joyce DC. Post-harvest - an introduction to the physiology and handling of fruits, vegetables and ornamentals. 5th Edition, CAB International, Oxford shire, UK, 2007.
55. Yamamoto HY. Comparison of the carotenoids in yellow and red fleshed *Carica papaya*. Nature. 1964;20:1049-1050.
56. Zadernowski R, Naczk M, Nesterowicz J. Phenolic acid profiles in some small berries. J Agric. Food Chem. 2005;53:2118–2124.