Enzymatic changes in plum (*Prunus salicina* Lindl.) subjected to some chemical treatments and cold storage.

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Abstract The objective of the present work is to see the effect of different chemical treatments on pectin methylesterase (PME) activity and softening of the fruits. Purple plums (cv. Satluj) fruits were harvested at colour break stage and treated for 5- minutes in aqueous solutions of salicylic acid at 138, 276 and 414 ppm, Ascorbic acid at 10,000, 20,000 and 30,000 ppm, and Gibberelic acid at 20, 40 and 60 ppm. For control the fruits were dipped in distilled water. Treated fruits were stored at low temperature conditions for 40 days. Physico chemical characteristics and PME activity were determined at 10 day interval. The colour of the fruits improved with respect to a* and b* values progressively throughout the storage, whereas, fruit firmness decreased. Total sugars and PME activity increased before showing a declining trend. Pre-storage application of salicylic acid (414 ppm) significantly delayed colour development. Fruits treated with salicylic acid (414 ppm) retained highest firmness, total sugars and PME activity at the end of storage.

Keywords Plum · Pectin methylesterase · Fruit firmness · Salicylic acid · Ascorbic acid · Gibberelic acid · Fruit softening

Introduction

Satluj Purple is an important cultivar of plum (*Prunus salicina* Lindl.), which performs well under subtropical climatic conditions. It is becoming popular among fruit growers of Punjab, India due to its early ripening behaviour, better size and excellent colour and quality. The fruits of this cultivar are available in different markets of Punjab in middle of May, when very few other fruits are available, thus sell for good prices. Quality deterioration of plum occurs soon after harvest. The fruit is highly susceptible to textural softening, fruit decay and loss of flavour during storage due to continued respiration and metabolic activities related to ethylene production (Valdes et al. 2009). Excessive softening is a major factor limiting the shelf life of plums (Crisosto et al. 2004). Fruit softening is the ripening-related process most sensitive to ethylene (Lelievre et al. 1997) and a suitable predictor of potential shelf-life for plums, when decay or chilling injury (CI) symptoms are not limiting factors. Plums ripened to a soft melting texture are considered ‘ready to eat’. A basic process underlying firmness loss is the breakdown of cell wall. This process has an enzymatic base which results in breakdown of the pectic moiety of the cell wall. Cell wall disassembly can result due to degradation (Brummell and Harpster 2001), solubilisation, and depolymerisation (Della-Penna et al. 1990) of pectic substances which are mainly deposited in the cell wall and the middle lamella. Pectic substances are derivatives of polygalacturonic acids and form protopectins, pectinic acids, pectin and pectic acids (Kertesz 1951). During ripening pectinates and soluble pectate content increase which leads to fruit softening (Loesecke 1950). PME is

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the enzyme which is responsible for demethylating the 6th carbon of galacturonosyl residue where PG acts on the methylated substrate (Koch and Nevins 1989). PG and PME cooperatively regulate the disassembly of cell wall. PG hydrolyses α -1-4 D Galacturonic acid, allowing de-esterification of pectin by PME. Demethylation changes the pH in the cell wall, leaving polyuronides susceptible to degradation by PG. This research aims to shed some light on (1) physico chemical changes in plum *cv.* Satluj Purple during cold storage for 40 days and (2) to study the influence of different prestorage chemical treatments on PME activity during cold storage. Being anti-oxidant and antisenescent, the chemicals selected were salicylic acid, ascorbic acid and gibberelic acid.

Materials and methods

Plant material and experimental design

Satluj Purple plums were harvested at colour break stage from an orchard in Ludhiana, Punjab, India. Physiologically mature, uniform and healthy fruits were selected and treated for 5- minutes in aqueous solutions of salicylic acid at 138, 276 and 414 ppm (T1, T2 and T3), Ascorbic acid at 10,000, 20,000 and 30,000 ppm (T4, T5 and T6), and Gibberelic acid at 20, 40 and 60 ppm (T7, T8 and T9). For control the fruits were dipped in distilled water (T10). Treated fruits were air dried under shade before packaging. For storage studies 1.0 kg fruits from each replication of each treatment were packed in corrugated fibreboard (CFB) boxes (5 % perforation) with paper lining and kept at low temperature conditions (0–1 °C and 90–95 % RH) for 40 days. Fruit samples were analysed after 10, 20, 30 and 40 days of storage for various physicochemical characteristics. The analyses were conducted in triplicate.

Physicochemical analysis

Soluble solids concentration (SSC)

The juice of ten randomly selected mature fruits in three replications was extracted by crushing and then strained through muslin cloth. SSC content of juice was determined with the help of a hand refractometer (Erma, Japan) in terms of Brix (%).

Titrateable acidity (TA)

Two mL of strained juice were diluted to 20 mL with distilled water and then titrated against 0.1 N NaOH solution using phenolphthalein as an indicator. The end point was noted with

change in colour from colourless to light pink. The acidity was expressed as ppm of anhydrous malic acid.

Juice pH

The juice of ten randomly selected mature fruits was extracted and strained through muslin cloth. pH of juice was determined with the help of a digital PICO pH meter (Labindia).

Fruit colour

Fruit colour was recorded for the with the help of a benchtop, ColorFlex EZ spectrophotometer, Reston, Virginia, USA. (Hunter 1975).

Fruit firmness

Firmness of ten randomly selected fruits was measured with the help of fruit pressure tester (Bertuzzi penetrometer) Model FT-327, Facchini, Alfonsine, Italy. About one square centimetre of the peel in each fruit from the shoulder end on both sides was removed with the help of a peeler and firmness of pulp was recorded and expressed in terms of kgf.

Total sugars

Total sugars were estimated by Lane and Eynon's titration method as reported by Ranganna (1986).

$$\begin{aligned} \text{Total sugars (\%)} = & \frac{\text{Fehlings Factor (0.05)}}{\text{Volume of filtrate used}} \\ & \times \frac{\text{Dilution made}}{\text{Weight of sample taken}} \\ & \times \frac{\text{Final volume made}}{\text{Volume of filtrate taken}} \times 100 \end{aligned}$$

Pectin methylesterase activity (PME)

PME extract

For enzyme extraction, fruit samples 100 g from each replication were stored immediately after harvest in a freezer for initial reading and for subsequent intervals fruit was directly taken from cold storage. Twenty grams of fruit pulp were blended in 60–100 mL NaCl solution (0.15 M), filtered through two layers of cheese cloth and centrifuged at 2000 rpm for 30 minutes at 4 °C. The supernatant was used as an enzyme source (Mahadevan and Sridhar 1982).

PME assay

PME activity was determined by measuring the increase in acidity after pectin hydrolysis by the enzyme. Pectin (1 g) dissolved in 100 mL of NaCl (0.2 M) was blended and passed through two layers of cheese cloth. For PME assay, 20 mL of the above solution was adjusted to 7.0 pH.

Ten mL of the enzyme solution was added in it and pH of this reaction mixture was immediately adjusted to 7.0 by adding 1 N NaOH. The reaction mixture was incubated in a water bath at 30 °C for 60 minutes. pH of the reaction mixture was measured and the reaction mixture was titrated back to pH 7 with 0.02 N NaOH at every 15 minute interval. Control was maintained with boiled enzyme as enzyme source. The activity was expressed as mL of 0.02 N NaOH required to maintain pH 7 (Mahadevan and Sridhar 1982).

Statistical analysis

The experimental design used was Factorial Completely Randomized Block Design (CRD) as described by Singh et al. (1998) and the data was analysed using SAS/STAT® (2011).

Results and discussion

Soluble solids concentration (SSC)

SSC at harvest was 10.8⁰Brix, which increased up to 20 days of storage irrespective of treatments (Table 1). The reason for the increase in total soluble solids could be attributed to water loss and hydrolysis of starch and other polysaccharides to soluble form of sugar. Wills et al. (1980) reported that starch is hydrolysed into mono and disaccharides, which in turn may

lead to an increase in TSS. With further increase in storage up to 30 days, the SSC was found to decline in all the treatments except in salicylic acid (414 and 276 ppm) and gibberellic acid (60 ppm) treatments (Table 1). The effect of treatments was significant and a higher concentration of salicylic acid (414 ppm) maintained a slow ripening process that resulted in maximum SSC values (12.93 %) towards the end of storage. SSC value is an indicator of maturity and ripening in fruits. The slower rates of increase in SSC values indicate that salicylic acid delayed the ripening process of plum fruits. Salicylic acid has been found effective in reducing respiration rates and metabolic activities and hence slowing down of ripening process (Pila et al. 2010). The results of present study are in agreement with the findings of Kaundal et al. (2000) who reported that during plum storage TSS and total sugars increased up to 20 days after storage and then progressively declined. Our findings also agree with Salari et al. (2013) and Srivastava and Dwivedi (2000) who found salicylic acid waseffective in delaying the increase in SSC in strawberry and banana fruits, respectively.

Titratable acidity and juice pH

The titratable acidity and juice pH followed a trend opposite to each other. Titratable acidity values in all treatments decreased significantly ($p > 0.05$) throughout the storage period, while the juice pH values increased significantly irrespective of treatments (Table 2). Maximum loss in TA was found in control and ascorbic acid at 10,000 ppm treated fruits. The decreasing pattern in acidity was much slower in samples treated with salicylic acid at 414 ppm followed by 276 ppm concentration that indicates the shelf stability of fruit (Table 2). Both SSC and TA are good indicators of fruit quality (Abdi et al. 1997). The Juice pH progressively increased with the

Table 1 Soluble solids concentration of plum fruits subjected to different chemical treatments under cold storage

Treatments	Soluble solids concentration (SSC)					
Storage interval (days)	0	10	20	30	40	Mean
T1-Salicylic acid 138 ppm	10.80	12.50	13.10	13.00	12.60	12.80
T2-Salicylic acid 276 ppm	10.80	12.20	12.70	13.20	12.80	12.70
T3-Salicylic acid 414 ppm	10.80	12.10	12.60	13.10	12.90	12.70
T4 -Ascorbic acid 10,000 ppm	10.80	13.20	13.70	12.60	12.10	12.90
T5 -Ascorbic acid 20,000 ppm	10.80	13.10	13.60	12.70	12.20	12.90
T6 -Ascorbic acid 30,000 ppm	10.80	12.90	13.60	12.80	12.30	12.90
T7-Gibberallic acid 20 ppm	10.80	12.70	13.40	12.80	12.40	12.80
T8-Gibberallic acid 40 ppm	10.80	12.60	13.10	12.90	12.50	12.80
T9-Gibberallic acid 60 ppm	10.80	12.40	12.80	13.10	12.70	12.70
T10 –Control	10.80	13.30	13.80	12.50	12.00	12.90
Mean	10.80	12.70	13.20	12.90	12.40	

CD (5 %) SSC,T:0.56,S:0.35,T × S:0.11

advancement of storage irrespective of treatments (Table 2). Juice pH is an indicator of acid composition. It may be suggested that titratable acidity declines in fruits as a result of breakup of acids to sugars during respiration. During maturation the fruit itself might utilize the acids so that the organic acid in the fruits during storage periods decrease (Bhattatai and Gautam 2006). Thus the sourness of plum fruit declines towards ripening and corresponding to this the pH value is increased. Titratable acidity and SSC contents are the prime contributors in determining the flavouring attributes of fruits (Raffo et al. 2007). Effectiveness of salicylic acid in maintaining titratable acidity of plum fruits is supported by the earlier findings of Han and Li (1997); Srivastava and Dwivedi (2000) and Davarynejad et al. 2015. The above authors showed that SA maintained higher acid content at the end of storage in apple and strawberry, respectively.

Fruit colour

Colour improved with the advancement of storage period. The mean minimum values for “a” and “b” (9.38 and 10.86, respectively) were noticed after storage of 10 days (Table 3). All the treatments resulted in a continuous increase in the “a” and “b” values with the increase in storage period and attained maximum value of 27.62 for ‘a’ and 23.55 for ‘b’ at the end of storage period (Table 3). The colour development during storage might be due to the degradation of the chlorophyll pigments of the fruits and increased synthesis of carotenoids and anthocyanin pigments (Wankier et al. 1970; Wang et al. 1971). The colour development was much faster in control fruits. However, fruits treated with salicylic acid at 414 and 276 ppm showed a significantly slower rate of colour development, indicating delayed ripening. The interaction between the treatments and storage period was significant. The

effectiveness of salicylic acid in delaying the skin colour development has been evaluated earlier in grapes (Asghari et al. 2013) and peach, where the highest luminosity (L) and lower anthocyanin (a) values were recorded in peach fruits treated with salicylic acid (Javed et al. 2012).

Fruit firmness

Fruit firmness decreased as the storage interval increased. Softening of fruits occurs due to the breakdown of insoluble protopectins into soluble pectins or by the cellular disintegration leading to increased membrane permeability (Mattoo et al. 1975). The maximum firmness (mean value) was recorded after 10 days of storage (2.12 kgf) and minimum (0.82 kgf) after 40 days (Table 4). After 10 days of cold storage, the minimum fruit firmness (1.95 kgf) was noted for control fruits. A similar trend was followed in 2nd, 3rd and 4th interval. During the entire storage period, the salicylic acid at 414 ppm retained the maximum (2.41–1.23 kgf) fruit firmness, were as, the minimum fruit firmness (1.95–0.44 kgf) was recorded in untreated fruits (Table 4). The interaction between treatment and storage period was found to be significant ($p > 0.5$). The role of salicylic acid in maintaining higher fruit firmness could be via its effectiveness in decreasing ethylene production. The suppression of loss in firmness may mostly be due to inhibitory effect of salicylic acid on 1-Aminocyclopropane-1-carboxylic acid (ACC) conversion to ethylene (Li et al. 1992). Similar results have been found in several crops such as strawberry (Babalar et al. 2007), apple (Mo et al. 2008) and Kiwifruit (Aghdam et al. 2010). This effect is attributed to the key role ethylene plays in triggering the induction of cell wall hydrolyzing enzymes (Wills et al. 1980). Moreover, salicylic acid affects cell swelling which leads to higher firmness of fruits (Zhang et al. 2003; Shafiee

Table 2 Titratable acidity and juice pH of plum fruits subjected to different chemical treatments under cold storage

Treatments	Titratable acidity % (TA)						Juice pH					
	0	10	20	30	40	Mean	0	10	20	30	40	Mean
Storage interval (days)												
T1-Salicylic acid 138 ppm	1.17	0.96	0.77	0.69	0.63	0.76	2.97	3.42	3.79	4.33	4.99	4.13
T2-Salicylic acid 276 ppm	1.17	1.08	0.83	0.72	0.67	0.83	2.97	3.14	3.51	3.76	4.34	3.68
T3-Salicylic acid 414 ppm	1.17	1.12	0.91	0.74	0.69	0.87	2.97	3.02	3.42	3.71	4.12	3.56
T4-Ascorbic acid 10,000 ppm	1.17	0.74	0.64	0.57	0.49	0.61	2.97	3.91	4.56	5.12	5.31	4.72
T5-Ascorbic acid 20,000 ppm	1.17	0.76	0.66	0.59	0.51	0.63	2.97	3.79	4.48	4.91	5.52	4.67
T6-Ascorbic acid 30,000 ppm	1.17	0.80	0.69	0.62	0.53	0.66	2.97	3.68	4.29	4.76	5.39	4.53
T7-Gibberallic acid 20 ppm	1.17	0.89	0.71	0.63	0.56	0.70	2.97	3.56	4.13	4.62	5.28	4.39
T8-Gibberallic acid 40 ppm	1.17	0.92	0.76	0.65	0.60	0.73	2.97	3.49	3.92	4.47	5.19	4.26
T9-Gibberallic acid 60 ppm	1.17	1.00	0.80	0.70	0.64	0.79	2.97	3.28	3.63	3.92	4.68	3.87
T10-Control	1.17	0.70	0.65	0.55	0.47	0.59	2.97	3.97	4.72	5.26	5.65	4.90
Mean	1.17	0.90	0.74	0.65	0.58		2.97	3.52	4.04	4.48	5.04	

CD (5 %) TA, T: 0.25,,S:0.25,T × S:0.51; Juice pH,T:0.18,S: 0.11,T × S:0.36

Table 3 Colour of plum fruits subjected to different chemical treatments under cold storage

Treatments	Storage interval (Days)											
	a*						b*					
	0	10	20	30	40	Mean	0	10	20	30	40	Mean
T ₁ -Salicylic acid 138 ppm	7.12	9.03	17.23	19.75	26.39	18.10	8.33	10.38	13.98	18.64	20.67	15.92
T ₂ -Salicylic acid 276 ppm	7.12	8.53	16.74	19.82	26.33	17.86	8.33	10.12	13.86	18.43	20.46	15.72
T ₃ -Salicylic acid 414 ppm	7.12	8.41	16.66	19.71	26.23	17.75	8.33	10.03	13.48	17.88	20.12	15.38
T ₄ -Ascorbic acid 10,000 ppm	7.12	10.04	19.41	23.36	28.93	20.44	8.33	11.31	16.43	19.68	23.95	17.84
T ₅ -Ascorbic acid 20,000 ppm	7.12	9.88	18.22	23.29	28.87	20.07	8.33	11.27	15.49	19.46	23.42	17.41
T ₆ -Ascorbic acid 30,000 ppm	7.12	9.76	18.03	23.01	28.42	19.81	8.33	11.03	15.12	19.22	22.44	16.95
T ₇ -Gibberallic acid 20 ppm	7.12	9.54	17.54	20.62	27.88	18.90	8.33	10.59	14.81	19.13	20.89	16.36
T ₈ -Gibberallic acid 40 ppm	7.12	9.32	17.37	20.45	26.58	18.43	8.33	10.49	14.75	18.92	20.74	16.23
T ₉ -Gibberallic acid 60 ppm	7.12	8.75	17.35	20.41	26.44	18.24	8.33	10.25	13.54	17.93	20.32	15.51
T ₁₀ -Control	7.12	10.53	19.79	25.22	30.14	21.42	8.33	13.15	21.22	28.97	32.44	23.95
Mean	7.12	9.38	17.83	21.56	27.62		8.33	10.86	15.27	19.83	22.55	

CD (5 %) Fruit colour a* value, T:0.25,S:0.16,T × S:0.51; b* value, T: 0.31,,S:0.20,T × S:0.63

et al. 2010). Delayed fruit softening in salicylic acid treated fruits has also been reported in earlier studies on banana fruits by inhibiting xylanase and cellulose (Srivastava and Dwivedi 2000) and kiwi fruits (Zhang et al. 2003; Wang et al. 2006). In, these studies, rapid softening of fruits during ripening was accompanied by rapid decrease in endogenous salicylic acid of fruits. The deterioration of cell membrane, known as a factor affecting fruit firmness, is related to lipid peroxidation. It has been reported that salicylic acid treatment helped in maintenance of cell membrane structure by reducing LOX (Lysyl oxidase) activity and superoxide free radical production in fruits (Zhang et al. 2003; Mo et al. 2008).

Total sugars

Fruit sugars are the main components of the SSC, accounting for 65–80 % of them (Brady 1993). The main sugars found in fresh plums were glucose, fructose and sucrose, although sorbitol, a sugar alcohol was also reported (Meredith et al. 1992). SSC is a critical factor in determining fruit quality. In the present investigation, the total sugars showed a progressive increase up to 20 days of cold storage in all treatments, there after a decline in total sugars was noticed in all treatments. However, the fruits treated with salicylic acid at 414 and 276 ppm and gibberellic acid at 60 ppm resulted in increase in total sugars up to 30 days of cold storage and declined

Table 4 Fruit firmness and total sugars of plum fruits subjected to different chemical treatments under cold storage

Treatments	Fruit firmness (Kgf)						Total sugars (%)					
	0	10	20	30	40	Mean	0	10	20	30	40	Mean
Storage interval (days)	0	10	20	30	40	Mean	0	10	20	30	40	Mean
T ₁ -Salicylic acid 138 ppm	2.82	2.15	1.76	1.33	0.97	1.42	7.43	9.49	9.68	9.53	8.76	9.37
T ₂ -Salicylic acid 276 ppm	2.82	2.24	1.94	1.43	1.16	1.69	7.43	9.24	9.43	9.67	9.00	9.34
T ₃ -Salicylic acid 414 ppm	2.82	2.41	1.96	1.49	1.23	1.77	7.43	9.12	9.37	9.69	9.12	9.33
T ₄ -Ascorbic acid 10,000 ppm	2.82	1.96	1.41	0.98	0.50	1.21	7.43	10.02	10.28	9.12	8.49	9.48
T ₅ -Ascorbic acid 20,000 ppm	2.82	2.03	1.44	1.00	0.56	1.26	7.43	9.96	10.15	9.19	8.57	9.47
T ₆ -Ascorbic acid 30,000 ppm	2.82	2.07	1.47	1.06	0.62	1.31	7.43	9.83	10.10	9.26	8.65	9.46
T ₇ -Gibberallic acid 20 ppm	2.82	2.09	1.51	1.12	0.74	1.37	7.43	9.75	9.98	9.32	8.63	9.42
T ₈ -Gibberallic acid 40 ppm	2.82	2.12	1.57	1.19	0.86	1.43	7.43	9.61	9.82	9.41	8.74	9.40
T ₉ -Gibberallic acid 60 ppm	2.82	2.19	1.86	1.38	1.09	1.63	7.43	9.37	9.52	9.65	8.88	9.36
T ₁₀ -Control	2.82	1.95	1.37	0.95	0.44	1.18	7.43	10.16	10.31	9.07	8.45	9.50
Mean	2.82	2.12	1.63	1.19	0.82		7.43	9.66	9.86	9.39	8.73	

CD (5 %) Fruit firmness, T:0.25,S:0.16,T × S:0.51; Total sugars, T: 0.25,,S:0.16,T × S:0.51

Table 5 PME activity of plum fruits subjected to different chemical treatments under cold storage

Treatments	Pectin methylesterase (PME) activity (ml of 0.02 N NaOH used)					
Storage interval (days)	0	10	20	30	40	Mean
T ₁ -Salicylic acid 138 ppm	1.21	1.68	1.84	1.57	1.42	1.62
T ₂ -Salicylic acid 276 ppm	1.21	1.52	1.62	1.67	1.59	1.60
T ₃ -Salicylic acid 414 ppm	1.21	1.33	1.65	1.69	1.61	1.57
T ₄ -Ascorbic acid 10,000 ppm	1.21	2.11	2.18	1.40	1.24	1.73
T ₅ -Ascorbic acid 20,000 ppm	1.21	1.99	2.13	1.46	1.29	1.71
T ₆ -Ascorbic acid 30,000 ppm	1.21	1.94	2.15	1.48	1.31	1.69
T ₇ -Gibberallic acid 20 ppm	1.21	1.89	1.98	1.52	1.37	1.69
T ₈ -Gibberallic acid 40 ppm	1.21	1.75	1.92	1.54	1.40	1.65
T ₉ -Gibberallic acid 60 ppm	1.21	1.61	1.76	1.59	1.47	1.60
T ₁₀ -Control	1.21	2.20	2.29	1.34	1.18	1.75
Mean	1.21	1.80	1.94	1.52	1.38	

CD (5 %) PME,T:0.81,S: 0.51,T × S:0.16

thereafter. Mean minimum total sugars of 8.73 % were recorded after 40 days and mean maximum total sugars of 9.86 % after 20 days of cold storage. After 10 days of storage, fruits under control showed maximum total sugars (10.16 %), followed by fruits treated with ascorbic acid at 10,000, 20,000 and 30,000 ppm respectively (Table 4). The minimum total sugars (9.12 %) were observed for fruits treated with 414 ppm in salicylic acid followed by those treated with 276 ppm of salicylic acid (9.24) and after 60 ppm of gibberellic acid (9.37). However, after 40th day of storage, the total sugars declined in all treatments. The maximum total sugars (9.12 %) were recorded in salicylic acid, followed by salicylic acid 276 ppm (9.00 %) treatments and minimum total sugars (8.45 %) were found in control fruits at 40th day of cold storage. Total sugars increased up to 20 days and later declined in all treatments except those treated with salicylic acid (414 and 276 ppm) and gibberellic acid (60 ppm). In these treatments the total sugar increased up to 30 days and then declined. The increase in total sugar content during cold storage might be attributed to physiological loss in weight of fruits and partly to hydrolysis of cell wall polysaccharides (Hulme and Rhodes 1971). Our results are in accordance with Sayyari et al. (2009) who reported a significantly slow reduction in total sugars in pomegranate fruit treated with salicylic acid. Awad (2013) treated peach *cv.* Flordaprince fruits with salicylic acid under cold stored conditions. He also reported that increasing salicylic acid concentration led to decrease in total sugar percentage in fruits.

Pectin methylesterase

Post-harvest treatment of salicylic acid at 414 ppm significantly lowered the PME activity as compared to control fruits. After 10 days of storage, the maximum PME activity (2.20) was recorded in control fruits, followed by ascorbic acid at 10,

000 ppm (2.11) treated fruits. The minimum PME activity (1.33) was noticed in fruits treated with 414 ppm salicylic acid. Similarly after 20 days of cold storage the maximum PME activity (2.29) was shown by control fruits and minimum PME activity (1.65) by salicylic acid (Table 5). At 30th and 40th day of storage the maximum PME activity was shown by fruits treated with 414 ppm salicylic acid, while the minimum PME activity was noticed in the reference fruits. The mean maximum PME activity (1.75) was shown by untreated fruits and the mean minimum PME activity (1.57) was shown by those treated with 414 ppm salicylic acid. During the first 10 days, the mean PME activity showed an increase of 49 %, while the increase was only 8 % during the next 10 days of cold storage. After 20 days of storage the maximum increase in PME activity was noticed in control fruits (104 %) and the minimum increase in PME activity (47 %) was observed in 414 ppm treated salicylic acid. However, the trend changed at the end of storage, where maximum PME activity (1.61) was recorded in salicylic acid at 414 ppm treated fruits and minimum PME activity (1.18) was noticed in untreated fruits. This might be due to the presence of high substrate level for PME activity at later stages in salicylic acid at 414 ppm treated fruits, which was already decomposed to the higher extent at the early stages of storage in other treatments. But, salicylic acid delayed the senescence and maintained the fruits in good condition up to 40 days of cold storage. PME activity increased up to 20 days of storage in all the treatments, before showing a decrease. This is in agreement with the previous study in mango (Ali et al. 2004). The decrease in PME activity at later stage of storage was also reported in apple (Mahajan 1994). Our results are in line with Jawandha et al. 2012, who reported an initial increase in PME activity upto 20 days in ber fruits followed by reduction in the activity of this enzyme. The positive effect of SA on suppression of fruit softening enzymes might account for firmer fruit in treated group as

compared to control (Champa et al. 2014). The decrease in PME activity at later stage could be attributed to the reduced substrate level due to decomposition.

Conclusion

Pre storage application of salicylic acid significantly delayed colour development and maintained SSC, titratable acidity, firmness and total sugars of the studied fruits. Salicylic acid reduced the activity of pectin methylesterase as such plum fruits remained in moderately acceptable condition up to 40 days of cold storage when pre-treated with salicylic acid at 414 ppm. After this period the elevated enzyme activity accelerated the maturation process and deteriorated the quality of fruits.

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