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Postharvest PGR's treatment to improve the storability of plum cv. Satluj Purple

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Abstract

Plum is a perishable fruit which deteriorates rapidly after harvesting thus, having a very short storage life. However, owing to its greater demand in the market, there is a need to increase its shelf life. Hence, a research study was conducted at Horticulture Laboratory, P.G. Department of Agriculture during 2023-24 with an aim to evaluate the effect of putrescine and salicylic acid on quality attributes of plum during cold storage. The plum fruits (cv. 'Satluj Purple) procured at the mature ripened stage were dipped in various concentrations of putrescine (1, 2 and 3 mM/L) and salicylic acid (0.5, 1 and 1.5 mM/L) along with distilled water (control) for 5 minutes. Then the treated fruits were packed in CFB boxes and stored at 4°C with 95 % relative humidity for 30 days. Experiment was carried out in completely randomized block design replicated thrice. The physico- biochemical fruit traits were assessed at 0, 5, 10, 15, 20, 25 and 30 days of storage intervals. The results revealed that during the entire storage period, the weight loss, TSS and pH increased significantly whereas, the fruit firmness, titratable acidity, ascorbic acid, total phenolics, carotenoids and chlorophyll content decreased significantly ($P \leq 0.05$) in all the treatments. The research outcomes showed that an exogenous treatment of putrescine and salicylic acid resulted in the retention of weight loss and fruit softening. Also they maintained titratable acidity, ascorbic acid, total phenols, carotenoids and chlorophyll activity in plum fruits during storage. The research study concluded that the application of both putrescine and salicylic acid proved effective in delaying the ripening processes and prevented senescence. Therefore it can be employed to prolong the fruit shelf life commercially with acceptable fruit quality in plum.

Keywords: CFB Boxes, Cold storage, Plum, Quality attributes, Shelf life, Total phenolics

Introduction

Plum (*Prunus domestica* L.) is taxonomically one of the important diverse deciduous stone fruit confined to temperate regions and have been accredited to be the first temperate fruit species to tempt human interest. It owes importance globally with possession of extensive genetic diversity and high economic value (Topp *et al* 2012; Wei *et al* 2021). Abundantly, plum contains bioactive compounds in the form of phenolic acids, anthocyanins, carotenoids, minerals and pectins. Predominantly, phenolic compounds such as caffeic acid, neochlorogenic acid, chlorogenic acid and cryptochlorogenic acid in plums have been reported. The fruit components have been employed as natural drugs extensively used in the treatment of leucorrhoea, irregular menstruation and miscarriage (Hussain *et al* 2021). These fruits contain many fiber and a natural laxative, called sorbitol. The plum juice is a good source of antioxidants (Wolfe *et al* 2008), iron, potassium, fluoride, phosphorous, magnesium, calcium, zinc, vitamins such as A, B_1 (thiamine), B_2(riboflavin), B_3(niacin), B_6, vitamin C (ascorbic acid),E (alpha-tocopherol), K (phylloquinone) and folate. Its low calorific value without any harmful fats have been advocated (Butu and Rodino 2019). Plum is a highly perishable fruit with a short shelf-life at room temperature and its quality deteriorates rapidly after harvest as postharvest decay thus acting as a major factor limiting the extension of its storage life (Perez-Vicente *et al* 2002). Low temperature storage is recommended to extend postharvest life, however plum fruit are particularly susceptible to chilling injury. Recently, the use of natural compounds for maintenance of fruit quality and extension of shelf life has created an increasing interest among the consumers. A widely distributed phenolic compound. Polyamines (PAs) are a group of natural compounds having low molecular weight and aliphatic nitrogen structure, present in the cells of all living organisms in the major forms including spermidine (triamine), spermine (tetramine) and putrescine, (diamine). They play a key role in many physiological processes such as cell growth and development and response to environmental stresses. The research studies reveal the maintenance of flesh firmness in peach (Bregoli *et al* 2004) and plum (Serrano *et al* 2003). Salicylic acid and polyamine treatments have the potential for commercial control of quality properties and increase in the shelf life of harvested fruit. However, little information exists on the use of salicylic acid and putrescine to preserve plum fruits quality during storage. To the best of our knowledge, the effect of SA treatment on physiological and biochemical changes associated with chilling injury and post-storage quality in plum fruit is not yet fully understood (Davarynejad *et al* 2015).

Materials and methods

Healthy and disease free fruits of plum cv. Satluj Purple were harvested manually at commercial maturity stage from 7 years-old trees from the plum block, Orchard of Khalsa College, Amritsar. The homogeneous fruits were randomized and divided into lots to perform treatments in 3 replications and washed with 100 ppm chlorinated water and then soaked in different concentrations of two materials including putrescine (1, 2, 3 mM/L) and salicylic acid (o.5, 1, 1.5mM/L) as well as distilled water (control) for 5 min. Treatments were performed by dipping fruits in 10 L of solution for 5 min, and then fruits were left to dry at room temperature and were packed in 3 ply CFB boxes (5% perforation) with paper lining and stored at 4°C and 95 % relative humidity (RH) for 30 days under cold store conditions. After 0, 5, 10, 15, 20, 25 and 30 days (5day intervals). 3 fruits from each replication for each treatment (12 fruits) were sampled for analytical determinations. The weight loss was calculated as follows: PLW (%) =(A-B) × 100/A Where A indicates the fruit weight at the time of harvest (Initial weight) and B indicates the fruit weight after storage intervals. Fruit firmness was determined by a fruit pressure tester penetrometer model FT 327 (3-271bf.) using stainless steel probe on pared surfaces from opposite sides of each one square cm of the peeled fruit and the results were expressed as lbf. The total soluble solids (TSS) was assessed by using a digital refractrometer (Erma, Tokyo). The titratable acidity was measured by after diluting 2 ml of strained juice to 20 ml with distilled water titration was performed against 0.IN NaOH solution with phenolphthalein as an indicator which resulted in the change in colour from colourless to light pink. Results were reported as g of malic acid per 100 g of fresh weight (g/100 g FW). The total phenolics were determined by using Folin-Ciocalteu method in which 1 g of plum tissue was extracted with 10 ml methanol (85 %). 250 µL of this extract was dissolved in a 250 µL of sterile distilled water, and then samples were mixed with 2.5 mL of 10-fold-diluted Folin-Ciocalteu reagent and 2 mL of 7.5 % sodium carbonate. The mixture was shaken for 1.5 to 2 h before the absorbance was measured by a UV–visible spectrophotometer (model 2010, Cecil Instr. Ltd., Cambridge, UK) at 765 nm. Gallic acid was used as a standard. The results were expressed as mg gallic acid equivalent in 100 g fresh weight (mg GAE/100 g FW).Carotenoids content was calculated by dipping the fruit tissue (0.1 g) was taken and dipped in 5 ml DMSO solution. The sample was kept in water bath at 60-70°C for 1hr for pigment extraction. The absorbance was recorded at 480, 645 and 663 nm using spectrophotometer (Spectronic 200, Thermo scentific, USA). The results were expressed as mg/g FW tissue. The experiment was conducted according to factorial based on completely randomized block design with 3 replicates. Data were analyzed by Statistical Analysis System software Statistix 8.1 (Windows) and differences among means were determined for significance at $P<0.05$ were calculated out.

Results and discussion

Physiological loss in weight (%)

Physiological loss in weight showed a progressive increase during the storage intervals with the lower level at the initial stage of the storage and the highest at the last observatory interval of 30th day of storage in the fruits treated with putrescine and salicylic acid. The present research results are in consensus with Davarynejad *et al* (2015) Decrease in weight loss was reported with the higher doses of both the chemicals used. Lowest average (1.20%) weight loss was noticed in 3mM/L putrescine followed by (1.26%) in 1.5mM/L salicylic acid while the highest

(1.51%) was in the untreated fruits. The storage on 5th day registered the lowest (0.56%) loss which increased with the prolongation of storage being the highest (2.73%) on the 30th storage day. weight loss of the plum fruits throughout the storage period could be due to the speed up of acceleration caused by the cellular disintegration. The detection of decreased weight loss with putrescine during storage can be attributed to the alteration of delay in the epicuticle wax. Removal of stomata closure leading to occurrence of lower weight loss as reported by Zheng and Zhang (2004), Enab *et al* (2020) in mandarin, Serrano *et al* (2003) in plum and Diaz-Mula *et al* (2009) in apple.

Table 1: Effect of putrescine and salicylic acid on PLW (%) of plum cv. Satluj Purple during cold storage.

Treatments	Storage interval (days)							
	0	5	10	15	20	25	30	Mean
Putrescine (1mM)	0.00	0.57	0.96	1.41	1.84	1.96	2.41	1.30
Putrescine (2mM)	0.00	0.55	0.97	1.54	1.89	1.94	2.66	1.36
Putrescine (3mM)	0.00	0.49	0.75	1.13	1.82	1.88	2.35	1.20
Salicylic acid (0.5mM)	0.00	0.57	0.98	1.14	1.86	1.98	2.78	1.31
Salicylic acid (1mM)	0.00	0.60	0.99	1.24	1.87	1.95	2.95	1.37
Salicylic acid (1.5mM)	0.00	0.54	0.92	1.06	1.80	1.90	2.63	1.26
Control	0.00	0.66	1.13	1.53	1.86	2.07	3.36	1.51
Mean	0.00	0.56	0.95	1.29	1.84	1.95	2.73	
CD($p \leq 0.05$)								
Treatment: 0.07								
Storage intervals: 0.07								
Treatment × Storage intervals: 0.18								

Fruit firmness (lbf)

The outcome of the results depicted a significant ($p \leq 0.05$) decrease in fruit firmness during storage in both the applied putrescine and salicylic acid treatments (Table 2). Since, control (untreated fruits) registered significantly lower firmness during storage. The results are in conformity with Diaz-Mula *et al* (2009) and Serrano *et al* (2003). Maximum (6.73lbf) firmness was reported on the day of fruit storage which was decreased with the storage intervals to (3.28 lbf) at the end of storage 30th day. The highest firmness (4.90 lbf) was reported with 3mM putrescine and (4.83 lbf) with salicylic acid treatments. The lowest (4.38) was recorded in the untreated fruits respectively. Serrano *et al* (2003) and Davaryenjad *et al* (2015) revealed that the plum fruits applied with putrescine resulted in the higher firmness during storage..An acceleration of the ripening process exhibits the deterioration of fruits quality resulting in loosen and fruit softening during storage. The influence of polyamines on firmness inflation can be ascribed to the crystallization of the pectin substances of the cell wall being detectable immediately after treatments (Abbott *et al* 1989). During storage the decreased activity of ethylene enzymes like aminocyclopropane-1-carboxylate synthase, inhibition of polyglacturonase might have maintained by the exogeneous application of putrescine and salicylic acid. Hence, by inhibiting the production of ethylene and lowering the activity of the fruits softening enzymes the application of putrescine and salicylic acid delayed the plum fruit softening thus maintaining the fruit firmness (Khan *et al* 2008).

Table 2: Effect of putrescine and salicylic acid on firmness (lbf) of plum cv Satluj Purple during cold storage.

Treatments	Storage interval (days)							Mean
	0	5	10	15	20	25	30	
Putrescine (1mM)	6.73	5.08	5.07	4.21	3.20	3.19	3.16	3.41
Putrescine (2mM)	6.73	5.06	5.49	4.28	3.22	3.21	3.20	4.45
Putrescine (3mM)	6.73	6.17	5.61	4.42	3.83	3.82	3.75	4.90
Salicylic acid (0.5mM)	6.73	5.19	4.99	4.77	3.68	3.52	3.17	4.57
Salicylic acid (1mM)	6.73	5.04	5.02	4.71	3.63	3.60	3.24	4.55
Salicylic acid (1.5mM)	6.73	5.62	5.58	4.88	3.77	3.67	3.61	4.83
Control	6.73	5.52	4.65	3.65	3.74	3.53	2.85	4.38
Mean	6.73	5.38	5.20	4.41	3.58	3.50	3.28	
CD($p \leq 0.05$)								
Treatment: 0.03								
Storage intervals: 0.03								
Treatment × Storage intervals: 0.08								

Total soluble solids (%)

It is apparent from the data shown in Table 3 that the content of total soluble solids increased significantly during storage at 4°C in both the polyamines (putrescine and salicylic acid). Similar results were also reported by Díaz-Mula *et al* (2009) and Serrano *et al* (2003). Irrespective of the treatments an increase in fruit TSS content was noticed with the advancement of storage interval to some extent. Afterwards it decreased upto the end of storage. It showed an increasing trend upto 20th day of storage and then there was a fall at 25th and 30th day of storage. The lowest (11.90 %) TSS was noted in the fresh plum fruits and it reached to 15.96 per cent as the maximum TSS on the 20th day of storage. Afterwards the TSS declined to 14.04 per cent with the least (12.55%) at the end of storage i.e. on 30th day of storage. Out of all the concentrations of putrescine and salicylic acid used, maximum average TSS content (15.30 %) was recorded in the untreated plum fruits while the minimum average TSS content (12.39 %) was registered in the fruits treated with salicylic acid 1.5 mM. Significant variations ($p \leq 0.05$) in levels of total soluble solids as affected by various treatments was the research outcomes. The total soluble solids during the cold storage at 4^{0}C were significantly affected by the exogenous application of both putrescine and salicylic acid treatments at various concentrations. During the storage, treatments of 1.5 mM/L salicylic acid had the lowest amount (11.99 %) of total soluble solids on 5th storage day which increased to 13.68 per cent at the end of storage while the untreated fruits treatment had the highest total soluble solids content of 14.88 per cent on the 5th day of storage with a retention to (13.68%). Highest range of TSS in untreated fruits can be attributed to heavy loss of water and hydrolysis of starch into simple sugars, which may have occurred at a slower rate in the polyamine-treated fruits compared to untreated fruits (Davarynejad *et al* 2015; Bregoli *et al* 2002). The rise in TSS concentration during storage might be attributed to breakdown of starch into sugars. A study by (Zokaee-Khosroshahi and Esna-Ashari 2008) pertaining to the effects of putrescine application on postharvest life and physiology of apricot fruit showed the lowest content of total soluble solids in the treatment of putresince (3 mmol/L) while the control treatment had the highest total soluble solids levels during storage.

Table 3: Effect of putrescine and salicylic acid on total soluble solids (%) of plum cv. Satluj Purple during cold storage.

Treatments	Storage interval (days)							Mean
	0	5	10	15	20	25	30	
Putrescine (1mM)	11.90	13.48	14.24	16.65	17.70	14.68	12.75	14.48
Putrescine (2mM)	11.90	13.84	15.06	16.98	17.01	14.88	12.93	14.65
Putrescine (3mM)	11.90	12.84	13.68	15.66	15.72	14.03	12.04	13.84
Salicylic acid (0.5mM)	11.90	13.04	14.12	16.65	16.58	14.04	12.92	13.96
Salicylic acid (1mM)	11.90	12.26	12.98	13.84	13.95	12.54	11.98	12.77
Salicylic acid (1.5mM)	11.90	11.99	12.56	13.24	13.30	12.27	11.50	12.39
Control	11.90	14.88	16.06	17.26	17.50	15.86	13.68	15.30
Mean	11.90	13.19	14.10	15.66	15.96	14.04	12.55	
CD($p \leq 0.05$)								
Treatment: 4.41								
Storage intervals: 4.41								
Treatment × Storage intervals: 1.08								

Titratable acidity (%)

Data indication showed that different treatments showed a declining trend of titratable acidity with the advancement of storage period (Table 4). The maximum titratable acidity (1.14 %) was recorded at the storage day which showed a steady decline during storage and at the end of storage (30th storage day) it reflected as the minimum (0.53 %).Regarding the treatment of salicylic acid and putrescine a significant variation was observed. During the fruit storage at 4^{0}C the highest level of titratable acidity (0.85 %) was detected in putrescine 3Mm while the lowest (0.71%) was registered in the fruits devoid of any treatment (untreated fruits).The interaction between treatments and storage intervals was found to be significant ($p \leq 0.05$). In plum fruit on 5th day, the highest titratable acidity (0.98 %) was recorded in the peach fruits treated with putrescine 3mM and the lowest titratable acidity (0.76 %) was recorded in untreated fruits. However, in plum fruit on 25th day of storage the highest titratable acidity (0.76 %) was recorded in putrescine 3mM treated fruit while the lowest titratable acidity (0.44 %) was recorded under control. According to Davarynejad *et al* (2015) in plum and Zokaee-Khosroshahi *et al* (2007) in strawberries the treatment of putrescine acquired the highest amount of titratable acidity during storage. In the maintenance of the fruit quality of plum the titratable acidity acts as an important component which has a direct relation to the quantity of organic acids present in the fruit. Davarynejad *et al* (2015) and Ishaq *et al* (2009) reported that the consumption of organic acids in fruits during respiration might be responsible to the decrease of titratable acidity content. The research outcome revealed that the treatments of both (putrescine and salicylic acid) retarded TSS degradation and preserved TA which can be attributed to a decrease in respiration and ethylene production (Valero *et al* 2002).

Table 4: Effect of putrescine and salicylic acid on titratable acidity (%) of plum cv. Satluj Purple during cold storage.

Treatments	Storage interval (days)							Mean
	0	5	10	15	20	25	30	
Putrescine (1mM)	1.14	0.86	0.74	0.60	0.59	0.58	0.57	0.75
Putrescine (2mM)	1.14	0.92	0.80	0.79	0.78	0.66	0.51	0.80
Putrescine (3mM)	1.14	0.98	0.90	0.86	0.85	0.68	0.65	0.85
Salicylic acid (0.5mM)	1.14	0.90	0.85	0.78	0.65	0.60	0.52	0.77
Salicylic acid (1mM)	1.14	0.83	0.81	0.80	0.69	0.63	0.54	0.75
Salicylic acid (1.5mM)	1.14	0.95	0.89	0.84	0.74	0.67	0.58	0.83
Control	1.14	0.77	0.75	0.72	0.63	0.53	0.43	0.71
Mean	1.14	0.88	0.81	0.77	0.71	0.63	0.53	

CD(p≤0.05)
Treatment: 0.01
Storage intervals: 001
Treatment × Storage intervals: 0.03

Total phenols (mg/100 g FW)

It is apparent from the data presented in Table 5 that the putrescine treated fruits and the untreated fruits showed significant differences displaying higher total phenolic content in putrescine treated samples compared to the untreated ones. The freshly harvested plum fruits registered the highest (99.52 mg/100 g FW) total phenolic content. During storage, maximum total phenols content of (92.68 mg/100 g FW) were recorded on 5th day of storage and minimum content of total phenols (86.85 mg/100 g FW) were recorded on 30th day of storage irrespective of treatments. Different treatments of salicylic acid and putrescine had a significant ($p \leq 0.05$) effect on the total phenolic content. The maximum total phenolic content (92.42 mg/100 g FW) was noticed in fruits treated with putrescine 3mM whereas minimum total phenolic content (84.16mg/100 g FW) was noticed in the untreated fruits. It has been advocated that the role of putrescine in maintenance of phenols can be ascribed to the delay of senescence process (Arora *et al* 2002; Razzaq *et al* 2014). Kibar *et al* (2021) suggested that the change in total phenolic and antioxidant activity after harvest in peach was lower with putrescine application. According to Abassi *et al* (2019) putrescine application delays the biochemical changes that occur by preventing ethylene synthesis in the fruit. In the study Kucuker *et al* (2023) observed that the amount of phenolic acid in fig fruit decreased during storage and putrescine doses prevented this decrease confirming that putrescine treatments can be used as an effective method to maintain postharvest fruit quality in figs.

Table 5: Effect of putrescine and salicylic acid on phenols (mg100g/ FW) of plum cv. Satluj Purple during cold storage.

	Storage interval (days)							
Treatments	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**Mean**
Putrescine (1mM)	95.52	93.80	92.74	91.76	90.79	89.84	87.02	91.63
Putrescine (2mM)	95.52	94.06	93.14	90.98	89.88	88.32	87.86	91.39
Putrescine (3mM)	95.52	94.46	93.66	92.24	91.35	90.35	89.42	92.42
Salicylic acid (0.5mM)	95.52	91.96	90.48	89.26	87.42	86.45	85.85	89.56
Salicylic acid (1mM)	95.52	91.54	90.02	88.58	86.70	86.26	85.84	88.63
Salicylic acid (1.5mM)	95.52	92.12	92.08	90.82	89.86	88.26	86.54	90.64
Control	95.52	90.86	88.22	87.50	86.85	85.42	84.16	88.10
Mean	95.52	92.68	91.62	90.62	88.55	88.12	86.85	
CD(p≤0.05)								
Treatment: 0.38								
Storage intervals:0.38								
Treatment × Storage intervals: 0.77								

Carotenoids (mg/100g FW)

The perusal from the data presented in Table 6 indicated that during the storage, the minimum carotenoids content (0.81 mg/100 g FW) was recorded on 5th storage day which showed an increase (1.93mg/100 g FW) as maximum value at the end of storage i.e. on 30th day. The fruits treated with putrescine 3mM had minimum (1.10mg/100 g FW) carotenoids content whereas the maximum (1.59 mg/100 g FW) was extracted in the untreated fruits. Statistically significant ($p \leq 0.05$) variations in carotenoids was found in the interaction between the treatments and storage intervals. There was an increase in the content as the storage was progressed. On 5th day of storage, the mean minimum (0.91 mg/100g FW) total carotenoids content was recorded in putrescine 3mM coated fruit. However, the plum fruits which were devoid of any application of polyamine (control fruits) had registered mean maximum (0.91 mg/100g FW) carotenoids. At the end of storage, the mean minimum total carotenoids decreased but was minimum (1.42 mg/100g FW) reported in the fruits treated with putrescine 3mM, while the fruit under controlled condition (untreated fruits) had the maximum total carotenoids content (2.46 mg/100g FW).In a research trial. Mallik and Singh (2000) reported in mangoes that exogenous application of polyamines at the final fruit development stage retarded the fruit skin colour development and improved the total carotenoids in the pulp..

Table 6: Effect of putrescine and salicylic acid on caretonoids (mg/100g FW) of plum cv. Satluj Purple during cold storage.

Treatments	Storage interval (days)							
	0	5	10	15	20	25	30	Mean
Putrescine (1mM)	0.81	1.00	1.12	1.26	1.36	1.46	1.80	1.25
Putrescine (2mM)	0.81	0.95	1.03	1.20	1.33	1.38	1.64	1.19
Putrescine (3mM)	0.81	0.91	1.00	1.14	1.18	1.26	1.42	1.10
Salicylic acid (0.5mM)	0.81	1.08	1.18	1.34	1.63	1.68	2.06	1.39
Salicylic acid (1mM)	0.81	1.12	1.24	1.40	1.45	1.72	2.18	1.41
Salicylic acid (1.5mM)	0.81	1.03	1.13	1.31	1.38	1.52	1.96	1.30
Control	0.81	1.22	1.34	1.52	1.88	1.95	2.46	1.59
Mean	0.81	1.04	1.14	1.31	1.45	1.56	1.93	
CD($p \leq 0.05$)								
Treatment: 0.06								
Storage intervals:0.06								
Treatment × Storage intervals: 0.12								

Conclusion

The research study concluded that the postharvest dip treatment of putrescine 3mM indicated higher efficacy in conserving the fruit quality and elongating the shelf life of plum cv. Satluj purple under cold storage. The analyzed data demonstrated that the use of putrescine 3mM portrayed a good score of sensory quality significantly inhibiting the decline of weight loss in fruit, as well as decreasing the degradation of peel color, retarded the rate of change in TSS, maintained chlorophyll pigments, carotenoids and total phenolic content as compared to salicylic acid throughout the storage period relative to the untreated fruits. Hence, the application of putrescine may be an efficacious way to maintain the postharvest quality of plum. Besides, biochemical analysis is needed for further studies. Alternatively, putrescine combined with other treatments can be used as a potential means in the expected functional mechanism with a view to improve the quality of plum. Nevertheless, future studies are required on use of putrescine in combination with other materials as treatments in reducing chilling injury and feasible mechanisms of action for increasing the shelf life of plum.

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