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Effect of Low Temperature and Different Chemicals on the Quality and Shelf Life of 'Satluj Purple' Plums

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Abstract: ***Satluj Purple plum has higher consumer acceptance than many other current sub-tropical plum cultivars, but it has a very short shelf-life. In this climacteric fruit ripening processes occur rapidly. This paper studies the effect of different chemical treatments on post-harvest quality of the fruits. Fruits were stored at low temperature conditions for 40 days. Physico-chemical characteristics were determined at 10 days interval. The physiological loss in weight and spoilage increased gradually with the advancement of storage. The pulp: stone decreased while as the TSS: acid increased continuously up to 40 days of storage in plum fruits. The reducing and non reducing sugars increased before showing a declining trend. Fruits treated with salicylic acid @ 3mmoL^{-1} were moderately to highly acceptable (7.42) and retained the highest pulp: stone (15.33), reducing (6.38 %) and non reducing sugars (2.54 %) even after 40 days of cold storage.***

Keywords: Physiological loss in weight, plum, storage, sugars, salicylic acid, TSS

1. Introduction

Plum is climacteric fruit and therefore highly perishable in nature. 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 with the evolution of ethylene. Excessive softening is a major factor limiting the shelf-life of plums. Fruit softening is the ripening-related process most sensitive to ethylene (10) and a suitable predictor of potential shelf-life for plums. Satluj Purple is an important cultivar of plum (*Prunus salicina* Lindal.), which performs well under subtropical climatic conditions. It is becoming popular among fruit growers of Punjab 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 fetch good prices. But, plum is a highly perishable fruit and cannot be stored for longer period or transported to longer distance under ambient conditions. At a temperature of 40 °C plum retains market quality for only 3-4 days (6). The postharvest losses of fruits during transportation and marketing are very high, particularly as slight bruises, hardly noticeable on freshly harvested crops, cause the fruits to rot during transportation under hot and humid conditions. Therefore, it is desirable to have postharvest treatment, which would retard the deterioration in quality during transportation and storage.

The objectives of this study were to shed some light on the influence of low temperature and different chemical treatments on biochemical attributes and storability of plum.

2. Material and Methods

Plum *cv.* Satluj Purple fruits 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 @ 1, 2 and 3mmolL^{-1} (T_1, T_2 and T_3), Ascorbic acid @1, 2 and 3% (T_4, T_5 and T_6), and Gibberallic acid @ 20, 40 and 60 ppm (T_7, T_8 and T_9),. For control the fruits were dipped in distilled water (T_{10}). 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 fibre board (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 physico-chemical characteristics.

Physical and biochemical parameters

A) Physiological loss in weight (PLW)

The weight of fruits after each interval of cold storage was recorded and per cent physiological loss in weight was calculated as follows:

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

B) Spoilage

The spoilage per cent of fruits was calculated on the number basis by counting the spoiled fruits and expressed in percentage.

$$\text{Spoilage (\%)} = \frac{\text{Number of spoiled fruits}}{\text{Total number of fruits}} \times 100$$

C) Palatability (Sensory rating (PR))

Sensory rating (PR) was recorded on the basis of hedonic scale (1-9) *viz*: 1 –extremely undesirable; 2 –very much undesirable; 3 –moderately undesirable; 4 –slightly undesirable, 5 –neither desirable nor undesirable, 6–slightly desirable, 7–moderately desirable, 8–very much desirable and 9–extremely desirable.

D) Pulp:Stone

The pulp and stone of individual fruits were separated and weighed. The ratio of pulp to stone was worked out and the mean was worked out.

E) Total soluble solids (TSS):Acid

TSS:Acid was calculated by dividing the value of total soluble solids with that of the corresponding total titratable acidity in each replication (12).

F) Reducing sugars

The reducing sugars were estimated by Lane and Eynon's titration method as reported by Ranganna (7). Ten mL of fresh juice was taken and the volume was made to 100 mL by distilled water. Extraneous material was precipitated with the help of lead acetate. Excess lead was removed with potassium oxalate. Thereafter, the solution was filtered with filter paper. This was used as aliquot for further studies. Then this filtrate was titrated against Fehlings solution A and B (5 mL each) using methylene blue as indicator. Tritration was continued till brick red colour appeared. The result was expressed in percentage.

Reducing sugars (%) =

$$\frac{\text{Fehlings Factor}\,(0.05)}{\text{Volume of filtrate used}} \times \frac{\text{Dilution made}}{\text{Volume of juice taken}} \times 100$$

G) Non reducing sugars

The non reducing sugars present in the sample were determined from the values of total sugars and reducing sugars as follows:

Percentage of non reducing sugars=(Percentage of total sugars – percentage of reducing sugars) × 0.93

Statistical Analysis

The experimental design used was Factorial Completely Randomized Block Design (CRD) (11) and the data was analysed using SAS/STAT® (2011) software.

3. Results and Discussion

Physiological loss in weight (PLW)

The percent loss in weight increased progressively with the increase in storage period (Table 1) irrespective of the treatments. The minimum average physiological loss in weight (2.71%) was noticed after 10 days of storage and the maximum (5.34%) average loss in fruit weight was noticed after 40 days of cold storage.The mean minimum PLW (2.75%) was found in salicylic acid @ 3mmolL^{-1} treatment and mean maximum physiological loss in weight (5.17%) was found in untreated fruits. All the treatments showed a significant difference in physiological loss in weight as compared to the control fruits. After 10 days of storage the minimum physiological loss in weight (1.43%) was noticed in fruits treated with salicylic acid @ 3mmolL^{-1}, which was followed by salicylic acid @ 2mmolL^{-1} (1.62%) and gibberallic acid @ 60ppm (1.71%), but the maximum physiological loss (3.98%) was noticed in control fruits. Similar trend in physiological loss in weight was noticed after 2nd, 3rd and 4th interval of storage. The interaction between treatments and storage was found to be significant.

The vapour-phase diffusion driven by a gradient of water vapour pressure at different locations is a reason for moisture loss from fresh fruits and vegetables (14). Weight losses are due to metabolic activity, respiration and transpiration. Among different post-harvest treatments ascorbic acid was least effective in checking the physiological loss in weight, where as gibberallic acid in low concentrations (20 and 40ppm) was intermediate. The superiority of salicylic acid in minimizing weight loss may be because salicylic acid acts as an electron donor and produces free radical which prevents normal respiration and it can also decrease respiration rate and fruit weight loss by closing stomata (7, 15). The observations recorded in present study are in line with earlier results (19), who treated pear fruits with salicylic acid and found a significant reduction in weight loss as compared to control fruits. The fruits of strawberry dipped in salicylic acid solution had less weight loss than control (25).

Spoilage

Spoilage percentage increased with the progression of storage period. No spoilage percentage was observed in any treatment up to 10 days of storage. However, after 20, 30 and 40 days of storage average spoilage of 0.20, 1.05 and 2.26 per cent was noticed, respectively (Table 1). Fruits treated with salicylic acid (3, 2 and 1 mmolL^{-1}) and gibberallic acid (60, 40 and 20ppm) significantly reduced the spoilage percent in fruits during storage. After 20 days of cold storage only untreated fruits showed the rotting at the tune of 1.92 per cent. On the 30th day of storage, control, ascorbic acid @ 1, 2 and 3% and gibberallic acid @ 20 ppm treated fruits showed spoilage. However, the fruits that received salicylic acid treatments showed no spoilage even after 40 days of storage. At the end of storage, maximum spoilage (9.23%) was recorded in control fruits, followed by fruits treated with ascorbic acid @ 1% (3.92%). The maximum fruit spoilage was noticed in control fruits ranging from 1.92 to 9.23 per cent during 20-40 days of cold storage.

Post-harvest treatments of salicylic acid were found effective in checking the spoilage of plum fruits in cold storage. Earlier it has been recorded a reduced decay with post-harvest treatment of salicylic acid in 'Ponkan' mandarin as compared to control (15). These results are also in agreement with the earlier findings (16, 18) who reported reduced fungal decay in sweet cherry through induction of the defence resistance system and stimulation of antioxidant enzymes (20) by post harvest salicylic acid treatment.

Palatability rating

The palatability in all treatments first improved upto 20 days of cold storage and then declined continuously, except in salicylic acid @ 3mmolL^{-1}, 2mmolL^{-1} and gibberallic acid @ 60ppm treatments, where palatability improved slowly upto 30 days of storage and then declined (Table 1). The quality deterioration of fruits with storage may be due to disturbed

TSS: acid ratio and development of off flavours. Similar results were also reported on peaches and apricots (1). The higher palatability rating in salicylic acid treated fruits at the end of storage could be due to retardation of ripening and softening process of fruit that led to the development of better juice, texture, flavour and sweetness. Similar results were obtained on plum *cv*. Satluj Purple and Kala Amritsari (13) who observed that palatability rating first increased up to 20 days and later it declined progressively up to 40 days of storage. Pomegranate fruits treated with salicylic acid @ 2mmolL^{-1} were found to be in excellent condition as compared to control and exhibited higher antioxidant activity and palatability rating (28).

Pulp: stone ratio

Pulp: stone ratio decreased with the progression of storage period. Among various treatments the pulp: stone ratio was found to be significantly higher in salicylic acid @ 3mmolL^{-1} treated fruits (Table 2). The mean pulp: stone ratio of fruits treated with salicylic acid @ 3mmolL^{-1} (15.54) which was at par with salicylic acid @ 2mmolL^{-1}(15.50) , followed by gibberallic acid @ 60ppm (15.41) treated fruits. The minimum mean pulp: stone ratio was recorded in control fruits (14.72) followed by ascorbic acid @ 3% (15.08) treated fruits. The interaction between treatments and storage period was found to be significant. The fruits treated with salicylic acid (1mmolL^{-1}, 2mmolL^{-1} and 3mmolL^{-1}) , and gibberallic acid (60ppm, 40ppm and 20ppm) recorded significantly higher pulp: stone ratio as compared to control while as, ascorbic acid treated fruits were at par with control. The decrease in pulp : stone ratio with the advancement of storage period may be due to the increase in moisture loss from plum fruits. Post-harvest application of salicylic acid has been reported to maintain higher firmness, which in turn maintained higher pulp:stone ratio in various fruits during cold storage *viz*; pear (19) and kiwi fruits (24). A decrease in pulp: stone ratio with advancement in storage in loquat fruits has been observed earlier (23).

TSS: acid ratio

With the advancement of storage period, an increase in TSS: acid ratio was observed in all treatments. The mean minimum TSS: acid ratio (14.20) was recorded after 10 days of storage, while the maximum TSS: acid ratio (21.58) was noticed after 40 days of storage (Table 2). Post-harvest treatment with salicylic acid significantly delayed the increase in TSS: acid ratio as compared to control. After 10 days of storage, the maximum TSS: acid ratio (19.01) was recorded in control fruits, followed by ascorbic acid @ 1% (17.86) treated fruits and the minimum TSS: acid (10.81) was noticed in salicylic acid @ 3mmolL^{-1} treated fruits, followed by salicylic acid @2mmolL^{-1} (11.37) treated fruits. Similar trend was followed on 20th, 30th and 40th days of cold storage. The interaction between the treatments and storage period was found to be significant. The increase in TSS: acid ratio with advancement of storage period might be attributed to the increase in total soluble solids and reduction in acidity in fruits with increase in storage period. The higher TSS: acid ratio in control fruits might be due to the increase in TSS and decrease in acidity at faster rates.

Reducing sugars

Reducing sugars increased up to 20 days of storage and then showed a declining trend in all the treatments. The mean minimum reducing sugars (6.76%) were recorded 10 day after cold storage and mean maximum total sugars (6.90%) were recorded after 20 days of cold storage (Table 2). After 10 days of storage the maximum reducing sugars (7.11%) were noticed in untreated fruits and minimum reducing sugars (6.38%) in salicylic acid @ 3 mmolL^{-1} treated fruits. Similar trend was followed after 20 days of cold storage, with maximum reducing sugars (7.22%) in control fruits and minimum reducing sugars (6.56%) in salicylic acid @ 3mmolL^{-1} treated fruits. On 30th and 40th days of storage the maximum reducing sugars (6.78 and 6.38%, respectively) were noticed in salicylic acid @ 3mmolL^{-1} treated fruits and minimum reducing sugars (6.35 and 5.92%, respectively) in reference fruits. The mean minimum reducing sugars (6.53%) were noticed in salicylic acid 3mmolL^{-1} treated fruits and the mean maximum reducing sugars (6.65%) were noticed in untreated fruits.

Non-reducing sugars

Non-reducing sugars increased up to 20 days of storage period, afterwards it declined continuously up to 40 days of storage in all the treatments. The mean minimum (2.44%) non-reducing sugars were estimated after 40 days of storage and the mean maximum non-reducing sugars (2.77%) were noticed after 20 days of cold storage (Table 2). Among all treatments the mean minimum non-reducing sugars (2.59%) were recorded in salicylic acid @ 3mmolL^{-1} treated fruits and mean maximum non-reducing sugars (2.67%) were recorded in reference fruits.

The increase in sugars during storage may be possibly due to the breakdown of complex organic metabolites into simple molecules or due to the hydrolysis of starch into sugars. The decline in sugar content at a later stage may be attributed to the fact that after the completion of hydrolysis of starch, no further increase in sugars occurs and instead there is a decline in sugars. This decline in sugars is probably due to the consumption of sugars along with organic acids in respiration (5; 21)

4. Conclusion

Exogenous salicylic acid treatments have shown improvement of plum storability under cold storage conditions. It can be concluded that plum fruits harvested at colour break stage can be successfully stored for 40 days by treating with higher concentrations of salicylic acid.

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Table 1: Effect of different chemicals on physiological loss in weight, spoilage and palatability rating in plum during cold storage

Treatments	Physiological loss in weight (PLW)					Spoilage (%)					Palatability rating (PR)				
Storage interval (days)	**10**	**20**	**30**	**40**	**Mean**	**10**	**20**	**30**	**40**	**Mean**	**10**	**20**	**30**	**40**	**Mean**
T_1-Salicylic acid @ 1mmolL^{-1}	1.88	2.69	3.74	4.78	**3.27**	0.00	0.00	0.00	0.00	**0.00**	6.78	7.94	7.32	6.94	**7.25**
T_2-Salicylic acid @ 2mmolL^{-1}	1.62	2.48	3.29	4.34	**2.93**	0.00	0.00	0.00	0.00	**0.00**	6.32	7.58	8.58	7.31	**7.44**
T_3-Salicylic acid @ 3mmolL^{-1}	1.43	2.32	3.07	4.21	**2.75**	0.00	0.00	0.00	0.00	**0.00**	6.21	7.32	8.68	7.42	**7.40**
T_4 -Ascorbic acid @ 1%	3.68	4.18	5.53	6.47	**4.96**	0.00	0.00	1.21	3.92	**1.28**	7.73	8.68	6.17	5.66	**7.06**
T_5 -Ascorbic acid @ 2%	3.51	3.99	5.36	5.89	**4.68**	0.00	0.00	0.89	3.49	**1.10**	7.57	8.63	6.28	5.93	**7.10**
T_6 -Ascorbic acid @ 3%	3.33	3.91	5.22	5.67	**4.53**	0.00	0.00	0.76	2.64	**0.85**	7.46	8.48	6.51	6.10	**7.14**
T_7-Gibberallic acid @ 20 ppm	3.10	3.88	5.10	5.53	**4.40**	0.00	0.00	0.72	2.32	**0.76**	7.31	8.30	6.71	6.33	**7.16**
T_8-Gibberallic acid @ 40 ppm	2.88	3.63	4.90	5.23	**4.16**	0.00	0.00	0.00	0.97	**0.25**	7.22	8.21	6.87	6.51	**7.20**
T_9-Gibberallic acid @ 60 ppm	1.71	2.54	3.62	4.59	**3.11**	0.00	0.00	0.00	0.00	**0.00**	6.53	7.83	8.12	7.18	**7.42**

T_{10} –Control	3.98	4.23	5.74	6.76	**5.17**	0.00	1.92	6.88	9.23	**4.51**	7.95	8.77	6.04	5.43	**7.05**
Mean	**2.71**	**3.38**	**4.55**	**5.34**		**0.00**	**0.20**	**1.05**	**2.26**		**7.11**	**8.17**	**7.12**	**6.49**	

CD at 5% level
PLW: A (Treatments):0. 24 , B (Storage):0.15 , A×B (Treatments ×Storage): 0.49
Spoilage: A (Treatments):0. 20 , B (Storage):0.13 , A×B (Treatments ×Storage): 0.41
Palatability rating: A (Treatments):0. 34 , B (Storage):0.29 , A×B (Treatments ×Storage): 0.61

Table 2: Effect of different chemicals on pulp:stone, TSS:acid, reducing sugars and non reducing sugars of plum during cold storage

Treatments	Pulp: Stone					TSS: acid					Reducing sugars (%)					Non-reducing sugars (%)				
Storage interval (days)	10	20	30	40	Mean	10	20	30	40	Mean	10	20	30	40	Mean	10	20	30	40	Mean
T_1-Salicylic acid @ 1mmolL^{-1}	15.63	15.38	15.17	14.96	**15.29**	13.04	17.01	18.84	20.05	**16.80**	6.64	6.78	6.67	6.13	**6.56**	2.66	2.70	2.66	2.44	**2.62**
T_2-Salicylic acid @ 2mmolL^{-1}	15.74	15.57	15.40	15.27	**15.50**	11.37	15.34	18.33	19.16	**15.47**	6.48	6.60	6.77	6.30	**6.54**	2.57	2.64	2.69	2.50	**2.60**
T_3-Salicylic acid @ 3mmolL^{-1}	15.77	15.60	15.47	15.33	**15.54**	10.81	13.89	17.77	18.74	**14.69**	6.38	6.56	6.78	6.38	**6.53**	2.53	2.60	2.70	2.54	**2.59**
T_4 -Ascorbic acid @ 1%	15.32	15.13	14.74	14.31	**14.88**	17.86	21.44	22.16	24.84	**21.20**	7.02	7.20	6.38	5.94	**6.64**	2.84	2.90	2.55	2.38	**2.67**
T_5 -Ascorbic acid @ 2%	15.41	15.25	14.83	14.42	**14.98**	17.24	20.73	21.54	24.00	**20.53**	6.97	7.11	6.43	6.00	**6.63**	2.79	2.88	2.56	2.39	**2.66**
T_6 -Ascorbic acid @ 3%	15.44	15.34	14.88	14.64	**15.08**	16.14	19.72	20.68	23.30	**19.58**	6.88	7.07	6.48	6.06	**6.62**	2.75	2.84	2.58	2.41	**2.65**
T_7-Gibberallic acid @ 20 ppm	15.50	15.21	14.96	14.83	**15.13**	14.36	18.94	20.43	22.20	**18.47**	6.83	6.99	6.52	6.04	**6.59**	2.73	2.80	2.61	2.41	**2.64**
T_8-Gibberallic acid @ 40 ppm	15.54	15.26	15.03	14.88	**15.18**	13.79	17.36	19.97	20.85	**17.53**	6.73	6.87	6.59	6.12	**6.58**	2.69	2.75	2.63	2.44	**2.63**
T_9-Gibberallic acid @ 60 ppm	15.70	15.43	15.28	15.23	**15.41**	12.46	16.01	18.74	19.94	**16.29**	6.56	6.66	6.76	6.22	**6.55**	2.61	2.66	2.69	2.48	**2.61**
T_{10} –Control	15.15	14.92	14.57	14.22	**14.72**	19.01	21.35	22.80	25.68	**21.86**	7.11	7.22	6.35	5.92	**6.65**	2.86	2.93	2.53	2.36	**2.67**
Mean	**15.52**	**15.31**	**15.03**	**14.81**		**14.20**	**17.90**	**19.97**	**21.58**		**6.76**	**6.90**	**6.57**	**6.11**		**2.70**	**2.77**	**2.62**	**2.44**	

CD at 5% level
Pulp:stone: A (Treatments):0.89, B (Storage):0.56 , A×B (Treatments ×Storage): 0.17. Basic value: 16.12
TSS:acid: A (Treatments):0.65 , B (Storage):0.41 , A×B (Treatments ×Storage): 0.13. Basic value: 9.32.
Reducing sugars: A (treatments): 0.30, B (storage): 0.19, A × B (treatments × storage): 0.61. Basic value: 5.12
Non Reducing sugars: A (treatments):0.25, B (storage):0.16, A × B (treatments × storage): 0.51. Basic value: 2.14