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Enhancement of storage life and quality maintenance of plum fruits

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ABSTRACT

The present study was conducted to evaluate the effect of pre-harvest application of calcium chloride at 0.0, 1.0, 1.5, 2.0% concentrations on various physico-chemical parameters and enzymatic activities in plum fruits cv. Satluj Purple at various storage intervals (0, 7, 14, 21, 28 and 35 days) under low temperature conditions. Two sprays of $CaCl_2$ @ 1.0% were most effective in maintaining the post-harvest quality attributes and efficiently reduced the physiological loss in weight (PLW), spoilage, pectin methyl esterase (PME) & cellulase activities and significantly delayed colour development & suppressed anthocyanin formation in plum fruits up to 28 days of cold storage. At the end of storage, two sprays of $CaCl_2$ (1.0%) recorded higher fruit firmness (54%), sensory quality (24%), higher total soluble solids (5.70%), titratable acidity (41%), total sugars (7.14%) and total phenols (13%) as compared to control.

Key words: *Prunus saliciana*, anthocyanin, cellulase, pectinmethyl esterase, total phenols.

INTRODUCTION

Satluj Purple is a commercially cultivated variety of plum fruit in north-western parts of India and has widely gained acceptance among growers due to its excellent flavour & quality, early ripening behaviour, high yield and attractive colour. However under regional conditions, the harvesting time of plum fruits coincide with high temperature and low relative humidity which shortens the shelf-life of fruits. Moreover, plum is a highly perishable fruit due its climacteric pattern of ripening exhibiting various physiological and biochemical changes after harvest. These changes results into the fast decay of fruit, weight loss and excessive softening that results in rapid deterioration in fruit quality leading to economic losses. Fruit is highly susceptible to textural softening due to dissolution of the middle lamella, reduction in cell to cell adhesion and weakening of perenchymal cell walls as a result of cell wall degrading enzymes. Calcium is a vital mineral nutrient as it maintains the cell wall structure, stabilizes the cell membrane & cation interaction in plants. Its application has been found to be effective in reducing the rate of respiration, breakdown of protein molecules, loss in weight, ethylene synthesis & spoilage of fruits. Pre-harvest spray of calcium salts during fruit development is a safe mode of supplementing the endogenous calcium in wide range of fruits. Calcium chloride treatment in peach proved to be efficient in retaining sensory quality attributes, prolonging the shelf-life and minimizing the loss in weight of fruits during cold storage (Kirmani *et al*., 8). Keeping in view the beneficial effects of calcium, the study on the effect of pre-harvest application of calcium chloride on storage life and fruit quality of plum *cv*. Satluj Purple was conducted with the aim to extend the shelf-life as well as to maintain the various physico-chemical properties of fruit under low temperature storage.

MATERIALS AND METHODS

For the experiment, twenty eight uniform and healthy plants of plum *cv.* Satluj Purple were selected at the Fruit Research Farm, Department of Fruit Science, Punjab Agricultural University, Ludhiana (India) during the year 2017. T-1, T-2 and T-3 (twelve trees) were sprayed once with calcium chloride (1.0 %, 1.5 % and 2.0 %) in 2nd week of April, while T-4, T-5 and T-6 (twelve trees) were sprayed twice with calcium chloride (1.0 %, 1.5 % and 2.0 %) in 2nd and 3rd week of April and T-7 (four trees) were water sprayed only. Fruits from treated and untreated plants were harvested at colour break stage. The experiment comprised of seven treatments with four replications in each treatment. The fruits were washed and air dried under shade before packaging in CFB boxes, and stored at 0–1 °C and 90–95 % RH. Fruit were analysed at 0 and after 7, 14, 21, 28 and 35 days of storage for various physico-chemical characteristics. PLW and titratable acidity (TA) were calculated as per the method described by Ranganna (10). The pericarp colour of sample fruit was recorded on colour coordinates as *L*, a* and b** from opposite positions of each fruit in *Commission International de L'Eclairage* (CIE) units using a ColorFlex spectrophotometer (HunterLab ColorFlex, Hunter Associates Inc., Reston,

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VA, USA) (Hunter, 5). Firmness of ten randomly selected fruits was measured with the help of fruit pressure tester penetrometer (Model FT-327, USA) and expressed in terms of lb force. The spoilage of fruits in each treatment was calculated by dividing the number of spoiled fruits by total number of fruits and expressed in percentage. TSS was determined with help of hand held digital refractometer (ATAGO, PAL -1, Japan) and expressed in ^{0}Brix (%). Sensory quality of fruits was observed on basis of colour, appearance, texture and taste and were sensory rated by panel a of 5 judges using nine point hedonic scale (1-9) as described by Amerine *et al*. (1). Total sugars were estimated by Lane and Eynon's titration method as reported by Ranganna (10). Anthocyanin content of pulp as well as peel of plum fruits was determined using the modified version of the method given by Zheng and Tian (14). Total Phenols were estimated by Swain and Hills (12) method. Fruit calcium content was analysed by Atomic Absorption Spectophotometer (AAnalyst 200, Perkin Elmer) and expressed as ppm of fresh weight sample. Pectinmethyl esterase (PME) and cellulase enzyme activities were determined as per the methods proposed by Mahadevan and Shridhar (9).

The data were statistically analyzed using the analysis of variance (ANOVA) procedure for Factorial Completely Randomized Design using statistical package SAS 9.3 and significant effects ($P \leq 0.05$) were noted. Significant difference amongst the means was determined by least significant difference (LSD). Results were expressed as means ± standard error. Further, some selected quality parameters were subjected to Pearson correlation coefficient analysis to assess the nature and extent of relationship between them.

RESULTS AND DISCUSSION

A significant increase in weight loss percentage (Table 1) with increase in storage period was observed in plum fruits irrespective of the treatments. However, fruits treated with two sprays of $CaCl_2$ @ 1.0% recorded minimum PLW as compared to control fruits. From 7 to 35 days of storage the weight loss in fruits treated with two sprays of $CaCl_2$ @ 1.0% increased from 1.94 to 5.57%, whereas, in untreated fruits it ranged from 2.92 to 6.51%. Minimum loss in weight in calcium treated fruits may be due to the effective barrier formed by calcium against CO_2 and O_2 which results in modification of internal atmosphere and slows down the respiration process. Similar trend was observed for fruit firmness (Fig. 1A) where two sprays of $CaCl_2$ @ 1.0% showed minimum (57.58%) decline in fruit firmness as compared to control fruits which recorded maximum (76.87 %) decrease in fruit firmness during the storage period (till 35 days). This might be due to the formation of calcium pectate which enhances the rigidity of middle lamella and stabilizes the plant cell wall which in turn protects it from cell wall degrading enzymes. These results are in agreement to the findings of Ashoori et al. (2) in apple fruit

As shown in Table 2, two sprays of $CaCl_2$ @ 1.0% significantly delayed the fruit peel colour development under low temperature storage. The decline in *L** value was effectively retarded by two sprays of $CaCl_2$ @ 1.0% followed by two sprays of $CaCl_2$ @ 1.5%. From the day of harvesting to 35 days of storage period, control fruits showed maximum reduction in *L** value by 40.01% as compared to two sprays of $CaCl_2$ @ 1.0% which recorded minimum reduction (30.36%) in *L** value. Irrespective of the treatments, a significant increase in *a** and *b** values

Table 1. Physiological loss in weight (PLW) % of plum fruits subjected to various treatments of calcium chloride during cold storage (0-1°C, 90-95% RH).

Parameters	Calcium chloride Conc. (%)	No. of sprays	Storage interval (Days)				
			0	7	14	21	28
Physiological loss in weight (PLW)%	1.0	1	2.64 ± 0.13^{a}	3.34 ± 0.08^{b}	4.23 ± 0.04^{ab}	5.37 ± 0.12	6.25 ± 0.10^{a}
	1.5	1	2.85 ± 0.21^{a}	3.52 ± 0.10^{ab}	4.31 ± 0.05^{a}	5.47 ± 0.04^{a}	6.42 ± 0.07^{a}
	2.0	1	2.90 ± 0.22^{a}	3.61 ± 0.11^{ab}	4.37 ± 0.05^{a}	5.53 ± 0.04^{a}	6.46 ± 0.08^{a}
	1.0	2	1.94 ± 0.12^{b}	2.56 ± 0.04^{d}	3.45 ± 0.05^{d}	5.05 ± 0.04^{c}	5.57 ± 0.10^{b}
	1.5	2	2.05 ± 0.03^{b}	2.83 ± 0.06^{cd}	3.84 ± 0.05^{c}	5.19 ± 0.02^{bc}	5.75 ± 0.11^{b}
	2.0	2	2.17 ± 0.05^{b}	2.92 ± 0.07^{c}	3.93 ± 0.06^{bc}	5.23 ± 0.06^{bc}	5.83 ± 0.05^{b}
	Control	-	2.92 ± 0.06^{a}	3.68 ± 0.15^{a}	4.40 ± 0.26^{a}	5.54 ± 0.07^{a}	6.51 ± 0.08^{a}
	P		0.46	0.32	0.37	0.21	0.29
	LSD (<0.05)		0.002	0.001	0.002	0.004	0.001

Means in a column with the same letter are not significantly different at ($p \leq 0.05$) according to LSD.

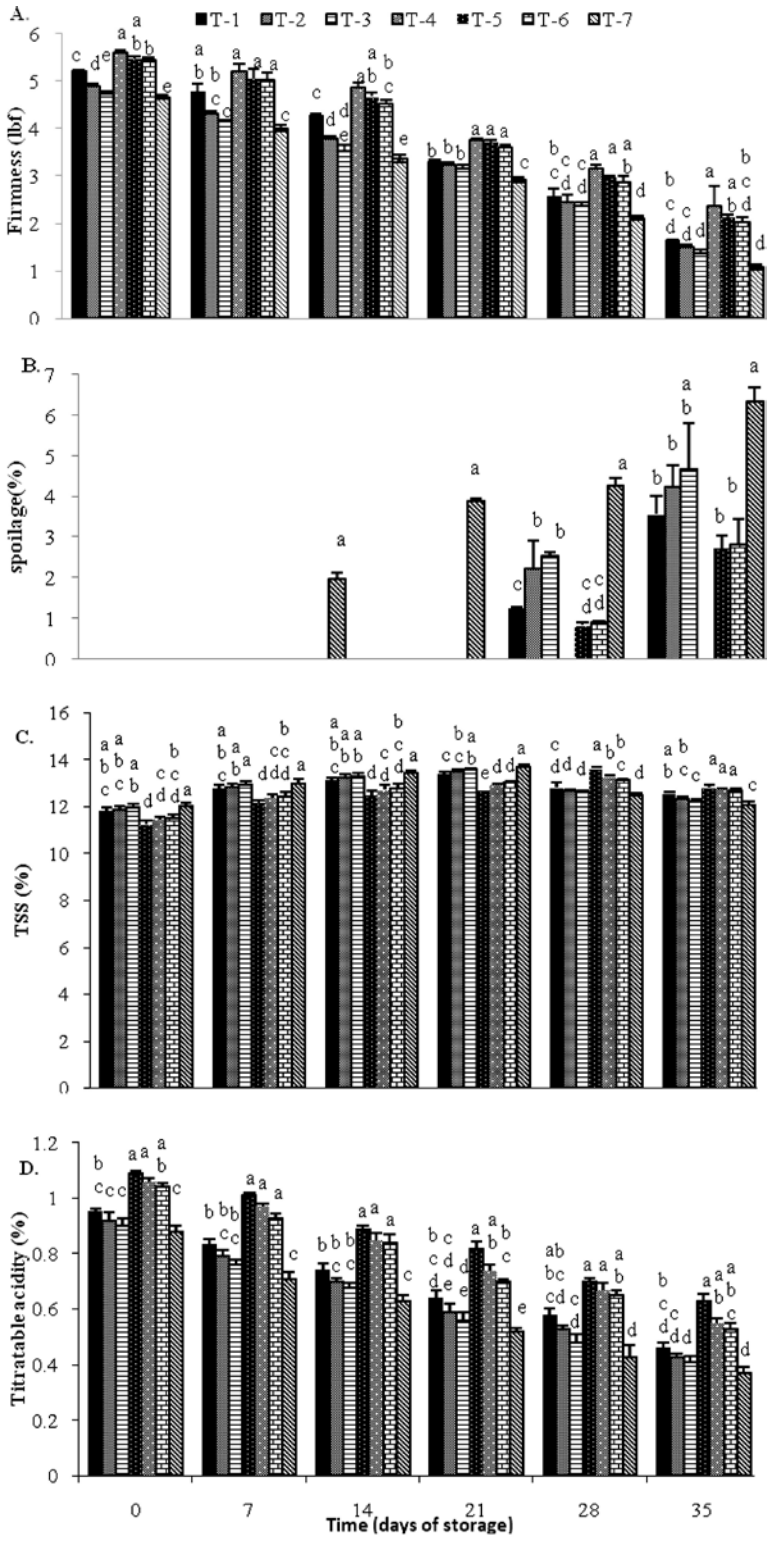

Fig. 1. Variation in (A.) fruit firmness, (B.) spoilage, (C.) total soluble solids (TSS), (D.) titratable acidity in plum *cv*. Satluj Purple during cold storage (0-1°C, 90-95% RH) in relation to pre-harvest treatment with different concentration of calcium chloride. Vertical bars represent ± Standard error of mean of 4 replicates, T-1: one spray $CaCl_2$ (1.0 %), T-2: one spray $CaCl_2$ (1.5 %), T-3: one spray $CaCl_2$ (2.0%), T-4: two sprays $CaCl_2$ (1.0%), T-5: two sprays $CaCl_2$ (1.5%), T-6: two sprays $CaCl_2$ (2.0%), T-7: control

Table 2. Peel colour L*, a* and b* values of plum fruits subjected to various treatments of calcium chloride during cold storage (0-1°C, 90-95% RH).

Parameters	Calcium chloride Conc. (%)	No. of sprays	Storage interval (Days)					
			0	7	14	21	28	35
L* value	1.0	1	56.95 ± 0.83^{bc}	52.74 ± 1.07^{c}	47.79 ± 0.54^{bc}	44.93 ± 0.69^{bc}	39.54 ± 0.48^{c}	35.16 ± 0.17^{b}
	1.5	1	55.68 ± 1.46^{c}	51.76 ± 1.98^{c}	45.84 ± 1.98^{c}	43.98 ± 1.28^{c}	36.93 ± 0.22^{d}	34.37 ± 1.10^{bc}
	2.0	1	54.46 ± 0.97^{c}	50.35 ± 0.17^{c}	45.28 ± 0.89^{c}	43.01 ± 1.63^{c}	35.67 ± 0.22^{de}	32.42 ± 0.89^{c}
	1.0	2	60.97 ± 0.17^{a}	57.34 ± 0.15^{ab}	52.69 ± 0.48^{a}	48.75 ± 0.38^{a}	44.94 ± 0.30^{a}	42.46 ± 0.58^{a}
	1.5	2	60.43 ± 0.62^{a}	56.98 ± 0.23^{ab}	50.47 ± 1.34^{ab}	48.09 ± 0.20^{a}	42.08 ± 0.14^{b}	36.05 ± 0.36^{b}
	2.0	2	59.35 ± 0.98^{ab}	56.66 ± 0.74^{b}	50.29 ± 1.23^{ab}	47.32 ± 1.01^{ab}	41.73 ± 0.80^{b}	35.86 ± 0.62^{b}
	Control	-	54.14 ± 1.05^{c}	50.26 ± 2.39^{a}	45.09 ± 0.17^{c}	42.98 ± 0.20^{c}	35.42 ± 0.20^{e}	32.37 ± 0.71^{c}
	P		0.004	0.001	0.001	0.002	0.001	.001
	LSD (<0.05)		3.24	3.20	3.76	3.14	1.35	2.36
*a** value	1.0	1	-9.6 ± 0.27^{d}	9.14 ± 0.21^{b}	16.11 ± 0.21^{bc}	20.72 ± 0.20^{c}	27.46 ± 0.18	31.11 ± 0.23^{c}
	1.5	1	-8.53 ± 0.27^{c}	9.46 ± 0.19^{b}	16.54 ± 0.21^{b}	22.46 ± 0.20^{b}	29.15 ± 0.19^{c}	32.14 ± 0.23^{b}
	2.0	1	-6.37 ± 0.28^{b}	9.75 ± 0.21^{b}	16.67 ± 0.20^{ab}	22.85 ± 0.21^{ab}	30.33 ± 0.19^{b}	32.28 ± 0.24^{ab}
	1.0	2	-11.76 ± 0.26^{f}	8.17 ± 0.18^{e}	14.35 ± 0.19^{d}	18.93 ± 0.18^{d}	23.76 ± 0.17^{f}	26.65 ± 0.24^{e}
	1.5	2	-11.48 ± 0.26^{f}	8.31 ± 0.19^{e}	15.46 ± 0.17^{c}	19.17 ± 0.19^{d}	24.18 ± 0.20^{ef}	29.61 ± 0.24^{d}
	2.0	2	-10.54 ± 0.31^{e}	8.42 ± 0.19^{e}	15.54 ± 0.19^{c}	19.59 ± 0.21^{d}	24.74 ± 0.21^{e}	30.52 ± 0.24^{c}
	Control	-	-5.19 ± 0.22^{a}	10.63 ± 0.20^{a}	17.33 ± 0.19^{a}	23.46 ± 0.20^{a}	31.52 ± 0.23^{a}	32.94 ± 0.21^{a}
	P		0.001	0.001	0.001	0.001	0.001	0.001
	LSD (<0.05)		0.91	0.67	0.66	0.67	0.67	0.79
*b** value	1%	1	9.15 ± 0.26^{bc}	11.67 ± 0.23^{bcd}	15.79 ± 0.26^{b}	17.34 ± 0.28^{bcd}	19.67 ± 0.26^{c}	21.78 ± 0.26^{bc}
	1.50%	1	9.42 ± 0.29^{b}	11.78 ± 0.22^{bc}	16.14 ± 0.26^{b}	17.96 ± 0.28^{bc}	21.75 ± 0.28^{b}	22.27 ± 0.27^{b}
	2%	1	9.56 ± 0.27^{ab}	12.21 ± 0.24^{b}	16.45 ± 0.21^{b}	18.17 ± 0.26^{b}	22.10 ± 0.27^{b}	22.35 ± 0.27^{b}
	1%	2	8.05 ± 0.26^{d}	10.64 ± 0.25^{e}	13.57 ± 0.27^{d}	15.62 ± 0.27^{e}	18.81 ± 0.27^{c}	20.49 ± 0.24^{d}
	1.50%	2	8.43 ± 0.26^{cd}	10.96 ± 0.23^{de}	14.18 ± 0.25^{ed}	16.87 ± 0.28^{d}	19.13 ± 0.28^{c}	21.05 ± 0.28^{cd}
	2%	2	8.76 ± 0.25^{bcd}	11.14 ± 0.24^{ede}	14.63 ± 0.24^{e}	17.09 ± 0.26^{cd}	19.17 ± 0.25^{c}	21.12 ± 0.26^{cd}
	Control	-	10.34 ± 0.27^{a}	13.95 ± 0.27^{a}	17.68 ± 0.26^{a}	21.73 ± 0.27^{a}	28.04 ± 0.27^{a}	30.11 ± 0.26^{a}
	P		0.001	0.001	0.001	0.001	0.001	0.001
	LSD (<0.05)		0.91	0.81	0.86	0.92	0.91	0.90

Means in a column with the same letter are not significantly different at ($p \leq 0.05$) according to LSD.

were observed throughout the storage period and after 35 days of storage period, the *a** and *b** values recorded in control fruits were 19.09% and 31.95% higher in contrast to fruits treated with two sprays of $CaCl_2$ @ 1.0%. Increase in *a** and *b** values with storage period may be due to degradation of chlorophyll content and synthesis of colouring compounds like carotenoids and anthocyanins.

In the present study (Table 3), two sprays of $CaCl_2$ (1.0, 1.5 and 2.0%) were found significantly efficient in maintaining sensory quality up to 28 days of storage, unlike the untreated fruits. Fruits given one spray of $CaCl_2$ (1.0, 1.5 and 2.0%) where sensory quality was retained only up to 21 days of storage and thereafter, declined at a faster pace. At the end of 35 days of storage, maximum sensory quality rating (6.67) was registered in two sprays of $CaCl_2$ @ 1.0% whereas, control fruits recorded minimum sensory quality rating (5.04). The higher sensory quality of fruits treated with calcium compounds at the end of storage may be due to retardation of ripening process. These results are in accordance to the findings of Serrano *et al*. (11) in plum fruits.

Calcium chloride treatments recorded less spoilage percentage (Fig. 1B) as compared to control fruits. Moreover, fruits applied with two sprays of $CaCl_2$ @ 1% did not show any spoilage till 35 days of storage period. From 7 to 21 days

Table 3. Sensory quality and calcium content (ppm) of plum fruits subjected to various treatments of calcium nitrate during cold storage (0-1°C, 90-95% RH).

Parameters	Calcium chloride Conc. (%)	No. of sprays	Storage interval (Days)					
			0	7	14	21	28	35
Sensory quality (1-9)	1.0	1	5.82 ± 0.03^{c}	7.24 ± 0.02^{b}	7.76 ± 0.04^{c}	8.42 ± 0.04^{bc}	7.14 ± 0.04^{c}	5.67 ± 0.03^{d}
	1.5	1	6.00 ± 0.01^{b}	7.40 ± 0.02^{a}	7.92 ± 0.02^{b}	8.56 ± 0.07^{ab}	6.72 ± 0.03^{d}	5.36 ± 0.04^{e}
	2.0	1	6.05 ± 0.02^{ab}	7.46 ± 0.05^{a}	8.04 ± 0.02^{ab}	8.59 ± 0.04^{a}	6.55 ± 0.04^{e}	5.21 ± 0.12^{ef}
	1.0	2	5.53 ± 0.03^{d}	6.57 ± 0.03^{d}	7.24 ± 0.04^{e}	7.93 ± 0.03^{f}	8.37 ± 0.04^{a}	6.67 ± 0.04^{a}
	1.5	2	5.60 ± 0.05^{d}	6.76 ± 0.06^{c}	7.53 ± 0.05^{d}	8.17 ± 0.03^{e}	8.21 ± 0.03^{b}	6.18 ± 0.05^{b}
	2.0	2	5.60 ± 0.05^{d}	6.89 ± 0.03^{c}	7.62 ± 0.04^{d}	8.21 ± 0.04^{de}	8.27 ± 0.03^{ab}	5.90 ± 0.02^{c}
	Control	-	6.15 ± 0.05^{a}	7.52 ± 0.05^{a}	8.11 ± 0.03^{a}	8.35 ± 0.04^{cd}	6.21 ± 0.03 ^{f}	5.04 ± 0.03 ^{f}
	P		0.001	0.001	0.001	0.001	0.002	0.001
	LSD (<0.05)		0.13	0.14	0.13	0.15	0.12	0.19
Calcium content (ppm)	1.0	1	51.00 ± 0.46^{c}	52.80 ± 1.33^{cd}	55.05 ± 1.34^{cd}	57.45 ± 1.87^{bc}	59.70 ± 1.02^{bc}	62.25 ± 2.10^{c}
	1.5	1	49.05 ± 1.03^{c}	51.00 ± 1.58^{d}	53.40 ± 1.25^{d}	55.95 ± 0.85^{c}	57.75 ± 1.62^{c}	60.60 ± 1.47^{c}
	2.0	1	48.30 ± 1.33^{c}	50.25 ± 1.73^{d}	52.65 ± 1.33^{d}	55.20 ± 1.05^{c}	57.45 ± 0.89^{c}	60.45 ± 2.12^{c}
	1.0	2	61.95 ± 1.38^{a}	62.70 ± 1.47^{a}	63.90 ± 1.33^{a}	65.10 ± 1.05^{a}	66.15 ± 1.00^{a}	67.80 ± 1.83^{a}
	1.5	2	57.15 ± 1.24^{b}	58.20 ± 1.40^{ab}	59.70 ± 1.23^{ab}	61.35 ± 0.66^{ab}	63.15 ± 0.71^{ab}	65.10 ± 1.35^{b}
	2.0	2	55.95 ± 1.33^{b}	57.15 ± 1.17^{bc}	58.80 ± 1.30^{bc}	60.60 ± 1.47^{b}	62.55 ± 1.04^{ab}	64.65 ± 2.45^{b}
	Control	-	47.10 ± 1.42^{c}	49.20 ± 1.33^{d}	51.75 ± 1.47^{c}	54.45 ± 1.02^{c}	57.00 ± 1.09^{c}	60.15 ± 1.24^{d}
	P		0.001	0.001	0.001	0.001	0.002	0.001
	LSD (<0.05)		4.12	4.89	4.49	4.08	3.68	1.92

Means in a column with the same letter are not significantly different at ($p \leq 0.05$) according to LSD.

of storage, no spoilage was observed in any of the calcium treated fruits, except control fruits, which started deteriorating after 14th day of storage. After 35 days of storage period, only the fruits that received two sprays of $CaCl_2$ @ 1.0% were able to maintain quality, whereas, control fruits recorded maximum spoilage (6.34%). Reduced decay in fruits treated with calcium may be due to its role in promoting the synthesis of phenolic compounds and it also reduces the risk of micro cracks in the cuticle which further resists the fungal attack (Elmer *et al*., 4). Similar results were reported earlier by Bhat *et al.* (3) in pear fruits.

A gradual increase in TSS (Fig. 1C) and total sugars (Fig. 2A) was observed in fruits treated with two sprays of $CaCl_2$ (1.0, 1.5 and 2.0%) up to 28 days, whereas, fruits treated with one spray of $CaCl_2$ (1.0, 1.5 and 2.0%) along with control fruits registered this increase only up to 21 days of storage and thereafter a sharp decline was noted. After 35 days of storage period, fruits treated with two sprays of $CaCl_2$ @ 1.0% were found effective in maintaining maximum TSS and total sugars (12.82% and 7.14%, respectively) as compared to control fruits. A slow increase in TSS and total sugars with application of calcium chloride might be due to formation of thin layer of calcium on the surface of fruit which delays the degradation process of polysaccharides (Turmanidze *et al*., 13). Similar view was shared by Jawandha *et al.* (6) in ber. Titratable acidity declined with the progression in storage period (Fig. 1D). However, the pace of decline significantly varied in different treatments given to plum fruits. From the day of harvesting to 35 days of storage, the rate of decrease in acidity in untreated fruits was higher (57.95%) as compared to fruits received two sprays of $CaCl_2$ @ 1.0% where this decrease was much slower (42.20%). These results are in line with the findings of Ashoori *et al*. (2) in apple fruit.

Application of different concentrations of calcium chloride on plum had a significant effect on anthocyanin (Fig. 2B) development in fruits. Fruits treated with two sprays of $CaCl_2$ @ 1.0% displayed a relatively slow increase in anthocyanin content as compared to other treatments. From the day of harvesting to 35 days of storage period the anthocyanin content in control fruits increased from 12.49 to 18.52 mg /100g FW which was much higher than any other treatments

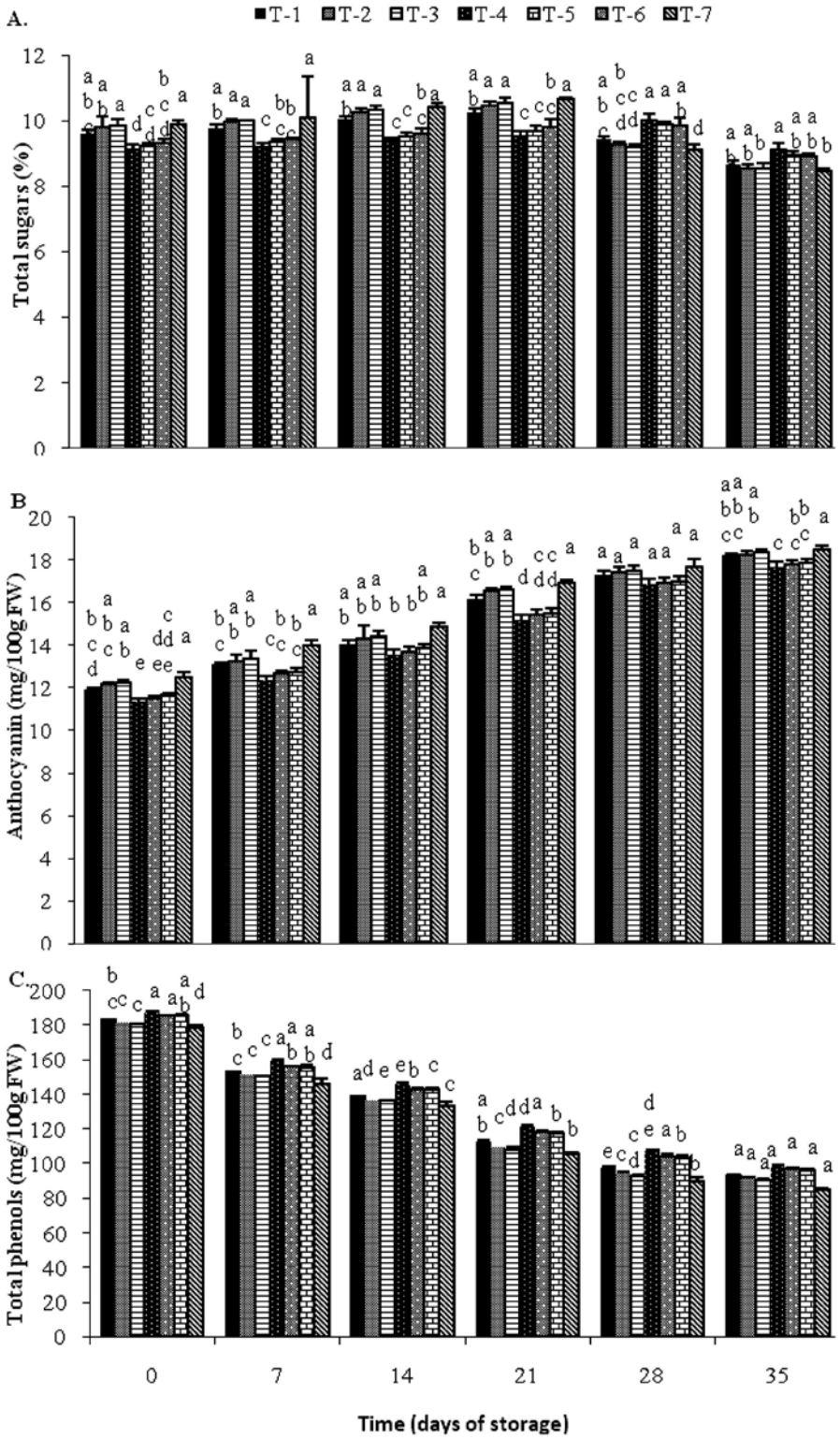

Fig. 2. Variation in (A.) total sugars (B.) anthocyanins and (C.) total phenols in plum *cv*. Satluj Purple during cold storage (0-1°C, 90-95% RH) in relation to pre-harvest treatment with different concentration of calcium chloride. Vertical bars represent ± Standard error of mean of 4 replicates, T-1: one spray $CaCl_2$ (1.0 %), T-2: one spray $CaCl_2$ (1.5 %), T-3: one spray $CaCl_2$ (2.0%), T-4: two sprays $CaCl_2$ (1.0%), T-5: two sprays $CaCl_2$ (1.5%), T-6: two sprays $CaCl_2$ (2.0%), T-7: control

and minimum (11.37-17.67 mg /100g FW) increase in anthocyanin content was found in fruits treated with two sprays of $CaCl_2$ @ 1.0%. After 35 days of storage, the anthocyanin content found in control fruits was 4.59% higher than fruits treated with two sprays of $CaCl_2$ @ 1.0%. Calcium plays an important role in cell biochemistry by delaying the progression of anthocyanin content which is directly proportional to the ripening process. As evident from Fig. 2C, maximum percent reduction (52.22) in phenolics was recorded in control fruits against 47.43% in fruits treated with two sprays of $CaCl_2$ @ 1.0% which showed minimum reduction in total phenols. It was inferenced that among all the treatments of calcium chloride, two sprays of $CaCl_2$ @ 1.0% were most effective in retaining total phenols throughout the storage period. Results are in accordance with the findings of Turmanidze *et al*. (13) in blackberry, raspberry and strawberry.

An increase in calcium content (Table 3) of both peel and pulp increased with the storage period, which might be due to the loss of moisture leading to manifestation of increased calcium content in fruits. From the day of harvesting to 35 days of storage, maximum calcium content (61.95 - 67.80 ppm) was noted in fruits treated with two sprays of $CaCl_2$ @ 1.0%, whereas minimum calcium content (47.10 - 60.15 ppm) was found in untreated fruits. On 35th day of storage, calcium content in fruits treated with two sprays of $CaCl_2$ @ 1.0% was found 11.36% higher as compared to control fruits. The elevated level of calcium content in fruit treated with higher concentration of calcium compounds may be due to its greater absorption and deposition. Similar trend of increase in calcium content was found by Serrano *et al*. (11) in plum.

It is evident from the data presented in Fig. 3A and 3B, that plum fruits subjected to two sprays of $CaCl_2$ (1.0, 1.5 and 2.0%) recorded increase in PME and cellulase activity up to 28 days, unlike other treatments where this increase was observed only up to 21 days of storage period and thereafter

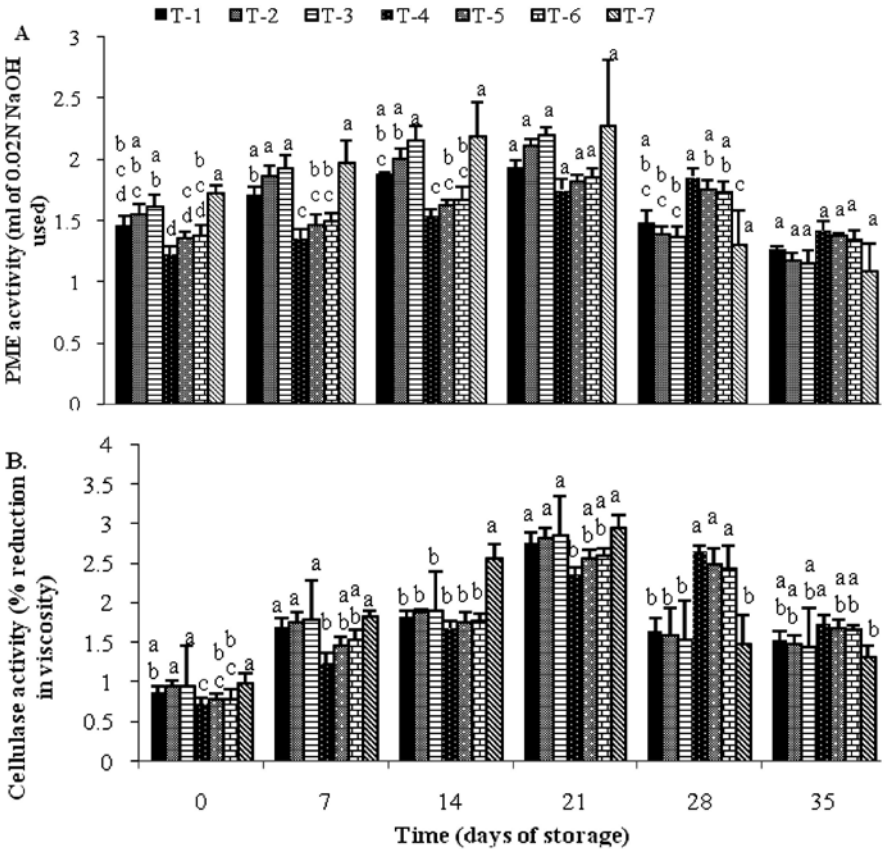

Fig. 3. Variation in (A.) PME activity and (B.) cellulase activity in plum *cv*. Satluj Purple during cold storage (0-1°C, 90-95% RH) in relation to pre-harvest treatment with different concentration of calcium chloride. Vertical bars represent ± Standard error of mean of 4 replicates, T-1: one spray $CaCl_2$ (1.0 %),T-2: one spray $CaCl_2$ (1.5 %), T-3: one spray $CaCl_2$ (2.0%), T-4: two sprays $CaCl_2$ (1.0%),T-5: two sprays $CaCl_2$ (1.5%), T-6: two sprays $CaCl_2$ (2.0%), T-7: control

it declined. At the end of 35 days of storage period, two sprays of $CaCl_2$ @ 1.0 % were effective in maintaining maximum PME and cellulase activity (1.42 mL 0.02N NaOH used and 1.73% reduction in viscosity, respectively) as compared to control fruits (1.09 mL 0.02N NaOH used and 1.31 reduction in viscosity, respectively). This signifies the retention of higher substrate level for PME and cellulase enzyme activities at later stages in fruits treated with two sprays of $CaCl_2$ @ 1.0 %, which was already decomposed to the higher extent at the early stages of storage in other treatments. The mean PME and cellulase activities observed in control fruits were 13.07% and 6.49% higher in contrast to fruits treated with two sprays of $CaCl_2$ @ 1.0%. Similar trend for PME and cellulase activity was also recorded by Jawandha *et al*. (7) in ber fruits.

A significant negative correlation was obtained between fruit firmness & PLW (r = -0.949, p≤ 0.01) and activities of PME (r = -0.796, p≤ 0.01) & cellulase enzymes (r = 0.276, p≤ 0.01) (Table 4). Consequently, calcium compounds form cross linkages with the carboxyl group of the pectic substances in the middle lamella which results in strengthening as well as increases the rigidity of cell wall. This binding further prevents the activity of cell wall degrading enzymes thus reducing the rate of softening during storage. Fruit spoilage showed a negative correlation with total phenols (r = -0.552, p≤ 0.01) as phenols have antioxidant properties and imparts disease resistance in fruits. There was a significant positive correlation of anthocyanins with *a** and *b** values (r = 0.927, p≤ 0.01 and r = 0.938, p≤ 0.01, respectively) of colour which indicates that anthocyanin content increases with the increase in *a** and *b** values as the fruits attained characteristic colour, whereas a negative correlation was observed between anthocyanin and *L** value (r = -0.917, p≤ 0.01) due to their inverse relationship.

Table 4. Correlations.

Variables compared	Pearson Correlation Coefficient (r)
Firmness vs. PLW	-0.949**
Firmness vs. PME	-0.796**
Firmness vs. Cellulase	-0.276**
Phenols vs. Spoilage	-0.552**
Lightness vs. Anthocyanin	-0.917**
*a** value vs. Anthocyanin	0.927**
*b** valuevs. Anthocyanin	0.938**

** Correlation is significant at the 0.01 level (2-tailed). PLW; physiological loss in weight, PME; pectin methyl esterase.

It can be summarized that two sprays of $CaCl_2$ @ 1.0% were effective to extend the storage life of plum fruits up to 28 days under cold storage conditions.

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