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Pre-harvest Application of Calcium Maintained Fruit Quality in Cold Stored Plum

Aeshna Sinha, S.K. Jawandha, P.P.S. Gill, Nirmaljit Kaur[1] and Anita Arora

Department of Fruit Science, [1]Department of Botany
Punjab Agricultural University, Ludhiana-141 004, India
E-mail: aeshnasinha@yahoo.ca

Abstract: An experiment was conducted to study the influence of pre-harvest applications of different concentrations of calcium nitrate on various physico-chemical parameters of plum (*Prunus salicina* L.) *cv.* Satluj Purple under cold storage conditions. Uniform and healthy plants of plum *cv.* Satluj Purple were sprayed with calcium nitrate (1.0, 1.5 and 2.0 %) in 2[nd] and 3[rd] week of April and control plants were water sprayed only. Fruits from both treated and control plants were harvested at colour break stage, and then stored at low temperature conditions (0–1 °C and 90–95 % RH) for 35 days. Evaluation of different physico-chemical parameters were made on 0 day and after 7, 14, 21, 28 and 35 days of storage. The results revealed that two sprays of $Ca(NO_3)_2$ @ 2.0 % retained maximum pulp: stone (15.37), total soluble solids (12.93 %), titratable acidity (0.69 %), reducing (6.52 %) & non-reducing sugars (2.64 %) and total phenolics content (101.19 mg $100g^{-1}$) at the end of storage. The fruits treated with two sprays of $Ca(NO_3)_2$ @ 2.0 % were effective in maintaining the quality of fruits without any spoilage up to 35 days under low temperature storage conditions.

Keywords: Calcium nitrate, Plum, Titratable acidity, Spoilage, Total phenolics content

Plum is an important stone fruit grown in north-western provinces of India. Amongst different varieties of Japanese plum, 'Satluj Purple' has gained a special importance among plum growers of north western India, due to its early ripening behavior, low chilling requirement, high yield, attractive colour, excellent flavour and better size. The fruit is rich in vitamins and minerals which makes them highly nutritious and contains certain phytochemical compounds like polyphenols and anthocyanins which imparts them anti-oxidative, anti-carcinogenic, anti-microbial, anti-allergic, anti-mutagenic and anti-inflammatory properties (Thanaa et al 2017). But its keeping quality under ambient conditions is poor due to the climacteric nature of ripening which ensues fruit softening and susceptibility to post-harvest spoilage, thus lowering its marketing value. The harvesting time of this fruit coincides with very hot and dry conditions in the region which further reduces the shelf-life of fruits. Thus, to overcome these post-harvest losses several pre- and post-harvest methods have been employed to enhance the storage life of plum fruits, by minimizing the spoilage, reducing the rate of respiration, ethylene emissions & transpiration losses. Calcium is considered as an important essential nutrient involved in various physiological processes in plant concerning the maintenance of membrane structure & function and various enzymatic activities (Sinha et al 2019b).It is a chief constituent of cell wall, involved in forming cross-bridges and therefore strengthens & maintains the rigidity of the cell wall and prevent fruit spoilage (Ayon-Reyna et al 2015). It effectively reduces the hydrolytic activities of enzymes thus delaying the degradation, softening and senescence of fruits and also inhibits the polygalacturonase and pectin methylesterase activity (Madani et al 2014). Pre-harvest treatment of guava fruits with calcium nitrate resulted in an increase in calcium concentration of the cell wall, maintained the fruit firmness & quality and effectively delayed the senescence (Bisen et al 2014). Calcium treatments efficiently retained the phenolic compounds and minimized decay percentage in pear (Khalaj et al 2017) and peach (Gayed et al 2017) fruits. Calcium application can be incorporated in the production system so as to improve the quality attributes of fruit as well to minimize the usage of chemical fungicides (Moradinezhad et al 2019). Keeping in view the concern of food safety among consumers and harmful effect of chemical residues, calcium nitrate has been found as a safe and effective method to reduce fruit spoilage and preserve its quality parameters. Hence, the aim of study was to determine the effect of application of calcium nitrate on fruit quality of plum fruits during low temperature storage.

MATERIAL 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) in the year 2017.

Twenty four plants were sprayed with calcium nitrate (1.0, 1.5 and 2.0 %) in 2nd and 3rd week of April and four were kept untreated. Fruits from treated and untreated plants were harvested at colour break stage. The fruits of uniform size, free from diseases and bruises were selected, washed and air dried under shade before packaging. The experiment comprised of seven treatments with four replications in each treatment. One kg of fruit from every replication of each treatment was packed in 5% perforated corrugated fibreboard (CFB) boxes lined with paper and stored at low temperature conditions (0-1°C and 90-95 % RH) for 35 days. For study of storage behaviour, fruit samples were analysed on 0 day and after 7, 14, 21, 28 and 35 days of storage period for various physico-chemical characteristics. After each interval of cold storage, pulp to stone ratio was calculated by separating and weighing the pulp and stone of individual fruits. The per cent of spoiled fruits was calculated by counting the spoiled fruits on the number basis and expressed in percentage. Total soluble solids (TSS) in fruit juice were determined by hand refractometer while titratable acidity was determined as malic acid percentage. Total phenolic content was estimated as per the method followed by Sinha et al (2019a), using folin-ciocalteu phenol reagent and the absorbance of resultant blue colour was determined in 'Spectronic-20 D+' colorimeter at 760nm wavelength against blank reagent. Methods followed by Kaur et al (2015) were used to determine the reducing and non-reducing sugars.

The data were statistically analyzed using using statistical package SAS 9.3 (The SAS system for Windows, Version 9.3, SAS Institute, Cary, NC)and significant effects ($P \leq 0.05$) were noted.

RESULTS AND DISCUSSION

Pulp: stone: Pulp: stone in fruits decreased with the advancement of storage period (Table 1) due to the loss of moisture irrespective of the treatments. However, this decrease was slower in calcium treated fruits as compared to untreated fruits. From the day of harvesting to 35 days of storage, fruits treated with two sprays of $Ca(NO_3)_2$ @ 2.0% recorded minimum decline (13.75%) in pulp-stone ratio as compared to control fruits (20.31%), followed by fruits received one spray of $Ca(NO_3)_2$ @ 1.0%. Similar view was shared by Raja et al (2015) in peachfruits.

Total soluble solids: During storage, TSS contents varied significantly with different calcium treatments. The data evidently shows that TSS content increased in fruits treated with two sprays of $Ca(NO_3)_2$ up to 28 days, whereas in untreated fruits TSS content increased only up to 21 days of storage period and, thereafter a sharp decline in the TSS content was recorded (Table 1). From the day of harvesting to 21 days of storage period, fruits treated with two sprays of $Ca(NO_3)_2$ (2.0%) registered minimum (11.39 %) increase in TSS content, whereas this increase was found maximum (12.38%) in control fruits. This slow increase in TSS content in calcium treated fruit at the initial stage of the storage period might be due to the formation of thin layer of calcium on the fruit surface which delays the solubilisation of polysaccharides. However, after 35 days of storage period TSS content recorded in fruits treated with two sprays of $Ca(NO_3)_2$ @ 2.0% was 6.5% higher as compared to untreated fruits. Maintenance of higher TSS content in fruits received two sprays of $Ca(NO_3)_2$ (2.0%) at the end of storage period may be attributed to the slower dehydration processes as well as the conversion of complex polysaccharides (like starches and pectins) into simple sugars. Similar results were reported by Khalaj et al (2017) in pears where higher TSS was retained in calcium treated fruit.

Titratable acidity: Titratable acidity registered an overall decreasing trend during the storage period irrespective of the treatments due to the breakdown of organic acids into sugars during respiration process (Table 1). However, the pace of decline of acidity in fruits treated with calcium was less as compared to control fruits. Titratable acidity is directly related to the concentration of principle organic acids, which is an important attribute in the maintenance of fruit quality. From the day of harvesting to 35 days of storage, fruits subjected to two sprays Ca $(NO_3)_2$ @ 2.0% registered lowest decline (40.52%) in acidity against 57.95% in control fruits. The reason for delayed reduction in acidity in calcium treated fruits may be due to suppression in the metabolic activities which in turn delay the organic acids utilization in the pyruvate decarboxylation pathway, during the ripening process (Wang et al 2014). Similar finding in view of slow decline in acidity was reported in calcium treated papaya fruits by Madani et al (2014).

Fruit spoilage: The spoilage of plum fruits increased with the progression of storage period (Table 1). However, fruits treated with calcium did not show any spoilage up to 21 days of storage, whereas control fruits started deteriorating after 14 days of storage period. Moreover, no spoilage was observed in fruits treated with two sprays of Ca $(NO_3)_2$ (1 %, 1.5 % and 2.0 %) till the end of storage period (35 days). Reduced spoilage percentage of calcium treated plum fruits may be due to increased deposition of calcium pectate resulting into thickening of middle lamella of the cell wall thus inhibiting the penetration and accessibility of hydrolase enzymes of pathogens in fruits (Ayon-Reyna et al2015). Calcium also accelerates the synthesis of phytoalexin and phenolic compounds which further inhibits the activity of enzymes secreted by the fungus (Awanget al 2011), thus preventing fruit spoilage. Similar results were reported earlier by Gayed et al (2017) in peach where pre-harvest application of calcium effectively minimized the fruit spoilage during low temperature storage conditions.

Total phenolics content: A declining trend in the phenolics content with storage was observed in all fruits regardless of the treatments (Table 2). However, this decline was slower in fruits treated with calcium as compared to control depicting the suppression of polyphenol oxidase activity with the application of calcium nitrate. From the day of harvesting to 35 days of storage, fruits subjected to two sprays $Ca(NO_3)_2$ @ 2.0 % recorded minimum decline in phenolics content by 46.94% in contrast to control fruits where maximum decline (52.22 %) in total phenolics content was recorded. At the end of 35 days of storage period fruits received two sprays $Ca(NO_3)_2$ @ 2.0 % recorded 8.38 % higher phenolics content in comparison to control fruits. This signifies the efficacy of two sprays $Ca(NO_3)_2$ @ 2.0 % in maintaining the phenolics content as calcium compounds strengthen the cell walls, maintains the selective exchange of ions and gases (Zeraatgar et al 2018), prevents the leaching of polyphenol compounds, therefore causing reduction in the oxidation of phenols (Turmanidze et al 2016).

Table 1. Pulp: stone, TSS, (B.) titratable acidity and (C.) fruit spoilagein plum *cv*. Satluj Purple during cold storage (0-1°C, 90-95% RH) in relation to pre-harvest treatment with different concentration of calcium nitrate

Parameter	Treatments	Storage time (days)					
		0	7	14	21	28	35
Pulp: stone	T1	17.08^{d}	15.25^{c}	14.81^{d}	14.50^{d}	14.29^{b}	13.95^{d}
	T2	17.19^{cd}	15.42^{c}	15.04^{c}	14.75^{cd}	14.54^{b}	14.26^{cd}
	T3	17.24^{cd}	15.49^{bc}	15.13^{c}	14.87^{c}	14.66^{b}	14.38^{c}
	T4	17.49^{bc}	15.83^{ab}	15.57^{b}	15.36^{b}	15.25^{a}	15.01^{b}
	T5	17.74^{ab}	16.11^{a}	15.89^{a}	15.70^{ab}	15.52^{a}	15.33^{ab}
	T6	17.82^{a}	16.17^{a}	15.94^{a}	15.76^{a}	15.59^{a}	15.37^{a}
	T7	16.69^{e}	14.79^{d}	14.30^{e}	13.81^{e}	13.48^{c}	13.13^{e}
TSS (%)	T1	11.89^{a}	12.85^{a}	13.23^{ab}	13.51^{ab}	12.75^{c}	12.43^{ab}
	T2	11.73^{ab}	12.67^{ab}	13.03^{abc}	13.28^{ab}	12.89^{bc}	12.61^{ab}
	T3	11.67^{ab}	12.62^{ab}	12.97^{abcd}	13.22^{abc}	12.97^{bc}	12.68^{ab}
	T4	11.38^{ab}	12.30^{ab}	12.62^{bcd}	12.85^{bcd}	13.50^{ab}	12.76^{ab}
	T5	11.09^{b}	12.01^{b}	12.32^{cd}	12.53^{cd}	13.78^{a}	12.91^{a}
	T6	11.04^{b}	11.94^{b}	12.24^{d}	12.46^{d}	13.85^{a}	12.93^{a}
	T7	12.03^{a}	13.03^{a}	13.45^{a}	13.73^{a}	12.52^{c}	12.09^{b}
Titratable acidity (%)	T1	0.94^{de}	0.81^{d}	0.71^{de}	0.62^{c}	0.56c^{d}	0.45^{bc}
	T2	0.97^{cde}	0.86^{cd}	0.77^{cd}	0.65^{c}	0.61b^{c}	0.48^{bc}
	T3	1.02^{bcd}	0.90^{c}	0.81^{bc}	0.68^{c}	0.64^{abc}	0.51^{bc}
	T4	1.07^{abc}	0.99^{b}	0.87^{ab}	0.79^{b}	0.69^{ab}	0.57^{ab}
	T5	1.12^{ab}	1.05^{ab}	0.91^{a}	0.85^{ab}	0.72^{ab}	0.65^{a}
	T6	1.16^{a}	1.08^{a}	0.94^{a}	0.89^{a}	0.75^{a}	0.69^{a}
	T7	0.88^{e}	0.71^{e}	0.63^{e}	0.52^{d}	0.43^{d}	0.37^{c}
Spoilage (%)	T1	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	1.76^{d}	3.82^{b}
	T2	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	1.11^{e}	3.19^{c}
	T3	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.98^{e}	3.08^{c}
	T4	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}
	T5	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}
	T6	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}	0.00^{f}
	T7	0.00^{f}	0.00^{f}	1.97^{d}	3.91^{b}	4.26^{b}	6.34^{a}

T-1: one spray $Ca(NO_3)_2$(1.0 %), T-2: one spray $Ca(NO_3)_2$(1.5 %), T-3: one spray $Ca(NO_3)_2$(2.0%), T-4: two sprays $Ca(NO_3)_2$(1.0 %), T-5: two sprays $Ca(NO_3)_2$(1.5 %), T-6: two sprays $Ca(NO_3)_2$(2.0%), T-7: control. Means in the columns and rows with the same letter are not significantly different at ($p \leq 0.05$) according to LSD.

Table 2. Total phenolics content, reducing sugars and non-reducing sugarsin plum *cv*. Satluj Purple during cold storage (0-1^{o}C, 90-95% RH) in relation to pre-harvest treatment with different concentration of calcium nitrate

Parameter	Treatments	Storage time (days)					
		0	7	14	21	28	35
Total phenolics content (mg 100g$^{-1)}$	T1	182.31^{d}	151.79^{d}	137.53^{d}	110.56^{b}	95.83^{e}	92.62^{c}
	T2	184.17^{cd}	154.56^{cd}	140.69^{c}	114.48^{b}	98.65^{d}	94.37^{c}
	T3	185.54^{bc}	155.73^{bcd}	142.65^{c}	115.72^{b}	99.84^{c}	95.56^{c}
	T4	186.65^{b}	158.82^{abc}	145.58^{b}	120.81^{a}	105.47^{b}	97.29^{b}
	T5	190.19^{a}	160.27^{ab}	147.79^{ab}	122.45^{b}	108.32^{a}	100.65^{a}
	T6	190.71^{a}	161.43^{a}	148.82^{a}	124.09^{a}	109.76^{a}	101.19^{a}
	T7	178.32^{e}	146.15^{e}	133.74^{e}	105.43^{c}	89.54^{f}	85.21^{d}
Reducing sugars (%)	T1	11.89^{b}	12.85^{b}	13.23^{ab}	13.51^{ab}	12.75^{d}	12.43^{c}
	T2	6.75^{c}	6.87^{c}	7.06^{bc}	7.20^{bc}	6.51^{c}	6.03^{bc}
	T3	6.57^{c}	6.66^{c}	6.82^{bc}	6.94^{bc}	6.68^{c}	6.12^{bc}
	T4	6.53^{d}	6.62^{d}	6.76^{cd}	6.89^{c}	6.73^{b}	6.15^{ab}
	T5	6.37^{d}	6.46^{de}	6.57^{cd}	6.68^{c}	6.93^{a}	6.31^{a}
	T6	6.31^{d}	6.37^{e}	6.50^{d}	6.57^{c}	7.02^{a}	6.49^{a}
	T7	6.26^{a}	6.32^{a}	6.43^{a}	6.51^{a}	7.08^{e}	6.52^{c}
Non-reducing sugars (%)	T1	2.73^{abc}	2.78^{abc}	2.86^{abc}	2.92^{ab}	2.64^{ab}	2.44^{bc}
	T2	2.66^{ab}	2.70^{ab}	2.76^{ab}	2.81^{ab}	2.71^{ab}	2.48^{c}
	T3	2.64^{ab}	2.68^{a}	2.74^{a}	2.79^{ab}	2.73^{b}	2.49^{c}
	T4	2.58^{c}	2.62^{c}	2.66^{d}	2.70^{c}	2.81^{ab}	2.56^{a}
	T5	2.56^{bc}	2.58^{c}	2.63^{cd}	2.66^{bc}	2.84^{ab}	2.63^{ab}
	T6	2.54^{abc}	2.56^{bc}	2.60^{bcd}	2.64^{abc}	2.87^{ab}	2.64^{ab}
	T7	2.79^{a}	2.85^{a}	2.94^{a}	3.01^{a}	2.56^{b}	2.39^{c}

See Table 1 for details.

Reducing and non-reducing sugars: Sugars have a critical role in determining the palatability of the fruits. The reducing and non-reducing sugars followed similar trend during storage studies (Table 2). Fruits treated with two sprays of $Ca(NO_3)_2$ showed an increase in both reducing and non-reducing sugars up to 28 days, whereas in untreated fruits this increase was recorded only up to 21 days of storage period and, thereafter it declined gradually. The initial increase in sugars is due to the breakdown of complex polysaccharides into simple sugars, which at later stages get utilized in the respiration process, thus resulting into decline of sugars (Adhikary et al 2021). From the day of harvesting to 21 days of storage period fruits subjected to two sprays $Ca(NO_3)_2$ @ 2.0% recorded minimum rate of increase (3.99 and 3.79%, respectively) in reducing and non-reducing sugars in fruits against 7.27% and 14.34% in control fruits. This might be due to slow conversion of starch into sugars and the gradual build up of sugars in calcium treated fruit may be associated with delayed ripening. These results are in line with the findings of Kaur et al (2015) in plum and Sidhu et al (2020) strawberries where calcium application effectively maintained reducing and non-reducing sugars in fruit.

CONCLUSION

In conclusion two sprays of $Ca(NO_3)_2$ @ 2.0% inhibited the spoilage of plum fruits up to 35 days of storage and was most effective in extending the storage life and maintaining the quality of plum fruits during cold storage.

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