**Postharvest Calcium Chloride Application Maintains Shelf Life and Quality of Loquat (Eriobotrya japonica L.) Fruit**

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**ABSTRACT**

Loquat (Eriobotrya japonica L.) is an important subtropical fruit with very limited postharvest life. Therefore, in the current study, we investigated the effect of calcium chloride (CaCl₂) treatments on the shelf life and quality of loquat fruit. After harvest, loquat fruit treated with different concentrations of CaCl₂; viz. 2%, 4% and 6% for 2 min were kept at room temperature (30±2°C) for 5 and 10 days. Untreated fruit were kept as control. The results showed that fruit treated with 6% CaCl₂ exhibited minimum fruit weight loss (9.1%), external browning (8.83%), and internal browning (9.1%) after 10 days shelf period in contrast with control fruit. Lowest total soluble solids contents (9.11%), highest titratable acidity (0.53%) and juice (28%) contents were found in fruit treated with 6% CaCl₂ as compared to other treatments. In conclusion, among the tested treatments, application of highest level of CaCl₂ (6%) effectively maintained the quality of loquat fruit at a room temperature.

**Keywords:** Calcium chloride, external browning, internal browning, loquat, total soluble solids.

**INTRODUCTION**

Loquat is a very famous member of the family Rosaceae (Ghasemnezhad et al., 2010) has been classified as non-climacteric fruit (Blumenfeld, 1980). It was originated from China where its cultivation had been reported about 2000 years back (Lin et al., 1999). At present, it is being cultivated commercially in more than 30 countries of the world (Feng et al., 2007). Being an important fruit of Pakistan, it is cultivated in Khyber Pakhtunkhwa and Punjab provinces at commercial scale (Hussain et al., 2007). Loquat fruit contain almost every type of the essential nutrients required for the human health and development. Particularly it is considered as rich source of minerals (phosphorus and calcium), vitamins (A, B and C), salts and carotenoids (Lin et al., 1999).

Loquat exhibits very limited shelf life as fruits start to decay quickly after harvest with substantial reduction in taste, titratable acidity, juice percentage and increase in internal browning (Lin et al., 1999). Calcium is a vital component of fruit tissues which plays key function in conserving their postharvest quality by maintaining cellular films and suspending senescence. Postharvest use of calcium maintains cell wall, cell turgor, membrane reliability and tissue firmness (Rizk-Ala and Meshreki, 2006). It has been examined that the postharvest treatment of calcium can maintain the fruit quality, inhibit physiological disorders, decrease the rate of respiration, and slow down ripening processes in many fruits especially apple, melons, tomato, and peach (Lester and Grusak, 2004; Burns and Pressey, 1987). Calcium has been found to inhibit postharvest disorders, prevent fruit softening, and cause significant reduction in postharvest fruit weight loss and deterioration (Lara et al., 2004; Lester and Grusak, 2004; Hernandez-Munoz et al., 2006). Similarly, calcium chloride (CaCl₂) application reduces physiological processes such as ethylene production, respiration rate and deterioration (Ali et al., 2013; Lester and Grusak, 2004; Mahajan and Sharma, 2000). Babu et al. (2015) found that 3% CaCl₂ application significantly extends the shelf-life of loquat by reducing weight loss (%) and maintaining firmness and vitamin C contents.

Use of calcium to improve postharvest quality of perishable horticulture commodities in well documented in literature with varying responses. Particularly it has been reported that calcium (1%) significantly increases the resistance against fungal diseases as well as maintain the cell walls structural integrity in strawberry (Lara et al., 2004) and kiwi fruit (Gerasopoulos and Drogoudi, 2005), custard apple (Jaishankar et al., 2018), pear...
(Mahajan and Dhatt, 2014) and Loquat (Akhtar et al., 2010) fruits. However, loquat is an important minor fruit of Pakistan and very limited research work has been carried out on its shelf-life extension and quality management. Therefore, it was hypothesized that the application of CaCl₂ will maintain firmness, total soluble solids, acidity and reduce browning index and weight loss of loquat fruit kept at ambient conditions.

MATERIALS AND METHODS

The experiment was conducted in the Laboratory of Horticulture Department, University College of Agriculture Sargodha, Punjab, Pakistan. Mature fruits were harvested at commercial maturity (“Brix > 10”) with the help of sharp secateurs from the plants grown in the Research Area of the Department. Fruits were dipped in the respective solutions of CaCl₂ (0, 2%, 4% and 4%) for 2 min and then kept at room temperature (30±2°C) for 5 and 10 days. Fifteen fruits were used as experimental unit replicated thrice. Following aspects were studied in the experiment.

Weight loss

Fruit weight of each sample was measured (g) by using digital electronic balance (A and D Limited, Tokyo, Japan). Weight loss was calculated by using the following formula: Weight loss (%) = [(A–B)/A] x 100, Where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after shelf period.

Fruit diameter

Fruit diameter (mm) of each sample was measured in mm around the fruit radius by using vernier caliper. Fruit diameter reduction was determined by the following formula: Diameter reduction = Diameter at harvest – diameter after shelf period.

External browning index

External browning index was assessed method described earlier by Wang et al. (2005) after 5 and 10 days of shelf interval. Fruit out skin tissues were assessed on the following scale: 0= no browning; 1= less than ¼ browning; 2= ¼ to ½ browning; 3= ½ to ¾ browning; 4= more than ¾ browning. The browning index was calculated using the following formula:

\[
\text{Browning Index} = \left[ \frac{(1 \times N1 + 2 \times N2 + 3 \times N3 + 4 \times N4)}{(4 \times N)} \right] \times 100
\]

Where N = total number of fruits observed and N1, N2, N3 and N4 were the number of fruits which were scored in each degrees of browning.

Internal browning index

Internal browning index of loquat fruit pulp tissues were noted in the same manner as external browning index.

Firmness

Fruit firmness was determined by means of digital fruit-firmness tester (53205, TR di Turoni, Forli, Italy), equipped with 8 mm plunger tip. Firmness was measured as the maximum force required to penetrate the plunger tip and value was expressed as force (N).

Juice percentage

Juice of each fruit was extracted manually and sieved to get a clear juice. Juice weight was measured (g) by using digital electric balance (A and D Limited, Tokyo, Japan) Juice percentage was determined by the following formula:

\[
\text{Juice \%} = \text{juice weight / fruit weight} \times 100
\]

pH of fresh juice

The pH of the juice was measured with the help of digital pH meter (HANA 8520, Italy) using 20 mL clear juice taken in 100 mL beaker.

Total soluble solids

Total soluble solids (TSS) contents of each fruit were measured by using digital refractometer (ATAGO, RX 5000). To calculate the amount of TSS, fruit juice was extracted, and 1-2 drops of juice were placed on refractometer lens. Reading was noted down in percentage (%).

Titratable acidity

Titratable acidity was calculated by using the formula

\[
\frac{(\text{milli-equivalent weight of citric acid} \times \text{volume of titrant}) \times \text{(volume of NaOH) \times (100)}}{\text{(mL of juice \times volume of aliquot)}}
\]

Where,

\[\text{milli-equivalent weight of citric acid} = 0.0064\]
\[\text{Total volume (mL)} = 30\]
\[\text{Extract juice sample (mL)} = 10\]
\[\text{Volume of aliquot (mL)} = 5\]

Juice sample (10 mL) of each replicate taken in a glass beaker was mixed with 20 mL distilled water (DW). Then 5 mL aliquot taken in a conical flask was titrated against NaOH (0.1 N) till end point (permanent light pink) using few drops of phenolphthalein indicator.

Statistical analysis

The experimental design was laid out according to completely randomized design (CRD) with two factors (treatment and shelf period in days). The impacts of different CaCl₂ treatments, shelf period in days were evaluated using least significant difference (LSD) test at 5% probability level by using Windows-based software Statistix 8.1.

RESULTS

Weight loss

All the treatments of CaCl₂ significantly affected the weight loss of loquat fruit (Table 1). Fruit treated with 6% CaCl₂ exhibited minimum fruit weight loss (6.40%) followed by 4% CaCl₂.
application (13%) and 2% CaCl₂ application (19.94%). However, maximum fruit weight loss was observed (29.53%) in untreated control after day 5 of shelf period. Among other levels, applications of 4% CaCl₂ was more effective (13%) than 2% CaCl₂ (19.94%) up to day 5 of shelf period. After 10 days of shelf period minimum fruit weight loss (9.08%) was observed in 6% CaCl₂ treated loquat fruit, while maximum fruit weight loss (32.49%) was recorded in untreated fruit (Table 1). On an average it was also observed that the loquat fruit exhibited less fruit weight loss up to 5 days of shelf period (17.2%) as compare to kept them for 10 days (20.08%) at ambient conditions.

**Fruit diameter reduction**

Postharvest CaCl₂ application significantly slow down the reduction in diameter of loquat fruit (Table 1). However, minimum loquat fruit diameter reduction was observed (11.76 mm) in 6% CaCl₂ treatment, while maximum fruit diameter reduction was observed in control fruit after 5 days of shelf period (Table 1). Similar trend was observed after 10 days of shelf period. In general, the higher reduction in fruit diameter was recorded after 10 days intervals (18.20 mm) compared with 5 days intervals (21.05 mm). The interaction between treatments and shelf period in days was found non-significant (P ≤ 0.05) for fruit diameter reduction.

**External browning Index**

Results indicated that among treatments, application of 6% CaCl₂ was more efficient in reducing external browning index in loquat fruit than other two levels (2%, and 4% CaCl₂) as well as untreated control fruit. However, maximum external browning of loquat fruit was observed (19.21%) in control while minimum fruit level was recorded in fruit (8%) treated with 6% CaCl₂ (6%) after 5 days of shelf period. Whereas loquat fruit treated with 2% and 4% CaCl₂ exhibited 16.47% and 11.86% external fruit browning after 5 days of shelf period, respectively (Table 2). After 10 days of shelf period minimum external browning (8.83%) was observed in loquat fruit treated with 6% CaCl₂ while maximum external browning (16.66%) was observed in control fruit. The interactive effect of treatments with shelf period (days) did not show any significant influence on the changes in the external browning of loquat fruit.

**Internal browning Index**

Irrespective of shelf period in days postharvest application of various level of CaCl₂ significantly reduced the internal browning in loquat fruit (Table 2). Application of 6% CaCl₂ was more effective than other two levels (2% and 4% CaCl₂), in reduction of internal browning of fruit. After 5 days of shelf period maximum fruit internal browning was observed (17.05%) in untreated control fruit control; while minimum fruit internal browning of loquat was recorded in fruit (7.13%)
The results showed that after 5 days of shelf period minimum firmness was observed (1.08) in untreated control fruit. Independent effect of shelf period and interactive effect of treatments and shelf period showed non-significant differences for changes in fruit firmness.

Total soluble solids

The results showed that after 5 days of shelf period minimum TSS (7.77%) contents were recorded in the juice of loquat fruit treated with 6% CaCl₂ followed by the 4% CaCl₂ (9.92%) and 2% CaCl₂ (12.02%) treatments (Table 3). Similarly, after 10 days of shelf period, minimum TSS (9.11%) of loquat fruit was observed in 6% CaCl₂ treated fruit as compared to control fruit (16.07%). In general, the highest TSS of loquat fruit was recorded after 10 days shelf period (12.51%) compared with 5 days shelf intervals (11.24%). The interaction between treatments and intervals as well as storage intervals was found non-significant for changes in TSS.

Acidity

The treatment of CaCl₂ has valuable effect on acidity of loquat fruit. The treatment of loquat fruit with highest level of CaCl₂ (6%) was more effective than lower levels (2% and 4% CaCl₂) and untreated control fruit. After 5 days of shelf period, minimum fruit acidity was observed (0.31%) in control fruit while maximum fruit acidity was recorded (0.59%) in fruit treated with 6% CaCl₂ (Table 3). However, 4% CaCl₂ treatment was more effective (0.45%) than 2% CaCl₂ treatment in which lower acidity was observed (0.37%) at 5-day storage of fruit. Similarly, maximum level of acidity (0.52%) of loquat fruit was observed in CaCl₂ (6%) treated fruit, while minimum acidity (0.29%) was observed in control treatment after 10 days of shelf time. In general, as expected, higher level of fruit acidity was observed after 5 day (0.43%) as compared with 10 days (0.39%) of shelf period.

| Table 3: Impact of calcium chloride (CaCl₂) on total soluble solid and titratable acidity of loquat fruit during storage. |
|---|---|---|---|---|---|
| Treatments | Total soluble solids (%) | Titratable acidity (%) | Shelf period (Days) | Shelf period (Days) |
| | 5 | 10 | Mean | 5 | 10 | Mean |
| Control | 15.25ab | 16.07a | 15.66A | 0.31c | 0.29c | 0.30C |
| 2% CaCl₂ | 12.02bcd | 13.80abc | 12.91B | 0.37bc | 0.34bc | 0.35 BC |
| 4% CaCl₂ | 9.92de | 11.07cde | 10.50C | 0.45abc | 0.41abc | 0.43B |
| 6% CaCl₂ | 7.77e | 9.11de | 8.44C | 0.59a | 0.52ab | 0.55A |
| Mean | 11.24B | 12.51A | 11.24B | 0.43A | 0.39A | 

LSD (P ≤ 0.05)

| Treatments (T) | 0.00 |
| Shelf period (SP) | 0.02 |
| T x SP | NS |

n = 3 replicates. Any two means in column or a row followed by different letters are significantly different. NS = not significant, T = Treatment, SP = shelf period.

| Table 4: Impact of calcium chloride (CaCl₂) on juice contents and pH value of loquat fruit juice during storage. |
|---|---|---|---|---|---|
| Treatments | Juice contents (%) | pH | Shelf period (Days) | Shelf period (Days) |
| | 5 | 10 | Mean | 5 | 10 | Mean |
| Control | 11.77de | 10.00e | 10.89D | 8.8 a | 8.4ab | 8.6A |
| 2% CaCl₂ | 18.82bcd | 14.15cde | 16.49C | 6.9abcd | 7.4abc | 7.2AB |
| 4% CaCl₂ | 23.50ab | 20.66bc | 22.08B | 5.9bcd | 6.3abcd | 6.1BC |
| 6% CaCl₂ | 30.12a | 28.01a | 29.06A | 4.4d | 5.2cd | 4.8C |
| Mean | 21.05A | 18.20B | 21.05A | 6.4 A | 6.9 A | 

LSD (P ≤ 0.05)

| Treatments (T) | 0.00 |
| Shelf period (SP) | 0.01 |
| T x SP | NS |

n = 3 replicates. Any two means in column or a row followed by different letters are significantly different. NS = not significant, T = Treatment, SP = shelf period.
Juice content

The highest level of CaCl₂ (6%) application to loquat fruit significantly maintained the juice content (%) at higher level as compare to 2% and 4% CaCl₂ applications and the control treatment (Table 4). After 5 and 10 days of shelf period minimum fruit juice contents (%) was observed (11.77% and 10%) in control fruit while maximum fruit juice (%) was recorded (30.12% and 28%) in 6% CaCl₂ application, respectively. The interaction between treatments and shelf period showed non-significant difference with respect to changes in loquat fruit juice contents.

pH of Juice

The results showed that, irrespective of shelf period (Days), CaCl₂ treatment significantly decreased pH of loquat fruit juice as compared to control (Table 4). Highest level of CaCl₂ (6%) performed better than lower levels (2% and 4% CaCl₂), as well as untreated control fruit (Table 4). Maximum fruit pH was observed (8.8 and 8.4) in control fruit, while minimum fruit pH of loquat was observed (4.4 and 5.2) in 6% CaCl₂ application after 5 and 10 days of shelf period. It was also found that after 5 days of shelf period loquat fruit showed highest mean decrease in fruit pH (6.4) as compare to 10 days (6.9) shelf period.

DISCUSSION

In the current study the improvement in the fruit physical characteristics such as reduction in weight loss, fruit diameter may be ascribed to the fact that calcium (Ca) is a vital component of fruit tissues that plays a key function in conserving postharvest quality of fruit by maintaining cellular films and suspending senescence. It may be due to application of the CaCl₂ as Ca retaining the integrity and functionality of membrane due to abridged loss of proteins and reduction in spoilage which consequently causes the reduction in weight loss. Calcium chloride and salicylic acid have been reported to retain firmness in strawberry fruit with reduction in rotting, weight loss and vitamin C (Shafiee et al., 2010). Similar results were found in the experiments conducted by Hajilou and Fakhimrezaei (2013) and Lester and Grusak, (1999) on apricot and muskmelon, respectively. Akhtar et al. (2010) also observed that CaCl₂ application reduced weight loss in loquat fruit. Earlier Ali et al. (2014) and Golomb (1983) observed that in peach and loquat application of Ca improved the fruit physical characteristics.

Postharvest application of Ca to loquat fruit resulted in significant reduction on internal as well as external browning index of loquat fruit. Earlier various studies have reported similar results that overall browning index including external as well as internal browning were reduced in various fruits and vegetables by application of CaCl₂ (Poovaiah, 1986) and the application of CaCl₂ also maintained the membrane stability (Thompson et al., 1987). High calcium concentrations result in decreased fresh browning symptoms which are directly associated with Ca content in pineapple fruit (Hewajulige et al., 2003). Akhtar et al. (2010) conducted an experiment on loquat cv. Surkh to study the effectiveness of CaCl₂ on loquat fruit. They reported valuable improvement in browning index (BI). Similar result about the overall browning index including external as well as internal browning were improved by application of CaCl₂ (Poovaiah, 1986). Prevention of browning in treated fruit may be due to the role of calcium to maintains the membrane stability (Thompson et al., 1987). Similar results were also reported by Sohail et al. (2015) who found that application of CaCl₂ positively improved firmness of peach fruits as compare to the control. Earlier postharvest application of calcium improved cell wall, cell turgor, membrane reliability, firmness in avocado fruit (Chaplin and Scott, 1980). Similar results have also been reported in strawberry (Lara et al., 2004) and loquat (Akhtar et al., 2010) fruits with calcium treatments. reported that Postharvest application of CaCl₂ on the apple also maintained their firmness at higher levels than untreated control fruit (Jan et al., 2013).

After harvest perishable commodities continue their deterioration by break down of energy rich compound into simpler molecules with release of energy to keep themselves alive. Sugars and acids are the main substrates which are consumed during cellular respiration more rapidly after harvest. Application of calcium has been found to slow down these metabolic processes and consequently helped to slowed down the degradation of sugars and acids. Same happened in the current study, all calcium treatments slow down the degradation of sugars and acids. Similarly, earlier Jaishankar et al. (2018) reported that application of CaCl₂ improved various biochemical traits of custard apple. Application of calcium has been found to delay senescence process in fruits with no harmful effect on consumer (Lester and Grusak, 2004). Acidity of fruits were reduced more quickly with initiation of senescence process in harvested fruit which may be ascribed to enzymatic action of respiratory enzymes (Hong et al., 2012; El-Anany et al., 2009; Ali et al., 2010). Maintenance of fruit acidity at higher level has also been reported earlier in peach, pomegranate, tomato, and mango fruit (Bakeer et al., 2016; Cheema et al., 2014; He et al., 2016; Manganaris et al., 2005).

CONCLUSION

In conclusion, postharvest application of 6% CaCl₂ has showed positive response in maintenance of physical (firmness, external browning, internal browning) and biochemical parameter (TSS, acidity and pH) of loquat fruit kept at ambient conditions for 10 days.

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