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Postharvest application of salicylic acid to improve the shelf life and quality of loquat (*Eriobotrya japonica* L.) fruit

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Abstract

Loquat (*Eriobotrya japonica* L.) is an important sub-tropical fruit with very limited post-harvest life. Loquat fruit is a sweet acidic fruit and rich in natural antioxidants. Loquat is an important member of the family Rosaceae and the genus is Eriobotrya. Loquat is a potentially important minor commercial fruit as well as medicinal use and other purposes. Therefore, in the current study, we investigated the impact of salicylic acid treatments on the quality and shelf life of loquat fruit. Fresh harvest loquat fruits were treated with various concentrations of salicylic acid (SA) *viz*. 1500, 2500 and 3000 ppm for 2 minutes and were kept at room temperature (30 ± 2 ^{o}C) for 5 and 10 days. Untreated fruits were kept as control. The results showed that fruit treated with 3000 ppm salicylic acid exhibited minimum fruit weight loss (12.09 %), external browning (8.17 %), and internal browning (7.80%) after 10 days of shelf-life in contrast with control fruit. The highest total soluble solids contents (12.05% and 13.17%) were found in fruit treated with 1500ppm salicylic acid with respect to other treatments of SA. In conclusion, between the tested treatments, application of the highest level of salicylic acid (3000 ppm) effectively maintained the external and external browning.

Keywords: External browning, Internal browning, Loquat, Salicylic acid, Total soluble solids

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Introduction

Eriobotrya is a very famous member of the family Rosaceae (Ghasemnezhad et al., 2010), loquat (*Eriobotrya japonica* (Thunb.) Lindl.), is the only cultivated species in this genus (Zhang, 2017), and has been classified in the non-climacteric fruit (Blumenfeld, 1980). Loquat fruit originated from China where its gardening had been reported almost 2000 years back (Lin et al., 2007; Xie et al., 2007). At present it is being cultivated commercially in more than 30 countries of the world (Feng et al., 2007). Being an imperative fruit of Pakistan, it is cultivated in *Khyber Pakhtunkhwa* and Punjab provinces at commercial scale (Hussain et al., 2007). Loquat fruit contains almost every type of the essential nutrients required for human health and development. Particularly it is considered as a rich source of minerals (phosphorus and calcium), vitamins (A, B and C), salts and carotenoids (Lin et al., 2007).

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). Salicylic Acid (SA) is an important phenolic compound and exogenous usage of SA may impact hindrance to ethylene biosynthesis, transpiration and stress resistance. SA proficiently used for interrupting ripening in the storage conditions (Khan, 2003). It is also responsible for lowering fruit ethylene synthesis, respiration rate, rate of weight loss, rate of softening and deterioration (Srivastava & Dwivedi, 2000; Babalar et al., 2007). SA reported to boost the physical attributes of fruits like weight, size and firmness (Zhang et al., 2003; Elwan & El-Hamahmy, 2009; Marzouk & Kassem, 2011). SA is the only molecule which is involved in the plant defense mechanism (Huang et al., 2008). It causes reduction in the ethylene production of bananas which causes the delay in ripening of fruit (Leslie & Romani, 1988). The post-harvest appliance of SA on peach fruit showed that the post-harvest life of the peach fruit was increased (Awad, 2013). SA plays a key role in plant growth, increasing resistance against diseases, in germination of seed, and also in production of ethylene. It is also responsible of decrease in rate of respiration and maintaining weight of fruit (Zheng & Zhang, 2004). Keeping in view the effectiveness of SA as explained by various scientists the current study was designed to investigate the role of SA treatments on the post-

harvest life and quality of loquat fruit. However, loquat is an important minor fruit of Pakistan and very rare research work has been carried out on its shelf-life extension and quality management. Therefore, it was hypothesized that the application of SA will maintain total soluble solids firmness, total soluble solids, acidity and reduce browning index and weight loss of loquat fruit kept at room temperature.

Materials and Methods

The experiment was executed in the Laboratory, Horticulture Department, College of Agriculture, University of Sargodha, Punjab, Pakistan. Mature fruits were collected at commercial maturity (ºBrix > 10) with the help of sharp secateurs from the plants of loquat fruit grown in the Research Area of the Department. Fruits were dipped in the respective solutions of salicylic acid (SA) (0, 1500ppm, 2500 ppm and 3000 ppm) for 2 min and kept at room temperature (30 ± 2 ^{o}C) for five and ten days. Fifteen fruits were used as an experimental unit replicated thrice. Following aspects were studied in the experiment:

Weight loss (%)

Fruit weight of a piece 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 is the weight of fruit at the time of harvest and B is the weight of fruit after shelf period.

Fruit diameter (mm)

Fruit diameter of each sample was measured in mm around the fruit radius by using vernier caliper. Fruit diameter reduction was obtained by using 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:
Browning Index = [(1 x N1 + 2 x N2 + 3 x N3 + 4 x N4) / (4 X N)] x 100
Where N = total number of fruits observed and N1, N2, N3 and N4 were the number of fruits which were scored in each degree of browning.

Fig.1 External browning of Loquat

Internal browning index

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

Firmness (N)

Fruit firmness was determined by means of a digital fruit-firmness tester (53205, TR di Turoni, Forli, Italy), equipped with 8 mm plunger tip. Firmness was measured as the highest 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:
Juice % = [Juice weight / fruit weight] x 100

pH of fresh juice

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

Total soluble solids

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

Titratable acidity

Titratable acidity was calculated by using the formula
Titratable acidity =

$$\frac{(\text{meq factor} 0.0064)\times(\text{volume of titrant})\times(\text{volume of NaOH})\times(100)}{(\text{mL of juice}\times\text{volume of aliquot})}$$

Where
Mili-equivalent weight of citric acid = 0.0064
Total volume (mL) = 30

Extract juice sample (mL) = 10
Volume of aliquot = 5 mL
Juice samples (10 mL) of each replicate taken in a glass beaker were 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 SA 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 SA significantly affected the weight loss of loquat fruit (Table 1). Fruit treated with 3000ppm SA exhibited minimum fruit weight loss (8.41%) followed by 2500 ppm SA application (12.79%) and 1500ppm salicylic acid application (23.04%) (Table 1). However, maximum weight loss of fruit was observed (29.98% and 33.97%) in untreated control at 5th and 10th day of shelf period at room temperature. Among other levels, applications of 2500 ppm of SA are more effective (12.79%) than 1500ppm SA (23.04%) up to day 5 of shelf period. After 10 days of shelf period minimum fruit weight loss (12.09%) was observed in 3000 ppm salicylic acid treated loquat fruit; while, highest fruit weight loss (33.97%) 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 (18.55%) as compared to keeping them for 10 days (22.65%) at ambient conditions.

Table 1 Impact of salicylic acid (SA) on weight loss and diameter reduction of loquat fruit during storage at room temperature

Treatments	Fruit weight loss (%)			Fruit diameter reduction (mm)		
	Shelf period (Days)			Shelf period (Days)		
	5	10	Mean	5	10	Mean
Control	29.98^{ab}	33.97^{a}	31.97^{A}	6.61^{ab}	6.81^{a}	6.71^{A}
1500 ppm SA	23.04^{abc}	26.66^{ab}	24.85^{A}	3.93^{cd}	4.33^{bc}	4.13^{B}
2500 ppm SA	12.79^{cd}	17.89^{bcd}	15.34^{B}	2.82^{b-e}	3.17^{cde}	2.99^{BC}
3000 ppm SA	8.41^{d}	12.09^{cd}	10.25^{B}	1.56^{e}	1.89^{de}	1.73^{C}
Mean	18.55^{B}	22.65^{A}		3.73^{A}	4.05^{A}	
LSD ($P\leq0.05$)						
Treatments (T)		0.001			0.001	
Shelf period (SP)		0.04			NS	
T x SP		NS			NS	

n = 45 (15 fruits × 3 replicates); Any two means in a row or a column followed by different letters are significantly different; NS = Not significant; T = Treatment; SP = Shelf period.

Fruit diameter reduction

Post-harvest salicylic acid application significantly slows down the reduction in diameter of loquat fruit (Table 1). However, minimum loquat fruit diameter reduction was observed (1.56 mm) in 3000 ppm salicylic acid treatment, while maximum fruit diameter reduction was observed (6.61) 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 10days intervals (4.05 mm) compared with 5 days intervals (3.73 mm). The interaction among treatments and shelf period in days was found non-significant ($P \leq$ 0.05) for fruit diameter reduction.

External browning index

Results showed that among treatments, application of 3000 ppm salicylic acid was more efficient in reducing external browning index in loquat fruit than other two levels (1500 ppm, and 2500 ppm SA) as well as untreated control fruit. However, maximum external browning of loquat fruit was observed (18.85%) in control while minimum fruit level was found in fruit (7.98%) treated with 3000ppm salicylic acid after 5 days of shelf period. Whereas loquat fruit treated with 1500 ppm and 2500 ppm salicylic acid exhibited 15.48% and 11.54% external fruit browning after 5 days of shelf period, respectively (Table 2). After 10 days of shelf period minimum external browning (8.17%) was observed in loquat fruit treated with 3000 ppm salicylic acid while maximum external browning (19.32%) was observed at control. 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 different levels of SA cause valuable reduction in the internal browning in loquat fruit (Table 2). Application of 3000ppm was more effective than other two levels (1500 ppm and 2500 ppm SA), in reduction of internal browning of fruit. After 5 days of shelf period maximum fruit internal browning was observed (17.03%) in untreated control fruit; while, lowest

fruit internal browning of loquat was observed in fruit (7.06%) treated with 3000 ppm salicylic acid. Similar results were also observed after 10 days of shelf period, where minimum internal browning (7.80%) of fruit was observed in 3000ppm treatment, while maximum internal browning (18.18%) was obtained in control fruit. In general, the higher fruit internal browning was recorded at 10day of shelf period (12.88%) compared with 5 days (11.89%) (Table 2). The interaction among different treatments and shelf period in days was recorded non-significant for fruit internal browning index.

Firmness (Newton)

The results showed that irrespective of shelf period in days, 3000ppm SA application was more effective among all the treatments to maintain fruit firmness at higher level (Table 2). Maximum fruit firmness (3.10 N) was observed in 300 ppm salicylic acid treatment, while lowest firmness of fruit was observed (1.08N) in control fruit after 5 days of shelf period. Similar results were also observed after 10 days of shelf period, where 3000ppm treated fruit exhibited the highest level of fruit firmness as compared to other levels of salicylic acid and 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.

Table 2 Impact of salicylic acid (SA) on firmness, external and internal browning of loquat fruit during storage at room temperature

Treatments	External browning index (%)			Internal browning index (%)			Fruit firmness (N)		
	Shelf period (Days)			Shelf period (Days)			Shelf period (Days)		
	5	10	Mean	5	10	Mean	5	10	Mean
Control	18.85^{a}	19.32^{a}	19.08^{A}	17.03^{ab}	18.18^{a}	17.61^{A}	1.08^{e}	1.03^{e}	1.05^{C}
1500 ppm SA	15.48^{ab}	16.27^{a}	15.87^{B}	13.04^{bc}	14.37^{abc}	13.71^{B}	1.39^{de}	1.70^{cde}	1.55^{C}
2500 ppm SA	11.54^{bc}	11.21^{c}	11.3^{C}	14.41^{cd}	11.16^{cd}	10.79^{C}	2.25^{bcd}	2.60^{abc}	2.43^{B}
3000 ppm SA	7.98^{c}	8.17^{c}	8.08^{D}	7.06^{d}	7.80^{d}	7.43^{D}	3.10^{ab}	3.40^{a}	3.25^{A}
Mean	13.46^{A}	13.74^{A}		11.89^{A}	12.88^{A}		1.95^{A}	2.18^{A}	
LSD ($P \leq 0.05$)									
Treatments (T)		0.001			0.001			0.001	
Shelf period (SP)		NS			NS			NS	
T × SP		NS			NS			NS	

n = 45 (15 fruits × 3 replicates); Any two means in a row or a column followed by different letters are significantly different; NS = Not significant; T = Treatment; SP = Shelf period.

Total soluble solids (TSS)

The results showed that after 5 days of shelf period minimum (8.85%) total soluble solids contents were recorded in the juice of loquat fruit treated with 3000ppm SA followed by 2500 ppm salicylic acid (10.61%) and 1500 ppm salicylic acid (12.05%) treatments (Table 3). Similarly, after 10 days of shelf period, minimum TSS (9.12%) of loquat fruit was observed in 3000 ppm salicylic acid treated fruit as compared to control fruit (16.25%). However, the highest TSS of loquat fruit was recorded after 10 days shelf period (13.05%) compared with 5 days shelf intervals (12.05%) at 1500 ppm of SA application. Independent effect of shelf period and interactive effect of treatments and shelf period showed non-significant differences for changes in fruit total soluble solids.

Table 3 Impact of Salicylic acid (SA) on total soluble solid and titratable acidity of loquat fruit during storage at room temperature

Treatments	Total soluble solids (%)			Titratable acidity (%)		
	Shelf period (Days)			Shelf period (Days)		
	5	10	Mean	5	10	Mean
Control	15.32^{ab}	16.25^{a}	15.78^{A}	0.30^{d}	0.29^{d}	0.29^{C}
1500 ppm SA	12.05^{c}	13.17^{bc}	12.61^{B}	0.37^{cd}	0.35^{cd}	0.36^{C}
2500 ppm SA	10.61^{cd}	11.07^{cd}	10.84^{C}	0.48^{abc}	0.43^{bcd}	0.45^{B}
3000 ppm SA	8.85^{d}	9.12^{d}	8.98^{D}	0.58^{a}	0.53^{ab}	0.55^{A}
Mean	11.70^{A}	12.40^{A}		0.43^{A}	0.40^{A}	
LSD ($P \leq 0.05$)						
Treatments (T)		0.00			0.00	
Shelf period (SP)		0.02			NS	
T × SP		NS			NS	

n = 45 (15 fruits × 3 replicates); Any two means in a row or a column followed by different letters are significantly different; NS = Not significant; T = Treatment; SP = Shelf period.

Titratable acidity

The treatment of salicylic acid has a valuable effect on acidity of loquat fruit. The application of loquat fruit with the highest level of salicylic acid (3000 ppm) was more effective than lower levels (2500 ppm, 1500 ppm salicylic acid) and untreated control fruit. After 5 days of shelf period, minimum fruit acidity was observed (0.30%) in control fruit while maximum fruit acidity was recorded (0.58%) in fruit treated with 3000ppm salicylic acid (Table 3). However, 2500 ppm salicylic acid treatment was more effective (0.48%) than 1500ppm salicylic acid treatment in which lower acidity was observed (0.37%) at 5-day storage of fruit. Similarly, maximum level of acidity (0.53%) of loquat fruit was observed in salicylic acid (3000 ppm) treated fruit, while minimum acidity (0.29%) in control treatment after 10 days of shelf time was observed. In general, as expected, higher levels of fruit acidity was observed after 5 day (0.43%) as compared with 10 days (0.40%) of shelf period.

Juice content

The highest level of salicylic acid (3000 ppm) application to loquat fruit significantly maintained the juice content (%) at a higher level as compared to 1500 ppm and 2500 ppm salicylic acid applications and the control treatment (Table 4). After 5 and 10 days of shelf period minimum fruit Juice contents (%) was observed (13.08% and 11.14%) in control fruit while maximum fruit Juice (%) was recorded (31.32% and 27.12%) in 3000 ppm application, respectively. The interaction between treatments and shelf period showed non-significant difference with respect to changes in loquat fruit juice contents.

Table 4 Impact of salicylic acid (SA) on juice contents and pH value of loquat fruit juice during storage at room temperature

Treatments	Juice contents (%)			pH		
	Shelf period (Days)			Shelf period (Days)		
	5	10	Mean	5	10	Mean
Control	13.08^{d}	11.14^{d}	12.11^{D}	7.9^{a}	8.1^{a}	8.0^{A}
1500 ppm SA	20.62^{bc}	15.76^{cd}	18.19^{C}	6.7^{ab}	7.2^{ab}	6.9^{AB}
2500 ppm SA	25.50^{ab}	21.30^{bc}	23.40^{B}	5.4^{ab}	6.1^{ab}	5.7^{BC}
3000 ppm SA	31.32^{a}	27.12^{ab}	29.22^{A}	4.5^{b}	4.8^{b}	4.7^{C}
Mean	22.63^{A}	18.83^{B}		6.1^{A}	6.5^{A}	
LSD ($P \leq 0.05$)						
Treatments (T)		0.00			0.00	
Shelf period (SP)		0.00			NS	
T × SP		NS			NS	

n = 45 (15 fruits × 3 replicates); Any two means in a row or a column followed by different letters are significantly different; NS = Not significant; T = Treatment; SP = Shelf period.

pH of juice

The results showed that, irrespective of shelf period (Days), salicylic acid treatment significantly decreased pH of loquat fruit juice with respect to control (Table 4). Highest level of salicylic acid (3000 ppm) performed better than lower levels (1500 ppm and 2500 ppm salicylic acid), as well as untreated control fruit (Table 4). Maximum fruit pH was observed (7.9 and 8.1) in control fruit, while, minimum fruit pH of loquat was observed (4.5 and 4.8) in 3000 ppm salicylic acidapplicationafter5 and 10 days of shelf period. It was also found that after 5 days of shelf period loquat fruit showed the highest mean decrease in fruit pH (6.1) as compared to 10 days (6.5) shelf period.

Discussion

It may be argued that salicylic acid retard respiration rate, transpiration rate as well as the metabolic actions which lead to decrease in weight loss in fruits and vegetables. SA improved characteristics of tomato fruit as firmness, rotting, weight loss and vitamin C (Shafiee et al., 2010) and also similar results were founded in the various experiments including peach, tomato (Zheng & Zhang, 2004; Awad, 2013; Zhu et al., 2016), Kinnow (Haider et al., 2020; Baswal et al., 2021, Iftikhar et al., 2021) and loquat (Ezzat et al., 2017; Shoukat et al., 2021). The same results were also recorded when salicylic acid was applied on kiwifruit (Fattahi et al., 2010). Same results were also found by Ali et al. (2014) when salicylic acid and calcium chloride were applied on the peach fruits. Amanullah et al. (2017) also found similar results for fruit diameter when applied salicylic acid on guava fruits. Similar results were obtained when salicylic acid and calcium chloride were applied on pomegranate fruit (Shaarawi et al., 2016). Ranjbaran et al. (2011) reported that the salicylic acid application stimulates the enzymes activity and found similar results as by application of salicylic acid reduced the browning index. The same consequences were founded by Cai et al. (2006) on loquat fruit. The similar results were found when salicylic acid was applied on grape berry fruit (Khalil, 2014). Similar results found by Aghdam et al. (2016) on pineapple fruit by using various concentrations of salicylic acid indicated that the application of salicylic acid, especially concentrations 3.0 or 5.0 mM reduced the internal

browning (IB) index. Similar results were also found by Ding et al. (2007) on mango fruit. Kumari et al. (2015) found that salicylic acid application on litchi fruit reduced internal browning. The similar results were recorded when salicylic acid was applied on grape berry fruit (Khalil, 2014). Lu et al. (2011) also showed that salicylic acid application reduced internal browning in pineapple fruit. Aghdam et al. (2016) found the similar results by the application of the salicylic acid on the fruit firmness of different horticultural crops including Strawberry, Kiwifruit, and Banana etc. Same results were also found by Kumari et al. (2015). Ezzat et al. (2017) also found similar results by salicylic acid application on apricot. The similar results were recorded when salicylic acid was applied on grape berry fruit (Khalil, 2014). The increase in total soluble content is due to the various factors respiration decelerates and metabolites production (Hernandez-Munoz et al. 2006; Hong et al., 2012). Similar results were also reported by the salicylic acid application (Khademi and Ershadi, 2013; Moreno et al., 2008; Davarynejad et al., 2013; Serrano et al., 2003, Iftikhar et al., 2021 and Diaz-Mula et al., 2009) on pomegranate, pineapple, plum, citrus and cherry. Similar results were found when salicylic acid applied on apricot fruit (Ezzat et al., 2017). Acidity of fruits were reduced when the senescence is occurs quickly as well as organic acid was main factor for the enzymatic action of respiration (El-Anany et al., 2009; Ali et al., 2010; Hong et al., 2012) and reduction of these factors take place through salicylic acid and calcium chloride application so acidity was increased. Similar results were found through salicylic acid application on tomato and kiwifruit respectively by (Kazemi et al., 2011; Gharezi et al., 2012). Also, similar results were observed when salicylic acid applied on apricot fruit (Ezzat et al., 2017). Similar results were found by various researchers including (Baninaiem et al., 2016) which observed 45% increase in juice % by salicylic acid application with concentration of 4 mM as pre-harvest application as well as post-harvest application on tomato. Ezzat et al. (2017) also found similar results when salicylic acid applied on apricot fruit. The pH increases by the increase in acidity as acidic compounds are formed and decreases with the increase in maturity in acidity (Riaz et al., 2015). Same findings were obtained when salicylic acid applied on apricot fruit (Ezzat et al., 2017). Similar results also determined by various types of fruits including tomato, plum and kiwi respectively by the SA application improves the value of pH (Pila et al., 2010; Davarynejad et al., 2013; Fatemi et al., 2013).

Conclusion

In conclusion, postharvest application of 3000 ppm of SA has maintained the external and internal browning and lowest weight loss in loquat fruit when stored at ambient conditions for 5 and 10 days. However, the highest TSS was higher at SA @1500 ppm when loquat was stored at room temperature for 5 and 10 days.

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