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CONTROL OF POST-HARVEST BROWNING IN LITCHI FRUIT THROUGH ORGANIC ACIDS APPLICATION

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ABSTRACT

Litchi (*Litchi chinensis Sonn.*) is a sub-tropical fruit having sweet, juicy and soft pulp with an attractive bright red peel. Garnered litchi fruit is highly perishable and bright red colour of the peel turns dull brown within 24 to 48 hours of harvesting at room temperature. Current study was conducted at Food Technology Section, Ayub Agricultural Research Institute, Faisalabad during 2019. The present study was intended to check whether different organic acids could potentially be applied for slowing down the pericarp browning in litchi fruit as acidic pH could be beneficial in retarding the polyphenol oxidase and peroxidase activities and maintaining the quality during storage. Lowest PPO and POD activity at the start and end of storage time was recorded in fruit samples treated with 10% oxalic acid (0.5 & 0.25 unit/mg protein and 3 and 1 unit/mg protein). Oxalic acid in 10% concentration proved best for maintaining quality parameters (acidity, firmness, ascorbic acid, total and reducing sugars, total soluble solids) during storage among all the tested organic acids and their concentrations. The information generated could be further explored for the metabolic process underlying the slowing of browning of the pericarp.

KEYWORDS: Litchi; browning; acids; peroxidase; polyphenol; enzyme; Pakistan.

INTRODUCTION

Litchi (*Litchi chinensis*) is a sub-tropical fruit cultivated in Punjab, Sindh and KPK on more than 3000 acres with an annual production of 9250 metric tons (MT). Fruit skin cracking is a big problem in Southern Punjab due to warm and dry weather (Rajwana *et al.,* 2010). Lack of quality nursery plants and irrigation water, imbalance nutrition's information and postharvest losses are major constraints potential of the fruit.

Garnered litchi fruit is highly perishable and bright red colour of the peel turns dull brown within 24 to 48 hours of harvesting at room temperature (Jiang *et al.,* 2004; Joas *et al.,* 2005). During storage, pH of the fruit is increased which results in the degradation of anthocyanins. The colour of anthocyanins vary from red to brown in a pH range of 3-5 (Flueki and Francis, 1968) which suggests that discoloration of anthocyanins is pH reliant and could be manipulated for avoiding colour degradation in litchi fruit. Anthocyanin pigments of litchi fruit change from highly red cations to a colourless base carbinol as pH increases during storage. Cyanidin 3-glucoside and cyaniding 3-rutinoside are the major monomeric of anthocyanin in litchi and highly unstable at basic pH (Jiang, 2000). Various authors have associated litchi pericarp browning to accelerate activity of polyphenol oxidase. The acidification of litchi pericarp modifies the anthocyanins of litchi, thereby inhibiting the degradation of the pigments.

Most common postharvest treatment of litchi fruit is fumigation with strong antioxidant and sulphur dioxide. This treatment blocks the oxidation reactions involved in pericarp browning. Fumigation treatments acidify the cellular contents of litchi fruit by stabilizing the anthocyanins of the pericarp (Zauberman *et al.,* 1991) but bleaching against Sulphur residues could be a potential health risk to individuals.

Several treatments alternative to fumigation have been tested for minimizing pericarp browning in litchi fruit including hot water brushing (Lichter *et al.,* 2000), use of benzyladenine, glutathione and citric acid (Jiang and Fu, 1998; Jiang *et al.,* 1999) but none of them have been recognized commercially. Chitosan coatings, soluble in organic acids are generally used for improving the shelf life of fruits. It was earlier demonstrated by Zhang and Quantick (1997) that chitosan dissolved in organic acids slowed down the pericarp browning process in litchi. The present study was intended to check whether different organic acids could potentially be applied for slowing down the pericarp browning in litchi fruit as acidic pH could be beneficial in retarding the polyphenol oxidase and peroxidase activities and maintaining the quality during storage.

MATERIALS AND METHODS

Physiologically mature litchi fruit at the fully colored stage was harvested from commercial orchard and pre-cooled quickly to 5°C by forced air-cooling unit. Fruits were sorted for color, shape and uniformity of size.

Physically damaged and injured fruits were separated. After sorting and grading litchi fruit was subjected to salicylic acid, oxalic acid and citric acid (organic acids) at concentrations 5, 7.5, 10 and 12.5%, respectively for 10 minutes within 4 hours of harvesting and allowed to air dry. Organic acids treated fruits were packed in polyethylene bags of 0.22mm thickness after drying and placed in cold storage at 5°C with relative humidity 90-95%. Litchi fruits without any acid treatment were also stored as control. POD (peroxidase) and PPO (polyphenol oxidase) activities were determined at start and end of the storage period. Different physico-chemical parameters i.e., pH, acidity, weight loss, firmness, ascorbic acid, total sugars, reducing sugars, and total soluble solids (TSS) were determined for organic acids treated and untreated litchi fruit samples after every week up to four weeks of storage.

POD and PPO activity: Litchi peroxidase and polyphenol oxidase activities were measured spectrophotometrically by following method outlined by Shin *et al.* (1997). 2.5 g of litchi pericarp was homogenized in 10 ml of 0.05 M potassium phosphate buffer solution of pH 6.2, 1 M KCl and 2% PVPP (polyvinyl polypyrrolidone). Homogenized extract was then centrifuged at 13,500 rpm for 30 minutes at 4°C temperature. The collected supernatant was used as crude enzyme extract. PPO activity was measured at 410 nm by using 100 mM 4-methyl catechol as a substrate. POD activity was determined at 470 nm. One unit of enzyme activity was defined as the amount that causes an increase of 0.01 in absorbance per min.

Acidity: Percent titratable acidity of litchi juice was measured using digital (portable) acidity meter (model GMK-835F).

Weight loss: Fruit weight was recorded at the start of the experiment and after every week (up to 4 weeks) by using a digital balance (Sartorius. AG, Germany, model: GM1501). Weight loss in percentage was calculated according to the following equation.

$$\%\text{weight loss} = \frac{\text{Fresh weight} - \text{weight after storage}}{\text{Fresh weight}} \times 100$$

Firmness: Firmness of litchi fruit was recorded with a penetrometer (PCE-FM 200) using a 2 mm plunger tip.

Ascorbic acid: Ascorbic acid contents in litchi fruit were determined by using the Assocation of Official Analytical Chemists method (AOAC, 2012). Five ml of fruit sample was homogenized with oxalic acid (0.4%) and made the volume up to 100 ml. Sample was then filtered and 10 ml of filtered sample was titrated against standard dye i.e. 2, 6 dichlorophenol indophenol (DCPIP) to a pink endpoint. The amount of ascorbic acid was calculated using the formula given below

$$\text{Ascorbic acid (mg/100 g of pulp)} = \frac{\text{Titer x volume make up x dye factor x 100}}{\text{Aliquot x sample weight}}$$

Reducing sugars (R.S): Lane and Eynone method was used for the determination of Reducing sugars (AOAC, 2012). In 250 ml of volumetric flask, 25 g of filtered juice of litchi fruit was taken and distilled water (100 ml) was added. Neutralized the diluted juice with 10 % NaOH and then lead acetate solution (2 ml) was added for 10 minutes. To remove the excess lead, potassium oxalate was added and the volume made with distilled water. Sugars were calculated as:

$$\text{Reducing sugars (\%)} = \frac{\text{Factor x dilution x 100}}{\text{Titre x weight of the sample}}$$

Total sugar: AOAC method was used for total sugar determination (AOAC, 2012).

Total soluble solids (TSS): The TSS value of samples were determined by using a digital refractometer (HANNA, HI 96801) and results were expressed as °Brix

Statistical analysis: Data was recorded in triplicate for each experiment and averaged facts were subjected to CRD factorial ANOVA by using statistical software Statistix 8.1.

RESULTS AND DISCUSSION

Polyphenol activity: Results for PPO activity at the time of application of organic acids and storage time (four weeks) in litchi fruit are presented in Fig. 1. It is obvious from the results that enzyme activity was less in almost all treatments after storage time except in samples treated with 7.5% oxalic acid. Lowest PPO activity at the start and end of storage time was recorded in fruit samples treated 10% oxalic acid (0.5 and 0.25 unit/mg protein). After the fourth week of storage, the highest PPO activity (1.5 unit/mg protein) was observed in control samples followed by litchi fruit samples treated with 10% salicylic acid. Neog and Saika (2010) reported the slowing down of PPO activity by dipping in 2% HCl for five minutes and retention of anthocyanin in litchi fruit throughout the storage period. Benjawan and Chutichudet (2009) also narrated the efficacy of organic acids in controlling pericarp browning of santol fruit by reducing PPO activity. They used ascorbic and citric acid in different combinations. During the present study, citric acid was not found effective in lessening PPO activity but Jiang and Fu (1998) indicated citric acid (100 mmol litre^{-1}) effective in inhibition of PPO activity up to 80-85% in litchi fruit. This effectiveness may be attributed to 100 mmol litre^{-1} glutathione which they used in combination.

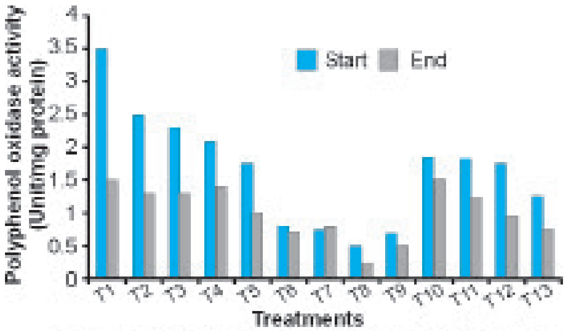

Fig. 1. Polyphenol oxidase activity in litchi fruit for different organic acids concentrations treatments

Peroxidase activity: Peroxidase activity is presented in Fig. 2 and it is quite clear that 10% oxalic acid proved to the best treatment for minimizing peroxidase activity during the storage of litchi fruit followed by 12.5% oxalic acid. At the start of storage and after completion of storage POD activity was 3 and 1 unit/ mg protein, respectively when 10% oxalic acid was applied to fruit. POD is an oxidative enzyme present in the pericarp of litchi and catalyzes the breakdown of phenolic compounds which result in pericarp browning. Different treatments including temperature, hot water and chemicals used by various researchers were found effective for inhibition of POD activity (Ciou *et al.,* 2011; Venkatachalam, 2015; Neog and Saika, 2010).

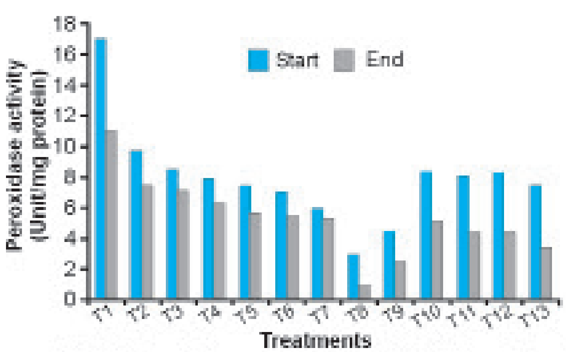

Fig. 2. Peroxidase activity in litchi fruit for different organic acids concentrations treatments

Acidity: Results for changes in the acidity of litchi fruit during storage after application of organic acids are presented in Table 1. It is obvious from the results that acidity was decreased during storage in all acid-treated samples and control. Among salicylic acid-treated samples, minimum change was recorded when salicylic acid was applied in 7.5% concentration. Minimum acidity changes in oxalic acid-treated samples were noted when oxalic acid was applied in 10% concentration while 12.5% citric acid-treated samples experienced minimum acidity changes during storage. Comparing samples of all tested concentrations of organic acids, the most effective acid was oxalic acid in 10% concentration in minimizing acidity changes. Hojo *et al.* (2011) recorded a decrease in the acidity of litchi after hydrothermal and hydrochloric acid treatment. Tripathi *et al.* (2016) also reported a declining trend in the acidity of litchi fruit during storage irrespective of treatment.

Table 1. Effect of different concentrations of organic acids and storage on acidity of litchi fruit

Treatments	Storage period (weeks)				
	0	1	2	3	4
Control	1.50^{AB}	1.02^{G-I}	0.95^{I-K}	0.42^{TU}	0.03^{d}
Salicylic acid					
5%	1.46^{AB}	1.26^{DE}	0.85^{LM}	0.21^{X-Z}	0.11^{a-d}
7.5%	1.51^{AB}	1.17^{EF}	0.61^{P-R}	0.47^{ST}	0.19^{Y-a}
10%	1.47^{AB}	1.06^{GH}	0.54^{RS}	0.35^{UV}	0.09^{b-d}
12.5%	1.42^{BC}	1.02^{G-I}	0.31^{VW}	0.21^{X-Z}	0.03^{d}
Oxalic acid					
5%	1.47^{AB}	1.04^{G-I}	0.81^{L-N}	0.65^{O-Q}	0.08^{cd}
7.5%	1.51^{AB}	1.17^{EF}	0.90^{J-L}	0.53^{RS}	0.18^{Y-b}
10%	1.52^{A}	1.33^{CD}	1.11^{FG}	0.83^{LM}	0.30^{V-X}
12.5%	1.42^{BC}	1.03^{G-I}	0.80^{MN}	0.69^{OP}	0.26^{V-Y}
Citric acid					
5%	1.47^{AB}	0.82^{LM}	0.64^{O-Q}	0.32^{VW}	0.08^{cd}
7.5%	1.47^{AB}	0.82^{LM}	0.64^{O-Q}	0.32^{VW}	0.08^{cd}
10%	1.43^{AB}	1.02^{G-I}	0.97^{H-J}	0.86^{K-M}	0.15^{Z-c}
12.5%	1.45^{AB}	1.24^{DE}	0.98^{H-J}	0.72^{NO}	0.24^{W-Z}

Weight loss: A gradual increase in weight loss of litchi fruit samples treated with different concentrations of organic acids and control was observed as the time of storage progressed. The highest weight loss (17.23%) was recorded in litchi fruit samples treated with 5% salicylic acid after the fourth week of storage (Table 2).

Table 2. Effect of different concentrations of organic acids and storage on weight loss of litchi fruit

Treatments	Storage period (weeks)				
	0	1	2	3	4
Control	0.00^{m}	2.66^{j}	9.62^{O}	11.60^{J}	16.18^{B}
Salicylic acid					
5%	0.00^{n}	2.81^{i}	6.81^{Y}	9.32^{P}	17.23^{A}
7.5%	0.00^{n}	2.99^{h}	7.02^{W}	10.47^{N}	12.94^{E}
10%	0.00^{n}	3.11^{g}	7.33^{V}	10.73^{M}	13.14^{D}
12.5%	0.00^{n}	1.96^{l}	3.18^{fg}	7.94^{U}	13.36^{C}
Oxalic acid					
5%	0.00^{n}	2.63^{j}	5.96^{b}	8.92^{R}	12.02^{H}
7.5%	0.00^{n}	2.21^{k}	5.02^{c}	8.03^{T}	11.23^{K}
10%	0.00^{n}	1.36^{m}	4.76^{d}	7.01^{W}	10.84^{L}
12.5%	0.00^{n}	2.16^{k}	5.07^{c}	8.76^{S}	11.28^{K}
Citric acid					
5%	0.00^{n}	3.54^{e}	6.63^{Z}	9.04^{Q}	12.55^{G}
7.5%	0.00^{n}	2.58^{j}	6.01^{b}	8.94^{R}	11.94^{I}
10%	0.00^{n}	3.19^{f}	6.36^{a}	9.08^{Q}	12.71^{F}
12.5%	0.00^{n}	3.12^{fg}	6.91^{X}	8.96^{R}	12.06^{H}

Samples treated with 10% oxalic acid experienced minimum weight loss during the course of storage. Weight loss in fruit during storage may be due to excessive water loss at ambient temperature. Mostly postharvest quality maintenance strategies for fruits and vegetables are aimed at lessening water loss. Molla *et al.* (2010) stated a similar gradual increase in weight loss of litchi fruit during storage.

Firmness: Firmness of litchi fruit experienced a decreasing trend during storage in organic acid-treated and control samples (Table 3). The maximum loss in firmness was recorded in control samples (1.66%). It is clear from the results that minimum loss in firmness was documented in litchi fruit samples treated with 10% oxalic acid (4.31%) followed by 7.5% oxalic acid-treated samples. Molla *et al.,* (2017) also documented the shrinkage of litchi fruit due to loss in firmness and correlated it with loss of water.

Table 3. Effect of different concentrations of organic acids and storage on firmness of litchi fruit

Treatments	Storage period (weeks)				
	0	1	2	3	4
Control	7.07^{A-D}	5.77^{M}	3.97^{VW}	2.64^{ef}	1.66^{k}
Salicylic acid					
5%	7.06^{B-E}	6.10^{IJ}	4.36^{T}	3.82^{X}	2.67^{e}
7.5%	7.10^{A-C}	5.95^{K}	4.13^{U}	3.53^{Z}	2.01^{h}
10%	6.99^{EF}	5.19^{P}	4.03^{V}	3.47^{Z}	1.92^{i}
12.5%	6.92^{F}	5.12^{P}	4.17^{U}	3.34^{a}	1.95^{hi}
Oxalic acid					
5%	7.05^{B-E}	6.59^{H}	5.63^{N}	4.19^{U}	3.03^{b}
7.5%	7.14^{A}	6.80^{G}	5.69^{N}	4.36^{T}	3.92^{W}
10%	7.03^{C-E}	6.92^{F}	5.85^{L}	4.94^{Q}	4.31^{T}
12.5%	7.05^{B-E}	6.13^{I}	5.29^{O}	4.49^{S}	3.63^{Y}
Citric acid					
5%	7.04^{B-E}	5.90^{KL}	4.84^{R}	2.94^{c}	1.83^{j}
7.5%	6.99^{EF}	5.95^{K}	4.51^{S}	2.86^{d}	1.97^{hi}
10%	7.11^{AB}	6.03^{J}	4.46^{S}	3.64^{Y}	2.35^{g}
12.5%	7.00^{DE}	6.06^{IJ}	4.92^{Q}	3.95^{W}	2.58^{f}

Ascorbic acid: It is clear from the results presented in Table 4 that ascorbic acid contents of litchi fruit followed a decreasing trend during storage in control and organic acids treated samples. Salicylic acid in 7.5% concentration was found more significant as compared to other treatments. It caused the minimum reduction of vitamin C in all tested concentrations whereas, oxalic acid in 7.5 and 10% concentration proved preeminent in controlling ascorbic acid reduction. Citric acid was found effective only in higher concentration i.e., 12.5%. Rajwana *et al.* (2010) attributed vitamin C loss during storage to utilization in fruit respiration and conversion to other sugars. Salam *et al.* (2010) further added oxidative deterioration responsible for vitamin C reduction.

Total sugars and reducing sugars: Results for total sugars in litchi fruit during storage after application of organic acids are depicted in Table 5. Total sugars followed an increasing trend up to 2nd week of storage and afterward, a declining tendency was observed up to the 4th week of storage. Minimum changes in total sugars contents were recorded in fruit samples treated with 10% oxalic acid.

Reducing sugars also followed a similar pattern as was depicted in total sugars during storage in control and organic acid-treated samples (Table 6). Oxalic acid in 10% concentration remained at the top in minimizing the change in reducing sugars during storage followed by 12.5% oxalic acid. Seemerbabu *et al.* (2007) determined an increase in total and reducing sugars in litchi fruit when stored under a modified atmosphere. This increase could be ascribed to metabolic processes taking place in fruit during storage. Pesis *et al.* (2002) also reported an escalation in the pool of total and reducing sugars.

Table 4. Effect of different concentrations of organic acids and storage on ascorbic acid of litchi fruit

Treatments	Storage period (weeks)				
	0	1	2	3	4
Control	22.13^{E}	17.51^{P}	12.33^{e}	10.52^{i}	9.36^{h}
Salicylic acid					
5%	22.17^{C-E}	19.83^{K}	16.51^{S}	13.54^{b}	10.46^{i}
7.5%	22.11^{E}	18.42^{N}	16.59^{S}	15.64^{V}	10.21^{j}
10%	22.13^{E}	18.62^{M}	16.00^{U}	12.24^{e}	10.05^{j}
12.5%	22.60^{B}	19.65^{L}	15.24^{W}	13.86^{a}	9.46^{gh}
Oxalic acid					
5%	22.12^{E}	20.11^{J}	17.32^{Q}	13.36^{c}	10.71^{h}
7.5%	21.77^{F}	20.25^{J}	18.09^{O}	13.96^{a}	11.05^{g}
10%	22.33^{C}	21.19^{G}	18.31^{N}	14.86^{X}	11.55^{f}
12.5%	22.16^{DE}	20.85^{H}	19.27^{KL}	14.24^{Z}	12.91^{d}
Citric acid					
5%	22.33^{C}	19.56^{L}	16.22^{T}	15.36^{W}	9.56^{gh}
7.5%	22.2^{CD}	20.65^{I}	17.53^{P}	14.64^{Y}	9.76^{fg}
10%	22.57^{B}	21.66^{F}	17.09^{R}	15.22^{W}	10.50^{i}
12.5%	22.84^{A}	22.53^{B}	18.34^{N}	15.64^{V}	11.58^{f}

Table 5. Effect of different concentrations of organic acids and storage on total sugars of litchi fruit

Treat-ments	Storage period (weeks)				
	0	1	2	3	4
Control	11.14^{Y}	12.54^{P}	14.20^{DE}	11.68^{W}	9.48^{e}
Salicylic acid					
5%	12.12^{T}	13.24^{L}	14.38^{C}	12.32^{Q}	11.34^{X}
7.5%	12.15ST	13.64^{H}	14.26^{D}	12.86^{N}	10.96^{Z}
10%	12.20^{RS}	13.76^{G}	14.16^{E}	11.88^{V}	10.54^{b}
12.5%	11.98^{U}	12.12ST	13.42^{JK}	12.68^{O}	10.037^{c}
Oxalic acid					
5%	11.93^{UV}	12.34^{Q}	13.68^{H}	12.54^{P}	9.94^{d}
7.5%	11.16^{Y}	12.64^{O}	13.19^{L}	12.86^{N}	10.56^{b}
10%	12.12^{T}	13.04^{M}	14.40^{C}	13.22^{L}	12.18^{R-T}
12.5%	12.20^{RS}	13.46^{J}	14.56^{B}	13.54^{I}	11.34^{X}
Citric acid					
5%	12.17^{R-T}	12.54^{P}	14.66^{A}	12.34^{Q}	10.54^{b}
7.5%	12.13ST	12.64^{O}	14.56^{B}	12.24^{R}	10.81^{a}
10%	11.91^{UV}	13.36^{K}	14.58^{B}	12.12ST	11.91^{UV}
12.5%	12.20^{RS}	14.04^{F}	14.60^{AB}	13.46^{J}	12.15ST

Total soluble solids: Mean values of changes in TSS of litchi fruit during storage after application of organic acids are presented in Table 7. Maximum increase in TSS was recorded in control samples which indicated that tested organic acids have curtailed the metabolic process in litchi fruit to some extent. Minimum increase (5.42° Brix) was recorded in fruit samples treated with 10% oxalic acid. Our findings are in line with Znidarcic and Pozrl (2006); Salam *et al.* (2010) and Molla *et al.* (2010) who narrated an increase in TSS during storage of tomato, mango and litchi, respectively. Contrary to present findings, Kumar *et al.* (2013) found salicylic acid most effective in controlling pericarp browning and increase in TSS. This may be due to use of salicylic acid in combination with antioxidants.

Correlation of quality parameters with storage time and treatments: Correlation coefficients of quality parameters with storage time and different organic acids are presented in Table 8. Acidity, firmness, reducing sugars, total sugars and ascorbic acid were negatively correlated with storage time while total soluble solids and an increase in weight loss were positively correlated with storage time. Contrary to these results, acidity, firmness, reducing sugars, total sugars and vitamin C were positively correlated with treatments (organic acids) and total soluble solids and increase in weight loss were negatively associated with treatments which show the efficacy of organic acids in controlling quality parameters of litchi fruit (Fig. 3). These results also suggest the usefulness of these quality parameters which could be used as quality indicators of litchi fruit during storage.

Table 6. Effect of different concentrations of organic acids and storage on reducing sugars of litchi fruit

Treat-ments	Storage period (weeks)				
	0	1	2	3	4
Control	9.63^{P}	10.33^{L}	11.13^{GH}	9.45^{Q}	$8.25^{Z\text{-}b}$
Salicylic acid					
5%	9.19^{UV}	10.53^{K}	11.63^{C}	10.53^{K}	8.76^{X}
7.5%	9.30^{ST}	10.65^{J}	11.85^{CD}	10.21^{MN}	$8.18^{b\text{-}d}$
10%	$9.24^{S\text{-}U}$	11.13^{GH}	11.39^{E}	9.41^{QR}	8.05^{e}
12.5%	9.65^{P}	10.83^{I}	11.10^{H}	9.01^{W}	8.09^{de}
Oxalic acid					
5%	9.13^{V}	9.33^{RS}	11.11^{H}	10.47^{K}	$8.14^{c\text{-}e}$
7.5%	9.17^{UV}	9.41^{QR}	11.53^{D}	10.79^{I}	$8.23^{a\text{-}c}$
10%	$9.22^{T\text{-}V}$	10.25^{LM}	11.93^{A}	11.05^{H}	8.96^{W}
12.5%	9.18^{UV}	10.85^{I}	11.66^{C}	10.87^{I}	8.59^{Y}
Citric acid					
5%	$9.21^{T\text{-}V}$	10.17^{MN}	11.26^{F}	10.23^{M}	$8.16^{b\text{-}d}$
7.5%	9.19^{UV}	10.53^{K}	11.36^{E}	10.13^{N}	8.24^{ab}
10%	9.23^{TU}	11.58^{CD}	11.21^{FG}	10.63^{J}	8.31^{Za}
12.5%	9.17^{UV}	9.83^{O}	11.83^{B}	11.41^{E}	8.34^{Z}

Table 7. Effect of different concentrations of organic acids and storage on total soluble solids (TSS) of litchi fruit

Treatments	Storage Period (Weeks)				
	0	1	2	3	4
Control	$15.55^{Z\text{-}b}$	16.95^{S}	$19.86^{J\text{-}M}$	21.63^{E}	24.19^{A}
Salicylic Acid					
5%	14.96^{Y}	16.23^{UV}	18.03^{QR}	$19.96^{J\text{-}L}$	$21.84^{C\text{-}E}$
7.5%	$14.72^{Y\text{-}a}$	$16.32^{T\text{-}V}$	17.95^{R}	19.48^{NO}	$21.94^{C\text{-}E}$
10%	$14.23^{b\text{-}d}$	$16.37^{T\text{-}V}$	18.15^{QR}	20.03^{JK}	22.18^{C}
12.5%	14.16^{cd}	16.55^{TU}	19.12^{OP}	21.05^{F}	23.09^{B}
Oxalic Acid					
5%	14.02^{d}	15.63^{X}	18.02^{QR}	19.56^{MN}	20.93^{FG}
7.5%	$14.48^{a\text{-}c}$	15.04^{Y}	17.83^{R}	19.02^{P}	21.02^{FG}
10%	$14.78^{Y\text{-}a}$	15.85^{WX}	17.92^{R}	$19.74^{K\text{-}N}$	20.20^{IJ}
12.5%	14.04^{d}	16.62^{ST}	19.02^{P}	20.65^{GH}	21.74^{DE}
Citric Acid					
5%	$14.73^{Y\text{-}a}$	17.93^{R}	18.33^{Q}	20.54^{HI}	$21.85^{C\text{-}E}$
7.5%	$14.82^{Y\text{-}a}$	$16.36^{T\text{-}V}$	18.14^{QR}	20.14^{J}	$21.86^{C\text{-}E}$
10%	14.87^{YZ}	16.02^{VW}	18.37^{Q}	20.16^{J}	21.90^{E}
12.5%	$14.72^{Z\text{-}b}$	$16.33^{T\text{-}V}$	$19.63^{L\text{-}N}$	21.03^{F}	22.05^{CD}

Table 8. Correlation coefficients of treatments and storage time with other quality parameters

Treatments	Acidity	Firmness	RS	TS	TSS	Vit C	Weight Loss
Firmness	0.9378						
RS	0.2866	0.2748					
TS	0.3176	0.3081	0.8948				
TSS	-0.9236	-0.9499	-0.2469	-0.2686			
Vit C	0.9340	0.9495	0.3499	0.3711	-0.9475		
Weight loss	-0.9073	-0.9379	-0.2647	-0.3109	0.9411	-0.9473	
Storage time	-0.9439	-0.9350	-0.2694	-0.2875	0.9650	-0.9548	0.9495
Treatments	0.0762	0.0778	0.0631	0.1804	-0.0184	0.1677	-0.0918

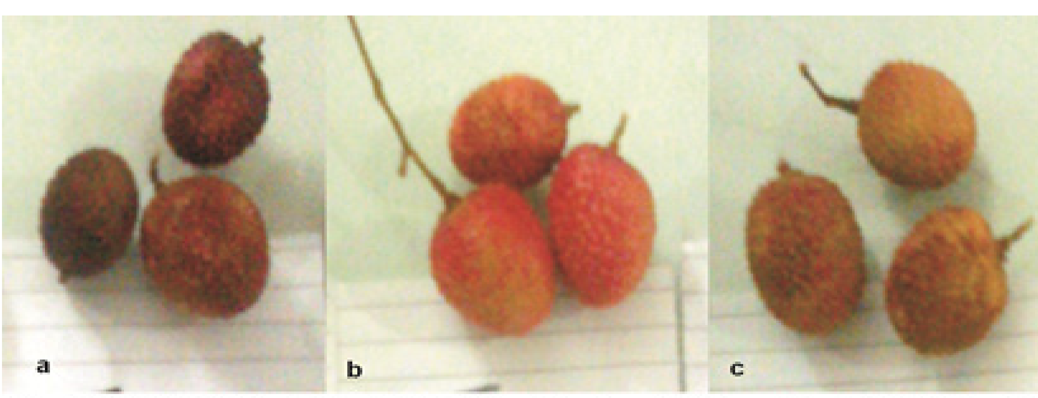

Fig. 3. Litchi fruits treated with 10% (a) salicylic acid, (b) oxalic acid © citric acid

CONCLUSION

In short, oxalic acid application (10%) gave best results regarding maintaining quality parameters during storage of litchi. This technology could be beneficial for increasing the shelf life of fruits during storage.

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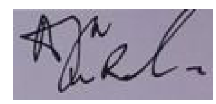
2.	Naeem Khalid	Suggested guidelines for experiments and helped in manuscript writing	
3.	Irrum Babu	Conducted research work	
4.	Ata-ur-Rehman	Proof reading of manuscript	
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