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EFFECT OF ADDITIVE TREATMENTS ON PHYSICOCHEMICAL AND PHYSIOLOGICAL PARAMETERS OF PEACH FRUITS DURING STORAGE

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Abstract

Peach (Prunus persica L.) fruits have short storage life after harvest and deteriorate quickly at ambient temperature because of climacteric nature and its rapid ripening process. The present research project is designed to minimize the post-harvest losses of peach fruits by the application of additives. Purposely, Peach fruits were dipped in CaCl2 (2.0%, 3.0%), oxalic acid (2 mM, 3 mM) and one combination of CaCl2 and oxalic acid (1% CaCl2 & 1 mM oxalic acid) along with other combination of CaCl2 and oxalic acid (1.5% CaCl2 & 1.5 mM oxalic acid). Peaches were then air-dried and stored at 5°C and 85% relative humidity for 35 days. Treated samples were analyzed every week and significant variations (P<0.05) were recorded. Results depicted that total soluble solids, pH, weight loss, fruit decay index, shrinkage index, malondialdehyde content, ion leakage, increased during storage however treated fruits showed better response than control. However firmness and % acidity decreased in all peaches during storage but this decrease was significantly less in additive treated peach fruits as compared to untreated (control) fruits. Ethylene rate increases till 14th day in control fruits then after climacteric peak decreases while in treated fruits it increases till 21st day and then decreases. Conclusively, oxalic acid (3 mM) concentration treatment better retained the physicochemical and physiological parameters of the peach fruits.

Keywords: Peach, Oxalic Acid, Calcium Chloride, Physicochemical, Physiological, Storage.

1. INTRODUCTION

Peach (*Prunus persica*) is stone fruit that belongs to family Rosaceae and genus Prunus. Morphologically, thin outer epicarp, fleshy edible mesocarp and in the centre endocarp (stone) covers the seed. Worldwide demand of stone fruit is high due to desirable taste and high nutritional importance. (Riva *et al*., 2020). Phytochemicals are abundantly present in stone fruits which contribute flavor and taste. (Lara *et al*., 2020). Peach is originated from Persian region, with first cultivation reported in China. During the Roman Era, it spread to the Europe and in 19^{th} century, it emerged as main fruit in United States

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of America and now being cultivated in countries of Mediterranean region as well (Samad *et al.,* 2019). Peach is the second most important stone fruit after apricot traditionally grown in northern regions of the Pakistan.

In Pakistan total production of peach fruit was 110,764 tons from an area of 15,295 hectares during the year 2020-21. KPK was the major peach producing province 69417 tons from followed by Baluchistan with 39457 tons from an area of 10081 hectares and 4973 hectares respectively as per Fruit and vegetable condiment statistics of Government of Pakistan in 2020-21 (Ayub *et al*., 2020). Peach fruits are rich sources of dietary fiber, phytochemicals including amino acids, vitamins C, organic acids, natural sugars, carotenoids, anthocyanins, flavonoids and phenolic acids. All these components contribute to unique nutritive value of both fruit as well as juice. The antioxidants present in peach fruit are procyanidins, catechins and anthocyanins (Ayub *et al*., 2020).

During storage softening and deterioration of fruits are the major challenges to the fruit industry that causes losses. Chemical treatments of fruits reduces postharvest losses of vegetables and fruits by controlling browning, synthesis of ethylene, retarding transpiration and respiration process and occurrence of disease (Khan *et al*., 2023). Perishable nature of peach fruits inhibits prolonged storage. Peach fruit decay and softening increases after harvest causing unacceptable quality and loss of commercial value. Quality conserving of peach is global problem which is accentuated by speedy ripening, senescent process and decay by microbial invasion after harvest (Du *et al.,* 2020).

Different postharvest techniques like ultraviolet light, ozonation, controlled atmosphere storage, cold storage, modified atmosphere packaging (MAP), low-pressure storage (hypobaric), ozonation, ultraviolet light, ultrasound application, and pre-storage heat treatments have shown significant results in extending storage life and maintaining quality during the postharvest period (Hasan *et al*., 2020; Maryam *et al*., 2021; Singh, 2022; Zhang and Jiang, 2019). Due to certain limitations in using these technologies and variations in responses of fresh horticultural produce, several food-safe chemical compounds have been tested, where a few have qualified for the next phase of commercialization (Hasan *et al*., 2023). Calcium application on fruits helps in senescence reduction having no side effect on consumer acceptance (Ayub *et al*. 2021). Calcium application stabilize the plant cell wall and protects it from cell wall degrading enzymes (Taran *et al*. 2022). Ca^{2+} presence increases cell walls cohesion (Nayak *et al*. 2020), has potential to retain postharvest quality of fruit, decrease ripening and senescence of fruits (Khan *et al*. 2020). Application of $CaCl_2$ provides resistance against fungus attack on fruits (Mehmood *et al*. 2020). Ca^{2+} forms calcium pectate from pectin of the cell wall and middle lamella. This employs the turgor pressure of tissues, strength cell wall, and decreases loss of firmness in peaches (Shalan 2020).

Oxalic acid (OA), organic acid that extend the shelf life of fruits by delaying ripening, inhibiting biosynthesis of ethylene and preventing browning of fruits (Erogul *et al*. 2023). OA is regarded as a GRAS (generally recognized as safe) food safe compound due to its eco-friendly nature (Ali *et al*., 2020). Exogenous OA application delay softening and

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ripening of fruits such as mango, peach and plum (Erogul *et al*. 2023, Hazarika *et al*., 2021). Peach fruit antioxidant enzymes including catalase, superoxide dismutase, peroxidase and ascorbate peroxidase activity increased by postharvest application of oxalic acid. These enzymes play a vital role in protecting the cells from the harmful effects of reactive oxygen species (Razavi *et al*., 2017).

The main purpose of current research project is shelf life extension of fresh peach fruits and to find an effective & economical control measures to lessen the postharvest losses so that it can be transported to distant markets for revenue generation.

2. MATERIALS AND METHODS

2.1 Procurement of peach fruits and chemicals

Peach fruits of uniform size, and maturity without any damage, were harvested from Agriculture Research Institute, Mingora Swat (Pakistan) and after packing in cardboard transferred to the Post Harvest Research Centre, Faisalabad (Pakistan) in controlled conditions for retaining good quality. Similarly, some of the analyses were also performed in the Food Safety Laboratory of National Institute of Food Science and Technology (NIFSAT), University of Agriculture, Faisalabad (Pakistan). After sorting and grading, the fruits were washed using solution of 150 ppm sodium hypochlorite. The laboratory grade chemicals were purchased from the local market.

2.2 Application of food additives

Peach fruits were dipped in different concentrations of calcium chloride ($CaCl_2$) and oxalic acid for 5 minutes as mentioned in treatment plan (as per Table. 1). After air drying for 15 minutes, fruits were kept in cold storage at 5°C and 85% relative humidity for a maximum acceptable period. The additive treated fruits were analyzed on weekly basis during storage.

Table 1: Treatment plan for the application of food additives

Treatments	Type of food additive
T_0	Control
T_1	2% $CaCl_2$
T_2	3% $CaCl_2$
T_3	2 mM Oxalic acid
T_4	3 mM Oxalic acid
T_5	1% $CaCl_2$ and 1 mM Oxalic acid
T_6	1.5% $CaCl_2$ and 1.5 mM Oxalic acid

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2.3 Analysis of peach fruits during storage conditions of 35 days

During storage, all additive dipped peach fruits were tested for physicochemical and physiological parameters at the interval of one week. The total study duration was 35 days.

2.3.1 Physicochemical analysis

2.3.1.1 Color

Peach fruits were analyzed at the start and periodically during storage for instrumental color values L, a*, and b* on opposite sides at the central point of the polar axis following the method reported by Mir *et al*. (2018) by using a chroma meter (Neuhaus Neotec, Germany).

2.3.1.2 Fruit firmness

The firmness of stored fruits was checked with a digital penetrometer (Effegi: FT-327, Milan, Italy) following the protocol of Hussain *et al.* (2012). The fruits were selected randomly after an interval of one week from each treatment and their firmness was estimated with the help of a penetrometer of 8 mm diameter plunger at two opposite points on the equator of fruits.

Intentionally, entire fruits were kept beneath the probe, and force was applied by using a penetrometer. A screen displayed the applied force on the fruit. The mean value of the fruits was taken as the firmness of the entire lot which was stated in Kg/cm^2.

2.3.1.3 Total soluble solids (ºB)

Total soluble solids of freshly extracted juice of composite peach fruits were determined with a digital refractometer (RA-600 Refractometer, Kyoto Electronics, Japan) by the method described by Abbasi *et al*. (2019) and results were uttered as brix. Triplicate readings were taken for each treatment.

2.3.1.4 Titratable acidity

Peach fruit's acid content was determined with a digital acidity meter according to the approach of Du *et al*. (2020) and stated as malic acid contents.

2.3.1.5 pH

The peach sample's pH was measured by using a digital pH meter according to the method of Mosie *et al*. (2019). In this regard, about 50 mL of the peach juice was taken in a 100 mL beaker and the electrode of the digital pH meter was dipped in the thoroughly mixed peach juice. The reading display on the screen of the meter is noted as pH.

2.3.2 Physiological analysis

2.3.2.1 Ethylene rate

Ethylene generated by fruits was measured by the protocol of Razavi *et al*. (2017) and Razzaq *et al*. (2015) with some modifications. The evolution of ethylene was estimated keeping two peach fruits at room temperature for an hour in a three-liter glass hermetically

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sealed desiccator with transmission valve. Ethylene meter was attached with desiccator through tube and valve was opened and after one-minute reading displayed on meter was noted. The obtained results were described in terms of microliters of ethylene released per kg of fruit per hr, respectively (µL/Kg/hr).

2.3.2.2 Weight loss

Randomly selected fruits from each treatment were weighed before and during storage on weighing balance. Loss in weight was determined after one-week interval. Weight loss % of fruit was estimated according to the method as reported in the literature by (Sohail *et al*. 2015).

$$\text{Weight loss (\%)} = \frac{(\text{Initial weight} - \text{Final weight}) \times 100}{\text{Initial weight}}$$

2.3.2.3 Fruit Decay Index

Fruits were visually monitored initially and after each one week of storage. Any fruit with noticeable visible growth of molds was reported as decayed fruits as described by Sohail *et al.* (2015).

The fruit decay was estimated visually in the beginning and after the interval of seven days' interval. Any peach fruit observed with visible growth of mold was counted as decayed.

Due to such reasons, the decay rate of the first fruit was calculated by determining the level of the decayed area on every fruit, and was named as 0, not decay; 1 for less than ¼ decay; 2 for 1/4-1/2 decay; 3 for 1/2-3/4 decayed. The decay index which is the average extent of fruit decay was estimated by using the following formula:

$$\text{\% Decay index} = [(1\times N_1+2\times N_2+3\times N_3) \times 100/ (3\times N)]$$

Where N is the total number of fruits estimated and N_1, N_2, and N_3 are the number of fruits describing various values for decay rates.

2.3.2.4 Shrinkage index

The shrinkage index was determined by using the procedure of Mani *et al.* (2017) and Mitra *et al.* (2020). The changes in diameter of peach fruits of different treatments during storage were recorded in millimeters with digital Vernier calipers after 7 days of interval and expressed as shrinkage index percentage by using the following formula:

$$\text{SI (\%)} = \frac{(D_o - D_1) \times 100}{D_0}$$

Where;

SI= Shrinkage index

D_o = Initial diameter at 0 day

D_1= Diameter at 7 days' interval

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2.3.2.5 Malondialdehyde content

Malondialdehyde content in the mesocarp of peach fruit was determined by adopting the procedure as reported by Gao *et al*. (2018). Malondialdehyde (MDA) content was taken by homogeneously mixing 2 g of flesh tissue with 10 mL of 10% trichloroacetic acid comprising 0.5% (w/v) thiobarbituric acid.

The homogenized solution was boiled for 10 min and then immediately cooled and centrifuged for 15 min at 5000 rpm. The absorbance of the supernatant was estimated with a spectrophotometer at different wavelengths *i.e.* 450, 532, and 600 nm and the measured amount of MDA content was expressed as μmol/g.

$$MDA = 6.45 \times (A_{532} - A_{600}) - 0.56 \times A_{450}$$

2.3.2.6 Ion leakage

Ion leakage was assessed by adopting the process of Shan *et al*. (2016). Ion leakage was determined from 20 flesh dicks (10 mm diameter and 5 mm thickness) by using a puncher of 1 cm diameter. Afterward, the disks were dipped for 30 min in 25 mL of distilled water.

The China conductivity meter was used to measure the initial conductivity of the solution expressed as L_0. In order to measure final conductivity, the solution (L_1) was boiled for 5 min and the total volume was re-adjusted to 25 mL. The ion leakage was measured by using the following formula:

$$\text{Ion leakage (\%)} = (L_0/L_1) \times 100.$$

2.4 Statistical analysis

All the obtained data were taken in triplicate and analyzed by using standard statistical procedures as described by Montgomery (2017). Furthermore, CRD under a two-factor factorial was used to establish the level of significance. Statistical significance ($P \leq 0.05$) of means differences was assessed by Tukey HSD Test.

3. RESULTS AND DISCUSSIONS

The results about application of $CaCl_2$ 2.0%, 3%, oxalic acid 2 mM, 3 mM and combination of $CaCl_2$, oxalic acid (1 % $CaCl_2$ & 1 mM Oxalic acid and 1.5 % $CaCl_2$ & 1.5 mM Oxalic acid) are discussed in detail here.

Peach fruit was analyzed for physicochemical analysis (color (L, a, b), firmness, total soluble solids, titratable acidity, pH), physiological analysis (ethylene rate, weight loss, fruit decay index, shrinkage index, malondialdehyde content, ion leakage). Similarly the results of storage study are also discussed in detail here.

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3.1. Physicochemical analysis

3.1.1. Color

3.1.1.1. L value

In quantitative terms the response values for L followed increasing trend with length of storage in untreated (control) up to 14th day and 21st day in treated peach fruits and then value started decreasing thereafter but this decrease was significantly ($P< 0.05$) less in treated fruits (Table 2).

Among treatment x storage interaction, the amount of L values varied between 61.19±1.53 in T_0 (untreated peach fruits) treatment on 35th day and 74.37±2.2 on 21st day in T_4. L values raised with advancement in storage time and was highest in all additive treatments on 21st day irrespective of treatment received. In control fruits L values showed rise and decline one week earlier than treated fruits depicting delayed ripening in peach fruits subjected to additive treatment. Overall, results depicted that treated sample revealed minimum changes in L values as compared to untreated samples throughout storage.

Table 2: Effect of additive treatments on values for color (L value) of peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21th Day	28th Day	35th Day
T_0	66.41±1.66^{d-i}	68.43±1.71^{a-h}	71.71±1.79^{a-d}	64.6±1.62^{e-i}	62.68±1.57^{hi}	61.19±1.53^{i}
T_1	66.68±1.66^{b-i}	66.68±1.66^{b-i}	68.03±1.85^{a-h}	68.31±0.81^{a-h}	66.32±1.66^{d-i}	63.41±1.59^{g-i}
T_2	66.94±2.74^{b-i}	70.45±0.6^{a-f}	71.58±1.79^{a-d}	72.7±2.57^{a-d}	71.31±2.57^{a-e}	70.13±1.62^{a-g}
T_3	66.82±1.67^{b-i}	68.44±1.71^{a-h}	68.74±1.72^{a-h}	70.56±1.5^{a-e}	67.44±3.43^{b-i}	67.25±4.39^{b-ip}
T_4	66.84±1.67^{b-i}	71.6±1.65^{a-d}	73.39±2.02^{ab}	74.37±2.2^{a}	72.69±2.19^{a-d}	70.91±3.47^{a-e}
T_5	66.56±1.66^{c-i}	68.16±1.7^{a-h}	69.28±1.73^{a-h}	69.49±1.74^{a-g}	63.76±1.59^{f-i}	62.61±1.57^{hi}
T_6	66.75±1.67^{b-i}	69.81±1.82^{a-g}	73.31±2.9^{a-c}	73.35±2.17^{ab}	71.78±2.7^{a-d}	69.5±1.1^{a-g}

Means carrying the similar letters are statistically non-significant

T_o = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

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3.1.1.2. a* value

The a* value followed increasing trend in storage irrespective of additive treatments applied in both treated as well as control fruits, however, the extent of increase was significantly less in treated as compared to control.

Among treatment x storage interaction, the amount of a* value varied between -5.89±0.88 in T_3 on 0 day and 8.50±0.94 in untreated fruits on 35th day as shown in Table 3 . In quantitative terms a* value increases with advance in storage duration and was highest in all treatments on 35th day irrespective of additive treatments received. Among treatments, T_0 (untreated) fruits exhibited highest value for a* value (8.5±0.94) while minimum (6.04±0.66) was observed in T_4 on 35th day. T_4 (3 mM Oxalic acid) revealed efficient control on a* value increase followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) and T_2 (3 % $CaCl_2$) as compare to control and other treatments.

Table 3: Effect of additive treatments on values for color (a* value) of peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21st Day	28th Day	35th Day
T_0	-5.52±0.83^{pq}	-1.51±0.23^{k-n}	2.69±0.4^{i}	5.05±0.76^{b-h}	6.37±0.76^{b-e}	8.5±0.94^{a}
T_1	-5.84±0.88^{q}	-2.56±0.38^{m-o}	0.53±0.08^{j}	3.66±0.55^{g-i}	5.22±0.63^{b-g}	6.66±0.73^{a-d}
T_2	-5.68±0.85^{q}	-2.48±0.37^{l-o}	-0.5±0.07^{j-l}	3.06±0.46^{hi}	4.65±0.56^{d-i}	6.19±0.68^{b-f}
T_3	-5.89±0.88^{q}	-3.25±0.49^{n-o}	-0.41±0.06^{jk}	4.31±0.65^{f-i}	5.52±0.66^{b-g}	6.78±0.75^{a-c}
T_4	-5.72±0.86^{q}	-3.44±0.52^{n-o}	-0.74±0.11^{j-m}	3.03±0.45^{hi}	4.76±0.57^{c-h}	6.04±0.66^{b-f}
T_5	-5.8±0.87^{q}	-3.11±0.47^{n-o}	-0.09±0.01^{jk}	4.32±0.65^{f-i}	5.22±0.63^{b-g}	6.84±0.75^{ab}
T_6	-5.74±0.86^{q}	-3.55±0.53^{o-p}	-0.65±0.1^{j-m}	3.49±0.52^{g-i}	4.54±0.54^{e-i}	6.57±0.72^{a-e}

Means carrying the similar letters are statistically non-significant

T_0 = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

3.1.1.3. b value

The extent of response value for b* followed increasing trend with storage duration in peach fruits up to 21st day and then value declined till end of storage, but this decline was significantly less in treated than untreated (control) peach fruits (Table 4). Among

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treatment x storage interaction, b* values ranged from 37.05±0.93 in T_0 (control) treatment on 35th day to 54.41±1.36 on 21st day in T_4. T_4 (3 mM oxalic acid) treatment effectively reduced the extent of change in b* values followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) and T_2 (3 % $CaCl_2$) as compared to other treatments on 35th day. Treated fruits revealed minimum variation in b* values as compared to control. Untreated fruits developed more prominent color due to speedy ripening owing to higher ethylene and respiration rates whereas treated fruits showed lower color change due to slow ripening. Fruits treated with calcium chloride and oxalic acid showed delayed ripening and senescence along with less color change by retaining more chlorophyll.

Tareen *et al*. (2012) reported less a* and greater L values in salicylic acid treated peach fruits as compared to greater a*, b* and lower L values in control fruits which in concordance with results from current study. Similar to color values for chemical treated peach fruits, the ethylene antagonists treated fruits retained higher L, b* and lower a* values in peach (Tareen *et al*., 2017). Similar to color scores for chemical treated peach fruits, the combined application of 1-MCP and ozone was most efficient in retaining color of peach fruits (Du *et al.,* 2020). In confirmation with results from present study, Kibar *et al.* (2021) noticed greater lightness for 1.6 millimolar putrescine treated peach fruits with lower a* and higher b* values in contrast to darker color for control fruits. Zhou *et al.* (2022) reported lower L, a* and b* values and higher hue depicting delayed browning and senescence in papaya fruits with combined use of ascorbic acid and chitosan which is similar to current research findings.

3.1.2. Fruit firmness

The fruit firmness for chemical additive treated peach fruits during storage is depicted in Figure 1. The value of fruit firmness followed decreasing trend with length of storage irrespective of treatments in both additive treated as well as fruits without any treatment, however, the extent of fruit firmness decrease was significantly greater in untreated as compared to additive treated peach fruits.

Among treatment x storage interaction, the amount of firmness varied between 0.85±0.12 Kg/cm^2 on 35th day in untreated (control) and 6.18±0.44 Kg/cm^2 on 0 day in peach fruits. In quantitative terms fruit firmness decreases with advancement in storage time and was lowest in all treatments on 35th day irrespective of additive treatment received.

The lowest mean for firmness among treatments was 0.85±0.12 Kg/cm^2 observed on 35th day in T_0 (control) fruits while highest 1.89±0.14 Kg/cm^2 was observed in T_4 (3 mM Oxalic acid) treatment on the same day.

Fruit firmness is main indicator of consumer acceptance. Decreased in firmness of fruit is mainly due to degradation of cell wall. Calcium chloride has main role in maintaining cell wall integrity as it forms calcium pectate by reacting with pectic acids of cell wall, it slows down the respiration rate of fruits, decreases the

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Table 4: Effect of additive treatments on values for color (b* value) of peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21th Day	28th Day	35th Day
T_0	$45.94 \pm 1.15^{g-j}$	$46.57 \pm 1.16^{f-i}$	$47.18 \pm 1.18^{e-h}$	53.61 ± 1.34^{ab}	$40.66 \pm 1.02^{k-n}$	37.05 ± 0.93^{n}
T_1	$45.85 \pm 1.15^{g-j}$	$49.97 \pm 1.25^{b-f}$	$50.56 \pm 1.26^{a-e}$	$50.99 \pm 1.27^{a-e}$	$39.76 \pm 0.99^{l-n}$	39.5 ± 0.99^{mn}
T_2	$45.91 \pm 1.15^{g-j}$	$50.87 \pm 1.27^{a-e}$	$52.15 \pm 1.3^{a-d}$	$52.43 \pm 1.31^{a-d}$	$43.21 \pm 1.08^{i-m}$	$42.54 \pm 1.06^{j-m}$
T_3	$45.74 \pm 1.14^{g-j}$	$48.72 \pm 1.22^{d-g}$	$51.24 \pm 1.28^{a-d}$	$52.75 \pm 1.32^{a-c}$	$43.62 \pm 1.09^{h-l}$	$42.85 \pm 1.07^{i-m}$
T_4	$45.96 \pm 1.15^{g-j}$	$51.41 \pm 1.29^{a-d}$	$52.73 \pm 1.32^{a-c}$	54.41 ± 1.36^{a}	$46.62 \pm 1.17^{f-i}$	$44.22 \pm 1.11^{h-k}$
T_5	$45.99 \pm 1.15^{g-j}$	$49.14 \pm 1.23^{c-g}$	$50.64 \pm 1.27^{a-e}$	$51.13 \pm 1.28^{a-d}$	$42.52 \pm 1.06^{j-m}$	$40.69 \pm 1.02^{k-n}$
T_6	$45.77 \pm 1.14^{g-j}$	$51.19 \pm 1.28^{a-d}$	$52.21 \pm 1.31^{a-d}$	54.31 ± 1.36^{a}	$45.31 \pm 1.13^{g-j}$	$44.34 \pm 1.11^{h-k}$

Means carrying the similar letters are statistically non-significant

T_O = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

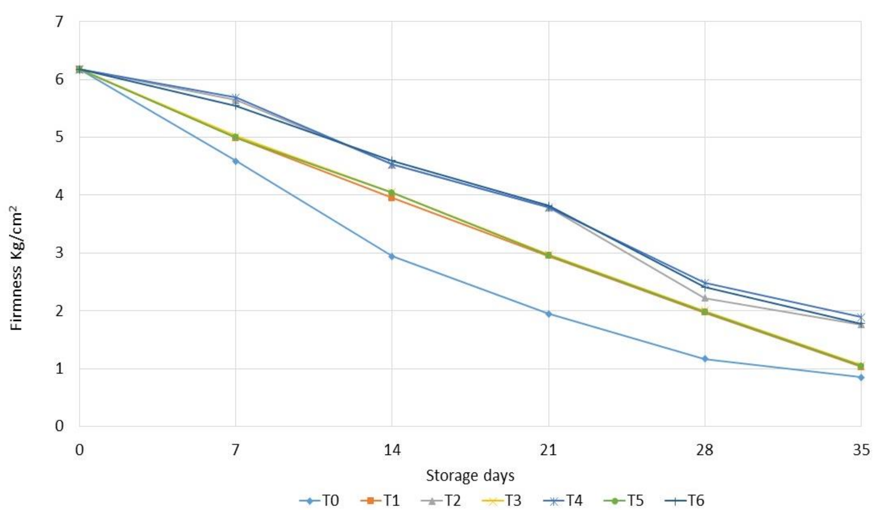

Fig 1: Effect of additive treatments on firmness of peach fruits during storage

T_O = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

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ripening process and increases fruits firmness by maintain structure of cell wall. Calcium gives rigidness to the cell, lessen fruit decay, retard softening and increases fruit firmness.

Shalan (2020) reported that fruit firmness decreases with the advancement of storage period however this decrease was more control Florida prince fruits as compared to calcium chloride and ascorbic acid treated fruits. Razavi *et al.* (2017) found that firmness of fruits gradually decreased throughout the storage, but oxalic acid treated fruits maintained higher firmness than control which is in confirmation with current study. The current study findings are in close agreement with the Singh *et al.* (2018) who stated that highest fruit firmness was noted in peach fruit treated with $CaCl_2$ and lowest in control fruits during storage.

3.1.3. Total soluble solids (TSS brix)

The results revealed highly significant impact of additives, storage and binary interaction on TSS ($P< 0.05$) as shown in Figure 2. The value of TSS followed increasing trend with length of storage irrespective of treatments, however, the extent of increase in TSS was significantly greater in untreated (control) as compared to treated peach fruits.

Among treatment x storage interaction, the amount of TSS varied between 11.2±0.1 °B on 0 day and 16.6±0.2 °B in untreated (control) fruits on 35th day. In quantitative term, TSS increased with advancement in storage duration and was highest in all treatments on 35th day irrespective of additive treatment received. Among treatments, T_0 (untreated) fruits exhibited highest value for TSS (16.6±0.2°B) on 35th day while on the other side, the minimum TSS (14.8±0.17°B) was observed in T_4 treatment on same day.

Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on TSS increase followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) as compared to other treatments ranging mean values between 11.2±0.1 to 14.8±0.17 °B and 11.2±0.1 to 14.9±0.1 °B from 0 day to 35th day.

The soluble solid contents denote the total sugars, mainly sucrose, fructose and glucose in soluble metabolites. This increase might be due to polysaccharide hydrolysis. Moreover, increase in TSS denotes the enzymatic break down of higher polysaccharides such as pectin into simple sugars during ripening. Shalan (2020) reported that soluble solid contents increase with the advancement of storage period however this increase was more prominent in control peach fruits as compared to fruits treated with calcium chloride and ascorbic acid.

Razavi *et al.* (2017) revealed that TSS of fruits gradually increased throughout the storage but this was increase was significantly less in oxalic acid treated fruits which is well aligned with TSS of chemical treated peach fruits.

The current findings are in close agreement with the Singh *et al.* (2018) also stated that TSS increased in peach fruits during storage, but this increase was low in fruit treated with $CaCl_2$ and high in control fruits during cold storage.

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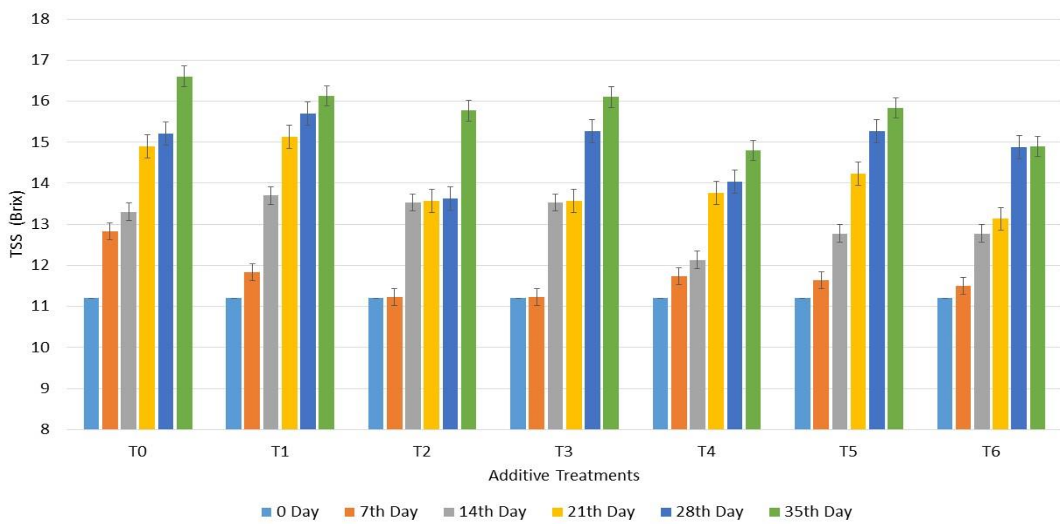

Fig 2: Effect of additive treatments on TSS of peach fruits during storage

$\mathbf{T_o}$ = No Additive (Control), $\mathbf{T_1}$ = 2 % $CaCl_2$, $\mathbf{T_2}$ = 3 % $CaCl_2$, $\mathbf{T_3}$ = 2 mM Oxalic acid, $\mathbf{T_4}$ = 3 mM Oxalic acid, $\mathbf{T_5}$ = 1 % $CaCl_2$ and 1 mM Oxalic acid, $\mathbf{T_6}$ = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

3.1.4. Titratable acidity

The titratable acidity for additive treated peach fruits during storage is depicted in Figure 3. The value of titratable acidity followed decreasing trend with length of storage irrespective of treatments in both chemical additive treated as well as fruits without any treatment, however, the extent of decreasing titratable acidity was significantly greater in untreated as compared to additive treated peach fruits.

Among treatment x storage interaction, the amount of titratable acidity varied between 0.35±0.02% on 35th day in untreated (control) and 0.62±0.02% on 0 day in peach fruits. In quantitative terms titratable acidity decline with advance in storage time and was lowest in all treatments on 35th day irrespective of additive treatment.

The lowest value for titratable acidity among additive treatments was 0.35±0.02% observed on 35th day in T_0 (control) fruits while highest 0.51±0.01% was observed in T_4 (3 mM Oxalic acid) treatment on the same day.

Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on titratable acidity decrease as compared to other treatments ranging mean values between 0.62±0.02 to 0.51±0.01% from 0 day to 35th day.

During storage, fruit respiration continued, and different types of gases were exchanged. As respiration is an enzymatic process and organic acids are used as a substrate by enzymes. $CaCl_2$ is beneficial in acidity preservation of fruit and delay ripening of fruits.

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Higher acidity may be due to the presence of higher amount of malic and citric acid, which degraded during process of respiration thus ultimately acidity decreases.

In confirmation with acidity of additive treated peach fruits from present study, Razavi *et al.* (2017) reported that titratable acidity of fruits gradually decreases throughout the storage however titratable acidity was higher in fruits treated with oxalic acid than control.

Kaur and Kaur (2019) that Florida price peach fruits delineated that titratable acidity decreases significantly during storage which is in support of acidity in additive treated peach fruits. Singh *et al.* (2018) also reported the decline of titratable acidity with increase of storage and increase of titratable acidity with increase in concentration of $CaCl_2$.

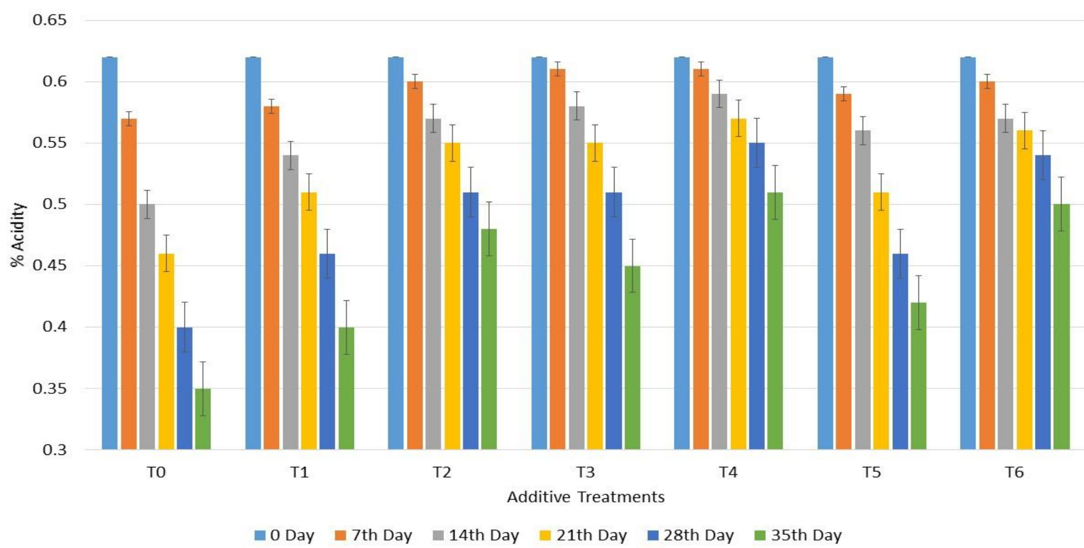

Fig 3: Effect of additive treatments on acidity of peach fruits during storage

T_0 = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

3.1.5. pH

The value of pH followed increasing trend with length of storage irrespective of additive treatments in both treated as well as fruits without treatment, however, the extent of pH increase was significantly ($P< 0.05$) greater in untreated (control) as compared to treated peach fruits (Table 5). Among treatment x storage interaction, the amount of pH varied between 3.73±0.02 on 0 day and 4.74±0.02 in untreated (control) fruits on 35th day. In quantitative term, pH increased with advancement in storage duration and was highest in all treatments on 35th day irrespective of additive treatment received. Among additive treatments, T_0 (untreated) fruits exhibited highest value for pH (4.74±0.02) on 35th day while on the other side, the minimum pH (4.28±0.02) was observed in T_4 treatment on same day. On overall basis, treatment T_4 (3 mM Oxalic acid) was most efficient in

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controlling pH increase followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) as compared to other treatments with mean values ranging between 3.73±0.02 to 4.28±0.02 and 3.73±0.02 to 4.29±0.03 respectively from 0 day to 35th day.The mechanistic reason behind the increase of pH during storage is the rate of metabolism especially due to respiration. Organic acids are catabolized due to metabolic activities owing to the action of different enzymes, especially during respiration which results in declined acidity. Decrease in titratable acidity results in an increase in pH due to an inverse relation among these parameters. Decrease in acidity may be the cause of increase in pH.

Razavi *et al.* (2017) found that pH of fruits gradually increases throughout the storage, but increase was significantly less in oxalic acid treated fruits than control. Similar trend of increase in pH during storage was observed by Oz *et al.* (2016) who revealed that value of pH increased during storage but maximum value of pH was observed in control fruits and minimum in oxalic acid treated fruit. Likewise, to pH of chemical treated peach fruits, Shah *et al.* (2016) reported that storage days have significant effect on pH value with steady increase in value of pH during entire storage period. The results of present research are in corroboration with the findings of Ezzat *et al.* (2017) who showed that juice pH increased in all samples with storage time, but the increase was considerably higher in water treated fruits than the fruits treated with methyl jasmonate (MeJA) and salicylic acid (SA) apricot during storage.

Table 5: Effect of additive treatments on pH peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21th Day	28th Day	35th Day
T_o	3.73±0.02^{p}	3.86±0.02^{k-m}	4.03±0.01^{hi}	4.24±0.03^{e}	4.49±0.04^{b}	4.74±0.02^{a}
T_1	3.73±0.02^{p}	3.8±0.01^{m-p}	4.03±0.03^{hi}	4.05±0.05^{gh}	4.14±0.02^{f}	4.5±0.01^{b}
T_2	3.73±0.02^{p}	3.78±0.03^{n-p}	3.81±0.01^{l-o}	3.88±0.02^{kl}	4.23±0.03^{e}	4.37±0.01^{d}
T_3	3.73±0.02^{p}	3.8±0.01^{m-p}	3.96±0.02ij	4.03±0.03^{hi}	4.12±0.03^{fg}	4.4±0.02^{cd}
T_4	3.73±0.02^{p}	3.75±0.01^{op}	3.82±0.03^{l-o}	3.86±0.01^{k-m}	4.13±0.02^{f}	4.28±0.02^{e}
T_5	3.73±0.02^{p}	3.8±0.03^{m-p}	3.93±0.03^{jk}	3.97±0.03^{ij}	4.01±0.01^{hi}	4.47±0.01^{bc}
T_6	3.73±0.02^{p}	3.75±0.02^{op}	3.83±0.01^{l-n}	3.88±0.01^{kl}	4.15±0.02^{f}	4.29±0.03^{e}

$\mathbf{T_o}$ = No Additive (Control), $\mathbf{T_1}$ = 2 % $CaCl_2$, $\mathbf{T_2}$ = 3 % $CaCl_2$, $\mathbf{T_3}$ = 2 mM Oxalic acid, $\mathbf{T_4}$ = 3 mM Oxalic acid, $\mathbf{T_5}$ = 1 % $CaCl_2$ and 1 mM Oxalic acid, $\mathbf{T_6}$ = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

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3.2. Physiological analysis

3.2.1 Ethylene rate

The ethylene rate for additive treated peach fruits during storage is depicted in Table 6. Ethylene content of peach fruits followed climacteric peak and then decreased throughout the storage in both treated as well as untreated peach fruits however the peak appeared on 14^{th} days one week earlier in untreated than treated fruits.

Among treatment x storage interaction, the amount of ethylene rate varied between 20.36±0.92 µL/ Kg/h in T_1 treatment on 0 day and 84.98±1.02 µL/ Kg/h on 14^{th} day in untreated peach fruits.

In quantitative terms ethylene rate increases till 14^{th} day in control fruits then after climacteric peak decreases while in treated fruits it increases till 21^{st} day and then decreases. Among additive treatments, untreated (control) fruits exhibited highest value for fruit ethylene rate (51.85±0.88 µL/ Kg/h) on 35^{th} day while on the other side, the lowest value of ethylene rate (34.48±0.59 µL/ Kg/h) was observed in T_4 at the same day.

Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on fruit ethylene rate production as compared to other treatments ranging mean values between 20.68±0.93 to 34.48±0.59 µL/ Kg/h followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) 20.57±0.93 to 35.43±0.6 µL/ Kg/h and T_2 (3 % $CaCl_2$) 20.48±0.92 to 37.12±0.63 µL/ Kg/h respectively from 0 day to 35^{th} day.

Ethylene synthesis increased during storage however value for ethylene was higher in control as compared to coated fruits. The rate of ethylene production followed 2^{nd} order polynomial relation with storage. Edible coatings decreased gaseous exchange O_2 ingress in fruits and resulted in lower respiration and ethylene production.

Postharvest application of oxalic acid significantly delayed and suppressed the production of ethylene during storage. Calcium chloride application suppress the ethylene increase and delay the ethylene production peak. The oxalic acid may inhibit the activity of 1-aminocyclopropane-1-carboxylic acid synthase, main enzyme involved in biosynthesis of ethylene.

Razavi *et al.*, (2017) reported that ethylene production increased during storage in acid treated peach fruits. Control peach fruits attained climacteric peak earlier, but no peak was observed in oxalic acid treated fruits which confirms the results for ethylene content from current study.

Razzaq *et al.* (2015) observed that exogenous application of oxalic acid on mango fruit ripening exhibited significant decrease in ethylene production in mango fruits. In support of results for ethylene in present investigation, Tareen *et al.* (2017) indicated that the production of ethylene increased with increment of storage time; however, control fruits exhibited higher ethylene production than the fruits treated with aminoethoxyvinylglycine alone or combination with nitric oxide or salicylic acid on peach fruits.

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3.2.2. Weight loss

The value of weight loss followed increasing trend with length of storage irrespective of treatments in both treated as well as fruits without any treatment, however, the extent of weight loss was significantly ($P< 0.05$) greater in untreated as compared to treated peach fruits (Figure 4).

Among treatment x storage interaction, the amount of weight loss varied between 1.97±0.04% in T_4 treatment on 7th day and 29.35±0.59% on 35th day in untreated (control) peach fruits.

In quantitative terms weight loss rise with advancement in storage time and was highest in all treatments on 35th day irrespective of treatment received. Among additive treatments, T_0 (control) exhibited maximum value for weight loss (29.35±0.59%) on 35th day while on the other side, the lowest weight loss (11.53±0.23%) among treated peach fruits was found in fruits receiving T_4 (3 mM Oxalic acid) treatment on last storage interval.

Table 6: Effect of additive treatments on ethylene rate of peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21th Day	28th Day	35th Day
T_0	20.43±0.92^{u}	63.59±0.95^{e}	84.98±1.02^{a}	70.65±0.99^{b}	60.45±0.91^{f}	51.85±0.88^{j}
T_1	20.36±0.92^{u}	47.51±0.71^{k-m}	60.11±0.84^{fg}	69.52±0.83^{b}	48.11±0.72^{kl}	40.23±0.68^{qr}
T_2	20.48±0.92^{u}	44.92±0.67^{m-o}	55.68±0.78^{hi}	64.88±0.78^{de}	45.99±0.69^{l-n}	37.12±0.63^{s}
T_3	20.49±0.92^{u}	47.81±0.72^{kl}	58.43±0.82^{fg}	66.42±0.8^{cd}	49.15±0.74^{k}	39.87±0.68^{r}
T_4	20.68±0.93^{u}	41.27±0.62^{qr}	53.39±0.75^{ij}	57.63±0.69^{gh}	42.83±0.64^{o-q}	34.48±0.59^{t}
T_5	20.48±0.92^{u}	46.51±0.7^{l-n}	58.85±0.82^{fg}	68.48±0.82^{bc}	47.98±0.72^{kl}	40.27±0.68^{qr}
T_6	20.57±0.93^{u}	42.11±0.63^{p-r}	54.36±0.76^{ij}	60.89±0.73^{f}	44.46±0.67^{n-p}	35.43±0.6st

T_o = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

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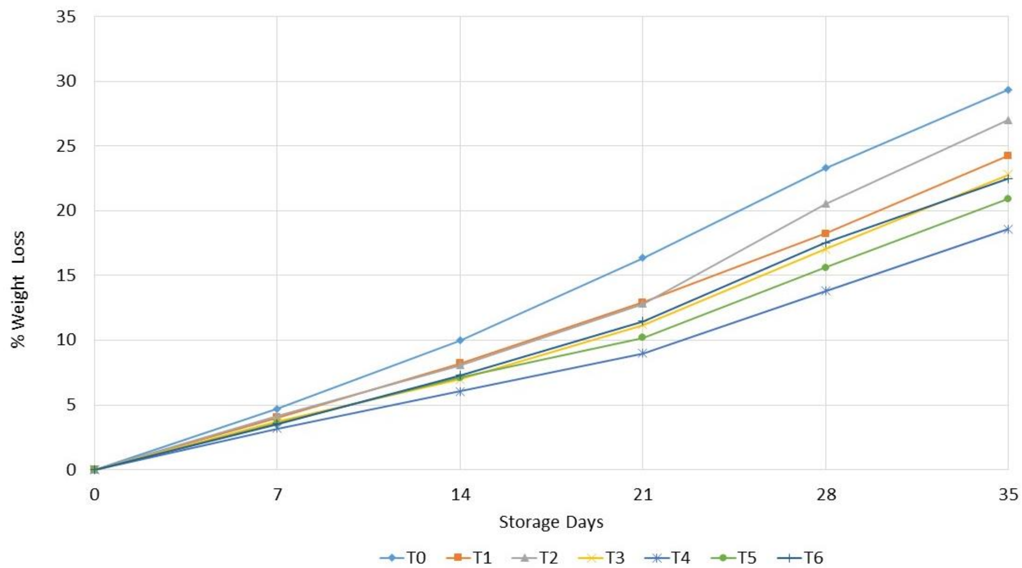

Fig 4: Effect of additive treatments on weight loss of peach fruits during storage

T_o = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on fruit weight loss as compared to other treatments ranging mean values between 1.97±0.04 to 11.53±0.23% followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) 2.17±0.04 to 12.99±0.26% from 7th day to 35th day. Weight loss mainly occur due to moisture loss and respiration from the skin. The skin of peach fruit is delicate which makes them vulnerable to prompt water loss, causing deterioration. $CaCl_2$ treatment minimize weight loss by delaying respiration, senescence and ripening Calcium chloride treatment controls water evaporation and delay dehydration by acting as a barrier.

Shalan (2020) indicated that weight loss increases with the advancement of storage period however this increase was more in control peach fruits as compared to fruits treated with calcium chloride and ascorbic acid which in in accordance with results from present study. Razavi *et al.*, (2017) reported that weight loss of fruits gradually increases throughout the storage irrespective of treatments but increase was significantly less in oxalic acid treated fruits. The weight loss of present study is less than Kaur and Kaur, (2019) delineated that weight loss was less in fruits treated with different chemicals on the postharvest quality of peach fruit Cv. Florida price.

3.2.3. Fruit decay index

The value of decay index followed increasing trend with length of storage irrespective of treatments in both treated as well as fruits without any treatment, however, the extent of decay index was significantly ($P < 0.05$) greater in untreated as compared to treated peach

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fruits (Figure 5). Among treatment x storage interaction, the amount of decay index varied between 1.67±0.58% in T_4 treatment on 21st day and 54.33±0.58% on 35th day in untreated (control) peach fruits. In quantitative terms decay index rise with advance in storage time and was highest in all treatments on 35th day irrespective of additive treatment received. Among additive treatments T_0 (control) exhibited maximum value for decay index (54.33±0.58%) on 35th day while on the other side, the lowest decay index (5.33±0.58%) among treated peach fruits was found in fruits receiving T_4 treatment. Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on fruit decay index as compared to other treatments ranging mean values between 1.67±0.58 to 5.33±0.58% followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) 2.83±0.76 to 6.33±1.15% from 21st day to 35th day.

Decay is one of the most important postharvest factors in reduction of quality and key factor reducing quality of horticultural crops. Sohail *et al.* (2015) denoted that CaCl2 treated fruits exhibited significantly less decay in contrast to untreated at the end of storage period which in line with results from current results. Likewise to results from current research, Abd El-Gawad (2021) that guava fruits treated with oxalic acid demonstrated less decay than the untreated guava. Hazarika and Marak (2022) noticed that fungal decay increased considerably with the increase of storage period despite of salicylic acid and oxalic acid however less decay was noticed in treated grapes as compared to control.

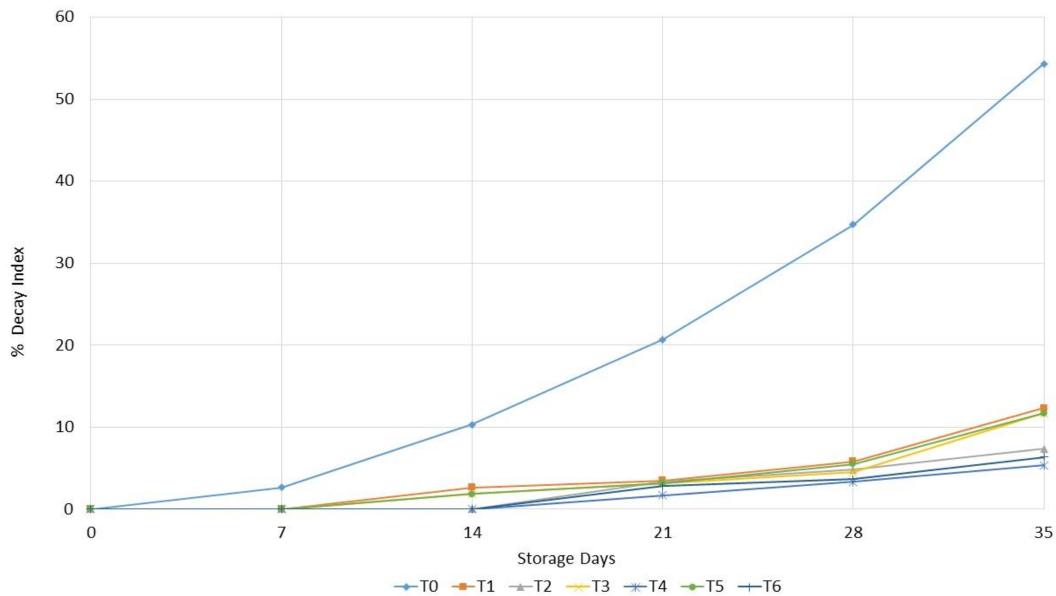

Fig 5: Effect of additive treatments on decay index of peach fruits during storage

T_o = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

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3.2.4. Shrinkage index

The value for shrinkage in width followed increasing trend with length of storage irrespective of treatments in both treated as well as fruits without any treatment, however, the intensity of width reduction was significantly greater in untreated as compared to treated peach fruits as depicted in Figure 6. Among treatment x storage interaction, the amount of width shrinkage varied between 1.05±0.27% in T_4 treatment on 7^{th} day and 14.56±1.65% on 35^{th} day in untreated (control) peach fruits. The minimum value for reduction (1.05±0.27%) in width was noted in peach fruits treated with C_4 on 7^{th} day while maximum mean (1.67±0.75%) in T_0 (control) fruits on same day.

In quantitative terms percent shrinkage in fruit width rise with advance in storage time and was highest in all treatments on 35^{th} day irrespective of additive treatments received. Among additive treatments, fruits treated with T_0 exhibited maximum value for width reduction (14.56±1.65%) on 35^{th} day while on the other side, the lowest width reduction (9.1±3.09%) among treated peach fruits was found in fruits receiving T_4 treatment on last storage interval.

On overall basis, treatment T_4 (3 mM Oxalic acid) revealed efficient control on shrinkage index which is statistically at par with T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) and T_2 (3 % $CaCl_2$) as compared to other treatments ranging mean values between 1.05±0.27 to 9.1±3.09%, 1.12±0.64 to 9.29±1.66% and 1.22±0.03 to 9.83±0.91% respectively from 7^{th} day to 35^{th} day.

Slow decrease of shrinkage in additive treated fruit is owing to anti-senescent effect of additive which restrain the biosynthesis of ethylene and delay the action of enzyme accountable for ripening. Chemical prevent cell degradation, thus moisture loss and exchange of respiratory gases reduced which result in delay of senescence and decrease of shrinkage percentage.

Similar to current study, Ndoro *et al*. (2020) found that precooked maize meal coated guava fruit showed less shrinkage index compared to other treatments during storage. Shrinkage index in current study is well aligned with findings reported by Mitra *et al*. (2020) who applied nanoliposomal coating on apple fruit and found that all the coated fruit sample had significantly less shrinkage index than uncoated fruits throughout the storage.

Xu *et al*. (2019) investigated the effect of hydrothermal calcium chloride treatments on the quality attributes of peppers. With the advancement of storage period's shrinkage of treated and untreated pepper increased but this increase was significantly higher in untreated peppers.

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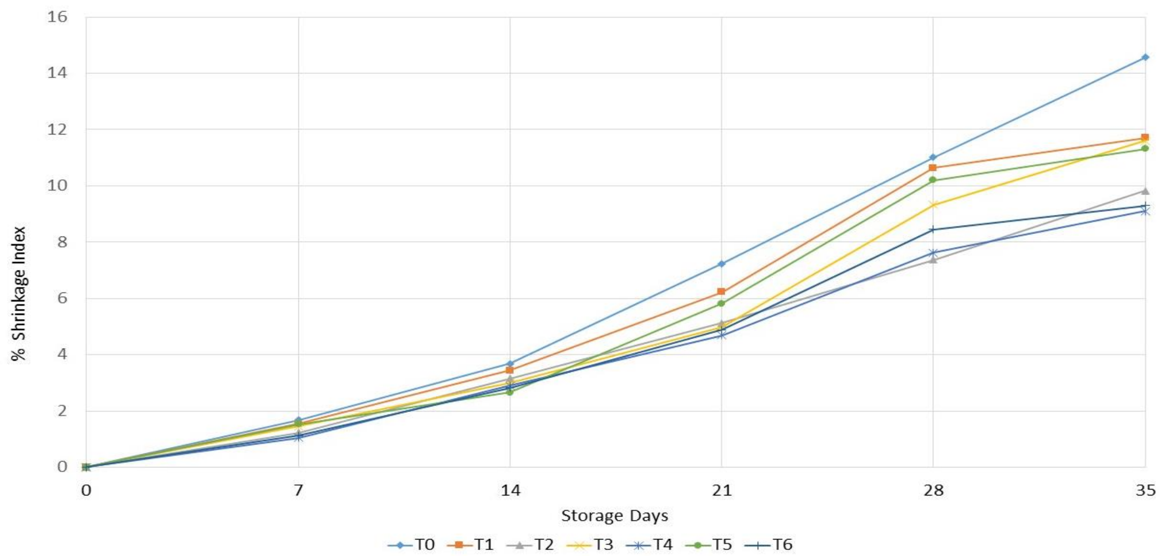

Fig 6: Effect of additive treatments on shrinkage index (width) of peach fruits during storage

T_0 = No Additive (Control), **T_1** = 2 % $CaCl_2$, **T_2** = 3 % $CaCl_2$, **T_3** = 2 mM Oxalic acid, **T_4** = 3 mM Oxalic acid, **T_5** = 1 % $CaCl_2$ and 1 mM Oxalic acid, **T_6** = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

3.2.5. Malondialdehyde content

The malondialdehyde content for chemical additive treated peach fruits during storage is depicted in Table 7. The value of malondialdehyde content followed increasing trend with length of storage irrespective of treatments in both chemical additive treated as well as fruits without any treatment, however, the extent of malondialdehyde content increase was significantly greater in untreated (control) as compared to additive treated peach fruits. Among treatment x storage interaction, the amount of malondialdehyde content varied between 0.74±0.04 µmol/g on 0 day and 2.85±0.14 µmol/g on 35th day in T_0 (control) peach fruits. In quantitative terms ion leakage rise with advance in storage time and was highest in all treatments on 35th day irrespective of any treatment received. The highest mean for malondialdehyde content among treatments was 2.85±0.14 µmol/g observed on 35th day in T_0 (control) fruits while lowest 1.78±0.09 µmol/g was observed in T_4 (3 mM Oxalic acid) treatment on the same day. Finally, treatment T_4 (3 mM Oxalic acid) revealed efficient control on malondialdehyde content increase followed by T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) as compared to control and other treatments ranging mean values between 0.74±0.04 to 1.78±0.09 µmol/g and 0.74±0.04 to 1.88±0.09 µmol/g respectively from 0 day to 35th day.

MDA secondary oxidative product of lipid membrane. It generally indicates the oxidative damage of cell. $CaCl_2$ may bind to proteins and phospholipids in the membranes to shelter the cellular membranes from the reactive oxygen species (ROS). Moreover, by accumulating antioxidant compounds such as ascorbic acid, postharvest calcium

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treatment can increase tissue antioxidant capacity. Nguyen *et al*. (2020) reported that MDA content increased during storage however, it was significantly less in nanochitosan coated fruits containing 3 and 4% $CaCl_2$ than control strawberry fruits during postharvest storage. $CaCl_2$ reduced the increase in MDA contents during storage in persimmon (Bagheri *et al.*, 2015) and papaya (Gao *et al.*, 2020) fruits which support the results for MDA content of chemical treated peach fruits.

Table 7: Effect of additive treatments on MDA contents of peach fruits during storage

Treatments	Storage days					
	0 Day	7th Day	14th Day	21th Day	28th Day	35th Day
T_0	$0.74±0.04^{r}$	$1.24±0.06^{m-o}$	$1.86±0.09^{c-g}$	$2.33±0.12^{b}$	$2.64±0.13^{a}$	$2.85±0.14^{a}$
T_1	$0.74±0.04^{r}$	$1.04±0.05^{n-q}$	$1.36±0.07^{k-m}$	$1.66±0.08^{f-i}$	$1.87±0.09^{c-f}$	$2.09±0.1^{bc}$
T_2	$0.74±0.04^{r}$	$0.97±0.05^{p-r}$	$1.18±0.06^{m-p}$	$1.41±0.07^{i-m}$	$1.64±0.08^{f-j}$	$1.92±0.1^{c-e}$
T_3	$0.74±0.04^{r}$	$1.02±0.05^{o-q}$	$1.33±0.07^{lm}$	$1.64±0.08^{f-j}$	$1.83±0.09^{d-g}$	$2.04±0.1^{cd}$
T_4	$0.74±0.04^{r}$	$0.89±0.04^{qr}$	$1.07±0.05^{n-q}$	$1.29±0.06^{f-i}$	$1.53±0.08^{h-l}$	$1.78±0.09^{e-h}$
T_5	$0.74±0.04^{r}$	$1.03±0.05^{o-q}$	$1.35±0.07^{lm}$	$1.66±0.08^{l-n}$	$1.86±0.09^{c-g}$	$2.07±0.1^{cd}$
T_6	$0.74±0.04^{r}$	$0.96±0.05^{p-r}$	$1.17±0.06^{m-p}$	$1.39±0.07^{j-m}$	$1.61±0.08^{g-k}$	$1.88±0.09^{c-f}$

$\mathbf{T_0}$ = No Additive (Control), $\mathbf{T_1}$ = 2 % $CaCl_2$, $\mathbf{T_2}$ = 3 % $CaCl_2$, $\mathbf{T_3}$ = 2 mM Oxalic acid, $\mathbf{T_4}$ = 3 mM Oxalic acid, $\mathbf{T_5}$ = 1 % $CaCl_2$ and 1 mM Oxalic acid, $\mathbf{T_6}$ = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

3.2.6. Ion leakage

The value of ion leakage followed increasing trend with length of storage irrespective of treatments in both treated and untreated fruits. However, the extent of ion leakage was significantly greater in untreated (control) as compared to treated peach fruits (Figure). Among treatment x storage interaction, the amount of ion leakage varied between 34.94±0.87% on 0 day and 80.43±1.21% on 35th day in untreated (control) peach fruits. In quantitative terms ion leakage rise with advancement in storage time and was highest in all treatments on 35th day irrespective of additive treatment received. The highest mean for ion leakage among additive treatments was 80.43±1.21% observed on 35th day in T_0 (control) fruits while lowest 57.23±0.86% was observed in T_4 (3 mM Oxalic acid) treatment on the same day. Thus, treatment T_4 (3 mM Oxalic acid) revealed efficient control on ion leakage increase which is statistically at par with T_6 (1.5 % $CaCl_2$ and 1.5 mM Oxalic acid) as compared to other treatments ranging mean values between 34.94±0.87 to 57.55±0.86% and 34.94±0.87 to 58.39±0.88% respectively from 0 day to 35th day.

Shalan (2020) indicated that electric conductivity increased with the progress of storage time however this increase was more in control peach fruits as compared to calcium chloride and ascorbic acid treated Florida prince peach fruits. Jin *et al.* (2014) observed that ion leakage gradually increased with the passage of storage in both oxalic acid treated and control fruits. Jiao *et al.* (2018) and Gao *et al.* (2020) reported that $CaCl_2$ treatment significantly delay the increase of ion leakage during storage in banana and papaya fruits respectively which is in agreement with results for ion leakage from additives treated peach fruits. Similar trend of increase of electrolyte leakage in peach fruits during storage was also reported by Huan *et al.* (2018), Abbasi *et al*. (2019) and Zhou *et al.* (2019).

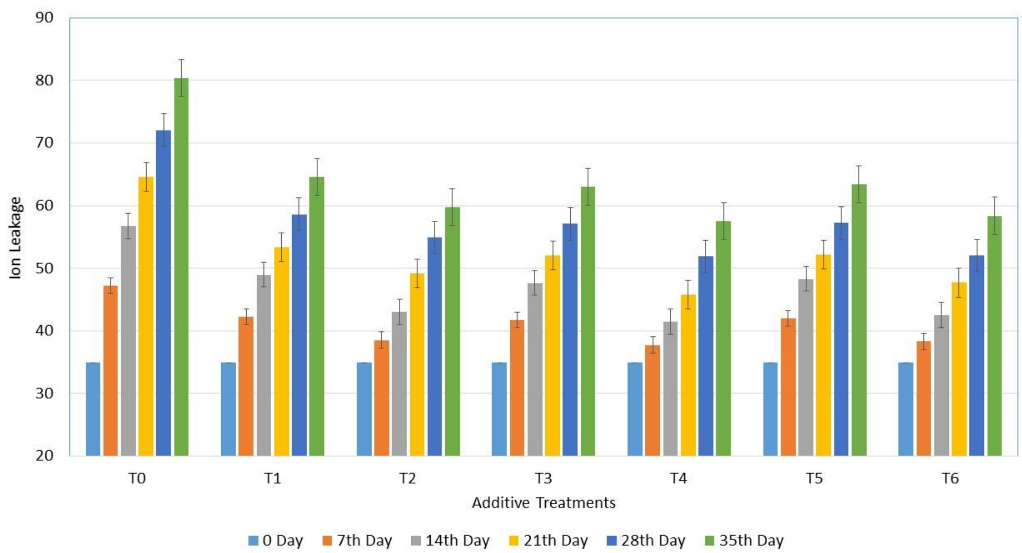

Fig 7: Effect of additive treatments on Ion leakage of peach fruits during storage

$\mathbf{T_o}$ = No Additive (Control), $\mathbf{T_1}$ = 2 % $CaCl_2$, $\mathbf{T_2}$ = 3 % $CaCl_2$, $\mathbf{T_3}$ = 2 mM Oxalic acid, $\mathbf{T_4}$ = 3 mM Oxalic acid, $\mathbf{T_5}$ = 1 % $CaCl_2$ and 1 mM Oxalic acid, $\mathbf{T_6}$ = 1.5 % $CaCl_2$ and 1.5 mM Oxalic acid

4. CONCLUSION

Present research study depicted that additive treatment effectively maintained the physicochemical and physiological parameters of peach fruits during cold storage of 35 days. During storage control fruits exhibited more changes in color however additive treated fruits revealed less changes in color. Results showed that additive treatments significantly reduced the decay index, shrinkage index and weight loss as compare to control. Moreover in oxalic acid (3 mM) treated peach fruits less increase was observed in pH, total soluble solids, malondialdehyde content and ion leakage than the untreated fruits. Furthermore oxalic acid (3 mM) treated fruits maintained acidity and higher firmness. Finally, it is concluded that, 3 mM oxalic acid revealed efficient control on physcochemical and physilogical properties of peach fruits as compared to control.

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Conflict of Interest

All authors declare that there are no conflict of interest.

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