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Research Article

Effect of calcium chloride and calcium lactate on shelf life extension of sweet orange

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Abstract

An experiment was conducted to investigate the effect of calcium chloride and calcium lactate coating on sweet orange. The fruits were treated with different concentration of calcium chloride and calcium lactate T_0 was use as control, T1 with 1% calcium chloride coating, T2 with 1.5% calcium chloride coating, T3 with 2% calcium chloride coating, T4 with 1% calcium lactate coating, T5 with 1.5% calcium lactate coating and T6 with 2% calcium lactate coating. Sweet oranges were stored for 35 days and analyzed after every 7 days during storage period. The stored samples were checked organoleptically for color, texture, taste, decay index and the overall acceptability and analyzed physicochemically for % acidity, total soluble solids (TSS), pH, ascorbic acid, firmness and weight loss. An increase was noticed in physicochemical attributes which includes the increase of TSS from 6.07 to 9.64°brix, the weight loss from 0 to 28.52%, the pH from 3.80 to 4.17 and the decay index from 0 to 30.83%. A decrease was noticed in the ascorbic acid from 76.04 to 47.98mg/100g, titratable acidity from 2.92 to 2.12%, and the firmness from 82.15 to 55.90kg/cm^2. During the storage all organoleptic attributes decreased. The texture decreased from 8.60 to 5.80, the color from 8.72 to 5.51, the taste from 8.62 to 5.71and the overall acceptability decreased from 8.62 to 5.85. From this research, it is reported that sample T_3 with 2% calcium chloride followed by the T_2 with 1.5% $CaCl_2$ was the best sample on the basis of the organoleptic and physicochemical attributes.

Keywords: Ascorbic Acid; Calcium chloride; Calcium lactate; Firmness; pH; Storage; Sweet orange; Titratable acidity; TSS; Weight loss

Introduction

Citrus is a vast kingdom that contains different cultivated species, including *Citrus reticulate* (tangerine & mandarin), *Cirrus sinensis* (sweet orange), *Citrus lemon* (lemon), *Citrus paradise* (grapefruit) and *Citrus grandis* (pummelo). Citrus is one of the most vital fruit crop cultivated in Pakistan. Sweet orange is type of the fruit which belongs to citrus sinensis included in family *Rutaceae* [1]. The production of citrus was about 2396.2 tons per year, cultivated over an area of about 193.7 hectares. The regions in Pakistan where it is grown mostly are Punjab (Sargodha, Multan, Faisalabad, Bahawalpur, and Gujranwala) Quetta area

of Balauchistan and Khyber Pakhtunkhwa [2].

Citrus fruits have a high commercial value in the fruit market. Among them, oranges can be considered as a good source of bioactive compounds, in which their consumption would have health benefits for humans. However, high moisture content and nutrient composition make this fruit more susceptible to fungi contamination. It should be noted that such products are also susceptible to softening, browning or color change and microbial contamination [3].

Methods have been studied to preserve and also extend shelf life of the commodities after harvesting [4]. The edible coatings techniques are commonly used for the improvement of the food appearance and the fruit preservation because they have the ability to provide the selective barriers against the moisture loss, decay and respiration [5]. Calcium plays a vital part in the fruit physiology such as calcium stabilizes the turgor pressure and the cell membranes. Calcium and the pectic acid combine in the fruit forming calcium pectate because of which the cell structure is stabilized. Moreover, it preserves the appearance of vegetables and fruits by preventing browning by means of reducing leakage of the polyphenol oxidase (PPO), its substrates on the cuts and the outer surfaces [6].

From previous work, observation has been made about the useful effects of calcium. It can be used to reduce respiration rate so the ripening and senescence slow down. Calcium plays a key role in stabilizing and giving mechanical hardness to the structure of cell which is the fruit stiffening agent. Calcium has been used more in the fruits and vegetables sector for the fresh cut, the overall commodities being as firming and a protective firming agent [7]. Almost in all previous work done the amount of calcium salts used ranges from 0.5–3% [8].The bond between pectin and calcium become stronger by the addition of the calcium salt because of which the structure of cell wall become stiff [9]. Cell wall's cohesion increases due to presence of calcium ions, therefore decreases the ripening and senescence of the fruits because of the calcium application to the surface of fruit. Storage life of the fruit is enhanced to some extent and the softening is delayed for a little time period when the calcium chloride is used for the fruit treatment to that of the fruits which are untreated [9].

Treatments of (Ca) either with calcium lactate or calcium chloride have made known to be very effective at retaining the firmness during the storage in various fresh cut vegetables and fruit studies. Some examples are mango [10, 11] carrot [12] melon [13-15]. Although the research study has been carried out about the applications of calcium to the fresh-cut mango but still it has not been used commercially. According to [16] the bitter and salty tastes related with calcium chloride are largely suppressed when calcium is combined with larger organic ions such as lactate, gluconate or glycerophosphate.

The use of calcium lactate and calcium chloride in different types of fruits as the firming agents is extensive. These compounds work as a result of binding to negatively charged carboxylic acid groups of the galacturonic acid remains in pectin chain and as a result forming an egg box gel model which results in firming up of the cell wall [17]. The losses after the harvest in the citrus fruits quality have commonly been observed [18]. The Biological [19] chemical and physical [20, 21] processes are usually taken on to eradicate the spores from fruits surfaces. The discussed methods are very effective to reduce the disease occurrence [22]. After harvesting the diseases damage almost (10% to 30%) of the entire yields, on the other hand in the unpreserved crops particularly in the developing countries the diseases damages more than (30%) of the yield crop [11].

Keeping in view the above mentioned literature, this research was done to investigate the calcium lactate and calcium chloride effects on the qualities of the sweet oranges after harvesting.

Materials and methods

Orange fruits at maturity were taken from Manki sharif, Nowshehra and then brought to the food processing lab of "Nuclear Institute for Food and Agriculture" Peshawar, Khyber Pakhtunkhwa, Pakistan where research work was carried out. Damaged and diseased portion of oranges was thrown away. The oranges were cleaned with water for the removal of dirt, dust and other chemicals.

Plan of study

Treatments	Calcium chloride (%)	Calcium lactate (%)
T_0	Fresh sweet orange (control)	(control)
T_1	1%	-
T_2	1.5%	-
T_3	2%	-
T_4	-	1%
T_5	-	1.5%
T_6	-	2%

Orange fruits were washed with tap water and dried under fan for 10-15 minutes. After the orange fruits were dried, they were divided into 7) lots (T_0, T_1 T_2, T_3, T_4, T_5, and T_6). Each lot contained 50 fruits. The fruits were dipped in solution of calcium lactate and calcium chloride for five minutes, as per the plan of study. Orange fruits were kept at room temperature for a period of (35) days and analysis was done after every (7) days.

Physicochemical analysis

Weight loss; TSS; Fruit firmness; ascorbic acid; titratble acidity; pH and decay index were analyzed using AOAC methods **[23]**.

Sensory evaluation

All the samples of orange fruit were investigated organoleptically for color, taste, texture and overall accessibility by the judges. The organoleptic analysis were evaluated for an interval of every 7 days at time of preservation for duration of 35days. Then it was evaluated using nine points of the hedonic scale of **[24]**.

Statistical analysis

The data was documented for Variance Analysis using "Complete Randomized Design" (CRD) with 2 factors **[25]**. Statistical computer software "statistics" was used for calculating anova. Mean was separated by applying LSD test.

Physicochemical analysis

pH

The readings of all the samples of first day from T_0 to T_6 were 3.82, 3.79, 3.81, 3.80, 3.82, 3.82, 3.80, which increased to 4.32, 4.22, 4.07, 4.08, 4.10, 4.18, 4.16, respectively during the thirty-five days storage time period. The mean pH values for storage significantly ($p<0.05$) increased from 3.80 to 4.17. The highest mean value observed in T_0 (4.12) followed by T_5 (4.09) whereas the minimum value was noted for T_3 and T_2 (3.92) followed by T_1 (3.96) in (Table 1). The statistical outcomes of the data have shown that both storage and the coating application had a significant ($p<0.05$) impact on the ph of orange fruit stored at room temperature (Appendix - VI). Similar trend of increasing ph with storage has also been published by **[26]** where pH increased from 3.60 to 3.83 in orange fruit. The increases in ph value of samples may be attributed to the decreasing acidity of the samples **[27, 28]** showed that ph increased from 4.035 to 5.910 within one month of storage using calcium chloride treatment on orange.

In the treated fruits calcium chloride dip effect the pH and titratable acidity.

Table 1. Effect of calcium chloride and calcium lactate coating on the pH of whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Increase	
T_0	3.82	3.94	4.14	4.32	4.22	4.32	13.0	4.12a
T_1	3.79	3.83	3.87	3.93	4.16	4.22	11.34	3.96d
T_2	3.81	3.72	3.93	3.99	4.03	4.07	6.82	3.92e
T_3	3.80	3.78	3.91	3.95	4.05	4.08	7.36	3.92e
T_4	3.82	3.85	3.95	4.02	4.50	4.10	7.32	4.04b
T_5	3.82	3.92	3.98	4.02	4.09	4.18	9.42	4.09c
T_6	3.80	3.89	4.01	4.13	4.14	4.16	9.47	4.02bc
Means	3.80e	3.84d	3.97c	4.05b	4.16a	4.17a		

The different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.0995
LSD value for storage intervals = 0.0921

Fruit firmness (kg/cm^2)

The first day readings of all the samples from T_0 to T_6 were 81.25, 82.22, 82.44, 82.67, 82.10, 81.98, 82.40 kg/cm^2 which decreased to 52.74, 51.85, 60.73, 59.68, 54.46, 55.35, and 56.54 kg/cm^2 respectively during 35 days of storage. The mean firmness values for storage significantly ($p<0.05$) decreased from 82.15 to 55.90 kg/cm^2. For treatments lowest mean value was observed T_0 (67.10) followed by T_4 (67.49) while highest mean value was noted for T_3 and T_2 (71.01) followed by T_1 (68.91) (Table 2). The statistical outcomes of the data revealed that both the coating application and storage period had a significant ($p<0.05$) impact on the firmness of orange sample stored at room temperature (Appendix - III). Similar trend of decreasing firmness with storage has also been published by [26] where fruit firmness decreased was about 46%-57% in orange fruit [29] showed the same trend 15.7 to 10.2kg/cm^2 of decreasing the firmness with in storage of 15 days in Jujube fruit. Calcium chloride retards the ripeness process, as indicated higher firmness lower activity of lipolytic enzymes relative to the control [30] showed that firmness decreased from 3.91 to 2.68kg/cm^2 with in storage of 28 days in mandarin fruit. Firmness might be due to moisture loss from the fruits cells [31] showed that firmness decreases from 25 to 17.5kg/cm^2 within 27 days of storage using 2% $CaCl_2$ for 2 minutes on apricot fruit [32] Also at their research showed that firmness decreases from 10 to 0.3 kg/cm^2 in apricot fruit. Calcium plays a key role in stabilizing and giving mechanical hardness to cell structure stiffing agent of fruits.

Ascorbic acid (mg/100g)

First day readings of all samples from T_0 to T_6 were 76.10, 76.20, 76.10, 76.00, 75.80, 76.00, and 76.10mg/100g which decreased to 44.42, 50.30, 51.48, 52.52, 42.14, 45.55, and 49.46 mg/100g respectively during 35 days of storage. The mean Ascorbic acid values for storage significantly ($p<0.05$) decreased from 76.04 to 47.98 mg/100g. From treatments lowest mean value was observed in T_0 (59.95) followed by T_5 (59.84) while maximum highest mean was noted in T_3 (65.74) followed by T_2 (64.22) in (Table 3). The statistical outcomes of the data

revealed that both the coating application and storage period had a significant ($p<0.05$) impact on the ascorbic acid of orange sample stored at room temperature (Appendix-IV). Similar trend of decreasing ascorbic acid content with storage has also been reported by **[33]** where the ascorbic acid content decreased from 71.149% to 45.734% in citrus **[34]** showed that ascorbic acid content decreases from 27.2mg-17.1mg/100g in grapes **[35]** showed that ascorbic acid content decreases from 1.57 to 0.85mg/100g in fig fruit **[36]** shows that ascorbic acid content decreases from 7.00 to 5.90mg\100gm in plum during their 15 days of storage interval in plum fruit of calcium application. **[37]** showed that ascorbic acid decreased from 32.61 to 22.67% with in storage of 28 days in mandarin fruit. Vitamin C decreasing due to degradation of the ascorbic acid during the storage. Calcium delays the oxidation process of the fruit and maintaining ascorbic acid content in fruits. Vitamin C decline with in storage intervals is due to oxidation process **[38]**.

Table 2. Effect of calcium chloride and calcium lactate coating on the firmness (kg/cm^2) of whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	81.25	76.32	69.14	64.55	58.62	52.74	35.08	67.10g
T_1	82.40	76.86	70.95	66.40	60.31	56.54	31.38	68.91c
T_2	82.44	77.44	72.11	67.42	64.38	60.73	26.33	70.75b
T_3	82.67	78.54	73.04	68.67	63.49	59.68	27.80	71.01a
T_4	82.10	75.39	70.47	64.22	58.33	54.46	50.75	67.49f
T_5	81.98	76.40	71.59	65.34	59.20	55.35	32.48	68.31d
T_6	82.22	72.21	70.03	65.43	59.71	51.85	36.93	67.74e
Means	82.15a	76.88b	71.04c	66.00d	60.57e	55.90f		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =1.5322
LSD value for storage intervals = 1.4186

Table 3. Effect of calcium lactate and calcium chloride coating on ascorbic acid (mg/100g) on whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	75.80	71.44	62.30	57.80	50.49	42.14	44.40	59.95g
T_1	76.20	70.37	65.00	59.27	54.39	50.30	51.49	62.58d
T_2	76.10	71.00	67.53	61.50	57.72	51.48	32.35	64.22b
T_3	76.00	74.11	69.29	64.37	58.16	52.52	30.89	65.74a
T_4	76.10	69.63	63.29	55.81	49.80	44.42	41.62	59.84f
T_5	76.00	70.38	63.50	56.17	51.80	45.55	40.06	60.56e
T_6	76.10	69.10	65.47	60.13	56.18	49.46	35.00	62.47c
Means	76.04a	70.86b	65.19c	59.29d	54.07e	47.98f		

Figures with different letters are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.9350
LSD value for storage intervals = 2.0625

Weight loss (%)

First day readings of all samples from T_0 to T_6 were 0, which increased to 9.5, 15.92, 19.31, 20.83, 24.93, 26.41, 29.29, 30.80, 32.45, and 33.42% individually during their 35 days of storage. Maximum mean value in T_0 (17.24) was determined by control followed by T_4 (17.34) while minimum value was in T_3 (10.15) followed by T_2 (14.23). Maximum % increase was (78.72) followed by (73.92) in (Table 4). The statistical analysis of the obtained data of treatment and storage showed a significant ($p<0.05$) change effect on the whole orange samples (Appendix -I). Same trend of increasing weight loss was also observed by [39]. They found increase in weight loss from 0-19.4%. Weight loss was because of rate of transpiration and respiration, as calcium chloride treatment reduced the rate of transpiration and respiration so the fruits treated with calcium chloride has less weight loss as compared to other treatments. Calcium chloride was very effective as compare to lactate in decreasing weight loss percent. [40] also showed same result. For every 5 days interval during a storage period of (25) days, there was a significant increase in weight loss from 1.039% to 8.014% in sweet orange [41] also showed the same result. There was a significant increase from (0%-25) weight loss significantly increased from 0 to 25% within storage intervals of 30 days. Calcium chloride treatment on orange. [42]. showed that weight loss increased from 5.61 to 18.07 with in storage of 28 days in mandarin fruit. Losses in the peel moisture content and weight loss were mostly due to the transpiration process in fruits which resulted in dried-up appearance and wilted rind [43]. Showed that weight loss increases from 0 to 10% within 27 days of storage using 3% $Cacl_2$ for 2 minutes in apricot fruit [44]. Showed the same increase in weight loss from 0 to17% with 20 days of storage in strawberry fruit. Calcium chloride act as a physical barrier for transcription loses [40]. The natural process like senescence, ripening and respiration are delayed by calcium [45] and the water loss through the processes like transpiring and respiration resulted in more weight loss during storage time period of fruits.

Table 4. Effect of calcium lactate and calcium chloride coating on weight loss (%) of whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Increase	
T_0	0	9.85	15.92	20.83	26.41	33.42	33.42	17.24a
T_1	0	6.22	12.13	17.81	24.34	29.24	29.24	14.96d
T_2	0	7.72	12.67	18.18	21.83	24.93	24.93	14.23e
T_3	0	5.52	8.36	12.47	15.24	19.31	19.31	10.15f
T_4	0	9.85	15.92	20.83	26.41	30.80	30.80	17.23ab
T_5	0	7.72	12.67	18.18	23.55	29.29	29.29	15.46c
T_6	0	8.64	15.98	20.84	25.45	32.45	32.45	17.23ab
Means	0f	7.79e	13.08d	18.52c	23.31b	28.52a		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.3702
LSD value for storage intervals = 2.1999

Total soluble solid (°Brix)

At the initial day of the research the TSS values of samples were 6.0, 6.0, 6.1, 5.8, 6.20, 6.00, 6.10° from T_0 to T_6 which increased to 10.60, 9.30, 9.00, 8.8, 10.80, 9.50, 9.50° respectively during the storage period of (35) days. There was significant increase in the mean values of storage

(p<0.05) increased from 6.07 to 9.64°. From treatments the highest value observed was in T_0 (8.78) followed by T_4 (8.71) whereas the lowest mean value was noted for T_3 and T_2 (7.71) followed by T_1 (7.83) (Table 5). The statistical outcomes of the data revealed that both the coating application and storage period had a significance (p<0.05) impact on the TSS of orange sample stored at room temperature (Appendix-II). Similar trend of increasing TSS with storage has also been published by **[44]**. Where they analyzed increased in TSS from 8.37-10.93% in peach. TSS increases in citrus is because of complex carbohydrates break down into sugar and moisture content of the fruit become lowering **[40]** also analyzed same result TSS increases from 10.47%-11.11% in sweet orange within 30 days of storage time **[45]** showed that TSS increases from 7.48 to 9.24mg\100gm in plum during the 15 days of storage interval. **[30]** showed that TSS increased from 10.92 to 12.88% with in storage of 28 days in mandarin fruit. In untreated fruits the faster increase in the TSS was because of the faster activities of metabolic through the transpiration and respiration process. Calcium chloride maintaining TSS, it may possibly be because of the calcium inhibitory effect that is responsible for turgor pressure failure and build up membrane integrity. Increase in the TSS is result of polysaccharides enzymatic alteration such as starches and pectin into simple sugar during the ripening stage 53 **[31]** showed that TSS increases from 11.5 to 13.5 within 27 days of storage using 1% $CaCl_2$ for 2 minutes in apricot fruit.

Table 5. Effect of calcium lactate and calcium chloride coating on TSS (Brix) on whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Increase	
T_0	6.0	7.60	8.50	9.40	10.20	10.60	76.60	8.78a
T_1	6.0	6.90	7.40	8.50	8.90	9.30	55.00	7.83d
T_2	6.1	7.00	7.50	8.20	8.80	9.00	47.50	7.76e
T_3	5.8	6.8	8.00	8.4	8.5	8.8	51.72	7.71f
T_4	6.20	7.50	8.30	9.50	10.40	10.80	74.19	8.71b
T_5	6.00	7.50	8.00	8.60	9.10	9.50	58.33	8.11c
T_6	6.10	7.60	7.90	8.70	9.00	9.50	55.73	8.13c
Means	6.07f	7.27e	7.94d	8.75c	9.27b	9.64a		

Figures with different letters are significantly different (p<0.05) from each other.
LSD value for treatments =0.3786
LSD value for storage intervals = 0.3488

Percent acidity (%)

The first day readings of all the samples from T_0 to T_6 were 2.87, 2.92, 2.88, 2.95, 2.90, 2.91, 2.94% respectively which decreased to 1.94, 1.97, 2.12, 2.43, 2.08, 2.16, 2.15% respectively during storage period of (35) days. The mean percent acidity values for storage significantly (p<0.05) decreased from 2.91 to 2.12. From treatments lowest mean value was observed in T_0 (2.39) followed by T_4 (2.46) while minimum highest mean was noted in T_3 and T_2 (2.69) followed by T_1 (2.50) in (Table 6). The statistical outcomes of the obtained data showed that both the storage period and coating application had a significant (p<0.05) impact on the percent acidity of orange sample stored at room temperature (Appendix-V). Similar trend of decreasing

percent acidity with storage has also been published by [44] analyzed same decrease in % acidity from (0.907) to (0.734) in peach during their storage interval of one month [33] attributed the same decrease in % acidity from (1.68) to (0.75) in sweet orange during their storage interval. The decreases in % acidity may be due to pattern of senescence [35] showed that acidity decreases from 0.53% to 0.35% with in storage interval in fig fruit [46] showed that acidity decreases from 1.590 to 1.244 in plum during their 15 days of storage interval [37] showed that acidity decreased from 0.86 to 0.53 with in storage of 28 days in mandarin fruit. During storage time period the acidity descending trend was because of the acid utilization in tricarboxylic acid cycle in the respiration process [43] showed that acidity decreases from 2.5 to 2.00 within 27 days of storage using 1% $CaCl_2$ for 2 minutes in apricot fruit. Fruits oxidation reaction is reduced by calcium of fruits and also fruits metabolic process is delayed [31]. Also it brings less decrease in the titratibility acidity.

Table 6. Effect of calcium chloride and calcium lactate coating on acidity (%) of whole orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	2.87	2.74	2.46	2.25	2.10	1.94	32.40	2.39d
T_1	2.92	3.06	2.70	2.33	2.09	1.97	32.53	2.50b
T_2	2.88	2.79	2.63	2.58	2.24	2.12	26.38	2.54b
T_3	2.95	2.77	2.77	2.68	2.54	2.43	17.62	2.69a
T_4	2.90	2.62	2.53	2.40	2.28	2.08	28.27	2.46c
T_5	2.91	2.77	2.58	2.46	2.30	2.16	25.77	2.53b
T_6	2.94	2.66	2.68	2.41	2.29	2.15	26.86	2.25b
Means	2.91a	2.77b	2.6c	2.44d	2.26e	2.12c		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.1129
LSD value for storage intervals = 0.1220

Decay index (%)

All the readings of first day samples from T_0 to T_6 were 0, from T_0 to T_6 respectively which increased to 40.25, 27.64, 26.51, 22.91, 33.57, 31.12, and 33.87% respectively during the storage period of 35 days. The storage mean decay index values increased significantly ($p<0.05$) from 0 to 30.83%. From treatments the highest mean value observed was T_0 (16.69) followed by T_5 (13.58) while the lowest mean was noted for T_3 and T_2 (9.94) followed by T_1 in (Table 7). The statistical outcomes of the data showed that both storage period and the coating application had a significant ($p<0.05$) impact on the decay index of orange sample stored at room temperature (Appendix –VII). Similar trend of increasing decay index with storage has also been published by [47] where decay index increased from (0) to (42.73) in peach fruit coating of calcium lactate. The increase in decay index value of samples may be attributed to the increasing decay index of the samples [48] analyzed same increase in decay index may be from (0) to (4.5) in grapes during their storage interval [37] showed that decay index increased from 1.89 to 16.70 with in storage of 28 days in mendareine fruit [5] also showed the same increase which were from 0 to 24.44 within 20 days of storage interval in tomato fruit. Increase in decay was due to

delay senescence that makes the commodities weaker to the pathogenic infection as the tissue or cellular integrity loss. The membrane is protected from lipid degradation by the calcium ions by making stable plasma membrane. This reduces the degradation chances bylipolytic enzymes. Calcium bridges formed in the cell walls have to reduce approach to bacterial hydrolysis or fungal that cause decay **[49]**.

Table 7. Effect of calcium chloride and calcium lactate coating on Decay index (%) of orange fruit during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Increase	
T_0	0	4.45	7.28	17.48	30.66	40.25	40.25	16.69a
T_1	0	3.41	6.72	13.12	19.95	27.64	27.64	11.81e
T_2	0	3.32	6.38	12.28	20.15	26.51	26.51	11.44f
T_3	0	3.12	5.68	11.17	16.72	22.91	22.91	9.94g
T_4	0	3.56	6.58	13.13	24.69	33.57	33.57	13.58b
T_5	0	3.83	6.48	13.21	23.32	31.12	31.12	13.00d
T_6	0	3.75	7.18	12.95	22.78	33.87	33.87	13.43c
Means	0.00f	3.63e	6.61d	13.33c	22.61b	30.83a		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =2.8684
LSD value for storage intervals = 2.6556

Sensory evaluation

Color

Initially the judges awarded the mean score for color samples were 8.6, 8.7, 8.7, 8.7, 8.8, 8.8, 8.8 from T_0 to T_6 respectively which increased to 5.0, 5.5, 5.9, 6.4, 5.2, 5.7, 4.9 respectively during the storage period of (35) days. The mean color values for storage significantly ($p<0.05$) decreased from 8.72 to 5.98. From treatments highest mean value was observed in T_0 (6.70) followed by T_4 (6.78) while minimum lowest mean was noted for T_3 and T_2 (7.61) followed by T_1 (7.11) in (Table 8). The statistical outcomes of the data revealed that both the coating application and storage period had a significant ($p<0.05$) impact on the color of orange sample stored at room temperature (Appendix-VIII). The means were applied by applying LSD test at 5% probability the values obtained (Table 4.8). Similar trend of decreasing with storage has also been published by **[48]** Calcium chloride and calcium lactate retard the peel physiology and also improve shining.]58 also showed decreased in appearance which was from 4.75 to 2.39 during their storage interval **[5]**. Also showed the same decrease which were from 8 to 4.4 within 20 days of storage interval in tomato fruit. Color score decreases with time due to loss of water content, which effects the fruits quality **[50]**. The same result showed by **[51]** too, who stated that the fruits quality may possibly be effected because of the respiration process.

Calcium chloride with edible coating material reduces the fruits respiration rate and others biological process.

Texture

Initially judges score for texture samples were 8.6, 8.5, 8.7, 8.6, 8.6, 8.5, 8.7 from T_0 to T_6 respectively which decreased to 4.7, 4.7, 5.1, 5.5, 4.8, 5.0, 5.1 respectively during storage period of 35 days. The mean storage Texture values decreased significantly ($p<0.05$) from 8.60 to 5.80. From treatments the highest mean value observed was in T_0 (6.60) followed by T_5 (6.50) while minimum lowest mean was noted in T_3 and T_2 (6.86) followed by T_1

(6.68) in (Table 4.9). The statistical outcomes of the data showed that the both the coating application and storage period had a significant ($p<0.05$) impact on the texture of orange sample stored at room temperature (Appendix-IX). The means were applied by applying LSD test at 5% probability values obtained (Table 9). Similar trend of decreasing with storage has also been published by [52] where texture decrease from 7.04-5.04 in sweet orange. At the stage of ripening and maturation protopect were slowly break down into lower molecular weight fraction that which are soluble in H_2O and became the reasons for softening [39, 53] showed that texture decreases from 6.2 to 4.3 during one month of storage in apricot fruit [54] showed that texture decreases from 3.37 to 1.89 within 14 days of storage in fig fruit. Calcium chloride coating maintain the texture of orange fruit. Same result are also demonstrated by [55]. The firmness in the fruits was retained by calcium chloride for a longer period, this was because membrane integrity is maintained by calcium, in results maintained the fruits structure for a longer time period [56].

Table 8. Effect of calcium chloride and calcium lactate coating on color (mean score of judges) on orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	8.6	7.8	7.1	6.3	5.4	5.0	41.86	6.70g
T_1	8.8	8.1	7.5	6.7	6.1	5.5	37.5	7.11c
T_2	8.7	8.2	7.8	7.0	6.5	5.9	32.18	7.35b
T_3	8.8	8.5	7.9	7.3	6.8	6.4	27.27	7.61a
T_4	8.7	7.9	7.0	6.3	5.6	5.2	40.22	6.78f
T_5	8.7	8.0	7.2	6.6	6.0	5.7	34.48	7.03d
T_6	8.8	8.0	7.4	6.4	5.5	4.9	44.31	6.83e
Means	8.72a	8.07b	7.41c	6.65d	5.98e	5.51f		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.3510
LSD value for storage intervals = 0.2323

Table 9. Effect of calcium lactate and calcium chloride coating for texture (mean score of judges) on orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	8.6	7.7	7.0	6.3	5.3	4.7	45.34	6.60c
T_1	8.5	6.8	6.8	5.9	6.4	4.7	44.70	6.68b
T_2	8.7	7.9	6.8	6.2	5.5	5.1	41.37	6.70b
T_3	8.6	7.7	7.0	6.5	5.9	5.5	36.04	6.86a
T_4	8.6	7.8	6.9	6.1	5.4	4.8	44.18	6.60c
T_5	8.5	7.5	6.8	6.0	5.2	5.0	41.17	6.50d
T_6	8.7	7.4	7.4	6.8	5.8	5.1	41.37	6.70b
Means	80.60a	7.54b	6.95c	6.25d	5.54e	5.80f		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.2960
LSD value for storage intervals = 0.2740

Taste

At the beginning of this research the Taste scores for samples were 8.7, 8.6, 8.6, 8.7, 8.6, 8.6, 8.6 from T_0 to T_6 respectively which decreased to5.2, 5.7, 5.8, 6.3, 5.4, 6.1 and 5.5 respectively for storage duration for (35) days. The mean taste values decreased significantly for storage ($p<0.05$) decreased from 86.2 to 5.71. From treatments highest mean value was observed in T_0 (6.73) followed by T_4 (6.88) while minimum lowest mean was noted in T_3 and T_2 (7.53) followed by T_1 (7.03) in (Table 10). The statistical outcomes of the data revealed that both the coating application and storage period had a potential ($p<0.05$) impact on the taste of orange sample stored at room temperature (Appendix-X). The means were applied by applying LSD test at 5% probability values obtained (Table 4.10). Similar trend of decreasing with storage has also been published by **[56]** analyzed decreases which may be 6.42-2.81 in sweet orange during their storage interval. Taste of fruits is due to sugar acid ratio but also due to volatile components. Sweetness in fruit is due to sugar and sourness is because of acid **[39, 54]** showed that taste decreases from 6.9 to 6.1 during 30 days of storage in apricot fruit **[57]** also showed decreased in taste which was from 4.50 to 3.02 during their storage interval. Calcium chloride coating are the best coating for delaying ripening and slow down respiration process and slow onset of senesce.

Table 10. Effect of calcium lactate and calcium chloride coating for taste (mean scores of judges) on orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	8.7	7.7	6.9	6.3	5.6	5.2	40.22	6.73f
T_1	8.6	7.8	7.3	6.7	6.1	5.7	33.72	7.03d
T_2	8.6	8.1	7.8	7.1	6.4	5.8	32.55	7.30b
T_3	8.7	8.2	7.8	7.3	6.9	6.3	27.58	7.53a
T_4	8.6	7.9	7.2	6.4	5.8	5.4	37.20	6.88e
T_5	8.6	8.0	7.5	6.9	6.5	6.1	29.06	7.26c
T_6	8.6	7.9	7.3	6.9	6.0	5.5	36.04	7.03d
Means	8.62a	7.94b	7.40c	6.80d	6.18e	5.71f		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments =0.2195
LSD value for storage intervals = 0.2032

Overall acceptability

The initial mean score by the judges for the overall acceptability samples were 8.7, 8.6, 8.68.7, 8.6, 8.6, 8.6 from T_0 to T_6 respectively which decreased to 4.7, 5.8, 6.2, 6.3, 5.9, 6.0, and 6.1 respectively for storage duration for 35 days. The mean overall acceptability values for storage significantly ($p<0.05$) decreased from 8.62 to 5.85. From treatments the highest mean value observed was in T_0 (6.58) followed by T_4 (7.06) while minimum lowest mean was noted in T_3 and T_2 (7.41) followed by T_1 (7.38) in (Table 11). The statistical outcomes of the data revealed that both the coating application and storage period had a potential ($p<0.05$) impact on the overall acceptability of orange sample stored at room temperature (Appendix-XI). Similar trend of decreasing with storage has also been published that decreases in overall acceptability are due to their high respiration rate **[39, 49]** showed that overall acceptability of apricot fruit

decreases from 7.3to 5.2 within a month of storage. Within the storage, orange fruits quality was significantly maintained by coating of calcium chloride. The overall loss in the orange fruits quality might be because of the fruits progressive degradation with increase storage duration [57].

Table 11. Effect of calcium lactate and calcium chloride coating for overall (mean scores of judges) acceptability on orange fruits during storage

Treatments	Storage intervals (days)							Means
	Initial	7	14	21	28	35	% Decrease	
T_0	8.7	7.7	7.0	6.4	5	4.7	46.51	6.58g
T_1	8.6	7.9	7.4	6.8	6.3	5.8	32.55	7.13e
T_2	8.6	8.1	7.6	7.2	6.6	6.2	27.90	7.38b
T_3	8.7	8.1	7.5	7.2	6.7	6.3	27.58	7.41a
T_4	8.6	7.6	7.2	6.8	6.3	5.9	31.39	7.06f
T_5	8.6	8.1	7.7	7.2	6.5	6.0	30.23	7.35c
T_6	8.6	7.8	7.5	6.9	6.4	6.1	29.06	7.21d
Means	8.62a	7.90b	7.41c	6.92d	6.25e	5.85f		

Different letters figures are significantly different ($p<0.05$) from each other.
LSD value for treatments = 0.2740
LSD value for storage intervals = 0.3702

Conclusion

From the overall results it can be concluded that Calcium chloride and calcium lactate have the ability to decrease orange fruits post-harvest losses. The results also showed that sample T_3 with 2% $CaCl_2$ followed by T_2 with 1.5% $CaCl_2$ was considered as the best sample on the basis of physicochemical and organoleptic quality. The storage stability of treated fruits was higher as compared to control fruits.

Authors' contributions

Conceived and designed the experiments: Sunila & A Riaz, Performed the experiments and analyzed the data: Mian A Raza, Contributed materials/ analysis/ tools: N Khan & Sunila, Wrote the paper: Z Rahman & Sunila.

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