

Article

Effect of Treatment With Chitosan, Citric Acid and Malic Acid on Storage of Valencia Orange Fruits

Ahmed Adnan Mohammed¹, Omar Thaer Kamil², Omar Turhan Jalil³

1. Department of Medicinal and Industrial Plants, College of Medicinal and Industrial Plants, University of Kirkuk, Kirkuk, Iraq.
2. Department of Medicinal and Industrial Plants, College of Medicinal and Industrial Plants, University of Kirkuk, Kirkuk, Iraq.
3. College of Agriculture, University of Kirkuk, Kirkuk, Iraq.

*Correspondence: dr.ahmedadnan@uokirkuk.edu.iq, omer.thk@uokirkuk.edu.iq, omarturhan@uokirkuk.edu.iq

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Abstract: The present investigation was carried out on season 2023 on Valencia orange fruit. The effect of postharvest treatments i.e. chitosan at 2%, citric acid 0.5% and malic acid 150 ppm as well as their combinations on some fruit quality parameters during cold storage at 5°C. 90-95% relative humidity, to assess the effect of treatments on Vitamin C (mg/100g), Juice weight (%), Fruit weight (%), Total sugars (mg/g), Fruit size (cm³) and Total Phenols (mg/100g FW). It was concluded from the results, that Valencia orange fruits treated with chitosan 2% + citric acid 0.5% + malic acid 150 ppm gave the best results during cold storage at 5°C after 90 days.

Keywords: orange, Valencia, cold storage, quality, Chitosan, malic, citric

Introduction

The importance of citrus growing in the world has been increasing steadily. This is reflected not only in the amount of production and export, but also in its relative position in the world fruit production.

Valencia oranges belong to the genus *Citrus*, of the family Rutaceae. The sweet orange is classified as *Citrus sinensis*; the sour, or Seville, orange as *Citrus aurantium*; the bergamot orange as *Citrus bergamia*; and the mandarin orange, or tangerine, as *Citrus reticulata*.

Valencia oranges turn golden as they become fully ripe, but as they remain on the tree during warmer weather, the orange skin will produce chlorophyll and, in some cases, it turns green again, which usually begins at the stem end. However, the fruit is actually fully ripe, sweet, juicy and bright orange inside.

Chitosan (poly-P 1341-4) N-acetyl-d-glucosamine, is a natural antimicrobial compound. On one hand, it can be obtained from crustacean shells (crabs, shrimp and crayfishes) either by chemical

or microbiological processes and on the other hand it can be produced by some fungi [1]. The Chitosan coating is safe [2], and shows antifungal activity against several species.

The use chitosan coating for mandarin was in the range of 1 to 2% [3].

Pilar et al indicated that, life of strawberry fruit could be extended by using chitosan 1.5% as a coating material, which increased fruit juice weight after harvest and during cold storage [4].

Romanazzi et al coated table grapes using chitosan 2% in a postharvest trial and reported that, chitosan increase fruits life and remained fruits quality by increasing fruit juice weight of fruits during storage [5].

Tang et al mentioned that, fruit juice weight of sugar Apple fruit during postharvest storage increased by coating fruits using chitosan 5% [6].

Gianfranco used chitosan 3% in coating sweet cherries before storage and said that, fruit weight of stored fruits increased during storage period [7].

Tang et al. mentioned that, fruit weight of sugar Apple fruit during postharvest storage increased by coating fruits using chitosan 5% [8].

Pilar et al indicated that, life of strawberry fruit could be extended by using chitosan 1.5% as a coating material, which increased fruit size after harvest and during cold storage [4].

Romanazzi et al coated table grapes using chitosan 2% in a postharvest trial and reported that, chitosan increase fruits life and remained fruits quality by increasing fruit size of fruits during storage [5].

In addition, El-Badawy stated that, chitosan as a postharvest treatment when used in coating Canino apricot increased fruit total sugars and remain good fruit quality by increasing life during cold storage at 50C [9].

Contreras et al in an experiment to study effects of chitosan coatings on quality of clementine mandarins, they mentioned that, the chitosan coating effectively decreased titratable acidity of mandarins [10].

Chein et al reported that, coating Murcott tangor with 4% chitosan resulted in decreased fruit total phenols of stored fruits during cold storage at 50C [11].

Contreras et al. in an experiment to study effects of chitosan coatings on quality of clementine mandarins, they mentioned that, the chitosan coating effectively increased vitamin C of mandarins [10].

Sowani and Zahng in a postharvest trial using citric acid with concentration of 0.6 – 0.8 and 1%, they treated cherry tomato fruits with citric acid before cold storage and found that citric acid with 0.6% concentration significantly increased fruit juice weight percentage during storage [12].

Tonie and Sharez reported that treating strawberry fruits with citric acid 0.4% increased fruit weight and fruit size during cold storage compared with control treatment [13].

Singh and Batchi reported that citric acid reduced the loss in vitamin C in grape fruit stored at 5 °C [14].

Malic acid is a well-known organic acid that presumably can reduced the number of bacteria in the solution and with decrease ACC-oxidase activity cause delay the onset of hydrolysis of structural cell components, decrease ethylene production and sensitivity [15]. Previous study had revealed that MA (malic acid) sprays during growth period increased chlorophyll content of cut flowers while post-harvest vase life [16].

Materials and Methods

The present investigation was carried out in the postharvest laboratory of the Faculty of Agriculture Cairo University, in a private Valencia orange orchard located at El-Giza Government, Egypt.

Fruits were harvested at mature stage determined by Kader [17]. Fruits chosen for this study were uniform in size, color and weight.

Fruits were immediately transported to the pomology laboratory. Fruits with any biotic or abiotic disorders were discarded. Fruits were thoroughly washed with distilled water, air dried and waxed with paraffin wax. The treatments were contained of Chitosan 2% [18], citric0.5% [19] and malic

acid 150 ppm [20], respectively or in different combinations whereas each 210 fruits were immersed in one of the following treatments for 10 minutes before cold storage.

The treatments were:

1. Chitosan 2%.
2. Chitosan 2% + citric acid 0.5%.
3. Chitosan 2% + malic acid 150 ppm.
4. citric acid 0.5%.
5. citric acid 0.5% + malic 150 ppm.
6. malic acid 150 ppm.
7. Chitosan 2% + citric 0.5% + malic 150 ppm.
8. Control (fruits were taken into storage with only paraffin wax)

After treatments application, Fruits from each treatment were placed in four carton boxes (one for weight loss studies, one for decay studies and two for interval samples analysis). Cartons were weighed and placed in cold storage at 5°C and 95% RH for 90 days.

Every 15 days, boxes dedicated for weight loss were weighed, boxes dedicated for decay studies were inspected and decayed fruits were counted and discarded and from each treatment 15 fruits i.e. each 5 acting as a replicate were taken to assess their quality parameters. The current study followed a complete randomized block design. The following physical and chemical measurements were done:

Fruit size (cm³):- By measuring the volume of water displaced by a certain number of fruits in a graduated cylinder.

Fruit weight (gm):- Weighing on an ordinary balance with 5gm sensitivity.

Juice weight percentage:- Fruit weighed with an electronic balance. Juice was extracted by machine and weight was taken. The juice percentage was expressed as percentage of total weight at the time of measurement. $\text{Juice weight/fruit weight} \times 100$.

Total sugars (mg/g):- Determined according to the method of Lane and Eynon (A.O.A.C., 1995).

Total Phenols (mg/100g fw):- Estimated by Folin-Ciocalteu method (A.O.A.C,1995).

Vitamin C (mg/100g juice):- Was measured using 2, 5-6 dichlorophenol indophenols, described by A.O.A.C. (1995).

Statistical analysis

The current study followed a complete randomized block design with Split-Split Plot, with three replicates for each treatment. Data obtained throughout the current study were tested for analysis of variance as indicated by Snedecor and [21] and means were compared using LSD test at 5% [22].

Results and Discussion

Fruit size (cm³)

Table (1) illustrate the effect of conducted treatments and number of storage days on fruit size (cm³) of Valencia orange fruits.

Fruit size decreased significantly with the storage. Concerning the effect of conducted treatments on fruit size (cm³), results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% treatment resulted in significantly the highest Fruit size (157.6 cm³), followed by Chitosan 2% + malic 150 ppm (155.8 cm³). Meanwhile, control treatment gave the lowest fruit size (131.00 cm³).

Corresponding to the effect of number of storage days, 0 days of storage had the highest significant fruit size (160.30 cm³). On the opposite, 90 days of storage gave the lowest significant fruit size (136.5 cm³).

In respect to the effect of interaction between conducted treatments and number of storage days on fruit size, results showed that, treating Valencia orange fruits with Chitosan 2% + malic 150 ppm + citric 0.5% at 0 days of storage gave the highest significant fruit size (166.3 cm³), followed by Chitosan 2% + malic 150 ppm (163.7cm³). On the other hand, control treatment at 90 days of storage gave the lowest fruit size of Valencia orange fruits (122.3 cm³).

These results were in harmony with Glenn and Pilar et al, Romanazzi et al, Tang et al. and Gianfranco who reported that, fruit size of fruits during postharvest storage increased by coating fruits using chitosan [4], [5], [7], [8].

In the same trend, Glenn and Dimitrios and Pavlina, Tonie and Sharez and Sowani and Zahng found that malic acid significantly increased fruit size during cold storage [12], [13], [23].

In addition, Kal and Nastron, Moran and Mahetra. and Singh and Batchi reported that citric acid treatment retained significantly higher fruit size, compared to control treatment which had the lowest fruit size [14], [24], [25].

Table 1. Fruit size (cm³) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season)

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	142.5	135.4	132.0	130.3	128.0	126.7	122.3	131.0 g
Malic 150 ppm	155.0	145.0	139.3	134.0	132.0	130.0	128.3	137.7 f
Chitosan + malic + citric	166.3	165.7	161.0	157.0	154.0	151.0	149.0	157.6 a
Citric 0.5%	153.7	149.7	147.0	142.3	141.7	139.3	137.3	144.4 e
Chitosan + malic	163.7	159.3	164.7	159.0	146.0	142.0	138.0	155.8 b
Chitosan + citric	160.3	159.3	155.0	150.3	148.0	146.7	143.7	152.3 c
malic + citric	158.0	157.0	162.0	152.7	141.7	138.0	136.0	152.5 c
Chitosan 2%	161.0	154.7	144.0	142.7	140.0	138.7	137.0	145.4 d
Mean (B)	160.3 a	155.8 b	150.6 c	146.0 d	141.4 e	139.0 f	136.5 g	
LSD 0.05	A= 0.84		B= 0.78			AB= 2.21		

Fruit weight (gm)

Table (2) illustrate the effect of conducted treatments and number of storage days on fruit weight (%) of Valencia orange fruits.

Fruit weight percentage decreased significantly with the storage. Concerning the effect of conducted treatments on fruit weight (%), results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% (153.8 %) and Chitosan 2% + malic 150 ppm (153.3 %) treatments resulted in significantly the highest fruit weight. Meanwhile, control treatment gave the lowest fruit weight (131.6 %).

Corresponding to the effect of number of storage days, 90 days of storage had the lowest significant fruit weight (131.6%). On the opposite, 0 days of storage gave the highest significant fruit weight (157.3%).

In respect to the effect of interaction between conducted treatments and number of storage days on fruit weight, results showed that, treating Valencia orange fruits with Chitosan 2% + malic 150 ppm + citric 0.5% at 0 days of storage gave the highest significant fruit weight (169.7%), followed by Chitosan 2% + malic 150 ppm (168.3 %). On the other hand, control treatment at 90 days of storage gave the lowest fruit weight of Valencia orange fruits (125.00 %).

These results were in harmony with Glenn and Pilar et al, Romanazzi et al, Tang et al and Gianfranco who reported that, fruit weight of fruits during postharvest storage increased by coating fruits using chitosan [4], [5], [6], [7].

In the same trend, Dimitrios and Pavlina, Tonie and Sharez and Sowani and Zahng found that malic acid significantly increased fruit weight during cold storage [12], [13], [23].

In addition, Kal and Nastron, Moran and Mahetra and Singh and Batchi reported that citric acid treatment retained significantly higher fruit juice, compared to control treatment which had the lowest fruit weight [14], [24], [25].

Table 2. Fruit weight (%) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season).

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	137.3	136.7	134.0	131.3	128.7	127.0	125.0	131.6 ^g
Malic 150 ppm	154.0	152.0	133.7	130.3	126.3	123.0	130.3	134.2 ^f
Chitosan + malic + citric	169.7	167.7	160.0	154.3	148.7	141.0	136.3	153.8 ^a
Citric 0.5%	150.7	144.7	141.0	137.3	132.7	128.0	126.3	137.2 ^e
Chitosan + malic	168.3	167.3	160.0	153.7	146.0	141.0	137.0	153.3 ^a
Chitosan + citric	166.0	162.0	156.3	151.0	148.0	143.3	141.3	152.6 ^b
malic + citric	162.0	155.3	152.0	141.0	138.3	134.0	131.0	144.8 ^c
Chitosan 2%	151.3	148.3	144.0	142.3	140.3	137.3	134.7	142.6 ^d
Mean (B)	157.3 ^a	154.3 ^b	147.6 ^c	142.7 ^d	138.6 ^e	134.3 ^f	131.6 ^g	
LSD 0.05	A= 0.61		B= 0.57			AB= 1.63		

Juice weight percentage

Table (3) illustrate the effect of conducted treatments and number of storage days on juice weight (%) of Valencia orange fruits.

Juice weight increased significantly with the storage. Concerning the effect of conducted treatments on Juice weight (%), results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% treatment resulted in significantly the highest Juice weight (96.56%), followed by Chitosan 2% + malic 150 ppm (93.12 %). Meanwhile, control treatment gave the lowest Juice weight (26.34 %).

Corresponding to the effect of number of storage days, 0 days of storage had the lowest significant Juice weight (80.59%). On the opposite, 90 days of storage gave the highest significant Juice weight (101.96 %).

In respect to the effect of interaction between conducted treatments and number of storage days on Juice weight, results showed that, treating Valencia orange fruits with Chitosan 2% + malic 150 ppm + citric 0.5% at 90 days of storage gave the highest significant Juice weight (107.00 %), followed by Chitosan 2% + malic 150 ppm (104.67%). On the other hand, control treatment at 0 days of storage gave the lowest Juice weight of Valencia orange fruits (72.73 %).

These results were in harmony with Glenn and Pilar et al, Romanazzi et al, Tang et al and Gianfranco who reported that, fruit juice weight of fruits during postharvest storage increased by coating fruits using chitosan [5], [6], [7].

In the same trend, Glenn and Dimitrios and Pavlina, Tonie and Sharez and Sowani and Zahng found that malic acid significantly increased fruit juice weight percentage during cold storage [12], [13], [23].

In addition, Kal and Nastron, Moran and Mahetra and Singh and Batchi reported that citric acid treatment retained significantly higher fruit juice weight percentage, compared to control treatment which had the lowest fruit juice weight percentage [14], [24], [25].

Table 3. Juice weight (%) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season).

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	72.73	74.60	76.98	79.30	83.58	93.43	96.30	82.42 g
Malic 150 ppm	73.42	74.33	76.42	77.79	83.55	97.83	100.03	83.05 g
Chitosan + malic + citric	86.00	94.33	95.13	96.30	98.28	98.91	107.00	96.56 a
Citric 0.5%	84.73	85.16	86.59	89.10	89.43	92.00	92.33	88.48 e
Chitosan + malic	80.83	92.08	92.44	93.61	95.44	97.80	104.67	93.12 b
Chitosan + citric	83.40	85.34	87.21	89.45	92.28	96.60	102.33	91.09 c
malic + citric	83.40	85.34	87.21	89.45	92.28	96.60	101.33	91.09 c
Chitosan 2%	82.17	82.91	84.05	85.98	87.27	98.00	100.67	89.58 d
Mean (B)	80.59 g	84.26 f	85.75 e	86.62 d	90.26 c	96.40 b	101.96 a	
LSD 0.05	A= 0.73		B= 0.68			AB= 1.94		

Total sugars (mg/g)

Table (4) illustrate the effect of conducted treatments and number of storage days on total sugars (mg/g) of Valencia orange fruits.

Total Sugars increased significantly with the storage. Concerning the effect of conducted treatments on total sugars (mg/g), results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% treatment resulted in significantly the highest total sugars (119.71 mg/g), followed by Chitosan 2% + malic 150 ppm (113.09 mg/g). Meanwhile, control treatment gave the lowest total sugars (91.71 mg/g).

Corresponding to the effect of number of storage days, 90 days of storage had the highest significant total sugars (161.19 mg/g). On the opposite, 0 days of storage gave the lowest significant total sugars (69.10 mg/g).

In respect to the effect of interaction between conducted treatments and number of storage days on total sugars, results showed that, treating Valencia orange fruits with Chitosan 2% + malic 150 ppm + citric 0.5% at 90 days of storage gave the highest significant total sugars (199.92 mg/g), followed by Chitosan 2% + malic 150 ppm (164.93 mg/g). On the other hand, control treatment at 0 days of storage gave the lowest total sugars of Valencia orange fruits (39.97 mg/g) in both seasons, respectively.

These results were in harmony with Fernando et al, Chein et al and Pilar et al. who indicated that, coating fruits with using chitosan gave a significantly increasing in fruit total sugars during cold storage [4], [11], [26].

In the same trend, Dimitrios and Pavlina, Tonie and Sharez and Sowani and Zahng reported that treating fruits with malic acid increased fruit total sugars content during cold storage compared with control treatment.[12], [13], [23]

In addition, Ding et al, Jiang et al. and Sowani and Zahng reported that treated fruits with citric acid before cold storage significantly increased fruit total sugars content during storage [12], [18], [27].

Table 4. Total sugars (mg/g) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season).

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	39.97	69.87	76.64	88.30	108.29	112.30	126.62	91.71 ^h
Malic 150 ppm	64.96	75.64	84.97	89.96	90.80	124.95	146.61	96.84 ^g
Chitosan + malic + citric	86.63	89.96	108.3	111.62	118.29	123.25	199.92	119.71 ^a
Citric 0.5%	76.64	81.63	83.30	93.30	111.62	119.95	136.61	100.44 ^f
Chitosan + malic	83.30	88.30	96.63	109.96	120.23	128.28	164.93	113.09 ^b
Chitosan + citric	76.64	79.97	81.63	84.97	109.96	131.61	156.58	111.62 ^c
malic + citric	68.31	91.63	96.63	108.29	121.62	128.28	146.61	108.77 ^d
Chitosan 2%	46.31	81.63	98.29	104.96	116.62	129.95	151.61	102.77 ^e
Mean (B)	69.10^g	82.33^f	90.80^e	98.92^d	112.18^c	124.82^b	161.19^a	
LSD 0.05	A= 0.57		B= 0.53			AB= 1.51		

Total Phenols (mg/100g fw)

Table (5) illustrate the effect of conducted treatments and number of storage days on total phenols (mg/100g FW) of Valencia orange fruits.

Total phenols decreased significantly with the storage. Concerning the effect of conducted treatments on total phenols, results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% (315.7 mg/100g FW) and Chitosan 2% + malic 150 ppm (312.9mg/100g FW) treatments resulted in significantly the lowest total phenols. Meanwhile, control treatment gave the highest total phenols (616.6 mg/100g FW).

Corresponding to the effect of number of storage days, 15 days of storage had the highest significant total phenols (607.84 mg/100g FW). On the opposite, 90 days of storage gave the lowest significant total phenols (432.09 mg/100g FW).

In respect to the effect of interaction between conducted treatments and number of storage days on total phenols, results showed that, treating Valencia orange fruits with Chitosan 2% + malic 150 ppm + citric 0.5% (315.7 mg/100g FW) and (Chitosan 2% + Malic 150 ppm) (319.3 mg/100g FW) at 90 days of storage gave the lowest significant total phenols. On the other hand, control treatment at 15 days of storage gave the highest total phenols of Valencia orange fruits (783.5 mg/100g FW).

These results were in harmony with Contreras et al and El-Badawy who indicated that, coating fruits using chitosan resulted in decreasing fruit total phenols during cold storage through a postharvest treatment [9], [10].

In the same trend, Dimitrios and Pavlina, Tonie and Sharez and Sowani and Zahng reported that treating fruits with malic acid decreased fruit total phenols content during cold storage compared with control treatment [12], [13], [23].

In addition, Ding et al., Jiang et al, Tonie and Sharez and Sowani and Zahng reported that citric acid with concentration significantly decreased fruit total phenols content during storage [12], [18], [27].

Table 5. Juice size (cm³) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season).

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	0.0	783.5	769.2	742.3	723.5	675.4	622.3	616.6 ^a
Malic 150 ppm	0.0	632.6	711.3	672.3	651.3	631.2	512.3	558.7 ^b
Chitosan + malic + citric	0.0	401.3	391.2	379.3	350.1	343.1	315.7	311.5 ^h
Citric 0.5%	0.0	623.7	697.3	671.3	643.1	573.1	476.3	540.7 ^d
Chitosan + malic	0.0	432.1	398.2	368.2	348.7	323.6	319.3	312.9 ^g
Chitosan + citric	0.0	543.3	523.1	497.3	473.6	431.6	359.3	404.1 ^e
malic + citric	0.0	523.1	489.4	472.4	463.1	412.4	329.4	384.3 ^f
Chitosan 2%	0.0	723.1	692.3	671.5	658.3	631.6	522.1	557.0 ^c
Mean (B)	0.0 ^g	607.84 ^a	584.00 ^b	559.33 ^c	538.96 ^d	502.75 ^e	432.09 ^f	
LSD 0.05	A= 0.99		B= 0.93			AB= 2.63		

Vitamin C (mg/100g juice)

Table (6) illustrate the effect of conducted treatment and number of storage days on vitamin C (mg/100g) of Valencia orange fruits.

Vitamin C decreased significantly with the storage. Concerning the effect of conducted treatments on vitamin C, results revealed that, Chitosan 2% + malic 150 ppm + citric 0.5% treatment resulted in significantly the highest vitamin C (29.30 mg/100g), followed by chitosan 2% + malic 150 ppm) (28.62 mg/100g). Meanwhile, control treatment gave the lowest fruit vitamin C (26.34 mg/100g).

Corresponding to the effect of number of storage days, 90 days of storage had the lowest significant vitamin C (23.20 mg/100g). On the opposite, 0 days of storage gave the highest significant vitamin C (30.46 mg/100g).

In respect to the effect of interaction between conducted treatments and number of storage days on vitamin C, results showed that, treating Valencia orange fruits with chitosan 2% + malic 150 ppm + citric 0.5% at 0 days of storage gave the highest significant vitamin C (33.50 mg/100g), followed by Chitosan 2% + malic 150 ppm (32.64 mg/100g). On the other hand, control treatment at 90 days of storage gave the lowest vitamin C of Valencia orange fruits (20.45 mg/100g).

These results were in harmony with Fernando et al, Romanazzi et al and Contreras et al. who indicated that, the chitosan coating effectively increased vitamin C of fruits [5], [10], [26],

In the same trend, Kal and Nastron, Moran and Mahetra and Singh and Batchi reported that malic acid reduced the loss in vitamin C in fruits stored at 5 °C [14], [24], [25].

In addition, Kal and Nastron, Moran and Mahetra and Singh and Batchi reported that citric acid treatment retained significantly higher vitamin C in fruits, compared to control treatment which had the lowest vitamin C [14], [24], [25].

Table 6. Vitamin C (mg/100g) as affected by conducted treatments of Valencia orange fruit during cold storage at 0oC (2022 season).

Treatments	Storage period (days)							Mean (A)
	0	15	30	45	60	75	90	
Control	29.17	24.12	27.90	29.03	27.00	26.73	20.45	26.34 ^e
Malic 150 ppm	31.41	30.30	29.03	26.10	28.35	29.40	21.51	28.01 ^{bcd}
Chitosan + malic + citric	33.50	30.41	31.50	31.20	26.72	30.67	28.07	29.30 ^a
Citric 0.5%	29.58	29.07	27.60	29.70	26.90	26.73	21.98	27.37 ^d
Chitosan + malic	32.64	30.07	30.60	27.45	29.89	30.85	21.82	28.62 ^{ab}
Chitosan + citric	28.75	29.52	25.65	28.62	28.01	29.85	26.55	28.14 ^{bc}
malic + citric	31.09	29.34	28.80	28.07	28.88	26.51	24.40	28.16 ^{bc}
Chitosan 2%	30.23	28.17	27.90	26.10	24.75	32.40	23.13	27.53 ^{cd}
Mean (B)	29.55^a	28.88^{abc}	28.62^{bc}	28.28^c	27.56^d	29.14^{ab}	23.49^e	
LSD 0.05	A= 0.74		B= 0.69		AB= 1.96			

Conclusions

The study demonstrates that the combination of Chitosan (2%), Citric Acid (0.5%), and Malic Acid (150 ppm) as postharvest treatments significantly improves the quality and storage life of Valencia orange fruits under cold storage conditions. The fruits treated with this combination exhibited the highest levels of fruit size, weight, juice weight, total sugars, and vitamin C after 90 days of storage. These treatments not only slowed down the deterioration process but also enhanced various quality attributes, providing a beneficial postharvest solution for extending the shelf life of citrus fruits. The control group, which was only treated with paraffin wax, showed lower quality and storage results, underscoring the effectiveness of the combined treatments.

Recommendations

Based on the findings, it is recommended that postharvest treatments involving Chitosan, Citric Acid, and Malic Acid be considered for commercial use in citrus industries aiming to prolong the shelf life and maintain the quality of Valencia oranges. Further studies should explore the optimal concentrations and application methods for these treatments across different citrus varieties to validate the consistency of these results. Additionally, long-term studies beyond 90 days of storage could provide more insight into the lasting effects of these treatments on fruit quality. Finally, it is suggested that the potential impact of these treatments on the economic viability of postharvest citrus handling be evaluated to ensure practical adoption by producers..

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