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CO_2 and Modified Atmosphere Packing Application for Removing Astringency of Persimmon Fruits and Its Incorporation into Quality and Shelf Life Characteristics

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Abstract

Modified atmosphere packaging (MAP) is the procedure to changing the internal atmosphere package composition for maintaining fruit quality and extending its shelf life. So, this work was carried out throughout 2021 and 2022 seasons on "Triumph" persimmon fruits to evaluate the effectiveness of packaging using three thicknesses of low-density polyethylene (LDPE) bags (2, 4 and 7 µm) with or without carbon dioxide (CO_2) treatment. Carbon dioxide gas at 100% was injected into the bags for replacing all of the normal air for every thickness polyethylene bags, and comparison with fruits packed in these bags of different thicknesses without carbon dioxide injection. Physical and chemical fruit properties were evaluated periodically after storage periods at 0ºC with 85-90% relative humidity (RH) and 7 days ripening at 20ºC with 80-85% (RH). The obtained results demonstrated that all parameters under investigation were positively impacted by the various treatments.

The results showed that after 45 days of storage at 0°C and 7 days ripening at 20°C, fruits packed in LDPE bags at thickness 7µm with 100 % CO_2 application were more effective than other thicknesses under the same conditions in maintaining fruit firmness and reducing fruit weight loss and respiratory rate. Also, this treatment recorded the highest values of Lightness (L*), ascorbic acid content, soluble solid content, and total phenols content, and the lowest values of Chroma (C*), total acidity, and total tannins content in "Triumph" persimmon fruits.

It can be recommended that the highest thickness 7 µm of low-density polyethylene (LDPE) packaging bags with CO_2 (100%) treatment are the most effective implementation for modified atmosphere packaging of "Triumph" fruits cv. persimmon for maintaining quality and extending shelf life.

Keywords : Persimmon, MAP, LDPE bags, carbon dioxide, respiration rate, phenols, tannins, ripening, storage, quality.

1. Introduction

Persimmon fruit (*Diospyros kaki* L.) belongs to family Ebenaceae is one of the climacteric and highly perishable fruits. Changes in the physiological characteristics of persimmon fruit significantly affect the quality and market value. Persimmon fruits are a good source of many biologically active compounds such as polyphenols, tannins, tocopherols, carotenoids and ascorbic acid. In addition to its high content of vitamins, carbohydrates and minerals like magnesium, potassium, iron, zinc, manganese and copper, proteins, lipids, dietary fiber and pectin [1]. Persimmons are generally classified as astringent and non-astringent types.

There are a variety of processing technologies, such as high CO_2 treatments [2], hot water treatments [3], ethanol treatments [4], and modified atmosphere packaging [5], which is used to remove astringency in persimmon fruits. The primary technique to eliminate the astringency and preserve fruit quality during cold storage without causing physiological harm to persimmon fruit is treating with high CO_2 concentrations [6]. The insolubilization of soluble tannin by the mediation of acetaldehyde produced during anaerobic respiration, which is activated while fruit are exposed to a high CO_2 atmosphere, is the basis for the efficiency of CO_2 treatment to reduce astringency [7].

Persimmon fruit treated with CO_2 for reducing astringency has a good texture and flavor, but it also has low storability and easy softening characteristics [4]. According to Khademi *et al.* [8], there is a strong correlation between the reduction in flesh firmness and increasing activity of pectin methyl esterase. This suggests that deastringency treatments may have a significant impact on fruit softening during and after cold storage, although the exact relationship between

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deastringency treatments and fruit softening varies depending on the cultivar [9].

Several techniques have been used to maintain fruit quality after long-term storage by using modified atmosphere packaging (MAP), where packing fruit in polyethylene (PE) films significantly delayed fruit ripening [10]. Types of packaging and storage treatments affect critical points in the degradation pathways of bioactive components, which are reflected in the qualitative traits of fresh persimmon fruits [11]. Using modified atmosphere packaging (MAP) can help fresh fruits alter the ripening process within the package, as packaging films allow for a natural correlation between product respiration rate and gas transfer [12]. The avoidance or delay of fruit ripening and the related physiological and biochemical alterations is one of the main advantages of MAP changes [13]. Many studies have concentrated on achieving high-quality persimmons fruit during extended storage through the use of MAP. According to Brackmann *et al.* [14], Fuyu' and 'Rama Forte' persimmons packed in 40 µm low-density polyethylene film maintain acceptable keeping quality for up to two months of storage. However, Cia *et al*. [15] noted that even while low-density polyethylene (LDPE) (80 µm) allowed fruit quality to be preserved, there was a risk of anaerobiosis because of ethanol and acetaldehyde are collected inside the packages. This negatively affects fruit quality of persimmon, as the key for post-harvest quality. For 'Fuyu' persimmon firmness of the flesh, fruit distributors and consumers prefer firm fruits with a crunchy texture [16]. Conversely, Park [17] found that after storage of 'Fuyu' persimmon fruit for 28 weeks at 0°C in a controlled atmosphere, air, or MAP (packaged in 60 µm polyethylene film), the incidence and severity of the fruit skin blackening were increased significantly. The highest levels of blackening were observed in the MAP and air treatments. Therefore, present study aimed to investigate the effects of high carbon dioxide exposure with different packaging film thickness during storage and ripening process of Triumph astringent persimmon fruits for removing their astringency, maintaining quality and extending storage and shelf life.

2. MATERIALS AND METHODS

Fruit respiration rate (ml CO_2/kg/h): It was determined according to Lurie and Pesis [18].

Fruit skin color: It was determined longitudinally on two spots from each fruit using Minolta instrument (Minolta Co., Ltd., Osaka, Japan), and expressed based on CIELAB color system (L*, a*, b*). Chroma values (a*, b*) were calculated using the methods described by Lopez and Gomez [19].

Fruit firmness (N): It was measured on the two opposite sides of fruit using Ametek pressure tester with a probe penetration 2 mm and the data were recorded in Newton units.

Fruit: Astringent persimmons (*Diospyros kaki* L.) "Triumph" cv. was collected from Nemous orchard located at Katta region, Giza Governorate, Egypt. Fruits were harvested at the appropriate maturity stage in October 2020 and 2021 at three- quarter color stage from eight-years-old trees of similar growth, grown in sandy loam soil and receiving the common horticultural practices. Uniform fruits in weight, shape, firmness and colour, free from visual defects and damage were harvested, graded, packed and immediately transported to the post-harvest laboratory. After arrival, persimmon fruits were washed, allowed to air-dry and received CO_2 applications and modified atmosphere packaging (AMP). Initial quality measurements at harvest and after ripening at 20ºC with 80-85% RH for 7 days are recorded in Table (1).

Modified Atmosphere Packaging (MAP) and CO_2 applications:

Persimmons were weighed and enclosed in low-density polyethylene (LDPE) bags at different three thicknesses (2, 4 and 7 µm). CO_2 (100%) was pumped into the bags from the cylinder until the natural air was completely replaced, while control fruits were packed at an air condition for each bags thickness. Three replicates were used for each treatment and sampling duration, each replicate consisted of six fruits. After processing, the packed fruits were placed in corrugated cardboard boxes and stored at 0°C with 85–90% relative humidity for 45 days. Every 15 days, the MAP container for each treatment was opened and aerated, and then fruits from the different treatments were transferred to fiberboard cartons and placed for 7 days in a temperature-controlled chamber at 20°C with 80-85% relative humidity for ripening, and then the physical and chemical properties of the fruit were evaluated.

2.1. Physical and chemical fruit characteristics assessments:

2.1.1. Fruit physical characteristics

Loss in fruit weight (LW %): *It was determined according to the following equation:*

$$LW\ \% = \frac{Initial\ fruit\ weight\ - Weight\ at\ sampling\ date}{Initial\ fruit\ weight}\ X\ 100$$

2.1.2. Fruit chemical characteristics

Percentage of soluble solid content (SSC %): It was measured in fruit juice using a T/C hand refractometer Instrone, Brix-readings 0-30 ranges (Model 10430, Bausch and Lomb Co. Calif., USA).

Percentage of total acidity (TA %): It was determined by titrating fruit juice with 0.1N NaOH and phenolphthalein was used as indicator.

Vitamin C (mg/100g FW): It was determined using 2, 6 dichlorophenol indophenol's method as described in AOAC [20].

Total tannins content (mg/100g FW): It was estimated volumetrically in the fresh samples using potassium permanganate method according to Winton and Winton [21].

Total phenols content (mg/100g FW): It was determined in the fruit juice using the Folin–Ciocalteu method according to AOAC [20].

Statistical analysis: A completely randomized design (CRD) with three replicates was used in this study. The analysis of variance (ANOVA) procedure of COSTAT program was used to examine the data. According to Duncan [22], means were compared at 5% level of probability in the average of two seasons of the study. Data was treated by analysis of variance with standard deviations.

Table (1): The initial quality measurements of "Triumph" Persimmon fruits

Fruit stages	Fruit firmness (N)	Respiration rate (ml/kg/h)	Soluble solid content (%)	Ascorbic acid (mg/100g FW)	Total tannins (mg/100 g FW)
At harvest	16.27 a ± 0.99	5.78 b ±1.35	25.13 a ± 2.66	31.07 a ± 0.27	1.47 a ± 0.05
After ripening	14.27 b ±1.17	7.82 a ±1.33	22.80 a ± 1.83	29.72 a ± 1.95	0.93 b ± 0.06

3. RESULTS AND DISCUSSION

3.1. Fruit physical properties

3.1.1. Fruit weight loss (WL %)

Changes in weight loss of "Triumph" persimmon fruits were varied significantly after the cold storage at 0ºC with 85-90 % RH + 7d ripening at 20ºC with 80-85 % RH due to different packaging thickness of low-density polyethylene (LDPE) bags at 2, 4 and 7 µm with or without CO_2 treatment as shown in Table (2).

The results showed that the percentage of weight loss of the fruit increased gradually and significantly until the end of the cold storage period (after 45 days) generally in all treatments. The percentage of weight loss in persimmon fruits decreased significantly with increasing thickness of LDPE bags, regardless of treatment with or without CO_2. After 45 days of cold storage, persimmon fruits treated with CO_2 and packed in highly thickness 7µm recorded the lowest value of weight loss percentage (11.27%) followed by 4 µm (12.84%), then 2 µm (15.86%), respectively.

3.1.2. Respiration rate (ml CO_2 /kg/h)

Respiration of fresh fruit is an indicator of ongoing metabolic processes after harvest and offers an indication of the potential shelf life of the product. Results in Table (3) indicate that all postharvest packaging thickness of low-density polyethylene (LDPE) bags (2, 4 and 7 µm) with or without 100% CO_2 treatment cleared a significant and gradual increase in CO_2 production with the advancement of storage periods until reaching its peak values up to 30 days storage, then it was decreased significantly at the end of storage period. The highly thickness of polyethylene bags (7µm) showed the lowest CO_2 production after 45 days of cold storage at 0ºC + 7days ripening at 20ºC, followed by 4 µm and 2 µm (3.62, 4.31 and 5.05 ml CO_2 /kg/h), respectively. Meanwhile, persimmon fruits packaged with different thickness without CO_2 application recorded the highest values with expanding storage period. Generally, Lee [23] mention that O_2 and CO_2 levels into the packages may differ based on the thickness of the bags, also the entire amount of fruits in the package. The MAP abilities not only a way to control the respiration rate of the fruit, but also a way to reduce of the intensity of catabolic activity and degradation processes [13,15].

3.1.3. Skin fruit colour parameters

Lightness (L*)

Results in Table (4), revealed that the lightness (L*) color parameter of skin persimmon fruit was increased gradually and slightly towards the end of the storage period (after 45 days) due to the postharvest treatments with different packages thickness of low-density polyethylene (LDPE) bags at 2, 4 and 7 µm with or without CO_2 application.

Treatment with carbon dioxide led to the highest lightness of fruits at all different thicknesses of LDPE bags, while fruits not treated with carbon dioxide showed the lowest values of lightness at those thicknesses as the storage period progressed.

At the end of the storage period, the highest values of lightness L* (54.98) were recorded for Triumph persimmon fruits when packed in high-thickness LDPE bags (7 µm) with CO_2 treatment, whereas the lowest values of lightness L* (50.05) were recorded in low-thickness LDPE bags (2 µm) without CO_2 treatment.

Chroma (C*)

In general, changes in skin color of Triumph persimmon fruit showed a marked significant gradual decrease of Chroma (C*) color parameter with progress of cold storage period at 0ºC 85-90 % RH + 7d ripening at 20ºC with 80-85 % RH (Table 5).

Significant differences were observed among different treatments. At the end of the storage period, the lowest significant value of Chroma (C*) parameter was recorded by highly packing thickness bags at 7 µm LDPE with CO_2 treatment (16.27). On the other hand, the highest value of Chroma (C*) color parameter was recorded by low packing thickness bags at 2µm LDPE without CO_2 treatment (20.38) at the same date.

Our findings align with those of Moura [24] who reported that after 72 days of storage at 0˚C, the "Taubate" persimmon in PVC film had higher amounts of chlorophyll than the control fruit. Chlorophyll and carotenoids biosynthesis loss were reduced when keeping the fruits in modified or controlled atmosphere [25]. After 90 days of storage at 0ºC and 7 days of ripeness, fruits that packed with 7 µm LDPE and had a 100% CO_2 treatment showed the greatest values for Lightness (L*) and Chroma (C*) color criteria [26].

Table (2): Changes in weight loss (%) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	9.12 jk ±1.01	11.76 fh ±1.22	8.92 kl ±1.49	10.6 1 hj ± 0.89	7.35 l ± 0.08	9.66 i-k ±2.64
30 d at 5^0C +7d at 20^0C	12.90 ef ± 1.43	14.60 cd ±1.06	10.86hi±1.30	14.01 de ± 3.07	10.46 hk ± 1.56	11.18 hi ±3.05
45 d at 5^0C +7d at 20^0C	15.86 bc ±1.81	18.38 a ± 2.05	12.84 eg ±1 .20	18.20 a ± 2.46	11.27 gi ± 1.14	17.05 ab ± 3.25

+ CO_2: Packages thickness with carbon dioxide application. − CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) were statistically differed at 5% level. Data are the means of two seasons ± SD.

Table (3): Changes in respiration rate (ml/kg/h) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	– CO_2	+ CO_2	– CO_2	+ CO_2	– CO_2
15 d at 5^0C +7d at 20^0C	4.04 hi ± 0.24	6.64 ac ± 2.32	3.47 ij ± 1	4.05 g-I ± 0.3	2.11 k ± 0.42	2.5 jk ±1
30 d at 5^0C +7d at 20^0C	6.89 ab ± 0.62	7.32 a ± 2.15	5.81 ce ± 1.08	6.11 bd ± 2.02	4.85 e-h ± 1.3	4.90 e-h ± 0.4
45 d at 5^0C +7d at 20^0C	5.05 e-g ± 0.3	5.17 df ± 1.84	4.31 fgi ± 1.71	4.11 g-I ± 0.39	3.62 I ± 0.35	3.94 hi ± 0.50

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

Table (4): Changes in skin color (L*) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	50.76 a-e ± 4.39	47.69 e ± 2.66	53.82 a-d ± 6.40	49.29 de ± 2.20	53.99 a-c ± 2.46	50.74 a-e ± 2.37
30 d at 5^0C +7d at 20^0C	51.74 a-e ± 5.02	49.02 e ±1.54	53.91 a-d ±9.78	50.29 b-e ± 5.64	54.69 ab ± 1.63	51.74 a-e ± 4.43
45 d at 5^0C +7d at 20^0C	52.09 a-e ± 5.83	50.05 c-e ±10.74	54.24 a-c ± 8.80	51.74 a-e ± 3.06	54.98 a ± 6.23	51.85 a-e ± 5.19

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

Table (5): Changes in skin color (C*) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions.

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	23.48 a-c ± 6.11	26.72 a ± 13.56	22.21a-e ± 0.4	22.95 a-d ± 4.28	17.49 d-f ± 2	20.74 b-f ± 6.51
30 d at 5^0C +7d at 20^0C	21.29 a-f ± 4.02	23.94 ab ± 8.97	20.22 bf ± 3.36	21.29 a-f ± 3.97	16.88 ef ± 8.38	20.19 b ± 8.05
45 d at 5^0C +7d at 20^0C	19.50 b-f ± 8.61	20.38 b-f ± 2.51	18.06 c-f ± 5.22	20 b-f ± 5.43	16.27 f ± 5.73	19.86 b-f ± 6.69

+ CO_2: Packages thickness with carbon dioxide application. − CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two season's ± SD.

3.1.4. Fruit firmness (Newton)

Firmness is one of the quality criteria that different researchers have established for various fruits. Changes in fruit firmness (N) of "Triumph" persimmon fruits due to different postharvest packing thickness of LDPE bags at 2, 4 and 7 µm and application with or without 100% CO_2 is cleared in (Table 6).

Results indicated a progressive and significant decline in fruit firmness with the progress of storage periods in all treatments. The modified atmosphere packaging with LDPE and 100% CO_2 treatment succeeded in reducing firmness changes and maintaining fruit firmness compared to the control fruits that packaged only in LDPE and non-CO_2 treated.

At the end of storage period, the thickness 7 µm of LDPE bags with CO_2 treatment was highly effective in keeping fruit firmness than other thickness (2 and 4 µm) with CO_2 treatment. Whereas, fruit packed in the thickness 2 µm of LDPE bags without CO_2 treatment recorded the lowest fruit firmness (5.37 N).

The same results were attained by Hejazi *et al*. [27] who noted that the commercial firmness of persimmon fruits cv. 'Rojo Brillante' (1.5-2.5 kg) obtained by packing the fruits in the polyethylene bags.

In addition, Fuyu persimmons kept their hardness levels constant for up to 120 days at 0°C when packaged in 60 or 80 µm polyethylene film [28].

Low level of O_2 and high CO_2 levels inside the packages of 58 µm PO and 50 µm LDPE films delayed fruit softening which resulted from senescence retardation due to respiration rate inhibition [15].

Table (6): Changes in firmness of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	13.67 ± 1.26	11.67 c-e ± 1.15	13.92 b ± 0.29	11.75 c-e ± 0.87	15.75 a ± 1.5	12.33 cd ± 1.15
30 d at 5^0C +7d at 20^0C	11.00 e ± 0	7.00 h ± 0.52	11.5 de ± 1.80	8.75 g ± 0.87	12.5 c ± 0.5	8.75 g ± 0.5
45 d at 5^0C +7d at 20^0C	8.75 g ±1	5.37 I ± 1.25	9.5 fg ± 1	5.88 I ± 0.75	9.77 f ± 0.84	6 I ± 1.5

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

3.2.1. Fruit chemical properties

3.2.2. Soluble solids content (SSC %)

Results in Table (7) cleared that there was a slight increase in soluble solids content (SSC %) of persimmon fruit cv. "Triumph" with the advance in cold storage at 0ºC with 85-90 %RH + 7d ripening at 20ºC with 80-85 %RH, using MAP and with or without CO_2 applications.

At the end of storage days, packed fruits in bags with highly thickness at 7 µm with CO_2 treatment gave the highest SSC (19.73 %) followed by 4 µm and 2 µm with CO_2 treatment (19.17 and 17%, respectively). While, packaged fruit in bags thickness at 2 µm without CO_2 treatment recorded the lowest percentages of SSC (16.25%).

The results obtained are parallel as mentioned by Turk [29] who observed that polyethylene film in 30 µm steadily decreased soluble solid content of Fuyu persimmon during 80 days of storage at 1°C. Fuyu persimmon fruit kept in 60 µm polyethylene film during 42 d at 7ºC observed slight variance in the soluble solid content [30]. Moreover, Mohla *et al*. [31] indicated a rise in SSC for storage intervals, may be attributed to the packaging of fruit.

3.2.3. Total acidity percentage (TA %)

The variations in total acidity of "Triumph" persimmon fruits throughout storage at 0ºC with 85-90 %RH + 7d ripening at 20ºC with 80-85 %RH subjected to modified atmosphere packaging and treatments with or without CO_2 are presented in Table (8).

The modified atmosphere packaging treatments showed a gradual and significant decrease in the total acidity content of persimmon fruits, regardless of treatment with or without carbon dioxide during storage periods.

The highly thickness of 7 and 4 µm with CO_2 treatment led to higher rate of reduction in the total acidity (0.08%), followed by 2 µm with CO_2 treatment (0.11%) , while the low thickness 2µm without carbon dioxide treatment led to the highest percentage of total acidity (0.117%) at the end of the storage periods (after 45 days).

The same behavior also is found by Senter [32] with cv. Fuyu when studied the different stages of persimmon ripening. The retention of pH levels resulting from 58 µM PO and 50 µM LDPE films may be related to the effects of simultaneously low O_2 levels and high CO_2 levels, which may contribute to delaying fruit metabolism. Hussain [33], found a slight difference in pH of the fruits during the storage.

Table (7): Changes in soluble solids content (SSC %) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	22.77 bc ± 0.12	20.15 ef ± 2.3	23.6 ab ± 2.2	20.17 ef ± 0.31	24.17 a ± 0.10	21.87 cd ± 0.23
30 d at 5^0C +7d at 20^0C	19.67 f ± 1.29	17.66 g ± 2	20.93 de ± 1.94	19.23 f ± 0.24	22.57 bc ± 3.04	19.3 f ± 0.72
45 d at 5^0C +7d at 20^0C	17 gh ± 1	16.25 h ± 1.5	19.17 ef ± 2.10	16.33 h ± 1.92	19.73 ef ± 0.54	16.63 gh ± 0.86

+ CO2: Packages thickness with carbon dioxide application. −CO2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

Table (8): Changes in the total acidity (TA %) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	0.19 a ± 0.01	0.19 a ± 0.01	0.16 c ± 0.01	0.17 b ± 0	0.14 d ± 0.01	0.14 d ± 0.01
30 d at 5^0C +7d at 20^0C	0.12 fg ± 0	0.13 de ± 0	0.12 fg ± 0	0.127 ef ± 0.01	0.10 I ± 0.01	0.14 d ± 0.01
45 d at 5^0C +7d at 20^0C	0.11h ± 0	0.117 gh ± 0.01	0.08 j ± 0	0.10 i ± 0.01	0.08 j ± 0	0.09 j ± 0.01

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

3.2.4. Ascorbic acid content (VC as mg/100g FW)

Ascorbic acid content of 'Triumph' persimmons varied significantly as a result of modified atmosphere packaging with and without CO_2 treatments (Table 9). The concentration of ascorbic acid was higher in fruits packed in different LDPE thicknesses and treated with CO_2 compared to fruits not treated with CO_2 and packed in the same thickness bags.

Persimmons packed in high thickness at 7 µm with CO_2 treatment recorded the highest ascorbic acid content followed by 4 and 2 µm with CO_2 treatment (14.42, 13.52 and 12.97 mg/100 g FW, respectively) at the end of the storage periods. On the other hand, the lowest ascorbic acid content recorded in low thickness at 2µm without CO_2 treatment (5.23 mg/100 g FW).This is consistent with mentioned by Abdel Hafeez [34, 35, 36], who stated that during the storage period, the vitamin C content of fruits increases.

Table (9): Changes in ascorbic acid content (VC as mg/100g FW) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	21.44 c ± 0.36	16.22 g ± 0	24 b ± 0.65	15.90 fg ± 0.65	31.46 a ± 0.65	18.00 d ± 0.32
30 d at 5^0C +7d at 20^0C	15.90 fg ± 0.65	15.50 g ± 0.73	16.22 f ± 0	15.86 fg ± 0	16.76 e ± 0.36	15.86 fg ± 1.44
45 d at 5^0C +7d at 20^0C	12.97 j ± 0	5.23 m ± 0.36	13.52 I ± 0.37	6.49 l ± 0.72	14.42 h ± 0	11.53 k ± 0

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

3.2.5. Total tannins content (mg/100 g FW)

Total tannins content in persimmon fruit showed a notable reduction with prolonging storage time up to 45 days at 0ºC + 7 days ripening at 20°C due to packaging in different thickness of LDPE and with or without CO_2 treatment (Table 10). At the end of the storage period, fruit packaged in LDPE at 7 µm thickness with CO_2 treatment recorded the lowest tannins content (1.35 mg/100g FW) compared with 4 µm with CO_2 treatment (1.60 mg/100g FW) and 2 µm with CO_2 treatment (1.69 mg/100g FW), while the fruit untreated with CO_2 recorded the highest value of total tannins content at the same thickness.

Bibi [37] showed that some astringent fruits recorded decrease in tannins at ripening stage because of decreasing extractability or polymerization accompanied through losing the fluidity and decreasing the astringency.

The application with high levels of CO_2 or N_2 gas is effective in removing astringency and the duration of the treatment depends on temperature and variety [38].

3.2.6. Total phenols content (mg/100g FW)

Results presented in Table (11) demonstrated that total phenols content in "Triumph" persimmon fruit recorded significant decreased with expanding storage period for packaged fruit in different thicknesses of LDPE bags with CO_2 treatment compared to fruits packed in bags of LDPE at the same thicknesses without CO_2 treatment.

The results also showed that different thickness of polyethylene packaging (LDPE) bags had a significant effect on preserving the total phenols content of the fruits. Packaged fruits with highly thickness at 7 µm with CO_2 treatment recorded the highest total phenols content (21.60 mg /100g FW) followed by 4 and 2 µm with CO_2 treatment (21.12 and 19.07 mg/100 g FW, respectively) at 45 days of storage period at 0ºC with 85-90% RH after ripening at 20°C with 80-85 %RH for 7 days. Meanwhile, packaged fruits with low thickness at 2 µm without CO_2 treatment recorded the lowest total phenols content (12.88 mg /100g FW) at the same date. Carbon dioxide treatments considerably reduced the total phenols content [35].

Table (10): Changes in total tannins content (mg/100 g FW) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	3.60 b ± 0.6	4.50 a ± 1	3.09 c ± 0.38	3.09 c ± 0.38	2.57 d ± 1	2.83 cd ± 0.64
30 d at 5^0C +7d at 20^0C	1.93 e ± 0.78	2.44 d ± 0.44	1.90 ef ± 0.2	1.93 e ± 0.26	1.80 e-g ± 0.4	1.90 ef ± 0.2
45 d at 5^0C +7d at 20^0C	1.69 e-g ± 0.86	1.70 e-g ± 0.2	1.60 e-g ± 0.1	1.43 fg ± 0.75	1.35 g ± 0.57	1.41 g ± 0.28

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

Table (11): Changes in total phenols content (mg/100 g FW) of 'Triumph' persimmon fruits packed in different packaging thickness bags and treatment with or without CO_2 under cold storage conditions

Storage days	Treatments					
	2 µm		4 µm		7 µm	
	+ CO_2	− CO_2	+ CO_2	− CO_2	+ CO_2	− CO_2
15 d at 5^0C +7d at 20^0C	36.57 bc ± 3.14	30.9 ef ± 3.36	37.17 ab ± 3.61	35.80 cd ± 5.54	38.48 a ± 4.34	35.53 cd ± 3.14
30 d at 5^0C +7d at 20^0C	27.3 fg ± 2.53	23.18 hi ± 0.5	31.42 e ± 4.84	23.67 g ± 2.27	32.46 de ± 2.07	26.74 gh ± 3.15
45 d at 5^0C +7d at 20^0C	19.07 ik ± 3.95	12.88 l ± 1.96	21.12 ij ± 3.76	15.97 kl ± 2.14	21.60 ij ±4.64	17.1 k ±3

+ CO_2: Packages thickness with carbon dioxide application. −CO_2: Packages thickness without carbon dioxide application.
Within the row, the means with different letter(s) are statistically different at the 5% level. Data are means of two seasons ± SD.

4. Conclusion

According to the current study, the thickness of low-density polyethylene (LDPE) bags with CO_2 application has a significant effect in preserving the quality characteristics of persimmon fruit during cold storage and shelf life. As bag thickness increases, fruit weight loss, respiration rate, acidity, and total tannins content decrease, as well as enhancing color, ascorbic acid content, soluble solid content, and total phenols content in persimmon fruits. Therefore, it can be recommended by using of packaging low-density polyethylene bags thickness 7 µm and treatment with CO_2 (100%) in order to cold storage at 0°C with 85-90 %RH for 45 days + 7 days ripening at 20°C with a relative humidity of 80-85% to remove the astringency, maintain the quality, and raise the market value of "Triumph" persimmon fruit.

5. Conflicts of interest

The authors declare that they have no conflict of interest.

6. Formatting of funding sources

No fund available.

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