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Effect of Some Essential Oils and Chitosan Coating on the Quality of Globe Artichoke During Cold Storage

[1]Sheren A. Atala, [2]S. Elkeleny and [3]Y. Ahmed

[1]Department of Postharvest and Handling of Vegetable Crops,
Horticulture Research Institute, Agricultural Research Center, Giza, Egypt
[2]Department of Postharvest and Handling of Vegetable Crops,
Horticulture Research Institute, Agricultural Research Center, Sbaheya, Alex
[3]Mycology Research and Disease Survey Dept.,
Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt

Abstract: Globe artichoke (*Cynara scolymus* L.) is considered as one of the important vegetable crops for local consumption and export in Egypt. Artichoke heads of the cultivar "French Hyrious" were obtained from private farm in Kafr El Dawar - Sidi Ghazi - Behera Governorate during two successive seasons of 2018 and 2019. Artichoke heads were harvested at the suitable maturity stage of marketing and then transported to the laboratory of Handling of Vegetable Crops Department, Horticulture Research Institute, Giza governorate, to evaluate the effect of postharvest jasmine, cinnamon, clove and chitosan application on storage ability and quality of artichoke head during cold storage at 0°C and 95 % RH. Results showed that all postharvest treatments of artichoke heads slowed the rate of weight loss, had the highest compactness, lowest score of discoloration and gave the highest value of L and hue angle values, resulted in lighter color and inhibit the loss of green color comparatively to the highest ones obtained from untreated control. Artichoke heads sprayed with jasmine oil and cinnamon oil reduced total microbial count and maintained ascorbic acid content and inulin content. Previous treatments showed good appearance at the end of storage period (28 days of storage) at 0°C and 95 % RH.

Key words: Artichoke heads · Jasmine oil · Cinnamon oil · Clove oil · Inulin · Appearance and cold storage

INTRODUCTION

Many storage techniques have been developed to extend the useful marketing distances and holding periods for fresh horticultural commodities after harvest. One method of extending postharvest shelf-life of globe artichoke (*Cynara scolymus* L.) heads is the use of edible coatings, such as essential oils (jasmine, cinnamon and clove) and chitosan. These coatings are made of edible materials that are safe and used to enrobe fresh produce, providing a semipermeable barrier to gases and water vapor.

Essential oils have recently attracted a great deal of attention for use in post-harvest treatments because of their anti-bacterial, antifungal, antioxidant and bio-regulatory properties [1].

Essential oils are volatile, natural, complex compounds characterized by a strong odor and are formed by aromatic plants as secondary metabolites. In nature, essential oils play an important role in the protection of the plants as antibacterial, antiviral, antifungal, insecticides and also against herbivores by reducing their appetite for such plants [2].

Jasmonates include jasmonic acid (JA) and methyl jasmonate (MJ), are a natural compound that is widely distributed in plants and first detected as a fragrant component of jasmine essential oil and other plant species [3]. Methyl jasmonate is a potential treatment to maintain quality and safety of fresh fruits and vegetables [4]. Methyl jasmonate efficiently reduce weight loss, shriveling, inhibited postharvest growth of sprouts and roots and retained quality of radish [5].

Corresponding Author: Sheren A. Atala, Department of Postharvest and Handling of Vegetable Crops,
Horticulture Research Institute, Agricultural Research Center, Giza, Egypt.

Mahmoud and Abd El Salam [6] found that the main component of cinnamon oil was cinnamic aldehyde which recorded 54.65%. Also, this oil contained thymol (7.23%), caryophyllene (5.32%), terpineol (5.23%), α-pinene (5.14%), β-pinene (4.99%), limonene (4.7%), α-phellandrene (4.11%) and myrecene (3.65%).

Cinnamon in nature, essential oils play an import role as antibacterial, antiviral, antifungal, insecticides and against herbivores by reducing their appetite for such plants [2, 7]. It could happen through several ways including cell wall deterioration, cytoplasmic membrane injury and leakage of cell contents, membrane protein damage, cytoplasm coagulation, depletion of proton motive force sites, inactivation of essential enzymes and disturbance of DNA and RNA [7].

Clove oils presented inhibitory effects on the fungi, Zeng *et al*. [8] suggested that Clove extract might be a viable alternative to synthetic fungicides to extend the post-harvest storage period and maintain fruits quality.

Chitosan is a commercial product; it includes chitosan 90-95% (2-Amino-2-deoxy-beta-D-glucosamine) [9]. Chitosan, a natural biopolymer has been reported to enhance resistance against many fungal diseases including *Penicillium digitatum*, *Penicillium italicum* of fruits and vegetables when applied as either a pre- or postharvest treatment [10]. In addition, chitosan can be directly antimicrobial and has been shown to interfere with the germination and growth of several phytopathogenic fungi [11]. Furthermore, chitosan coatings are considered the best edible and biologically safe preservative coatings for different types of vegetables and fruits, with functional advantages; where chitosan coating acts as a semipermeable barrier against oxygen, carbon dioxide and moisture, thereby reduced respiration rates, water loss, maintained the quality, extended storage periods, reduce color changes and controlled microbial growth [12-17].

Thus, the aim of this study was to evaluate the potential use of essential oils and chitosan treatments in controlling the losses and maintaining quality of artichoke head during refrigerated storage.

MATERIALS AND METHODS

Artichoke marketable heads of the cultivar "French Hyrious" were harvested at the suitable maturity stage of marketing with a dimension of (7-12 cm) on 5th and 9th of February in 2018 and 2019 seasons respectively from private farm in Kafr El Dawar - Sidi Ghazi - Behera Governorate and transported to the laboratory of Vegetable Handling Research Department, Horticultural Research Institute, Agricultural Research Center, Ministry of Agriculture, Giza governorate, Egypt. Heads were cleaned with dry towels, graded and free from blemishes were selected for storage experiment.

Artichoke heads were randomly selected for 5 groups and subjected to the following treatments:

- Control (untreated heads).
- Spraying heads with jasmine oil at 1000 ppm.
- Spraying heads with cinnamon oil at 1000 ppm.
- Spraying heads with clove oil at 1000 ppm.
- Spraying heads with solution of chitosan at 1000 ppm.

All samples of artichoke heads were air dried, the artichoke heads from each treatment were packed in polypropylene bags 30 μm thickness and each had three artichoke heads represented as one replicate and then heat sealed. Twelve replicates were prepared for each treatment. The samples were arranged in complete randomized design with three replicates and stored at 0° C and 95% RH for 28 days. Three replicates from each treatment were examined immediately after harvest and every 7 days intervals for the following properties.

Loss in weight percentage calculated by the following equation: Loss in weight % = Initial weight of head - weight of head at sampling date / the initial weight of the head X100. The general appearance: as evaluated using a scale from 9 to 1, where 9= excellent, 7= good, 5= fair, 3= poor and 1= unsalable heads rating (5) or below were considered as unmarketable, as described by Kader *et al.* [18]. The compactness: Score rating from 5 to 1, where 5= tight, 4= few basal bracts pointing a way from rather than toward tip of bud, 3= several whorls of bracts. pointing a way from rather than toward tip of bud, 2= all or most outer bracts open, 1= all outer and more antrally located bracts open. Discoloration was evaluated as a scale of 1 to 5 where 1= none, 2= slight, 3= moderate, 4= severe and 5= extra severe as described by Cantwell *et al.* [19]. External surface color was evaluated by a color meter (Minolta CR 200) to measure the lightness (L value) and hue angle (h°) values. Ascorbic acid content (as indicated for vit. C) was determined (as fresh samples of heads) by titration method using 2, 6 discloro phenol indophenols as described in Ranganna [20]. Inulin sugar: Inulin was determined in flower heads according to the method of Winton and Winton [21]. Total microbial count: Artichoke heads used as replicates from each treatment were weighted and similar weight of sterile waster per volume

(1:1 w/v) was added. All samples were shaken at 150 rpm for 1hour in orbital shaker. The bacteria were determined on Nutrient agar media following incubation at 30°C for 72 hr and represented as log CFU/g for bacteria.

Statistical Analysis: Data were statistically analyzed using the analysis of variance described by Snedecor and Cochran [22]. The method of Duncan multiple range test was applied for than comparison between means according to Waller and Duncan [23].

RESULTS AND DISCUSSION

Weight Loss Percentage: Data in Table (1) showed that weight loss percentage increased with extending cold storage period. Highest losses of weight were obtained at the end of storage period [24]. Normally, the weight loss occurs during the fruit storage due to respiratory process, the transference of humidity and some processes of oxidation [25].

Concerning the effect of postharvest treatments, data revealed that there were significant differences among treatments in weight loss percentage during storage in the two seasons. All postharvest treatments retained their weight during storage as compared with untreated control. Moreover, artichoke heads sprayed with jasmine oil and cinnamon oil were the most effective treatment in reducing weight loss% with no significant differences between them in the first season followed by clove oil. Chitosan treatment was less effective in this concern. These results were achieved in the two seasons and were in agreement with Nilpraprucк *et al*. [26] for jasmine oil, Eletreby *et al.* [27] for cinnamon oil, Shaaban and Hussein [28] for clove oil and Xu *et al.* [29] for chitosan.

Minimizing weight loss percentage from essential oil treatments might be attributed to the forming of a thin film of oil surrounding the fruit peel and induced a modification of microclimatic of fruits, the reason for such effect of essence resulted in reducing water losses and reduction in respiration rate [30, 31].

Concerning the favorable effect of jasmine oil in reduction of weight loss, Cao *et al.* [32] suggested that this reduction of weight loss might be associated with stomata closure induced by MeJA.

The favorable effect of chitosan treatment in reducing weight loss may be due to the formation of thin layer covering the fruit, which prevents moisture loss, reduces gas exchange and subsequently inhibits metabolic activities, resulting in lowering weight loss [33].

In general, the interaction between postharvest treatments and storage periods was significant effect on weight loss percentage in the two seasons. After 28 days of storage, the lowest value of weight loss was recorded from heads treated with jasmine oil while the highest ones were obtained from untreated control.

General Appearance (GA): Data in Table (2) show that general appearance (score) of artichoke heads was decreased with the prolongation of storage period. These results were in agreement with those obtained by Mohamedien *et al.* [24]. The decreases in GA of artichoke heads during storage might be due to shriveling, color change and decay [34].

Table 1: Effect of cinnamon, clove, jasmine and chitosan coating on weight loss percentage of artichoke heads during refrigerated storage.

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	0.00 m	0.08 k-m	0.28 h-j	0.68 d-f	0.83 de	0.37 B
Cinnamon oil	0.00 m	0.05 lm	0.19 i-l	0.35 hi	0.54 fg	0.23 CD
Clove oil	0.00 m	0.07 lm	0.26 h-k	0.43 gh	0.65 ef	0.28 C
Jasmine oil	0.00 m	0.04 lm	0.15 j-m	0.29 h-j	0.42 gh	0.18 D
Control	0.00 m	0.86 d	1.79 c	2.99 b	4.11 a	1.95 A
Mean	0.00 E	0.22 D	0.53 C	0.95 B	1.31 A	
			2019			
Chitosan 1%	0.00 o	0.20 l-n	0.27 kl	0.97 e	1.11 d	0.51 B
Cinnamon oil	0.00 o	0.13 mn	0.33 jk	0.61 h	0.76 f	0.37 D
Clove oil	0.00 o	0.17 l-n	0.38 ij	0.74 fg	0.89 e	0.44 C
Jasmine oil	0.00 o	0.09 no	0.24 k-m	0.48 i	0.63 gh	0.29 E
Control	0.00 o	0.95 e	2.21 c	3.38 b	4.58 a	2.23 A
Mean	0.00 E	0.31 D	0.69 C	1.24 B	1.60 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Table 2: Effect of cinnamon, clove, jasmine and chitosan coating on general appearance (score) of artichoke heads during refrigerated storage

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	9.00 a	9.00 a	8.33 ab	7.67 bc	5.00 d	7.80 B
Cinnamon oil	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.60 A
Clove oil	9.00 a	9.00 a	8.33 ab	7.00 c	6.33 cd	7.93 B
Jasmine oil	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.60 A
Control	9.00 a	9.00 a	7.00 c	5.67 d	4.33 e	7.00 C
Mean	9.00 A	9.00 A	8.33 B	7.40 C	6.20 D	
			2019			
Chitosan 1%	9.00 a	9.00 a	7.67 bc	7.00 cd	6.33 d	7.80 B
Cinnamon oil	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.60 A
Clove oil	9.00 a	9.00 a	7.67 bc	7.00 cd	6.33 d	7.80 B
Jasmine oil	9.00 a	9.00 a	9.00 a	8.33 ab	7.67 bc	8.60 A
Control	9.00 a	9.00 a	6.33 d	5.00 e	3.67 f	6.60 C
Mean	9.00 A	9.00 A	7.93 B	7.13 C	6.33 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Concerning the effect of postharvest treatments, data revealed that there were significant differences between postharvest treatments and untreated control during storage. Artichoke heads treated with all postharvest treatments had significantly the highest score of appearance as compared with untreated control. However, artichoke heads sprayed with jasmine oil and cinnamon oil were the most effective treatments for maintaining general appearance with no significant differences between them followed by clove oil and chitosan treatments, while untreated control recorded the lowest ones in this concern. These results were achieved in the two seasons and were in agreement with Chanjirakul *et al.* [35] and Attia and Atress [36] for jasmine oil, Atress and Rashid [37] for clove oil and Ardakani and Mostofi [14] for chitosan.

In this regard, essential oils had positive effects on storage life by reducing fruit decay. Previous reports indicated that fruit decay was reduced during postharvest treatments with volatile compounds in raspberries [38]. Essential oils mainly conjugated to phenolic compounds that accumulate in some plant cells and show useful effect for pathogen control [39].

For jasmine oil Chanjirakul *et al.* [35] reported that a postharvest MeJA treatment maintained higher levels of bioactive compounds and enhanced antioxidant capacity for maintenance fruit quality by reducing decay and enhancing antioxidant activity. As antioxidant content is becoming an increasingly important parameter with respect to fruit and vegetable quality.

Essential oils act as a protective layer of against different Bactria and fungi and therefore stopped up of damaged fruits [40]. It also maintained cell wall carbohydrate metabolism during storage which associated with decreased susceptibility to infection by fungal pathogens and therefore improves quality.

Atress and Rashid [37] showed that clove oil treatment effectively maintained the greater acceptance comparing to control treatment. This acceptance was due to low levels of weight loss, glossy appearance and vivid color imparted by clove oil.

The favorable effect of chitosan treatments in reducing decay of cucumber, may be due to chitosan coating, can inhibit the increase of oxidative enzyme (peroxidase and polyphenol oxidase) activity. An increase in antioxidant enzyme activity and free radical scavenging capacity during storage would reduce the physiological deterioration and enhance the resistance of tissue against microbial invasion and reduce the spoilage of fruit [41].

Chitosan coating is act as a semipermeable barrier on the surface of fruit and vegetables against oxygen, carbon dioxide and moisture, thereby reducing respiration, water loss, respiratory activity and degradation by enzymes and microbial rot of fruits, counteracting the dehydration and shrinkage of the fruit and ethylene production and maintaining the overall quality [42]. Chitosan coatings can also improve the sensory attributes such as appearance and color during the low-temperature storage time [14].

In general, the interaction between postharvest treatments and storage periods was significant in the two seasons. Results recorded that artichoke heads sprayed with jasmine oil and cinnamon oil did not show any changes in GA till 21 days of storage and showed good appearance at the end of storage period (28 days of storage). While, clove oil and chitosan 1% treatments rated good appearance at the same period. On the other hand, untreated control had the poor appearance after 28 days of storage at 0°C.

Table 3: Effect of cinnamon, clove, jasmine and chitosan coating on compactness (score) of artichoke heads during refrigerated storage

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	5.00 a	5.00 a	4.67 ab	4.00 cd	3.67 d	4.47 B
Cinnamon oil	5.00 a	5.00 a	5.00 a	5.00 a	4.33 bc	4.87 A
Clove oil	5.00 a	5.00 a	5.00 a	4.33 bc	4.00 cd	4.67 AB
Jasmine oil	5.00 a	5.00 a	5.00 a	5.00 a	4.67 ab	4.93 A
Control	5.00 a	4.67 ab	3.67 d	3.00 e	2.33 f	3.73 C
Mean	5.00 A	4.93 AB	4.67 B	4.27 C	3.80 D	
			2019			
Chitosan 1%	5.00 a	5.00 a	4.33 bc	3.33 ef	3.00 fg	4.13 B
Cinnamon oil	5.00 a	5.00 a	5.00 a	4.33 bc	4.00 cd	4.67 A
Clove oil	5.00 a	5.00 a	4.67 ab	4.00 cd	3.67 de	4.47 A
Jasmine oil	5.00 a	5.00 a	5.00 a	4.33 bc	4.33 bc	4.73 A
Control	5.00 a	4.33 bc	3.33 ef	2.67 g	2.00 h	3.47 C
Mean	5.00 A	4.87 A	4.47 B	3.73 C	3.40 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Table 4: Effect of cinnamon, clove, jasmine and chitosan coating on discoloration (score) of artichoke heads during refrigerated storage

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	1.00 f	1.00 f	1.33 ef	2.00 d	3.00 c	1.67 B
Cinnamon oil	1.00 f	1.00 f	1.00 f	1.33 ef	1.67 de	1.20 CD
Clove oil	1.00 f	1.00 f	1.33 ef	1.67 de	2.00 d	1.40 BC
Jasmine oil	1.00 f	1.00 f	1.00 f	1.00 f	1.33 ef	1.07 D
Control	1.00 f	1.33 ef	2.67 c	3.67 b	4.67 a	2.67 A
Mean	1.00 D	1.07 D	1.47 C	1.93 B	2.53 A	
			2019			
Chitosan 1%	1.00 i	1.00 i	1.67 gh	2.67 de	3.33 c	1.93 B
Cinnamon oil	1.00 i	1.00 i	1.00 i	1.67 gh	2.00 fg	1.33 CD
Clove oil	1.00 i	1.00 i	1.67 gh	2.00 fg	2.33 ef	1.60 C
Jasmine oil	1.00 i	1.00 i	1.00 i	1.00 i	1.67 gh	1.13 D
Control	1.00 i	1.67 gh	3.00 cd	4.33 b	5.00 a	3.00 A
Mean	1.00 D	1.13 D	1.67 C	2.33 B	2.87 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Compactness: Data in Table (3) showed that compactness (score) of artichoke heads was significantly decreased with the prolongation of storage period. These results were in agreement with Mohamedien *et al.* [24]. The decreases in compactness of heads during storage may be due to water loss and a decrease in firmness [43].

Regarding the effect of postharvest treatments, data revealed that there were significant differences between postharvest treatments and untreated control. The highest score of head compactness were obtained by artichoke heads sprayed with jasmine oil, cinnamon oil and clove oil with no significant differences between them, followed by chitosan treatment, while the lowest values of head compactness score were recorded from untreated control. These results were achieved in the two seasons.

In general, the interaction between postharvest treatments and storage periods was significant in the two seasons. After 28 days of storage, artichoke heads sprayed with jasmine oil and cinnamon oil resulted in higher compactness score with no significant differences between them, while untreated control gave the lowest ones in the same period in the two seasons.

Discoloration: Data in Table (4) show that there was an increment in discoloration for the cut surface of artichoke heads as the storage period was prolonged in the two

Table 5: Effect of cinnamon, clove, jasmine and chitosan coating on color (L. value) of artichoke heads during refrigerated storage.

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	46.11 a	45.25 a-c	44.65 a-d	42.85 d-g	41.35 fg	44.04 B
Cinnamon oil	46.11 a	45.67 a	45.03 a-d	44.16 a-e	43.21 b-f	44.84 AB
Clove oil	46.11 a	45.49 ab	44.82 a-d	43.02 c-f	42.11 e-g	44.31 B
Jasmine oil	46.11 a	46.04 a	45.65 a	45.07 a-d	44.37 a-e	45.45 A
Control	46.11 a	44.17 a-e	42.27 e-g	40.63 g	37.71 h	42.18 C
Mean	46.11 A	45.33 AB	44.48 B	43.15 C	41.75 D	
			2019			
Chitosan 1%	45.37 a	44.36 a-c	43.85 a-e	42.07 f-h	40.63 hi	43.26 C
Cinnamon oil	45.37 a	44.96 ab	44.39 a-c	43.26 c-f	42.74 d-g	44.14 AB
Clove oil	45.37 a	44.65 a-c	44.15 a-d	42.45 e-g	41.59 gh	43.64 BC
Jasmine oil	45.37 a	45.28 a	44.91 ab	44.32 a-d	43.61 b-f	44.70 A
Control	45.37 a	43.39 b-f	41.47 gh	39.75 i	36.92 j	41.38 D
Mean	45.37 A	44.53 B	43.75 C	42.37 D	41.10 E	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

seasons. These results were in agreement with those obtained by Atala [44]. The change in color development is related primarily to the oxidation of phenolic compounds to o-quinones, a reacting catalyzed by polyphenol oxidase (PPO). Quinones then polymerize to dark brown, black or red polymers. Moreira *et al*. [45] reported that PPO activity increased when broccoli florets were separate and that the activity of phenolase was closely associated with the development of browning.

Concerning the effect of postharvest treatments, data revealed that all treatments reduced the incidence of discoloration compared to untreated control. Artichoke heads treated with all postharvest treatments had significantly the lowest score of discoloration as compared with untreated control. However, artichoke heads sprayed with jasmine oil and cinnamon oil were the most effective treatments in prevented discoloration, which showed the lower score of discoloration with no significant differences between them, followed by clove oil and chitosan treatments with no significant differences between them in the first season. On the contrary, untreated control showed the higher score in discoloration during storage. These results were achieved in the two seasons.

The lower PPO activity may be due to the antioxidant activity of essential oils as cinnamon oil [46].

Delay in color change might be due to the other component in cinnamon oil which could be able to delay, retard, or prevent oxidation processes of phenolic compounds by reacting with free radicals, chelating metals and acting as oxygen scavengers [47].

Badawy and Rabea [48] reported that chitosan coating could provide the ability to remove the metal ions and has the potential effect used to inhibit the PPO activity in litchi fruit. The coordinated action of SOD and POD, two important oxyradical detoxification enzymes in fruits, could help to reduce the oxidative damage in regeneration of ascorbate and glutathione metabolites [49]. Chitosan coating could induce the activities of defense-related enzymes and promote the protection for fruits [50].

In general, the interaction between postharvest treatments and storage periods was significant in the two seasons. Results recorded that artichoke heads sprayed with jasmine oil did not show any changes in discoloration and gave none to slight score of discoloration at the end of storage period. Cinnamon oil and clove oil treatments gave a slight score after 28 days of storage. Chitosan treatment gave moderate score at the same period. On the other hand, untreated control resulted in severe discoloration with the highest score after 28 days of storage at 0°C. These results were achieved in the two seasons.

Color (L value): Changes in lightness (L value) were observed during storage compared to initial value. Lightness of artichoke heads was affected by storage time. A decrement in L value was detected by prolonging the storage period (Table 5), resulted darker color. These results were achieved in the two seasons and in agreement with Mohamedien *et al.* [24] on artichoke heads. Ardakani and Mostofi [14] showed that decreasing in L value relates to water loss in fruit.

Table 6: Effect of cinnamon, clove, jasmine and chitosan coating on color (hue angle hº) of artichoke heads during refrigerated storage.

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	96.31 a	95.66 a-d	94.07 c-g	92.71 f-h	89.85 jk	93.72 C
Cinnamon oil	96.31 a	95.86 a-c	94.62 a-e	93.89 d-g	92.33 g-i	94.60 AB
Clove oil	96.31 a	95.74 a-d	94.29 b-f	93.05 e-h	90.64 ij	94.01 BC
Jasmine oil	96.31 a	96.08 ab	95.59 a-d	94.75 a-e	93.59 e-g	95.26 A
Control	96.31 a	94.12 c-g	91.44 hij	88.67 k	85.78 l	91.26 D
Mean	96.31 A	95.49 A	94.00 B	92.61 C	90.44 D	
			2019			
Chitosan 1%	95.08 a	94.41 a-d	92.85 c-g	91.46 f-h	88.67 jk	92.49 C
Cinnamon oil	95.08 a	94.61 a-c	93.34 a-f	92.65 d-g	91.12 g-i	93.36 AB
Clove oil	95.08 a	94.46 a-d	92.93 b-g	91.64 e-h	89.27 i-k	92.67 BC
Jasmine oil	95.08 a	94.81 ab	94.35 a-d	93.46 a-e	92.37 e-g	94.01 A
Control	95.08 a	92.91 c-g	90.21 h-j	87.48 k	84.54 l	90.04 D
Mean	95.08 A	94.24 A	92.73 B	91.34 C	89.20 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Concerning the effect of postharvest treatments, data showed that there were significant differences among postharvest treatments and untreated control during storage. Artichoke heads sprayed with jasmine oil and cinnamon oil being the most effective treatments in maintaining the L values, resulted lighter color (high L value) with no significant differences between them in the two seasons, while untreated control give the lowest one of L values during storage in the two seasons, resulted in darker color (low L value). The other treatments were less effective in this concern. These results were agreement with Attia and Atress [36] for jasmine oil, Eletreby *et al.* [27] for cinnamon oil; Shaaban and Hussein [28] for cinnamon oil and clove oil and Ardakani and Mostofi [14] for chitosan.

Lightness (L*) shows the darkness or brightness of the fruit color, in a way that reduced L* coincides with the darkening of fruits. Although the Essential oils mechanism in maintaining Lightness is unknown, retarding of ripening might be the main factor [51]. Maintenance of L* in treated fruits can also be related to reduction of weight loss [52].

Color (Hue Angle Values): Changes in hue angles of artichoke heads are good indicator of senescence. As shown in Table (6) showed that the hue angle values of artichoke heads gradually decreased as the storage period extended, indicating that artichoke heads turned to slight yellow as the storage period prolonged. These results were true in the two seasons and in agreement with [44, 24].

Concerning the effect of postharvest treatments, data showed that all treatments had significantly higher hue angle values as compared with untreated control. Heads sprayed with jasmine oil and cinnamon oil were the most effective treatments in reducing the loss of hue angle values indicated that heads retained more green color (higher value of hue angle) with no significant differences between them in the two seasons during storage. On the other hand, untreated control gave the lower value of hue angle as an important de-greening or intense yellowing. These results were true in the two seasons and in agreement with Eletreby *et al.* [27] for cinnamon oil; Shaaban and Hussein [28] for cinnamon oil and clove oil and Ahmed *et al.* [15] for chitosan.

This may be due to the effect of essential oil on the physiological processes involved the degradation of chlorophyll (decreased activity of chlorophyllase and consequence reduced color change Eletreby *et al.* [27]. Also, Shaaban and Hussein [28] found that essential oil delayed fruits ripening and senescence which indicated as decrease in color development.

Maintaining of green color of fruit during storage by using chitosan may be attributed to chitosan reduced the respiration rate resulted in lower activity of chlorophyllase, thus reduced color change [53].

Ascorbic Acid Content: Data in Table (7) showed that ascorbic acid content of heads was significantly decreased with the prolongation of storage period. Similar results were obtained by Mohamedien *et al.* [24].

Table 7: Effect of cinnamon, clove, jasmine and chitosan coating on ascorbic acid content (mg/100gm f.w) of artichoke heads during refrigerated storage.

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	82.73 a	82.13 ab	80.73 a-d	78.20 c-g	75.97 gh	79.95 B
Cinnamon oil	82.73 a	82.40 a	81.53 a-c	79.60 a-f	78.07 d-g	80.87 AB
Clove oil	82.73 a	82.27 ab	81.27 a-d	78.87 b-g	76.37 f-h	80.30 AB
Jasmine oil	82.73 a	82.47 a	81.93 ab	80.93 a-d	79.80 a-e	81.57 A
Control	82.73 a	80.11 a-e	77.00 e-h	73.60 h	69.53 i	76.60 C
Mean	82.73 A	81.88 AB	80.49 B	78.24 C	75.95 D	
			2019			
Chitosan 1%	80.53 a	79.53 ab	78.33 a-c	75.80 c-f	73.60 fg	77.56 B
Cinnamon oil	80.53 a	80.07 a	79.20 a-c	77.33 a-e	75.73 c-f	78.57 AB
Clove oil	80.53 a	79.80 ab	78.80 a-c	76.33 b-f	73.80 e-g	77.85 AB
Jasmine oil	80.53 a	80.13 a	79.60 ab	78.60 a-c	77.47 a-d	79.27 A
Control	80.53 a	77.73 a-d	74.47 d-g	71.00 g	66.87 h	74.12 C
Mean	80.53 A	79.45 AB	78.08 B	75.81 C	73.49 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

The reduction in ascorbic acid contents during storage may be due to the higher rate of sugar loss through respiration than the water loss through transpiration [25].

Regarding the effect of postharvest treatments, data showed that all treatments had significantly higher ascorbic acid content as compared with untreated control. Heads sprayed with jasmine oil; cinnamon oil and clove oil were the most effective treatments in maintaining ascorbic acid content with no significant differences between them in the two seasons. The lowest values resulted in untreated control. These results were achieved in the two seasons and were in agreement with those obtained by Zhang *et al.* [54] for jasmine oil, Shaaban and Hussein [28] for cinnamon oil and clove oil and Suseno *et al.* [16] for chitosan.

Cinnamon oil as the anti-browning agents provides better preserve on the vitamin C contents in fruits. Also, vitamin C in fruits might be protected by antioxidant activity of cinnamon oil [55].

The higher level of ascorbic acid in chitosan-coated fruits might reflect the low oxygen permeability, which reduced the activity of the enzymes involved in the oxidation of ascorbic acid [56]. Also, Hong *et al.* [57] found that modified atmosphere created by chitosan coating (low O_2 and high Co_2) suppresses the loss of ascorbic acid content during storage.

Coverings such as chitosan increase the activity of cytochrome oxidase by decreasing the internal O_2 in fruits and this enzyme can decrease significantly the decomposition rate of ascorbic acid [58]. Mahmoud *et al.* [17] found that chitosan treatment succeeded to inhibit damage which causing oxidation of ascorbic acid in Navel orange during storage in both seasons. While, the minimum of vitamin C in control fruits probably due to physiological disorders, decay and weight loss which led to rapid the oxidation reaction in vitamin C, so decreased and showed the lowest level in control fruits.

In general, the interaction between postharvest treatments and storage periods was no significant in the two seasons. After 28 days of storage, artichoke heads sprayed with jasmine oil and cinnamon oil resulted in higher ascorbic acid content with no significant differences between them in the two seasons, while untreated control gave the lowest ones in the same period in the two seasons.

Inulin Content: Data in Table (8) showed that inulin content of heads was significantly decreased with the prolongation of storage period. Similar results were obtained by Atala [44]. The loss of inulin content during the storage period may be attributed to respiration and other senescence related metabolic processes during storage [25].

Regarding the effect of postharvest treatments, data revealed that artichoke heads sprayed with jasmine oil; cinnamon oil and clove oil were the most effective treatments in maintaining inulin content with no significant differences between them followed by chitosan at 1%. The lowest values resulted in untreated control. These results were achieved in the two seasons and were in agreement with those obtained by Wang [38] for jasmine oil; Ibraheim *et al.* [59] for clove oil and Haggag *et al.* [60] for chitosan.

Table 8: Effect of cinnamon, clove, jasmine and chitosan coating on inulin content (g/100gm d.w) of artichoke heads during refrigerated storage.

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	15.84 a	15.39 a-d	14.63 b-g	14.17 e-i	13.43 hi	14.69 B
Cinnamon oil	15.84 a	15.51 a-c	15.02 a-f	14.57 b-g	13.94 f-i	14.97 AB
Clove oil	15.84 a	15.46 a-d	14.79 a-g	14.35 d-h	13.71 g-i	14.83 AB
Jasmine oil	15.84 a	15.63 ab	15.24 a-e	15.03 a-f	14.44 c-h	15.24 A
Control	15.84 a	14.71 b-g	13.12 ij	12.31 j	10.97 k	13.39 C
Mean	15.84 A	15.34 A	14.56 B	14.08 B	13.30 C	
			2019			
Chitosan 1%	15.49 a	15.02 a-d	14.28 b-g	13.79 e-i	13.06 hij	14.33 B
Cinnamon oil	15.49 a	15.14 a-c	14.67 a-f	14.19 b-h	13.58 f-i	14.61 AB
Clove oil	15.49 a	15.08 a-d	14.39 a-g	13.91 d-h	13.22 g-i	14.42 AB
Jasmine oil	15.49 a	15.27 ab	14.86 a-e	14.61 a-f	14.04 c-h	14.85 A
Control	15.49 a	14.34 a-g	12.68 ij	11.89 j	10.51 k	12.98 C
Mean	15.49 A	14.97 A	14.17 B	13.68 B	12.88 C	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Table 9: Effect of cinnamon, clove, jasmine and chitosan coating on total microbial count (log CFU/g) of artichoke heads during refrigerated storage

	Storage period (days)					
	2018					
Treatments	0	7	14	21	28	Mean
Chitosan 1%	0.45 o	1.12 k-m	1.77 hi	2.13 fg	2.40 e	1.57 B
Cinnamon oil	0.45 o	0.92 mn	1.20 k	1.77 hi	2.10 fg	1.29 D
Clove oil	0.45 o	0.99 l-n	1.43 j	1.89 h	2.30 ef	1.41 C
Jasmine oil	0.45 o	0.90 n	1.17 kl	1.57 ij	1.97 gh	1.21 D
Control	0.45 o	2.70 d	3.30 c	4.57 b	5.27 a	3.26 A
Mean	0.45 E	1.33 D	1.77 C	2.38 B	2.81 A	
			2019			
Chitosan 1%	0.65 o	1.27 k-m	1.83 hi	2.13 fg	2.70 d	1.72 B
Cinnamon oil	0.65 o	1.02 mn	1.50 jk	1.93 gh	2.43 de	1.51 C
Clove oil	0.65 o	1.09 l-n	1.63 ij	2.07 gh	2.53 de	1.60 BC
Jasmine oil	0.65 o	0.92 no	1.32 kl	1.87 g-i	2.00 gh	1.35 D
Control	0.65 o	2.40 ef	3.11 c	4.36 b	5.37 a	3.18 A
Mean	0.65 E	1.34 D	1.88 C	2.48 B	3.01 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test

Wang [38] found that treating raspberries with methyl jasmonate (MJ) enhanced the soluble sugar content and slowed the loss of organic acids.

Daniels *et al.* [61] found that using eucalyptus essential oil in storing potatoes for long period gave the highest level of sucrose and reducing sugars. Also accumulations of reducing and non- reducing sugars are affected by essential oils concentration and time of application- dependent.

The reduction of inulin loss of heads during storage by using chitosan treatment may be attributed to these materials reduced the ethylene production by fruit thus respiration rate and enzymatic activity resulted in reducing consumption of inulin during storage [62].

In general, the interaction between postharvest treatments and storage periods was no significant in the two seasons. After 28 days of storage, artichoke heads sprayed with jasmine oil, cinnamon oil, clove oil and chitosan 1% resulted in higher inulin content with no significant differences between them while, untreated control gave the lowest ones in the same period. These results were true in the two seasons.

Total Microbial Count: Data in Table (9) indicate that microbial growth in artichoke heads increased significantly with increasing the storage period particularly in untreated control. These results were true in the two seasons. Similar results were reported by Ibraheim *et al.* [59] on Jerusalem artichoke.

Concerning the effect of postharvest treatments, data revealed that there were significant differences in microorganism growth between all postharvest treatments and control. The artichoke heads treated with all used treatments had lower levels of microbial load in comparison to control treatment. Artichoke heads sprayed with jasmine oil and cinnamon oil provided the lowest count in all types of microorganisms with no significant differences between them in the first season followed by clove oil and chitosan. Untreated control had higher levels of microbial load. These results were true in the two seasons and agree with Ghasemnezhad and Javaherdashti [63] for jasmine oil; Salvador-Figueroa *et al.* [64] for cinnamon oil; Shaaban and Hussein [28] for clove oil and Chong *et al.* [65] for chitosan.

Also, the active component of essential oils contains more phenol compounds that had a great antifungal activity and phenol compounds could affect the enzymes responsible for spore germination of fungi and have also been recognized as bioactive components, this leading to improve storability and extend market life of plum fruits [66, 67].

Ghasemnezhad and Javaherdashti [63] demonstrated that MeJA increases the resistance of tissues against decay by enhancing their antioxidant system and their free radical scavenging capability.

Salvador-Figueroa *et al.* [64] showed that the effect of major compounds responsible for the antimicrobial activity of cinnamon oil were cinnamaldehyde, linalool, eugenol and cineol.

The antimicrobial of chitosan is probably caused by the interaction between chitosan and the microbial cell membranes, which leads to the leakage of proteinaceous and other intracellular constituents. Chitosan can also penetrate to the nuclei of fungi and interferes with RNA and protein synthesis [68]. Also, this was probably due to the fungicidal action of chitosan that caused alteration in the function of the cellular membrane [69].

Concerning the interaction between postharvest treatments and storage periods, data revealed that Artichoke heads sprayed with jasmine oil and cinnamon oil were the most effective treatments in reducing the levels of microbial load followed by clove oil with no significant differences between them, while untreated control had the highest value of microbial count after 28 days of storage at 0°C in the two seasons.

CONCLUSION

Artichoke heads sprayed with jasmine oil and cinnamon oil treatments produced an improvement in market quality; it would reduce weight loss percentage, color change, total microbial count and maintained ascorbic acid content and inulin content and did not show any change in general appearance till 21 days of storage and showed good appearance at the end of storage period (28 days of storage) at 0°C and 95% RH.

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