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Effect of some Natural Substances on Fruit Quality of Washington Navel Orange under Cold Storage

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Authors' contributions

This work was carried out in collaboration between all authors. Author CON designed the study, performed the statistical analysis. Author ENE performed the experiment and wrote the first draft of the manuscript. Author CEU managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To study the response of Washington navel orange fruits to some natural post harvest treatments under cold storage.
Study Design: A randomized complete block design with three replicates was used.
Place and Duration of Study: This study was carried out during two successive seasons 2013 and 2014 in the post harvest laboratory of Agricultural Development System project in Faculty of Agriculture, Cairo University, Egypt.
Methodology: Harvested fruits were directly transferred to the laboratory. Experimental fruits were divided into six similar groups. Each group was subjected to one of the following treatments: Control tap water plus tween (80), Black cumin oil at 2%, Black cumin oil at 3%, Ginger oil at 2%, Ginger oil at 3% and Wax. Fruits were stored at 5℃ and 85-90% relative humidity for 63 days. Changes in some physical and chemical fruit properties were determined at seven days intervals.
Results: The results showed that, fruit weight loss (%), decay (%), total soluble solids (TSS) percentage and respiration rate (ml/kg/h) of Washington navel orange fruits were increased in most

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cases with advancing the storage period. Meanwhile, total acidity (%) and ascorbic acid (V.C) as (mg/100 ml juice) were decreased with prolonging the storage period. Furthermore, the lowest values of weight loss (%), decay (%), ascorbic acid, respiration rate and fruit shelf life (days) were scored by wax treatment, as well as, the best results of total soluble solids with the same bare with control especially in the first season. Meanwhile the lowest total acidity content was gained by the control.

Conclusion: Treatment of Washington navel orange fruits with wax proved to be the most efficient treatment in enhances fruit quality and storability under cold storage.

Keywords: Washington navel orange; post harvest; ginger oil; black cumin oil; wax; fruit quality.

1. INTRODUCTION

Orange industry is important for Egyptian national income. Although orange occupies the greatest planted area among all fruit area of citrus grown in Egypt, the exportation of fresh orange fruits to foreign markets are still limited compared with the produced quantity. Therefore, any effort directed towards maintaining fruit quality and reducing post harvest losses is important for increasing our national income.

No doubt that the process of fruit handling and storage for local market and export is as important as horizontal and vertical extension of agriculture production. The storage life of most fruits is lengthened, if they are cooled quickly after harvest. Temperature has a direct effect on the respiration rates of fruits and on the activity of decay caused by microorganisms. Generally, low storage temperatures are used to extend fruit postharvest life [1].

Postharvest diseases, such as soft rot of fruits, due to fungal infections cause significant economic losses for the citrus industry during storage, transport and marketing [2]. The main method to control postharvest diseases is based on application of synthetic chemical products. However, nowadays consumers desire for fruit, free from synthetic chemical residues is a driving cause for a trend towards reduced using of post harvest chemicals.

Application of essential oil is a very attractive method for controlling postharvest diseases. Production of essential oils by plants is believed to be predominantly a defense mechanism against pathogens and pests and indeed, essential oils have been shown to possess antimicrobial and antifungal properties [3]. Essential oils and their components are gaining increasing interest because of their relatively safe status, their wide acceptance by consumers and their exploitation for potential multi-purpose functional use [4].

Essential oils are made up of many different volatile compounds and the composition of the oil quite often varies between species [5]. It is difficult to associate the antifungal activity to single compounds or classes of compounds. It seems that the antifungal and antimicrobial effects are the result of many compounds acting synergistically [6]. Thus, there would be negligible chance of development of resistant races of fungi after application of essential oils to fruit and vegetables. As a consequence essential oils are one of the most promising candidate groups of natural compounds for the development of safer antifungal agents.

The essential oil of ginger *(Zingiber officinale)* have shown significant fungi toxic activity and enhanced the shelf life of grapes during storage by protecting them from grey mould [7]. Also, spraying citrus fruits at different concentrations (500-5000 ppm) of ginger ethanol extract has improved postharvest quality characteristics in the store by reducing the weight loss and numbers of the undesirable fruits [8]. Furthermore, Edible starch-based coating including black cumin (*Nigella sativa*) oil appeared to be a good mixture for maintaining the quality of pomegranate fruits during storage [9]. The actual use of natural products for the control of postharvest pathogens of fruits generally and in particular for citrus pathogens is however still limited [10].

The coatings have emerged as an emerging technology for post harvest storage, shelf life extension and improvement of fruit quality. Its use lies in generating a modified atmosphere in order to reduce weight loss, color, texture and firmness of the fruit after harvest that affect the growth of post harvest losses.

Wax coating on citrus fruit is often using to increase glossiness of the peel and to reduce

fruit weight loss. Moreover, waxing of the fruits reduce chilling injury. However, it may cause off flavor development and peel disorder [11].
The purpose of this research is to study the possibility of using essential oils from ginger and black cumin and commercial wax to reduce fruit decay and weight losses and maintain fruit quality of Washington navel orange.

2. MATERIALS AND METHODS

2.1 Fruit Material, Post Harvest Treatments and Storage Period

This study was conducted during two successive seasons of 2013 and 2014 on mature Washington navel orange fruits, to evaluate the effect of emulsifying fruits with some natural products on physical and chemical properties under cold storage.

Harvested fruits were directly transferred to the laboratory at the Agricultural Development System (ADS) project, Faculty of Agriculture, Cairo University.

Defective fruits including wounded and other disorders were excluded, the remained fruits were washed with tap water and air dried.

Experimental fruits were divided into six similar groups. Each group was subjected to one of the following treatments:

1- Control (tap water plus tween 80)
2- Black cumin oil at 2%
3- Black cumin oil at 3%
4- Ginger oil at 2% (commercial)
5- Ginger oil at 3% (commercial)
6- Wax (commercial wax)

The oil emulsion of ginger or black cumin were prepared by mixing oil with tween 80 in water according to Ju et al. [12].

Each treatment was replicated three times and each replicate was about 5kg weight putted as one layer in a carton box (60X40X15). Experimental boxes were stored at 5˚C and 85 - 90% relative humidity for 63 days.

Changes in some physical and chemical fruit properties were determined at seven days intervals.

2.2 Measurements

2.2.1 Fruit physical properties

2.2.1.1 Fruit weight loss percentage

The initial weight of Washington navel orange fruits was recorded in each treatment and on weekly intervals, then fruit weight loss percentage was calculated using the following formula:

$$\textbf{Fruit weight loss}\ (\%) = \frac{\text{Initial weight} - \text{Weight at specific interval}}{\text{Initial weight}} x100$$

2.2.1.2 Fruit decay percentage

The decayed fruits of each treatment were discarded and weighed. The weight of such discarded fruits related to the initial weight of fruits per each treatment was estimated and decay percentage was calculated using the following formula:

$$\textbf{Decay Percentage}\ (\%) = \frac{\text{Weight of discard fruits}}{\text{Initial weight}} x100$$

2.2.2 Fruit chemical properties

Total soluble solids (TSS %) of fruit juice were measured using a hand refractometer. The total soluble solids were expressed as a percent. Moreover, fruit titratable acidity measured as (grams of citric acid per 100 ml of juice and ascorbic acid (V.C) content shown as (milligrams ascorbic acid per 100 ml fruit juice). Besides, respiration rate was measured by carbon dioxide produced from the fruits after harvest, then every two weeks and at the end of cold storage and CO_2 levels produced by the fruit were calculated as ml CO2/ kg fruits/hr according to AOAC [13].

2.2.3 Shelf life (days)

At the end of cold storage period, samples of the treated fruits were taken and left at room conditions (20±5˚C and 70-75% R.H.) and the number of days at which treated fruits still with good appearance were counted and shelf life was determined.

2.3 Statistical Analysis

Data obtained in the two studied seasons were subjected to the analysis of variance according to Snedecor and Cochran [14], least significant differences (L.S.D.) was used to differentiate the obtained values.

3. RESULTS AND DISCUSSION

3.1 Effect of Post Harvest Treatments on Fruit Physical Properties

3.1.1 Fruit weight loss percentage

Table 1 illustrated that, all tested treatments succeeded in reducing weight loss percentage of Washington navel orange fruits. Generally, wax treatment proved to be the most efficient treatment in reducing weight loss percentage, followed descendingly by ginger oil at 3% treatment. Moreover, control treatment scored significantly the highest fruit weight loss percentage in both seasons.

In regard to the effect of storage period, Table 1 showed that, fruit weight loss percentage was increased with advancing the storage period under cold storage at 5 ℃, so seven days storage period scored the lowest values, while the highest values was gained after sixty three days storage period. The rest storage period registered an intermediate values in comparison with the previously two mentioned categories. The differences between the evaluated storage periods were so high to be significant.

Referring to the interaction effect between the tested post harvest treatments and storage period, results revealed that, the lowest fruit weight loss percentages were registered by the combinations of seven days cold storage period, especially ginger oil at 3% treated fruits in the first season and black cumin oil 3% in the second one. The highest fruit weight loss percentages were obtained by the interactions of sixty three days cold storage period, particularly control fruits in both seasons. The remained interactions of the tested storage periods came in between them.

The loss in fruit weight percentage is mainly due to water loss as a result of evaporation and transpiration and the amount of dry matter was lost by respiration.

The effect of ginger essential oil in reducing fruit weight losses of Washington navel orange go in line with findings of [8] on citrus and [15] on tomatoes. They mentioned that ginger extract reduced physiological fruit weight loss. Moreover, Oz and Ulukanl [9] showed that treatments with 300 and 600 ppm black cumin oil greatly reduced weight loss of pomegranate fruits.

Table 1. Effect of post harvest treatments on weight loss percentage of Washington navel orange fruits under cold storage at 5℃ during 2013 and 2014 seasons

Season 2013										
	Storage periods (days)									
Treatment	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	0.69	1.32	1.96	2.55	3.13	4.27	5.31	6.53	8.23	3.78 A
Ginger oil at 2%	0.63	1.16	1.69	2.36	3.00	4.00	4.62	5.56	7.03	3.34 D
Ginger oil at 3%	0.60	1.13	1.72	2.38	2.68	3.82	4.36	5.31	6.97	3.22 E
Black cumin oil at 2%	0.75	1.30	2.05	2.51	3.07	4.05	4.81	5.72	7.33	3.51 B
Black cumin oil at 3%	0.67	1.30	1.84	2.47	2.85	4.00	4.67	5.92	7.10	3.43 C
Wax	0.63	1.13	1.34	1.76	2.49	3.10	3.86	4.56	5.30	2.69 F
Mean	0.66 I	1.22 H	1.77 G	2.34 F	2.87 E	3.87 D	4.61 C	5.60 B	7.00 A	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.229										
Season 2014										
Treatment	**7**	14	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	0.51	1.09	1.72	2.56	3.40	4.40	5.06	6.00	7.81	3.62 A
Ginger oil at 2%	0.51	1.00	1.67	2.22	3.23	3.84	4.53	5.23	6.32	3.17 C
Ginger oil at 3%	0.53	1.00	1.57	2.07	3.00	3.75	4.39	4.89	6.10	3.03 D
Black cumin oil at 2%	0.53	1.06	1.73	2.46	3.31	4.00	4.66	5.61	6.80	3.35 D
Black cumin oil at 3%	0.50	1.06	1.70	2.33	3.31	3.81	4.51	5.20	6.14	3.17 C
Wax	0.52	1.02	1.50	1.93	2.47	3.12	3.82	4.53	5.67	2.73 E
Mean	0.52 I	1.04 H	1.65 G	2.26 F	3.12 E	3.82 D	4.50 C	5.24 B	6.47 A	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.280										

3.1.2 Fruit Decay percentage

Data in Table (2) demonstrated that, wax treatment showed to be the superior one in reducing fruit decay percentage followed by ginger oil at 3% treatment when compared with other treatments in both seasons. Looking to the effect of storage period, Table 2 indicated that, fruit decay percentage of Washington navel orange was increased as the storage period prolonged. So, sixty three days of cold storage period scored the highest values in this concern.

Regarding to the interaction effect between the tested postharvest treatments and storage period, it is obvious from Table 2 that, all combination of seven, fourteen and twenty one days cold storage duration (irrespective the control at twenty one days in the second season) succeeded in preventing fruit decay percentage. On contrary, the highest fruit decay percentages were observed by the interactions of sixty three days cold storage period, particularly control fruits in both seasons. The remained interactions of the tested storage periods came in between them.

Application of essential oils for postharvest disease control of fresh product, as a novel emerging alternative to hazardous anti-fungal treatments will allow a safer and environmentally more acceptable management of post harvest diseases [16]. The inhibitory effects of plant oils might be regarded to which act as cidal agent against fungal growth and showed abnormal conidia and malformations as swollen, often septated and pale color of hypha [17]. In addition, some essential oils showed inhibitory effect on pectinase and cellulose enzymes [18,19]. Pectinase and cellulase enzymes produced by fruit rotting fungi play a prominent role in disease development during host pathogen interaction [20]. Therefore, essential oils can inhibits the fungi growth by acting on enzymes related to an early stage pathogenesis in the fruits. Some studies related the antifungal property of essential oils to their major compounds especially phenolic compounds such as thymol and carvacrol [21,22,23]. On the other hand, Ginger oil has been recommended by Chinese medicine for over 2,500 years. It was called the universal medicine. The antifungal activity of its oil is well documented [24].

The obtained results of ginger and black cumin essential oils in reducing fruit decay of Washington navel orange are in harmony with the analogous ones mentioned by[8,10] on citrus, [7] on grapes, [25] on mango, [26] on date palm and [9] on pomegranate. They mentioned that ginger or black cumin essential oils was more effective in controlling spoilage microorganisms and decreased the decay.

Table 2. Effect of post harvest treatments on decay percentage of Washington navel orange fruits under cold storage at 5℃ during 2013and 201 4 seasons

Season 2013										
Treatment	**Storage periods (days)**									
	7	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	0.00	0.00	0.00	3.29	8.96	19.47	28.43	39.21	52.51	16.87 A
Ginger oil at 2%	0.00	0.00	0.00	1.80	5.06	14.47	24.55	32.26	40.30	13.16 BC
Ginger oil at 3%	0.00	0.00	0.00	1.68	3.52	11.67	20.86	31.07	39.83	12.07 CD
Black cumin oil at 2%	0.00	0.00	0.00	3.97	5.47	14.41	26.84	34.25	45.73	14.52 B
Black cumin oil at 3%	0.00	0.00	0.00	1.79	3.50	12.13	26.51	33.88	42.70	13.39 BC
Wax	0.00	0.00	0.00	0.00	3.25	10.22	20.29	28.08	32.71	10.51 D
Mean	0.00 G	0.00 G	0.00 G	2.09 F	4.96 E	13.73 D	24.58 C	33.13 B	42.30 A	
L.S.D for the interaction effect between treatments and storage periods at 5%=5.00										
Season 2014										
Treatment	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	0.00	0.00	1.73	1.73	7.11	19.21	30.18	42.13	50.63	16.97 A
Ginger oil at 2%	0.00	0.00	0.00	1.76	5.20	14.07	26.32	34.25	42.91	13.83 BC
Ginger oil at 3%	0.00	0.00	0.00	2.10	3.54	12.27	24.21	31.54	40.18	12.65 CD
Black cumin oil at 2%	0.00	0.00	0.00	3.48	5.35	16.71	28.62	36.36	45.37	15.10 B
Black cumin oil at 3%	0.00	0.00	0.00	2.10	5.24	14.20	25.84	33.79	42.15	13.70 BC
Wax	0.00	0.00	0.00	0.00	3.61	12.94	21.72	29.55	36.98	11.64 D
Mean	0.00 F	0.00 F	0.29 F	1.86 F	5.01 E	14.90 D	26.15 C	34.60 B	43.04 A	
L.S.D for the interaction effect between treatments and storage periods at 5%=4.99										

3.2 Effect of Post Harvest Treatments on Fruit Chemical Properties

3.2.1 Total soluble solid percentage (TSS)

It was obvious from results in Table 3 that, TSS percentage of Washington navel orange was greatly affected by using all examined postharvest treatments in both seasons. Anyway, the highest values of TSS were scored by untreated fruits (control) on the same bare with wax treatment in the first season, while, in the second one control gave the highest value of TSS followed by wax treatment.

Regarding the effect of cold storage periods, data in Table 3 cleared that, TSS percentage was increased with increasing cold storage period till reach the maximum increasing after seven weeks in the first season and eight weeks in the second one. With respect to interaction effect between postharvest treatments and cold storage periods, results in Table 3 declared that, all combinations of the storage periods succeeded in increasing TSS of Washington navel orange fruits. However, the highest fruits TSS content was observed by wax treated fruits under cold storage for nine weeks in the first season, and those of untreated fruits after cold storage for seven weeks at the second one.

3.2.2 Acidity percentage

Results in Table 4 demonstrated that, fruit acidity percentage of Washington navel orange was influenced by exposing the fruits to all tested postharvest treatments as compared with control in both seasons. However, the lowest percentages of acidity were recorded by untreated fruits. On the opposite, the highest percentages of acidity were recorded by using the treatment of wax in the first season and the treatment of black cumin oil at 3% in the second season.

Regarding the effect of storage periods, results showed that, fruit acidity percentages of Washington navel orange were decreased with advancing the storage periods under cold storage at 5℃. Therefore, irrespective the initial values, seven days storage period scored the highest values, whereas nine weeks storage period registered the lowest values in this concern. This trend was true in both seasons. With respect for the interaction effect between post harvest treatments and storage periods, data in Table 4 revealed that, all combinations of the storage periods decreased fruit acidity percentage as compared with the initial values in both seasons. However, the combination of seven days storage period scored the highest percentage of acidity, especially those treated with black cumin at 3% as an average of both seasons.

Table 3. Effect of post harvest treatments on total soluble solids (TSS) percentage of Washington navel orange fruits under cold storage at 5℃ during 2013and 2014 seasons

Season 2013											
	Storage periods (weeks)										
Treatment	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	12.73	13.00	13.27	13.50	13.57	13.77	13.80	13.80	13.73	13.77	13.49 A
Ginger oil at 2%	12.73	12.93	12.97	13.00	13.27	13.47	13.73	13.77	13.63	13.77	13.33 B
Ginger oil at 3%	12.73	12.77	12.87	12.93	13.10	13.40	13.63	13.70	13.63	13.43	13.22 C
Black cumin oil at 2%	12.73	12.83	13.10	13.33	13.53	13.63	13.77	13.80	13.80	13.43	13.40 B
Black cumin oil at 3%	12.73	12.77	13.20	13.27	13.40	13.53	13.67	13.70	13.77	13.37	13.34 B
Wax	12.73	13.07	13.23	13.33	13.43	13.77	13.77	13.80	13.87	13.90	13.49 A
Mean	12.73 G	12.90 F	13.11 E	13.23 D	13.38 C	13.60 B	13.73 A	13.76 A	13.74 A	13.61 B	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.2343											
Season 2014											
Treatment	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	11.23	11.77	12.00	12.20	12.50	13.00	13.03	13.37	12.60	12.27	12.40 A
Ginger oil at 2%	11.23	11.33	11.40	11.57	11.60	11.70	11.83	12.40	12.90	12.53	11.85 C
Ginger oil at 3%	11.23	11.33	11.33	11.50	11.50	11.50	11.60	12.27	12.53	12.43	11.72 D
Black cumin oil at 2%	11.23	11.40	11.50	11.90	11.97	12.00	12.60	12.60	13.20	12.60	12.10 B
Black cumin oil at 3%	11.23	11.30	11.33	11.70	11.70	11.80	12.30	12.40	13.00	12.50	11.93 C
Wax	11.23	11.30	11.47	11.97	12.13	12.23	12.40	12.87	12.90	12.67	12.12 B
Mean	11.23 G	11.41 F	11.51 F	11.81 E	11.90 DE	12.04 D	12.29 C	12.65 B	12.86 A	12.50 B	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.3860											

Table 4. Effect of post harvest treatments on acidity percentage of Washington navel orange fruits under cold storage at 5℃ during 2013and 201 4 seasons

Season 2013											
	Storage periods (weeks)										
Treatment	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	1.03	0.84	0.78	0.74	0.70	0.60	0.60	0.58	0.56	0.55	0.70 D
Ginger oil at 2%	1.03	0.84	0.87	0.75	0.72	0.62	0.60	0.60	0.56	0.56	0.72 D
Ginger oil at 3%	1.03	0.92	0.91	0.82	0.73	0.62	0.62	0.60	0.57	0.58	0.74 C
Black cumin oil at 2%	1.03	0.97	0.89	0.82	0.77	0.66	0.65	0.65	0.63	0.62	0.77 B
Black cumin oil at 3%	1.03	0.99	0.94	0.83	0.82	0.67	0.67	0.66	0.63	0.59	0.78 AB
Wax	1.03	0.97	0.84	0.83	0.83	0.79	0.67	0.67	0.66	0.64	0.79 A
Mean	1.03 A	0.92 B	0.87 C	0.80 D	0.76 E	0.66 F	0.64 G	0.63 G	0.60 H	0.59 H	
L.S.D for the interaction effect between treatments and storage periods at 5 % = 0.061											
Season 2014											
Treatments	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	1.03	0.86	0.70	0.68	0.64	0.58	0.57	0.58	0.55	0.55	0.67 D
Ginger oil at 2%	1.03	0.89	0.73	0.64	0.64	0.64	0.61	0.58	0.55	0.55	0.69 CD
Ginger oil at 3%	1.03	1.01	0.84	0.80	0.74	0.64	0.62	0.58	0.58	0.58	0.74 A
Black cumin oil at 2%	1.03	0.95	0.80	0.77	0.68	0.64	0.62	0.60	0.55	0.55	0.72 B
Black cumin oil at 3%	1.03	1.00	0.84	0.78	0.77	0.67	0.61	0.60	0.61	0.55	0.75 A
Wax	1.03	0.89	0.71	0.68	0.68	0.65	0.64	0.60	0.60	0.58	0.71 BC
Mean	1.03 A	0.93 B	0.77 C	0.73 D	0.69 E	0.64 F	0.61 FG	0.59 GH	0.57 HI	0.56 I	
L.S.D for the interaction effect between treatments and storage periods at 5 % = 0.069											

3.2.3 Ascorbic acid (V.C.)

Data in Table 5 revealed that, V.C. of Washington navel orange registered high significant increment as a result of exposing to all tested postharvest treatments. However, the highest values of V.C. were gained by using the treatments of wax and black cumin oil at 3% as compared with other treatments in both seasons. As for the effect of storage periods, data showed that, there were gradual decreases in V.C. of Washington navel orange with prolonging the cold storage period.

Hence, stored Washington navel orange for nine weeks scored the lowest V.C. content as compared with other storage periods in both seasons. While, Washington navel orange fruits stored after harvest till one week recorded high V.C. content in both seasons of the study. Referring to the interaction effect between post harvest treatments and storage periods data indicated that, irrespective the initial values, the combination of one week storage period recorded the highest values, especially 3% black cumin oil treated fruits and wax treated fruits in the first season. While, wax treated fruits showed its superiority in this concern and 3% black cumin oil treated fruits in the second season. On contrary, the lowest values of this parameter were registered by using the combination of nine weeks cold storage period, particularly those of untreated fruits as an average of both seasons. The rest treatments came in-between the abovementioned treatments in both seasons.

The obtained results of ginger essential oil in enhancing chemical fruit quality of Washington navel orange are in harmony with[15]. They mentioned that tomatoes keeping quality was improved by using 10% ginger extract. Also, Oz and Ulukanl [9] declared that, edible starch-based coating including black cumin oil appeared to be a good mixture for maintaining the quality of fruits during storage.

3.2.4 Respiration rate

Data in Table 6cleared that, all studied post harvest treatments succeeded in decreasing respiration rate of Washington navel orange fruits with superior for wax treated fruits as compared with untreated fruits in both seasons. As for the effect of storage period (Table 6) revealed that, the initial readings, respiration rate of fruits Washington navel orange was rapidly increased with increasing the storage periods scored the lowest values, while the highest values were recorded under cold storage for nine weeks. This attitude was true in both seasons of this study.

Regarding the effect of interaction between post harvest treatments and storage periods, data showed that, the lowest respiration rate of Washington navel orange fruits was greatly decreased by using the combination of two

weeks storage period, especially those treated with wax in both seasons. On the reverse the highest respiration rate was induced by using the combination of nine weeks storage period, particularly those of untreated fruits in both seasons.

The results of essential oils in this respect are in harmony with the analogous ones mentioned by [27,28] on apple fruits.

Table 5. Effect of post harvest treatments on ascorbic acid (V.C.) as (mg/100ml) of Washington navel orange fruits under cold storage at 5℃ durin g 2013 and 2014 seasons

Season 2013											
	Storage periods (weeks)										
Treatment	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	48.63	45.96	43.46	42.39	40.76	40.73	40.12	38.59	38.48	37.08	41.62 D
Ginger oil at 2%	48.63	47.40	45.20	43.88	43.72	41.38	40.88	40.07	38.94	37.18	42.73 C
Ginger oil at 3%	48.63	47.60	45.80	43.66	43.68	41.50	40.88	40.37	39.64	37.18	42.89 BC
Black cumin oil at 2%	48.63	47.80	46.60	44.58	44.46	42.02	41.50	40.49	39.96	36.07	43.21 B
Black cumin oil at 3%	48.63	48.30	47.40	45.12	44.60	43.00	41.75	40.79	40.50	36.91	43.70 A
Wax	48.63	48.21	48.01	45.08	42.80	41.86	41.38	40.76	41.10	40.30	43.81 A
Mean	48.63 A	47.55 B	46.08 C	44.12 D	43.34 E	41.75 F	41.09 G	40.18 H	39.77 H	37.45 I	
L.S.D for the interaction effect between treatments and storage periods at 5%=1.358											
Season 2014											
Treatment	**0**	**7**	**14**	**21**	**28**	**35**	**42**	**49**	**56**	**63**	**Mean**
Control	48.31	46.26	46.17	44.31	42.27	41.56	41.25	40.23	39.28	36.18	42.58 C
Ginger oil at 2%	48.31	47.12	46.43	45.12	44.25	42.29	41.62	40.44	40.24	38.98	43.48 B
Ginger oil at 3%	48.31	47.12	46.15	45.24	45.12	44.29	42.05	41.00	40.92	39.59	43.98 AB
Black cumin oil at 2%	48.31	47.30	46.25	45.31	44.25	43.22	42.00	41.00	40.65	38.56	43.69 AB
Black cumin oil at 3%	48.31	47.32	46.36	45.84	44.22	44.24	43.36	41.54	41.25	39.56	44.20 AB
Wax	48.31	48.16	46.95	46.55	45.55	44.66	41.85	40.66	40.56	40.15	44.34 A
Mean	48.31 A	47.21 B	46.39 BC	45.40 C	44.28 D	43.38 D	42.02 E	40.81 F	40.48 F	38.84 G	
L.S.D for the interaction effect between treatments and storage periods at 5%= 2.585											

Table 6. Effect ofpost harvest treatments on respiration rate (ML/Kg/Hr) of Washington navel orange fruits under cold storage at 5℃ during 2013 and 2014 seasons

Season 2013							
	Storage periods (weeks)						
Treatments	**0**	**14**	**28**	**42**	**56**	**63**	**Mean**
Control	11.65	3.21	4.20	4.31	8.30	10.61	7.05 A
Ginger oil at 2%	11.65	2.53	2.70	3.60	6.80	9.00	6.05 D
Ginger oil at 3%	11.65	2.40	3.31	3.20	6.00	8.90	5.91 D
Black cumin oil at 2%	11.65	2.90	3.90	3.90	7.40	9.43	6.53 B
Black cumin oil at 3%	11.65	2.60	3.60	3.61	7.70	8.91	6.35 C
Wax	11.65	2.30	2.51	3.20	6.00	7.73	5.57 E
Mean	11.65 A	2.66 F	3.37 E	3.64 D	7.03 C	9.10 B	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.368							
Season 2014							
Treatment	**0**	**14**	**28**	**42**	**56**	**63**	**Mean**
Control	11.60	2.29	3.82	5.15	7.11	9.20	6.53 A
Ginger oil at 2%	11.60	1.61	2.95	3.37	5.85	6.06	5.24 C
Ginger oil at 3%	11.60	1.66	2.81	3.26	4.61	6.10	5.01 D
Black cumin oil at 2%	11.60	1.71	2.99	3.54	5.81	7.10	5.46 B
Black cumin oil at 3%	11.60	1.68	2.67	3.53	5.59	6.60	5.28 C
Wax	11.60	1.53	2.35	3.03	4.73	6.10	4.89 E
Mean	11.60 A	1.75 F	2.93 E	3.65 D	5.62 C	6.86 B	
L.S.D for the interaction effect between treatments and storage periods at 5%=0.268							

3.3 Shelf Life

Data in Table 7 revealed that, the marketability of Washington navel orange fruits was noticeable increased by applying wax, ginger oil at 3% and black cumin oil at 3% in the first season without no significant differences between them. While, all tested post harvest treatments recorded high values than the control in the second one.

Table 7. Effect of some postharvest treatments on shelf life (days) of Washington navel orange fruits during 2013 and 2014 seasons

Treatment	Shelf life (days)	
	Season 2013	Season 2014
Control	11.70 C	12.00 B
Ginger oil at 2%	13.70 BC	13.7 AB
Ginger oil at 3%	14.30 AB	14.3 AB
Black cumin oil at 2%	12.70 BC	13.3 AB
Black cumin oil at 3%	14.00 AB	13.7 AB
Wax	16.00 A	15.3 A

The obtained results of essential oil treatments on extending the shelf life of Washington navel orange are in harmony with those of [29] on sweet cherry, [30,31,32] on table grape and [33] on papaya. They mentioned that application of essential oil constituents such as thymol, carvacrol, eugenol and menthol increased the shelf life of fruits through reducing the loss in weight and reduce molds.

4. CONCLUSION

Through the previous results it could be concluded that, treatment of the Washington navel orange fruits with wax proved to be the most efficient treatment in reducing weight loss percentage, reducing fruit decay percentage, increasing the fruit content of total soluble solids (TSS) with the same bare with the control, wax also had a positive effect of increasing the fruit content of ascorbic acid (V.C.) while led to an increase of the fruit content of the acidity. Also wax treatment reduces the respiration rate and prolongs the shelf life of the Washington navel orange fruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Manning K. Soft fruits. In: Seymour GB, Taylor JE and Tucker GA editors. Biochemistry Fruit Ripening. London: Chapman & Hall; 1996.
2. Poppe L, Vanhoutte S, Hofte M. Modes of action of *Pantoea agglomerans* CPA2, an antagonist of postharvest pathogens on fruits. Eur J Plant Pathol. 2001;109:963-973.
3. Ahmet C, Saban K, Hamdullah K, Ercan K. Antifungal properties of essential oil and crude extracts of *Hypericum linarioides* Bosse. Biochem Syst Ecol. 2005;33:245-256.
4. Jobling J. Essential Oils: A new idea for postharvest disease control. Good Fruit and Vegetables Magazine. 2000;11-50.
5. Mishra AK, Dubey NK. Evaluation of some essential oils for their toxicity against fungi causing deterioration of stored food commodities. Applied Environ Microbiol. 1994;60:1101-1105.
6. Bagamboula CF, Uyttendaele M, Debevere J. Inhibitory effect of thyme and basil essential oils, carvacrol, thymol, estragol, linalool and p-cymene towards *Shigella sonnei* and *S. flexneri*. Food Microbiol. 2004;21:33-42.
7. Tripathi P, Dubey NK, Shukla AK. Use of some essential oils as post-harvest botanical fungicides in the management of grey mould of grapes caused by *Botrytis cinerea*. World J Microbiol Biotechnol. 2008;24:39.
8. Singh H, Ghassan A, Mohd S. Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of citrus. Intern J of Scientific and Res Publications. 2012;2(3):1-4.
9. Oz AT, Ulukanl Z. Application of edible starch-based coating including glycerol plus *Oleum nigella* on arils from long-stored whole pomegranate fruits. J of Food Processing and Preservation. 2012;36(1):81-95.
10. Singh H, Ghassan F, Mohd S. Anti-fungal activity of *Capsicum frutescence* and

Zingiber officinale against key post-harvest pathogens in citrus. International Conference on Biomedical Engineering and Technology 2011;Vol.11. Available: http://www.ipcbee.com/vol11/1-B30016.pdf

11. Cohen E, Shalom Y, Rosenberger I. Postharvest ethanol build up and off-flavor in murcott tangerine fruit. J Amer Soc Hort Sci. 1990;115(5):9-15.
12. Ju AT, Warcup JH, Wright WM, Pugh GJF. The effect of fungicide on certain chemical and microbial of soil. Soil Biol Biochem. 2000;6(4):263-267.
13. AOAC. Association of Official Analytical Chemist. Official Methods of Analysis 4th ed. pp. Benjamin Franklin Station, Washington. D.C., USA 1985;495-510.
14. Snedecor W, Cochran WG. Statistical Methods. 8th ed. Iowa State Univ Press Ames Iowa USA; 1989
15. Surekha C, Kumar KVC, Lakshmipathy R.Enhancement of shelf-life of tomatoes using herbal extracts. J of Phytology. 2010;2(1):13-17.
16. Hadizadeh I, Peivastegan B, Hamzehzarghani H. Antifungal activity of essential oils from some medicinal plants of Iran against *Alternaria alternate*. Am J Applied Sci. 2009;6(5):857-861.
17. Suwitchayanon P, Kunasakdakul K. *In vitro* effects of clove and turmeric extracts controlling crucifer pathogens. J Agric Techn. 2009;5(1):193-199.
18. Dubey RK, Kumar JR, Dubey NK. Evaluation of *Eupatorium cannabinum* Linn. oil in enhancement of shelf life of mango fruits from fungal rotting. World J Microbiol Biotechnol. 2007;23:467-473.
19. Dubey RK, Kumar J R, Chansouria JPN, Dubey NK. Evaluation of *Amomum subulatum* Roxb. oil as a source of botanical fungi toxicant for the protection of mango fruits from fungal rotting. J. Food Saf. 2008;28:400-412.
20. Yakoby N, Freeman S,Dinoor A, Keen NT, Prusky D. Expression of pectatelyase from *Colletotrichum gloeosporioides* in C. magna promotes pathogenicity. Mol Plant Microbe Interact. 2000;13:887–891.
21. Nychas GJE. Natural antimicrobials from plants. In: Gould GW (ed). New Methods Food Preservation. London: Blackie Academic Professional; 1995.
22. Rasooli I,Mirmostafa SA. Bacterial susceptibility to and chemical composition of essential oils from *Thymus kotschyanus* and *Thymus persicus*. J Agric Food Chem. 2003;51:2200-2205.
23. López-Malo A, Palou E, León-Cruz R, Alzamora SM. Mixtures of natural and synthetic antifungal agents. In: (Hocking AD, Pitt JI, Samson RA, Thrare U (eds). Adv. Food Mycol., Springer, US; 2006.
24. Ficker C, Smith ML, Akpugana K, Gbeassor M, Zhung J, Durst T, Assabgui R, Arnason T. Bioassay-guided isolation and Identification of antifungal compounds from ginger. Pharmaceutical Biol. 2003;41:392–397.
25. Hossain M, Uddin MMS, Mortuza MG, Islam MS, Islam MS. Efficacy of plant extracts to control post harvest anthracnose and stem-end rot of mango. International Journal of Sustainable Agricultural Technology. 2010;6(7):9-12.
26. Atia MMM. Efficiency of physical treatments and essential oils in controlling fungi associated with some stored date palm fruits. Australian Journal of Basic and Applied Sciences. 2011;5(6):1572-1580.
27. Rabiei V, Shirzadeh E, Angourani HR and Sharafi Y. Effect of thyme and lavender essential oils on the qualitative and quantitative traits and storage life of apple 'Jonagold' cultivar. Journal of Medicinal Plants Research. 2011;5(23):5522-5527.
28. Shirzadeh E, Kazemi M. Effect of essential oils treatments on quality characteristics of apple (*Malus domestica* var. Gala) during storage. Trends in Applied Sciences Research. 2012;7(7):584-589.
29. Serrano M, Martínez-Romero D, Castillon S, Guillén F, Valero D. The use of natural antifungal compounds improves the beneficial effect of MAP in sweet cherry storage. Innov Food Sci Emerg Technol. 2005;6:115–123.
30. Valverde JM, Guillén F, Martínez-Romero D, Castillo S, Serrano, Valero MD. Improvement of table grapes quality and safety by the combination of modified atmosphere packaging (MAP) and eugenol, menthol, or thymol. J Agric Food Chem. 2005;53:7458-7464.
31. Valero DV, Martínez-Romero JMD, Guillén F, Castillo S, Serrano M. The combination of modified atmosphere packaging with eugenol or thymol to maintain quality,

safety and functional properties of table grapes. Postharvest Biol and Technol. 2006;41:317-327.

32. Martínez-Romero D, Guillén F, Valverde JM, Bailén G, Zapata PJ, Serrano M, Castillo S, Valero D. Influence of carvacrol on survival of *Botrytis cinerea* inoculated in table grapes. International J Food Microbiol. 2007;115:144–148.

33. Bosquez-Molina E, Ronquillo-de Jesus E, Bautista-Banos S, Verde-Calvo JR, Morales-Lopez J. Inhibitory effect of essential oils against *Colletotrichum gloeosporioides* and *Rhizopus stolonifer* in stored papaya fruit and their possible application in coatings. Postharvest Biology and Technology. 2010;57(2):132-137.

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