Research Journal of Agriculture and Biological Sciences, 8(5): 420-428, 2012
ISSN 1816-1561
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Efficacy of propolis and wax coatings in improving fruit quality of "Washington" navel orange under cold storage

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ABSTRACT

This study was conducted during two successive seasons 2011 and 2012 to evaluate the effect of propolis at 2 and 3% and wax treatments as edible coatings on some fruit quality parameters of "Washington" navel orange fruits under cold storage at 5±2˚C. Fruit weight loss (%), decay (%), T.S.S (%) and respiration rate (ml CO_2/kg fruits/hr) of "Washington" navel orange fruits were increased in most cases with prolonging the storage period. Whereas, titratable acidity (%) and V.C (mg/100 ml juice) were decreased with advancing the storage period. However, the lowest values of weight loss (%), decay (%) and respiration rate (ml Co_2 /kg fruits/hr) as well as the best results of shelf life, titratable acidity and V.C (mg/100 ml juice) were gained by wax treatment followed by 3% propolis treatment without significant differences in most cases. In addition, the highest fruit T.S.S (%) was scored by control and wax treatments during storage at 5±2^{o}C.

Key words: Washington navel orange, post-harvest, propolis, wax, cold storage and fruit quality.

Introduction

Orange industry is important for Egyptian National income. Orange Planted area in Egypt reached 314115 Feddans, while the productive area reached 241102 feddans producing 2401020 tons of orange fruits (Ministry of Agriculture and Land Reclamation Statistics, Egypt, 2010). Although orange occupies the greatest planted area among all citrus grown fruit area 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 processes 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 organisms. Generally, low storage temperatures are used to extend fruit postharvest life (Manning, 1996).

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 (Poppe *et al.,* 2001). 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 use of post harvest chemicals.

Recent studies show that edible films and coatings can be used to help in fruits and vegetables preservation because they provide a partial barrier to moisture, O_2 and CO_2. Also they can improve mechanical handling properties, carrying additives, avoiding volatiles loss and even contribute to the production of aroma volatiles (Olivas & Barbosa-Ca novas, 2005).

The coatings have emerged as an emerging technology for post harvest storage periods, shelf life extension and improvement of fruit quality. Its use lies in generating a modified atmosphere, in order to, reduce the ability of mass transfer of gases that cause weight loss, color, texture and firmness of the fruit after harvest that affect the growth of post harvest losses. Figueroa *et al.,* (2011) studied the effect of edible coatings on the conservation of mango and avocado fruits and noted the use of propolis as a natural alternative in its formulation. Propolis is a waxy resinous substance collected by honeybees it is used as a dietary supplement with positive effects on human health and inhibitory activity against *Alternaria alternata* (Ojeda-Contreras *et al.,* 2008). Various biological activities of propolis such as antibacterial, antifungal, antiviral, anti-inflammatory and aesthetic properties were found (Marcucci, 1995 and Burdock, 1998).

In addition, Ozdemir *et al.,* (2010) dipped Star Ruby grapefruit in ethanol-extracted propolis (EEP) in various concentrations (1%, 5%, and 10%) immediately after harvest. They reported that treatment with 5%

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EEP was effective in preventing fungal decay. The percentage of weight loss was significantly higher in the control fruits than in those treated with 5% EEP and 10% EEP.

Wax coating on citrus fruit is often used 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 flavour development and peel disorder (Cohen, *et al.,* 1990). Hagenmaier and Shaw (1992) reported that the permeability of wax should be high for O_2, CO_2 and C_2H_4 and low for water vapour.

The present study aimed to evaluate the effect of propolis edible coating and commercial wax coating to extend storage life and maintain fruit quality of Washington navel orange.

Materials and Methods

This study was conducted during two successive seasons of 2011 and 2012 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 Systems (A.D.S.) 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 four similar groups. Each group was subjected to one of the following treatments as fruit coating by using a hand sprayer.

1- Control (tap water)
2- Propolis (alcoholic extract at 2%)
3- Propolis (alcoholic extract at 3%)
4- Wax (commercial wax)

Gas chromatography analysis of ethanolic propolis extract is presented in Table (1) according to Sobhi *et al.,* (2006).

Table 1: Chemical composition of ethanolic extracts of Egyptian propolis.

Compounds	% TIC*
Aliphatic acids	
Malic acid	1.92
Palmitic acid	3.12
Oleic acid	3.18
Octadecenoic acid	3.29
Octadecadienoic acid	0.59
Stearic acid	1.57
Aromatic acids	
2-Amino-3-methoxybenzoic acid	3.18
Benzenepropionic acid	0.90
Cinnamic acid	2.04
4-Hydroxycinnamic acid	2.85
4-Methoxycinnamic acid	2.80
Caffeic acid	2.59
Alcohols/ Phenols/ Aldehydes	
Glycerol	2.76
2-Naphthalenemethanol derivatives	4.79
2-Methoxy-4-vinylphenol	4.10
Esters	
4-Methoxyhydrocinnamate	2.77
3-Methyl-3-butenyl isoferulate	2.55
Others	
5,7-Dihydroxyflavone	0.30
5,7-Dihydroxydihydroflavone	2.75
1,7-Dihydroxy-3-methoxy-6-methylanthraquinone	0.67
1-(Dihydroxyphenyl)-3-phenylpropenone	4.50
5-Hydroxy-7-methoxy-2-phenyl- 4H-1-benzopyran-4-one	2.78

*TIC = The ion current generated by a compound depends upon its characteristics.

Each treatment was replicated three times and each replicate was about 15 kg weight put as one layer in three carton boxes (60×40×15 cm). Experimental boxes were stored at 5±2˚C and 90% relative humidity for 63 days (9 weeks).

Effect of the tested treatments on Washington navel orange fruits were evaluated through the following determinations:-

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1. Fruit physical properties:

1.1. Fruit weight loss percentage:

The initial weight of Washington navel orange fruits was recorded in each treatment and at weekly intervals, then fruit weight loss% was calculated by weighing the same fruits at each interval and at the end of cold storage duration using the following formula:

$$\text{Fruit weight loss \%} = \frac{\text{Initial weight} - \text{Weight at specific interval}}{\text{Initial weight}} \times 100$$

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.

1.3. 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. Fruit chemical properties:

Total soluble solids (T.S.S) of fruit juice were measured using a hand refractometer and expressed as a percent. Moreover, fruit titratable acidity (grams of citric acid per 100ml of juice and ascorbic acid (V.C) content (milligrams ascorbic acid per 100ml fruit juice) according to A.O.A.C. (1985). Besides, respiration rate was measured by carbon dioxide produced from the fruits after harvest (Initial reading was scored under room temperature), then every two weeks and at the end of cold storage and CO_2 levels produced by the fruit were then calculated as ml CO_2/kg fruits/hr according to Pesis and Ben-Arie (1984) & Lurie and Pesis (1992).

Statistical Analysis:

Data obtained in the two studied seasons were subjected to the analysis of variance according to Snedecor and Cochran (1989), least significant differences (L.S.D.) was used to differentiate the obtained values.

Results and Discussion

Effect of propolis and wax treatments on:

1. Fruit physical properties:

1.1. Fruit weight loss percentage:

In regard to the effect of the tested post harvest treatments**,** Table (2) demonstrates that all evaluated post harvest treatments succeeded in reducing decay percentage of Washington navel orange fruits during storage duration in comparison with untreated fruits “control” in both seasons. Generally, the treatment of wax proved to be the most efficient treatment in this concern, followed by propolis extract at 3% treatment, without significant difference in the second season.

As for the effect of storage periods**,** it is quite clear from Table (2) that Washington navel orange fruits showed loss in their weight with the advancement of storage period. So, nine weeks storage period under cold storage recorded the highest value, whereas the lowest value was obtained after one week under cold storage in both seasons. The statistical analysis emphasizes that the differences between the aforementioned cold storage periods were high to be significant.

Considering the interaction effect between storage period and tested post harvest treatments, data presented in Table (2) show that the interactions of one week storage duration under cold storage at 5±2°C recorded statistically the lowest percentages of weight loss especially, wax treated fruits in the first season and tap water “control” and 2% propolis extract treated fruits in the second season. On the opposite, the highest percentage of

weight loss was observed on those of nine weeks storage period combinations, particularly those treated with tap water "control" in both seasons. The other combinations showed an intermediate values in this concern.

Table 2: Effect of propolis and wax treatments on weight loss (%) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season									
	Storage periods (weeks)									
	1	2	3	4	5	6	7	8	9	Mean
Control	0.69	1.32	1.96	2.55	3.13	4.27	5.31	6.53	8.23	3.78 a
Propolis extract at 2%	0.72	1.33	1.70	1.96	2.72	3.50	4.07	5.27	5.70	3.00 b
Propolis extract at 3%	0.65	1.13	1.50	1.87	2.52	3.36	3.92	4.77	5.63	2.82 c
Wax	0.63	1.13	1.34	1.76	2.49	3.10	3.86	4.56	5.30	2.69 d
Mean	0.67 I	1.23 H	1.63 G	2.04 F	2.72 E	3.56 D	4.29 C	5.28 B	6.22 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.225										
Treatment	2012 season									Mean
Control	0.51	1.09	1.72	2.56	3.40	4.40	5.06	6.00	7.81	3.62 a
Propolis extract at 2%	0.51	1.05	1.47	2.00	2.75	3.38	4.34	5.02	6.23	2.97 b
Propolis extract at 3%	0.49	1.00	1.50	1.93	2.53	3.15	3.95	4.81	6.16	2.84 c
Wax	0.52	1.02	1.50	1.93	2.47	3.12	3.82	4.70	5.67	2.75 c
Mean	0.51 I	1.04 H	1.55 G	2.11 F	2.79 E	3.51 D	4.29 C	5.13 B	6.47 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.282										

The recorded results of wax on weight losses of Washington navel orange go in line with findings of Miller *et al*., (2001) on 'Fallglo' tangerine, 'Marsh' grapefruit, and 'Valencia' orange, Rodriguez *et al*., (2001) on 'Valencia' orange, Mohamed *et al.*, (2005) on lime, Porat *et al.*, (2005) on "Mor"mandarin, Ansari and Feridoon (2007) on Valencia and local Siavarz orange cvs., Hammash and El-Assi, (2007) on 'Shamouti' orange, Malgarim *et al*., (2007) on Navelina orange and Abdel-Wahab and Rashid (2012) on Navel orange. They found that all wax formulations reduced water loss.

1.2. Fruit Decay percentage

Analyzing the effect of post harvest treatments, Table (3) demonstrates that wax treatment showed to be the superior in reducing fruit decay percentage followed by propolis extract at 3% treatment, without significant different in both seasons.

Evaluating the effect of storage periods, data presented in Table (3) illustrate that fruit decay percentage showed a steadily increment with extending the storage periods in both seasons of this study. However, nine weeks cold storage at 5°C scored significantly the highest fruit decay percentages, followed descendingly by those cold stored for eight weeks. On the other hand, one, two and three weeks cold storage durations in the first season and one and two weeks cold storage durations in the second season produced statistically the lowest fruit decay percentages. The rest storage periods came in-between the aforesaid storage durations.

Table 3: Effect of propolis and wax treatments on decay (%) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season									
	Storage periods (weeks)									
	1	2	3	4	5	6	7	8	9	Mean
Control	0.00	0.00	0.00	3.63	8.96	19.47	28.43	39.21	52.51	16.91 a
Propolis extract at 2%	0.00	0.00	0.00	1.16	3.25	14.21	23.96	33.56	40.07	12.91 b
Propolis extract at 3%	0.00	0.00	0.00	0.00	3.18	13.24	20.50	28.62	34.12	11.07 c
Wax	0.00	0.00	0.00	0.00	3.25	10.22	20.29	28.08	32.71	10.51 c
Mean	0.00 F	0.00 F	0.00 F	1.20 F	4.66 E	14.29 D	23.30 C	32.37 B	39.85 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 4.465										
Treatment	2012 season									Mean
Control	0.00	0.00	1.73	1.73	7.11	19.21	30.18	42.13	50.63	16.97 a
Propolis extract at 2%	0.00	0.00	0.00	1.87	5.35	15.01	27.33	36.00	43.45	14.33 b
Propolis extract at 3%	0.00	0.00	0.00	0.00	5.28	13.81	25.30	33.28	36.98	12.74 c
Wax	0.00	0.00	0.00	0.00	3.61	12.94	21.72	29.55	36.98	11.64 c
Mean	0.00 F	0.00 F	0.43 F	0.90 F	5.34 E	15.24 D	26.13 C	35.24 B	42.01 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 4.663										

Examining the interaction effect between storage periods and the tested post harvest treatments, it is obvious from Table (3) that all combinations of one, two and three weeks cold storage duration (irrespective the control at three weeks in the second season) succeeded in preventing fruit decay percentage of Washington

navel orange. On the reverse, the highest fruit decay (%) were registered by the interactions of nine weeks cold storage period, particularly those interacted with control in both seasons. The remained interactions of the tested storage periods came in-between and the differences between the different storage periods interactions were significant in most cases, where all of them found that wax coating decreased fruit decay.

The results achieved by wax coating in this respect are in agreement with the findings of Rodriguez *et al*., (2001) on 'Valencia' orange, Mohamed *et al.,* (2005) on lime, Ansari and Feridoon (2007) on Valencia and local Siavarz orange cvs., Malgarim *et al*., (2007) on Navelina orange and Abdel-Wahab and Rashid (2012) on Navel orange, where all of them found that wax coating decreased fruit decay.

1.3. Shelf life:

Data presented in Table (4) clear that all tested postharvest treatments succeeded in extended the shelf life of "Washington" navel orange fruits as compared with control in both seasons. However, the highest values of this parameter were scored by wax-treated fruits and 3% propolis-treated fruits. The differences between the aforementioned two treatments were non-significant in both seasons.

The gained results of wax on this concern go in line with the findings of Oosthuyse (1997) on mangoes and Mahajan and Chopra (1992) on apples. They mentioned that wax application enhanced the shelf life of fruits.

Table 4: Effect of propolis and wax treatments on shelf life (days) at 20±5°C of Washington navel orange fruits after nine weeks cold storage at 5±2°C during 2011and 2012 seasons.

Treatment	Shelf life (days)	
	2011 season	2012 season
Control	11.7 B	12.00 B
Propolis extract at 2%	14.00 A	13.3 B
Propolis extract at 3%	15.7 A	15.3 A
Wax	16.00 A	15.3 A

2. Fruit chemical properties:

2.1. Total soluble solid percentage (T.S.S %):

Data in Table (5) reveal that T.S.S of "Washington" navel orange fruits was affected by using the different tested post-harvest treatments in both seasons. However, the highest value of this parameter was gained by untreated fruits in both seasons. Also, wax-treated fruits in the first season and 2% propolis extract-treated fruits in the second season increased T.S.S as compared with the other treatments.

Referring to the effect of cold storage period, Table (5) show that T.S.S. of "Washington" navel orange fruits steadily increased with advancing the storage periods till reach the maximum increase after seven weeks under storage period then started to decrease till the end of storage period in both seasons. As for the interaction effect between the tested post-harvest treatments and storage periods, data in the same Table (5) indicated that all resulted combinations succeeded in increasing T.S.S of "Washington" navel orange fruits as compared with the initial readings, and the superiority was for the combinations of seven weeks storage period in most cases in both seasons. Anyway, the highest values of this parameter were scored by wax-treated fruits under cold storage for nine weeks at the first season, and the treatments of 2% propolis extract-treated fruits either for eight or nine weeks as they gave the same values in the second season. On the contrary, the lowest values of this parameter were related to the combination of one week storage period in both seasons.

2.2. Total acidity percentage:

Data in Table (6) show that the lowest fruit acidity (%) of "Washington" navel orange was gained by untreated fruits in both seasons, whereas the highest fruit acidity content was scored by those treated by wax in both seasons. It was interesting to note from data in Table (6) that there was a negative relationship between fruit acidity and storage periods. Hence, as the storage period increased, the values of fruit acidity decreased to reach the maximum decrease at the highest storage period (nine weeks). This trend was true in both seasons.

As for the interaction effect between the studied post-harvest treatments and storage periods, data in Table (6) declare that the lowest values of this parameter were recorded by using the combination of nine weeks storage periods, particularly those of untreated fruits and 2% propolis extract-treated fruits in both seasons. While "irrespective of the initial reading" the highest values of this parameter were scored by using the combination of one week storage period. The remained treatments occupied an intermediate position between the aformentioned treatments in both seasons.

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Table 5: Effect of propolis and wax treatments on total soluble solid (%) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season										
	Storage periods (weeks)										
	0	1	2	3	4	5	6	7	8	9	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
Propolis extract at 2%	12.73	13.00	13.27	13.40	13.53	13.73	13.77	13.80	13.50	13.47	13.42 ab
Propolis extract at 3%	12.73	12.97	13.10	13.10	13.47	13.73	13.77	13.77	13.53	13.60	13.38 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 F	13.01 E	13.22 D	13.33 CD	13.50 BC	13.75 A	13.78 A	13.79 A	13.66 AB	13.69 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.341											
Treatment	2012 season										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
Propolis extract at 2%	11.23	11.40	11.50	11.95	12.20	12.55	12.57	13.13	13.40	13.40	12.33 ab
Propolis extract at 3%	11.23	11.40	11.53	11.80	12.30	12.33	12.47	13.07	13.37	13.27	12.28 b
Wax	11.23	11.30	11.47	11.97	12.13	12.23	12.40	12.87	12.90	12.67	12.12 c
Mean	11.23 G	11.47 F	11.63 F	11.98 E	12.28 D	12.53 C	12.62 C	13.11 A	13.07 AB	12.90 B	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.364											

Table 6: Effect of propolis and wax treatments on total acidity (%) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season										
	Storage periods (weeks)										
	0	1	2	3	4	5	6	7	8	9	Mean
Control	1.03	0.84	0.78	0.74	0.70	0.60	0.60	0.58	0.56	0.55	0.70 c
Propolis extract at 2%	1.03	0.95	0.80	0.75	0.75	0.61	0.62	0.56	0.56	0.56	0.72 b
Propolis extract at 3%	1.03	0.98	0.84	0.77	0.77	0.73	0.72	0.64	0.65	0.64	0.78 a
Wax	1.03	0.97	0.84	0.83	0.83	0.79	0.67	0.67	0.66	0.64	0.79 a
Means	1.03 A	0.94 B	0.82 C	0.77 D	0.76 D	0.68 E	0.65 F	0.61 G	0.61 G	0.60 G	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.056											
Treatment	2012 season										Mean
Control	1.03	0.86	0.70	0.68	0.64	0.58	0.57	0.58	0.55	0.55	0.67 c
Propolis extract at 2%	1.03	0.83	0.70	0.71	0.64	0.60	0.60	0.60	0.58	0.55	0.68 bc
Propolis extract at 3%	1.03	0.83	0.70	0.70	0.70	0.67	0.65	0.60	0.58	0.58	0.70 ab
Wax	1.03	0.89	0.71	0.68	0.68	0.65	0.64	0.60	0.60	0.58	0.71 a
Mean	1.03 A	0.85 B	0.70 C	0.69 CD	0.67 D	0.63 E	0.62 E	0.60 EF	0.58 F	0.57 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.065											

2.3. Ascorbic acid (V.C mg/100 ml juice):

Data in Table (7) declare that all tested post-harvest treatments statistically increased V.C of "Washington" navel orange fruits, with superior for wax-treated fruits as compared with control in both seasons. As for the effect of storage periods, Table (7) show that V.C of "Washington" navel orange fruits decreased with prolonging the storage periods in both seasons. So, one week storage period scored the highest values in this sphere, while nine weeks storage period registered the lowest values in this respect. This trend was true in both seasons.

Referring to the interaction effect between post-harvest treatments and storage periods, data in Table (7) clear that the combination of one week storage period “regardless of the initial reading” showed to be the most promising in producing the highest values of this parameter, especially those treated by wax in both seasons. On the reverse, the lowest values of this parameter were scored by the combination of nine weeks storage periods, particularly those of untreated fruits in both seasons. The remained combinations came in-between the abovementioned treatments in both seasons.

The obtained results of wax coating in improving fruit chemical properties of Washington navel orange go in line with those of Mohamed *et al.,* (2005) on lime, Ansari and Feridoon (2007) on Valencia and local Siavarz orange cvs., Hammash and El-Assi (2007) on 'Shamouti' orange. Also, Abdel-Wahab and Rashid (2012) on navel orange mentioned that wax coating fruits delayed changes loss in acidity, ascorbic acid and total soluble solids percentage compared with control fruits.

Table 7: Effect of propolis and wax treatments on ascorbic acid (mg/100ml juice) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season										
	Storage periods (weeks)										
	0	1	2	3	4	5	6	7	8	9	Mean
Control	48.63	45.96	43.46	42.39	40.76	40.73	40.12	38.59	38.48	37.08	41.62 c
Propolis extract at 2%	48.63	46.80	44.40	44.19	42.48	42.02	42.00	40.23	39.94	39.19	42.99 b
Propolis extract at 3%	48.63	45.20	45.40	44.42	42.84	42.38	42.13	40.04	39.50	39.20	42.97 b
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	46.54 B	45.32 C	44.02 D	42.22 E	41.75 EF	41.41 F	39.91 G	39.76 G	38.94 H	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.463											
Treatment	2012 season										Mean
Control	48.31	46.26	46.17	44.31	42.27	41.69	41.25	40.16	39.15	36.18	42.58 b
Propolis extract at 2%	48.31	47.10	46.94	45.11	43.44	42.42	41.94	41.10	40.13	40.11	43.66 a
Propolis extract at 3%	48.31	48.10	47.13	45.68	43.55	42.99	41.94	41.05	40.41	40.22	43.94 a
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	47.41 AB	46.80 B	45.41 C	43.70 D	42.94 DE	41.75 EF	40.74 FG	40.06 GH	39.17 H	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.766											

2.4. Respiration rate (ml CO_2/kg fruits/hr):

It was clear from the results in Table (8) that all examined post-harvest treatments succeeded in decreasing the respiration rate of naval orange fruits in both seasons. However, the highest respiration rate of "Washington" navel orange fruits was recorded by untreated fruits followed in descending order by 2% propolis extract-treated fruits, whereas the lowest values of this parameter were scored by wax-treated fruits followed in ascending order by 3% propolis extract-treated fruits. This trend was true in both seasons.

Table 8: Effect of propolis and wax treatments on respiration rate (ml CO_2/kg fruits/hr) of Washington navel orange fruits stored at 5±2°C during 2011and 2012 seasons.

Treatment	2011 season						
	Storage periods (weeks)						
	0	2	4	6	8	9	Mean
Control	11.65	3.21	4.20	4.31	8.30	10.61	7.05 a
Propolis extract at 2%	11.65	3.00	3.10	3.10	7.10	8.61	6.09 b
Propolis extract at 3%	11.65	2.90	3.00	3.20	6.21	7.97	5.82 c
Wax	11.65	2.30	2.51	3.20	6.00	7.73	5.57 d
Mean	11.65 A	2.85 F	3.20 E	3.45 D	6.90 C	8.73 B	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.353							
Treatment	2012 season						Mean
Control	11.60	2.29	3.82	5.15	7.11	9.20	6.53 a
Propolis extract at 2%	11.60	2.23	3.42	3.43	5.76	7.45	5.65 b
Propolis extract at 3%	11.60	1.56	2.85	3.40	5.60	7.33	5.39 c
Wax	11.60	1.53	2.35	3.03	4.72	6.10	4.89 d
Mean	11.60 A	1.90 F	3.11 E	3.75 D	5.80 C	7.52 B	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.249							

Referring to the effect of storage periods, Table (8) indicate that, regardless of the initial reading, the respiration rate of "Washington" navel orange fruits was progressively increased as the cold storage period was increased from two to nine weeks. However, stored "Washington" navel orange fruits for nine weeks scored the highest values as compared with storage periods for two weeks in both seasons. Regarding the interaction effect between the tested post-harvest treatments and storage periods, data in Table (8) demonstrate that, irrespective of the initial data (zero storage period) the lowest values of respiration rate were recorded by the combination of two weeks storage periods, especially wax-treated fruits. On the contrary, the highest values of this parameter were registered by the combination of nine weeks storage periods, particularly those of untreated fruits in both seasons. This trend was true in both seasons.

The results of wax treatment in this respect go in line with Lim *et al.,* (1998) on apple fruits. They found that control fruits produced more CO_2 and C_2H_2 than wax-coated fruits.

The effect of propolis in reducing the severity of fruits and vegetables post harvest disease was recommended by Troncoso-Rojas and Tiznado-Hernandez (2007), Ojeda-Contreras *et al.,* (2008), and Ordonez *et al.,* (2011). They mentioned that extracted propolis treatments were effective in preventing fungal decay. In addition, Ozdemir *et al.,* (2010) dipped Star Ruby grapefruit in ethanol-extracted propolis (EEP) in various concentrations (1%, 5%, and 10%) immediately after harvest. They mentioned that treatment with 5% EEP was effective in preventing fungal decay. The percentage of weight loss was significantly higher in the control fruits

than in those treated with 5% and 10% EEP at the end of the storage period. Star Ruby grapefruit treated with 5% EEP was successfully stored at 8 °C for 5 months. On the other hand, ethanol extracted propolis treatments were effective in preventing fungal decay in cherries for 4 weeks, but adversely affected sensory quality and stem colour of cherries (Candr *et al.,* 2009).

Acknowledgment

The authors greatly thank the National Research Center, Egypt for financial support and providing facilities to conduct this work under the project "Post-harvest Technology of Horticultural Crops" No. 9050409.

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