

The effectiveness of plant essential oils and Arabic gum on the postharvest treatments of Zaghloul dates fruit during cold storage

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Abstract: This study was carried out during two successive seasons (2012 & 2013) at the experimental Research station, faculty of Agriculture, Cairo University, Giza, Egypt. The composite effects of Arabic gum (15 %), Black cumin oil (1 %) and lemon grass oil (0.5 %) alone or in combination on fruit physical and chemical properties of Zaghloul fruits stored at 0 ± 1 °C and 85-90 % relative humidity (RH) for 60 days fruit quality characteristics *i.e.* weight loss and decay percentages, fruit firmness (Lb/inch^2), total soluble solid percentage (TSS %), total acidity percentage (TA %) and total soluble sugars were evaluated.

The results showed that after 60 days of cold storage, the weight loss and decay percentage of fruits treated with 10 % Arabic gum + 1 % black cumin oil + 0.5 % lemon grass oil were lower than the control. All combination treatments gave the highest value of fruit TSS % and total soluble sugars while decreasing total acidity percentage and weight loss percentage during cold storage for 60 days. On the other hand, the control treatment showed the highest reduction values among of all other treatments. The total soluble solids and total sugars values were increased gradually according to the increase of storage period. The results suggested that all combination treatments preservative material and improves the postharvest quality during cold storage.

Key Words: Date palm – postharvest - Arabic gum – black cumin oil - lemon grass oil - physical and chemical properties.

Introduction

Date palm (*Phoenix dactylifera* L.), one of the ancient domestic fruit trees in the Middle East countries and their fruits play an important role in the nutritious pattern of many people. It can grow well under drastic environmental conditions which may be not suitable for many fruit species. In Egypt many date palm cultivars are grown in different regions according to the diversity of their climatic necessity, particularly average temperature and relative humidity that affect fruit growth and development.

Zaghloul dates are demanded in the Egyptian and many foreign markets. The date palm is a popular human food and passes through four different stages from fruit setting to maturity. The physical changes periodically occur at various maturity stages have been reported by various researchers^{1,2}.

Cumin (*Cuminum cyminum* L.) is an aromatic plant in the family Apiaceae. Its fruit known as cumin seed is a lateral fusiform with abundant content of essential oil.

In indigenous medicine, cumin seeds have long been considered as a stimulant and carminative and are used for therapeutic Purposes³.

Lemongrass (*Cymbopogon Citrates* L.) oil was reported to be antifungal activity against several plant pathogens. Fungal spore production, spore germination and germ tube length of *C. coccodes*, *B. cinerea*, *c. herbarium* and *R. stolonifer* was inhibited with lemongrass oil treatments⁴, Moreover, using lemongrasses essential oils by spraying or dipping fruits for controlling postharvest diseases of several fruits has been reported⁵.

Arabic gum is a natural or slightly acidic salt of a complex polysaccharide containing calcium, magnesium and potassium ions⁶, obtained from the stems or branches of *Acacia* species, and is commonly used in the industrial sector as a food additive⁷. The gum derived from *Acacia Senegal* is the main gum used for commercial purposes because it has better emulsification properties as compared to the gum obtained from *Acacia Senegal*⁸.

More than 50% of the world's production of Arabic gum is used in confectionary to delay sugar crystallization and for thickening of candies, Jellies, glazes and Chewing gums. It has also been approved as a safe compound by the joint FAO/Who Expert committee on food additives⁹.

The aim of this work was study the effect of different concentrations of lemongrass oil, black cummin essential oil and Arabic gum alone or in combination on fruits quality assessments during cold storage periods of Zaghoul date palm cultivar.

Materials and Methods

The presents study was carried out during two successive seasons (2012 & 2013) at the Experimental Research Station, faculty of Agriculture, Cairo University, Giza, Egypt.

Harvested fruits were transferred to the laboratory for further treatments at the same day. Fruits were thoroughly washed with water, surface sterilized with sodium hypochlorite for 3 min (0.5 % of stock solution), then washed again in distilled water and left for air drying. Experimental fruits were divided into eight similar groups. Each group was subjected to one of the following treatments:

- Control group (tap water plus tween 80)
- Arabic gum at 10%
- Black cummin oil at 1%
- Lemongrass oil at 0.5%
- Arabic gum 10% + black cummin oil 1%
- Arabic gum 10% + lemongrass oil 0.5%
- Lemon grass 0.5% + black cummin oil 1%
- Arabic gum 10% + black cummin oil 1% + lemongrass oil 0.5%

Tween 80 was used as a wetting agent with all treatments.

After treatment, fruits were packed in perforated carton boxes in three replicates for each treatment (2.0 Kg/replicate). Each treatment packed in six boxes, it's classified into two groups. The 1st group (3 boxes) contain fruits for periodical determination the physical properties. The other contained fruits were used for determination of chemical properties. Fruits stored at 0 ± 1 °C with relative humidity (RH) 85-90% for 60 days in the laboratory of Agriculture Development system (ADS) project, faculty of Agric, Cairo, Univ., Egypt. Changes in some physical and chemical fruits properties were determined at 15 days intervals up to 60 days.

Fruit quality assessments

1. Physical properties

1.1. Weight loss percentage

Date fruits were periodically weight and the losses were recorded for each replicate. Date of weight loss was calculated as percentage from the initial weight.

1.2. Decay Percentage

Percentage of fruit decay was calculated in relation to the initial weight of stored fruits. At every storing date, rotted date fruits removed and weighted, Also, the percentage of fruit decay was calculated in marketing period.

1.3. Fruit firmness (Lb/inch²)

Fruit firmness was determined as Lb/inch² by using fruit pressure tester mod. FT 32-7 (3-27 Lbs).

2. Chemical properties

2.1. Total soluble solids percentage (TSS)

Total soluble solids percentage was determined in date palm fruit juice using a hand refractometer.

2.2. Total sugars (g/100g fresh weight)

Total sugars (g/100g fresh weight) were determined in stored date fruits by method described by Smith *et al.*,¹⁰.

2.3. Total Acidity percentage (TA %)

Total acidity percentage was estimated as g citric acid and malic acid\ 100 ml juice according to A.O.A.C.,¹¹.

Statistical Analysis

The obtained data was subjected to analysis of variance and the method of Duncan was used to differentiate means at 0.5% Level¹².

Results and Discussions

1. Physical properties

1.1. Weight loss percentage

Table (1) showed that, fruit weight loss is directly proportional and coincided with the increase of storage duration in all treatments under study of Zaghloul date palm fruit. After 15 days storage, treated with 10 % Arabic gum + 0.5 % lemongrass oil and 0.5 % lemongrass oil in the first season as well as treated with 10 % Arabic gum + 1 % black cumin oil, 0.5 % lemongrass oil + 1 % black cumin oil and control in the second season treatments with significantly differences.

Meanwhile, after 30 days storage, the percentage of weight loss was very low for fruit treated by 10 % Arabic gum + 0.5 % lemongrass oil in the first season and 10 % Arabic gum + 1 % black cumin oil in the second season with significant differences. However, the percentage of weight loss was very low for fruit treated by 10 % Arabic gum + 1 % black cumin oil + 0.5 % lemongrass oil in the first season as well as fruit treated by 10 % Arabic gum, 0.5 % lemongrass oil and 10 % Arabic gum + 0.5 % lemongrass oil in the

second season were significant at 45 days. In addition, after 60 days storage, fruit treated by 0.5 % lemongrass oil + 1 % black cumin oil in the first season and fruit treated by 10 % Arabic gum + 0.5 % lemongrass oil in the second season showed significant lower weight loss as compared to other used treatments and the control as the weight loss increased gradually during storage period. Generally, all treatments were effective in reducing the rate of weight loss percentage as compared to control. The lowest fruit weight percentage was obtained with 10 % Arabic gum + 1 % black cumin oil + 0.5 % lemongrass oil in the first season as well as 10 % Arabic gum + 0.5 % lemongrass oil in the second season. Meanwhile, the highest fruit weight loss percentage was recorded for untreated fruits.

The results from this study are in agreement with ^{13,14}. They found that, the reduction in weight loss was probably due to the effect of composite coating which served as a semi permeable barrier against oxygen, carbon dioxide and moisture, thus reducing respiration, water loss and oxidation reaction. However, Mehdi *et al.*,¹⁵ observed that, 5 and 20 % Arabic gum plus 1 % chitosan treatments showed significantly higher weight loss as compared to 10 and 15 % Arabic gum incorporated with 1 % chitosan which could be explained by the thickness of composite coatings. A coating of 5% arabic gum plus 1% chitosan was not so thick that it can provide enough barriers against water loss, whereas a 20 % Arabic gum plus 10 % chitosan composite coating was so thick that it completely covered the surface of the fruit and blocked the lenticels.

Table 1. Effect of some postharvest treatments on weight loss percentage of date palm cv Zaghloul stored at $0 \pm 1^\circ\text{C}$ for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	0.00	1.00	1.77	3.63	4.88	2.25 A
Arabic gum 10%	0.00	1.53	1.97	3.70	4.20	2.28 A
Black cumin oil 1%	0.00	1.53	1.93	2.40	3.63	1.90 AB
Lemon grass 0.5%	0.00	0.83	1.32	2.00	2.89	1.41 BC
Arabic gum 10% + black cumin oil 1%	0.00	1.17	1.23	2.52	3.37	1.66 ABC
Arabic gum 10% + lemon grass 0.5%	0.00	0.77	1.07	2.80	3.73	1.67 ABC
Lemon grass 0.5% + black cumin oil 1%	0.00	1.29	1.49	1.71	2.20	1.34 BC
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	0.00	1.17	1.21	1.63	2.03	1.21 C
Mean	0.00 D	1.16 C	1.50 C	2.55 B	3.37 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.41						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	0.00	0.43	0.63	1.40	1.52	0.80 BC
Arabic gum 10%	0.00	0.50	0.78	0.83	1.73	0.77 BC
Black cumin oil 1%	0.00	0.54	0.97	1.23	1.50	0.85 AB
Lemon grass 0.5%	0.00	0.57	0.60	0.83	1.20	0.64 DE
Arabic gum 10% + black cumin oil 1%	0.00	0.25	0.38	1.45	1.83	0.78 BC
Arabic gum 10% + lemon grass 0.5%	0.00	0.51	0.68	0.73	0.83	0.55 E
Lemon grass 0.5% + black cumin oil 1%	0.00	0.43	0.66	0.92	1.50	0.70 CD
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	0.00	0.73	0.77	1.25	1.81	0.91 A
Mean	0.00 E	0.50 D	0.68 C	1.08 B	1.49 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.61						

1.2. Fruit decay percentage

Data in table (2) indicated that, fruit decay percentage was gradually increased as a function of cold storage period at 0°C up to 60 days either treated or untreated fruits of Zaghloul date palm under study in both seasons. Meanwhile, all treatments were effective in reducing the rate of decay percentage compared to the control but the effect was more pronounced with 10 % Arabic gum + 1 % black cumin oil + 0.5 % lemongrass oil in both seasons as well as 10 % Arabic gum + 0.5 % lemongrass oil in the second season as compared with the control. However, after 60 days storage untreated fruits lost 23.98 and 24.45 for fruit first and second season respectively. In addition, after 60 days storage fruit with 10 % Arabic gum + 1 % black cumin oil + 0.5 % lemongrass oil treatment was the best followed by 10 % Arabic gum + 0.5 % lemongrass

oil as compared with the control in a descending order in the first season. However, results in the second season behaved the same as that of the first season.

Generally it could notice that, all treatments were effective in reducing the rate of fruit decay at any time of storage and the control. Also, the highest fruit decay was recorded for untreated fruits during the two seasons. The obtained data are similar to ¹⁶, the effect of Arabic gum as an edible coating was observed on apple fruit during cold storage. It was found that apple fruit coated with Arabic gum showed a significant delay in ripening and therefore, decayed slowly as compared to control. Also, *Ali et al.*,¹⁷ found that, 10 % Arabic gum used alone enhanced the shelf life of fruit up to 20 days during storage. In addition, 10 % Arabic gum incorporated with 1 % chitosan was the optimal concentration in controlling decay (80 %), showing a synergistic effect in reduction of *C. musae* in artificially inoculated bananas¹⁵.

Table 2. Effect of some postharvest treatments on decay percentage of date palm cv Zaghloul stored at 0± 1 °C for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	0.00	5.42	7.04	13.82	23.98	10.05 A
Arabic gum 10%	0.00	5.36	6.64	12.74	21.56	9.26 B
Black cumini oil 1%	0.00	5.16	6.56	13.27	20.57	9.11 B
Lemon grass 0.5%	0.00	4.58	5.13	11.12	20.55	8.28 C
Arabic gum 10% + black cumini oil 1%	0.00	5.07	7.20	13.03	21.75	9.41 B
Arabic gum 10% + lemon grass 0.5%	0.00	5.00	6.25	11.85	19.53	8.53 C
Lemon grass 0.5% + black cumini oil 1%	0.00	5.05	6.00	9.90	20.93	8.38 C
Arabic gum 10% + black cumini oil 1% + Lemon grass 0.5%	0.00	4.80	5.51	12.08	16.49	7.78 D
Mean	0.00 E	5.06 D	6.29 C	12.22 B	20.67 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.91						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	0.00	3.15	8.65	16.70	24.45	10.59 A
Arabic gum 10%	0.00	2.66	6.34	12.46	18.94	8.08 BC
Black cumini oil 1%	0.00	2.54	6.39	13.06	19.01	8.20 B
Lemon grass 0.5%	0.00	1.43	5.30	9.76	17.93	6.88 E
Arabic gum 10% + black cumini oil 1%	0.00	3.78	6.76	13.15	18.00	8.34 B
Arabic gum 10% + lemon grass 0.5%	0.00	1.63	5.45	11.97	17.92	7.39 DE
Lemon grass 0.5% + black cumini oil 1%	0.00	1.93	5.80	12.13	18.23	7.62 CD
Arabic gum 10% + black cumini oil 1% + Lemon grass 0.5%	0.00	1.67	5.42	11.09	17.75	7.19 DE
Mean	0.00 E	2.35 D	6.26 C	12.54 B	19.03 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 3.016						

1.3. Fruit firmness (Lb\inch²)

A glance to table (3) indicated that, fruit firmness for all treatments in this study gradually decreased by storage periods advanced in fruits treated on untreated in both seasons. Meanwhile, the lowest fruit firmness was obtained with 10 % Arabic gum + 1 % black cumini oil treatment in the first season and fruit treated with 1 % black cumini oil treatment in the second season during 60 days storage period. However, the highest fruit firmness was recorded for untreated fruits in the first season and both 0.5 % lemongrass oil and 0.5 % lemongrass oil + 1 % black cumini oil treatments in the second season.

There was no significant difference in all treatments under study after 60 days of storage period. Fruit softening is normally attributed to the destruction of cell structure and the deterioration in cell wall composition and intracellular materials. It is a biochemical process that involves the hydrolysis of pectin and starch by enzymes, for example, wall hydrolyses¹⁸. These results confirm the finding of *Fahad et al.*,¹⁹ they found that fruit coated with Arabic gum had significant ($P \leq 0.05$) higher firmness values during storage than the control and the fruit firmness decreased gradually during the storage period.

Table 3. Effect of some postharvest treatments on fruit firmness (Lb/inch²) of date palm cv Zaghloul stored at 0 ± 1 °C for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	17.47	17.33	17.17	17.07	16.63	17.13 A
Arabic gum 10%	17.47	17.27	17.17	17.00	16.87	17.15 A
Black cummin oil 1%	17.47	17.23	17.17	17.13	17.03	17.21 A
Lemon grass 0.5%	17.47	17.30	17.17	16.73	16.50	17.03 A
Arabic gum 10% + black cummin oil 1%	17.47	17.30	17.20	17.17	17.13	17.25 A
Arabic gum 10% + lemon grass 0.5%	17.47	17.33	17.30	17.23	16.53	17.17 A
Lemon grass 0.5% + black cummin oil 1%	17.47	17.37	17.37	16.70	16.40	17.06 A
Arabic gum 10% + black cummin oil 1% + Lemon grass 0.5%	17.47	17.33	17.20	17.20	16.57	17.15 A
Mean	17.47 A	17.31 AB	17.22 BC	17.03 C	16.71 D	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.45						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	17.35	17.30	17.10	16.50	16.03	16.86 AB
Arabic gum 10%	17.35	17.27	17.17	17.00	16.87	17.13 A
Black cummin oil 1%	17.35	17.23	17.17	17.13	17.03	17.18 A
Lemon grass 0.5%	17.35	16.93	16.47	16.30	15.97	16.60 B
Arabic gum 10% + black cummin oil 1%	17.35	17.20	17.03	16.82	16.33	16.95 AB
Arabic gum 10% + lemon grass 0.5%	17.35	17.23	17.23	17.03	16.73	17.12 A
Lemon grass 0.5% + black cummin oil 1%	17.35	17.32	16.80	16.80	15.47	16.75 AB
Arabic gum 10% + black cummin oil 1% + Lemon grass 0.5%	17.35	17.30	17.03	16.50	16.43	16.92 AB
Mean	17.35 A	17.22 A	17.00 AB	16.76 B	16.36 C	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.71						

2. Chemical properties

2.1. Total soluble solids (TSS %)

Data illustrated in table (4) indicated that, total soluble solids percentage of all treatments used increased with prolonging period of fruit storage in both seasons. However, most combinations treatments of Zaghloul particularly recorded the highest values of fruit total soluble solids percentage content in the second season took nearly the same trend in the first one. In addition, after 60 days storage fruit treated by 10 % Arabic gum + 1 % black cummin oil + 0.5 % lemongrass oil in the first season and fruit treated by 10 % Arabic gum + 1 % black cummin oil as well as fruit treated by 10 % Arabic gum + 0.5 % lemongrass oil in the second season showed significantly higher TSS % as compared to the other used treatments and the control.

The gradual increase of total soluble solids with increase of storage temperature and the progress of storage period could be due to the degradation of complex in soluble compounds like starch to simple soluble compounds like sugar which are the major component of soluble solids content in the fruits. Meanwhile, the changes increased with the progress of storage period, where it allowed the accumulation of soluble solids in fruits.

Our results are in agreement with the findings of *Zuhair et al.*,²⁰ they found that, the total soluble solids was significantly ($P \leq 0.05$) higher in control sample as compared to treated papaya fruits with Arabic gum. It must be noted that the lowest TSS % was at the 7 and 15 days of storage in fruit treated with Arabic gum at 10% (11.33 and 10.33). Beside this, the findings of the present study also revealed that 5% Arabic gum treatment also lower the TSS value in comparison to Arabic gum 5% fruit, which indicate that Arabic delay the softening process in fruit²¹.

Table 4. Effect of some postharvest treatments on total soluble solids percentage of date palm cv Zaghloul stored at 0 ± 1 °C for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	26.58	27.44	29.38	31.04	32.28	29.34 BCD
Arabic gum 10%	26.58	27.48	29.65	31.86	33.13	29.74 BCD
Black cummin oil 1%	26.58	27.60	28.07	29.92	33.39	29.11 D
Lemon grass 0.5%	26.58	27.90	28.84	29.39	33.41	29.22 CD
Arabic gum 10% + black cummin oil 1%	26.58	28.30	30.68	31.17	32.66	29.88 BC
Arabic gum 10% + lemon grass 0.5%	26.58	27.87	27.82	31.30	33.46	29.41 BCD
Lemon grass 0.5% + black cummin oil 1%	26.58	27.50	29.52	31.83	34.35	29.96 AB
Arabic gum 10% + black cummin oil 1% + Lemon grass 0.5%	26.58	27.33	29.68	32.64	36.94	30.63 A
Mean	26.58 E	27.86 D	29.20 C	31.14 B	33.70 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.51						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	28.50	29.36	30.31	31.64	32.68	30.50 C
Arabic gum 10%	28.50	30.04	31.72	32.10	32.94	31.06 AB
Black cummin oil 1%	28.50	29.89	31.51	32.20	32.60	30.94 ABC
Lemon grass 0.5%	28.50	30.06	31.72	32.00	33.17	31.09 AB
Arabic gum 10% + black cummin oil 1%	28.50	30.79	31.76	32.27	33.35	31.34 A
Arabic gum 10% + lemon grass 0.5%	28.50	30.79	31.94	32.09	33.20	31.30 A
Lemon grass 0.5% + black cummin oil 1%	28.50	29.90	31.12	31.39	32.42	30.67 BC
Arabic gum 10% + black cummin oil 1% + Lemon grass 0.5%	28.50	29.07	30.88	32.02	32.43	30.58 BC
Mean	28.50 E	29.99 D	31.37 C	31.96 B	32.85 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.17						

2.2. Fruit total sugars content

It is quite evident from table (5) that total sugars content of different treatments increased with increasing the period of storage in both seasons. However, after 60 days storage, fruit treated by 10 % Arabic gum + 1 % black cummin oil + 0.5 % lemongrass oil in the first season and fruit treated by 10 % Arabic gum in the second season showed significantly higher total sugars content as compared to other used treatments and the control as the total sugars content decreased gradually during the storage period. Meanwhile, significant differences between black cummin oil and lemongrass treatments regarding fruit content of total sugars during the storage period in both seasons. The results of storage temperature and storage period on sugar constituents confirmed by the reports of some researchers on date palm. They mentioned that total sugars content and inverted sugars were increased during storage^{22,23}.

2.3. Fruit acidity (%)

Table (6) showed that, fruit recorded the lowest values of acidity after 60 days storage period. Meanwhile, all treatments under study of both seasons were effective in reducing values of acidity compared to the control but the effect was more pronounced with 1 % black cummin oil treatment in first season and fruit treated with 0.5 % lemongrass oil in the second season. However, the different between all combination treatments were lacking from statistical stand point in both seasons. The decrease in total acidity (citric and malic acids) during storage at different treatments could be due to its consumption in respiratory activities with the progress of storage time and the increase in storage temperature, as citric and malic acid could be used as organic substrate in the respiration process.

The results of storage period and this respect go in line with the finding of *hafez et al.*,²³ on date palm and *Brackman et al.*,²⁴ on Valencia orange, they mentioned that the percentage of total acidity was slightly decrease as a results of storage temperature. Also, *Zuhair et al.*,²⁰ found that Arabic gum affected significantly ($P \leq 0.05$) the total acidity in papaya fruit at different concentrations with storage days the highest values were recorded in sample control (untreated fruit) and the lowest values in 10 and 5% Arabic gum treatments.

Table 5. Effect of some postharvest treatments on total sugar (g/100 FW) of date palm cv Zaghloul stored at 0 ± 1 °C for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	22.10	22.33	23.58	23.93	24.17	23.22 C
Arabic gum 10%	22.10	22.37	23.80	24.57	26.63	23.89 B
Black cumin oil 1%	22.10	22.47	22.53	23.07	25.67	23.17 C
Lemon grass 0.5%	22.10	22.23	22.37	23.13	25.70	23.11 C
Arabic gum 10% + black cumin oil 1%	22.10	23.03	24.63	24.80	25.87	24.09 B
Arabic gum 10% + lemon grass 0.5%	22.10	22.20	22.33	23.50	26.13	23.25 C
Lemon grass 0.5% + black cumin oil 1%	22.10	23.10	24.16	24.85	26.73	24.19 B
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	22.10	23.97	24.57	25.50	27.70	24.77 A
Mean	22.10 E	22.71 D	23.50 C	24.17 B	26.07 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.64						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	23.70	23.90	24.33	25.93	27.67	25.11 E
Arabic gum 10%	23.70	24.45	26.83	28.72	29.50	26.64 A
Black cumin oil 1%	23.70	24.60	26.67	27.87	28.37	26.24 ABC
Lemon grass 0.5%	23.70	24.47	25.47	27.13	28.33	25.82 BCD
Arabic gum 10% + black cumin oil 1%	23.70	25.33	25.50	26.17	27.97	25.73 CD
Arabic gum 10% + lemon grass 0.5%	23.70	25.60	26.44	27.07	28.60	26.28 AB
Lemon grass 0.5% + black cumin oil 1%	23.70	24.33	25.20	26.31	27.27	25.36 DE
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	23.70	24.60	25.72	26.66	28.40	25.82 BCD
Mean	23.70 E	24.66 D	25.77 C	26.98 B	28.26 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.50						

Table 6. Effect of some postharvest treatments on total acidity percentage of date palm cv Zaghloul stored at 0 ± 1 °C for 60 days during 2012 and 2013 seasons.

Season 2013						
Storage periods (days)						
Treatment	0	15	30	45	60	Mean
Control	1.02	0.86	0.70	0.66	0.64	0.78 B
Arabic gum 10%	1.02	0.90	0.84	0.80	0.70	0.85 A
Black cumin oil 1%	1.02	0.73	0.63	0.53	0.50	0.68 C
Lemon grass 0.5%	1.02	0.83	0.78	0.70	0.72	0.81 AB
Arabic gum 10% + black cumin oil 1%	1.02	0.75	0.70	0.67	0.65	0.76 A
Arabic gum 10% + lemon grass 0.5%	1.02	0.97	0.87	0.72	0.68	0.85 A
Lemon grass 0.5% + black cumin oil 1%	1.02	0.98	0.83	0.78	0.63	0.85 A
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	1.02	0.97	0.82	0.76	0.70	0.85 A
Mean	1.02 A	0.87 B	0.77 C	0.70 D	0.65 D	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.143						
Season 2014						
Treatment	0	15	30	45	60	Mean
Control	0.84	0.63	0.57	0.48	0.42	0.59 A
Arabic gum 10%	0.84	0.56	0.47	0.45	0.33	0.53 AB
Black cumin oil 1%	0.84	0.64	0.50	0.49	0.42	0.58 AB
Lemon grass 0.5%	0.84	0.60	0.46	0.39	0.32	0.52 B
Arabic gum 10% + black cumin oil 1%	0.84	0.62	0.43	0.38	0.35	0.52 AB
Arabic gum 10% + lemon grass 0.5%	0.84	0.74	0.52	0.42	0.35	0.58 AB
Lemon grass 0.5% + black cumin oil 1%	0.84	0.60	0.49	0.47	0.36	0.55 AB
Arabic gum 10% + black cumin oil 1% + Lemon grass 0.5%	0.84	0.59	0.55	0.50	0.39	0.58 AB
Mean	0.84 A	0.62 B	0.50 C	0.45 C	0.37 D	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.102						

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