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Impact of gelatin, lemongrass oil and peppermint oil on storability and fruit quality of Samany date palm under cold storage

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Abstract

Background: This study was carried out during two successive 2016 and 2017 seasons in the postharvest laboratory of the Agricultural Development System (ADS) project in the Faculty of Agric, Cairo University, Giza Governorate, Egypt, to study the efficiency of using some natural substances i.e., gelatin at 1, 2, and 4%, lemongrass oil at 0.25 and 0.5%, and peppermint oil at 5 and 10%, beside untreated fruits as control on storability of Samany date palm fruits and their quality under cold storage at 0.0 °C ± 2 and 90–95% R.H.

Results: The results obtained from this study showed that it was evident that those two conflicted trends were detected with the advancement of storage duration during both seasons. Hence, the percentage of fruit weight loss, decay, fruit juice total soluble solids, total sugars, and total phenolic content were increased. Moreover, flesh firmness, total acidity%, and total protein content were relatively reduced. Moreover, not only is the response of different Samany fruit measurements to various investigated dipping treatments varied from one treatment to another, but also each characteristic reflected its trend.

Conclusion: It could be generally concluded that all dipping treatments significantly decreased the percentage of both fruit weight loss and decay below control (water dipping), whereas 0.50% lemongrass oil treatment was superior, while 1% gelatin ranked last. On the other hand, fruit juice total acidity was slightly responded by different treatments, and the difference was more pronounced particularly with both 0.25 and 0.50% lemongrass oil during two seasons. Besides, fruit flesh firmness and fruit juice total sugars did not significantly respond to various treatments. Meanwhile, fruit juice total soluble solids percentage, total protein content, and total phenolic content showed considerable different influence to most investigated treatments in both seasons of study.

Keywords: Date palm, Samany, Natural substances, Gelatin, Lemongrass oil, Peppermint oil, and Cold storage

Background

The date palm (*Pheonix dactlifera,* L.) belongs to the palmaceae family, possibly the oldest cultivated plant. Fruits of the date palm are very commonly consumed in many parts of the world and are a vital component of the diet and a portion of staple food (Vayalil, 2002). Arab countries are the primary source of date palm in the world (Mohamed, 1982).

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

Recently, bioactive studies have shown that the various components of essential oils contain antimicrobial, antifungal, antibacterial, and mosquito repellent properties (Schaneberg and Khan, 2002). However, lemongrass oil has many other uses: (1) It is used in herbal tea because of its

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sharp lemon flavor. (2) Also, it is used in the perfumery and soap industries. (3) Moreover, it is used in the manufacture of synthetic vitamin A and in the medicine to treat various health ailments, including acne, athlete's foot, flatulence, muscle aches, and scabies (Masamba et al., 2003, Abbas and El-Saeid, 2012).

Lemongrass (*Cymbopogon citratus*) which is one of the natural sources used to control plant diseases is grown widely in Thailand for direct consumption such as cooking ingredients in curries, salad, and spicy soup (Tomyum Kung). Only the lower part of its leaf sheath is used, whereas the leftover is discarded in the field, though some cosmetic industries use this in a mixture of shampoo or toilet cleaner. It is the fact that essential oil, as secondary metabolites, is made up of different volatile compounds, which are almost entirely classified as terpenes and phenylpropenes. Furthermore, lemongrass contains terpenes, alcohols, ketones, aldehyde, esters, and flavonoids (luteolin, isoorientin 2′-Orhamnoside, quercetin, kaempferol, and apigenin) (Shah et al., 2011).

Peppermint oil is obtained from the leaves of the perennial herb, *Mentha piperita*, L., and *M. arvensis* var. piperascens a member of the Labiatae family. This family includes many well-known essential oil plants such as spearmint, basil, lavender, rosemary, sage, marjoram, and thyme. This is a great and vital medicinal plant widely used in several indigenous systems of medicine for various therapeutic benefits viz. analgesic, anesthetic, antiseptic, astringent, carminative, decongestant, expectorant, nervine, stimulant, stomachic, inflammatory diseases, ulcer, and stomach problems (Shrivastava Alankar, 2009).

Gelatin is an essential functional biopolymer widely used in foods to improve elasticity, consistency, and stability (Mariod and Adam, 2013).

However, few numbers of researches to date have been conducted on using gelatin and essential oil as an edible coating material for fresh fruits and vegetables. Thus, this study planned to evaluate the potential use of some selected edible coating substances, namely gelatin, lemongrass oil, and peppermint oil as antifungal, antibacterial, and antimicrobial agents for extending the storability of Samany date palm fruits and maintaining their quality under cold storage.

Materials and methods

Plant material

Date palm (*Phoenix dactylifera* L.) Samany was obtained from researches and experiments station at the Faculty of Agriculture, Cairo University, Giza Governorate, Egypt. Fruits were collected at the maturity and coloring stage (Khalaal) during 2016 and 2017 seasons, and selected mature fruits, undamaged, free from apparent pathogen infection, and were uniformed in shape, weight, and color for cultivar of study. Fruits were transported to the laboratory of Agriculture Development Systems (ADS) project in the Faculty of Agriculture, Cairo University.

Treatments and storage condition

The selected fruits were washed, air dried, placed into plastic baskets, and divided into eight similar groups to carry out the following treatments:

1. Control (tap water)
2. Gelatin at 1%
3. Gelatin at 2%
4. Gelatin at 4%
5. Lemongrass oil at 0.25%
6. Lemongrass oil at 0.50%
7. Peppermint oil at 5%
8. Peppermint oil at 10%

Gelatin was obtained as commercial grade, and then dipping solution was prepared at the concentration of 1, 2, and 4% (w/v) using distilled water. The essential oil of lemongrass (*Cymbopogon citratus* Stapf) extracted by steam distillation and emulsified in water at 0.25 and 0.5% as described by Shaarawi et al. (2013). Peppermint oil is obtained from the leaves of the perennial herb, *Mentha piperita* L. The solution may show opalescence. Peppermint oil is extracted from the whole aboveground system just before flowering. The oil is extracted by steam distillation from the fresh or partly dried plant and the yield is 0.1–1.0%, respectively (Shrivastava Alankar, 2009).

The selected fruits were immersed at the abovementioned solutions for 5 s. Moreover, all the treated and untreated fruits were left to dry aerobically. Each treatment was divided into two sections; the first, to estimate the physical properties (percentages of weight loss, decay, and fruit firmness) and the second, to evaluate the chemical characteristics (fruit content of total soluble solids, total sugars, total acidity, fruit tannins, total soluble proteins, and total phenol compounds). Each section has three replicates with the rate 1.5 Kg/replicate. Then, each replicate was packed in perforated carton boxes. All treated and untreated fruits stored at 0 ± 2°C and relative humidity (RH) 90–95%. The initial fruit quality characteristics of date palm cv. Samany after treatments were measured (zero time). After 15 days' intervals, fruit samples were removed from cold storage and fruit quality measurements were assessed.

Measurements

Physical properties

Weight loss (%) Fruits were periodically weighed, and the loss in mass weight was recorded for each replicate.

Data were calculated as a percentage from the initial weight. The following formula is used:

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

Decay percentage (%) Decay Percentage is evaluated by skin appearance, shriveling, chilling injury, and pathogenic rots. In every inspection, decayed fruits were discarded, and the weight of fruits per replicate was used to express decay percentage. Storage was stopped when decay assessment reached 50% in stored fruits. The following formula is used:

$$\text{Decay Percentage}\ (\%) = \frac{\text{Weight of discard fruits}}{\text{Initial weight}} \times 100$$

Fruit firmness (Lb\inch^2) Fruit firmness was determined as Lb/inch^2 by using fruit pressure tester mod. FT 327 (3–27 Lbs.).

Chemical properties

Total soluble solids percentage (TSS %) Determined in date palm fruit juice using a hand refractometer

Total sugars (g/100 g "fresh weight" FW) Determined in stored date fruits by the method described by (Dubois et al., 1956)

Total acidity (TA) Estimated as gram citric acid and malic acid/100 ml juice according to (A.O.A.C., 1995)

Total soluble proteins Total soluble proteins concentration was quantified in the crude tissue extract by using of Coommassi Brilliant Blue-G 250 according to the method of Bradford (1976).

Total phenols compounds (g/100 g FW) Extraction of phenol compounds was conducted according to the method described by (Daniel and George 1972).

Statistical analysis

The statistical analysis of the present data was carried out according to (Snedecor and Cochran 1989). Means of the obtained results at different treatments were compared using L.S.D. test at 5% level.

Results and discussions

Effect of some postharvest treatments on fruit physical properties of Samany date palm

Fruit weight loss percentage

It is easy to notice from Table 1 that prolonged storage period after the postharvest treatment increased fruits weight loss percentage of Samany date palm. The obtained data declare this result, where the highest fruit weight loss percentages (4.45 and 4.42) were recorded after a 45-day cold storage period, followed descendingly by those of the 60-day cold storage period (3.56 and 3.36) against (2.85 and 2.16) for the analogous ones kept for 45 days, (2.33 and 1.99) for those stored for 30 days, and (1.40 and 1.34) for those left for 15 days after cold storage in 2016 and 2017 seasons, respectively. The differences between the evaluated storage periods in this respect were pronounced significant at 5% level in both seasons.

Considering the effect of the tested postharvest treatments, recorded data in Table 1 indicate that

Table 1 Effect of gelatin, lemongrass oil, and peppermint oil on weight loss (%) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

	Storage periods (days)					
	15	30	45	60	75	Mean
Treatment	2016					
Control	1.46	2.36	3.03	4.12	5.17	3.23 a
Gelatin 1%	1.43	2.30	2.90	3.54	4.43	2.92 b
Gelatin 2%	1.50	2.40	2.83	3.50	4.40	2.93 b
Gelatin 4%	1.45	2.40	2.88	3.43	4.31	2.89 b
Lemongrass oil 0.25%	1.37	2.49	2.91	3.40	4.30	2.90 b
Lemongrass oil 0.50%	1.34	2.13	2.73	3.40	4.17	2.76 b
Peppermint oil 5%	1.37	2.22	2.80	3.56	4.40	2.87 b
Peppermint oil 10%	1.30	2.30	2.75	3.50	4.40	2.55 b
Mean	1.40 E	2.33 D	2.85 C	3.56 B	4.45 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.5416						
Treatment	2017					
Control	1.53	2.18	2.95	3.80	4.78	3.05 a
Gelatin 1%	1.40	2.10	2.95	3.70	4.70	2.97 a
Gelatin 2%	1.37	2.10	2.73	3.70	4.62	2.90 a
Gelatin 4%	1.27	1.88	2.57	3.25	4.29	2.65 b
Lemongrass oil 0.25%	1.29	1.80	2.33	3.18	4.25	2.57 bc
Lemongrass oil 0.50%	1.20	1.77	2.30	3.07	4.13	2.49 c
Peppermint oil 5%	1.37	2.06	2.56	3.10	4.30	2.68 b
Peppermint oil 10%	1.30	2.00	2.50	3.10	4.27	2.63 bc
Mean	1.34 E	1.99 D	2.16 C	3.36 B	4.42 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.3448						

the lowest fruit weight loss percentages were produced by 0.50% lemongrass-treated fruits (2.76 and 2.49) with non-significant differences between the all tested treatments irrespective the control treatment in the first season only while in the second one the differences between treatments and control were significant in most cases. Moreover, untreated fruits "control" scored significantly higher weight loss percentages (3.23 and 3.05) in the first and second seasons, respectively.

With respect to the interaction effect between storage periods and tested postharvest treatments, the resulted combinations reported in Table 1 illustrate that the 15-day cold storage period interactions showed to be the most effective combinations in inducing the lowest fruit weight loss percentages, especially 10% peppermint oil and 0.50% lemongrass in the first and second season, respectively.

On the opposite, the highest fruit weight loss percentages were scored by the 75-day cold storage period combinations, followed in descending order by those of the 60-day cold storage period.

Fruit decay percentage

Looking at the effect of storage periods, it is worthy to notice from Table 2 that there was a steady increase in fruit decay percentage with prolonging cold storage period. The gained data confirmed this result. Hence, the highest fruit decay percentages (42.21 and 41.82) were recorded after a 75-day storage period, followed in descending order by 60-day storage period (31.34 and 30.78) as compared with the similar ones cold-stored for 15 days during the two seasons. The differences between the tested cold storage periods were pronounced significant in both seasons.

Focusing on the effect of the tested postharvest treatments, data in Table 2 show that all tested treatments decreased fruit decay percentages in comparison with the control in both seasons. Consequently, lemongrass at 0.50% induced the lowest fruit decay percentages (17.55 and 17.11), followed ascendingly by 10% peppermint oil-treated fruits (18.86 and 18.43) against (26.63 and 24.76) for the control in the first and second seasons, respectively.

Table 2 Effect of gelatin, lemongrass oil, and peppermint oil on decay (%) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

	Storage periods (days)					
	15	30	45	60	75	Mean
Treatment	2016					
Control	1.87	11.70	27.10	38.15	54.31	26.63 a
Gelatin 1%	1.92	11.51	25.13	35.23	50.39	24.84 b
Gelatin 2%	1.62	10.39	22.32	32.19	47.92	22.89 c
Gelatin 4%	1.53	8.76	21.70	29.62	38.74	20.07 d
Lemongrass oil 0.25%	1.57	8.86	23.52	30.18	37.15	20.26 d
Lemongrass oil 0.50%	1.23	7.20	18.30	26.73	34.29	17.55 e
Peppermint oil 5%	1.50	9.10	20.57	30.20	39.15	20.10 d
Peppermint oil 10%	1.34	8.70	20.10	28.43	35.73	18.86 de
Mean	1.57 E	9.53 D	22.34 C	31.34 B	42.21 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 3.135						
Treatment	2017					
Control	1.52	9.76	23.81	37.32	51.38	24.76 a
Gelatin 1%	1.50	9.72	22.19	36.18	47.19	23.36 b
Gelatin 2%	1.32	8.15	19.67	33.07	45.62	21.57 c
Gelatin 4%	1.23	7.62	18.15	28.15	40.38	19.11 de
Lemongrass oil 0.25%	1.20	7.52	20.05	30.20	40.27	19.85 d
Lemongrass oil 0.50%	0.96	7.15	16.52	25.72	35.19	17.11 f
Peppermint oil 5%	1.35	8.10	20.30	28.47	37.37	19.12 de
Peppermint oil 10%	1.05	7.72	19.10	27.13	37.14	18.43 e
Mean	1.27 E	8.22 D	19.97 C	30.78 B	41.82 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.717						

Examining the interaction effect between cold storage periods and tested postharvest treatments, data presented in Table 2 realize that the interactions of the 15-day cold storage period, especially 0.50% lemongrass and 10% peppermint oil-treated fruits, recorded the lowest fruit decay percentages in both seasons. On the opposite, the highest values of fruit decay percentage were registered by the combinations of the 75-day cold storage period, particularly untreated fruits "control" in both seasons (54.31 and 51.38). The other combinations occupied an intermediate position between the categories as mentioned above in both seasons of study.

Fruit firmness (Lb/inch^2)

Data in Table 3 demonstrate that fruit firmness decreased as the storage period prolonged. The disclosed data indicate this result. Hence, the initial readings of Samany fruit firmness scored the highest fruit firmness, whereas cold-stored fruits produced the lowest fruit firmness for 75 days during the first and second seasons.

As for the effect of the tested treatments, statistical analysis in Table 3 emphasize that fruit firmness of Samany date palm showed no significant response to the all studied postharvest treatments. However, 0.50% lemongrass-treated fruits approved to be the most effective treatment and recorded the highest values of fruit firmness, whereas untreated fruits produced the lowest values of fruit firmness in the first and second seasons. The rest of the treatments occupied an intermediate position between the abovementioned treatments in both seasons.

Pointing to the interaction effect between the tested postharvest treatments and storage period, it is easy to realize that the freshly harvested fruits, i.e., before cold storage, were more firm than those stored for all cold storage periods in both seasons. Additionally, irrespective the initial readings, the highest values of fruit firmness were registered by the combinations of 15-day storage duration mainly lemongrass at 0.50% and 0.25% in both seasons. On the reverse, the lowest values were noticed with the interactions of 70-day storage duration, especially untreated fruits (control) in both seasons. The remaining interactions gave in-between values in this respect.

Table 3 Effect of gelatin, lemongrass oil, and peppermint oil on fruit firmness (Lb/inch^2) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

	Storage periods (days)						
	0	15	30	45	60	75	Mean
Treatment	2016						
Control	18.10	17.43	17.23	16.52	13.72	10.13	15.52 a
Gelatin 1%	18.10	17.47	17.35	16.58	14.20	12.07	15.96 a
Gelatin 2%	18.10	17.53	17.43	16.75	14.43	12.31	16.09 a
Gelatin 4%	18.10	17.60	17.45	16.91	14.52	12.30	16.15 a
Lemongrass oil 0.25%	18.10	17.60	17.53	17.01	15.13	13.41	16.46 a
Lemongrass oil 0.50%	18.10	17.73	17.60	17.05	15.20	13.50	16.53 a
Peppermint oil 5%	18.10	17.50	17.45	16.95	14.67	12.70	16.23 a
Peppermint oil 10%	18.10	17.50	17.50	16.97	14.92	12.70	16.28 a
Mean	18.10 A	17.55 B	17.44 B	16.84 C	14.60 D	12.39 E	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.7909							
Treatment	2017						
Control	18.17	17.21	16.85	15.75	14.57	12.10	15.77 a
Gelatin 1%	18.17	17.31	17.07	16.63	15.15	13.40	16.29 a
Gelatin 2%	18.17	17.77	17.23	17.13	15.52	13.72	16.59 a
Gelatin 4%	18.17	17.80	17.30	17.20	15.65	14.07	16.70 a
Lemongrass oil 0.25%	18.17	17.97	17.52	17.32	16.13	14.10	16.87 a
Lemongrass oil 0.50%	18.17	17.96	17.60	17.35	16.30	14.87	17.04 a
Peppermint oil 5%	18.17	17.90	17.50	16.96	15.47	13.52	16.59 a
Peppermint oil 10%	18.17	17.93	17.42	17.13	15.69	13.60	16.66 a
Mean	18.17 A	17.73 B	17.31 C	16.93 D	15.56 E	13.67 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.7067							

Effect of postharvest treatments on fruit chemical properties

Total soluble solid percentage (TSS %)

Data reported in Table 4 reveal that the fruit total soluble solid percentage was gradually increased as the storage period prolonged. Hence, the initial readings, i.e., before the storage period (zero-day storage), registered the lowest values of fruit total soluble solid percentage. Generally, cold-stored fruits for 75-day cold storage produced the highest fruits reading total soluble solid percentage. On the other hand, irrespective the initial readings, the poorest fruits in their percentage of total soluble solid were cold-stored fruits for 15 days in both seasons.

Considering the effect of the tested treatments, tabulated data illustrate that control treatment fruits showed to be the most effective one in enhancing fruit total soluble solid percentage in both seasons. On the contrary, the lowest values of this parameter were scored by 0.50 and 0.25% lemongrass treatments in both seasons. The other tested treatments showed in-between values in this concern.

Evaluating the interaction effect between the storage period and the studied postharvest treatments, tabulated data declare that as the storage period prolonged, the fruit total soluble solid content increased. Thereupon, the highest fruit total soluble solid percentage were observed by the interactions of 75-day cold storage period, mainly untreated fruits followed descendingly by 1% gelatin-treated fruits in both seasons. On the reverse, the interactions of the 15-day storage period (regardless initial storage period) recorded the lowest fruit total soluble solid percentage especially, 0.50% lemongrass-treated fruits in both seasons. The other combinations occupied an intermediate position between the categories as mentioned above in both seasons of study.

Total sugar (g/100 FW)

Data presented in Table 5 illustrate that prolonging cold storage period of Samany date palm fruits resulted in increasing fruit total sugar content. In this respect, the initial readings, i.e., before cold storage (zero-day storage) scored the lowest values, whereas prolonging cold storage period up to 75 days recorded the highest values in

Table 4 Effect of gelatin, lemongrass oil and peppermint oil on the total soluble solid percentage (TSS %) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

	Storage periods (days)						
	0	15	30	45	60	75	Mean
Treatment	2016						
Control	21.70	21.93	22.76	23.20	23.97	24.27	22.97 a
Gelatin 1%	21.70	21.90	22.20	23.10	23.68	24.20	22.80 ab
Gelatin 2%	21.70	21.87	22.25	22.87	23.50	24.10	22.71 ab
Gelatin 4%	21.70	21.80	22.10	22.80	23.30	24.10	22.63 ab
Lemongrass oil 0.25%	21.70	21.75	21.97	22.37	23.03	24.03	22.48 b
Lemongrass oil 0.50%	21.70	21.70	21.90	22.30	23.10	23.97	22.44 b
Peppermint oil 5%	21.70	21.80	22.13	22.77	23.00	24.10	22.58 ab
Peppermint oil 10%	21.70	21.80	22.10	22.70	23.10	24.07	22.58 ab
Mean	21.70 E	21.82 E	22.18 D	22.76 C	23.34 B	24.10 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.003							
Treatment	2017						
Control	21.77	22.27	23.37	24.03	25.17	25.20	23.63 a
Gelatin 1%	21.77	22.20	22.93	23.77	24.80	25.10	23.43 ab
Gelatin 2%	21.77	22.20	22.87	23.50	24.53	25.00	23.31 ab
Gelatin 4%	21.77	22.00	22.80	23.50	24.80	24.90	23.29 ab
Lemongrass oil 0.25%	21.77	22.00	22.73	23.27	24.10	24.37	23.04 b
Lemongrass oil 0.50%	21.77	21.97	22.75	23.20	24.00	24.30	23.00 b
Peppermint oil 5%	21.77	22.13	23.10	23.47	24.37	24.53	23.23 ab
Peppermint oil 10%	21.77	22.10	23.10	23.28	24.30	24.53	23.18 ab
Mean	21.77 E	22.11 D	22.96 C	23.50 B	24.51 A	24.74 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.7196							

Table 5 Effect of gelatin, lemongrass oil, and peppermint oil on total sugar (g/100 FW) of Samany date palm fruits stored at 0.0 ± 2 °C during two experimental seasons

	Storage periods (days)						
	0	15	30	45	60	75	Mean
Treatment	2016						
Control	20.18	20.51	20.67	21.40	22.03	22.35	21.19 a
Gelatin 1%	20.18	20.50	20.70	21.13	21.98	22.30	21.13 a
Gelatin 2%	20.18	20.37	20.56	21.10	21.74	22.27	21.04 a
Gelatin 4%	20.18	20.40	20.56	20.97	21.68	22.28	21.01 a
Lemongrass oil 0.25%	20.18	20.35	20.53	20.80	21.52	21.96	20.89 ab
Lemongrass oil 0.50%	20.18	20.32	20.49	20.67	21.38	21.90	20.82 b
Peppermint oil 5%	20.18	20.42	20.50	20.87	21.85	22.17	21.00 a
Peppermint oil 10%	20.18	20.32	20.45	20.80	21.72	22.10	20.93 ab
Mean	20.18 E	20.40 DE	20.56 D	20.97 C	21.74 B	22.17 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.6237							
Treatment	2017						
Control	20.23	20.51	20.98	21.72	22.51	22.70	21.44 a
Gelatin 1%	20.23	20.50	20.95	21.48	21.99	22.53	21.28 a
Gelatin 2%	20.23	20.42	20.73	21.40	22.03	22.50	21.22 a
Gelatin 4%	20.23	20.38	20.80	21.36	21.82	22.45	21.17 a
Lemongrass oil 0.25%	20.23	20.30	20.62	21.17	21.80	22.26	21.06 ab
Lemongrass oil 0.50%	20.23	20.30	20.43	20.92	21.57	22.02	20.91 b
Peppermint oil 5%	20.23	20.42	20.72	21.30	21.74	22.39	21.13 a
Peppermint oil 10%	20.23	20.40	20.64	21.27	21.64	22.18	21.06 ab
Mean	20.23 E	20.40 E	20.73 D	21.33 C	21.89 B	22.38 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.8609							

both seasons. The differences between the studied storage periods were so high to be significant.

Pointing to the effect of the tested postharvest treatments, the statistical analysis indicates that the results have the same trend regarding the response of fruit total sugar content to the studied treatments throughout this study in both seasons. However, the highest fruit total sugar content was produced by control; gelatin at 1, 2, and 4%; and 5% peppermint oil treatments with non-significant differences between them, whereas 0.50% lemongrass oil treatment scored the lowest fruit total sugar content.

Regarding the interaction effect between storage periods and tested postharvest treatments, data in Table 5 demonstrate that the interactions of the 75 day cold storage period, especially untreated fruits, scored the highest values of total sugar content in both seasons. On the contrary, regardless of 0-day storage, the lowest fruit total sugar content was observed with the combinations of cold-stored Samany date palm fruits for 15 days, especially those treated with 0.50% lemongrass and 10% peppermint oil in the first season and 0.25 and 0.50% lemongrass in the second one. The rest of the interactions came in-between in this concern in both seasons.

Total acidity (percentage)

It is quite evident that the decrease in fruit total acidity content is proportionate with the advancement of storage period (Table 6). The scored data indicate this result. Hence, the initial readings, i.e., before cold storage, registered the highest values of fruit total acidity content. Whereas, the lowest values of this parameter were scored when the fruits were stored for 75 days cold storage during 2016 and 2017 seasons.

Looking at the effect of the tested postharvest treatments, in both seasons, statistical analysis declares that most tested treatments induced higher and similar impact on fruit total acidity content, except control treatment which produced lower value in this sphere, followed by 1% gelatin and 5% peppermint oil treatments in both seasons. The remaining treatments took an intermediate position between the abovementioned treatments.

Considering the interaction effect between the storage period and tested postharvest treatments, tabulated data illustrate that as the storage period prolonged, the fruit acidity content decreased. Thereupon, the interactions of 15-day cold storage period (irrespective the initially readings) registered the highest values of fruit total

Table 6 Effect of gelatin, lemongrass oil, and peppermint oil on total acidity (%) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

	Storage periods (days)						
	0	15	30	45	60	75	Mean
Treatment	2016						
Control	0.320	0.300	0.263	0.250	0.223	0.180	0.256 b
Gelatin 1%	0.320	0.320	0.280	0.257	0.253	0.220	0.275 ab
Gelatin 2%	0.320	0.310	0.277	0.260	0.260	0.240	0.278 a
Gelatin 4%	0.320	0.317	0.300	0.280	0.260	0.240	0.286 a
Lemongrass oil 0.25%	0.320	0.310	0.300	0.283	0.257	0.250	0.287 a
Lemongrass oil 0.50%	0.320	0.313	0.297	0.283	0.277	0.247	0.289 a
Peppermint oil 5%	0.320	0.303	0.280	0.270	0.250	0.230	0.276 ab
Peppermint oil 10%	0.320	0.320	0.300	0.273	0.260	0.230	0.289 a
Mean	0.320 A	0.312 A	0.287 B	0.270 C	0.255 C	0.230 D	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.04864							
Treatment	2017						
Control	0.293	0.257	0.240	0.220	0.200	0.200	0.235 b
Gelatin 1%	0.293	0.280	0.247	0.243	0.220	0.200	0.247 ab
Gelatin 2%	0.293	0.280	0.270	0.250	0.230	0.220	0.257 a
Gelatin 4%	0.293	0.270	0.270	0.260	0.230	0.220	0.257 a
Lemongrass oil 0.25%	0.293	0.280	0.260	0.260	0.230	0.230	0.259 a
Lemongrass oil 0.50%	0.293	0.280	0.270	0.260	0.253	0.230	0.264 a
Peppermint oil 5%	0.293	0.267	0.270	0.253	0.220	0.200	0.251 ab
Peppermint oil 10%	0.293	0.283	0.267	0.257	0.230	0.220	0.258 a
Mean	0.293 A	0.275 B	0.262 BC	0.250 C	0.227 D	0.215 D	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.04585							

acidity content especially 1% gelatin and 10% peppermint oil-treated fruits in the first season and 10% peppermint oil-treated fruits in the second one. On the opposite, the lowest values of this parameter were recorded by the combinations of 75-day cold storage period, mainly, untreated fruits in the first season and 1% gelatin and 5% peppermint oil-treated fruits besides untreated fruits "control treatment" in the second one. Other interactions took an intermediate position between the combinations described above categories in both seasons.

Fruit total protein content (mg total protein/100 g fruit fresh weight)

It is obvious from Fig. 1 that the decrement in total protein content is proportionate with the advancement of storage period. Thus, 75 days of cold-stored fruits scored the lowest values of total protein content. On the contrary, the freshly harvested fruits (zero-day storage) scored the highest values in this respect. Other values of cold storage periods occupied an intermediate position between the previously mentioned two categories. The differences between the studied storage periods were obvious to be significant during both seasons. Concerning the specific effect of postharvest treatments, statistical analysis of data in Fig. 1 indicates that all studied treatments failed to induce a remarkable effect on reduction total protein content.

Obtained data during both seasons, as shown in Fig. 1 pointed out that each investigated treatment reflected its specific effect. Thereupon, eight combinations of 75 days storage period stored generally the lowest total protein content values, but differences were so little to be significant as compared to the similar ones of 30-day storage. Meanwhile, as the cold storage was advanced, the differences became more pronounced in each level of significance, particularly with comparing total protein content values of seven combinations after 15-day storage to either those of 60 or 75-day cold storage during two seasons. In other words, the rate of reduction in total protein content values became more low after 45 days cold storage, whereas differences between eight combinations of such date (45 days) were significant compared to the 16 combinations of the two earlier dates (15 and 30 days) regardless of postharvest treatments applied during both seasons.

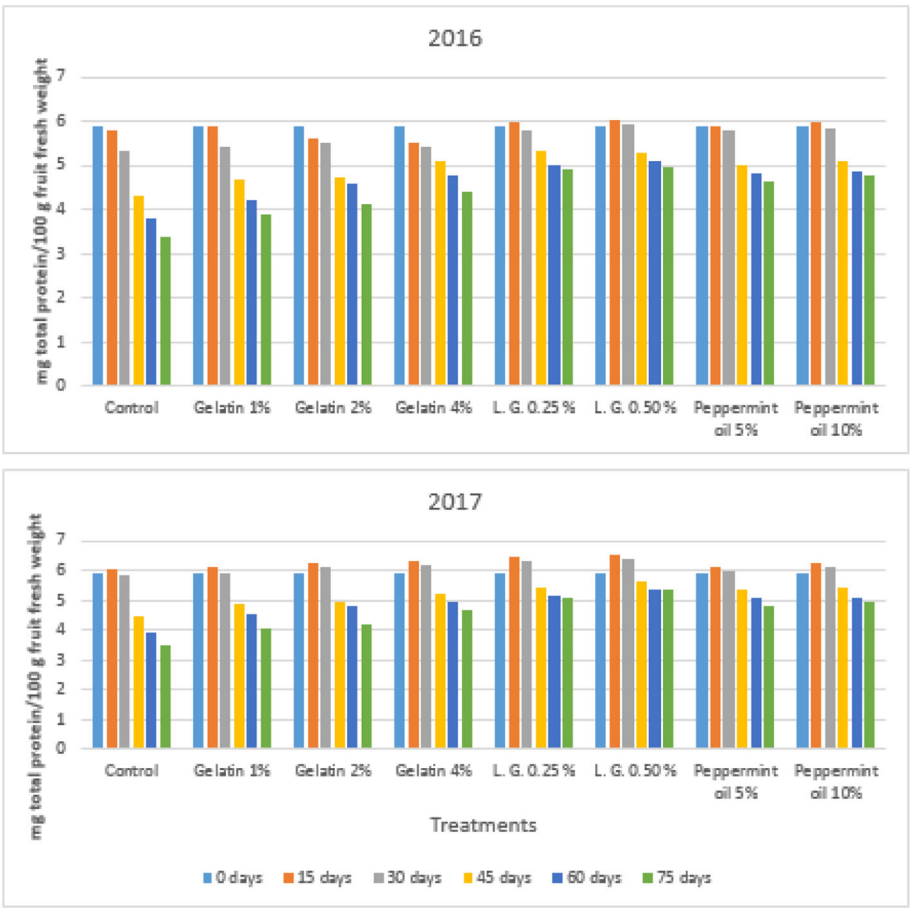

Fig. 1 Effect of gelatin, lemongrass oil and peppermint oil on fruit total protein content (mg total protein/100 g fruit fresh weight) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

Fruit total phenol content (mg total phenol/100 g fruit fresh weight)

It was clear from the results in Fig. 2 that all examined postharvest treatments succeeded in decreasing the total phenolic content in both seasons. However, the highest the total phenolic content was recorded by untreated fruits followed in descending order by Gelatin at 1%-treated fruits, whereas the lowest values of this parameter were scored by lemongrass at 0.50%- and peppermint oil at 10%-treated fruits during both seasons of study.

Referring to the effect of storage periods, Fig. 2 indicates that regardless of the initial reading, the total phenolic content was progressively increased as the cold storage period was increased from 15 to 75 days. However, stored fruits for 75 days scored the highest values as compared with storage periods for 15 days in both seasons. Regarding the interaction effect between the tested postharvest treatments and storage periods, data in Fig. 2 demonstrate that, irrespective of the initial data (zero storage period) the lowest values of total phenolic content were recorded by the combination of 30-day storage periods, especially with lemongrass at 0.50%- and peppermint oil at 10%-treated fruits. On the contrary, the highest values of this parameter were registered by the combination of 60 and 75 days storage periods, particularly those of untreated fruits in both seasons. Such a trend was actual during both seasons.

Discussion

Recent studies show that edible films and coatings can be used to help in fruits and vegetable preservation because they provide a partial barrier to moisture, O_2, and CO_2. In addition, they can improve mechanical handling properties, carrying additives, avoiding volatiles loss, and even contribute to the production of aroma volatiles (Olivas and Barbosa-Cánovas, 2005). Gelatin is an essential functional biopolymer widely used in foods to improve elasticity, consistency, and stability (Mariod and Adam, 2013).

Essential oils are made up of many different volatile compounds, and the composition of the oil quite often varies between species (Mishra and Dubey, 1994). It is

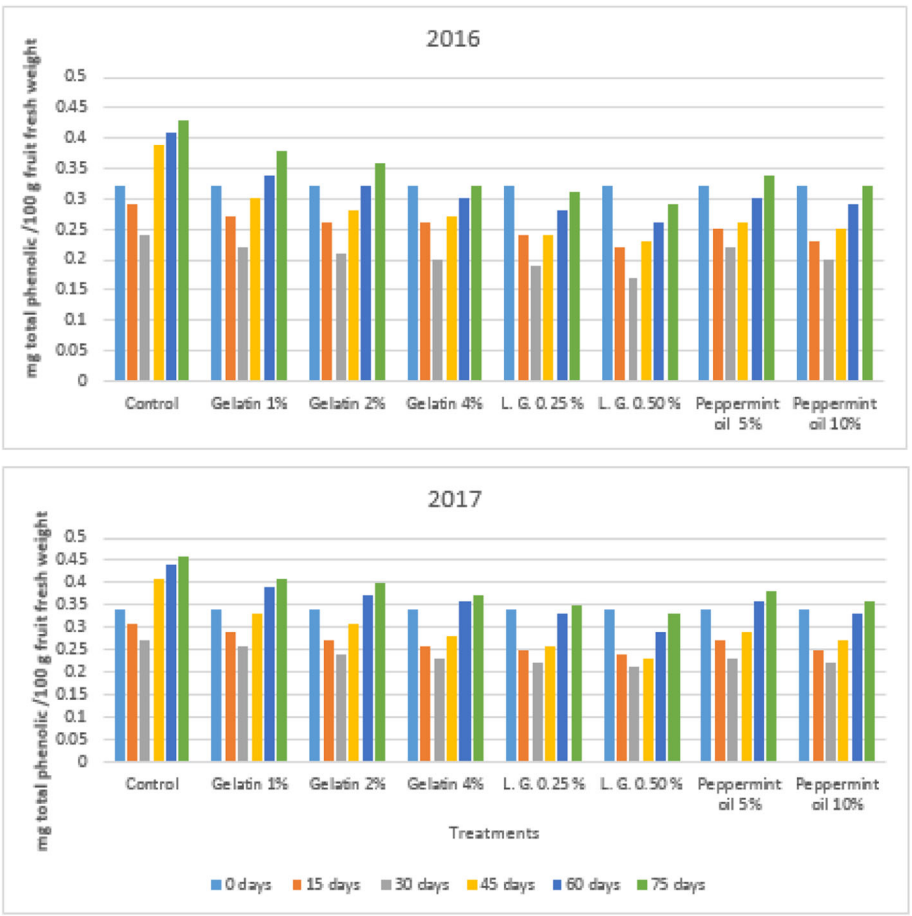

Fig. 2 Effect of gelatin, lemongrass oil and peppermint oil on fruit total phenolic content (mg total phenolic/100 g fruit fresh weight) of Samany date palm fruits stored at 0.0 °C ± 2 during two experimental seasons

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 (Bagamboula et al., 2004). Thus, there would be a negligible chance of development of resistant races of fungi after application of essential oils to fruit and vegetables. Consequently, essential oils are one of the most promising candidate groups of natural compounds for the development of safer antifungal agents. The role of essential oil has been discussed in terms of antibiotic activity, allelopathy, attractants, feeding deterrents, and phytoalexin. Many researches point out that essential oil from different herbal plants demonstrates antifungal activity against a wide range of postharvest pathogen (Dube et al., 1989; Deans, 1991; Jobling, 2001; Duamkhanmanee, 2008; Mahanta et al., 2007). Lemongrass (*Cymbopogon citratus* L.) is an aromatic herb and mainly grown as an ornamental plant. Its leaves and stem are used to extract oil by the hydro-distillation method that produces a yellow color oil which contains the following compounds: (1) Geranial (41.67%) "Citral A", (2) Neral (40.33%) "Citral B", (3) Myrcene (9.99%), (4) Borneol (1.62%), (5) Methyl-2, 4-decadienoate (1.28%), and (6) Geranyl acetate (0.95%) (Masamba et al., 2003). It is known that oil of lemongrass is one of the most important essential oil-bearing herbaceous species of the *Gramineae* because of its high citral content (up to at least 75% of the oil) (Jayasinha, 1999).

Recently, bioactive studies have shown that the various components of this essential oil contain antimicrobial, antifungal, antibacterial, and mosquito repellent properties (Schaneberg and Khan, 2002). However, lemongrass has many other uses: (1) It is used in herbal tea because of its sharp lemon flavor. (2) Also, it is used in the perfumery and soap industries. (3) Moreover, it is used in the manufacture of synthetic vitamin A and in the medicine to treat various health ailments, including acne, athlete's foot, flatulence, muscle aches, and scabies (Masamba et al., 2003, Abbas and El-Saeid, 2012).

Anyhow, the weight loss is attributed to the loss of water during metabolic processes like respiration and transpiration. Besides, the epidermal layers provided with guard cells

and stomata usually control moisture loss and gaseous exchange from the fruits. Thus, the coating reduces this action because it forms a film on the top of the skin, acting as an additional barrier to moisture loss. These barrier properties also reduce the oxygen uptake by the fruit, which in turn slowed down the rate of respiration and associated weight loss from the fruit surface (Toğrul and Arslan, 2004 and Abbasi et al., 2011). The aforementioned results go in line with those obtained on date palm (Abd El-Moneim-Eman et al., 2015), on mango (Manzano et al., 1997; Carrillo et al., 2000; Jitareerat et al., 2007; Shaarawi et al., 2013), on orange (Attia, 1995; Baiea and EL-Badawy, 2013), on Pomegranate fruits (Abd El-Moneim-Eman et al., 2019), on longan fruit (Jiang and Li, 2000), and on apple (Rojas-Graü et al., 2007).

Moreover, the observed changes in TSS may be due to the hydrolytic conversion of polysaccharides into soluble sugar during the ripening process that increased TSS of the fruits (Abbasi et al., 2011). These results are also in agreement with those obtained by Carrillo et al., (2000) on Haden mango. The abovementioned results are in agreement with those obtained by on Zaghloul date palm cv (Abd El-Moneim-Eman et al., 2015), on orange (Attia, 1995; El-Badawy, et al., 2012; Baiea and EL-Badawy, 2013), on avocado (Mpho et al., 2013), on longan fruit (Jiang and Li, 2000), on peach and pear (Toğrul and Arslan, 2004), and on apple (Rojas-Graü et al., 2007; Raybaudi-massilia et al. 2008).

The obtained results showed that coatings slowed the changes on titratable acidity and effectively delaying fruit senescence. This was probably because the film formed by materials used on the surface of the fruit might have modified the internal atmosphere, i.e., the endogenous CO_2 and O_2 concentration of the fruit, thus retarding ripening (Bai et al., 1988 and Lowings and Cutts, 1982). The aforementioned results go on the same line with those obtained on Zaghloul date palm cv (Abd El-Moneim-Eman et al., 2015), on mango (Manzano et al., 1997; Carrillo et al., 2000; Jitareerat et al., 2007; Baloch et al., 2013), on orange (Attia, 1995; El-Badawy, et al., 2012; Baiea and EL-Badawy, 2013), on avocado (Mpho et al., 2013), on pomegranate fruits (Abd El-Moneim-Eman et al., 2019), on longan fruit (Jiang and Li, 2000), on peach and pear (Toğrul and Arslan, 2004), on apple (Rojas-Graü et al., 2007; Raybaudi-massilia et al. 2008), and on lemongrass (Abbasi et al., 2011).

The obtained results coincided with those scored by Rojas-Graü et al. (2007), Raybaudi-massilia et al. (2008), and Jha et al. (2012) on apple; Mpho et al. (2013) on avocado; and Tzortzakis and Economakis (2007) on lemongrass. Conclusively, the tested essential oils have shown antifungal effects against different postharvest pathogens (Feng and Zheng 2007). Lambert et al. (2001) found that the essential oils (due to their hydrophobic nature) affect the partitioning of the lipids of the plasma membrane and change its integrity, permeability, and the inorganic ion equilibrium. Also, the essential oils often involve in mitochondrial structure disorganization, interference with enzymatic reactions of the mitochondrial membranes, such as respiratory electron transport, proton transport, and phosphorylation mechanism (Knobloch et al., 1989). It has been speculated that the mode of action for essential oil with the absence of phenolic groups could be due to membrane disruption by the lipophilic compounds (Mendoza et al., 1997).

Furthermore, edible coatings are applied to enhance the quality and extend the shelf life of fruit by decreasing moisture loss and respiration rate. An edible coating can have a positive effect on the surface of fruit by incorporating functional ingredients, such as antimicrobials, antioxidants, colorants, and flavors (Valencia-Chamorro et al., 2012). Besides, an edible coating improves the esthetic value by providing a glossy appearance (Trezza and Krochta, 2000).

Conclusion

It could be generally concluded that all dipping treatments significantly decreased the percentage of both fruit weight loss and decay below control, whereas 0.50% lemongrass oil treatment was superior, while 1% gelatin ranked last. Besides, fruit flesh firmness and fruit juice total sugars did not significantly respond to various treatments. Meanwhile, fruit juice total soluble solids percentage, total protein content and total phenolic content of Samany date palm fruits showed considerable different influence to most investigated treatments in both seasons of the study. Anyhow, efficiency of storability and fruit quality of Samany date palm under cold storage increased with using lemongrass oil at 0.25 and 0.50% under similar conditions.

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Authors' contributions

ESF and BMHM wrote the manuscript, designed this work, and revised it. BMHM performed the chemical analysis of the samples and analysis of data. ESF coordinated the data collection. All authors read and approved the final manuscript.

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The datasets generated and/or analyzed during the current study are included in this published study.

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Competing interests
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References

Abbas SM, El-Saeid HM (2012) Effects of some growth regulators on oil yield, growth and hormonal content of lemon grass (*Cymbopogon citrates*). Botanica Serbica. 36(2):97–101
Abbasi KS, Anjum N, Sammi S, Masud T, Ali S (2011) Effect of coatings and packaging material on the keeping quality of mangoes (*Mangifera indica* L.) stored at low temperature. Pakistan Journal of Nutrition. 10(2):129–138
Abd El-Moneim-Eman AA, EL-Gioushy SF, Baiea MHM (2015) Effect of some natural coating materials on storability and fruit quality of Zaghloul date palm cv. under cold storage. Middle East J. Agric. Res. 4(3):602–612
Abd El-Moneim-Eman AA, Yousef ARM, El-Gioushy SF (2019) Modern vision to enhancement pomegranate storage. World Applied Sciences Journal. 37(5): 375–386
Alankar S (2009) A review on peppermint oil. Asian Journal of Pharmaceutical and Clinical Research 2(2):27–33
AOAC, (1995) Association of Official Agricultural Chemists; Official Methods of Analysis, 14th Ed. Benjamin Franklin Station. Washington, D. C., U.S.A., 8-9 International suite 4002200 Wilson Boulevard Arlington, Virginia 22201-3301, USA. 1995, 490-510.
Attia MM (1995) Effect of post-harvest on quality of oranges through cold storage. J. Agric. Res. 40:349–363
Bagamboula CF, Uyttendaele M, Debevere J (2004) Inhibitory effect of thyme and basil essential oils, carvacrol, thymol, estragole, linalool and cymene towards Shigellasonnei and S. flexneri. Food Microbiol. 21:33–42
Bai RK, Huang MY, Jiang YY (1988) Selective permeabilities of chitosan-acetic acid complex membrane and chitosan-polymer complex membrane for oxygen and carbon dioxide. Polym. Bull. 20(1):83–88
Baiea MHM, El-Badawy HEM (2013) Response of Washington navel orange to thyme and clove oils as natural postharvest treatments under cold storage conditions. Journal of Applied Sciences Research. 9(7):4335–4344
Baloch MK, Bibi F, Jilani MS (2013) Effect of coatings over the quality and shelf life of mango (*Mangifera indica* L.) fruit. Journal of Food Processing and Preservation. 37(1):66–73
Bradford MM (1976) A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Analytical biochemistry. 72:248–254
Carrillo LA, Ramirez-Bustamante F, Valdez-Torres JB, Rojas-Villegas R, Yahia EM (2000) Ripening and quality changes in mango fruit as affected by coating with an edible film. J. Food Qlty. 23:479–486
Daniel HD, George CM (1972) Peach seed dormancy in relation to endogenous inhibitors and applied growth substances. J. Amer. Soc. Hort. Sci. 97:651–654
Deans SG (1991) Evaluation of antimicrobial activity of essential (volatile) oils. In: Linskens HF, Jackson JF (eds) Modern methods of plant analysis new series, vol 12. Springer, Berlin Heidelberg New York., pp 309–320
Duamkhanmanee R (2008) Natural essential oils from lemongrass (*Cymbopogon citratus*) to control postharvest anthracnose of mango fruit. Int. J. Biotechnol. 10:104–108
Dube S, Upadhyay PD, Tripathi SC (1989) Antifungal, physicochemical and insect repelling activity of the essential oils of Ocimum basilicum'. Canadian Journal of Botany. 67:2085–2087
Dubois M, Gilles KA, Hamilton JK, Rebers PT, Smith F (1956) Colorimetric method for determination of sugars and related substances. Analytical chemistry 28(3):350–356
El-Badawy HEM, Baiea MHM, Eman AA (2012) Abd El-Moneim. Efficacy of propolis and wax coatings on fruit quality of Washington navel orange under cold storage. Research Journal of Agriculture and Biological Sciences. 8(5):420–428
Feng W, Zheng X (2007) Essential oils to control Alternaria alternata in vitro and in vivo. Food Control. 18(9):1126–1130
Jayasinha, P., Lemongrass (Cymbopogon). Medicinal and aromatic plant series; 1999, No 9.
Jha SN, Rai DR, Shrama R (2012) Physicochemical quality parameters and overall quality index of apple during storage. Journal of Food Science and Technology. 49:594–600
Jiang YM, Li YB (2000) Effects of chitosan coating on post-harvest life and quality of longan fruit. Food Chem. 73:139–143
Jitareerat P, Paumchai S, Kanlayanarat S (2007) Effect of chitosan on ripening enzymatic activity and disease development in mango (*Mangifera indica* L.) fruit. New Zealand J. Crop Hort. Sci 35:211–218
Jobling, J., Essential oils: a new idea for postharvest disease control. Available online at http://www.postharvest.com.au. 2001.
Knobloch K, Pauli A, Iberl B, Weis N, Weigand H (1989) Antibacterial activity and antifungal properties of essential oil components. J. Essent. Oil Res. 1:119–128
Lambert RLW, Skandamis PN, Coote PJ, Nychas GJE (2001) A study of the minimum inhibitory concentration and mode of action of oregano essential oil, thymol, and carvacrol. J. Appl. Microbiol. 91:453–462
Lowings PH, Cutts DF (1982) The preservation of fresh fruits and vegetables. In: Proceedings of the Institute of the Food Science and Technology, Annual Symposium, Nottingham, UK 15:52–54
Mahanta JJ, Chutia M, Bordoloi M, Pathak MG, Adhikary RK, Sarma TC (2007) Cymbopogon citratus L. essential oil as a potential antifungal agent against key weed moulds of Pleurotus spp. Spawns', Flavour and Fragrance Journal 22(6):525–530
Manzano JE, Perez Y, Rojas E (1997) Coating waxes on Haden mango fruits (*Mangifera indica* L.) cultivar for export. Acta Hort. 455:738–746
Mariod AA, Adam HF (2013) Review: gelatin, source, extraction, and industrial applications. Acta Sci. Pol., Technol. Aliment 12(2):135–147
Masamba WR, Kamanula JF, Henry EM, Nyirenda GK (2003) Extraction and analysis of lemongrass (*Cymbopogon citrates*) oil: an essential oil with potential to control the Larger Grain Borer (*Prostephanus truncates*) in stored products in Malawi. Malawi J. Agric. Sci 2:56–64
Mendoza L, Wilkens M, Urzua A (1997) Antimicrobial study of the resinous exudates and of diterpenoids and flavonoids isolated from some Chilean Pseudognaphalium (Asteraceae). J. Ethnopharmacol. 58:85–88
Mishra AK, Dubey NK (1994) Evaluation of some essential oils for their toxicity against fungi causing deterioration of stored food commodities. Appl. Environ. Microbiol 60(4):1101–1105
Mohamed A.R.,. The economics of date palms in the Arab World. Proc. 1st Symposium on Date Palm,King Faisal Univ. Al. Hassa, Saudi Arabia, 1982, PP: 716-724.
Mpho M, Sivakumar D, Sellamuthu PS, Bautista-Baños S (2013) Use of lemongrass oil and modified atmosphere packaging on control of anthracnose and quality maintenance in avocado cultivars. Journal of Food Quality 36:198–208
Olivas GI, Barbosa-Cánovas GV (2005) Edible coatings for fresh-cut fruits. Critical reviews in food science and nutrition 45(7-8):657–670
Raybaudi-massilia RM, Rojas-Graü MA, Mosqueda-Melgar J, Martín-Belloso O (2008) Comparative study on essential oils incorporated into an alginatebased edible coating to assure the safety and quality of fresh-cut Fuji apples. Journal of Food Protection 71:1150–1161
Rojas-Graü MA, Raybaudi-Massilia RM, Soliva-Fortuny RC, Avena-Bustillos RJ, McHugh TH, Martin-Belloso O (2007) Apple pureee alginate edible coating as carrier of antimicrobial agents to prolong shelf-life of freshcut apples. Postharvest Biol. Technol. 45:254–264
Schaneberg BT, Khan IA (2002) Comparison of extraction methods for marker compounds in the essential oil of lemon grass by GC. Journal of Agricultural and Food Chemistry. 50(6):1345–1349
Shaarawi SAMA, Abd-Allah ASE, El-Moniem EAAA (2013) Effect of some natural edible coating materials on mango fruit characteristics during cold storage. Journal of Applied Sciences Research. 9(10):6508–6520
Shah G, Shri R, Panchal V, Sharma N, Singh B, Mann AS (2011) Scientific basis for the therapeutic use of *Cymbopogon citratus*, stapf (lemongrass). J. Adv. Pharm. Tech. Res. 2:3–8
Snedecor GW, Cochran WG (1989) Statistical methods, 8th edn. Iowa State Univ. Press Iowa, Ames
Toğrul H, Arslan N (2004) Extending shelf-life of peach and pear by using CMC from sugar beet pulp cellulose as a hydrophilic polymer in emulsions. Food hydrocolloids 18(2):215–226

Trezza TA, Krochta JM (2000) The gloss of edible coatings as affected by surfactants, lipids, relative humidity and time. Journal of Food Science 65: 658–662

Tzortzakis NG, Economakis CD (2007) Antifungal activity of lemongrass (*Cympopogon citratus* L.) essential oil against key postharvest pathogens. Innovative Food Science & Emerging Technologies 8(2):253–258

Valencia-Chamorro SA, Palou L, Rio MA, Perez-Gago MB (2012) Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: a review. CRC Critical Reviews in Food Science and Nutrition 51: 872–900

Vayalil PK (2002) Antioxidant and antimutagenic properties of aqueous extract of date fruit (*Phoenix dactylifera* L. Arecaceae). Journal of Agricultural and Food Chemistry 50(3):610–617

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