How to Cite:
Emam, H. E., Abdel-Hak, R. S., Ali, E. A. M., Amin, O. A., & El-Moniem, E. A. A. A. (2021). Prolonging post-harvest quality and storage life of pomegranate wonderful as affected by Arabic gum and different edible coatings. *International Journal of Health Sciences*, *5*(S2), 617–636. https://doi.org/10.53730/ijhs.v6nS8.12940

Prolonging post-harvest quality and storage life of pomegranate wonderful as affected by Arabic gum and different edible coatings

Hala E. Emam
Horticulture Crops Technology Department, National Research Centre, El Buhouth St., Dokki, Cairo, Egypt

Rasha S. Abdel-Hak
Pomology Department, National Research Centre, El Buhouth St., Dokki, Cairo, Egypt

Enas A. M. Ali
Horticulture Crops Technology Department, National Research Centre, El Buhouth St., Dokki, Cairo, Egypt

Amin O. A.
Horticulture Crops Technology Department, National Research Centre, El Buhouth St., Dokki, Cairo, Egypt

Eman A. A. Abd El-Moniem
Horticulture Crops Technology Department, National Research Centre, El Buhouth St., Dokki, Cairo, Egypt

***Abstract*---**Due to the rising interest in healthy products, super foods such as pomegranate have spread widely on the international market in recent years. Several postharvest treatments have been applied in order to maintain the quality and extend shelf life of pomegranate arils. This study evaluated the effect of Arabic gum treatment as well as different edible coatings (Jojoba oil, Gelatin, Wheat Germ oil and Rosemary oil) on shelf life and fruit quality parameters of Wonderful pomegranate during cold storage at 5°C with 85-90% relative humidity for 45 days. Fruit characteristics, such as fruit weight, volume, firmness, and weight loss%, total juice weight and volume, total soluble solids, total acidity, ascorbic acid (Vitamin C), total anthocyanin, total sugars % and total phenols were determined periodically along a storage period of 45 days. It is clear that, all fruit characteristics were positively affected by different edible coating treatments. Pomegranate fruits coated with rosemary oil at 2% in combination with Arabic gum at 10% effectively reduced weight loss%,

maintained higher firmness, fruit weight, fruit volume, juice weight and juice volume. Also, it retained total soluble solids as higher values, suppressed total acidity degradation, and decreased the loss of ascorbic acid, maintained higher amounts of anthocyanin content and decreased total phenols. The obtained results suggest that, Arabic gum coating treatment could be used as a commercial wax to improve postharvest storability, extend storage period, and maintain the nutritional value of Wonderful pomegranate fruits up to 45 days of cold storage at 5°C. Jojoba oil at 2% in combination with Arabic gum at 10% came at the second rank and may have no significant differences among some fruit characteristics.

***Keywords*---**pomegranate, Arabic gum, gelatin, jojoba oil, rosemary oil, wheat germ oil, post-harvest quality.

Introduction

Pomegranate (*Punica granatum* L.) is an important deciduous shrub belonging to the Lythraceae family [1]. Pomegranates are widely distributed around the world. It is one of the most important fruit trees in tropical and sub-tropical regions and grown successfully in Egypt, not only in the old lands but also in the newly reclaimed lands [2]. The Egyptian cultivar Wonderful is known for its sweet taste, plentiful juice. The pomegranate fruit is considered to be part of the so-called Super Fruits group, which is a term used to highlight the excellent nutritional qualities and health promoting phytochemicals of certain fruits [3-5]. Pomegranate is an important source of several bioactive compounds with beneficial properties such as antioxidant, anti-inflammatory, anti-aging, prebiotic, anticancer effects [6]. Arils, the edible portion, have grown in popularity due to their high sugar, pectin, ascorbic acid, ellagic acid, amino acids, minerals, fibres, anthocyanin, phytoestrogens, and flavonoids content [7]. Moreover, arils are susceptible to weight loss, textural and nutritional degradation which limits their shelf life [8].

To maintain aril quality and increase shelf life, several postharvest procedures have been applied. It's becoming more desirable to utilize biodegradable edible coatings to protect the post-harvest quality of minimally processed products [9]. Edible coatings which obtained from natural sources, safer and biodegradable applied in liquid form on fresh produce which suppress water loss and modify internal atmosphere thereby minimizing quality loss [10, 11]. They serve as carriers for active ingredients like antioxidants, antimicrobials, colors and flavors as well as barriers against gases or vapors [12]. These features increase the quality of food goods, extending their shelf life and enhancing their safety [13]. Gelatin is a functional biopolymer such as polysaccharides and proteins [14] that have a good film forming ability [15], biodegradability [16] and strong water vapor barrier properties [17]. Gelatin films have been used as ecofriendly edible packaging materials to preserve the shelf life of foods, especially those sensitive to the quality changes induced by moisture absorption [18].

A family of naturally occurring carbohydrates known as "gum" is described by the name. These carbohydrates are often water soluble and have a variety of uses, including coating. Gum-based edible coatings provide a semi-permeable membrane to CO2 and O2, so regulating respiration and oxidation reaction rates and resulting in the creation of a unique atmosphere surrounding the fruit or vegetable. Gums have various benefits over other coating agents, including safety for consumers and human health, renewable resources, economic viability, and environmental friendliness [19- 21]. Arabic gum (AG) coating might reduce the sources of energy, hormones, water and nutrients which lead to a rapid initiation of senescence. Moreover, using Arabic gum as an edible covering causes a reduction in water loss, weight of fruits and delay fruit ripening.

Essential oils (EOs) are extremely intricate blends of volatile fragrant molecules created by plants. These compounds serve a variety of ecological purposes, including luring pollinators and providing protection against harmful microorganisms [25- 27]. Among the EOs studied so far, the antimicrobial activity of EOs from *Rosmarinus officinalis* L. (rosemary) [28, 29]. Applying the plant with EOs allows controlling plant diseases and preserving fruits during postharvest. Moreover, EOs does not pose any risk to human health and rather improve the fruit quality [30]. Numerous plant pathogens, especially postharvest infections, can be successfully controlled by using plant essential oils or plant extracts [31–34]. The antifungal and antibacterial properties of plant essential oils vary depending on the plant species and applied oil concentrations [35, 36]. Different concentrations of essential oils from various portions of oregano, thyme, lavendula, rosemary, and fennel plants were found to lessen tomato blight infection; the oils from the oregano and thyme plants were the most successful [28].

Rosemary oil caused extravasation of cellular fluid and inhibited the growth of *Fusarium verticillioides* [38] and used as antioxidant activity and has antimicrobial properties [39]. Jojoba (*Simmodsia chinensis)* oil is frequently referred to as liquid wax because of its unusual physical and chemical characteristics and lack of color and flavor. Additionally, it is simple to hydrogenate jojoba oil to create a soft wax that can be used as candle wax, in a variety of polishes, and as a substance for coating fruits and pills [40]. Jojoba oil presents no risks to humans or the environment, the oil has been used for decades in cosmetics, pharmaceuticals, and as an industrial lubricant [41].

Wheat germ (2–3% of grain) can be separated as a by-product during wheat milling. It is regarded as a significant by-product and has a variety of uses, including in food, pharmaceuticals, and other biological applications [42]. Nonpolar lipids, glycolipids, phospholipids, alcohols, esters, n-alkanols, sterols, 4-methyl sterols, triterpenols, hydrocarbons, pigments, and volatile substances make up wheat germ oil (WGO). Therefore, The aim of this study is evaluated the effect of Arabic gum treatment as well as different edible coatings (jojoba oil, gelatin, wheat germ oil and rosemary oil) on shelf life and fruit quality parameters of Wonderful pomegranate during cold storage.

Materials and Methods

Pomegranate fruits (*Punica granatum* L.) cv. 'Wonderful' were harvested from 8-years-old trees grown in experimental station of National Research Centre, at Al-Nobaria district, Al-Behera governorate, Egypt during 2018 and 2019 seasons. Pomegranate trees were similar in growth and received the common horticultural practices. Mature fruits were selected for uniformity of weight, size and free from any visible blemishes and then transported to the laboratory.After the required fruits had been selected, washed and air dried, they were divided into nine main similar groups as follow:

1. Control (distilled water).
2. Jojoba oil at 2% (JO).
3. Jojoba oil at 2%+Gelatin at 8% (JO +G).
4. Jojoba oil at 2% + Arabic gum at 10% (JO +AG).
5. Jojoba oil at 2%+ Wheat Germ Oil at 2% (JO +WGO).
6. Rosemary oil at 2% (RO).
7. Rosemary oil at 2% +Gelatin at 8% (RO +G).
8. Rosemary oil at 2% + Arabic Gum at 10% (RO +AG).
9. Rosemary oil at 2% + Wheat Germ Oil at 2% (RO +WGO).

After postharvest coating treatments, fruits were air dried and packed in carton boxes and placed in a cold storage room at 5ºC and 85 - 90% RH for a total storage period of 45 days and compared with the untreated fruits (control). Three replicates for each treatment and sampling time (7 days) were used and each replicate consisted of 5 fruits. Fruit quality measurements were assessed after storage at 5ºC in each sampling date.

Gelatin coating preparation

Gelatin coating was prepared by dissolving 8 g of gelatin powder in 100 ml distilled water (at room temperature) and the mixture was stirred until the gelatin completely dissolved then heated to 45 ºC for 15 min, then after 5 g of glycerin and 1 ml thyme essential oil were added to the gelatin coating solution and used for coating the fruits [18].

Jojoba coating preparation

Jojoba oil at 5% was prepared by mixing 5ml of jojoba oil with tween 80 in 100 ml of water [43].

Arabic gum preparation

Arabic gum at 10% was prepared by dissolving 100 g of Arabic gum powder in 1.0 L distilled water with stirring at low heat 40˚C for 30 min using a hotplate magnetic stirrer. The solution was then left to cool to 20˚C. Each replicate group of the fruits was dipped in the respective concentrations of Arabic gum solution for 1 h until the coating solution uniformly covered the surface [44].

Essential oils treatment

Treatments with essential oils such as, jojoba, rosemary and wheat germ oils were performed by dissolving the requisite amounts of each oil (2 ml/L) in 23 ml of 0.05 % tween-80 and then mixed with 975 ml of water.

Postharvest measurements
Physical properties

Weight loss (%): At each date, samples of each treatment were weighed and weight loss (%) was calculated as follows**:**

$$\text{Fruit weight loss (\%)} = [(A-B)/A)] \times 100.$$

Where: A= initial fruit weight B= fruit weight at each sampling date.
Fruit weight (gm), fruit volume (cm^3) of each replicate (5 fruits) were measured in each sampling date.

Fruit firmness ($Ib/inch^2$)

Fruit firmness was determined using Lefra Texture Analyser (Mod.TA1000). Firmness of 5 fruits from each replicate was measured and the results were calculated as $Ib/inch^2$ [45]. Fruit juice, weight and volume were detected.

Chemical properties:

Total soluble solids (TSS %)

Total Soluble Solids percentage in fruit juice was measured using a digital pocket refractometer (Model PAL 1, ATAGO TM, Tokyo Tech.) [46].

Total acidity (TA, %): was determined by titrating 5ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator and expressed as citric acid as the method described by Husia [47] .
Ascorbic acid content (VC) (mg/ 100 g. F. W.) was measured using 2, 6 dichlorophenol indophenols' method that described by Swain [48].
Anthocyanin content (mg/100 ml): was determined calorimetrically at 535 nm in fruit juice as described by Dubois [49].

Determination of phenolic compounds (mg/g F.W.)

Total phenolic content was determined spectrophotometrically using folin – ciocalteu calorimetric method [50] at the wave length of 725 nm, standard curve from p-hydroxyl benzoic acid was used to calculate the amount of phenols as mg per g fresh weight.

Total sugars determination (mg/g F.W.)

Phenol-sulfuric acid method was applied to determine the total sugars content of juices [51].

Statistical analysis

The experiment was set as a complete randomized blocked design (CRBD).The obtained data (average of both seasons) were tabulated and statistically tested for analysis of variance using COSTAT and the significant differences among the various treatments were compared using Duncan values at probability of 0.05 according to Mphahlele [52]. Combined analysis for both seasons was used.

Results

Fruit physical Characteristics
Fruit Weight Loss (%)

Average results of both seasons presented in Table (1) showed that, as long as the storage period increased, the fruit weight loss percentage of pomegranates fruits is increased. As 45 days of cold storage recorded the highest percentage of weight loss (25.21%), 15 days of cold storage recorded the least value (7.40%). Moreover, results cleared that, all fruits treated with different oils and edible coating treatments showed a decrease in weight loss % compared with the control treatment which scored the greatest significant value of weight loss percentage (24.66). Meanwhile, rosemary oil at 2% in combination with Arabic gum at 10% proved to be the best treatment in decreasing weight loss % (5.20). Considering the interaction, it was clear that, fruit treated with jojoba oil at 2% in combination with Arabic gum at 10% scored the lowest fruit weight loss percentage after 15 days of cold storage (1.01%) compared with the control (16.61%).

Fruit weight (gm)

Results in Table (1) represented the effect of different oils and edible coatings on fruit weight of pomegranate cv. Wonderful. It is cleared that, fruit weight was decreased significantly throughout storage period. The lowest value of fruit weight (220.61gm) was recorded after 45 days of storage. Referring to the effect of different oils and edible coating treatments, it is obvious that, rosemary oil treatment at 2% in combination with Arabic gum at 10% was reflected positively on fruit weight as it scored the greatest fruit weight number (279.62gm) followed by jojoba oil at 2% in combination with Arabic gum at 10% (277.62gm). Results showed a significant interaction between different fruit edible coating treatments and storage period since rosemary oil at 2% in combination with Arabic gum at 10% treatment gave the greatest significant fruit weight (263.0gm) after 45 days of cold storage.

Table 1: Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on weight loss % and fruit weight (gm) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

.

Treatments	Weight loss %					Fruit weight(gm)				
	0	15	30	45	M	0	15	30	45	M
Control	0t	16.61i	32.71b	49.32a	24.66a	295.00a	246.00l	198.50s	149.50t	222.25g
Jojoba oil at 2%	0t	15.93i	16.94i	25.76e	14.65b	295.00a	248.00k	245.00l	219.00p	251.75f

Jojoba oil at 2%+ gelatin at 8%	0t	7.79o	9.15m	20.84h	9.44f	295.00a	293.00b	261.50i	219.50p	267.25c
Jojoba oil at 2%+Arabic gum at 10%	0t	1.01s	7.79o	14.74k	5.88g	295.00a	292.00b	272.00f	251.50i	277.62b
Jojoba oil at 2%+wheat germ oil at 2%	0t	6.77p	15.42i	24.40f	11.64d	295.00a	275.00e	249.50k	223.00o	260.62d
Rosemary oil at 2%	0t	6.61p	22.03g	28.30c	14.23c	295.00a	275.50e	230.00 n	211.50r	253.00e
Rosemary oil at 2%+ gelatin at 8%	0t	1.18s	8.47n	27.11d	9.19f	295.00a	291.50b	270.00g	215.00q	267.87c
Rosemary oil at 2%+ Arabic gum at 10%	0t	4.06r	5.93q	10.84l	5.20h	295.00a	283.00c	277.50d	263.00i	279.62a
Rosemary oil at 2%+ wheat germ oil at 2%	0t	6.70p	11.35l	25.59e	10.91e	295.00a	272.00f	268.00 h	233.50m	267.12c
Mean	0.0d	7.40c	14.42b	25.21a		295.00a	275.11b	252.44c	220.61d	

Fruit volume (cm^3)

Results presented in Table (2) reveal that, all fruits covered with oils and edible coatings showed an increment in fruit volume compared with the control, as fruits treated with both jojoba oil or rosemary oil combined with Arabic gum recorded the greatest significant value of fruit volume without any significant difference in between (330.0) compared with the control fruit who scored the lowest value (301.25). On the other hand, it is clear that, fruit volume was gradually reduced significantly as long as the storage period increased (290 cm^3 after 45 days of storage). As for the interaction, it can be noticed that, the highest value of fruit volume was obtained with fruit treated with jojoba oil in combination with Arabic gum (350.0 cm^3) followed by rosemary oil in combination with wheat germ oil (348.0 cm^3).

Fruit firmness ($Lb/inch^2$)

Pomegranate fruit firmness was affected significantly by different oils and edible coatings, results in Table (2) reveal that, fruit firmness was decreased as long as storage period increased, whereas, combined analysis of both seasons showed that cold storage for 45 days recorded the lowest fruit firmness (12.70) compared with the uncoated fruits. Coating fruits with rosemary oil combined with Arabic gum gave the highest significant of firmness value (15.68) followed by jojoba oil in combination with Arabic gum (15.62) or jojoba oil combined with gelatin without any significant differences between them. Referring to the interaction, it is clear that, a decrease in fruit firmness was observed across all coating treatments (oils and edible coatings) with prolonging the storage period compared with control fruits.

Table(2) **:** Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on fruit volume (cm^3) and fruit firmness ($Lb/inch^2$) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Fruit volume(cm^3)					Fruit firmness($Lb/inch^2$)				
	0	15	30	45	M	0	15	30	45	M
Control	360.00a	300.00j	295.00k	250.00n	301.25e	17.00a	15.80abcd	13.63fgh	10.85k	14.32c
Jojoba oil at 2%	360.00a	323.00f	316.00h	295.00k	323.50d	17.00a	15.40bcd	13.86efgh	11.30ij	14.39c
Jojoba oil at 2%+ gelatin at 8%	360.00a	340.00e	320.00g	290.00l	327.50b	17.00a	15.70abcd	15.00cdef	14.50defg	15.55ab
Jojoba oil at 2%+ Arabic gum at 10%	360.00a	350.00b	315.00h	295.00k	330.00a	17.00a	16.30abc	15.60abcd	13.60fgh	15.62ab
Jojoba oil at 2%+wheat germ oil at 2%	360.00a	340.00e	320.00g	280.00m	325.00c	17.00a	15.80abcd	14.40defg	12.60hi	14.95bc
Rosemary oil at 2%	360.00a	320.00g	315.00h	300.00j	323.75d	17.00a	15.40bcd	13.80fgh	11.50ij	14.42c
Rosemary oil at 2%+ gelatin at 8%	360.00a	340.00e	310.00i	300.00j	327.50b	17.00a	16.15abc	15.80abcd	13.50gh	15.61ab
Rosemary oil at 2%+ Arabic gum at 10%	360.00a	345.00d	315.00h	300.00j	330.00a	17.00a	16.23abc	15.00cdef	14.50defg	15.68a
Rosemary oil at 2%+ wheat germ oil at 2%	360.00a	348.00c	300.00j	300.00j	327.00c	17.00a	16.80ab	15.30cde	12.00ijj	15.27ab
Mean	360.00a	334.00b	311.77c	290.00d		17.00a	15.95b	14.71c	12.70d	

Juice weight (gm) and Juice volume (cm^3)

Results presented in Table (3) show a significant gradual reduction in both pomegranate juice weight (79.11gm) and volume (78.22cm^3) with expanding storage period until 45 days of cold storage compared with the control (190.66). Meanwhile, all coated fruits treatments either with oils or edible coatings reflected positively on both juice weight and volume, since rosemary oil in combination with Arabic gum caused a significant increase in both juice weight (130.91gm) and juice volume (142.16 cm^3) compared with control (109.4gm &114.9 cm^3), respectively. As for the interaction, it is obvious that, after 45 days of cold storage coating pomegranate fruits with oils and different edible coatings, rosemary in combination with Arabic gum proved to be the most effective treatment in keeping weight and volume of fruit juice (95.00gm & 90.00cm^3) compared with the control as it recorded (50gm & 69cm^3), respectively.

Table(3) **:** Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on juice weight (gm) and juice volume (cm^3) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Juice weight (gm)					Juice volume(cm^3)				
	0	15	30	45	M	0	15	30	45	M
Control	190.66a	102.00gh	95.00j	50.00q	109.41h	190.66a	100.00j	100.00j	69.00p	114.91h
Jojoba oil at 2%	190.66a	106.00e	97.00i	63.00p	114.16g	190.66a	140.00c	90.00m	48.00q	117.16g
Jojoba oil at 2%+ gelatin at 8%	190.66a	107.00de	98.00i	90.00k	121.41d	190.66a	122.00f	110.00i	83.00n	126.41d
Jojoba oil at 2%+ Arabic gum at 10%	190.66a	142.00b	98.00i	77.00n	126.915b	190.66a	125.00e	110.00i	94.00k	129.91b
Jojoba oil at 2%+wheat germ oil at 2%	190.66a	107.00de	95.00j	83.00m	118.91f	190.66a	137.50d	92.00l	68.00p	122.04e
Rosemary oil at 2%	190.66a	106.00e	104.00f	74.00o	118.66f	190.66a	110.00i	92.00l	83.00n	118.91f
Rosemary oil at 2%+ gelatin at 8%	190.66a	103.50f	102.00gh	95.00j	122.79c	190.66a	121.00fg	120.00g	79.00o	127.66c

Rosemary oil at 2%+ Arabic gum at 10%	190.66a	130.00c	108.00d	95.00j	130.915 a	190.66a	163.00b	125.00e	90.00m	142.16a
Rosemary oil at 2%+ wheat germ oil at 2%	190.66a	103.00fg	101.00h	85.00l	119.91e	190.66a	113.00h	110.00i	90.00m	125.91d
Mean	190.66a	111.83b	99.77c	79.11d		190.66a	125.72b	105.4c	78.22d	

Fruit Chemical Characteristics
Total Soluble Solid (TSS) (%)

Results in Table (4) represent the effect of different oils and edible coating treatments on TSS% of Wonderful pomegranates fruits (average of both seasons). The obtained results showed that, prolonging storage period until 45 days caused a significant increase in TSS%, as it recorded 19.14 compared with the control (16.50). Moreover, TSS % was affected positively by exposing all coating treatments, however, rosemary oil at 2% in combination with Arabic gum at 10% gave the highest significant TSS% (18.62) followed by jojoba oil at 2% in combination with Arabic gum at 10% without any significant difference in between (18.12). Regarding the effect of interaction between both tested coating treatments and storage time, it can be noticed that, after 45 days of storage, rosemary oil at 2% in combination with Arabic gum at 10% scored the greatest significant percentage of TSS of pomegranate fruits (20.50) compared with the other treatments.

Table (4)**:** Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on Total Soluble Solids (TSS %) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	TSS%				
	0	15	30	45	M
Control	16.50h	17.00gh	17.50efgh	18.75cd	17.43d
Jojoba oil at 2%	16.50h	17.10gh	18.00defg	18.25def	17.46d
Jojoba oil at 2%+ gelatin at 8%	16.50h	18.00defg	18.50cde	19.00bcd	18.00bc
Jojoba oil at 2%+ Arabic gum at 10%	16.50h	18.00defg	18.50cde	19.50abc	18.12ab
Jojoba oil at 2%+wheat germ oil at 2%	16.50h	17.30fgh	18.00defg	18.50cde	17.57cd
Rosmary oil at 2%	16.50h	17.00gh	18.00defg	18.80cd	17.57cd
Rosmary oil at 2%+ gelatin at 8%	16.50h	17.00gh	18.50cde	20.00ab	18.00bc
Rosmary oil at 2%+ Arabic gum at 10%	16.50h	18.00defg	19.50abc	20.50a	18.62a
Rosmary oil at 2%+ wheat germ oil at 2%	16.50h	17.15gh	18.50cde	19.00bcd	17.78bcd
Mean	16.50d	17.39c	18.33b	19.14a	

Titratable Acidity (%)

Results in Table (5) clear that, there was quite evidence that total acidity % was decreased as the storage period increased until it reached the lowest significant

level (0.90) after 45 days of cold storage. Meanwhile, all coated fruit treatments recorded the lowest percentage of total acidity, where pomegranates fruits coated with rosemary oil at 2% in combination with Arabic gum at 10% recorded the lowest significant percentage of acidity (1.44) compared with the control which recorded the greatest significant percentage (1.72). Concerning the interaction between period of storage and coating treatments, it can be noticed that, coating pomegranate fruits with rosemary oil at 2% in combination with Arabic gum at 10% gave the least percentage of total acidity (0.64) after 45 days of cold storage compared with control (0.96).

Ascorbic acid content

Results in Table (5) reveal that, ascorbic acid content was declined significantly throughout cold storage, as it scored the least value after 45days of storage (30.55%). It can be noticed that, all coated fruit treatments with essential oils (Eos) or Arabic gum maintained with a high vitamin C content, especially when pomegranate fruits were coated with rosemary oil at 2% in combination with Arabic gum at 10% which gained the greatest significant value of VC (44.00%) compared with the control (28.75%). Significant interaction was detected between all coating treatments. Generally, after 45days of cold storage, coated fruits with rosemary oil at 2% in combination with Arabic gum at 10% kept its high content of VC (39.00%) compared with the control (20.00%).

Table (5)**:** Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on total acidity percentage and ascorbic acid content (mg/100 g F.W) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Total acidity %					Ascorbic acid content(mg100 g^{-1} F.W)				
	0	15	30	45	M	0	15	30	45	M
Control	2.10a	2.03b	1.79g	0.96o	1.72a	47.00a	25.00p	23.00q	20.00r	28.75h
Jojoba oil at 2%	2.10a	1.92d	1.72h	0.83p	1.64b	47.00a	37.00i	30.00mn	25.00p	34.75g
Jojoba oil at 2%+ gelatin at 8%	2.10a	1.85e	1.17m	0.96o	1.52e	47.00a	43.00de	39.00h	32.00kl	40.25c
Jojoba oil at 2%+ Arabic gum at 10%	2.10a	1.79g	1.21l	0.84p	1.48g	47.00a	46.00ab	43.00de	37.00i	43.25a
Jojoba oil at 2%+wheat germ oil at 2%	2.10a	1.84ef	1.42j	0.98n	1.58d	47.00a	40.00gh	35.00j	29.00n	37.75e
Rosemary oil at 2%	2.10a	1.98c	1.60i	0.83p	1.62c	47.00a	39.00h	33.00k	27.00o	36.50f
Rosemary oil at 2%+ gelatin at 8%	2.10a	1.72h	1.25k	0.96o	1.50f	47.00a	45.00bc	42.00ef	35.00j	42.25b
Rosemary oil at 2%+ Arabic gum at 10%	2.10a	1.79g	1.23kl	0.64q	1.44h	47.00a	46.00ab	44.00cd	39.00h	44.00a
Rosemary oil at 2%+ wheat germ oil at 2%	2.10a	1.82f	1.23kl	0.96o	1.52e	47.00a	41.00fg	37.00i	31.00lm	39.00d
Mean	2.10a	1.786b	1.40c	0.90d		47.00a	40.22b	36.22c	30.55d	

Anthocyanin's content

The effect of different oils and coating treatments on anthocyanin content of pomegranate fruits are presented in table (6). Results indicate that, there was a gradual increase in total anthocyanin content of the fruits, this increment is associated with extending the storage period, as it scored the highest significant level (7.12) after 45 days of storage. Moreover, treating pomegranate fruits with rosemary oil at 2% in combination with Arabic gum at 10% proved to be the best

coating treatments in increasing total anthocyanin content as it gave the greatest significant value (8.48) compared with the control (5.56). Significant interaction was obtained between cold storage period and all coated treatments. It can be concluded that after 45 days of cold storage, pomegranate fruits coated with rosemary oil at 2% in combination with Arabic gum at 10% had about double anthocyanin content (9.88) compared with the control (5.98).

Total Phenols content

Results in Table (5) indicate that, total phenols content was decreased gradually as long as the period of cold storage increased. Minimum total phenols content was recorded after 45 days (0.313 mg). Meanwhile, there were significant differences between all coating treatments and the uncoated one during the cold storage, where coating treatments with rosemary oil at 2% in combination with Arabic gum at 10% scored the lowest value of total phenols content (0.594mg) compared with the control (0.350mg). Regarding the interaction, it was clear that, after 45 days of cold storage, pomegranate fruits coated with rosemary oil at 2% in combination with Arabic gum at 10% recorded the lowest total phenols content (0.497) compared with the control (0.107).

Table (6): Effect of jojoba, rosemary oil solely or in combination with different edible coatings (gelatin, Arabic gum and wheat germ oil) on anthocyanin content (mg/100 g F.W) and total phenols content (mg/100 g F.W) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Anthocyanin (mg/100gm F.W.)					Total phenols(mg/ g F.W)				
	0	15	30	45	M	0	15	30	45	M
Control	5.21u	5.39s	5.67r	5.98n	5.56g	0.694a	0.381p	0.219x	0.107z	0.350i
Jojoba oil at 2%	5.21u	5.33t	5.84p	6.13l	5.62f	0.694a	0.495l	0.275v	0.207y	0.417h
Jojoba oil at 2%+ gelatin at 8%	5.21u	5.76q	6.43k	7.10h	6.12d	0.694a	0.547f	0.374q	0.350r	0.491d
Jojoba oil at 2%+ Arabic gum at 10%	5.21u	7.85f	7.92e	8.00d	7.24b	0.694a	0.594c	0.527h	0.441m	0.564b
Jojoba oil at 2%+wheat germ oil at 2%	5.21u	5.39s	6.11l	6.52j	5.80e	0.694a	0.518i	0.301t	0.294u	0.451f
Rosemary oil at 2%	5.21u	5.34st	5.94no	6.00m	5.62f	0.694a	0.507j	0.294u	0.225w	0.430g
Rosemary oil at 2%+ gelatin at 8%	5.21u	5.39s	6.52j	7.71g	6.20c	0.694a	0.581e	0.400n	0.397o	0.518c
Rosemary oil at 2%+ Arabic gum at 10%	5.21u	9.32c	9.53b	9.88a	8.48a	0.694a	0.603b	0.584d	0.497k	0.594a
Rosemary oil at 2%+ wheat germ oil at 2%	5.21u	5.39s	5.92o	6.81i	5.83e	0.694a	0.530g	0.337s	0.300t	0.465e
Mean	5.21d	6.12c	6.65b	7.12a		0.694a	0.528b	0.367c	0.313d	

Total sugars content (g/100 FW)

Results presented in Table (7) demonstrate that, pomegranate fruits stored for 45days resulted in a gradual significant increase in total sugars (12.31%). Moreover, as a results of exposing to all tested coating treatments, a significant increase in total sugars content was noticed, especially when pomegranate fruits treated with rosemary oil at 2% in combination with Arabic gum at 10% which scored the greatest significant value of total sugars (11.91%) followed by jojoba oil at 2% in combination with Arabic gum at 10% (11.67%) without any significant differences between them. Regarding the interaction effect between the storage periods and all coated treatments, results reveal that, the highest total sugars

content was obtained when pomegranate fruits were coated with rosemary oil at 2% in combination with Arabic gum at 10% after 45 days of cold storage (13.25%) compared with the control (11.97%).

Table (7): Effect of jojoba, rosemary oil solely or in combination with different edible coating (Gelatin, Arabic gum and Wheat germ oil) on total sugars of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Total sugars (mg/ g F.W)				
	0	15	30	45	M
Control	10.40n	11.00m	11.64g-k	11.97e-h	11.25d
Jojoba oil at 2%	10.40n	11.25klm	11.84f-i	11.61h-l	11.27d
Jojoba oil at 2%+ gelatin at 8%	10.40n	11.14lm	11.69g-k	12.72b	11.48bcd
Jojoba oil at 2%+gum Arabic at 10%	10.40n	11.80f-j	12.00e-h	12.50b-d	11.67ab
Jojoba oil at 2%+wheat germ oil at 2%	10.40n	11.12m	11.89e-i	12.11c-g	11.38cd
Rosemary oil at 2%	10.40n	11.32j-m	11.79g-j	12.01d-h	11.38cd
Rosemary oil at 2%+ gelatin at 8%	10.40n	11.72g-k	11.86e-i	12.35b-e	11.58bc
Rosemary oil at 2%+ gum Arabic at 10%	10.40n	11.42i-m	12.58bc	13.25a	11.91a
Rosemary oil at 2%+ wheat germ oil at 2%	10.40n	11.43i-m	11.72g-k	12.29b-f	11.46b-d
Mean	10.40d	11.35c	11.89b	12.31a	

Discussion

During the past decades, the desire of the consumers to maintain better health has increased their demand for healthy vegetables and fruits or juices that preserve their natural nutritive value also increased it. However, the nutritive composition and bioactive properties in pomegranate fruits or juice are strongly influenced by microclimate, cultivar, maturity status, extraction method and cold storage treatments [53-55]. Therefore, alternative eco-friendly materials such as essential oils (EOs) which have been largely used to preserve the quality of food and preferable choice for food industry due to their antimicrobial, antifungal activity as EOs were able to inhibit mycelia growth and conidial germination of the pathogen, in addition to their antioxidant activities [56] that leads to increase consumer acceptability, stability and shelf-life of food products.

Water content of fruits is a major factor in maintaining their quality. Therefore, low weight loss is important in maintaining the quality of fruits over a longer duration. The highest percentage of weight loss is due to higher moisture loss and increasing respiration rate. Edible coatings based on gums create an especial atmosphere around the fruit or vegetable by providing a semi permeable membrane to CO_2 and O2, thus controlling respiration and oxidation reaction rates. This delayed senescence helps to extend the shelf life of the fruits as demonstrated here that with Arabic gum coatings [57 -58].

Fruit physical Characteristics
Weight loss percentage

According to the obtained results, it can be concluded that, coating pomegranate fruits with rosemary oil at 2% in combination with Arabic gum at 10% had succeeded in reducing weight loss percentage of pomegranate fruits. The reducing of water and weight loss by essential oils or Arabic gum can be attributed to controlling of decay and its damages and act as permeable barrier against oxygen, carbon dioxide, moisture, thereby reducing respiration, water loss and oxidation reaction rates . Also, essential oils protected fruit skin and delayed dehydration and therefore less weight loss was occurred in the treated fruits during the storage. The positive effect of both essential oils and Arabic gum in reducing weight loss was reported by many researchers on guava, Kinnow mandarin, Ponkan (*Citrus reticulata* Blanco), Zaghloul date Palm, guava, Barhee date palm, mangoes, Samany date palm, pomegranate arils, pomegranate fruits, Le Conte pear fruits, and nectarine fruits [56, 58, 59, 60-68]since they reported that, the essential oils application or Arabic gum significantly decreased weight loss percentage and increased life storage fruits.

Fruit firmness

One of the most crucial factors in fruit eating quality and consumer acceptance is fruit flesh firmness. Fruit quality degrades as a result of pectin degradation in the fruit cell wall and hydrolysis of starch to sugar associated with fruit ripening, and maintaining fruit firmness is a crucial component in extending the shelf life of fresh products. Because these coating ingredients slowed metabolism and extended storage life, edible coating performed well in terms of maintaining fruit firmness. Essential oils function as a layer of defense against many bacteria and fungus, preventing fruit deterioration [69]. The highest values of firmness were achieved in pomegranates fruits that coated with rosemary oil at 2% in combination with Arabic gum at 10%.

The aforementioned results go in line with those obtained on guava, Zagloul date palms, Guava, Barhee date palms, on Samany date palms, strawberry fruits pomegranates, Le Conte pear, plum, and nectarine fruits [30, 58, 59, 62-66, 68, 70] since the essential oils application or Arabic gum significantly had succeeded in maintaining firmness of pomegranate fruits.

Fruit Chemical Characteristics
Total Soluble Solids (TSS %)

Total soluble solids are regarded as a crucial characteristic that reflects the nutrient value of harvested fruits. When rosemary oil at 2% and Arabic gum at 10% were applied, the degradation of TSS was greatly postponed, and a higher TSS content was successfully preserved during cold storage compared to the control. Our findings show that the TSS% of uncoated pomegranate fruits increased sharply, possibly as a result of water loss from the fruit and the ripening condition, which caused the breakdown of complex carbohydrates into simple sugars and increased TSS [71]. In contrast, for coating treatments with Arabic gum, a film is formed on the fruit's surface that inhibits ethylene

synthesis, delaying ripening and ultimately TSS accumulation [72]. Moreover, a hydrolytic conversion of polysaccharides into soluble sugar was happened during the ripening process which resulted in an increase in TSS of the fruits [73]. Our results are matched with those reported on guava, Ponkan (*Citrus reticulata* Blanco), pomegranates, and Le Conte pear [58, 59, 61, 66, 67], where the fruits coated with essential oils or Arabic gum showed a significant increase of TSS % during the cold storage.

Titratable acidity (%)

Pomegranate juice sweetness depends on sugar types, while, its acidic taste isa result of organic acids majorly. So, the sweet pomegranate cultivars having high sugar content and low organic acid levels, meanwhile, sour cultivars have higher organic acid and low sugar content levels [74]. The titratable acidity was relatively high at harvest and then it decreased during ripening as a natural phenomenon. Titratable acidity reduction is attributed to the metabolism and respiration of the pomegranate arils, such that the acidic substances participate in series biochemical reactions and convert to other nonacidic compounds. Similar results were reported on guava, pomegranates, Ponkan (*Citrus reticulata* Blanco), Barhee date palm, and Le Conte pear [58, 59, 61, 64, 67, 75], since the coating treatments with essential oils (Eos) or Arabic gum caused a gradual decline in juice fruit titratable acidity **(**TA %) during the cold storage.

Ascorbic acid content

Ascorbic acid is an important quality factors, which is very sensitive to degradation due to its oxidation during storage. Vitamin C in pomegranates fruits was declined gradually during the storage period. Maximum loss of vitamin C was occurred with untreated fruits. Concerning retention of vitamin C, better response was scored with the fruits coated with oils or Arabic gum as they scored less degradation of the ascorbic acid during storage. The decrease in vitamin C content during the storage period was attributed due to the oxidation of ascorbic acid into dehydroascorbic acid [76]. Additionally, ascorbic acid is lost during storage due to the actions of the enzymes phenol oxidase and ascorbic acid oxidase [49]. The retention of ascorbic acid by the therapies could be attributed to the retardation of oxidation process, also due to the slow rate of conversion of L-ascorbic acid by ascorbic acid oxidase [71]. This clears that Arabic gum treatment is appropriate for ascorbic acid retention during the cold storage of pomegranate.
Equivalent results are reported on guava, Ponkan (*Citrus reticulata* Blanco), pomegranate**,** Barhee date palms, [59, 61, 64, 75, 77] since the maximum loss in vitamin C was observed in control fruits, while coating fruits with oils or Arabic gum decreased the loss of ascorbic acid.

Anthocyanin content

Anthocyanin is the main phenolic compounds responsible for the purple-red colors of pomegranate. Pomegranate fruit anthocyanin was found to possess higher antioxidant activity than Vitamin-C, Vitamin E, and β-carotene. Total anthocyanin content of pomegranate fruits cv. Wonderful had a gradual and significant increase with the advance of the storage period. Our results showed

that the edible coating treatments reduced the degradation of anthocyanin content during the storage period. It is most possibly because the edible coatings lessen the activity of polyphenol oxidase and peroxidase enzymes in response to the changes in the internal atmosphere of the coated fruits [78], it found that, the degradation of anthocyanins in litchi fruit is affected by polyphenol oxidase and peroxidase, but application of chitosan coating decreased enzyme activity during the storage period on pomegranates [62]. Our results confirmed an increment of total anthocyanin content for pomegranate fruits coated with rosemary oils in combination with Arabic gum. Similar findings were observed on pomegranates [62, 67, 75, 77].

Total sugars content

Prolonging the cold storage period of Samany date palm fruits resulted in increasing fruit total sugars content. In this respect, the initial readings, i.e., before cold storage (zero-day storage) scored the lowest values on Samany and Zagloul date palms [63, 65].

Total Phenol

Phenolic compounds play a vital role in eliminating free radicals and decrease the development of senescence stress [30]. All coating treatments had succeeded in decreasing the phenolic compound with extending the storage period. Our results go in line with those obtained on Guava, Ponkan (*Citrus reticulata* Blanco), Samany date palm, Zagloul date palms and pomegranates [59-61-65-63-66].

Conclusions

The presented results suggest that the physical and chemical properties of Wonderful pomegranate fruits during cold storage at 5±1˚C and 85-90% RH were positively affected by different edible coating treatments. Pomegranate fruits coated with rosemary oil at 2% in combination with Arabic gum at 10% effectively reduced weight loss%, maintained higher firmness, fruit weight, fruit volume, juice weight and juice volume. Also, it retained total soluble solids as higher values, suppressed total acidity degradation, and decreased the loss of ascorbic acid, maintained higher amounts of anthocyanin content and decreased total phenols. The obtained results suggest that, Arabic gum coating treatment could be used as a commercial wax to improve postharvest storability, extend storage period, and maintain the nutritional value of Wonderful pomegranate fruits up to 45 days of cold storage at 5^{o}C. Jojoba oil at 2% in combination with Arabic gum at 10% came at the second rank and may have no significant differences among some fruit characteristics.

Referances

1. A.O.A.C. (1990). Official methods of analysis. Association of official agricultural chemists. International. 13th ed. AOAC International. Gaithersburg, MD, USA, Method No. 950.46.
2. A.O.A.C. (2000).Official Methods of Analysis. Association of official agricultural chemists. 17th Ed, Washington DC. USA, 490-520.

3. Abbasi, K..; N. Anjum; S. Sammi; T. Masud and S. Ali (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.
4. Abd El Wahab and M. Sahar (2015). Maintain postharvest quality of nectarine fruits by using some essential oils. Middle East J. Appl. Sci., 5(4): 855-868.
5. Abd El-Moneim, Eman A.A.; Z.A. Zaki; K.S. Nagy and Aml R.M. Yousef (2019). Effect of local and imported smart films on the quality of pomegranate fruits to enhance the export. Journal of Horticultural Science & Ornamental Plants, 11 (2): 97-106.
6. Aboryia, M.S. and Asmaa S.M. Omar (2020). Effectiveness of some edible coatings on storage ability of Zaghloul date palm fruits. J. of Plant Production, Mansoura Univ., 11 (12):1477 – 1485.
7. Aitboulahsen, M.; S. Zantar; A. Laglaoui ; H. Chairi; A. Arakrak; M. Bakkali and M.H. Zerrouk (2018). Gelatin- based edible coating combined with menthe pulegium essential oil as bioactive packaging for strawberries. Journal of Food Quality, 15: 1-7.
8. Ali, A.; M. Maqbool; S. Ramachandran and P.G. Alderson (2010). Gum Arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato (*Solanum lycopersicum* L.). Fruit Postharvest Biology and Technology, 58:42–47.
9. Almela, L.; B. Sachez; J.A. Fernandez; M. Roca and V. Rabe (2006). Liquid chromatographic mass spectrometric analysis of phenolics and radical scavenging activity of rosemary extract from different raw material. J. Chromatography A, 1120: 221-229.
10. Alparslan, Y.; T. Baygar; C. Metin ; H.H. Yapici and T. Baygar (2019). The role of gelatin-based film coating combined with orange peel essential oil on the quality of refrigerated shrimp. Acta Aquatica Turcica, 15(2): 197-212.
11. Amaral, L.D.P.; J.S.M. Tondolo; B. Schindler; D.T. da Silva ; C.G. Pinheiri and S.J. Longhi (2015). Seasonal influence on the essential oil production of *Nectandra megapotamica* (Spreng.) Mez. Braz. Arch. Biol. Technol., 58, 12–21.
12. Arras, G; M. Usai (2001). Fungitoxic activity of twelve essential oils against four postharvest Citrus pathogens: chemical analysis of *Thymus capitatus* (L.) oil and its effect in sub atmospheric pressure conditions. J Food Prot.; 64:1025–1029.
13. Artharn, A.; T. Prodpran and S. Benjakul (2009). Round scad protein-based film: Storage stability and its effectiveness for shelf-life extension of dried fish powder. LWT-Food Science and Technology, 42(7): 1238-1244.
14. Awad, A.M.; A.A.A. Mohdaly; N.A.A. Elneairy (2015). Wheat Germ: An Overview on nutritional value, antioxidant potential and antibacterial characteristics. Food and Nutrition Sciences, 6: 265-277.
15. Bomfim, N.D.S.; L.P. Nakassugi, J.F.P. Oliveira; C.Y. Kohiyama; S.A.G. Mossini; R. Grespan; S.B. Nerilo; C.A. Mallimann; B.A. Abreu Filho and J.R. M. Machinski (2015). Antifungal activity and inhibition of fumonisin production by *Rosmarinus officinalis* L. essential oil in *Fusarium verticillioides* (Sacc.) Nirenberg. Food Chemistry, 166:330- 336.
16. Caleb, O.J.; U.L Opara and C. Witthuhn (2012). Modified atmosphere packaging of pomegranate fruit and arils: A review. Food Bioprocess. Technol., 5, 15–30.

17. Camele, I.; V. De Feo; I. Altieri; E. Mancini; L. De Martino and G. Luiqi Rana (2010). An attempt of postharvest orange fruit rot control using essential oils from
Mediterranean plants. J. Med. Food., 23:45–52.
18. Chandra, R.; D.K. Babu; V.T. Jadha. and J.A.T. da Silva (2010). Origin, history and domestication of pomegranate. Fruit Veg. Cereal Sci. Biotechnol., 4, 1–6.
19. Combrinck, S; T. Regnier and Kamatou G.P.P. (2011). In vitro activity of eighteen essential oils and some major components against common postharvest fungal pathogens of fruit. Ind. Crops Prod., 33(2):344–349.
20. Costa, L.C.B.; J.E.B.P. Pinto; S.K.V. Bertolucci; J.C.B. Costa; P.B. Alves and E.S. Niculau (2015). In vitro antifungal activity of *Ocimum selloi* essential oil and methylchavicol against phytopathogenic fungi. Cienc. Agron., 2, 428–435.
21. Czieczor, L.; C. Bentkamp; L. Damerow and M. Blanke (2018). Non-invasive determination of the quality of pomegranate fruit. Postharvest Biol. Technol., 136:74–79.
22. Daisy, L.L.; J. M. Nduko; W.M. Joseph and S.M. Richard (2020). Effect of edible gum Arabic coating on the shelf life and quality of mangoes (*Mangifera indica*) during storage. J. Food Sci. Technol., 57(1):79–85.
23. De Almeida, W.S.; S.G. De Lima; H.M. Barreto; L.M. De Sousa Andrade; L. Fonseca and C.A. Sobrinho (2018). Chemical composition and antimicrobial activity of the essential oil of *Lippia lasiocalycina* Cham. (Verbenaceae). Ind. Crops Prod. 125, 236–240.
24. Dubois, M.; K. Gilles; J. Hamilton P. Rebers and F. Smith (1956). Colorimetric method for determination of sugars and related substances. Analytical Chemistry, 28(3): 350-356.
25. El-Anany, A.M.; G.F.A. Hassan and A.M.R. Ali (2009). Effects of edible coatings on the shelf-life and quality of Anna apple *(Malus domestica* Borkh) during cold storage. J. Food Technol., 7:5-11.
26. EL-Gioushy S.F. and M.H.M. Baiea (2020). Impact of gelatin, lemongrass oil and peppermint oil on storability and fruit quality of Samany date palm under cold storage. Bulletin of the National Research Centre, 44(14):1-13.
27. El-Gioushy, S.F.; M.F.M. Abdelkader; M.H. Mahmoud; Hanan M. Abou El Ghit; M. Fikry; Asmaa M.E. Bahloul; Amany R. Morsy; A.A. Lo'ay; A.M.R.A. Abdelaziz; Haifa A.S. Alhaithloul; Dalia M. Hikal; M.A. Abdein; K.H.A. Hassan and M.S. Gawish (2022). The effects of a gum Arabic-based edible coating on guava fruit characteristics during storage. Coatings, 12(90):1-16.
28. El-Sharony, T.; O. Amin; A. Abd-Allah (2015). Effect of some postharvest treatments on quality and storability of date palm fruits Zaghloul and Samany cultivars. Catrina: Int. Res. J. Environ. Sci., 10: 49-58.
29. Falguera, V.; J.P. Quintero; A. Jiménez; J.A. Muñoz and A. Ibarz (2011). Edible films and coatings: Structures, active functions and trends in their use. Trends Food Sci. Technol., 22, 292–303.
30. Fan, X.; S.M. Blankenship and J.P. Mattheis (1999). 1-Methylcyclopropene inhibits apple ripening. J. Am. Soc. Hort. Sci., 124(6):690–695.
31. Fischer, U.A; R. Carle and D.R. Kammerer (2011). Identifcation and quantifcation of phenolic compounds from pomegranate (*Punica granatum* L.) peel, mesocarp, aril and differently produced juices by HPLC-DAD–ESI/ MSN. Food Chem., 127:807–821.

32. Gómez-Guillén, M.C., M. Ihl, V. Bifani, A. Silva and P. Montero (2007). Edible films made from tuna-fish gelatin with antioxidant extracts of two different murta ecotypes leaves (*Ugni molinae* Turcz). Food Hydrocolloids, 21(7): 1133-1143.
33. Guilbert, S. and N. Gontard, (2005). Agro-polymers for edible and biodegradable films: review of agricultural polymeric materials, physical and mechanical characteristics. In: Innovations in Food Packaging. (Ed.): J.H. Han. Elsevier Academic, Oxford, UK, pp. 263-276.
34. Hosseni, S.; J. Amini; J.N. Rafei, and J. Khorshidi (2020). Management of strawberry anthracnose using plant essential oils as bio-fungicides, and evaluation of their effects on quality of strawberry fruit. J. Oleo Sci., 69 (4): 377-390.
35. Hsia, C.L.; B.S. Luh and C.O. Chichester (1965). Anthocyanins in freestone peaches. J. Food Sci., 30: 5-12.
36. Huang, Q.; C. Wan; Y. Zhang; C. Che and J. Chen (2021). gum Arabic edible coating reduces postharvest decay and alleviates nutritional quality deterioration of Ponkan Fruit during cold storage. Frontiers in Nutrition, 8:1-11.
37. Ibrahim, R.A.; M.T. El-Mahdy; M.A.M. Taha and M.M. Shaaban (2021). Improving the quantitative and qualitative of Manfalouty pomegranate cultivar. SVU-International Journal of Agricultural Sciences, 3 (1): 31-52.
38. Jain, S.K. and S. Mukherjee (2011). Enhancing keeping quality of fruits in mango cv. Langra. Ind. J. Hort., 68:142–144.
39. Jokar, A.; H. Barzegar; N. M.Azad and M. Shahamirian (2021). Effects of cinnamon essential oil and Persian gum on preservation of pomegranate arils. Food Sci. Nutr., 9:2585–2596.
40. Jongjareonrak, A.; S. Benjakul; W. Visessanguan; T. Prodpran and M. Tanaka (2006). Characterization of edible films from skin gelatin of brown stripe red snapper and big eye snapper. Food Hydrocolloids, 20(4): 492-501.
41. Ju, A.; J. Warcup; W. Wright; G. Pugh (2000). The effect of fungicide on certain chemical and microbial of soil. Soil Biol. Biochem., 6: 263-267.
42. Kawhena, T.G; A.A. Tsige; U.L. Opara and O.A. Fawole (2020). Application of gum Arabic and methyl cellulose coatings enriched with Thyme oil to maintain quality and extend shelf life of “Acco” Pomegranate arils. Plants, 9:1-20.
43. Khorram F.; A. Ramezanian; S.M. Hosseini and S. Shellac (2017). Gelatin and Persian gum as alternative coating for orange fruit. Sci. Hort., 225:22– 28.
44. Kumar, N. and D. Neeraj (2018). Study on physico-chemical and antioxidant properties of pomegranate peel. J. Pharmacogn Phytochem, 7: 2141–2147.
45. Lalitha, V., Kiran B. and Ravesha K.A. (2011). Antifungal and antibacterial potentiality of six essential oils extracted from plant source. Int. J. Eng. Sci. Technol., 3: 1029–3038.
46. Lavoro, A.; L. Falzone; G. Gattuso; R. Saliemi; G. Cultrera; M. Leone; G. Scandurra; S. Candido and M. Libra (2021). Pomegranates: A promising avenue against the most common chronic diseases and their associated risk factors (Review). International Journal of Functional Nutrition, 2 (6):1-12.
47. Maklad, M. F. (2015). Effects of some edible coating on the quality and shelf-life of Pioneer plum fruits (*Prunus salicina* L.) at room temperature. Egypt. J. Hort., 42(1): 419-426.

48. Malekshahi, G. and B. Valizadeh Kaji (2021). Effects of postharvest edible coatings to maintain qualitative properties and to extend shelf-life of pomegranate (*Punica granatum*. L). Int. J. Hort. Sci. Technol., 8 (1):67-80.
49. Mari, M.; S. Bautista-Baños and D. Sivakumar (2016). Decay control in the postharvest system: role of microbial and plant volatile organic compounds. Postharvest Biol. Technol., 122: 70–81.
50. Mariod, A.A. and H.F. Adam (2013) Review: gelatin, source, extraction, and industrial applications. Acta Sci. Pol., Technol. Aliment, 12(2):135–147.
51. Mditshwa, A.; O.A. Fawole; F. Al-Said; R. Al-Yahyai and U.L. Opara (2013). Phytochemical content, antioxidant capacity and physicochemical properties of pomegranate grown in different microclimates in South Africa. S. Afr. J. Plant Soil, 30: 81–90.
52. Melgarejo, P.; D.M. Salaza and F. Artes (2000). Organic acids and sugars composition of harvested pomegranate fruits. European Food Res. Technol., 211: 185-190.
53. Miller, K.S.; S.K. Upadhyaya, and J.M. Krochta (1998). Permeability of d-limonene in whey protein films. J. Food Sci., 63: 244-247.
54. Mohan, A.A.S.; J. Singh Jatinder and V. Chhabra (2021). Extension of post-harvest quality and storage life of kinnow as affected by various elements. The Pharma Innovation Journal, 10 (5): 29-34.
55. Motlagh S; P. Ravines; K.A. Karamallah and Q. Ma (2006). The analysis of Acacia gums using electrophoresis. Food Hydrocol., 20:848-854.
56. Mphahlele, R.R.; T. Genis; O.A. Fawole and U.L. Opara, (2018). Sensory, quality and biochemical attributes of pomegranate juice as affected by method of extraction. Acta Hort.:1201. doi: 10.17660/ActaHortic.2018.1201.16
57. Naqvi, H. and I. Ting (1990). Jojoba: a unique liquid wax producer from the American desert, Advances in new crops. Proceedings of the First National Symposium' New crops: research, development, economics', Indianapolis, Indiana, USA, 23-26. October, 1988. Timber Press, pp. 247-251.
58. Ncama, K.; L.S. Magwaza; A. Mditshwa and S.Z. Tesfay (2018). Plant-based edible coatings for managing postharvest quality of fresh horticultural produce: A review. Food Packaging, Shelf Life, 16, 157–167.
59. Ozcan, M.M.; and J.C.S. Chalchat (2008). Chemical composition and antifungal activity of rosemary (*Rosmarinus officinalis* L.) oil from Turkey. Int. J. Food Sci. Nutr., 59, 691–698.
60. Pareek, S.; D. Valero and M. Serrano (2015). Postharvest biology and technology of pomegranate, J. Sci. Food Agric., 95(12): 2360–2379.
61. Plaza, P.; R. Torres; J. Usall; N. Lamarca and I. Vinas (2004). Evaluation of the potential of commercial post-harvest application of essential oils to control citrus decay. J. Hortic. Sci. Biotechnol., 79 (6):935–40.
62. Rajasekar, D.; C.C. Akoh; K.G. Martino and D.D. Maclean (2012). Physicochemical characteristics of juice extracted by blender and mechanical press from pomegranate cultivar grown Georgia. Food Chem., 133: 1383–1393.
63. Saleh, M.A.; Zaied, N.S.; M. Maksoud; O.M. Hafez (2019). Application of Arabic gum and essential oils as the postharvest treatments of Le Conte pear fruits during cold storage. Asian J. Agro. Hort., 3(3):1-11.
64. Salehi, F. (2020). Edible coating of fruits and vegetables using natural gums: A review. International Journal of Fruit Science, 20:570–S589.

65. Sarrwy, S.M.A; Dorria M.M. Ahmed and Aml R.M. Yousef (2021). Thermal post storage treatment for maintaining fruit quality and extending storage life of pomegranate Wonderful cultivars. Egypt. J. Chem., 64(11): 6375 – 6383.
66. Sawires, Z.R.; N.G. Iskander, and M.A. Ahmed (1995). Toxic action of some plant extracts against Tetranychus urticae Koch. Proc. 8th Nat. Conf. of Pest. & Dis. of Vegetables & Fruits in Egypt. P. 156-177.
67. Şerban, E.S.; M. Ionescu; D. Matinca; S. Maier; and M. Boji (2011). Screening of the antibacterial and antifungal activity of eight volatile essential oils. Farmacia, 59(3):440-446.
68. Shao, P.; P. Sun; Y. Ying (2008). Response surface optimization of wheat germ oil yield. Food Biopro. Process. 86, 227–231.
69. Soylu, E.M.; S. Soylu and S. Kurt (2006). Antimicrobial activity of the essential oils of various plants against tomato late blight disease agent Phytophthora infestans. Mycopathologia, 161, 119–128.
70. Swain, T. and W.E. Hillis (1959). The qualitative analysis of phenolic constituent. J. Soc. Food. Agric.,10:63.
71. Tahir, H.E.; Z. Xiaobo; G.K. Mahunu; M. Arslan; M. Abdalhai and L. Zhihua (2019). Recent developments in gum edible coating applications for fruits and vegetables preservation: A review. Carbohydr. Polym., 224, 115-141.
72. Valencia-Chamorro, S.A.; L. Palou; M.A. Del Río and M.B. Pérez-Gago (2011). Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: A review. Crit. Rev. Food Sci. Nutr. , 51, 872–900.
73. Varasteh, F.; K. Arzani, M. Barzegar, Z. Zamani (2012). Changes in anthocyanins in arils of chitosan-coated pomegranate (*Punica granatum* L. cv. Rabbabe-Neyriz) fruit during cold storage. Food Chem., 130, 267–272.
74. Waller, A. and D.B. Duncun (1969). Multiple range and multiple tests, Biometrics, 11:1-24.
75. Wills, R.B.H.; W.B. Mc Glasso;. D. Graham; T.H. Lee and E.G. Hall (1981). Postharvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. New South Wales University Press Limited Kensington, England.
76. Yousef, A.R.M.; Eman A.A. Abd El-Moniem and Thanaa Sh. M. Mahmoud (2020). Edible coating of soyprotein or gelatin as a carrier of thyme oil for maintaining quality of “Barhee” dates fruits during cold syorage. Plant Archives, 20(2):9311-9322.