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Effect of Agar and Some Natural Oils Coating on Pectinase Activity, Antioxidant Content, Storability and Fruit Properties of Pomegranate Wonderful Cultivar

Hala E. Emam; Aml R. M. Yousef*; Thanaa Sh. M. Mahmoud and Eman A.A. Abd El-Moniem

Horticultural Crops Technology Dept., National Research Centre, 33 Bohouth St., Dokki, Giza, Egypt

Abstract

Edible coatings are widely used as a protective barrier for the reduction of transpiration and respiration, therefore reducing the ripening process in fruits and improving their quality. So, this study was conducted during two consecutive seasons of 2019 and 2020 to evaluate the effectiveness of edible coating with agar at 1, 2 and 3 % combined with almond seed oil either or coconut fruit oil as 0.1% concentration to maintain fruits quality and extend storage period of "Wonderful" pomegranate fruits during storage at 5°C and 85-90 % relative humidity for 0, 15, 30 and 45 days. Arils weight (gm), juice weight (gm), juice volume (cm^3), weight loss percentage (WL %) and fruit firmness (Ib/ $inch^2$) parameters were measured. Fruits were also analyzed for soluble solids content (SSC %), total acidity (TA %), ascorbic acid (vitamin C, mg\100g F.W), total antioxidant content (TAC), and pectinase enzyme activity (PE, u/g F.W). In general, the coated fruits by agar with coconut either or almond oil had achieved better results and had a positive effect on prolonging fruit storage period with good fruit properties comparing with the untreated fruits (control). Coated fruits by 1% agar with almond oil recorded the least fruit weight loss, highest fruit firmness, highest SSC %, lowest TA%, and highest ascorbic acid. While, the highest values of arils weight, juice weight and juice volume recorded by coating fruits with agar at 1 and 2% plus coconut fruit oil. The lowest pectinase activity and highest content of total antioxidant content were showed due to coat fruits by agar at 3% with coconut oil.

Keywords: Pomegranates, agar, almond oil, coconut oil, fruit quality, pectinase activity, cold storage

1. Introduction

Wonderful pomegranate (*Punica granatum* L.) is the most cultivated and consumed globally [1]. It's have a great nutritional and health benefits, and therefore the global demand for it is steadily increasing all over the world, which necessitates supplying markets with high-quality pomegranates for long periods. Wonderful pomegranate is late cultivar with high yield, large fruit, rich red aril, high juice, and good palatability [2]. Wonderful is currently one of the most desired planted pomegranate cultivars in Egypt since it offers best balance combination yield and quality [3]. However, pomegranate is a perishable fruit despite its low respiratory rate [4].

Edible coatings are one of the most widely accepted post-harvest technologies for extending the life of fruits and is an innovative method of enhancing fruit quality by reducing post-harvest microbial losses. Moreover, coating materials influence on fruit fresh appearance and nutritional composition [5].

The most significant benefits of edible coatings are the contribution to food health and safety, and reduction of synthetic packaging waste with meeting environmental requirements [6, 7]. There are many materials commonly used as edible coatings or films such as polysaccharides, lipids, proteins, resins and other natural products that are safe and environmentally friendly alternatives to synthetic

*Corresponding author e-mail: amlgabr@yahoo.com; (Aml R. M. Yousef).
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preservatives [8]. The surface edible coating is a potential postharvest treatment that preserves fruit quality through reducing quality changes and quantity losses [9-11].

Agar is a carbohydrate that has a high gelling ability consisting of a mixture of agarose and agar-pectin. Agar is also a mixture of polysaccharides composed of a combination of linear dextrose and levo galactose [12]. The chemical structure of agar is mainly consisted of repeating units of D-galactose and 3, 6-anhydro-L-galactose, with slight variations and low content of sulfate esters. It can form reversible gels simply by heating and cooling [13] and characterized by melting points well above the initial gelation temperature [14]. Agar was used as a base material for edible films in many studies and the results showed that agar films have transparent, flexible, homogeneous, clear mechanical properties, good physical properties and easy handling. Also, agar films have good functional properties that make them suitable for use as coating and wrapping materials for food [15,16].

Lipid edible coatings have better properties to protect perishable food products from deterioration by water barrier which retarding dehydration, suppressing respiration, improving textural quality, helping retain volatile flavor compounds and reducing microbial growth, and improving appearance by adding glossiness [17].

The addition of pure coconut oil to edible coatings of fruit provides anti-aging properties by controlling the rates of transpiration, respiration, and biosynthesis process of ethylene [18]. Coconut oil is a natural food product rich in lauric acid. There is evidence that a part of this acid converts endogenously to monolaurin that is known to possess a broad spectrum of antiviral, antibacterial and antifungal activities [19]. The application of almond oil as edible coating reduced the water loss, respiration rate, softening, weight loss, delayed microbial decay and improve fruits appearance [20, 10, 21].

Therefore, the objective of this study was to investigate the effect of edible coating by different concentrations of agar either with almond or coconut oil for improving 'Wonderful' pomegranate fruits quality attributes and storage period prolonging.

2. Experimental

2.1. Fruits

Matured fruits cv. Wonderful (*Punica granatum* L.) harvested from experimental station of National Research Centre, at Al-Nobaria district, Al-Behera governorate, Egypt, from seven years old trees. Fruits were similar in growth vigor, subjected to the common horticultural treatments and free of any noticeable pathological or mechanical injuries. Fruits were immediately packed and transported to the laboratory, all fruits washed by tap water and air dried. The initial quality characteristics were determined. The show results are an average of two successive seasons (2019 and 2020).

2.2. Treatments

Pomegranate fruits were coated with different concentrations of agar at 1, 2 and 3% combined with almond (*Prunus dulcis* Mill) seed oil or coconut (*Cocos nucifera*) fruit oil as 0.1% concentration, which prepared from the oil extraction unit of National Research Centre. The glycerol at 5% was then added to the agar plus oils mixture.

2.3. Agar coating preparation

Coatings were prepared according to the method of Arham *et al.* [13] with some modification. Agar powder was dissolved in distilled water at 95ºC for at least 30 min under stirring. The concentration of agar solution was 1, 2, and 3% (w/v). The solution was cooled down to 40°C then glycerol and oils were added to the agar solution at a concentration of 5% and 0.1% (w/w), respectively and used in the coating fruit.

2.4. Almond and coconut oils preparation

Almond and Coconut oils were prepared by dissolved 0.1ml oil in 100 ml of distilled water to 0.1% concentration. The glycerol at 5 % concentration was prepared by dissolved 5 ml glycerol in 100 ml of distilled water, and used in the further experiment.

Pomegranate fruits were air dried after coating treatments, and packed in corrugated cardboard boxes and placed in a cold storage room at 5^{o}C and 85 - 90% RH for a total cold storage period (45 days) and compared with the untreated fruits (control). Each treatment consists of three replicates and each replicate consists of three fruits. The measurements of fruit quality were determined after storage at 5^{o}C in each sampling date.

2.5. Postharvest determinations

2.5.1. Fruit physical characteristics

Fruit aril weight (gm), Juice weight (gm) and volume (cm^3) were measured during each sampling date (15 days).

Weight loss percent (%): Fruits were weighed at the beginning and after an interval of two weeks. The percentage was calculated as the following equation:

Weight loss (%) = (wt. of 1st interval – wt. of 2nd interval) x100 / wt. of the 1st interval

Fruit firmness ($Ib/inch^2$): Fruit firmness was determined using Ametek pressure tester, fitted with an 8 mm hemispherical probe (probe penetration 2 mm). Firmness of pomegranate fruits were measured at two opposite points on the equator of each and the results were calculated as $Ib/inch^2$ [22].

2.5.2. Fruit chemical characteristics

Freshly juice of pomegranate fruits samples was used to determine TSS, TA and ascorbic acid content.

Total soluble solid content was measured using a T/C hand refractometer.

Total Acidity (TA) expressed as malic acid was determined by titrating 5 ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator. Ascorbic acid content (VC) was measured using 2, 6 di-chlorophenol indophenols' method [22].

Total antioxidant content (TAC): Antioxidant activity in the pomegranate arils was assessed by using the free radical DPPH method [23].

Pectinase activity (PA): Sample of 0.5 ml of supernatant enzyme extraction were used and mixed in acetate buffer then incubated at 45 °C for l0 min for pectinase. The reaction was stopped with 3 ml of 3, 5-dinitrosalicylic acid reagent, the color was obtained after heating for 10 min., and measured at wavelength of 570 nm and expressed as one unit of pectinase activity liberates 1 Mmol D-galactouronic acid in milliliter per min [24].

2.6. Statistical analysis

The design for this experiment was a completely randomized design (CRD) with three replications. The collected data on various parameters were statistically analyzed using variance (ANOVA) according to Gomez and Gomez [25], using Costate Software Program Version 6.303 (2004) and LSD at 0.05 level of significance was used for the comparison between means.

3. Results

Fruit physical characteristics

Impact of edible coating using different concentrations of agar with almond or coconut oil on the physical characteristics of "Wonderful" pomegranate was evaluated as following:

Weight of arils (gm): Table (1) showed that weight of "Wonderful" pomegranate arils tended to gradually and significantly decrease during the storage period in all treatments under the study. Highest arils weight (53.74 gm) recorded by coating fruits with Agar 2%+ coconut oil, while lowest arils weight (42.43 gm) was obtained due to Agar 3% + almond oil. The other treatments gave intermediate values compared with untreated fruits (32.43 gm) after 45 days of the storage period.

Fruit juice weight (gm): As pointed out in Table (2) it was clear that post-harvest treatments with Agar1-3% plus coconut oil and almond oil induced significantly and gradually decrease in juice weight (gm) after 45 days of the storage period compared with untreated fruits in average of two seasons. In this concern, the highest juice weight (38.42 gm) was recorded by fruits coating with Agar1%+ coconut oil. In addition, Agar at 1-3 % + almond oil produced fruits with less juice weight (29.83, 28.65 and 30.85gm) respectively at the end of storage period, compared with untreated (control) fruit which recorded the least juice weight ranged from 52.62 gm at harvest to 26.45 gm after 45 days of storage period.

Fruit juice volume (cm^3): The results in Table (3) show that the juice volume decreases in general during the storage periods in all coating treatments, and the maximum decrease was observed after 45 days compared to zero day. Coating "Wonderful" pomegranate fruits with Agar1-3% plus coconut oil resulted in the best positive effects on juice volume under cold storage compared with almond oil and untreated fruits. Pomegranate fruits "Wonderful" coating by Agar 2 % plus coconut oil achieved the resulted in the best positive effects on juice volume under cold storage compared with almond oil and untreated fruits. Pomegranate fruits "Wonderful" coating by Agar 2 % plus coconut oil achieved the highest juice volume (39.25 cm^3) followed in decreasing order by agar1% + almond oil (25.16 cm^3) comparing with untreated fruits which recorded the least volume (21.96 cm^3).

Table 1
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate arils weight under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Arils weight (gm)	0	77.67 a	77.67 a	77.67 a	77.67 a	77.67 a	77.67 a	77.67 a
	15	70.26 bc	71.35 b	76.53 a	67.51 cd	76.84 a	72.97 b	70.87 b
	30	65.18 de	61.12 fg	60.7 fgh	62.77 ef	59.89 gh	65.59 d	58.11 h
	45	46.1 0 g	44.01 gh	42.43 h	51.33 i	53.74 i	44.19 gh	32. 43 i

Table 2
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate juice weight under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Juice weight (gm)	0	52.62 a	52.62 a	52.62 a	52.62 a	52.62 a	52.62 a	52.62 a
	15	48.87 b	49.18 b	51.17 a	43.78 d	48.59 bc	50.87 ab	46.36 c
	30	36.55 g	46.30 cd	44.21 d	41.18 ef	41.28 e	43.63 de	38.67 f
	45	29.83 h	28.65 hi	30.85 h	38.42 fg	37.11 g	36.45 g	26.45 i

Table 3
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate juice volume under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Juice volume (cm3)	0	49.84 a	49.84 a	49.84 a	49.84 a	49.84 a	49.84 a	49.84 a
	15	42.48 cd	43.74 c	40.35 d	42.48 cd	46.33 b	46.80 b	44.72 bc
	30	36.67 fg	38.61 ef	39.30 e	40.24 de	42.72 c	42.55 c	36.08 g
	45	25. 16 j	26.69 h	25.76 h	37.01 f	39.25 e	38.65 e	21.96 i

Weight loss (%): Data shown in Table (4) indicated that weight loss percentage of "Wonderful" pomegranate fruit increased gradually and significantly with extending cold storage periods. At the end of storage period, control fruits (uncoated) recorded the highest percent of weight loss (42.92 %), while the lowest percent of weight loss recorded by coating fruits with agar 1% + almond oil (32.4%) followed by agar 3% + coconut oil.

Fruit firmness (Ib/inch^2): Fruit firmness is a major attribute that dictates the postharvest life and quality of fruit. Changes in fruit firmness of pomegranate fruits cv. Wonderful varied after cold storage at 5°C due to different edible coating treatments as shown in Table (5). The data illustrated that the pomegranate fruit firmness was decreased gradually and significantly until the end of cold storage period at 5˚C (after 45 days) compared with zero day for all treatments. Untreated fruits were recorded the lowest firmness (6.10 Ib/inch^2) at the end of storage period. Meanwhile, edible coating fruits by 1% agar + almond oil recorded the highest firmness (9.75 Ib/inch^2) followed by 2% agar + almond oil (8.9 Ib/inch^2) or 3% agar + Coconut oil (8.80 Ib/inch^2) without any differences between them.

Table 4
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate weight loss under cold storage in average of 2019 and 2020 seasons

Storage days \ Treatment		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
weight loss (%)	0	0 l	0 l	0 l	0 l	0 l	0 l	0 l
	15	13.63 jk	12.75 k	13.82 jk	14.33 ij	13.59 jk	13.74 jk	15.33 i
	30	23.6 h	14.85 ij	30.90 f	24.85 h	24.52 h	29.45 g	30.25 fg
	45	32.4 e	36.30 c	34.67 d	40.95 b	36.35 c	33.60 de	42.92 a

Table 5
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate firmness under cold storage in average of 2019 and 2020 seasons

Storage days \ Treatment		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Fruits firmness (lb/inch2)	0	18 a	18 a	18 a	18 a	18 a	18 a	18 a
	15	12 b	11.85 b	10.75 bcd	12.00 b	9.45 cde	9.8 b-e	7.75 e-i
	30	10 b-e	11.00 bc	9.35 cde	10.10 bcd	8.50 d-h	9.45 cde	7.00 f-i
	45	9.75 b-e	8.9 c-f	8.60 d-g	6.45 ghi	6.25 hi	8.80 c-f	6.10 i

Fruit chemical characteristics

Impact of edible coating using different concentrations of agar with almond or coconut oil on the chemical characteristics of "Wonderful" pomegranate was evaluated as following:

Soluble solids content (%): Table (6) presented that SSC (%) increased gradually during the storage periods in all treatments. At the end of the storage periods, the differences between coating treatments were significant. Highest SSC percentage recorded by coating fruits with 1% agar + almond oil (18.45%) followed without significance by 3% agar + almond oil (18.15 %). The other treatments did not differ significantly from the control, which recorded the lowest value (17.50 %).

Total acidity (%): The changes in titratable acidity of "Wonderful" pomegranate fruits during cold storage at 5°C subjected to post-harvest coating treatments are presented in Table (7). The results revealed that titratable acidity (%) of treated fruits decreased significantly and gradually until the end of storage period (after 45 days) which recorded the lowest value for each treatment. However, Agar 1-2% + almond oil recorded lower percentages of total acidity after 45 days of storage comparing with the other treatments. While, coating with Agar 3%+ coconut oil recorded the highest percent followed by Agar1%+ coconut oil without significance.

Table 6
Effect of agar coating combined with almond or coconut oils on soluble solid content of "Wonderful" pomegranate under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Soluble solid content (%)	0	13.40 d	13.40 d	13.40 d	13.40 d	13.40 d	13.40 d	13.40 d
	15	16.73 abc	16.15 c	16.80 abc	16.37 bc	17.05 abc	17 abc	16.45 bc
	30	17.30 abc	17.05 abc	17.75 abc	16.95 abc	17.10 abc	17.20 abc	16. 53 bc
	45	18.45 a	17.55 abc	18.15 a	17.03 abc	17.50 abc	17.65 abc	17.50 abc

Table 7
Effect of agar coating combined with almond or coconut oils on "Wonderful" pomegranate total acidity under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Total acidity (%)	0	1.33 a	1.33 a	1.33 a	1.33 a	1.33 a	1.33 a	1.33 a
	15	0.77 b-f	0.96 bcd	1.02 ab	0.93 bcd	0.90 bcd	0.70 c-f	0.90 bcd
	30	0.49 f-i	0.50 f-i	0.99 bc	0.78 b-f	0.83 b-e	0.67 d-g	0.57 e-h
	45	0.25 i	0.22 i	0.38 ghi	0.48 f-i	0.33 hi	0.58 e-h	0.73 b-f

Ascorbic acid content (mg/100g): During storage, ascorbic acid is degraded by oxidation, and this is evident from the results tabulated in Table (8) which revealed that ascorbic acid content decreased gradually with the advance in cold storage period (after 45 days at 5°C). The post-harvest treatment on "Wonderful" pomegranate fruits coating with Agar1-3% plus almond oil resulted in the best positive effects on ascorbic acid content under cold storage compared with coconut oil. The highest value (15.83%) was recorded in fruits coated with 1% agar + almond oil followed by 3% agar + almond oil. On the other hand, the uncoated fruits exhibited the least values (5.67%) at the end of the experiment.

Total antioxidant content (µg/ml juice): It is clear from the results shown in Table (9) that total antioxidant content in fruit juice increased gradually as a result of the extended storage period. After 45 days storage, the maximum value of antioxidant content (212.3 µg/ ml juice) recorded in coated pomegranates by 3% agar + coconut oil, followed by 1 or 2% agar + almond oil (119.6 µg/ ml juice). While the minimum value of antioxidant content recorded by uncoated pomegranates (40 µg/ ml juice).

Pectinase enzyme activity (U/g pulp): Pectinase enzyme activity in "Wonderful" pomegranate fruits after 45 days storage at 5°C under post-harvest coating treatments with 1-3% agar plus coconut oil or almond oil were showed in Table (10). Wonderful pomegranate fruits showed great increase in pectinase enzyme activity which reached to 7.819 and 7.396 U/g pulp after agar 1% + coconut oil and agar 3% + almond oil at 45 days storage at 5°C respectively compared with the initial value of 1.602 l U/g pulp at harvest. Meanwhile, the control fruits showed the highest significant pectinase activity 12.565 U/g pulp compared to other treatments at the end of the cold storage period.

Table 8
Effect of agar coating combined with almond or coconut oils on ascorbic acid content of "Wonderful" pomegranate fruit under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Ascorbic acid content (mg/100g)	0	28 a	28 a	28 a	28 a	28 a	28 a	28 a
	15	24 b	18 cde	26 ab	18 cde	20 c	18 cde	17.33 cde
	30	18 cde	16.33 c-f	19 cd	14.33 efg	16.33 c-f	15.67 def	10.33 h
	45	15.83 def	13 fgh	14.67 efg	11 gh	13 fgh	11.13 gh	5.67 i

Table 9
Effect of agar coating combined with almond or coconut oils on total antioxidant content of "Wonderful" pomegranate under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Total antioxidant content (µg/ml juice)	0	19.8 p	19.8 p	19.8 p	19.8 p	19.8 p	19.8 p	19.8 p
	15	57 k	45.66 l	76.90 h	59.20 jk	61.4 ij	63.40 i	24.10 o
	30	91 f	86.44 g	93.42 f	87.32 g	92.90 f	98.55 e	33.15 n
	45	119.6 c	119.6 c	159.2 b	102.6 d	117.60 c	212.3 a	40 m

Table 10
Effect of agar coating combined with almond or coconut oils on pectinase activity of "Wonderful" pomegranate under cold storage in average of 2019 and 2020 seasons

Treatment / Storage days		Almond oil			Coconut oil			Control
		Agar 1%	Agar 2%	Agar 3%	Agar 1%	Agar 2%	Agar 3%	
Pectinase activity (U/g pulp)	0	1.602 l	1.602 l	1.602 l	1.602 l	1.602 l	1.602 l	1.602 l
	15	2.588 jk	2.075 kl	2.412 k	4.529 gh	3.343 ij	2.789 jk	7.431 c
	30	4.234 gh	3.875 hi	5.434 f	6.245 de	4.823 fg	3.372 ij	9.862 b
	45	6.544 d	5.523 ef	7.396 c	7.819 c	5.543 ef	4.565 gh	12.565 a

4. Discussion

It's clear from the above results that physical or chemical properties of pomegranate fruits cv. Wonderful during cold storage at 5°C had a positive affect by edible coatings with agar and almond or coconut. Edible coatings provide the retention of the nutritional and sensory fruit qualities and a protective potential that prevents microbial decomposition, biochemical and enzymatic spoilage, prevents fruits structural and physical deterioration during post-harvest period [10, 11, 26, 27].

Almond and coconut oils have been used as natural edible coatings for fruits in many studies and the

results show that they impart antimicrobial properties and a moisture barrier to hydrophilic coatings [20, 7], anti-aging by controlling respiration rate, transpiration rate and fruit weight loss which primarily related to evaporation of moisture through the surface of the fruit [28, 29]. Edible coatings reduce water loss from the fruits surface by fills the minute cracks on the pericarp of fruit, closing of stomata and lenticels leading to delay the weight loss phenomenon [30]. Result is in conformity with similar results was reported by Ziedan *et al*. [31] who concluded that the weight loss reduction for fruit coated with agar was probably due to the effect of agar as a barrier against gas exchange (O_2 and CO_2) and water vaporization, so reduces fruits transpiration and respiration. Accordingly, the extended storage life of pomegranate fruits coated with agar colloid could be due to the modification of the internal atmosphere and water loss reduction [32].

Polysaccharides such as agar coatings have a good barrier property against O_2 and odor transfer at medium and low relative humidity. Moreover, it has a poor barrier property against to water vapour transport due to its hydrophilic nature [33]. Therefore, the addition of oils can modify the properties of the coating in order to barrier the water vapour, and this explains the result obtained when using a composite coating of agar with almond or coconut oil in reducing weight loss.

The results are in accordance of those reported with Yaman and Bayoindirli_[34] and Ziedan *et al*. [31], which found that agar application significantly reduced firmness loss of pomegranate fruit, by reduce the porosity of the fruit and decreases the activity of cell wall hydrolases, and thereby, delays fruit ripening and reduces fruit firmness loss.

Soluble solid content (SSC) is a measure of sweetness in fruit, rises steadily as fruit ripens. The high percentage of soluble solid content is due to the breakdown of complex carbohydrates into simple sugars and loss of moisture during storage. Several studies have demonstrated the efficacy of edible coatings in raising soluble solids content in fruit during cold storage [11, 35]. This may be due to the low rate of respiration of the fruits, which subsequently leads to slowing down the metabolic activities such as the hydrolysis of starch. Moreover, the edible coating prevents moisture loss from the fruit which also contributes to the preservation of soluble solids content.

The titratable acidity (TA) is considerable another important characteristic that influences consumer acceptance of taste. The change of TA during storage in pomegranate fruits could be the result from ripening process, as previously reported by Sayyari *et al*. [36], Abd El-Moneim *et al.* [37], Zhang *et al*. [38] that it usually decreases during storage. The decrease in fruit acidity during storage period may be due to the metabolic changes in fruits or due to the use of organic acids in respiratory process [39]. The composite coating formed of Gum and clove oil was effective in decreasing TA during papaya storage reported by Arpit *et al*. [40].

Fruit storage duration is believed to cause a decline in the concentration of ascorbic acid [41]. Pomegranates have low ascorbic acid content compared to many other fruits, ranging from 0.49 to 30 mg 100 g^{-1} of juice [36]. Ascorbic acid is lost due to the activities of phenol oxidase and ascorbic acid oxidase enzymes during storage [37]. The higher levels of ascorbic acid in coated fruits by agar can be attributed to the good barrier properties of agar against O_2, and thus preventing oxidation of ascorbic acid [31]. The same results were obtained by Salehi [42] who noted that almond oil and Arabic gum-based edible coatings as a polysaccharide coating agent resembles agar on delay the oxidation of ascorbic acid during storage as a result of reduced the respiration rate, water loss and less oxygen availability.

Our findings showed that coating pomegranate fruits by agar with almond or coconut oil had a higher antioxidant activity than uncoated fruits. These results in the same line of Synowiec *et al*. [43] in apples, Chauhan *et al*. [44] in grape, Yang *et al.* [45] in blueberry and Mahmoud *et al*. [10] in pomegranate.

The initial increase in enzymatic activity is known to be associated with the sudden release of enzymes accumulated in the vacuoles [46], which occurs during storage as a result of respiration, ethylene production and fruit ripening. The edible coating can reduce the fruits response to environmental conditions by modifying the atmosphere on the fruit surface, thus delaying fruit ripening and reducing water loss, respiration rate, and ethylene production [47]. This may explain the effect of agar as a coating agent in reducing pectinase activity through its role in preventing excess respiration and transpiration. Thus, slow down ripening and reduces enzyme activity in the coated pomegranate.

5. Conclusions

The presented data suggested that physical, chemical properties and pectinase activity of pomegranate fruits cv. Wonderful are affected by edible coating with agar + coconut oil either or almond oil during 45 days storage at 5°C and 85-90% relative humidity compared with the control fruits. Fruits coated with 1% agar plus almond oil showed a least fruit weight loss and highest fruit firmness, TSS%, ascorbic acid and lowest TA%. The highest values of arils weight, juice weight and juice volume were noticed by 1 %

agar plus coconut fruit oil. Coated fruits with agar 3%+ coconut oil were revealed the lowest pectinase activity and highest content of total antioxidant. Therefore, it can be recommended to coating pomegranate fruits cv. Wonderful by using agar with almond oil either or coconut oil to protective coating agent for prolonging post-harvest life and preserve fruit quality properties during cold storage.

6. Conflicts of interest

The authors declare that they have no conflict of interest.

7. Formatting of funding sources

Not applicable.

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