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Impact of Some Fixed and Essential Oils Application on Fruit Quality of Pomegranate During Cold Storage

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Abstract

This study evaluated the effect of some fixed oils (olive and wheat germ) and some essential oils (sage, tea seed and citrus peel) as edible coatings on wonderful pomegranate's shelf life and fruit quality characteristics during 45 days cold storage, maintained at 5°C and 85–90% relative humidity (RH). Over a period of 45 days of storage, fruit properties were measured at regular intervals. The weight, volume, firmness, and weight loss percentage of the fruit; the total weight and volume of the juice; the total soluble solids; the total acidity; the ascorbic acid (Vitamin C); the total anthocyanin; the total sugars; and the total phenols were among them. Applying edible coatings infused with essential oils positively affects each fruit trait. Pomegranate fruits coated with three percent wheat germ oil and then three percent citrus peel oil maintained greater firmness, fruit weight, and juice weight while reducing weight loss. Additionally, it reduced the loss of ascorbic acid, inhibited the breakdown of total acidity, preserved greater values of total soluble solids, decreased total phenols, and maintained higher amounts of anthocyanin content. The results obtained indicate that the application of wheat germ oil at 3 % coating treatment may enhance postharvest storability, prolong the storage time, and keep the nutritional content of these wonderful pomegranate fruits for up to 45 days in cold storage at 5°C and 85–90% relative humidity.

Keywords: pomegranate, olive oil, sage oil, tea oil, wheat germ oil, citrus peel oil, post-harvest quality.

1. Introduction

The pomegranate (*Punica granatum* L.) is a noticeable deciduous tree of the Lythraceae family **[1]**. It grows in many places of the world. It is effectively grown in Egypt on both newly reclaimed and old soils **[2]**. Wonderful, an Egyptian cultivar, is admired for its rich juice and sweet flavor. Pomegranate as "Super Fruits" refers to specific fruits that have remarkable nutritional qualities and health-promoting compounds **[3-5]**.

Prebiotics, anti-inflammatory, anti-aging, antioxidants, and anticancer agents are just a few of the advantageous bioactive substances that pomegranates contain **[6]**. A growing number of people are consuming arils, the edible part, due to their high concentration of minerals, fibres, sugar, pectin, ascorbic acid, ellagic acid, amino acids, anthocyanin, phytoestrogens, and flavonoids **[7]**. Furthermore, the shelf life of arils is restricted because they are easily damaged by nutritional, textural, and weight loss decline **[8]**.

Number of postharvest techniques have been used to preserve aril quality and lengthen shelf life. Furthermore, it's been proposed that improving food presentation and prolonging the shelf life of perishable produce can be achieved more safely by utilizing natural components in edible coating applications **[9]**. By decreasing moisture loss, respiration, gas exchange, and postponing ripening processes such fruit softening, colour changes, loss of organic acids, and starch breakdown into sugars, edible coatings (ECs) of fresh fruits with semipermeable film might increase the fruit's shelf life after harvest. They act as gas or vapour barriers, as well as carriers for active substances such as flavors, colours, antioxidants, and antimicrobials

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[10]. These characteristics improve food quality, boosting their safety and shelf life **[11].**

Essential oils (EO) that come from aromatic plant species are a cheap source of unsaturated fatty acids that have antioxidant and antibacterial qualities that can help with postharvest storage. It has been demonstrated that natural extracts like sage oil **[13]** and citrus **[12]** can postpone microbial activity and lengthen the shelf life of tomatoes and strawberries. Essential oil (EO) can be added to or used in place of edible fruit covering.

Environmental, agronomic, and genetic factors also affect the physicochemical properties of olive oil **[14]**. Glycerides, or free fatty acids, tri-, di-, and monoglycerides, make up the majority of olive oil. The remaining portion is made up of what are known as minor components, which include hydrocarbons, phenols, tocopherols, waxes, pigments (carotenes and chlorophylls), and volatiles **[15]**.

Sage (*Salvia spp*.) is a widely cultivated plant species whose essential oil has been used for postharvest preservation in apricot, nectarine, and plum (EO from *Salvia officinalis* L.) **[16]** as well as in pepper (EO from *Salvia fruticosa* L.) **[17]**.

Tea seed oil is considered edible in several countries **[18, 19]**. It is a natural substance that contains bioactive components not found in olive oil, such as polyphenol, glycoside, and saponin **[20]**. Each plant typically produces about 100 grammes of seeds. Previously, seeds were utilized to create seedlings. However, cuttings are increasingly applied for propagation of plants. Therefore, large number of seeds are provided in tea gardens that are currently unused. If they can be used, they will increase the farmer's income and help to expand and manage the tea garden **[21].**

Wheat germ oil (WGO) is extracted from wheat germ by a milling process, and wheat endosperm contains roughly 10% oil. WGO has numerous uses in the food and cosmetic industries **[22, 23**]. WGO is thought to have medicinal properties, and its protein composition has been observed to be high in amino acids such as methionine, threonine, and lysine **[24].** WGO is a specialized oil that has a rich nutritional component that includes vitamin E. A significant amount of flavonoids, sterols, octacosanols, policosanols, phytosterols, tocopherols, carotenoids, thiamin, riboflavin, glutathione, steryl ferulates, and several enzymes are present in WGO **[25, 26].**

Citrus essential oils (CEOs) have received attention due to their broad-spectrum insecticidal, antibacterial, and antifungal effects, as well as their high yields, smells, and flavors **[27].** CEOs improve the taste properties of fruits while preventing microbial development at low concentrations. Furthermore, CEOs are non-toxic, hypoallergenic, and safe to consume **[28, 29].**

Therefore, the purpose of this study is to assess how various food coatings, such as oils of olive, sage, tea, wheat germ, and citrus peel, affect the wonderful pomegranate's shelf life and fruit quality measurements when stored in the cold.

Materials and Methods

Pomegranate fruits (*Punica granatum* L.) cv. were produced by 8-year-old trees at the National Research Center's experimental station in the Al Nobaria region of Al-Behera governorate, Egypt, during 2021–2022 growing seasons. "Wonderful." pomegranate trees grew similarly and were treated with standard gardening techniques. The fruits were brought in for the lab after being selected on the basis of their size, weight, and maturity as well as the lack of obvious defects. Following their selection, washing, and air drying after that fruits were treated with the following treatments:

1. Olive oil at 3%
2. Sage oil at 3%
3. Tea seed oil at 3%
4. Wheat germ oil at 3%
5. Citrus peel oil at 3%
6. Control (distilled water).

Oils were obtained from Moringa oils Unit, NRC. After dipping fruits for 30sec., fruits were dried out in the air, packed in carton packages, and kept in a cold chamber at 5ºC and 85-90% RH for 45 days. The treated fruits were then compared to the untreated fruits (control). Each treatment had three replicates, each of which contained five fruits. Fruit quality measurements were taken at each sampling date (seven-day sample period) after being stored at 5ºC.

Oils treatment:

Olive, sage, tea, wheat germ, and citrus peel oils, were used in treatments. The necessary amounts of each oil, 2 milliliters per liter, were dissolved in 23 milliliters of 0.05 percent tween-80 and then combined with 975 milliliters of water.

Post harvest measurements

Physical characteristics

Weight loss (%):

Samples of each treatment were weighed at each date, and the equation that follows was used to determine weight loss (%): Fruit weight loss (%) is equal to 100 x [(A-B) /A)]. Where: A= fruit weight at first B= the weight of the fruit on each sample date.

Each replication (5 fruits) had its fruit weight (grammes) and fruit volume (cm^3) assessed at each sampling day.

Fruit firmness (Ib/inch^2)

Utilizing the Lefra Texture Analyser (Mod.TA1000), fruit firmness was assessed. Five fruits from each replicate were tested for firmness, and the results were expressed as Ib/inch^2 **[30]**.

Fruit juice, volume and weight

Fruit juice, volume and weight were evaluated.

Chemical characteristics:

Total soluble solids (TSS %)

A digital pocket refractometer (Model PAL 1, ATAGO TM, Tokyo Tech.) was used to determine the percentage of total soluble solids in fruit juice **[31].**

Total acidity (TA,%): was calculated using Husia's method **[32]** by titrating 5 milliliters of juice with 0.1 N sodium hydroxide and using phenolphthalein as an indicator. The result was expressed as citric acid.

The ascorbic acid content (VC) (mg/100 g. F. W.): was determined by employing the Swain **[33]** technique of 2, 6 dichlorophenol indophenols.

Fruit juice's anthocyanin concentration (mg/100 ml): was measured using a calorimetric method at 535 nm, as per Dubois **[34].**

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

Spectrophotometric analysis was used to determine the total phenolic content at a wavelength of 725 nm using the folin-ciocalteu calorimetric method **[35]**. A reference curve made from p-hydroxyl benzoic acid was used to calculate the amount of phenols in mg per g of fresh weight.

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

To find the total sugars content of juices, the phenol-sulfuric acid method was used **[36].**

Statistical analysis

The study employed a fully randomized blocked design (CRBD). The average of both seasons' worth of data was acquired, collated, and statistically analyzed for analysis of variance using COSTAT. Mphahlele **[37]** states that significant differences between the various treatments were compared using Duncan values at a probability of 0.05. The analysis for the two seasons was combined.

Results

Fruit physical Characteristics

Fruit weight loss (%)

Table (1) displays the average results for both seasons, which indicate that the percentage of fruit weight loss in pomegranate fruits increased with the duration of storage. A weight loss of 6.63% was found after 15 days of cold storage, while 18.84 percent was recorded after 45 days of cold storage. Furthermore, none of the fruits that were treated with various oils or edible coatings lost as much weight as the control treatment, which had the most significant weight reduction percentage (15.56%). In the meantime, 3% of wheat germ oil was the most effective treatment for decreasing the percentage of weight loss (4.47%). The fruit treated with wheat germ oil showed the least amount of fruit weight loss (1.13%) after 15 days of cold storage as compared to the control group (15.34%), as the interaction illustrates.

Fruit weight (gm)

The impact of various oils as edible coatings on the fruit weight of pomegranate cv Wonderful was shown by the results in Table (1). It is evident that the fruit's weight dropped dramatically throughout the storage time. After 45 days of storage, the fruit weight with the lowest value (262.66gm) was recorded. Regarding the effects of various oils as edible coating treatments, it is clear that the application of wheat germ oil at 3% had a favorable impact on fruit weight, as seen by the fruit weight number of 309.16 gm, which was followed by the application of citrus peel oil at 3% (305.54 gm). Citrus peel oil at 3% treatment produced the largest significant fruit weight (290.50 gm) after 45 days of cold storage, indicating a strong interaction between the various fruit edible coating treatments and storage duration, according to the results.

Fruit volume (cm^3)

Table (2) displays the results, which indicate that all fruits coated with oils had a higher fruit volume than the control. Notably, fruits treated with 3% citrus peel oil had the highest significant fruit volume value (408.75 cm^3) when compared to the control fruit, which had the lowest value (351.25 cm^3). However, it is evident that fruit volume decreased noticeably over time as long as the storage duration was extended (341.66 cm^3 after 45 days). Regarding the interaction, it can be shown that fruit treated with citrus peel oil (425 cm^3) produced the highest value of fruit volume, followed by wheat germ oil (410 cm^3).

Fruit firmness (Lb/inch^2)

Different oils used as edible coatings had a significant impact on the firmness of pomegranate fruits. When compared to the uncoated fruits, 45 days of cold storage resulted in the lowest fruit firmness (11.03 Lb/inch^2), according to the combined analysis of both seasons. Table (2)'s results indicate that fruit firmness reduced as storage length rose. Tea oil coating produced the greatest significant firmness value (14.30 Lb/inch^2), followed by oil from citrus peel (14.27 Lb/inch^2). With regard to the interaction, it is evident that, when compared to control fruits, a decrease in fruit firmness was seen with all coating treatments when the storage period was extended.

Table 1: Effect of olive, sage, tea, wheat germ and citrus peel oil solely 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**
Olive oil	0.00s	3.60p	16.73g	21.83c	**10.54c**	323.66a	312.00d	269.16l	253.00o	**289.45d**
Sage oil	0.00s	4.99o	7.31m	18.12f	**7.60d**	323.66a	307.00e	300.00g	265.00m	**298.91c**
Tea oil	0.00s	12.40i	19.66d	25.07b	**14.28b**	323.66a	283.50j	260.00n	242.50p	**277.41e**
Wheat germ oil	0.00s	1.13r	6.38n	10.39j	**4.47f**	323.66a	320.00b	303.00f	290.00i	**309.16a**
Citrus peel oil	0.00s	2.36q	9.78l	10.24k	**5.59e**	323.66a	316.00c	292.00h	290.50i	**305.54b**
Control	0.00s	15.34h	19.51e	27.39a	**15.56a**	323.66a	274.00k	260.50n	235.00q	**273.29f**
M	**0.00d**	**6.63c**	**13.22b**	**18.84a**		**323.66a**	**302.08b**	**280.77c**	**262.66d**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level.

Table 2: Effect of olive, sage, tea, wheat germ and citrus peel oil solely 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**
olive oil	430a	400abcd	380abcd	340e	**387.50c**	16.33a	13.50i	12.56m	10.86q	**13.31f**
Sage oil	430a	390abcd	370bcd	350de	**385.00d**	16.33a	14.90f	13.96g	11.10p	**14.07c**
Tea oil	430a	400abcd	355cde	350de	**383.75e**	16.33a	15.15e	13.30k	12.45n	**14.30a**
Wheat germ oil	430a	410abc	370bcd	350de	**390.00 b**	16.33a	15.85b	12.66l	10.20r	**13.76e**
Citrus peel oil	430a	425ab	400abcd	380abcd	**408.75a**	16.33a	15.80c	13.45j	11.50o	**14.27b**
Control	430a	385abcd	310f	280g	**351.25b**	16.33a	15.63d	13.63h	10.12s	**13.92d**
M	**430a**	**401.66b**	**364.16c**	**341.66d**		**16.33a**	**15.13b**	**13.26c**	**11.03d**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level

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

Juice volume (cm^3) and weight (gm) in comparison to the control (201.66 & 186.00 respectively), the results shown in Table (3) demonstrate a substantial steady drop in both pomegranate juice weight (78.66gm) and volume (86.33cm^3) with expanding storage period till 45 days of cold storage. All coated fruit treatments with oils, however, had a positive impact on the weight and volume of the juice. Citrus peel oil significantly increased the volume of the juice (125.75 cm^3) while wheat germ oil significantly increased the weight of the juice (159.41 gm) when compared to the control (133.66 gm & 122.00 cm^3). In terms of the interaction, it is evident that after 45 days of cold storage, the treatments that were most successful in preserving the weight and volume of fruit juice (103.00gm and 91.00cm^3) were citrus peel oil and wheat germ oil. The control group recorded 88 gm and 83 cm^3, respectively.

Table 3: Effect of olive, sage, tea, wheat germ and citrus peel oil solely 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**
olive oil	201.66a	149.50d	91.00m	76.00p	**129.29e**	186.00a	141.00b	84.30m	71.00o	**120.57c**
Sage oil	201.66a	123.00h	107.00ij	27.00q	**114.66f**	186.00a	110.00e	107.00f	100.00i	**125.75a**
Tea oil	201.66a	139.00e	103.00k	82.00o	**131.41d**	186.00a	125.00c	97.00j	78.00n	**121.50b**
Wheat germ oil	201.66a	180.00b	153.00c	103.00k	**159.41a**	186.00a	103.00g	97.00j	95.00k	**120.25c**
Citrus peel oil	201.66a	134.00g	106.00j	96.00l	**134.41b**	186.00a	125.00	101.00hi	91.00l	**125.75a**
Control	201.66a	137.00f	108.00i	88.00n	**133.66c**	186.00a	117.00d	102.00gh	83.00m	**122.00b**
M	**201.66a**	**143.75b**	**111.16c**	**78.66d**		**186.00a**	**120.16b**	**98.05c**	**86.33d**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level

Fruit Chemical Characteristics

Total Soluble Solid (TSS) (%)

Table 4 showed the effects of various oils as edible coating treatments on Wonderful pomegranate fruits' TSS%. The findings demonstrated that increasing the storage period to 45 days caused the TSS% to significantly increase, as recorded at 19.50% against the control (15.00%). Additionally, TSS% increased upon exposure to all coating treatments; however, the highest significant TSS% (18.37%) was created by sage oil at 3%, and the highest significant TSS% (17.75%) was produced by wheat germ oil at 3%. After 45 days of storage, pomegranate fruits treated with 3% citrus peel oil had the highest significant percentage of TSS (20.75%) when compared to the control, demonstrating the impact of the interaction between the two coating treatments under study and the storage duration.

Titratable Acidity (%)

With an increasing storage period, Table (4) shows a clear decline in total acidity%; after 45 days of cold storage, the lowest meaningful level (0.78%) is obtained. In comparison to the control, which had the highest significant percentage of acidity (1.32%), the pomegranate fruits coated with 3% sage oil had the lowest significant percentage (1.14%). All coated fruit treatments, on the other hand, had the lowest overall acidity percentage. After 45 days of cold storage, coating pomegranate fruits with 3% tea oil resulted in the lowest percentage of total acidity (0.64%) compared to the control (1.15%), suggesting that the coating treatments and storage length interact.

Table 4: Effect of olive, sage, tea, wheat germ and citrus peel oil solely on Total Soluble Solids (TSS %) and total acidity percentage of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	TSS%					Total acidity %				
	0	15	30	45	M	0	15	30	45	M
olive oil	15.00o	17.33j	17.50i	18.00g	**16.95d**	1.74a	1.35 d	1.05g	0.72m	**1.21c**
Sage oil	15.00o	19.00e	19.50c	20.00b	**18.37a**	1.74a	1.31e	0.78k	0.73lm	**1.14f**
Tea oil	15.00o	16.75l	17.50i	18.25f	**16.87e**	1.74a	1.38bc	0.92j	0.64n	**1.17e**
Wheat germ oil	15.00o	16.75l	19.25d	20.00b	**17.75b**	1.74a	1.39b	1.02h	0.74l	**1.22b**
Citrus peel oil	15.00o	15.75n	17.25k	20.75a	**17.18c**	1.74a	1.38bc	0.94i	0.72m	**1.19d**
Control	15.00o	16.65m	17.50i	17.90h	**16.76f**	1.74a	1.37c	1.02h	1.15f	**1.32a**
M	**15.00d**	**17.03c**	**18.08b**	**19.15a**		**1.74a**	**1.36b**	**0.95c**	**0.78d**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level

Ascorbic acid content (vitamin C)

Table (5) results indicated that ascorbic acid concentration dramatically decreased during cold storage, where it scored the lowest after 45 days of storage (30.66 mg/100 g F.W). As can be seen, all coated fruit treatments with oils used in this study (Eos) retained a high vitamin C content. This was particularly the case for pomegranate fruits coated with 3% citrus peel oil, which increased the value of VC by the maximum amount (43.00 mg/100 g F.W) when compared to the control (28.75 mg/100 g F.W). A notable degree of interplay was seen among all the coating applications. In general, coated fruits with 3% citrus peel oil after 45 days of cold storage maintained their high VC content (37.00 mg/100 g F.W) in comparison to the control (20.00 mg/100 g F.W).

Anthocyanin content

Table (5) shows how different oils as coating treatments affect the anthocyanin concentration in pomegranate fruits. The findings indicate that the fruits' overall anthocyanin concentration increased gradually. This increase relates to extending the storage period, as it reached its highest significant level (7.80 mg/100gm F.W) after 45 days. Furthermore, treating pomegranate fruits with 3% tea oil was found to be the most effective coating treatments for boosting total anthocyanin content, with a significant value of 7.20 mg/100gm F.W compared to the control (4.30 mg/100gm F.W). A significant interaction was seen between the cold storage duration and all coating treatments. Fruits coated with 3% tea oil and kept in cold storage for 45 days contained nearly twice as much anthocyanin.

Table 5: Effect of olive, sage, tea, wheat germ and citrus peel oil solely on ascorbic acid content (mg/100 g F.W) and anthocyanin content (mg/100 g F.W) of Wonderful pomegranate fruits (average of both seasons) during the cold storage

Treatments	Ascorbic acid content(mg100 g^{-1} F.W)					Anthocyanin (mg/100gm F.W)				
	0	15	30	45	M	0	15	30	45	M
olive oil	47.00a	40.00de	35.00g	30.00i	**38.00d**	3.20r	3.39q	6.19j	8.26d	**5.26c**
Sage oil	47.00a	44.00bc	43.00c	34.00g	**42.00b**	3.20r	3.39q	6.17k	6.91g	**4.91e**
Tea oil	47.00a	41.00d	39.00e	31.00hi	**39.50c**	3.20r	6.83h	9.32b	9.47a	**7.20a**
Wheat germ oil	47.00a	43.00c	39.00e	32.00h	**40.25c**	3.20r	6.27i	8.18e	9.00c	**6.66b**
Citrus peel oil	47.00a	45.00b	43.00c	37.00f	**43.00a**	3.20r	4.61n	6.10m	7.02f	**5.23d**
Control	47.00a	25.00j	23.00k	20.00l	**28.75e**	3.20r	3.51p	4.34o	6.15l	**4.30f**
M	**47.00a**	**39.66b**	**37.00c**	**30.66d**		**3.2d**	**4.66c**	**6.71b**	**7.80a**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level

Total sugars content (mg/g F.W)

Pomegranate fruits stored for 45 days caused a slow but significant rise in total sugars (12.51 mg/g F.W), as Table (6) demonstrates. Additionally, pomegranate fruits treated with sage oil at 3% showed the highest significant value of total sugars (12.11 mg/g F.W), followed by wheat germ oil at 3% (11.94 mg/g F.W), with significant differences between the two treatments. This was after the fruits were exposed to all of the coating treatments that had been tested. The results indicate that, following 45 days of cold storage, pomegranate fruits coated with 3% wheat germ oil had the highest total sugar content (13.22 mg/g F.W) as compared to the control group (11.17 mg/g F.W), indicating an interaction effect between storage periods and all coated treatments.

Total phenols content (mg/100 g F.W)

As the length of cold storage extended, the results in Table (6) show a gradual decrease in the total phenol concentration. After 45 days, the minimum amount of total phenols was measured (0.316 mg). During cold storage, there were notable variations between all coating treatments and the uncoated one. Of these, coating treatments using 3% citrus peel oil had the lowest total phenol concentration (0.548 mg) as compared to the control (0.317 mg). In terms of the interaction, it was evident that the control had the lowest total phenol concentration (0.104g/100 g F.W) after 45 days of cold storage.

Table 6: Effect of olive, sage, tea, wheat germ and citrus peel oil solely on total sugars (mg/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	Total sugars(mg/ g F.W)					Total phenols (mg/ g F.W)				
	0	15	30	45	M	0	15	30	45	M
olive oil	10.40r	11.27o	11.64j	12.30f	**11.40d**	0.631a	0.510abc	0.312ef	0.300ef	**0.438b**
Sage oil	10.40r	12.12g	12.75d	13.19b	**12.11a**	0.631a	0.527abc	0.400cde	0.332def	**0.472ab**
Tea oil	10.40r	11.29n	11.57k	11.65j	**11.22e**	0.631a	0.515abc	0.324ef	0.316ef	**0.447b**
Wheat germ oil	10.40r	11.52l	12.64e	13.22a	**11.94b**	0.631a	0.531abc	0.509abcd	0.413cde	**0.521ab**
Citrus peel oil	10.40r	10.93p	11.72i	12.81c	**11.46c**	0.631a	0.601ab	0.528abc	0.432bcde	**0.548a**
Control	10.40r	10.89q	11.45m	11.94h	**11.17f**	0.631a	0.327ef	0.206fg	0.104g	**0.317c**
M	**10.40d**	**11.33c**	**11.96b**	**12.51a**		**0.631a**	**0.502b**	**0.380c**	**0.316c**	

Means within a column followed by different letter(s) are statistically different at the 5% significance level

Discussion

Over the past few decades, consumers' desire to stay healthy has increased demand for nutritious fruits and vegetables as well as juices that retain their natural nutritional value. On the other hand, the nutritional makeup and bioactive characteristics of pomegranate fruits and juice are significantly influenced by the following factors: environment, cultivar, maturation stage, extraction technique, and cold storage treatments **[38–40].** Because of their antimicrobial and antifungal activity, essential oils (Eos) have been widely used to preserve food quality and are a preferred option for the food industry. They have also been shown to have antioxidant properties, which have increased the consumer acceptability, stability, and shelf-life of food products and to be able to inhibit the pathogen's mycelia growth and conidial germination **[41]**.

Water fruit content plays an important role in sustaining their quality. As a result, low weight loss is essential for sustaining fruit quality over time. The highest percentage of weight loss is ascribed to elevated respiratory rate and moisture loss. By functioning as a semi-permeable membrane to CO_2 and O_2, edible coatings create a distinct environment around the fruit or vegetable, affecting the rates of respiration and oxidation reactions. Postponed senescence extends the shelf life of fruits **[42–43].**

Fruit physical characteristics

Weight loss percentage

Using the collected data, it was feasible to conclude that pomegranate fruits percentage of weight loss had been decreased by applying 3% of wheat germ oil. By acting as a permeable barrier against moisture, carbon dioxide, and oxygen, oils reduce the pace of oxidation reactions, respiration, and water loss. This can be linked to their ability to control decay and associated harms. Additionally, oils prevented fruit skin damage and delayed dehydration, which prevented the treated fruits from losing weight while being stored.

The advantageous effects of essential oils in reducing weight loss have been documented in numerous studies 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 **[41, 43, 44, 45-53]**. According to these tests, using oils greatly reduced the percentage of weight loss and increased the life storage of fruits.

Fruit firmness

Fruit eating quality and consumer acceptance are largely dependent on the firmness of the fruit's flesh. Fruit ripening causes pectin in the fruit cell wall to break down and starch to be hydrolyzed into sugar, which lowers fruit quality. Preserving fruit firmness is essential to prolonging the shelf life of fresh products. Edible coating did a good job of keeping fruit solid since these coating components slowed metabolism and maintained storage life. Fruit deterioration is prevented by essential oils, which act as a barrier against many bacteria and fungi **[54]**. The pomegranate fruits coated with three percent tea oil had the highest firmness values.

The results reported above are consistent with those on guava, Zagloul date palms, Guava, Barhee date palms, Samany date palms, strawberry fruits, pomegranates, Le Conte pear, plum, and nectarine fruits **[43, 44, 47-51, 53, 55]** because the application of essential oils greatly preserved the firmness of the pomegranate fruits.

Fruit Chemical Characteristics

Total Soluble Solids (TSS %)

An indicator of the nutritional content of harvested fruits is total soluble solids. In comparison to the control, the application of 3% sage oil significantly delayed the breakdown of TSS% and successfully sustained a greater TSS% content during cold storage. Our research indicates that the TSS% of uncoated pomegranate fruits increased significantly, most likely due to fruit water loss and the ripening environment, which broke down complex carbohydrates into simple sugars and raised TSS% **[56].** However, fruit coated with sage oil develops a layer on its surface that inhibits ethylene synthesis, delaying ripening and ultimately the build-up of TSS **[57]**. Furthermore, throughout the ripening phase, a hydrolytic conversion of polysaccharides into soluble sugar occurred, which raised the fruits' TSS **[58].** Our findings are consistent with studies on guava, pomegranates, Ponkan (*Citrus reticulata* Blanco), and Le Conte pear **[43, 44, 46, 51, 52],** where fruits coated with essential oils shown a considerable increase in TSS% during cold storage.

Titratable acidity (%)

It was a naturally occurring phenomena that the titratable acidity naturally dropped during ripening from a very high level at harvest. The lowering of titratable acidity is ascribed to the pomegranate arils' metabolism and respiration, whereby the acidic components interact with a sequence of biological events and transform into other nonacidic compounds. According to previous research, guava, pomegranates, Ponkan (*Citrus reticulata* Blanco), Barhee date palm, and Le Conte pear all saw a steady drop in juice fruit titratable acidity (TA%) during cold storage as a result of the essential oil (Eo) coating treatments **[43, 44, 46, 49, 52, 59].**

Ascorbic acid content

One crucial component of quality is ascorbic acid. Pomegranate fruits gradually lost vitamin C over the duration of storage. Fruits that had not been treated saw the greatest loss of vitamin C. When it came to vitamin C retention, fruits coated in oil performed better because there was less ascorbic acid breakdown during storage. Ascorbic acid's conversion to dehydroascorbic acid after storage was thought to be the cause of the drop in vitamin C level **[60].** Furthermore, the enzymes phenol oxidase and ascorbic acid oxidase cause ascorbic acid to be lost during storage **[61].** Because ascorbic acid oxidase converts ascorbic acid at a slow rate, the treatments ability to retain ascorbic acid may be attributable to their delay of the oxidation process **[56].** Since the control fruits showed the greatest loss of vitamin C, equivalent results have been recorded for guava, Ponkan (*Citrus reticulata* Blanco), pomegranate, and Barhee date palms [44, 46, 49, 59]. Ascorbic acid loss was reduced when fruits were coated with oils.

Anthocyanin content

The primary phenolic ingredient that gives pomegranates their purple-red colour is called anthocyanin. As the storage time progressed, the total anthocyanin content of pomegranate fruits cv. Wonderful increased steadily and significantly. Our findings demonstrated that the edible coating treatments slowed the anthocyanin content's deterioration over time. The simplest explanation is that, in response to alterations in the inner environment of the coated fruits, the edible coatings limit the activity of the enzymes polyphenol oxidase and peroxidase. The breakdown of anthocyanins in litchi fruit was found to be influenced by polyphenol oxidase and peroxidase, although chitosan coating on pomegranates was found to reduce enzyme activity over time **[47].** Our findings demonstrated that pomegranate fruits coated in tea seed oil had an increase in overall anthocyanin content. On pomegranates, similar results were noted **[47, 52, 59].**

Total sugars content

Extending the cold storage duration of Samany date palm fruits led to a rise in the overall sugar content of the fruit. For Samany and Zagloul date palms, the initial readings that is, those taken prior to cold storage, or zero-day storage scored the lowest values in this regard **[48, 50].**

Total Phenol

Phenolic chemicals are essential for removing free radicals and preventing the development of senescence stress **[62]**. By prolonging the storage duration, all coating methods were successful in reducing the phenolic compound. Our findings are consistent with those on pomegranates, Guava, Samany date palm, Ponkan (*Citrus reticulata* Blanco), and Zagloul date palms **[44, 46, 50, 48, 51, 63].**

Conclusions

The study found that using essential oils as an edible covering improved the physical and chemical properties of Wonderful pomegranate fruits during cold storage at 5±1˚C and 85-90% relative humidity. The above results showed that the lowest weight loss, the lowest reduction in fruit weight and volume and juice weight were observed when pomegranate fruits were coated with 3% wheat germ oil followed by citrus peel oil. Additionally, it reduced the loss of ascorbic acid, inhibited the breakdown of total acidity, preserved greater values of total soluble solids, decreased total phenols, and maintained higher amounts of anthocyanin content. The acquired results indicate that Wonderful pomegranate fruits might be kept fresher for up to 45 days at 5°C in cold storage by using essential oils as an edible coating treatment. This would also lengthen the fruit's storage period and preserve its nutritional value.

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