Assiut Journal of Agricultural Sciences 56 (2) 2025 (293-311)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Effect of Natural Coating and Packaging on Storability and Fruit Properties of Manfalouty Pomegranate During Cold Storage

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DOI: 10.21608/AJAS.2025.347843.1447

Abstract

The experiment was carried out in two consecutive seasons in 2022 and 2023 to evaluate the effects of storage, edible coating, glycerol, jojoba oil, and polyethylene (LDPE), aluminum foil packaging, individually or together, and duration during storage at 7°C and 85-90% relative humidity for 0, 20, 40, 60, 80, 100, and 120 days on physical, chemical, and quality properties of pomegranate fruit (cv. Manfalouty).

The results showed that the coated fruits with jojoba oil that were packed in polyethylene bags achieved better results and had a positive effect on prolonging the fruit storage period with good fruit properties compared with the untreated fruits (control). Edible coating with jojoba oil or glycerol and packing in polyethylene bags recorded the least fruit weight loss, fruit decay, and highest fruit firmness and ascorbic acid. These findings show that coating with jojoba oil or glycerol that packed in polyethylene bags enhances the shelf life and maintains the quality of pomegranate fruit. They can also be employed as a chemical-free, environmentally friendly alternative method of preserving the pomegranate fruit's quality after harvest.

Keywords: *Chemical-free, Fruit storage, Jojoba oil, Packaging, Quality.*

Introduction

Assiut Governorate, Upper Egypt Region, has long been the focal point of the Manfalouty pomegranate cultivar's growing area in Egypt, and it is one of the most often grown pomegranate cultivars in this region.

Due to its potential as an export crop in Egypt, pomegranate cultivation has recently expanded on recently restored sandy soils, and some new types have been developed. M.A.L.R. (2022) reported that the pomegranate total area increased to 83268 feddan, and the fruiting area reached 79227 feddan, yielding approximately 995477 tons with an average of 12.57 tons/feddan. According to Abd El-Moneim *et al*. (2019), the pomegranate fruit is regarded as a member of the so-called Super Fruits group, a phrase used to highlight the exceptional nutritional properties and health-promoting phytochemicals of particular fruits. According to Aboryia and Omar (2020), pomegranates are a significant source of a number of bioactive chemicals that have anti-inflammatory, anti-aging, antioxidant, prebiotic, and anticancer activities. Because of its high quantity of sugar, pectin, ascorbic acid, ellagic acid, amino acids, minerals, fibers, anthocyanin, phytoestrogens, and flavonoids, arils the edible part have become more

Received: 29 December 2024/ Accepted: 1 March 2025/ Published online: 13 April 2025

and more popular (Emam *et al.,* 2022). Arils' shelf life is shortened by their susceptibility to weight loss, textural deterioration, and nutritional deterioration (Abd El-Moneim *et al*., 2019). Edible coatings are an innovative approach to increase fruit quality by reducing post-harvest microbial losses and are one of the most widely used post-harvest technologies for extending fruit life. Furthermore, fruit's fresh appearance and nutritional makeup are impacted by coating materials (ÖZ and Eker, 2017). Edible coatings have two key benefits: they improve food safety and health and can cut down on waste from synthetic packaging while still adhering to environmental regulations (Kamboj and Kaur, 2018). Indeed, it is essential to investigate non-toxic means of controlling post-harvest diseases, especially those with low residues, good efficiency, and little to no toxicity to species other than the intended target (Abou-Zaid *et al*., 2024). As natural ingredients in edible coverings for whole and fresh-cut fruit, essential oils have gained attention as research topics (Ju *et al*. 2019). Applying the plant with Eos enables postharvest fruit preservation and plant disease management. Furthermore, Eos enhances the quality of the fruit rather than endangering human health (Abou-Zaid *et al*., 2024; Sanchez-Tamayo *et al.,* 2024). Plant extracts or essential oils can effectively prevent a variety of plant diseases, particularly postharvest infections (Hosseni *et al.,* 2020 and Liguori *et al.,* 2024).

Unsaturated fatty acids and straight-chain monoesters of alcohols in the Cl8–C24 range make up the majority of jojoba (*Simmodsia chinensis*) oil, which is almost colorless and odorless. It may be seen as a possible low energy alternative to traditional oils because human lipase enzymes are unable to digest it. It showed excellent resistance to rancidity and good oxidative stability at temperatures as high as 110˚C. It is extensively used in cosmetic and medical purposes. Additionally, it has antibacterial, anti-parasitic, and anti-inflammatory qualities. Because of its peculiar physical and chemical properties as well as its lack of flavor and color, it is commonly referred to as liquid wax. Jojoba oil can also be easily hydrogenated to produce soft wax that can be used as candle wax, in various polishes, and as a covering for pills and fruits (Jongjareonrak *et al*., 2006). According to Al-Reza *et al*. (2010), jojoba oil and essential oil can be used as natural food preservatives to stop food from spoiling and food-borne illnesses brought on by known causal agents. Applying jojoba oil to Washington navel orange fruits reduced fruit degradation and weight loss, as shown by Abd El Moneim and Abd El Mageed (2006). Applying jojoba oil to Costata persimmon fruits postponed ripening and reduced the percentage of decay and weight loss, according to Abd Allah *et al*. (2012).

Glycerol coating helped to extend the shelf life of harvested fruits by reducing weight loss caused by the natural migration of gases and moisture. One of cutin's primary precursors, glycerol, can bind cutin monomers' hydroxy fatty acids via an esterification reaction. It is widely utilized in a variety of industries, including food, syrups, pharmaceuticals, and cosmetics, because of its non-toxic qualities. Glycerol is also used as a softening agent in baked goods and confections, and as a plasticizer to create edible films when combined with starch or water-soluble fish protein (Sanchez-Tamayo *et al*., 2024). Additionally, using glycerol spray to citrus fruit can lessen peel damage and trigger oxidative stress-related defense mechanisms (Romero and Lafuente, 2022). Furthermore, research has demonstrated that glycerol possesses a wide range of

antimicrobial properties (Schlievert and Peterson, 2012). Few studies have examined the potential effects of exogenous glycerol on the cuticle and postharvest storability of citrus fruit, despite its significance as a component of fruit cuticle.

In order to ensure the safe handling and delivery of both fresh and processed agricultural products from producer to consumer, packaging is an essential part of food processing (Opara and Mditshwa, 2013). The application of plastic materials for food storage is endless, depending on their tensile strength, rigidity, temperature, water barrier, vapor, and moisture qualities. The usage of polyethylene bags reduced the EO percentage of Mentha spicata L. the least, followed by kraft paper bags, polypropylene bags, and linen bags, according to Abd El-Aleem and Hamed (2018). According to reports, the polyethylene bag fared better than every other package that was assessed in terms of preserving the product's quality.

One of the most popular and reasonably priced packaging materials is aluminum ziplock bags. The various material compositions that make up these packing materials guarantee that the goods inside remain hygienic and fresh. Depending on the storage environment, they have an 18–24 month shelf life. Polyethylene (PE), the first layer (external layer) of an aluminum foil bag, provides mechanical strength against a range of temperatures. Aluminum foil made up the majority of the second layer. According to TED, Packaging Bags and Pouches (2024), it protects the contents within the aluminum foil bags from moisture and other harmful substances. In contrast, the third layer is made of low-density polyethylene.

Therefore, the aim of this investigation was to study the effect of some postharvest treatments including coating with glycerol, jojoba oil and polyethylene (LDPE), aluminum foil packaging on the quality and storability of Manfalouty pomegranate cultivar under cold storage.

Materials and Methods

This study was conducted on Manfalouty Pomegranate fruits which were harvested from experimental orchard of the private farm for Badari Assiut during two successive seasons of 2022 and 2023. Fruits were meticulously gathered at the right maturity stage. They were disease, insect, defect, and mechanical damage free and in good health. Fruits were gathered by hand and positioned in the orchard’s shade. After a day, sorting was done to remove any fruits that were cracked, bruised, or sick. On the second day, over 540 healthy fruits were delivered to the Department of Pomology Agriculture lab. All fruits were first cleaned, weighted, and cleaned with tap water before being allowed to dry air. For treatments, the fruits were split into nine equal groups as follows:

1-Control T1

2-Coating fruits with jojoba oil 10 % T2

3-Coating fruits with glycerol T3

4-Packaging fruits with polyethylene (LDPE) bags T4

5-Packaging fruits with Aluminum foil T5

6-Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags T6

7-Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil T7

8-Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags T8

9-Coating fruits with glycerol + packaging fruits with Aluminum foil T9

Each treatment consisted of three replicates. Fruits were stored in a refrigerator at (7 °C) with R.H 85-90 %. Two fruits per replication from each treatment (total sixteen fruits from each treatment) were selected for decay percentage determination and weight loss percentage. Fruits were exposed to quality evaluation at 0, 20, 40, 60, 80, 100, and 120 days of storage as P1, P2, P3, P4, P5, P6 and P7, respectively. The fruits quality was evaluated by studying the changes in some physical and chemical characteristics.

Measurements

A. Storability Measurements

1. Percentage of Fruit Weight loss

The physiological loss in weight of fruits was recorded by using an electronic balance. Pomegranate fruits were weighed at the beginning of the storage period (initial weight). Initial weight was compared with the weight at the specified time of sampling. Weight loss was expressed as percentage using the following equation:

$$\textbf{Fruit weight loss \%} = \frac{\text{Initial weight (g)- Weight at the time of sampling (g)}}{\text{Initial weight (g)}} \times 100$$

2. Percentage of Fruit Decay

Fruits appearing any visible decay were counted and calculated according to the following equation as percentage:

$$\textbf{Fruit decay \%} = \frac{\text{Total number of decayed fruits}}{\text{Total number of initial stored fruits}} \times 100$$

3. Fruit firmness.

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 each equator.

B. Chemical Characteristics

1. Total Soluble Solids percentage (TSS %) in extracted juice from arils were measured by a hand refract meter.
2. Titratable acidity (%) was identified by direct titration of sodium hydroxide 0.1 N utilizing phenolphthalein 1% as an indicator and was expressed as citric acid percentage (A.O.A.C. 2005).
3. Vitamin C: By titrating against 2,6-dichlorophenol-indophenol, vitamin C was measured as mg/L ascorbic acid/100 mL of juice (A.O.A.C., 2005).
4. Total anthocyanin analysis was performed in accordance with Onayemi *et al*. (2006).

Statistical analysis

The experiment includes two factors arranged in a split-plot design with three replicates. Periods of storage assigned in the main plot and studied treatments were considered as the sup-plot. The obtained data were statistically analyzed according to Snedecor and Cochran (1990) by using Statistix 8.1 software Analytical Software (2005) using L.S.D test at 5% of probability to evaluate the significant difference among various treatment means.

Results

1. Effect of jojoba oil, glycerol and packaging fruits with polyethylene and Aluminum foil on Storability traits

- **The percentage of fruit weight loss and fruits decay**

The edible coating packed in polyethylene (LDPE) bags with jojoba oil and its effects on the percentage of weight loss and fruit decay of "Manfalouty" pomegranates during cold storage in the 2021 and 2022 seasons were displayed in Figures 1 and 2. It was clear that during the two seasons under study, the outcomes followed a similar pattern. Current data shows that as the cold storage duration lengthened, there was a noticeable increase in both fruit weight loss and fruit decay % from the start of cold storage to the 60-day, these characteristics increased marginally over time, then quickly until the 120-day. During storage, weight loss reaches values of when compared to control (untreated fruits), which had the highest weight loss values (27.66 % and 25.12 %) after 120 days during the 2022 and 2023 seasons, respectively.

Data in the current figures clearly show that the percentage of weight loss markedly increased with the advance of the cold storage period. These traits were slightly increased gradually from the beginning of cold storage until the 40 days, then a rapid increase until the 120 days. The percentage of weight loss and fruit increase during storage, reaching values of (72.67and 25.12%) after 120 days during the two studied seasons, respectively. Also, data showed that there was no decay until 40 days and then markedly increased with the advance of the cold storage period that recorded (10.21 and 9.35%) after 120 days during the two studied seasons, respectively.

In response to coating types, it was apparent that all coating treatments significantly decreased the percentage of weight loss and fruit decay during cold storage compared with control. Coating jojoba oil, glycerol and packing polyethylene (LDPE), the best results, which gave the least percentage of weight loss (12.97 and 9.55%) and fruit decay percentage of (2.70 and 3.44%). These results show that coating the fruit with jojoba oil and packed in polyethylene causes a decrease in the percentage of weight loss about (27 to 41%) and fruit decay percentage about (30 to 42%) compared to untreated. No significant differences in percentage of weight loss and fruit decay as a result of using edible coating glycerol, jojoba oil and polyethylene (LDPE), aluminum foil packaging individually during the two study seasons, respectively.

The fruit decay % was (4.67, 3.58, 3.63, 4.73, 3.11, 2.70, 2.85, 3.48 and 3.48%) and (4.76, 3.64, 3.29, 3.40, 3.60, 3.44, 1.86, 2.90 and 3.17%) due to use control (T1), polyethylene packaging (T2), Al-foil packaging (T3), coating jojoba oil (T4), coating glycerol (T5), jojoba + pol (T6), glycerin + pol (T7), jojoba + aluminum foil packaging

(T8) and glycerol + aluminum (T9) during the studied seasons, respectively. Data also cleared that, there was a significant interaction among treatments and storage periods for the percentage of weight loss and fruit decay of pomegranate fruits in both seasons the decay was attained (13.33, 11.1, 12.10, 11.10, 7.78, 7.78, 8.87, 9.89 and 9.90%) and (13.33, 9.71, 10.18, 9.45, 9.45, 9.86, 5.93, 7.42 and 8.81%) as well as , weight loss % (31.85, 27.22, 27.82, 28.65, 25.46, 25.79, 27,33 and 26.84%) and (29.72, 24.18, 25.64, 25.86, 23.81, 24.68, 23.80 and 22.40%) due to T1 to T9 during the two studied seasons, respectively. No significant differences in percentage of weight loss and fruit decay due to the use coating jojoba oil, glycerol and packing polyethylene (LDPE) during the two studied seasons.

The variation in increasing percentage of weight loss and fruit decay depends on the coating type used where the use of coating jojoba oil, glycerol and packing polyethylene (LDPE) gave the least percentage of weight loss and fruit decay compared to the other treatments. The results indicated that using coating treatments proved effective in increasing the percentage of weight loss and fruit decay hence, keeping the pomegranate fruits for a long period with the best fruit quality and appearance.

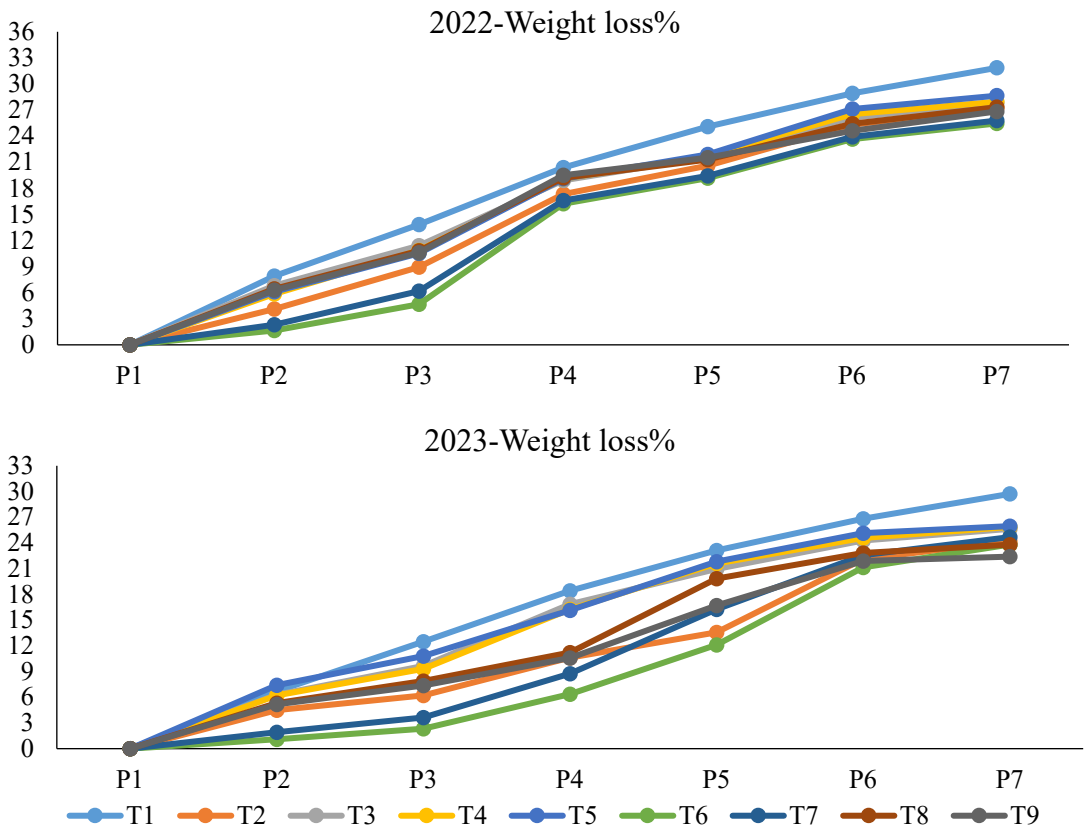

Fig 1. Effect of coating with some essential oils and packaging on weight loss% of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons. T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

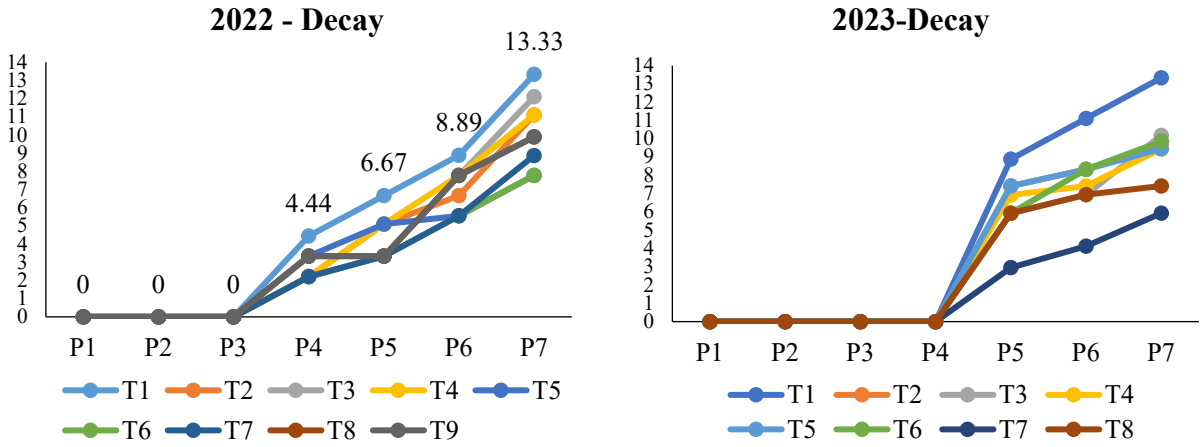

Fig 2. Effect of coating with some essential oils and packaging on decay % of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons. T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

- **The firmness percentage**

Information displayed in Tables 1 demonstrated the impact of consequences of the coatings, either separately or in combination, of glycerol, jojoba oil, polyethylene (LDPE), and aluminum foil packaging on firmness. This characteristics of the "Manfalouty" pomegranate was evaluated during cold storage in the 2022 and 2023 seasons. It was obvious that results took a similar trend during the two studied seasons. Data in the current tables clearly shows that the firmness percentage markedly decreased with the advance of the cold storage period. This trait was slightly decreased gradually from the beginning of cold storage till the 60 days, then a rapid decrease until the 120 days. The firmness decreases during storage, reaching values of (8.34 and 10.81IB/Inch) after120 days during the two studied seasons, respectively.

In response to coating types, it was apparent that all coating treatments significantly increased the firmness during cold storage compared with control. Coating jojoba oil or glycerol that packing polyethylene (LDPE) had the best results, which gave the highest firmness percentage of (14.45 and 16.09%) and (14.45, 16.11%) during the two studied seasons, respectively. The fruit firmness was (11.73, 14.18, 13.36, 13.67, 12.92, 14.45, 14.45, 13.89 and 13.62%) and (13.02, 15.84, 14.92, 15.32, 14.52, 16.08, 16.11, 15.65 and 15.43%) due to use T1 to T9 during the two studied seasons, respectively. These results show that coat jojoba oil and packed in polyethylene causes an increase the firmness percentage about (22 to 24%) compared to untreated. No significant differences in firmness as a result of using edible coating glycerol, jojoba oil and polyethylene (LDPE), aluminum foil packaging individually during the two study seasons, respectively.

Table 1. Effect of coating with some essential oils and packaging on firmness (IB/insh) of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons

Treatment	2022- firmness (IB/inch)							
	Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	18.51	15.84	12.85	10	9.65	8.34	6.68	11.73 B
T2	18.51	17.63	15.67	14	13.4	11.18	8.46	14.18 A
T3	18.51	16.39	14.38	13	12.4	10.56	8.19	13.36 A
T4	18.51	16.92	14.86	14	12.8	10.81	8.23	13.67 A
T5	18.51	15.62	14.68	13	11.8	10.28	8.06	13.91 A
T6	18.51	17.84	15.93	15	13.7	11.35	9.26	14.45 A
T7	18.51	17.99	15.84	14	13.8	11.42	9.15	14.45 A
T8	18.51	17.21	14.96	14	13	11.16	8.62	13.89 A
T9	18.51	16.8	14.63	13	12.7	10.96	8.44	13.62 A
Mean	18.51 A	16.92 B	14.87 C	13.44 D	12.58 D	10.67 E	8.34 F	
LSD.05	A: 1.21 B: 1.33 AB: 3.54							
Treatment	2023-firmness (IB/insh)							
	Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	20.08	17.22	14.1	11.2	10.7	9.34	8.54	13.02 B
T2	20.08	19.41	16.9	15.8	15	12.55	11.18	15.84 B
T3	20.08	17.86	15.86	14.4	13.8	11.88	10.58	14.92 A
T4	20.08	18.58	16.43	15.1	14.2	12.11	10.66	15.32 A
T5	20.08	17.31	15.18	13.9	13.2	11.58	10.5	14.52 A
T6	20.08	19.49	17.55	16.2	15.2	12.79	11.31	16.08 A
T7	20.08	19.68	17.61	16.1	15.4	12.89	11	16.11 A
T8	20.08	19.11	16.55	15.3	14.5	12.56	11.46	15.65 A
T9	20.08	18.48	16.22	14.7	14.1	12.25	12.11	15.43 A
Mean	20.08 A	18.57 B	16.27 C	14.74 D	14.01 D	11.99 E	10.81 E	
LSD.05	A: 1.46 B: 1.60 AB: 4.23							

T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

Data also cleared that there was a significant interaction among treatments and storage periods for the firmness of pomegranate fruits in both seasons the firmness was attained (6.68, 8.46, 8.19, 8.23, 8.06, 9.26, 9.15, 8.62, and 8.44 %) and (8.54, 11.18, 10.58, 10.66, 10.5, 11.31, 11, 11.46 and12.11%) during the two studied seasons, respectively.

No significant differences in firmness due to the use coating jojoba oil or glycerol and packing polyethylene (LDPE) during the two studied seasons. The variation in reduction of firmness depends on the coating type used where the use of coating jojoba oil or glycerol and packing polyethylene (LDPE) gave the highest firmness compared to the other treatments. The results indicated that using coating treatments proved effective increasing the firmness during storage hence, keeping the pomegranate fruits for a long period with the best fruit quality and appearance.

Fruits treated with jojoba oil maintained higher firmness levels throughout the storage period compared to untreated fruits. The firmness measurements indicated that treated fruits had an average firmness of approximately 14.18 lb/in², while controls averaged around 11.73 lb/in². This suggests that the coating helps preserve the structural integrity of the fruit during storage.

2. Fruit quality

- Total Soluble Solids percentage and Juice anthocyanin contents

According to the data in Tables 2 and 3 showed that the percentage of total soluble solids and anthocyanin contents in fruit juice increased consistently when the storage period was extended. TSS was significantly increased and attained (15.3, 15.3, 15.5, 15.8, 16.2, 16.5 and 17.0 %) and (16.2, 16.3, 16.3, 16.5, 16.7, 16.9 and 17.3%) as well as anthocyanin contents (53.18, 55.54, 59.71, 63.31, 66.68, 69.68 and 72.63) and (58.11, 60.85, 63.04, 64.76, 66.51, 68.12 and 70.38 mg/100g) due to storage for 0, 20, 40, 60, 80, 100, 120 days during the two studied seasons, respectively.

Table 2. Effect of coating with some essential oils and packaging on TSS % of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons.

Treatment	2022-TSS% Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	15.3	15.7	16	17	17.3	17.5	18.5	16.7 A
T2	15.3	15.4	15.5	16	16.2	16.3	17.1	15.9 B
T3	15.3	15.2	15.5	16	16.2	16.4	17.2	15.9 B
T4	15.3	15.4	15.6	16	16.3	16.6	16.9	16.0 B
T5	15.3	15.3	15.5	16	16.1	16.4	16.8	15.9 B
T6	15.3	15.2	15.2	15	16.1	16.4	16.4	15.7 B
T7	15.3	15.2	15.4	16	15.8	16.1	16.4	15.7 B
T8	15.3	15.2	15.4	16	15.9	16.5	16.8	15.8 B
T9	15.3	15.4	15.4	16	16.1	16.3	16.6	15.8 B
mean	15.3 C	15.3 C	15.5 C	15.8 B	16.2 B	16.5 A	17.0 A	
LSD.05	A: 0.63 B: 0.76 AB: 2.00							
Treatment	2023-TSS% Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	16	16.6	17.1	17.5	17.9	18.4	19.1	17.5 A
T2	15	16.3	16.3	16.5	16.8	16.9	17.2	16.6 B
T3	16	16.3	16.4	16.5	16.6	16.8	17.3	16.5 B
T4	16	16.1	16.1	16.4	16.7	16.9	17.3	16.5 B
T5	16	16.2	16.3	16.5	16.7	17	17.4	16.6 B
T6	16	16.3	16.3	16.4	16.6	16.8	16.9	16.5 B
T7	16	16.3	16.3	16.5	16.7	16.8	16.8	16.5 B
T8	16	16.1	16.2	16.2	16.3	16.6	16.8	16.3 B
T9	16	16.2	16.3	16.4	16.6	16.6	16.8	16.4 B
Mean	16.0 B	16.3 B	16.3 B	16.5 B	16.7 A	16.9 A	17.3 A	
LSD.05	A: 0.64 B: 0.80 AB: 2.11							

T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

Table 3. Effect of coating with some essential oils and packaging on Juice total content anthocyanin(mg/100g) of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons

Treatment	2022-Juice total content anthocyanin (mg/100g)							
	Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	53.18	56.88	61.52	67.93	72.38	75.53	78.86	66.61 A
T2	53.18	55.18	59.4	61.48	66.54	70.28	71.69	62.54 B
T3	53.18	55.86	60.18	64.55	65.83	69.73	72.45	63.11 B
T4	53.18	56.40	60	62.63	64.76	68.31	70.65	62.28 B
T5	53.18	55.21	60.28	63.11	65.4	69.45	71.29	62.56 B
T6	53.18	54.15	61.11	65.28	68.19	70.44	72.18	63.50 B
T7	53.18	54.81	56.38	60.1	63.78	66.4	70.66	60.76 B
T8	53.18	55.38	58.9	62.43	66.65	68.35	72.73	62.52 B
T9	53.18	55.95	59.63	62.24	66.6	68.63	73.18	62.77 B
mean	53.18 F	55.54 F	59.71 E	63.31 D	66.68 C	69.68 B	72.63 A	
LSD.05	A: 2.53 B: 2.98 AB: 7.91							
Treatment	2023-Juice total content anthocyanin (mg/100g)							
	Days of cold storage							
	P1	P2	P3	P4	P5	P6	P7	Mean
T1	58.11	63.71	66.91	70.83	72.34	75.36	79.65	69.56 A
T2	58.11	59.52	62.33	63.35	64.1	65.18	68.48	63.01 B
T3	58.11	60.10	62.89	63.85	66.55	68.84	71.74	64.58 B
T4	58.11	60.83	63.25	64.11	67.16	68.78	69.96	64.60 B
T5	58.11	61.14	62.69	64.38	66.23	67.29	68.39	64.03 B
T6	58.11	62.48	63.88	64.35	66.5	67.3	69.64	64.61 B
T7	58.11	60.88	61.9	63.64	65.16	66.99	69.18	63.69 B
T8	58.11	59.19	61.38	64.22	65.5	67.25	68.99	63.52 B
T9	58.11	59.80	62.16	64.11	65.1	66.13	67.38	63.26 B
Mean	58.11 D	60.85 C	63.04 C	64.76 B	66.52 B	68.12 A	70.38 A	
LSD.05	A: 2.77 B: 3.31 AB: 8.74							

T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil, T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

In response to coating and packaging, it was apparent that all coating and packaging treatments significantly decreased the TSS and anthocyanin contents during cold storage compared with control. Using coating jojoba oil or glycerol and packing polyethylene (LDPE), gave the best results, which gave the least percentage of TSS (15.7 and 15.7%) and (16.47 and 16.49%) during the two studied seasons, respectively. In addition, the obtained results at the end of storage period, it was noticed significant effect of interaction between tested treatments and storage periods. The total soluble solids and anthocyanin contents were higher in untreated fruits, with averages reaching up to (18.5 and 18.8%) and (78.86 and 79.65 mg/100g) indicating the TSS and anthocyanin contents that retention compared to control fruits. These results show that coating jojoba oil and packed in polyethylene causes a decrease in the TSS about (11.35 to 11.52%) and anthocyanin contents of about (8.5 to 12.5%) compared to untreated. The results indicated that using coating treatments proved effective in reducing the TTS

and anthocyanin contents, hence, keeping the pomegranate fruits for a long period with the best fruit quality and appearance.

- **Juice Vitamin C and acidity**

Data presented in Tables 4 and 5 demonstrated the impact of the consequences of the coatings, either separately or in combination, of glycerol, jojoba oil, polyethylene (LDPE), and aluminum foil packaging on Juice Vitamin C and acidity. The following characteristics of the "Manfalouty" pomegranates were evaluated during cold storage in the 2022 and 2023 seasons. It was obvious that results took a similar trend during the two studied seasons.

Table 4. Effect of coating with some essential oils and packaging on V.C % of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons.

Treatment	2022-V.C mg/100ml Days of cold storage							
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**Mean**
T1	22.43	21.18	19.69	19	17.8	16.99	15.81	18.93 B
T2	22.43	21.89	21.11	20	19.3	18.52	17.32	20.11 A
T3	22.43	21.76	20.9	20	19.1	18.31	17.1	19.93 A
T4	22.43	21.55	20.83	20	19.0	18.32	17.25	19.89 A
T5	22.43	21.65	20.96	20	19.1	18.25	17.1	19.92 A
T6	22.43	21.48	21.00	20	19.2	18.45	17.25	20.00 A
T7	22.43	21.8	21.05	20	19.2	18.32	17.31	20.04 A
T8	22.43	21.91	21.13	20	19.3	18.38	17.36	20.11 A
T9	22.43	21.63	20.89	20	19	18.25	17.14	19.89 A
Mean	22.43 A	21.65 A	20.84 B	19.80 C	19.00 C	18.18 D	17.05 E	
LSD.05	A: 0.83 B: 0.99 AB: 2.61							
Treatment	**2023-V.C mg/100ml Days of cold storage**							
	P1	P2	P3	P4	P5	P6	P7	mean
T1	24.17	22.71	20.85	19.6	18.8	17.03	15.68	19.83 B
T2	24.17	23.51	21.86	20.8	20.2	18.81	17.41	20.97 A
T3	24.17	23.45	21.81	20.6	19.9	18.58	17.28	20.84 A
T4	24.17	23.31	21.68	20.4	19.8	18.46	17.16	20.73 A
T5	24.17	23.45	21.88	20.6	20.0	18.61	17.25	20.87 A
T6	24.17	23.28	21.45	20.2	19.7	18.35	17.1	20.62 A
T7	24.17	23.19	21.58	20.1	19.5	18.25	16.89	20.55 A
T8	24.17	23.39	21.85	20.3	19.7	18.36	16.98	20.69 A
T9	24.17	23.11	21.63	20.2	19.3	18.77	17.31	20.66 A
Mean	24.17 A	23.28 A	21.63 B	20.32 C	19.66 C	18.38 D	17.01 E	
LSD.05	A: 0.90 B: 1.07 AB: 2.83							

T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

Data in the tables clearly show that the Juice Vitamin C and acidity percentage markedly decreased with the advance of the cold storage period. These traits were

slightly decreased gradually from the beginning of cold storage till the 40 days, then a rapid decrease until the 120 days. The Juice Vitamin C and acidity decrease during storage, reaching values of (17.05and 17.01 mg/100ml) and (0.89 and 0.84%) after120 days during the two studied seasons, respectively.

Table 5. Effect of coating with some essential oils and packaging on Acidity % of "Manfaluty" pomegranate fruits under cold storage during 2022 and 2023 seasons.

Treatment	2022-Acidity %							
	Days of cold storage							
	0	20 d	40 d	60 d	80 d	100 d	120 d	mean
T1	1.18	1.07	0.97	0.91	0.86	0.83	0.78	0.94 B
T2	1.18	1.14	1.07	1.04	1.00	0.98	0.96	1.05 A
T3	1.18	1.14	1.05	1.03	0.99	0.94	0.93	1.04 A
T4	1.18	1.10	1.05	1.03	0.98	0.95	0.93	1.03 A
T5	1.18	1.10	1.05	1.01	0.98	0.95	0.95	1.03 A
T6	1.18	1.15	1.09	1.05	1.00	0.96	0.92	1.05 A
T7	1.18	1.15	1.10	0.98	0.94	0.90	0.87	1.02 A
T8	1.18	1.14	1.10	1.04	0.98	0.91	0.87	1.03 A
T9	1.18	1.11	1.09	1.01	0.98	0.93	0.88	1.03 A
mean	1.18 A	1.12 A	1.06 B	1.01 B	0.97 C	0.93 C	0.90 C	
LSD.05	A: 0.07 B: 0.08 AB: 0.22							
Treatment	**2023-Acidity %**							
	Days of cold storage							
	0	20 d	40 d	60 d	80 d	100 d	120 d	Mean
T1	1.24	1.11	0.97	0.9	0.82	0.74	0.68	0.92 B
T2	1.24	1.16	1.1	1.03	0.98	0.91	0.86	1.04 A
T3	1.24	1.17	1.1	1.04	0.98	0.92	0.88	1.05 A
T4	1.24	1.17	1.1	1.03	0.98	0.92	0.88	1.05 A
T5	1.24	1.16	1.08	1.01	0.95	0.89	0.85	1.03 A
T6	1.24	1.18	1.1	1.02	0.95	0.89	0.85	1.03 A
T7	1.24	1.20	1.12	1.05	0.98	0.92	0.89	1.06 A
T8	1.24	1.16	1.06	1	0.95	0.88	0.83	1.02 A
T9	1.24	1.17	1.06	0.99	0.93	0.88	0.84	1.02 A
Mean	1.24 A	1.16 A	1.08 B	1.01 B	0.95 C	0.88 C	0.84 D	
LSD.05	A: 0.08 B: 0.10 AB: 0.27							

T1:Control , T2: Packaging fruits with polyethylene (LDPE) bags, T3: Packaging fruits with Aluminum foil T4: Coating fruits with jojoba oil 10 %, T5: Coating fruits with glycerol, , T6: Coating fruits with jojoba oil 10 % + packaging fruits with polyethylene (LDPE) bags, T7: Coating fruits with jojoba oil 10 %+ packaging fruits with Aluminum foil, T8: Coating fruits with glycerol + packaging fruits with polyethylene (LDPE) bags, T9: Coating fruits with glycerol + packaging fruits with Aluminum foil. P1, P2, P3, P4, P5, P6 and P7 are the storage periods as 0, 20, 40, 60, 80, 100, and 120 days, respectively.

In response to coating types, it was apparent that all coating treatments significantly increased the juice vitamin C and acidity during cold storage compared with control. Coating jojoba oil or glycerol that packing polyethylene (LDPE) had the best results, which gave the highest Juice Vitamin C and acidity percentage that (17.25 and 17.31%) and (17.10, 16.89 mg/100ml) and (0.92 and 0.87) and (0.85 and 0.89%) during the two studied seasons, respectively. These results show that coat jojoba oil and packed in polyethylene causes an increase the Vitamin C about (9%) and acidity about (17.9 to 25.0%) compared to untreated. No significant differences in Juice Vitamin C and acidity as a result of using edible coating glycerol, jojoba oil and polyethylene

(LDPE), aluminum foil packaging individually during the two study seasons, respectively.

Vitamin C was (18.39, 20.11, 19.93, 19.82, 19.92, 20.00, 20.04, 20.11 and 19.89) and (19.83, 20.97, 20.84, 20.73, 20.87, 20.61, 20.54, 20.69 and 20.66 mg/100ml) as well as (0.94, 1.05, 1.04, 1.03, 1.03, 1.05, 1.02, 1.03 and 1.03) and (0.92, 1.04, 1.05, 1.05, 1.03, 1.03, 1.06, 1.02 and 1.02%) due to use T1 to T9 during the two studied seasons, respectively.

Data also cleared that there was a significant interaction among treatments and storage periods for the Juice Vitamin C and acidity of pomegranate fruits in both seasons. The Juice Vitamin C was attained (15.81, 17.32, 17.1, 17.25, 17.10, 17.25, 17.31, 17.36, and 17.14) and (15.68, 17.41, 17.28, 17.16, 17.25, 17.10, 16.89, 16.98 and17.31 mg/100ml) as well as acidity was (0.78, 0.96, 0.93, 0.93, 0.95, 0.92, 0.87, 0.87 and 0.88) and (0.68, 0.86, 0.88, 0.88, 0.85, 0.85, 0.89, 0.83, 0.84 and 0.84%) during the two studied seasons, respectively. No significant differences in Juice Vitamin C and acidity due to the use coating jojoba oil or glycerol and packing polyethylene (LDPE) during the two studied seasons. The variation in increasing Juice Vitamin C and acidity depends on the coating type used where the use of coating jojoba oil or glycerol and packing polyethylene (LDPE) gave the highest Juice Vitamin C and acidity compared to the other treatments. The results indicated that using coating treatments proved effective in retaining the juice properties hence, keeping the pomegranate fruits for a long period with the best fruit quality and appearance. Fruits treated with jojoba oil maintained higher vitamin C and acidity throughout the storage period compared to untreated fruits.

Discussion

The demand for nutritious fruits, vegetables, and juices that retain their inherent nutritional value has grown over the past few decades as a result of customers' desire to maintain better health. However, the microclimate, cultivar, maturity stage, extraction technique, and cold storage treatments all have a significant impact on the nutritional makeup and bioactive qualities of pomegranate fruits or juice (Emam *et al.,* 2022). As a result, alternative environmentally friendly materials like essential oils (Eos) have been used extensively to preserve food quality and are a preferred option for the food industry because of their antimicrobial and antifungal properties. Eos have been shown to enhance consumer acceptability, stability, and shelf-life of food products by inhibiting the growth of mycelia and conidial germination of the pathogen, in addition to their antioxidant properties (Mphahlele *et al.*, 2018).

Fruits' water content plays a key role in preserving their quality. Low weight loss is therefore crucial for preserving fruit quality over an extended period of time. Increased respiratory rate and increased moisture loss account for the largest percentage of weight loss. As storage duration rose, the proportion of weight loss in fruits increased as well. The fruit weight loss was probably caused by the high porosity of the pomegranate peel, which raised the respiration and transpiration ratio. An additional aspect is the difference in water vapor pressure between the surrounding air and the fruit tissue (Kader, 2006 and Nasrin *et al*., 2018). Oil coating and wrapping treatments can

reduce respiration and water loss because they create a semi-permeable barrier that blocks oxygen, carbon dioxide, and moisture from the fruit peel and the outside atmosphere (Nasrin *et al*., 2020). Additionally, essential oils preserved the fruit's exterior and postponed dryness, which prevented the treated fruits from losing weight while being stored. The findings of Wijewardane and Guleria (2013) on apple fruits, Kahramanoğlu *et al*. (2018) on pomegranate fruits, Sebastian *et al.,* (2018) on guava fruits, and Alotaibi *et al.* (2024) on Medjool Date Palm Fruits support earlier findings regarding the beneficial effects of the combination of essential oil coating and wrapping on reducing weight loss during storage.

Fruit flesh firmness is one of the most important aspects of fruit eating quality and consumer approval. Maintaining fruit firmness is essential to extending the shelf life of fresh products because pectin degradation in the fruit cell wall and the hydrolysis of starch to sugar associated with fruit ripening cause fruit quality to deteriorate. Edible coating did a good job of preserving the firmness of the fruit since these coating elements slowed metabolism and prolonged storage life. Fruit deterioration is prevented by essential oils, which act as a barrier against numerous bacteria and fungi (Emam *et al*., 2022). Pomegranate fruits with oil coatings and wrapping procedures had the highest firmness scores.

It has been observed that the primary cause of pomegranate fruit deterioration during storage is Penicillium sp. Phenolic chemicals included in essential oils interact with membrane proteins to alter the permeability of microbial cells. The fungal cell's structure and functionality would be distorted as a result (Rattanapitigorn *et al*., 2006). Our earlier findings were consistent with those of Badawy *et al.* (2016) and Kahramanoğlu *et al*. (2018) on the impact of wrapping and essential oil coating on the percentage of fruit decay.

One important factor that is thought to indicate the nutritional content of harvested fruits is the total soluble solids. The conversion of insoluble polysaccharides to simple soluble sugars may be the cause of the increase in total soluble solids and sugar content over the storage time. However, another explanation could be the loss of fruit moisture during storage due to transpiration or evaporation, which increased the concentration of juice (Emam *et al*., 2022). Faster metabolic processes through transpiration and respiration may be the cause of the untreated fruits' higher rate of TSS% increment (Abou-Zaid *et al.*, 2024). However, when compared to control kept fruits, pomegranate fruits wrapped in polypropylene or polyethylene film had the lowest acidity percentage, according to Artés *et al*. (2000) and Fatma *et al*. (2017). Although pomegranate juice contains a variety of organic acids, including citric, malic, fumaric, tartaric, lactic, and acetic acids, citric acid is the primary source of the juice's acidity. Fruit respiration may be the primary cause of the drop in acidity % over the storage time (Alotaibi *et al*., 2024). Fruits that are wrapped and coated with essential oils have slower respiration rates, which delays the use of organic acid in respiration enzymatic reactions (Cong *et al*., 2007).

Because it oxidizes during storage, ascorbic acid is a crucial quality ingredient that is highly susceptible to deterioration. Over the course of storage, the vitamin C content of pomegranate fruits gradually decreased. Fruits that were left untreated experienced

the greatest loss of vitamin C. Fruits coated with oils and wrapped in protective materials responded better in terms of vitamin C preservation because they showed reduced ascorbic acid breakdown over storage. According to Yousef et al. (2020), the oxidation of ascorbic acid into dehydroascorbic acid was the cause of the drop in vitamin C concentration over the storage period. Furthermore, the enzymes phenol oxidase and ascorbic acid oxidase cause ascorbic acid to be lost during storage (Mari *et al*., 2016). According to Tahir *et al*. (2019), the slow pace at which ascorbic acid oxidase converts L-ascorbic acid may further contribute to the treatments' preservation of ascorbic acid by delaying the oxidation process. Since control fruits showed the greatest loss of vitamin C, comparable results are reported for pomegranates and Barhee date palms (Emam *et al*., 2022, Yousef *et al*., 2020).

The primary phenolic ingredient that gives pomegranates their purple-red hues is anthocyanin. It was discovered that the anthocyanin in pomegranate fruit had more antioxidant activity than β-carotene, vitamin C, and vitamin E. As the storage period went on, the total anthocyanin content of pomegranate fruits cv. Manfalouty increased gradually and significantly. According to our findings, the anthocyanin content deteriorated less during the storage period when the edible coating and wrapping procedures were used. Based on the changes in the interior atmosphere of the coated fruits, the enzymes polyphenol oxidase and peroxidase may be less active due to the edible coatings **(**Emam *et al*., 2022). Our findings demonstrated that pomegranate fruits coated with packaging polyethylene (LDPE), glycerol, and jojoba oil had an increase in their overall anthocyanin content. Pomegranates showed similar results (Şerban *et al.,* 2011 and Rajasekar *et al*., 2012).

Conclusion

According to the results, several edible coating treatments had a good impact on the Manfalouty pomegranate fruits' physical and chemical characteristics when they were being stored at 7±1˚C and 85–90% relative humidity. Fruits packed in polyethylene (LDPE) and coated with 10% jojoba oil effectively decreased weight loss and fruit deterioration while maintaining greater firmness. Additionally, it prevented the degradation of total acidity, reduced the loss of ascorbic acid, and preserved higher levels of anthocyanin content while retaining higher levels of total soluble solids and anthocyanins. Then, to enhance postharvest storability, prolong storage time, and preserve the nutritional content of Manfalouty pomegranates, fruits could be coated with jojoba oil or glycerol and packaged in polyethylene (LDPE) bags.

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تأثير التغليف والتعبئة الطبيعية علي قابلية التخزين وخصـــائص ثمار الرمان المنفلوطي أثناء التخزين البارد

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الملخص

يتم اســـتخدام بعض الزيوت الطبيعية الصـــالحة للأكل في كثير من الأحيان كحاجز لمنع النتح والتنفس، مما يبطئ عملية النضج ويحسن جودة ثمار الفاكهة.

تم تنفيذ تجربه معمليه خلال موســـمين متتاليين في عامي 2022 ،2023 لتقييم تأثيرات التخزين، والتغليف الجلسرين، وزيت الجوجوبا مع التعبئة في البولي إيثيلين (LDPE)، او رقائق الألومنيوم، بشكل فردي أو معًا، وتم التخزين عند 7 درجات مئوية ،85 -90% رطوبة نســـبية لمدة 0، 20، 40، 60، 80، 100، 120 يومًا على القدرة التخزينية والخصائص الفيزيائية والكيميائية لثمار الرمان (منفلوطي).

أظهرت النتائج أن الثمار المطلية بزيت الجوجوبا او الجلســـرين والمعبأة في أكياس البولي إيثيلين حققت نتائج أفضـــل وكان لها تأثير إيجابي في إطالة فترة تخزين الثمار مع احتفاظ الثمار بخواص ثمرية جيدة مقارنة بالثمار غير المعاملة (المقارنة). ســـجل التغليف بزيت الجوجوبا أو الجلســـرين المعبأ في أكياس البولي إيثيلين أقل نقصـــا في وزن الثمار ونســـبه الثمار التالفة وأعلى صـــلابة للثمار وحمض الأسكوربيك. حيث تظهر هذه النتائج أن التغليف بزيت الجوجوبا أو الجلسرين والتعبئة في أكياس البولي إيثيلين يزيد مدة التخزين والصـــلاحية ويحافظ على جودة ثمار الرمان. ويمكن اســـتخدامها أيضًـــا كعلاج بديل مقبول بيئيًا وخالي من المواد الكيميائية للحفاظ على جودة ثمار الفاكهة بعد الحصاد لأطول فترة.

الكلمات المفتاحية: *التعبئة والتغليف، الجودة، تخزين الفاكهة، خالية من المواد الكيميائية، زيت الجوجوبا.*