

Evaluation of the Pomegranate Peel Extract Treatment in Extending Storage Period and Improving Quality of Jujube Fruits *Ziziphus mauritiana Lam*. cv. Tufahi

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Abstract
Post-harvest spoilage of sidr fruits (jujube) and the deterioration of their quality caused by fungal pathogens and physiological damage is one of the most important challenges facing researchers in the field of horticultural produce preservation. Hence the need arose to use environmentally friendly compounds as a natural alternative to chemical compounds, in order to maintain fruit quality after harvest and extend the marketing period. Pomegranate peel extract was therefore used at three concentrations: 0, 1.5%, and 3%. The fruits were immersed in these solutions for 3 minutes, then air-dried and stored for periods of 5, 10, and 15 days at 5 ± 1 °C. The results showed that treating the fruits with pomegranate peel extract had a significant effect: it gave the lowest rates of weight loss, spoilage, and total soluble solids, and the highest firmness and total acidity, compared with the untreated fruits, which recorded the highest weight loss, spoilage, and total soluble solids and the lowest firmness and total acidity.

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Keywords: Sidr Fruits (Jujube), Pomegranate Peel Extract; Postharvest Preservation, Fruit Quality

Introduction

Sidr fruits, also known as nabq or unnab, are a rich source of carbohydrates, organic acids, carotenoids, minerals, and vitamins. They also contain many phenolic compounds, which are known for their strong antioxidant properties and their health and therapeutic benefits (Aldhanhani *et al*., 2022; Sharif *et al*., 2019) [3, 34]. Recent studies have indicated that the sidr plant contains large amounts of phenolic compounds and flavonoids at various stages of maturity, which enhances its potential use as a functional ingredient in dietary supplements and fortified food products (Zandiehvakili and Khadivi, 2021; Asfaw *et al*., 2024) [8, 40]. The fruits are consumed mainly fresh or dried, and consumer demand for them is increasing because of their distinctive flavor and crunchy texture, especially in the Tuffahi cultivar. However, their availability in the markets is somewhat limited because of their short shelf life after harvest, as they are highly perishable fruits affected by several factors such as agricultural practices and storage conditions. They are also susceptible to infection by pathogens and to mechanical and physiological damage during marketing and handling (Al harbi *et al*., 2026; Soliva-Fortuny *et al*., 2002) [4, 37], since metabolic activity increases under unsuitable storage conditions, leading to deterioration of fruit quality (Fattahi *et al*., 2010) [10].

The use of synthetic compounds to control post-harvest fungal infections often leads, through their accumulation, to long-term environmental and health harm (Guynot *et al*., 2005) [14]. To meet these challenges, various post-harvest techniques have been used, including cold storage and controlled (or modified) atmosphere systems to reduce respiration and moisture loss, calcium treatments to maintain fruit firmness, ozone, ultraviolet (UV-C) radiation, cold atmospheric plasma (CAP) technology, and edible coatings to control microbial contamination and delay browning. These strategies aim to preserve the nutritional and sensory quality of the fruits (Muqaddas *et al*., 2025) [23].

The coatings used in packaging differ according to their components; they may include polysaccharides, waxes, proteins, and hydrocolloids. Other types of edible coatings have been developed that are safe and environmentally friendly and that help extend the shelf life of products, reduce water and moisture loss, inhibit microbial growth, and delay ripening, especially in fresh

fruits and vegetables. A new concept has recently emerged in this field, known as "Herbal Edible Coating," which gives better results and greater health benefits, since fruits and vegetables coated with these herbal materials contain nutrients and act as natural remedies (Kumar and Bhatnagar, 2014) [18]. In this modern technique, herbs are processed or mixed with other edible coating materials. The herbs most commonly used in edible coatings include aloe vera gel, neem, lemongrass, rosemary, turmeric, and ginger. They are distinguished by their antimicrobial properties and are rich in essential vitamins, minerals, and antioxidants (Douglas *et al*., 2005) [20]. Recent studies have revealed the possibility of using pomegranate peels or their extracts as natural coatings with antioxidant properties in the food industry, because they contain biologically active compounds, notably tannins, flavonoids, and polyphenols, as well as gallic acid and ellagic acid, in addition to their ability to inhibit microbial growth (Singh *et al*., 2023; Giri *et al*., 2023) [12, 36]. Hamd (2011) [16] demonstrated the positive effect of pomegranate peel extract on some storage characteristics of apricot fruits, such as weight loss, spoilage, total sugars, respiration rate, and TSS. On the other hand, Parsa (2021) [28] indicated that using a pomegranate peel extract coating improved the quality of sweet cherry fruits during storage, reducing weight loss, spoilage, and respiration rate, and maintaining the highest acidity and firmness. In a study by Pangallo *et al*. (2021) [27], Valencia orange and clementine fruits were sprayed with different concentrations of pomegranate peel extract, and were also immersed after harvest, in order to control rots affecting the fruits during storage; both treatments reduced the spoilage percentage compared with untreated fruits. Fozi *et al*. (2022) [11] showed that the effect of pomegranate peel extract on mandarin fruits during storage was positive, as it maintained fruit firmness, reduced spoilage, and improved eating characteristics, which enhanced their acceptance among evaluators.

Despite the wide use of edible coatings on many fruits as a post-harvest preservation technique, studies on sidr fruits remain somewhat limited and insufficient. This study therefore aimed to apply sustainable, environmentally friendly strategies by making use of pomegranate peels and evaluating their efficiency in inhibiting fungal growth, adopting them as a promising preservation technique to replace synthetic additives in order to maintain fruit quality and extend shelf life.

Materials and Methods

The study was carried out during the 2022 season in the laboratories of the Department of Horticulture and Landscape Engineering, College of Agriculture, Al-Qasim Green University, to evaluate the efficiency of pomegranate peel extract in enhancing the quality and extending the shelf life of sidr fruits, Tuffahi cultivar. The fruits were harvested at commercial maturity from a private orchard in Karbala Governorate and transported to the laboratory, where they were washed and sorted, and fruits as uniform as possible in size and color were selected. The fruits were immersed for 5 minutes in three concentrations of pomegranate peel extract: 0 (distilled water), 1.5%, and 3%. They were then placed in 1 kg perforated plastic bags (6 holes on each side) and stored at 5 ± 1 °C and 85–90% relative humidity for 5, 10, and 15 days. The following characteristics were measured periodically according to these intervals:

Percentage of weight loss: calculated using the following equation:

> Weight loss (%) = (initial fruit weight − fruit weight after a given period) / total fruit weight × 100

Fruit firmness (kg·cm^{-2}): measured using a penetrometer.

Percentage of total spoilage: a fruit was considered spoiled as soon as any infection appeared, whether fungal or physiological.

> Total spoilage (%) = weight of spoiled fruits / total weight of fruits in the treatment × 100

Percentage of total soluble solids (TSS): measured using a hand refractometer.

Percentage of titratable acidity (%): acidity was determined as described in Ranganna (1977) [30], by titrating a specific volume of filtered fruit juice against 0.1 N NaOH using phenolphthalein indicator, on the basis that malic acid is the predominant acid, and was calculated using the following equation:

> Total acidity (%) = volume of base × normality × equivalent weight of malic acid × 100 / (volume of juice × 1000 × 100)

Preparation of Pomegranate Peel Extract

The aqueous extract of pomegranate peels was prepared according to the method described by Malviya *et al*. (2014) with some modifications. Ripe, sound pomegranate fruits were prepared and the peels were separated by hand, washed thoroughly with distilled water, and then dried at room temperature (25–28 °C) until constant weight. They were then ground in an electric grinder to obtain a fine powder. The aqueous extract was prepared at two concentrations (1.5% and 3%) weight/volume (w/v) by soaking 15 g and 30 g of pomegranate peel powder, respectively, in 1000 ml of distilled water. The mixture was left for 24 hours at room temperature with intermittent stirring. After soaking, the extract was filtered first through a clean piece of cloth and then through Whatman No. 1 filter paper to obtain a clear extract, which was stored in dark glass containers in the refrigerator at 4 °C until use. The sidr fruits were immersed in the treatments (control: distilled water; 1.5% aqueous extract; 3% aqueous extract) for 5 minutes and then left to air-dry before storage.

Experimental Design and Statistical Analysis

A factorial experiment was carried out according to a Completely Randomized Design (CRD) with two factors (3 × 3) and three replicates, with 1 kg per replicate. The first factor was pomegranate peel extract at three concentrations (0, 1.5, 3%), and the second factor comprised three storage periods (5, 10, and 15 days). The data were analyzed using the Genstat statistical software, and differences between means were compared using the least significant difference

(L.S.D.) test at the 0.05 probability level (Alsahuoky and Waheeb, 1990) [6].

Results and Discussion

Percentage of Weight Loss

Weight loss is one of the most important characteristics to monitor during storage, and a fundamental indicator in evaluating the efficiency of the storage process, fruit quality, and storability. The results in Table 1 indicate a gradual increase in the percentage of weight loss as the storage period continued, across all concentrations. However, the significant effect of pomegranate peel extract at the 3% concentration was clear in reducing this percentage to the lowest value of 0.42%, followed by the 1.5% concentration at 0.46%, compared with the untreated fruits, which recorded 1.00%. The interaction between 3% pomegranate peel extract and the 5-day storage period also gave the lowest value, 0.37%, while the interaction between the control treatment and the final storage period of 15 days gave the highest value, 1.607%.

The gradual decrease in fruit weight during storage is attributed to the continuation of biological processes within the fruit and the consumption of food reserves through transpiration and respiration (Siboza *et al*., 2014) [35]. Any factor that inhibits these two processes will therefore help reduce this loss. Pomegranate peel extract helped reduce the percentage of weight loss through its effectiveness in slowing the fruits' biological activity, as it forms a thin semi-permeable film that limits gas exchange between the fruit and the external environment and preserves the fruit's moisture content (Gol *et al*., 2015; Mahmoud *et al*., 2017) [13, 19]. The hydrophobic properties of pomegranate peel extract are believed to play an important role in reducing water vapor permeability (Nair *et al*., 2018) [24]. These results agree with previous studies by Nair *et al*. (2018) [24] on guava, Taherpour *et al*. (2020) [38] on citrus, and Parven *et al*. (2020) [29] on papaya. Samad *et al*. (2019) [33] indicated that Chinese jujube fruits treated with certain herbal extracts showed a significant reduction in weight loss during the storage period, and this was confirmed by Munir and Iqbal (2023) [22] in their study on banana fruits.

Table 1: Effect of Pomegranate peel extract, storage periods, on the percentage of weight loss in Sidr fruits cv. Tufahi (%)

PPE	Storage Periods (Day)			Average Transactions
	5	10	15	
Control	0.60	0.80	1.60	1.0
Pomegranate peel extract 1.5%	0.42	0.45	0.50	0.46
Pomegranate peel extract %3	0.37	0.42	0.46	0.42
Average Storage Periods	0.46	0.56	0.85	
L.S.D	PPE 0.032	Interference0.055	Storage Periods 0.032	

Fruit Firmness

The data in Table 2 showed a gradual decrease in the firmness of sidr fruits, and an increase in their softness, as the storage period progressed, particularly in the control treatment, which recorded the lowest value, 7.35 kg·cm^{-2}. In contrast, the fruits treated with pomegranate peel extract at both concentrations, 1.5% and 3%, retained their firmness, which reached 8.12 kg·cm^{-2} and 8.24 kg·cm^{-2}, respectively. As for the interaction between the two study factors, the 3% extract concentration with the first storage period (5 days) gave the highest firmness value, 8.43 kg·cm^{-2}, followed by the interaction between the 1.5% concentration and the same period, which reached 8.32 kg·cm^{-2}. The control treatment in the last period (15 days) recorded the lowest fruit firmness value, 6.55 kg·cm^{-2}.

This is attributed to the physiological and chemical changes that occur after harvest, which alter the structure of the cell wall and break down its components through the action of pectin-degrading enzymes. Water loss from the tissues also reduces cell cohesion and causes the fruits to soften. In addition, the accelerated metabolic processes, the breakdown of starch into sugars, and the breakdown of protopectin into pectic acid contribute to this (Samad *et al*., 2019; Al-Saikhan, 2018) [7, 33].

The positive effect of pomegranate peel extract in maintaining the firmness of sidr fruits at the end of the storage period is attributed to its content of phenolic compounds and antioxidants, which delay the ripening process, maintain cell wall integrity, and reduce the activity of degrading enzymes, thereby preserving fruit firmness for a longer period (Hosseinifarahi *et al*., 2020) [17]. These results agree with the findings of Bertolo *et al*. (2025) [9] and Megha *et al*. (2021) [21], who indicated that coatings enriched with pomegranate peel extract delayed fruit deterioration and maintained firmness during storage.

Table 2: Effect of Pomegranate peel extract, storage periods, on the Firmness in Sidr fruits cv. Tufahi kg/cm²-

PPE	Storage Periods (Day)			Average Transactions
	5	10	15	
Control	7.97	7.53	6.55	7.35
Pomegranate peel extract 1.5%	8.32	8.13	7.93	8.12
Pomegranate peel extract %3	8.43	8.24	8.06	8.24
Average Storage Periods	8.29	7.96	7.51	
L.S.D	PPE 0.102	Interference 0.117	Storage Periods 0.102	

Percentage of Total Spoilage

The results in Table 3 showed significant differences in the spoilage rates of sidr fruits, Tuffahi cultivar, according to the pomegranate peel extract concentration and the storage period. The highest spoilage rate was found in the untreated fruits at the end of the storage period, reaching 1.88%. This is due to their weight loss (Table 1) and reduced firmness (Table 2), which increased their degree of ripeness and in turn lowered their resistance to infection by pathogens.

On the other hand, pomegranate peel extract showed a significant superiority in reducing the infection rate in the treated fruits, which reached 1.12% and 0.07% for the 1.5%

and 3% concentrations, respectively. This is attributed to its antimicrobial effect and its content of phenolic compounds, especially punicalagin, which is one of the most important compounds found in pomegranate peels and one of the main reasons for their antifungal activity (Salahvarzi *et al*., 2011; Tehranifar *et al*., 2011) [32, 39]. Rongai *et al*. (2018) [31] indicated that the mechanism of action of this compound is through its effect on the integrity of the fungal cell membranes. These results agree with the findings of Fozi *et al*. (2022) [11], as well as Nicosia *et al*. (2016) [25], Osorio *et al*. (2010) [26], and Taherpour *et al*. (2020) [38].

Table 3: Effect of Pomegranate peel extract, storage periods, on the percentage of decay in Sidr fruits cv. Tufahi

PPE	Storage Periods (Day)			Average Transactions
	5	10	15	
Control	0.60	1.30	2.49	1.46
Pomegranate peel extract 1.5%	0.27	1.59	1.76	1.12
Pomegranate peel extract %3	0.22	0.49	1.38	0.70
Average Storage Periods	0.36	1.12	1.88	1.08
L.S.D	PPE 0.05	Interference0.09	Storage Periods 0.05	

Percentage of Total Soluble Solids (TSS)

Total soluble solids (TSS) are among the most important factors affecting fruit taste, and in general this characteristic increases gradually as the storage period continues. The data in Table 4 showed that the highest value was in the untreated fruits, at 8.97%, while it decreased to 8.85% in fruits treated with pomegranate peel extract at the 3% concentration.

The increase in TSS values can be attributed to the continuation of biological processes within the fruit, especially transpiration and evaporation, and the resulting weight loss, which increases the concentration of soluble materials in the fruit juice. This percentage also rises because of increased activity of the enzymes responsible for breaking down starch into soluble sugars (Abbasi *et al*., 2009) [1]. This result agrees with that obtained by Parven *et al*. (2020) [29] in their study on papaya fruits.

On the other hand, pomegranate peel extract helped limit weight loss through the coating layer surrounding the fruits, which was reflected in the TSS value (Fozi *et al*., 2022) [11]. These results are consistent with earlier studies by Nair *et al*. (2018) [24] and Alqahtani *et al*. (2023) [5], who used pomegranate peel extract and obtained positive results by enhancing the quality of the treated fruits.

Table 4: Effect of Pomegranate peel extract, storage periods on percentage of Total Soluble Solids in Sidr fruits cv. Tufahi

PPE	Storage Periods (Day)			Average Transactions
	5	10	15	
Control	8.92	9.07	8.94	8.97
Pomegranate peel extract 1.5%	8.96	9.05	8.81	8.93
Pomegranate peel extract %3	8.70	8.83	9.04	8.85
Average Storage Periods	8.86	8.98	8.92	
L.S.D	PPE 0.097	Interference 0.169	Storage Periods 0.097	

Percentage of Total Acidity

The results in Table 5 showed that sidr fruits, Tuffahi cultivar, experienced a decrease in total acidity percentage in general. However, this decrease was less severe in the fruits treated with pomegranate peel extract, which retained the highest acidity, 0.61% for both the 1.5% and 3% concentrations, while it fell to the lowest value, 0.56%, in the control treatment. It was also observed that the length of the storage period had a significant effect on this characteristic, as acidity decreased from 0.64% in the first period (5 days) to 0.53% after 15 days of storage.

The decrease in acidity is attributed to the continuation of biological processes within the fruit and the consumption of organic acids in respiration (Gol *et al*., 2015) [13]. The breakdown of organic acids during fruit ripening is linked to the enzymatic activity of respiration, since they are essential substrates for energy production (Habibi *et al*., 2019) [15]. Their consumption may also be related to fruit exposure to spoilage and increased ethylene production, as both factors lead to lower acid levels in the fruit and thus reduce its acidity (Fozi *et al*., 2022) [11]. On the other hand, the use of pomegranate peel extract helped slow the metabolic activity of the fruits and delay changes in acidity, TSS, and weight loss (Fozi *et al*., 2022) [11]. The results of this study agree with those of previous studies by Mahmoud *et al*. (2017) [19] on orange fruits, Samad *et al*. (2019) [33] on Chinese jujube fruits, and Parven *et al*. (2020) [29] on papaya fruits, in which different herbal coatings were used to treat the fruits and enhanced quality indicators during storage.

Table 5: Effect of Pomegranate peel extract, storage periods on percentage of Total Acidity in Sidr fruits cv. Tufahi

PPE	Storage Periods (Day)			Average Transactions
	5	10	15	
Control	0.60	0.58	0.51	0.56
Pomegranate peel extract 1.5%	0.64	0.61	0.60	0.61
Pomegranate peel extract %3	0.68	0.66	0.50	0.61
Average Storage Periods	0.64	0.61	0.53	
L.S.D	PPE 0.024	Interference 0.042	Storage Periods 0.024	

Conclusions

It can be concluded from this study that treating sidr fruits, Tuffahi cultivar, with pomegranate peel extract after harvest helped extend the shelf life of the fruits and enhance quality indicators by reducing weight loss and spoilage and inhibiting the growth of rots. Its efficiency was evident in slowing the fruits' metabolic activity and delaying ripening and deterioration, owing to its content of phenolic compounds and its antioxidant and antimicrobial properties. It can therefore be adopted in post-harvest treatments as a natural and sustainable strategy in place of chemical compounds, limiting their use and avoiding their negative effects on humans and the environment, in line with the global trend toward environmentally friendly, safe, and low-cost edible wraps or coatings. It also makes use of pomegranate processing waste and reduces wastage, and it encourages future studies to evaluate its efficiency in the physiological, biological, and chemical aspects of the fruits.

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