Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURE SCIENCES JOURNAL

Volume 8, Issue 1, 2025, Pages 130–149

Available online at https://aasj.journals.ekb.eg

DOI: https://dx.doi.org/10.21608/aasj.2025.446618

Production and storage stability of a blended fruit leather from date, pomegranate, and fig to reduce post-harvest waste

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Abstract

This study aimed to evaluate the impact of 120-day ambient storage on the chemical, physical, functional, sensory, and microbiological properties of fruit leathers prepared from dates, pomegranates, and figs-individually and as a 3:2:1 blended formulation—with varying levels of added pectin. The analyses included moisture content, total soluble solids (TSS), total and reducing sugars, total acidity, pH, ascorbic acid, total phenolic content, antioxidant activity, sensory evaluation, and microbiological safety. The results revealed significant changes ($P<0.05$) across most parameters due to storage. Increases were observed in moisture, TSS, total and reducing sugars, while decreases occurred in bioactive compounds such as phenolics, ascorbic acid, and antioxidant activity. Blended samples fortified with pectin (particularly those with 1.5 g and 2.5 g pectin additions) showed notable stability in structural, functional, and sensory attributes compared to single-fruit or non-fortified samples. Sensory evaluations remained high initially (>7.0 on a 9-point scale) and acceptable after 120 days (>5.0), while microbiological analysis confirmed the absence of pathogenic bacteria and fungi, indicating product safety throughout the storage period. The study recommends the development of pectin-fortified blended fruit leathers as a promising functional food product, offering chemical, sensory, and microbiological stability, with extended shelf life and minimal loss in nutritional value and quality.

Keywords: fruit leather, food preservation, pectin fortification, storage stability, antioxidant activity, waste reduction.

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1. Introduction

Fresh fruits have short harvest seasons and are sensitive to deterioration; therefore, fruit sheets are produced to preserve them through the addition of various additives and preservatives. These products are consumed as snacks or desserts and provide concentrated fruit flavors and nutritional benefits (Ali Nesreen, 2019). Blending two or more fruit and vegetable juices to produce delightful, delicious, and more functional beverages with improved organoleptic and nutritive values has become popular. Juice blending may enhance the aroma, taste, and nutrient content of beverages. Moreover, new product development through blending can create natural health drinks that may also serve as appetizers (Deka and Sethi, 2001). Therefore, this work aims to maximize the benefits of combining dates, pomegranates, and figs to produce fruit sheets with high nutritional value, while evaluating their chemical, organoleptic, and microbiological properties. Date palm fruit (*Phoenix dactylifera* L.) is considered one of the most important fruits in arid and semi-arid regions. Egypt is the leading global producer of dates, with 1,590,414 tons produced annually (FAO, 2019). Several studies have incorporated dates into various food products including bakery items, date bars, beverages, jams, jellies, and fruit sheets (El-Samahy *et al*., 2002; El-Samahy and Youssef, 2009; Mostafa *et al*., 2002). Date fruits are rich in essential nutrients including carbohydrates, minerals, dietary fiber, vitamins, and small amounts of fat and protein. Although Egypt ranks first internationally in date production, minimal quantities are exported due to limited awareness, technology, and facilities for post-harvest treatment, processing, and packaging. Dates have played an important role in human nutrition for over 7,000 years (Ahmed *et al*., 1995). Pomegranate (*Punica granatum*) is a tree fruit with arils that are predominantly red, sometimes white, or various intermediate colors. Pomegranates are utilized in various forms including fresh fruit, juice, paste, jam, and fruit bars. They are rich in antioxidants and potassium, contributing to a reduced risk of heart disease and cancer while helping decrease blood cholesterol levels (Lansky and Newman, 2007). Fresh pomegranate juice contains 85.4% moisture and significant amounts of total soluble solids, sugars, reducing sugars, anthocyanins, phenolics, organic acids, ascorbic acid, vitamins, polysaccharides, proteins, and essential minerals. Pomegranate consumption has increased in various processing industries for producing juice, vinegar, paste, jelly, jam, and marmalade (Tezcan *et al*., 2009). Fig (*Ficus carica* L.), a deciduous tree belonging to the Moraceae family, is one of the earliest cultivated fruit trees and is widespread in warm, dry climates. This fruit is a characteristic of Mediterranean diets and can be eaten fresh, dried, or processed as jam. A large portion of dried figs are consumed in Egypt during Ramadan as a popular drink which is an excellent source of minerals, vitamins, dietary fibers, and amino acids; it is also free of fat and cholesterol (Solomon *et al*., 2006; Veberic *et al*., 2008). Fruit leather is a form of dehydrated fruit puree with a chewy texture, a long shelf life, and 10–20% moisture content (Rosida *et al*., 2017). It serves as an economical and convenient alternative to natural fruits, offering high nutritional

value, particularly in terms of energy, minerals, antioxidants, and fiber (Barman *et al*., 2021). They are intermediate moisture food products and can be made from a variety of fruits or fruit mixtures (Khan and Zubairi, 2022). The edible portion of the fruit is pureed, mixed with other ingredients, heated, formed into a thin layer on flat trays, and then dried until a cohesive fruit leather is obtained (Phimpharian *et al*., 2011). Therefore, the purpose of the current study was to develop fruit leathers from dates, pomegranates, and figs—individually and as a blend—and to evaluate the effect of pectin fortification and 120-day ambient storage on their chemical, physical, functional, sensory, and microbiological properties.

2. Materials and methods

Date palm fruits (Siwi cultivar), pomegranate fruits (Manfaloty cultivar), and fresh fig fruits (Sultani cultivar) were purchased from a local market in Assiut governorate, Egypt.

2.1 Chemical and reagents

All chemicals and reagents used in the analytical methods were of analytical grade and purchased from El-Gomhouria Trading for Chemicals and Drugs (Assiut, Egypt). Distilled water was used for the preparation of all solutions. This research was conducted at the Department of Food Science, Faculty of Agriculture, Al-Azhar University (Assiut, Egypt).

2.2 Preparation of samples

Fresh fruits were transported to the Food Science laboratory, washed with tap water, cleaned, and prepared for processing as described below.

2.2.1 Date pulp preparation

Washed and deseeded date fruits (2000 g) were cut into small pieces and blended in an electric blender with 150 mL of distilled water for 2 minutes. The resulting pulp was filtered through muslin cloth and stored in polyethylene bags in a deep freezer until further use.

2.2.2 Pomegranate juice preparation

After washing under running tap water, the pomegranates were carefully cut, and the arils were extracted. The arils were sorted to remove any damaged ones, then blended in an electric blender. The juice was filtered through muslin cloth and stored in polyethylene bags in a deep freezer until further use.

2.2.3 Fig pulp preparation

Fresh fig fruits (1000 g) were washed with tap water, cleaned, and cut into small pieces using a stainless-steel knife. The chopped figs were blended, and the pulp was filtered through muslin cloth and stored in polyethylene bags in a deep freezer until further use.

2.2.4 Mixed fruit pulp preparation (3:2:1 ratio)

Date, pomegranate, and fig pulps were combined in a 3:2:1 ratio by weight, respectively. The pulps were thoroughly

mixed in a blender to achieve a uniform consistency.

2.3 Fruit sheet preparation

2.3.1 Control samples

C_1 (100% Date Pulp), C_2 (100% Pomegranate Pulp), C_3 (100% Fig Pulp). Each control sample was prepared using 300 g of the respective fruit pulp.

2.3.2 Blended fruit sheet preparation

A total of 1800 g of the mixed fruit pulp (date, pomegranate, and fig in a 3:2:1 ratio) was combined with 1.5 g of citric acid and 500 g of sugar. The mixture was heated to 80-90°C for 10 minutes and then cooled. The blended pulp was divided into three equal portions for the following treatments:

T_3^0: 300 g of blended pulp (0% added pectin)

T_3^a: 300 g of blended pulp + 1.5 g pectin (0.5% w/w)

T_3^b: 300 g of blended pulp + 2.5 g pectin (0.83% w/w)

Each of the control (C_1, C_2, C_3) and blended (T_3^0, T_3^a, T_3^b) formulations was poured onto butter-smeared trays (25.5 cm × 13 cm × 2 cm) and dried at 60-70°C for 7-16 hours. Once completely dried, the fruit sheets were removed from the trays, cut, packaged in polyethylene bags, and stored at room temperature for further analysis (Figure1).

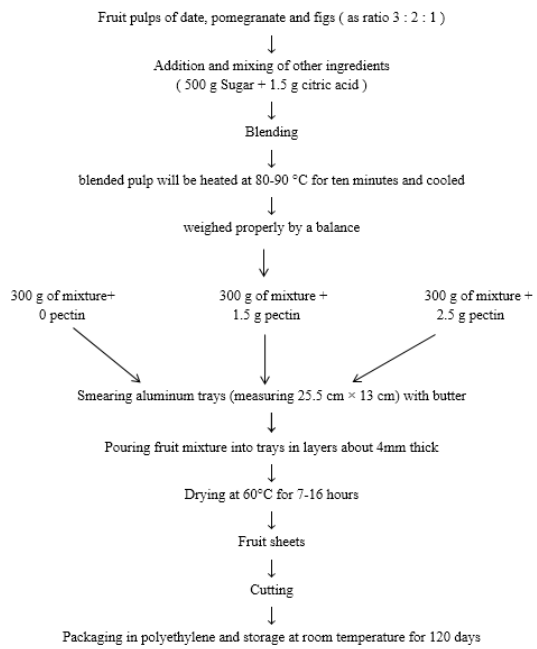

Figure (1): Preparation of blended fruit sheets.

2.4 Storage conditions

The packaged fruit sheet samples were stored at room temperature (22 ± 3°C) for 120 days. Physicochemical, microbiological, and sensory analyses were conducted at 30-day intervals.

2.5 Analytical methods

2.5.1 Moisture and ash content

Determined according to AOAC (2000) official methods.

2.5.2 pH

Measured using a pH meter (OAKTON, pH/mV/°C meter, USA) with a glass electrode at 20°C (AOAC, 1995).

2.5.3 Total titratable acidity (TTA)

Determined by the official method of AOAC (1995).

2.5.4 Total soluble solids (TSS)

Measured using a refractometer as per AOAC (1995).

2.5.5 Sugars

Total, reducing, and non-reducing sugars were determined by the Lane and Eynon method (AOAC, 2005). Non-reducing sugars were calculated by difference.

2.5.6 Ascorbic acid

Determined by the 2,6-dichlorophenolindophenol dye method (AOAC, 1995).

2.5.7 Total phenolic content

Measured using the Folin-Ciocalteu method as described by Gündeşli *et al*. (2021).

2.5.8 Antioxidant activity

Determined by the DPPH (2,2-diphenyl-1-picrylhydrazyl) method according to Lee and Lee (2010).

2.6 Microbiological examination

Total viable count, as well as yeast and mold counts, were determined according to the methods recommended by the American Public Health Association (APHA, 1978). Note: A more recent edition of the APHA manual should be cited if possible.

2.7 Sensory evaluation

Sensory evaluation was conducted at the Department of Food Science and Technology, Faculty of Agriculture, Al-Azhar University (Assiut), Egypt. Ten trained panelists evaluated the fruit sheet samples for color, taste, odor, texture, and overall acceptability using a 9-point hedonic scale (1 = dislike extremely, 9 = like extremely), as described by Larmond (1977).

2.8 Statistical analysis

The obtained data were subjected to a one-way analysis of variance (ANOVA) using

IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). Significant differences between means were determined using the F-test at a significance level of $p < 0.05$.

3. Results and discussion

3.1 Moisture content

The moisture content of the fruit sheet samples was analyzed over a 120-day storage period at room temperature, and the results are presented in Table (1). A gradual and statistically significant ($P < 0.05$) increase in moisture was observed in all samples. This included those prepared from individual fruit pulps—C1 (date sheet), C2 (pomegranate sheet), and C3 (fig sheet)—and the blended mixtures T_3^0 (0% pectin), T_3^a (1.5g pectin), and T_3^b (2.5g pectin). At the beginning of the storage period (day 0), the initial moisture content varied significantly among the samples, reflecting the inherent characteristics of the different fruit pulps. The blended sample without pectin (T_3^0) had the lowest moisture content (9.31%), while the fig-based sheet (C3) had the highest (18.10%). The initial moisture contents for the other samples were as follows: T_3^a (10.18%), T_3^b (11.14%), C2 (11.10%), and C1 (17.53%). After 120 days of storage, all samples showed a significant increase in moisture content. The final moisture contents were: T_3^0 (10.93%), T_3^a (12.95%), T_3^b (14.27%), C2 (12.43%), and C3 (19.15%). The moisture content in the date-based sheet (C1) also showed a significant, albeit gradual, increase from 17.53% to 18.10% over the storage period, a correction from the original text that inaccurately described it as "relatively stable". The samples with higher pectin concentrations (T_3^a and T_3^b) exhibited more significant moisture increases. Statistical analysis confirmed that the changes in moisture content were significant ($P < 0.05$) across all samples and storage times. This increase may be attributed to the hygroscopic nature of date pulp (El-Samahy *et al*., 2002), as well as the water-retention properties of pectin. Pectin, as a hydrocolloid, likely absorbed moisture from the ambient environment, contributing to the observed increases. These findings are consistent with previous studies, where El-Said *et al*. (2016) reported slight increases in date sheets, Kumar *et al*. (2020) observed increasing moisture in pomegranate leathers, Sood and Bandral (2015) documented a rise in jamun fruit leathers, and Attri *et al*. (2014) noted an increase in papaya leather. These results suggest that moisture changes during storage are governed by fruit composition, pectin concentration, and storage conditions. Despite the observed increases, the moisture levels remained within acceptable ranges, ensuring the product's stability over the storage period. This highlights the potential of using blended fruit pulps and controlled pectin levels to develop fruit sheets with favorable storage characteristics.

Table (1): Effect of a 120-day storage period at room temperature on the moisture content (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	17.53 ± 0.43^{E}	17.57 ± 0.44^{E}	17.70 ± 0.45^{E}	17.85 ± 0.47^{DE}	18.10 ± 0.36^{CD}	17.75
C2	11.10 ± 0.34^{O}	11.62 ± 0.16^{M}	11.97 ± 0.10^{L}	12.11 ± 0.12^{KL}	12.43 ± 0.05^{JK}	11.85
C3	18.10 ± 0.10^{CD}	18.32 ± 0.07^{C}	18.47 ± 0.08^{BC}	18.72 ± 0.10^{B}	19.15 ± 0.16^{A}	18.55
T_3^0	9.31 ± 0.06^{S}	9.77 ± 0.09^{R}	10.69 ± 0.06^{P}	10.83 ± 0.04^{OP}	10.93 ± 0.02^{OP}	10.31
T_3^a	10.18 ± 0.10^{Q}	11.49 ± 0.08^{MN}	12.14 ± 0.07^{KL}	12.80 ± 0.04^{HI}	12.95 ± 0.07^{HI}	11.91
T_3^b	11.14 ± 0.07^{NO}	12.66 ± 0.07^{IJ}	13.12 ± 0.13^{H}	13.67 ± 0.34^{G}	14.27 ± 0.09^{F}	12.97
Mean	12.89	13.57	14.015	14.33	14.64	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.2 Total soluble solids

Total soluble solids (TSS), primarily composed of sugars, are a key indicator of the solid constituents dissolved within a food product (Ijaz *et al*., 2021). The analysis of TSS in the fruit leather samples over the 120-day storage period revealed a statistically significant ($p < 0.05$) increase across all treatments (Table 2). This trend was observed in the single-fruit control leathers—C1 (date), C2 (pomegranate), and C3 (fig)—as well as the blended formulations T_3^o (0% pectin), T_3^a (1.5 g pectin), and T_3^b (2.5 g pectin). At the beginning of the storage period (day 0), initial TSS values varied considerably, reflecting the natural composition of the raw fruits. The date leather (C1) exhibited the highest initial TSS at 81.52%, which is consistent with the high sugar content characteristic of dates. The pectin-fortified blended samples, T_3^b (78.23%) and T_3^a (76.34%), also showed high TSS values. In contrast, the pomegranate leather (C2) had the lowest TSS at 6.97%, while the fig leather (C3) and the non-pectin blend ($T3_o$) recorded moderate initial values of 27.94% and 60.66%, respectively. By the end of the 120-day storage period, TSS had increased in all samples. For instance, C1 rose to 82.63%, T_3^b increased to 79.92%, and C2 reached 8.14%. This upward trend during storage is likely due to the hydrolysis of complex carbohydrates (polysaccharides) into simpler, soluble sugars like glucose and fructose, a process that can occur over time. A secondary contributing factor may be the slight concentration of solids resulting from minor moisture changes during storage. These findings are consistent with a body of literature documenting similar increases in TSS during the storage of fruit-based products. For example, gradual increases in TSS have been reported in leathers made from pomegranate (Kumar *et al*., 2020), guava (Basha, 2018), fig (Kotlawar, 2008), and sapota. Phimpharian *et al*. (2011) also noted an increase in the TSS of their fruit leather, from 82.42% to 86.9%. This consistent pattern across different fruit types suggests that the slow conversion of carbohydrates into soluble sugars is a common

phenomenon in intermediate-moisture fruit products during ambient storage.

Table (2): Effect of a 120-day storage period at room temperature on the total soluble solids (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	81.52 ± 0.44^{B}	81.55 ± 0.44^{B}	82.58 ± 0.45^{A}	82.61 ± 0.45^{A}	82.63 ± 0.45^{A}	82.18
C2	6.97 ± 0.43^{Q}	7.49 ± 0.10^{P}	7.68 ± 0.04^{OP}	7.94 ± 0.10^{OP}	8.14 ± 0.09^{O}	7.64
C3	27.94 ± 0.28^{N}	28.43 ± 0.18^{M}	28.94 ± 0.11^{L}	29.58 ± 0.50^{K}	30.19 ± 0.16^{J}	29.02
T_3^0	60.66 ± 0.25^{I}	60.72 ± 0.26^{I}	60.80 ± 0.28^{I}	60.88 ± 0.28^{I}	61.01 ± 0.28^{I}	60.81
T_3^a	76.34 ± 0.18^{H}	76.56 ± 0.18^{GH}	76.77 ± 0.18^{FGH}	76.93 ± 0.15^{FG}	77.08 ± 0.18^{F}	76.74
T_3^b	78.23 ± 0.05^{E}	78.32 ± 0.06^{E}	78.46 ± 0.08^{DE}	78.86 ± 0.14^{D}	79.92 ± 0.17^{C}	78.758
Mean	55.2766667	55.5116667	55.87166667	56.13333333	56.495	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.3 Total acidity

The total acidity of the fruit leather samples, presented in Table (3), showed varied and statistically significant ($p < 0.05$) changes over the 120-day storage period. A notable divergence in trends was observed: the date leather (C1) exhibited a slight decrease in acidity, whereas all other samples, including the pomegranate (C2), fig (C3), and blended leathers (T_3^o, T_3^a, T_3^b), showed a gradual increase. The acidity of the date leather (C1) decreased from an initial value of 0.88% to 0.85% by the end of storage. This trend aligns with findings from previous studies on similar fruit products. For instance, a slight decrease in acidity was reported in papaya leather after six months of storage (Attri, 2014), and similar reductions were observed in stored guava puree powder and dried guava sheets (Ibrahim, 1990; Mohamed, 1989). This phenomenon in date-rich products may be linked to the utilization of organic acids in non-enzymatic browning reactions during storage. In contrast, all other samples demonstrated a consistent increase in total acidity. The most pronounced change was in the pomegranate leather (C2), which increased from 0.09% to 0.41%. The fig leather (C3) also saw a rise from 0.41% to 0.44%. The blended samples showed slight increases as well, with T_3^o rising from 0.24% to 0.25%, T_3^a from 0.26% to 0.27%, and T_3^b from 0.27% to 0.29%. The observed increase in acidity is a commonly reported phenomenon in the storage of fruit leathers and is supported by extensive literature. Researchers have documented rising acidity in leathers made from pomegranate (Azmat Zarmeena *et al*., 2017), fig (Dhumal *et al*., 2018), mango, and various blended products like guava-papaya and guava-apple (Parmar, 2008). This increase can be attributed to several factors, including the breakdown of pectin into pectic acid, the formation of acids from the degradation of monosaccharides, and the

concentration of organic acids due to minor moisture loss during storage (Azmat Zarmeena *et al*., 2017; Khan and Zubairi, 2022).

Table (3): Effect of a 120-day storage period at room temperature on the total acidity (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	0.89 ± 0.03^{J}	0.88 ± 0.04^{IJ}	0.88 ± 0.04^{IJ}	0.87 ± 0.04^{IJ}	0.85 ± 0.04^{I}	0.874
C2	0.09 ± 0.01^{A}	0.12 ± 0.01^{B}	0.32 ± 0.01^{F}	0.36 ± 0.01^{G}	0.41 ± 0.01^{H}	0.26
C3	0.41 ± 0.01^{H}	0.42 ± 0.00^{H}	0.43 ± 0.01^{H}	0.44 ± 0.00^{H}	0.44 ± 0.00^{H}	0.428
T_3^0	0.24 ± 0.01^{C}	0.24 ± 0.01^{C}	0.24 ± 0.01^{C}	0.25 ± 0.01^{CD}	0.25 ± 0.01^{CD}	0.244
T_3^a	0.27 ± 0.02^{CDE}	0.27 ± 0.02^{CDE}	0.27 ± 0.02^{FGH}	0.27 ± 0.02^{CDE}	0.27 ± 0.01^{CDE}	0.27
T_3^b	0.29 ± 0.00^{E}	0.28 ± 0.00^{DE}	0.28 ± 0.01^{CDE}	0.27 ± 0.01^{CDE}	0.27 ± 0.01^{CDE}	0.278
Mean	0.37	0.37	0.4	0.41	0.41	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.4 Total acidity

The pH of the fruit leather samples, a measure of acidity, was monitored over the 120-day storage period, with the results presented in Table (4). A consistent and statistically significant ($p < 0.05$) decrease in pH was observed across all samples, indicating a gradual increase in acidity over time. At the start of the experiment (day 0), the initial pH values were largely dictated by the natural characteristics of the fruits. The pomegranate leather (C2) was the most acidic, with the lowest initial pH of 3.61. The date (C1) and fig (C3) leathers had higher pH values of 5.42 and 5.10, respectively. The blended leather without pectin (T_3^o) recorded the highest initial pH at 5.53. By the end of the 120-day storage period, the pH had declined in all treatments. The most substantial drop was observed in the pectin-fortified blended leather T_3^a, which decreased from 5.43 to 4.87. The other samples showed more modest declines; for example, C1 decreased to 5.40 and C2 to 3.59. This universal trend toward lower pH is inversely related to the increase in total acidity discussed previously. The observed decrease in pH during storage is a well-documented phenomenon in fruit-based products and is supported by numerous studies. Researchers have reported similar pH reductions in guava-apple leather, guava bars (Shakoor *et al*., 2015), and pineapple leather (Phimpharian *et al*., 2011). This trend is attributed to several biochemical reactions, including the formation of acidic compounds from the degradation of sugars, the oxidation of ascorbic acid, and the hydrolysis of pectin into pectic acid (Khan and Zubairi, 2022). While these chemical changes occurred, the final pH values remained within a stable range, indicating that the product's overall quality and safety were not compromised.

Table (4): Effect of a 120-day storage period at room temperature on the pH value of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	5.42 ± 0.01^{B}	5.42 ± 0.01^{B}	5.42 ± 0.01^{B}	5.40 ± 0.01^{BC}	5.40 ± 0.01^{BC}	5.41
C2	3.61 ± 0.01^{I}	3.61 ± 0.01^{I}	3.61 ± 0.01^{I}	3.60 ± 0.01^{I}	3.59 ± 0.01^{I}	3.6
C3	5.10 ± 0.01^{F}	5.09 ± 0.01^{F}	5.08 ± 0.01^{F}	5.07 ± 0.01^{FG}	5.07 ± 0.01^{FG}	5.08
T_3^0	5.53 ± 0.06^{A}	5.50 ± 0.00^{A}	5.43 ± 0.06^{B}	5.37 ± 0.06^{BC}	5.27 ± 0.06^{D}	5.42
T_3^a	5.43 ± 0.06^{B}	5.23 ± 0.06^{D}	5.07 ± 0.06^{FG}	5.00 ± 0.00^{G}	4.87 ± 0.06^{H}	5.12
T_3^b	5.33 ± 0.06^{C}	5.27 ± 0.06^{D}	5.23 ± 0.06^{D}	5.17 ± 0.06^{E}	5.03 ± 0.06^{FG}	5.2
Mean	5.07	5.02	4.97	4.94	4.87	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.5 Total sugars

The total sugar content of the fruit leather samples showed a statistically significant ($p < 0.05$) increase during the 120-day storage period, as detailed in Table 5. This trend was consistent across all formulations. Initially, on day 0, the sugar content varied widely among the samples, reflecting the natural composition of the fruits. The date leather (C1) had the highest concentration at 79.30%, while the pomegranate leather (C2) had the lowest at 19.16%. The fig leather (C3) and the blended samples (T_3^o, T_3^a, and T_3^b) fell in between, with initial values ranging from 61.56% to 70.70%. Over the 120-day storage period, the total sugar content rose in all samples. For example, the pomegranate leather (C2) showed a substantial increase from 19.16% to 32.25%, while the date leather (C1) saw a more modest rise from 79.30% to 80.45%. This general increase in total sugars is likely attributable to the hydrolysis of complex carbohydrates, such as starches and non-reducing sugars, into simpler, measurable sugars like glucose and fructose. A minor concentration effect from slight moisture loss during storage may also have contributed. These findings are in agreement with previous research. Basha (2018) and Kumar *et al*. (2020) reported similar increases in sugar content in guava and pomegranate leathers, respectively, during ambient storage. The slight but significant increase observed in the high-sugar date leather is also consistent with the findings of Ali Nesreen (2016), who noted a similar trend. This indicates that even in sugar-rich products, further hydrolysis of polysaccharides can occur, contributing to changes in the product's chemical profile over time.

3.6 Reducing sugars

The reducing sugar content of the fruit leathers showed a statistically significant ($p < 0.05$) increase across most samples during the 120-day storage period (Table 6). This trend reflects the ongoing biochemical changes within the products, particularly the conversion of non-reducing to reducing sugars. At the start of

the storage period (day 0), the initial concentration of reducing sugars was highest in the date leather (C1) at 44.00% and the fig leather (C3) at 58.53%, consistent with the natural sugar profiles of these fruits. The pomegranate leather (C2) had the lowest initial value at 16.99%. The blended samples (T_3^o, T_3^a, T_3^b) showed intermediate values, ranging from 47.20% to 48.81%. Over 120 days, all samples exhibited an increase in reducing sugars. The most substantial relative increase occurred in the pomegranate leather (C2), which rose from 16.99% to 28.89%. The other samples showed more modest increases; for example, the fig leather (C3) increased from 58.53% to 59.20%. This gradual rise is primarily due to the acid hydrolysis of non-reducing sugars, like sucrose, which break down into their constituent reducing monosaccharides, glucose and fructose.

Table (5): Effect of a 120-day storage period at room temperature on the total sugar content (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	79.30 ± 0.69 ^{C}	79.74 ± 0.7 ^{BC}	80.19 ± 0.6 ^{AB}	80.46 ± 0.55 ^{A}	80.45 ± 0.55 ^{A}	80.09
C2	19.16 ± 0.34 ^{M}	19.89 ± 0.30 ^{L}	29.71 ± 0.26 ^{K}	31.50 ± 0.29 ^{J}	32.25 ± 0.23 ^{I}	26.5
C3	70.70 ± 0.13 ^{F}	70.93 ± 0.10 ^{EF}	71.16 ± 0.13 ^{DEF}	71.45 ± 0.13 ^{DE}	71.83 ± 0.11 ^{D}	71.21
T_3^0	61.56 ± 0.23 ^{H}	61.72 ± 0.20 ^{H}	61.90 ± 0.17 ^{H}	62.08 ± 0.17 ^{H}	62.27 ± 0.15 ^{H}	61.91
T_3^a	63.20 ± 0.45 ^{G}	63.23 ± 0.46 ^{G}	63.37 ± 0.45 ^{G}	63.52 ± 0.39 ^{G}	63.65 ± 0.38 ^{G}	63.39
T_3^b	63.53 ± 0.52 ^{G}	63.57 ± 0.51 ^{G}	63.71 ± 0.46 ^{G}	63.79 ± 0.45 ^{G}	63.88 ± 0.43 ^{G}	63.7
Mean	59.76	59.84	61.67	62.13	62.39	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

Table (6): Effect of a 120-day storage period at room temperature on the reducing sugar content (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	44.00 ± 0.26 ^{F}	44.02 ± 0.27 ^{F}	44.04 ± 0.27 ^{F}	44.08 ± 0.26 ^{F}	44.09 ± 0.25 ^{F}	44.05
C2	16.99 ± 0.12 ^{A}	17.63 ± 0.12 ^{B}	26.55 ± 0.63 ^{C}	28.26 ± 0.24 ^{D}	28.89 ± 0.22 ^{E}	23.66
C3	58.53 ± 0.12 ^{K}	58.65 ± 0.11 ^{K}	58.77 ± 0.11 ^{KL}	58.95 ± 0.07 ^{KL}	59.20 ± 0.08 ^{L}	58.82
T_3^0	47.20 ± 0.36 ^{G}	47.32 ± 0.33 ^{GH}	47.41 ± 0.32 ^{GH}	47.54 ± 0.29 ^{GH}	47.67 ± 0.25 ^{H}	47.43
T_3^a	48.63 ± 0.15 ^{I}	48.66 ± 0.16 ^{IJ}	48.74 ± 0.18 ^{IJ}	48.86 ± 0.17 ^{IJ}	48.97 ± 0.18 ^{IJ}	48.77
T_3^b	48.81 ± 0.28 ^{IJ}	48.88 ± 0.29 ^{IJ}	48.99 ± 0.27 ^{IJ}	49.07 ± 0.30 ^{IJ}	49.15 ± 0.30 ^{J}	48.98
Mean	44.04	44.2	45.75	46.12	46.31	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

These results are well-supported by previous research on fruit leathers. A consistent increase in reducing sugars during storage has been reported in leathers made from pomegranate (Kumar *et al*., 2020), guava-chiku blends (Khan

and Zubairi, 2022), pear-grape blends (Ahmed *et al*., 2021), and wood apple-mango blends. This chemical change is a recognized characteristic of stored fruit products, as the breakdown of complex carbohydrates continues over time (Chavan and Shaik, 2015). Despite these changes, the final values remained within an acceptable range, indicating that the product quality and stability were maintained throughout the storage period.

3.7 Ascorbic acid (Vitamin C)

Ascorbic acid, or vitamin C, is highly susceptible to degradation during food processing and storage due to its sensitivity to oxygen, heat, and light. As expected, the analysis of the fruit leather samples revealed a statistically significant ($p < 0.05$) decrease in ascorbic acid content across all treatments over the 120-day storage period (Table 7). At the beginning of the storage period (day 0), the initial ascorbic acid content was highest in the pomegranate leather (C2) at 12.81 mg/100g, followed by the pectin-fortified blended leathers T_3^a (11.89 mg/100g) and T_3^b (11.37 mg/100g). The fig leather (C3) contained the lowest initial amount at 6.59 mg/100g. These initial concentrations reflect the natural vitamin C levels of the constituent fruits. By the end of 120 days, ascorbic acid levels had declined in all samples. For instance, the content in the pomegranate leather (C2) decreased to 9.97 mg/100g, while the fig leather (C3) dropped to 4.62 mg/100g. This loss is primarily due to oxidative processes, where ascorbic acid is converted to dehydroascorbic acid and other compounds, a common occurrence in stored fruit products. These findings are consistent with a large body of research. Significant decreases in ascorbic acid during storage have been documented in leathers made from pomegranate (Mohit Kumar *et al*., 2020), pear-grape blends (Ahmed *et al*., 2021), papaya (Attri *et al*., 2014), and guava (Mounisha *et al*., 2022; Shakoor *et al*., 2015). This degradation is a well-understood consequence of exposure to processing conditions and ambient storage. Despite these losses, the leathers, particularly those containing pomegranate, retained a substantial portion of their vitamin C, highlighting their potential as a shelf-stable source of this essential nutrient.

3.8 Total phenols

Phenolic compounds are key contributors to the antioxidant capacity of fruits, but they are susceptible to degradation during processing and storage. The analysis of total phenolic content in the fruit leathers revealed a statistically significant ($p < 0.05$) decrease across all samples over the 120-day storage period (Table 8). At the beginning of the study (day 0), the date leather (C1) contained the highest concentration of total phenols at 267.21 mg/100g. The blended leather without pectin (T_3^o) and the pomegranate leather (C2) also had high initial values of 235.15 and 218.17 mg/100g, respectively. The lowest initial phenolic content was found

in the pectin-fortified blend T_3^b, at 178.37 mg/100g. By the end of the 120-day storage period, phenolic content had declined in all treatments. For instance, the date leather (C1) decreased to 242.89 mg/100g, and the pomegranate leather (C2) dropped to 198.53 mg/100g. This loss is primarily attributed to oxidative reactions, where phenolic compounds are degraded through exposure to oxygen, light, and enzymatic activity. These results are consistent with previous studies that have documented the degradation of phenolic compounds in fruit leathers during storage. A decline in total phenols has been observed in leathers made from pomegranate (Das and Kumar, 2019; Kumar *et al*., 2020), various fruit rolls (Sharma *et al*., 2013), and guava (Basha, 2018). The rate of degradation can be influenced by numerous factors, including the specific fruit matrix, processing conditions, and storage environment (Savikin *et al*., 2009). Despite the observed losses, the leathers retained a substantial portion of their initial phenolic content, indicating that they remain a valuable source of these beneficial antioxidant compounds.

Table (7): Effect of a 120-day storage period at room temperature on the ascorbic acid content (mg/100g) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	8.95 ± 0.19^{F}	8.87 ± 0.13^{FG}	8.80 ± 0.09^{FG}	7.34 ± 0.10^{J}	6.44 ± 0.08^{K}	8.08
C2	12.81 ± 0.60^{A}	12.70 ± 0.29^{A}	12.59 ± 0.36^{A}	11.48 ± 0.30^{C}	9.97 ± 0.17^{E}	11.91
C3	6.59 ± 0.38^{K}	6.55 ± 0.37^{K}	6.37 ± 0.20^{K}	5.31 ± 0.31^{L}	4.62 ± 0.26^{M}	5.888
T_3^0	8.77 ± 0.03^{FGH}	8.39 ± 0.02^{HI}	8.23 ± 0.08^{I}	8.15 ± 0.15^{I}	8.13 ± 0.14^{I}	8.334
T_3^a	11.89 ± 0.13^{B}	11.27 ± 0.16^{C}	10.58 ± 0.10^{D}	8.69 ± 0.12^{FGH}	8.67 ± 0.10^{FGH}	10.22
T_3^b	11.37 ± 0.07^{C}	11.13 ± 0.07^{C}	10.16 ± 0.03^{E}	8.50 ± 0.03^{GHI}	8.49 ± 0.03^{GHI}	9.93
Mean	10.06	9.82	9.45	8.25	7.72	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

Table (8): Effect of a 120-day storage period at room temperature on the total phenols content (mg/100g) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	267.21 ± 0.97^{A}	266.42 ± 0.88^{B}	264.35 ± 0.56^{C}	255.84 ± 0.46^{D}	242.89 ± 0.35^{E}	259.34
C2	218.17 ± 0.44^{I}	216.01 ± 0.04^{J}	211.62 ± 0.37^{M}	205.81 ± 0.05^{P}	198.53 ± 1.32^{S}	210.02
C3	214.36 ± 0.55^{K}	213.93 ± 0.76^{KL}	213.19 ± 0.48^{L}	211.61 ± 0.08^{M}	208.85 ± 0.28^{O}	212.38
T_3^0	235.15 ± 0.05^{F}	234.40 ± 0.22^{F}	230.22 ± 0.08^{G}	219.53 ± 0.25^{H}	210.56 ± 0.13^{N}	225.97
T_3^a	204.30 ± 0.16^{Q}	203.87 ± 0.12^{Q}	202.49 ± 0.08^{R}	194.28 ± 0.15^{T}	181.79 ± 0.54^{U}	197.34
T_3^b	178.37 ± 0.21^{V}	177.29 ± 0.10^{W}	175.38 ± 0.33^{X}	171.93 ± 0.04^{Y}	166.35 ± 0.09^{Z}	173.86
Mean	219.59	218.65	216.2	209.83	201.49	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.9 Antioxidant activity

The antioxidant activity of the fruit leathers, a measure of their ability to neutralize free radicals, was observed to decline significantly ($p < 0.05$) across all samples during the 120-day storage period (Table 9). This trend is expected, as the bioactive compounds responsible for this activity, such as phenolics and ascorbic acid, are known to degrade over time due to oxidative stress. At the beginning of the storage period (day 0), the single-fruit leathers exhibited the highest antioxidant activity. The date leather (C1) had the highest initial activity at 73.52%, followed closely by the pomegranate leather (C2) at 70.58% and the fig leather (C3) at 55.88%. The blended samples showed lower initial activity, ranging from 41.33% in the T_3^b sample to 43.96% in the T_3^o sample. By the end of 120 days, antioxidant capacity had diminished in all treatments. For instance, the activity in the date leather (C1) decreased to 67.36%, while the pomegranate leather (C2) dropped to 51.21%. The blended samples also saw a notable decline, with T_3^o falling to 27.23%. This loss in antioxidant activity is strongly correlated with the degradation of total phenols and ascorbic acid, as discussed in the previous sections. These findings are consistent with the existing literature. A gradual decrease in antioxidant activity during storage has been reported for guava and pineapple leathers (Basha, 2018; Shakoor *et al*., 2015). Kumar *et al*. (2020) also directly linked the decline in antioxidant activity in pomegranate leather to the corresponding loss of its phenolic content. Despite the reduction, the leathers retained a considerable level of antioxidant capacity, particularly the single-fruit variants, underscoring their potential as functional foods with shelf-stable health benefits.

Table (9): Effect of a 120-day storage period at room temperature on the antioxidant activity (%) of different fruit leather samples.

Treatments	0 Days	30 Days	60 Days	90 Days	120 Days	Mean
C1	73.52 ± 0.38 ^{A}	72.59 ± 0.36 ^{B}	72.16 ± 0.08 ^{B}	70.15 ± 0.12 ^{C}	67.36 ± 0.14 ^{D}	71.15
C2	70.58 ± 1.07 ^{C}	70.58 ± 1.07 ^{C}	66.30 ± 0.21 ^{E}	62.13 ± 0.12 ^{F}	51.21 ± 0.48 ^{I}	57.59
C3	55.88 ± 0.58 ^{G}	54.65 ± 0.88 ^{H}	51.84 ± 0.26 ^{I}	47.33 ± 0.78 ^{J}	41.21 ± 0.35 ^{M}	50.18
T_3^0	43.96 ± 0.11 ^{K}	43.17 ± 0.04 ^{L}	38.50 ± 0.08 ^{NO}	33.46 ± 0.29 ^{P}	27.23 ± 0.82 ^{Q}	37.26
T_3^a	43.03 ± 0.28 ^{L}	42.82 ± 0.29 ^{L}	39.06 ± 0.42 ^{N}	33.31 ± 0.06 ^{P}	25.74 ± 0.37 ^{R}	36.79
T_3^b	41.33 ± 0.89 ^{M}	40.71 ± 0.61 ^{M}	38.25 ± 0.15 ^{NO}	33.08 ± 0.50 ^{P}	24.56 ± 0.19 ^{S}	35.58
Mean	54.71	53.37	50.32	44.75	37.3	

Values represent the mean ± standard deviation of five replicates. Means followed by different superscript letters (A, B, C, etc.) are significantly different from each other ($P < 0.05$). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.10 Microbiological evaluation

The microbiological quality of the fruit leathers was assessed over the 120-day storage period, with results for Total Viable Bacterial Count (TVBC) and Total

Molds and Yeasts (TMY) presented in Table (10). Overall, the microbial counts remained well within acceptable safety limits for all samples throughout the study. At the beginning of the storage period (day 0), all samples showed low initial microbial loads. The pectin-fortified blended leathers (T_3^a and T_3^b) were particularly notable, showing no detectable bacteria or yeast and mold counts. The single-fruit leathers (C1, C2, C3) and the non-pectin blend (T_3^o) had low but measurable counts, typically ranging from 1.0×10^2 to 2.5×10^2 CFU/g for bacteria and 2.5×10^3 to 3.5×10^3 CFU/g for yeasts and molds. As the storage period progressed, a general trend of decreasing microbial counts was observed, particularly from day 60 onwards. By day 120, the bacterial counts in all blended samples (T_3^o, T_3^a, T_3^b) and the pomegranate leather (C2) were nil. Similarly, yeast and mold counts were either nil or had decreased to very low levels (0.5×10^3 CFU/g) in these samples. The low and decreasing microbial load across all treatments can be attributed to the products' low water activity (low moisture content), high sugar concentration, and low pH, all of which create an environment that is inhospitable to most microbial growth. The results indicate that the fruit leathers were microbiologically safe and stable throughout the 120-day storage period. The pectin-fortified sample (T_3^a) demonstrated the most robust microbial stability, suggesting that the addition of pectin may enhance the product's preservative qualities.

Table (10): Effect of a 120-day storage period at room temperature on the microbiological quality (CFU/g) of different fruit leather samples.

Treatments	0 Days		30 Days		60 Days		90 Days		120 Days	
	TVBC	TMY	TVBC	TMY	TVBC	TMY	TVBC	TMY	TVBC	TMY
C_1	2×10^2	3×10^3	2.5×10^2	4.5×10^3	2.5×10^2	4×10^3	1.5×10^2	2×10^3	Nil	0.5×10^3
C_2	1.5×10^2	3.5×10^3	2×10^2	4×10^3	2×10^2	4×10^3	1.5×10^2	2×10^3	Nil	1×10^3
C_3	1.5×10^2	2.5×10^3	2.5×10^2	3.5×10^3	2×10^2	3.5×10^3	1×10^2	1.5×10^3	Nil	0.5×10^3
T_3^0	1×10^2	3×10^3	2×10^2	3.5×10^3	0.5×10^2	3.5×10^3	Nil	0.5×10^3	Nil	Nil
T_3^a	Nil	1×10^3	Nil	1.5×10^3	Nil	1×10^3	Nil	Nil	Nil	Nil
T_3^b	Nil	0.5×10^3	Nil	1.5×10^3	Nil	2.5×10^3	Nil	0.5×10^3	Nil	Nil

TVBC: Total Viable Bacterial Count; TMY: Total Molds and Yeasts. All counts are in Colony Forming Units per gram (CFU/g). C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

3.11 Sensory evaluation

The sensory attributes of fruit leathers, including color, taste, odor, texture, and overall acceptability, were evaluated using a 9-point hedonic scale. As shown in Table (11), a statistically significant ($p < 0.05$) decline was observed in most sensory scores across all samples during the 120-day storage period. However, the blended formulation with a moderate pectin level (T_3^a) consistently outperformed

all other treatments. At the beginning of the storage period (day 0), the T_3^a sample achieved the highest scores in all categories, including color (8.57), taste (9.07), odor (8.00), texture (8.73), and overall acceptability (8.67). This indicates a strong initial preference for the blended product. The success of this formulation can be attributed to the harmonious combination of flavors from the date, pomegranate, and fig blend, along with the desirable mouthfeel and reduced stickiness provided by the 1.5g addition of pectin. In contrast, the single-fruit leathers, particularly C2 (pomegranate) and C3 (fig), received lower scores, especially for odor and texture. After 120 days of storage, while all samples experienced a decline in sensory scores, the T_3^a sample remained the most preferred, with an overall acceptability score of 8.00. This demonstrates its superior sensory stability compared to the other formulations. The results suggest that while blending fruits creates a desirable flavor profile, the addition of a moderate amount of pectin is crucial for achieving an optimal texture that is highly rated by consumers. The sample with a higher pectin concentration (T_3^b) did not perform as well, suggesting that excessive pectin can negatively impact the final sensory characteristics.

Table (11): Sensory evaluation scores of different fruit leather samples on Day 0 and Day 120 of storage.

Treatment	Storage period	Color	Taste	Odor	Texture	Overall acceptability
C1	Day 0	7.63 ± 0.15	8.23 ± 0.25	8.00 ± 0.00	8.20 ± 0.17	8.13 ± 0.12
	Day 120	6.07 ± 0.12	6.70 ± 0.26	6.40 ± 0.20	6.73 ± 0.25	6.67 ± 0.35
C2	Day 0	6.93 ± 0.06	6.70 ± 0.26	6.07 ± 0.12	6.00 ± 0.00	6.00 ± 0.00
	Day 120	5.27 ± 0.64	5.13 ± 0.23	4.37 ± 0.32	4.60 ± 0.10	4.80 ± 0.17
C3	Day 0	7.20 ± 0.17	6.07 ± 0.12	6.87 ± 0.12	6.47 ± 0.15	6.67 ± 0.29
	Day 120	5.70 ± 0.10	4.73 ± 0.12	6.17 ± 0.29	5.00 ± 0.20	4.70 ± 0.53
T_3^o	Day 0	7.53 ± 0.15	8.13 ± 0.12	7.53 ± 0.06	8.17 ± 0.06	8.00 ± 0.00
	Day 120	6.83 ± 0.25	7.83 ± 0.06	7.07 ± 0.12	7.50 ± 0.10	7.27 ± 0.12
T_3^a	Day 0	8.57 ± 0.12	9.07 ± 0.12	8.00 ± 0.00	8.73 ± 0.25	8.67 ± 0.29
	Day 120	7.67 ± 0.29	8.17 ± 0.29	7.33 ± 0.29	8.07 ± 0.12	8.00 ± 0.00
T_3^b	Day 0	7.27 ± 0.06	8.07 ± 0.12	7.17 ± 0.06	7.77 ± 0.06	7.50 ± 0.00
	Day 120	6.13 ± 0.12	6.57 ± 0.12	5.83 ± 0.15	6.23 ± 0.25	6.00 ± 0.00

Values represent the mean ± standard deviation of five replicates, based on a 9-point hedonic scale. C1 (Control): Date leather. C2 (Control): Pomegranate leather. C3 (Control): Fig leather. T3 Pulp (Base Mixture): A blend of date, pomegranate, and fig pulps (3:2:1 ratio) with 1.5 g citric acid and 500 g sugar per 1800 g of pulp. T_3^o: Leather made from 300 g of T3 pulp with 0 g pectin. T_3^a: Leather made from 300 g of T3 pulp with 1.5 g pectin. T_3^b: Leather made from 300 g of T3 pulp with 2.5 g pectin.

4. Conclusion

This study evaluated the effects of a 120-day ambient storage period on the physicochemical, functional, sensory, and microbiological properties of fruit leather developed from dates, pomegranates, and figs. The results demonstrated that while storage induced significant changes, such as an increase in moisture and sugar

content and a decrease in bioactive compounds like ascorbic acid and total phenols, all products remained microbiologically safe and stable. The key finding of this research was the superior performance of the blended fruit leather fortified with a moderate concentration of pectin (1.5 g), designated as sample T_3^a. This formulation consistently achieved the highest scores in sensory evaluations for color, taste, texture, and overall acceptability at both the beginning and end of the storage period. Furthermore, it maintained a favorable balance of chemical and functional properties, indicating enhanced stability compared to single-fruit or non-fortified leather. Therefore, this study concludes that the development of blended fruit leather using dates, pomegranates, and figs, fortified with 1.5 g of pectin, presents a promising strategy for creating a high-quality, nutrient-rich, and shelf-stable functional food. This formulation is recommended for commercial applications to produce a value-added product with excellent sensory appeal and extended shelf life, offering a practical solution for fruit preservation and waste reduction.

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