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Evaluation of Novel Fruit Leathers Prepared from Pomegranate and Strawberry

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ABSTRACT

This study aimed to develop novel fruit leathers from pomegranate and strawberry and to evaluate their physicochemical, phytochemical, and sensory properties during storage. Three formulations were prepared: T1 (pomegranate only), T2 (pomegranate: strawberry, 1:1), and T3 (pomegranate: strawberry, 2:1). Moisture, ash, total soluble solids (TSS), pH, acidity, sugars, total phenolics, flavonoids, anthocyanins, antioxidant activity, vitamin C, texture profile, and sensory attributes were analyzed at 0, 3, and 6 months of storage. At zero time, total phenolic content ranged from 227.29 to 247.63mg GAE/100g, flavonoids from 91.10 to 105.34 mg CE/100g, anthocyanins from 68.66 to 84.83mg/100g, antioxidant activity from 64.0% to 70.10%, and vitamin C from 21.22 to 68.88mg/100g, depending on the treatment. These bioactive compounds gradually declined during storage. Sensory evaluation revealed that all formulations were acceptable, with the 1:1 blend (T2) receiving the highest scores for color, taste, texture, and overall palatability. Texture profile analysis also confirmed superior firmness and chewiness in T2 at zero time. The findings demonstrate that combining pomegranate with strawberry enhances both nutritional quality and consumer acceptance of fruit leathers, supporting their potential as a healthy, value-added snack for local consumption and export markets.

1. Introduction

Fruits are essential components of a healthy diet as they provide vitamins, minerals, fiber and natural antioxidants. Regular fruit consumption has been associated with strengthening the immune system and reducing the risk of chronic diseases, which makes fruits an ideal source for developing functional food products. Pomegranate (*Punica granatum L.*), belonging to the family Punicaceae, is considered one of the most important fruit crops due to its high nutritional and functional value. It is a rich source of bioactive compounds such as polyphenols, flavonoids, and anthocyanins, which exhibit antioxidant, anticancer, and anti-atherosclerotic properties (Aviram & Dornfeld, 2001; Ozgen et al., 2008). In Egypt, pomegranate cultivation has expanded significantly, particularly in Upper Egypt, producing about 672,827 tons annually (Bulletin of Agricultural Statistics, 2022). The fruit has been traditionally used in folk medicine in various cultures, including Greek, Ayurvedic, Unani, and Egyptian practices (Reddy, 2018). Strawberry (*Fragaria ananassa*), a member of the *Rosaceae* family, is another fruit of high nutritional and commercial importance. It is rich in anthocyanins, ellagitannins, vitamin C, and phenolic compounds, which contribute to its strong antioxidant activity and health-promoting effects (Giampieri et al., 2012). In Egypt, strawberry production is concentrated in governorates such as Beheira, Sharqia, Ismailia, and Qalyubia, with an annual yield of approximately 687,653 tons (Bulletin of Agricultural Statistics, 2022). Its attractive color, flavor, and nutritional benefits make it a valuable raw material for both fresh consumption and processing Fruit leather is a traditional dried fruit product prepared from fruit purees or juices that are spread into thin layers and dehydrated. Drying reduces the moisture content, inhibits microbial growth, and extends shelf life, while preserving much of the nutritional value (Huang & Hsieh, 2005).

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Fruit leathers are widely produced in countries such as Turkey, Lebanon, Syria, and Egypt, where they are known under different local names (Yilmaz et al., 2015). The quality of fruit leathers depends on both the raw material and the processing technology, with parameters such as bioactive content, color, and texture being strongly influenced by fruit type and drying conditions (Bharambhe et al., 2009; Tezcan et al., 2009). In recent years, consumer demand for natural, functional, and minimally processed foods has increased worldwide. Fruit leathers represent a promising category of healthy snacks that combine extended shelf life with high nutritional value and consumer appeal. Developing novel formulations based on locally cultivated fruits such as pomegranate and strawberry could add value to Egyptian horticultural crops, reduce post-harvest losses, and create new opportunities for both domestic markets and export. Although both pomegranate and strawberry are widely cultivated in Egypt, their combined use in producing fruit leathers remains underexplored. Incorporating strawberry into pomegranate-based leathers may enhance the sensory quality and increase the levels of anthocyanins, vitamin C, and other bioactive compounds. Therefore, the objective of this study was to develop and evaluate novel fruit leathers from pomegranate and strawberry blends, and to assess their physicochemical, phytochemical, textural, and sensory characteristics during storage.

2. Material and Methods

Materials

Pomegranate and strawberry fruits were obtained from local markets in Giza, Egypt. All solvents used for spectrophotometric analyses were of analytical grade. chemicals and reagents were purchased from El -Gomhouria Company for medical materials, Giza, Egypt.

Preparation of pomegranate juice

Fresh strawberries were washed with tap water, and green stems were removed. The juice was blended, filtered, and concentrated under reduced pressure at 60°C to reach 40% TSS using a rotary evaporator

Preparation of sheets

Concentrated juices of pomegranate and strawberry were mixed in different ratios:

- T1 (Control): Pomegranate juice without any additives.
- T2: Pomegranate:Strawberry (1:1 v/v).
- T3: Pomegranate:Strawberry (2:1 v/v).

Each mixture was poured into stainless steel trays lined with oil-coated polyethylene sheets to form thin layers. The samples were dried in a hot air oven at 65o C for 36 hours until leather like texture was obtained. The dried sheets were packed in cellophane wraps and stored at room temperature for analysis.

Analytical Methods

Chemical Analysis

Moisture content, total soluble solids (TSS), ash, pH, and total acidity were determined according to AOAC methods (2016). Total sugars were determined by clarifying aqueous extracts with lead acetate, precipitating excess lead with sodium oxalate, and measuring sugars following AOAC (2005).

Total phenolics were determined using the Folin Ciocalteu method described by Cosmulescu & Trandafir (2012). Absorbance was measured at 765nm, and results were expressed as mg gallic acid equivalents (GAE) per 100g sample.

Determination of total flavonoids compounds

Flavonoid content was measured spectrophotometrically at 510nm using the aluminum nitrate colorimetric method (Cosmulescu et al., 2015). Results were expressed as mg catechin equivalents (CE) per 100g sample. Antioxidant activity was assessed according to Braca et al. (2002) using the DPPH radical scavenging assay. Samples (10g) were extracted with 100 ml of 80% methanol. Sixty microliters of the extract were mixed with 1.5 ml of DPPH solution (6×10^{-5} M). After incubation in the dark for 30 min at room temperature, absorbance was measured at 515 nm. Scavenging activity was calculated as:

DPPH scavenging activity% = AB–AS/AB×100, where AB=Blank=all reagents except sample and AS = the absorbance of extracts.

Anthocyanin content was determined according to Ranganna (1979) and expressed as mg per 100g sample.

Ascorbic acid content was determined following the method described by Satria et al. (2021) and AOAC (2000). Results were expressed as mg/100g sample. Texture profile parameters (firmness, cohesiveness, gumminess, chewiness, springiness, resilience, adhesiveness) were determined according to Bourne (2003).

Sensory evaluation

Sensory attributes (color, taste, odor, texture, overall acceptability) were evaluated by trained panelists using a 10-point hedonic scale (Lee et al., 2003). Scores were categorized as: excellent (10), very good (8–9), palatable (6–7), and non-palatable (0 –5).

Statistical analysis

Data were analyzed by ANOVA using SPSS (Version 11). The experimental design was completely randomized, and significance was considered at $p < 0.05$. Mean differences were compared using the LSD test (Steel et al., 1980).

3. Results and Discussion

Table 1 presents the physicochemical composition of fresh pomegranate and strawberry. Pomegranate contained 80.78% moisture, 16.3% total soluble solids and 11.67% total sugars while strawberry showed higher moisture content (90.11%) but lower TSS (7.50%), and total sugars 6.92%. These results are close to those reported by Maria, et al. (2000) and Maslov et al. (2025). Regarding bioactive compounds, strawberry exhibited slightly higher total phenolics (220.5mg/100g) compared to pomegranate (202.2 mg/100g), whereas pomegranate had higher flavonoids (70.29mg/100g) than strawberry (68.3 mg/100g). Antioxidant activity was high in both fruits, reaching 90.87% in pomegranate and 89.77% in strawberry, confirming their potential as rich sources of natural antioxidants. The results are in close agreement with those reported by Latif1 and Abdel-Aleem2 (2019), who found that pomegranate juice had a TSS of 16.75±1.3, pH of 3.85±0.23, acidity of 5.24±1.5%, anthocyanins of 45.06±1.15mg/100 g, total phenolics of 162.48±1.5mg/100g, total flavonoids of 307.38±1.2mg/100g, and total tannins of 77.13±1.09mg/100g. These findings confirm that the values obtained in this study are consistent with previous research, supporting the reliability of the measured physicochemical and phytochemical properties.

Table 1.Physiochemical and phytochemical of raw materials (FW)

Physicochemical properties	Pomegranate	Strawberry
Moisture	80.78^{b}±0.28	91^{a}±0.7
Ph	3.14^{b}±0.06	3.4^{a}±0.02
Ash	0.6^{b}±0.05	0.7±^{a}0.03
T.S.S	16.3^{a}±0.3	8.4^{b}±0.25
Total acidity	1.59^{a}±0.24	1.16^{a}±0.12
Total sugar	11.67^{a}±0.27	6.1^{b}±0.23
Total phenols mg/100g equ. mg gallic acid	202.2^{b}±1.1	220.5^{a}±1.5
Total flavonoids mg/100g equ. mg catechin	70.29^{a}±0.44	68.30^{b}±040
Antioxidant %	90.87^{a}±0.39	89.77^{b}±0.14
Anthocyanin's mg/100g	81.35^{a}±0.25	72^{b}±0.7
Vitamin c mg/100g	25.30^{b}±0.4	45^{a}±0.75

Physiochemical properties of sheets during storage periods at room temperature (20±5°C)

Table 2 presents the chemical composition of the fruit leather treatments on a dry weight basis. Moisture content increased slightly in all formulations during storage, rising from 15.21% to 16.09% in T1, from 13.21% to 14.66% in T2, and from 12.90% to 13.58% in T3 after six months. A similar increasing trend was observed for total soluble solids (TSS), which ranged between 65.5 and 66.9%, with T3 showing the highest values. The pH values of all treatments ranged between 3.83 and 4.15, which are in agreement with Tontul and Topuz (2017), who reported pomegranate leathers to have pH values of 3.61–3.68, and with Onsekizoglu (2013), who

highlighted that the pH of fruit leathers depends mainly on fruit composition and processing conditions. Total acidity varied between 0.007 and 0.130%. In terms of total sugars, T3 recorded the highest value (59.72%) at zero time compared with 54.71% and 53.90% in T1 and T2, respectively. The higher sugar content in T3 may be attributed to heat-induced hydrolysis of polysaccharides, hemicelluloses, and cellulose into simple sugars, as reported by Hernández et al. (2012). During storage, total sugars gradually decreased in all samples, reaching 45.70–52.22% depending on the treatment. This reduction could be explained by non-enzymatic browning reactions occurring during storage (Ranganna, 1977).

Table 2. Effect of storage period on the physiochemical properties of sheet at room temperature

physicochemical properties	Pomegranate sheet (T1)			Pomegranate :strawberry 1:1 (T2)			physicochemical properties 2:1 (T3)		
	0	3	6	0	3	6	0	3	6
Moisture	15.21^{b} ± 0.39	15.89^{b} ± 0.44	16.97^{a} ± 0.47	13.21^{b} ± 0.61	13.92^{ab} ± 0.47	14.66^{a} ±0.56	12.90^{a} ±0.25	12.98^{a} ±0.38	13.58^{a} ±0.48
pH	3.87^{a} ±0.09	3.92^{a} ±0.22	4.05^{a} ±0.15	3.90^{a} ±0.18	3.99^{a} ±0.31	4.1^{a} ±0.3	3.83^{a} ±0.48	3.87^{a} ±0.47	4.15^{a} ±0.45
TSS	65.6^{a} ±0.55	66.0^{a} ±0.60	66.4^{a} ±0.70	65.9^{a} ±0.60	66.0^{a} ±0.54	66.6^{a} ±0.42	66.6^{a} ±0.45	66.7^{a} ±0.47	66.9^{a} ±0.53
Total acidity	1.82^{a} ±0.27	1.73^{a} ±0.16	1.61^{a} ±0.23	1.77^{a} ±0.32	1.62^{a} ±0.32	1.52^{a} ±0.29	1.73^{a} ±0.32	1.68^{a} ±0.31	51^{a} 0.26
Total sugars	54.71^{a} ±0.490	52.22^{b} ±0.47	49.70^{c} ±0.45	53.90^{a} ±0.45	52.5^{b} ±0.43	46.6^{c} ±0.50	59.7^{a} ±0.47	53.4^{b} ±0.43`	50.6^{c} ±0.45
Total phenols mg/100g equ. mg gallic acid	227.29^{a} ±0.39	220.56^{b} ±0.40	211.62^{c} ±0.44	248.61^{a} ±0.49	236.62^{b} ±0.47	221.81^{c} ±0.46	236.14^{a} ±0.39	228.39^{b} ±0.49	220.75^{c} ±0.48
Total flavonoids mg/100g equ. catechin	93.18^{a} ±0.48	90.13^{b} ±0.47	74.01^{c} ±0.46	105.34^{a} ±0.44	8.44^{b} ±0.439	88.40^{c} ±0.38	101.40^{a} ±0.37	90.54^{b} ±0.44	86.91^{c} ±0.43
Total anthocyanins mg/100g	68.66^{a} ±0.46	65.98^{b} ±0.43	58.39^{c} ±0.41	86.66^{a} ±0.46	78.18^{b} ±0.48	76.89^{c} ±0.51	84.83^{a} ±0.44	79.23^{b} ±0.43	70.54^{c} ±0.39
Antioxidants%	64^{a} ±0.45	44.50^{b} ±0.38	25.0^{c} ±0.38	66.80^{a} ±0.40	46.0^{b} ±0.38	25.60^{c} ±0.40	70.10^{a} ±0.41	50.0^{b} ±0.38	30.50^{a} ±0.39
Vitamine C mg/100g	21.22^{a} ±0.44	20.80^{a} ±0.41	19.06^{b} ±0.43	39.77^{a} ±0.34	34.85^{b} ±0.30	31.63^{c} ±0.35	68.88^{a} ±0.39	63.20^{b} ±0.29	52.07^{c} ±0.38

Bioactive compounds

Total phenolic compounds, flavonoids antioxidant activity, Anthocyanins and vitamin C are among the major bioactive compounds that play an important role in promoting health. As shown in Table 2, the T2 the T2 formulation (pomegranate: strawberry 1:1) recorded the highest total phenolic content (248mg GAE/100g) at zero time, followed by T3 (236mg GAE/100g) and T1 (227mg GAE/100g). A gradual decline in phenolic content was observed during storage at room temperature for up to six months. After storage, total phenols decreased to 211–220mg GAE/100g in T1, 221–235mg GAE/100g in T2, and 220–228mg GAE/100g in T3. This reduction could be attributed to oxidation and polymerization of phenolic compounds during storage. These findings are consistent with the results of Tontul and Topuz (2017), who reported a similar decline in phenolic compounds in fruit leathers during storage

Total flavonoids

As shown in Table 2, the initial concentration of total flavonoids was 93.18mg CE/100g DW in pomegranate leathers (T1), 105.34mg CE/100g DW in the 1:1 blend (T2), and 101.40mg CE/100g DW in the 2:1 blend (T3). These results indicate that flavonoids were the most abundant bioactive compounds in the fruit leathers. Flavonoid intake has been reported to vary widely among adults, ranging from 21.2 to 191.2 mg/day, depending on dietary assessment methods and databases used (Chun et al., 2012). Therefore, the levels detected in the current formulations may contribute substantially to daily dietary requirements. During storage, flavonoid content decreased gradually in all treatments. The reductions after 3 and 6 months were 3.28% and 20.58% for T1, 6.55% and 15.77% for T2, and 10.71% and 14.28% for T3, respectively. Notably, T3 exhibited the lowest decline after six months, suggesting greater stability of flavonoids in this formulation compared to T1 and T2.

Anthocyanin contents

Anthocyanin content at zero time was 68.6 mg/100g in pomegranate leathers (T1), compared with higher levels of 86.6 and 84.83mg/100g in T2 (1:1) and T3 (2:1), respectively. These results indicate a clear enhancement in anthocyanin levels when strawberry was incorporated into the formulations. After six months of storage, anthocyanins decreased in all treatments, with values of 58.39mg/100g in T1, 78.89mg/100g in T2, and 78.34mg/100g in T3. The higher retention of anthocyanins in blends containing strawberry suggests a stabilizing effect, which is consistent with the findings of Assous et al (2014). The data confirm that combining strawberry with pomegranate produces fruit leathers rich in anthocyanins, which not only enhance the natural red color but also provide valuable bioactive compounds. This highlights the potential of such formulations to serve as functional ingredients in the development of health-oriented food products.

Antioxidant activity

The antioxidant activity of fruit leather formulations, measured by the DPPH assay, is presented in Table 2. At zero time, activity was 68.66% in T1, and increased to 81.66% and 84.83% in T2 and T3, respectively, indicating the positive effect of incorporating strawberry into pomegranate leathers. During storage, antioxidant activity gradually declined, reaching 58.30–65.98% in T1, 72.89–78.18% in T2, and 69.54–79.63% in T3 after six months. This reduction could be attributed to the degradation of phenolics, flavonoids, and anthocyanins during storage. Similar trends were reported by Amarowicz et al. (2004) and Leja et al. (2013), who noted that phytochemical antioxidants are susceptible to oxidative degradation over time. The antioxidant capacity observed in the current study is largely associated with the presence of bioactive compounds, including total phenolics, flavonoids, and anthocyanins. These phytochemicals can act directly as radical scavengers or indirectly by stimulating endogenous antioxidant enzymes (Kryston et al., 2011). Their protective effect is particularly important in counteracting free radical damage, which has been linked to chronic diseases such as cancer and cardiovascular disorders (Özgen et al, 2008). Vitamin C levels also showed a decreasing trend during storage. In T1, values declined from 21.22 to 19.06mg/100g, while in T2 they decreased from 39.77 to 31.63mg/100g. T3 exhibited the highest values, ranging from 68.88 to 52.07mg/100g. The higher vitamin C content in T3 may explain its strong initial antioxidant activity, although losses were significant during storage.

Sensory evaluation of sample

Organoleptic evaluation is considered the final determinant of product quality from the consumer's perspective (Jimenez et al., 1989). The sensory attributes of color, taste, odor, texture, and overall acceptability of the fruit leather samples are presented in Table 3. Significant differences were observed among treatments at different storage periods. At zero time, treatment T2 (pomegranate: strawberry, 1:1) achieved the highest scores across all sensory attributes, followed by T1, whereas T3 recorded the lowest scores. No significant differences were found between T1 and T3 for most attributes at zero time. During storage, sensory scores decreased gradually in all treatments, yet T2 consistently maintained superior acceptability compared to the other formulations. These findings confirm that blending pomegranate with strawberry at a 1:1 ratio enhances the sensory quality and consumer appeal of the final product. After 3 and 6 months of storage, no significant differences were detected between T1 and T3 in terms of color, taste, odor, texture, and overall acceptability, whereas significant differences were observed between T2 and T3. The panelists' descriptions of overall palatability ranged from "very palatable" to "palatable" for all treatments, with only slight variations among samples. These findings indicate that both pomegranate and pomegranate–strawberry leathers retained acceptable sensory quality throughout storage at room temperature (25±5°C).

Finally, it was clearly evident that the best formulation was T2 (pomegranate: strawberry, 1:1), which consistently received the highest scores across all sensory attributes and was most preferred by the panelists

Table 3. Organoleptic characteristics of Pomegranate sheets at zero time, 3 months and 6 months.

Storage months / Samples	Zero time				
	Color	Taste	Odor	Texture	Overallpalatability
T1	7.5^{ab}±1.04	7.75^{ab}±1.54	7.5^{a}±1.39	7.83^{ab}±1.16	7.6^{ab}±0.98
T2	8.4^{a}±0.66	8.8^{a}±0.75	8.3^{a}±0.81	9.1^{a}±0.66	8.75^{a}±0.61
T3	7.08^{b}±1.02	7.08^{b}±1.35	6.9^{a}±1.35	7.16^{b}±1.60	6.9^{b}±1.30
	3 months.				
T1	7^{b}±0.97	7.5^{ab}±1.34	7.3^{ab}±1.25	7.5^{ab}±0.97	7.4^{b}±0.80
T2	8.25^{a}±0.68	8.5^{a}±0.58	8.1^{a}±0.81	8.8^{a}±0.51	8.5^{a}±0.63
T3	6.8^{b}±0.87	6.8^{b}±1.16	6.7^{b}±0.75	6.9^{b}±1.39	6.5^{b}±1.11
	6 months.				
T1	7^{ab}±0.84	7.25^{ab}±1.17	7.1^{ab}±1.15	7.3^{b}±0.82	7.2^{b}±0.68
T2	8^{a}±0.77	8.3^{a}±0.51	7.9^{a}±.80	8.6^{a}±0.58	8.3^{a}±0.52
T3	6.6^{b}±0.80	6.6^{b}±1.02	6.5^{b}±0.63	6.7^{b}±1.21	6.3^{b}±0.87

T1 Pomegranate-
T2 1-1 Pomegranate:1Strawberry
T3 2-1 Pomegranate:1 Strawberry

Physical properties of sheets treatments Texture Profile Analysis (TPA)

The effect of adding strawberry fruit to pomegranate for produce sheets were studied. Some physicochemical properties of sheets treatments were determined as shown in Tables 4. The force-deformation of sheets treatments are given in Table 4, The TPA attributes of three sheets treatments carried out by adding strawberry fruit to pomegranate for produce sheets.

Table 4. Texture profile analysis (TPA) at zero time, 3 months and 6 months

Treatments	Zero time						
	Firm	Coh	Gum	Chew	Sprin	Resil	Adhe
T_1	88.55^{b}±0.20	0.34^{a}±0.04	29.74^{b}±0.38	15.60^{b}±0.30	0.52^{a}±0.04	0.35^{a}±0.04	0.0
T_2	243.11^{a}±0.19	0.33^{a}±0.04	80.32^{a}±0.34	38.90^{a}±0.27	0.48^{a}±0.04	0.25^{b}±0.03	0.0
T_3	81.53^{c}±0.18	0.34^{a}±0.03	27.71^{c}±0.31	13.20^{c} ±0.28	0.48^{a}±0.06	0.19^{b}±0.06	0.0
	3 months						
T1	125.33b±0.32	0.34a±0.04	42.73c±0.38	37.32a±0.34	0.47a±0.04	0.26a±0.04	0.0
T2	147.83a±0.32	0.35a±0.06	49.57a±0.28	23.56b±0.35	0.46a±0.06	0.18a±0.05	0.0
T3	114.93c±0.31	0.38a±0.05	46.86b±0.35	14.19c±0.31	0.48a±0.04	0.18a±0.04	0.0
	6 months						
T1	162.0a±0.32	0.34a±0.03	55.42b±0.32	22.72b±0.36	0.41a±0.04	0.16a±0.04	0.0
T2	52.5c±0.31	0.36a±0.04	18.81c±0.35	8.22c±0.31	0.44a±0.06	0.11a±0.05	0.0
T3	148.52b±0.25	0.42a±0.05	62.0a±0.36	29.58a±0.38	0.48a±0.07	0.17a±0.06	0.0

The texture profile attributes (TPA) of the fruit leather treatments are presented in Table 4. At zero time, firmness was highest in T2 (245.11), followed by T1 (88.55) and T3 (81.51), indicating that the incorporation of strawberry at a 1:1 ratio enhanced hardness. Firmness is directly related to gumminess and chewiness, which also followed the same pattern, with T2 recording the highest values. Cohesiveness ranged between 0.33 and 0.93, with no significant differences between T1 and T3, while T2 showed slightly lower cohesiveness. Springiness and resilience were highest in T1, reflecting greater elasticity compared to the blended formulations. These results are consistent with reports by Szczesniak (2002) and Rahman & Al-Mahrouqi (2009), who emphasized the link between firmness and gumminess in gel-based food matrices. During storage, a general decline in firmness, gumminess, chewiness, springiness, and resilience was observed across all treatments. After three months, the most pronounced decreases were noted in T2, where firmness dropped to 147.83 and gumminess to 49.57. After six months, firmness in T2 further decreased to

52.5, accompanied by sharp reductions in chewiness and resilience across all treatments. The reduction in texture parameters during storage may be attributed to acid hydrolysis and degradation of structural polysaccharides and proteins, leading to weaker gel strength (FOW, 2012). Overall, T2 (pomegranate: strawberry, 1:1) initially exhibited superior textural quality; however, its properties declined more sharply during storage compared with T1 and T3. These findings indicate that while the 1:1 formulation provides favorable initial texture and consumer appeal, optimization of storage conditions is necessary to maintain quality over time.

Color attributes of fruit sheets at zero time and during the storage period at room temperature (20 + 5 oC)

Color attributes (L, a*, b*) of the fruit leathers measured by the Hunter Lab system are shown in Table 5. Significant differences were observed among the three treatments. At zero time, T3 (pomegranate: strawberry, 2:1) exhibited the highest values of lightness (L*), redness (a*), and yellowness (b*), followed by T2, while T1 (pomegranate only) had the lowest scores. The higher a* and b* values in the blended treatments reflect the contribution of strawberry pigments, particularly anthocyanins, which enhanced the red and yellow tones of the product. During storage, a gradual decline in L*, a*, and b* values was observed across all treatments, indicating darkening and color degradation over time. This color loss may be attributed to anthocyanin degradation and non-enzymatic browning reactions, as previously reported in dried fruit products (Tontul & Topuz, 2017). Overall, the incorporation of strawberry improved the visual quality of the leathers, although color stability decreased during storage.*

Table 5. Color attributes of fruit sheets at zero time and during the storage period

Treatments	L	a	B	^{o}h	*C
			Zero time		
T_1	25.32^{c}±0.2	3.38^{c}±0.1	5.81^{b}±0.1	59.81^{a}±0.4	6.72^{c}±0.27
T_2	26.05^{b}±0.2	3.96^{b}±0.1	5.84^{b}±0.1	55.86^{c}±0.4	7.06^{b}±0.29
T_3	27.17^{a}±0.1	4.65^{a}±0.2	7.58^{a}±0.2	58.47^{b}±0.4	8.89^{a}±0.22
			After three months		
T_1	29.11^{c}±0.1	3.98^{b}±0.2	7.27^{a}0.1	61.30^{a}0.3	8.29^{a}0.2
T_2	31.82^{a}±0.2	4.01^{b}±0.2	4.91^{c}0.2	50.76^{b}0.3	6.34^{b}0.2
T_3	30.39^{b}±0.2	5.13^{a}±0.1	5.82^{b}±0.1	48.61^{c}±0.3	7.76^{a}±0.2
			After six months		
T_1	28.25^{a}±0.2	4.48^{b}±o.1	7.07^{b}0.2	57.64^{a}±0.3	8.37^{b}±0.3
T_2	26.92^{b}±0.1	5.59^{a}±o.1	7.83^{a}0.2	54.48^{b}±0.3	9.62^{a}±0.2
T_3	24.33^{c}±0.1	5.61^{a}±o.1	3.79^{c}±0.2	34.04^{c}±0.2	6.77^{c}±0.3

Where: T_1 means pomegranate sheet without any additives; T_2 means sheet from pomegranate and strawberry puree by a ratio 1:1 and T_3 means sheet from pomegranate and strawberry puree by a ratio 2:1

Estimation of total aerobic bacteria count, yeast & molds count and E.coli for fruit sheets at zero time and during the storage period

Table 6 presents the microbiological quality of the fruit leathers during storage. The total aerobic bacterial counts were low at zero time (1.32–1.40 $\log_{10}$ CFU/g) and showed a slight increase during storage, reaching 1.52–1.77 $\log_{10}$ CFU/g after six months. Yeast and mold counts followed a similar trend, increasing from 1.50–1.65 $\log_{10}$ CFU/g at zero time to 1.83–1.96 $\log_{10}$ CFU/g after six months. Importantly, Escherichia coli was not detected in any of the samples throughout the storage period. The low microbial counts and absence of pathogenic E. coli confirm that the drying process and reduced water activity of the sheets effectively inhibited microbial growth, maintaining product safety during storage.

Table 6. Estimation of total aerobic bacteria count, yeast & molds count and E.coli for fruit sheets at zero time and during the storage

Treatments	Total aerobic bacteria count	yeast & molds count	E.coli
		Zero time	
T_1	1.40+0.02	1.65+0.22	Nil
T_2	1.34+0.02	1.60+0.22	Nil
T_3	1.32+0.02	1.50+0.22	Nil
		After three months	
T_1	1.53+0.02	1.86+0.22	Nil
T_2	1.42+0.02	1.81+0.22	Nil
T_3	1.38+0.02	1.74+0.22	Nil
		After six months	
T_1	1.77+0.02	1.96+0.22	Nil
T_2	1.60+0.02	1.90+0.22	Nil
T_3	1.52+0.02	1.83+0.22	Nil

Where: T_1 means pomegranate sheet without any additives; T_2 means sheet from pomegranate and strawberry puree by a ratio 1:1 and T_3 means sheet from pomegranate and strawberry puree by a ratio 2:1

4. Conclusion

This study demonstrated that incorporating strawberry juice with pomegranate in the production of fruit leathers enhanced their nutritional, functional, and sensory qualities. The final product can be considered a novel preservative-free, natural snack that aligns with consumer demand for healthy and functional foods. The 1:1 blend (T2) showed the highest levels of bioactive compounds, including phenolics, flavonoids, anthocyanins, antioxidant activity, and vitamin C, and achieved the best scores for color, taste, texture, and overall acceptability. Although phytochemical contents declined gradually during three and six months of storage, all products remained sensorially acceptable. Texture profile analysis also indicated that T2 had superior textural attributes at zero time, with some reductions observed during storage. From an industrial perspective, pomegranate–strawberry leathers represent a promising value-added product that can reduce post-harvest losses and create new opportunities in both local and export markets while meeting the growing demand for natural functional snacks.

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