Production and evaluation of high nutritional sheets formulated from red beetroot puree and pomegranate juice

Omar Turki Mamdoh Ershidat[1], Eatemad M. El-Sayed[2], Shaymaa A. Hozifa[2], Marwa Fawzi Ahmed El-Farsy[2], Dalia M. El-Mesiry[2], Soher Abd-Elfattah ElMeslamy[2], Rehab A. Shehata[3], Marwa A. Ahmed[3], Asmaa Antar Faramawy[4] and Essam Mohamed Elsebaie[5]*

[1]Department of Applied Science, All-Huson College University, Al-Balqa Applied University, Jordon; [2]Food Science and Technology Department, Faculty of Agriculture for Girls, Al-Azhar University, Cairo, Egypt; [3]Department of Food Science and Nutrition, College of Science, University of Bisha, P.B.551, Bisha, 61922, Saudi Arabia; [4]Nutrition and Food Science Department, Faculty of Home Economics, Al-Azhar University, Tanta, Egypt; [5]Food Technology Department, Faculty of Agriculture, Kafrelsheikh University, El Gish Street, Kafr El-Shaikh, Egypt

[*]**Corresponding Author:** Essam Mohamed Elsebaie, Food Technology Department, Faculty of Agriculture, Kafrelsheikh University, El Gish Street, Kafr El-Shaikh, Egypt. Email: Essam.ahmed@agr.kfs.edu.eg

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Abstract

The objective of this investigation was studying the Physicochemical characteristics and microbiological stability of five innovative fruit sheets containing red beetroot puree (RBRP) and pomegranate juice (PJ) in ratios of 100:0, 75:25, 50:50, 25:75, and 0:100 during 6-month storage at room temperature (25–30°C). The results showed that moisture content (ranging from 14.64% to 14.96%), water activity (ranging from 0.638 to 0.642), total phenols (ranging from 18.94 to 19.20 mg GAE/g), total flavonoids (ranging from 16.50 to 16.59 mg rutin [RE]/g), 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity (ranging from 73.66% to 77.02%), and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) scavenging activity (ranging from 50.13% to 52.09%) in 100% RBRP sheets were more than in 100% PJ sheets. In contrast, 100% RBRP sheets had a lower pH (ranging from 4.09 to 4.13), total soluble solids (TSS) (ranging from 63.99 Brix to 65.08 Brix), total sugars (ranging from 59.58% to 59.90%), and hardness (ranging from 12.88 N to 14.10 N) than that of 100% PJ sheets. In addition, the findings revealed that at zero time when the replacement percentage of PJ for RBRP increased in the sheets formula from 25% to 100%, there was increase in TSS (from 65.11 Brix to 67.41 Brix), acidity (from 1.03% to 1.90%), total sugars (from 59.29% to 61.72%), and hardness (from 12.27 N to 13.85 N) as well as decrease in moisture content (from 15.01% to 14.75%), water activity (from 0.652 to 0.630), total phenols content (18.71 to 17.01 mg GAE/g), total flavonoids content (15.74 to 12.97 mg RE/g), DPPH scavenging activity (from 72.19% to 63.28%), ABTS scavenging activity (from 50.86% to 44.28%), and L^* value (from 22.80 to 21.86). Significant decrease ($p \leq 0.05$) was observed in pH, moisture, water activity, total sugars, total phenol contents, total flavonoid contents, and antioxidant activity during the storage period. All sheets were found to be extremely sensory-acceptable and microbiologically safe. In conclusion, RBRP and PJ or a mix of them could be used as functional sheets with high storage stability.

Keywords: antioxidant capacity; healthy sheets; nutritive value; pomegranate sheet; red beet root sheet

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Introduction

Fruits are an essential component of a balanced and healthy diet. According to Hoque (2023), fruits are excellent for weight reduction and eye health due to their high content of phenolic compounds, antioxidants, carotenoids, anthocyanin, minerals, and vitamins. Fruits provide dietary fiber, minerals, and vitamins (thiamine, E, A, and C) that help prevent and treat a variety of illnesses, including heart disease, cancer, and stroke (Pruteanu *et al.*, 2023). Fruits with high dietary fiber content improve digestive tract functioning, which helps to relieve constipation (Dreher *et al.,* 2018). Fresh vegetables and fruits have a limited shelf life and are perishable. Fruit sheets, which are glossy, elastic, and rubbery to touch, are dried products with a long shelf life. These taste sweet. According to Neog *et al.* (2023), fruit sheets can be produced from one type of fruit, a blend, or a combination of fruits and vegetables. In order to produce a puree, fruits are often macerated and dried to appropriate consistency (Zhang *et al.*, 2023). Fruit sheets are a helpful procedure to preserve fruits because of their appearance and storage simplicity. Fruit sheets, especially for children and young adults, are an efficient strategy to enhance intake of fruits Chen *et al.*, 2024).

Fruit sheets are prepared by dehydrating just a small amount of fruit puree or a concentrated combination of fruit juice into a leather-like sheet with or without additives (Neog *et al.*, 2023). This renders them a more wholesome and practical snack option than chocolates and confections, particularly for kids and teenagers as well as for populations impacted by natural catastrophes or in war zones where food is scarce (Bandaru and Bakshi, 2020). Fruit leather is commonly eaten as a dessert or snack, and it's also a common ingredient in foods such as biscuits and morning cereal (Barman *et al*., 2021).

Additionally, it can be blended with water or other liquids to create "Qamar El-Din" drinks, which are extremely famous during Ramadan in Egypt and other Arabic nations. The drink is regarded as an excellent energy source due to its substantial amount of carbohydrates and high nutritional content, which includes vitamins and minerals (da Silva Simão *et al.*, 2020). In addition, it contains calories fewer than 100 kcal per serving, although this is much less than the calories found in other snacks (Huang and Hsieh, 2005).

Red beetroot (*Beta vulgaris* L.), a member of the Chenopodiaceae family, is a common global vegetable. It is also known as beetroot or table beet. Beetroot is a common food item consumed regularly (Ceclu and Nistor, 2020). Red beetroot has many nutritional and bioactive components, such as fibers, carbohydrates, minerals, vitamins, and betalains. It is also a great source of natural dyes and has many health benefits that are essential for human growth and development (Trishitman *et al.*, 2021).

Beetroot is regarded as a premium dietary supplement because of its abundant phytochemical compounds (ascorbic acid, phenolic acids, and carotenoids), which have demonstrated pharmacological applications and have been used for hundreds of years in traditional medicine to treat joint pain, gastrointestinal distress, and constipation (Hamedi and Honarvar, 2019). Additionally, because of its anti-lipid, anemic, and blood pressure-lowering effects (Dhiman *et al.*, 2021), the juice of beetroot has excellent antioxidant activity and exhibits antihypertensive and hypoglycemic properties (Babarykin *et al.*, 2019).

Globally, pomegranates (*Punica granatum* L.), which belong to the Punicaceae family, are grown in a range of microclimates. According to Naeem (2023), Egypt produced a total of 405,000 tonnes of pomegranates in 2018, which accounts for 13.6% of the global production. Pomegranate juice (PJ) contains a number of bioactive compounds, such as anthocyanins, flavonoids, and polyphenols, which exhibit anti-inflammatory, anti-cancer, and antioxidant effects as well as impacts atherosclerosis.

Pomegranate juice is a highly nutrient beverage with a sour-and-sweet taste that comes from the combination of glucose and phenolic molecules. Nevertheless, the fruit's architecture, such as the thick rind around the juicy arils within, can occasionally make it an eating challenge.

Relatively little information is available regarding employing red beetroot puree (RBRP) and PJ in the preparation of fruit sheets, despite the fact that a significant literature on the processing of fruit sheets from other types of fruit pulp has been published. The purpose of this study was to create novel fruit sheets from RBRP and PJ in five different formulations (100% RBRP, 100% PJ, 50% RBRP+50% PJ, 75% RBRP+25% PJ, and 25% RBRP+75% PJ). We evaluated the impact of blending ratio and storage for 6 months at room temperature (25–30°C) on the physicochemical parameters, bioactive components content, antioxidant activity, microbiological load, and sensory properties of the prepared sheets.

Materials and Methods

Materials

Fresh red beetroots (*Beta vulgaris*), variety Pablo, fresh pomegranate (*Punica granatum* L.) fruits, variety Manfaluti, citric acid, sugar, olive oil, and pectin were purchased from the local market in Tanta city, El-Gharbia Governorate, Egypt.

2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), gallic acid, 2,2-diphenyl-1-picrylhydrazyl (DPPH), and Folin–Ciocalteu reagent were acquired from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Other chemicals were acquired from Merck Co. (Darmstadt, Germany). Every chemical used in this research was of High-performance liquid chromatography (HPLC) quality, with 99.9% purity.

All media (nutritional agar, MacConkey broth, and potato dextrose agar) were bought from Difco Lab (Detroit, MI, USA).

Preparation of RBRP

Beetroot was cleaned with tap water after removing their rind; then their peels were removed and cut into slices. The slices were soaked in water (750-g red beetroots/150-mL water) and cooked for 15 min, after which the mixture (red beetroot and water) was crushed with a blender for 5 min to produce an extremely fine and homogenized puree, as indicated by Pandeirot and Handoko (2022).

Preparation of PJ

Hand washing, peeling, and manual removal of arils were performed on freshly pomegranate fruits before extraction of juice using a machine. The juice was filtered twice using a piece of cheesecloth to get clean juice. The filtered juice was heated at 70±5°C in a vacuum pan with continuous swirlling to prepare a PJ concentrate. Samples were heated to 50 Brix before being canned in glass bottles and chilled until used.

Fruit sheets processing

Fruit sheets were prepared from PJ and RBRP, either alone or in combination with citric acid, sugar, and pectin as indicated in Table 1. The contents were continuously swirled to obtain fine dispersion. Subsequently, the contents were placed into 50×40-cm trays coated with 8-mm-thick olive oil. Next, the contents were dried for 2 h at 70°C in a UNOX (XBC605) electric air oven (Roma, Italy) and then chilled for 10 h at 55°C. The dried sheets were rolled, coated in cellophane films, and kept in a cabinet at room temperature (between 25°C and 30°C) and 60–77% humidity until further examination.

Physicochemical characteristics of formulated sheets

The produced sheets were analyzed for their physicochemical attributes (pH, total soluble solids [TSS], acidity, moisture, water activity (a_w), total sugars, reducing sugars, non-reducing sugars, texture, and color) at every third month for 6 months.

pH, total soluble solids, and acidity measurement

pH was determined using a JENCO laboratory pH metre (Virginia, USA) by the standard procedure as assumed by AOAC International and Latimer (2016). Reichert digital refractometer (Osaka, Japan) was used to calculate TSS (as Brix) at room temperature according to the standard methodology outlined by AOAC International and Latimer (2016). The standard technique of Ranganna (2007) was used to measure titrable acidity (%) by utilizing 0.1-N sodium hydroxide.

Moisture content and water activity measurement

The moisture content of all sheets was measured using procedure No. 926.11 of the AOAC International and Latimer (2016). A Hygrolab3 Rotronic Water Activity Metre (Lucerne, Switzerland) was used to measure water activity at 25±3°C (AOAC International and Latimer, 2016).

Determination of total, reducing, and non-reducing sugars

The colorimetric techniques of Miller (1959) were used for estimating the contents of reducing sugar. 70%

Table 1. Formula of sheet samples prepared from RBRP and PJ concentrate.

Ingredients	Formula type				
	100% RBRP sheet	100% PJ sheet	50% RBRP+ 50% PJ sheets	75% RBRP+ 25% PJ sheets	25% RBRP+ 75% PJ sheets
Red beetroot puree (gm)	100	0	50	75	25
Pomegranate juice concentrate (gm)	0	100	50	25	75
Sugar (gm)	20	20	20	20	20
Pectin (5 g/kg)	0.5	0.5	0.5	0.5	0.5
Citric acid (gm)	0.5	0.5	0.5	0.5	0.5

RBRP: red beetroot puree; PJ: pomegranate juice.

ethanol, 50 mL, was used to extract 2 g of sample, which was then incubated for 3 h at 70°C in a water bath. Then the mixture was filtered. Distilled water was added to filtrate to make it up to 100 mL. After pipetting 3 mL of filtrate in a test tube and adding 3 mL of 3,5-dinitrosalicylic acid, the tube was shaken vigorously, heated to a precise temperature of 100°C for 10 min, and then left to cool under a stream of tap water. Color intensity measurements were done at 550 nm. To create a standard curve, different concentrations of pure glucose solution were used.

The previous filtrate was used to measure the total sugar content. After adding 5 mL of 6-N HCl to 10 mL of filtrate, the flask was placed in an incubator at 100°C for 2 h. Following the incubation period, 5 mL of 6-N NaOH was gradually added for neutralization, bringing the volume up to 25 mL. The procedure for measuring color and conducting the reaction was followed by decrease in sugars. By calculating difference between the total and reduced sugar contents, the amount of non-reducing sugars was measured.

Texture profile analysis

Hardness of fruit sheets was evaluated using the methodology described in Kurniadi *et al.* (2022). In short, an AMETEK TA2 texture analyzer (Florida, USA) with a 0.4-cm diameter cylindrical probe was used to perform the piercing test. The probe's test speed was 2 mm/s whereas its pre-test speed was 0.5 mm/s. The highest force with which the probe could pierce a sheet (2.5×2.5 cm) at a penetrating distance of 2 mm was used to assess hardness (N).

Color properties measurement

Colors of the prepared sheet samples were assessed by using the Lab Scan XE Hunter Lab color system (Virginia, USA). A white tile was used to calibrate the instrument (L^* = 92.46; b^* = -0.16, and a^* = -0.86). According to Giacalone *et al.* (2019), color values were denoted as L^* (bright/dark), a^* (red/green), and b^* (yellow/blue). The analysis was done in five replicates.

Bioactive compound of sheets

Fruit sheets extract preparation

With some modifications, the extract used to measure samples' levels of bioactive chemicals and antioxidant activity was prepared according to Kamiloglu *et al.* (2014). After homogenizing the sample with 80% methanol (6% w/v), it was sonicated for 10 min in an ultrasonic bath. After 1 h of continuous stirring at 250 rpm in an orbital shaker, the sample was finally filtered using a filter paper. With the leftover pulp, the same procedure was carried out. After combining all aliquots, 80% methanol was added to produce a final amount of 150 mL.

Determining total phenol content (TPC) and total flavonoid content (TFC)

According to Waterhouse (2002), TPC (mg GAE/g) was measured using the Folin–Ciocalteu reagent. TFC (mg rutin [RE] equivalent/g) was determined according to Chang *et al.* (2002).

DPPH radical scavenging activity

The approach outlined by Nizamlioglu *et al.* (2022) was used to determine the impact of DPPH radical-scavenging activity. Briefly, an aliquot of 100 µL of methanol extract was added into 2,900-µL freshly prepared DPPH solution and left at room temperature for 30 min. The absorbance of samples and control (methanol) were read at 517 nm using a laboratory spectrophotometer (Shimadzu UV-1800, Kyoto 604–8511, Japan). The scavenging activity was estimated based on the percentage of DPPH radical scavenged according to the following formula:

$$\text{inhibition } \% = \left[\frac{\text{Blank absorbance} - \text{Sample absorbance}}{\text{Blank absorbance}}\right] \times 100 \quad (1)$$

ABTS activity

The antioxidant activity of sheets was measured by the ABTS+ technique, as described by Pegu and Arya (2021) with minor modification. Briefly, ABTS+ solution (3.9 mL) was mixed with 0.1-mL extract and shaken violently in an Eppendorf (EP) tube. The mixture was allowed to stand in the dark for 10 min at room temperature before the absorbance was measured at 734 nm. Methanol was used as a negative control in place of extract. The following formula was used to express the results:

$$\text{inhibition } \% = \left[\frac{\text{Blank absorbance} - \text{Sample absorbance}}{\text{Blank absorbance}}\right] \times 100 \quad (2)$$

Ferric reducing antioxidant power (FRAP)

The antioxidant activity of sheets was measured by the FRAP technique, as described by Addai *et al.* (2016). Briefly, FRAP reagent (1 mL) was mixed with 100-µL extract and shaken violently in an EP tube. The mixture was allowed to stand for 30 min at room temperature before the absorbance was measured at 595 nm. Methanol was used as a negative control in place of the extract. Trolox's calibration curve was prepared to estimate sample's activity capacity. The final result was expressed as (mg) of Trolox equivalent (TE)/100 g.

Phenolic compounds identification

The methanolic extract of sheets was analyzed by HPLC at the Food Chemistry Laboratory of the National Research Center in Egypt. The phenolic quantitative measurement for sheets extracts was conducted using

the protocol described by Elsebaie and Essa (2018) using Shimadzu LC-10A HPLC Instruments (Kyoto; Japan).

Microbiological analysis

Microbial investigation of fruit sheets was performed at the time of manufacturing and then after 6 months. In brief, 1 g of a fruit sheet was cut into small pieces, vortexed, and agitated in a test tube containing 9 mL of saline solution. Duplicate serial dilutions were then prepared all the way up to 10^{-3}. Every sample was examined thrice. Using the pour plate technique, the total plate bacterial enumeration (TPE) was performed using 1 mL of sample solution and 15 mL of nutrient agar medium, incubated for 48 h at 37°C (AOAC International and Latimer, 2016).

The spread plate method was used to measure the amount of yeast and mould. Mixture of 0.1-mL sample and saline was spread out on potato dextrose agar medium. The plates underwent a 5-day incubation at 24°C. The enumeration results were represented as log CFU/g. The total coliform enumeration of samples was determined by using MacConkey broth media by 48 h of incubation at 37°C with 0.1 mL of sample solution added to a tube containing 10 mL of MacConkey broth (Naeem, 2023).

Sensory evaluation

Ten panellists from the Department of Food Science and Technology, Faculty of Home Economics at Al-Azhar University, evaluated produced sheets based on their sensory qualities. Using a 1–9 hedonic scale, panellists assessed taste, flavor, color, texture, and overall acceptability of prepared sheets (Ohijeagbon *et al.*, 2024). A score of 1 denoted dislike extremely whereas a score of 9 indicated like extremely.

Statistical Analysis

Variance of analysis in SPSS examined the results statistically (Coakes and Steed, 1997). Statistically significant discrepancies between individual mean values were analyzed using Duncan's (1995) multiple range tests.

Results and Discussion

Physicochemical characteristics

pH, TSS, and acidity measurements

Table 2 shows the pH of sheets prepared from pomegranate, red beetroot, and a mix of both as a function of storage and mixing ratio. According to Table 2, all treated sheet samples had a pH of 2.80–4.13 at zero (0) time and 2.75–4.09 after 6 months of storage. The 100% RBRP sheets had maximum pH values (range: 4.09–4.13), followed by 50% RBRP+50% PJ sheets (range: 3.84–3.90), 100% PJ sheets (range: 3.49–3.52), 75% RBRP+25% PJ sheets (range: 3.27–3.29), and 25% RBRP+75% PJ sheets (range: 2.75–2.80). As a result, it was anticipated that these sheets would not require any preservative and would have a steady shelf life of many months. These findings concur with those of Safaei *et al.* (2019), who suggested that fruit sheets should have a pH of 2.5–4.5.

Furthermore, Table 2 demonstrates that all treated sheets had a modestly declining tendency in their pH values during the period of storage. The 25% RBRP+75% PJ sheets had the highest declining rate of pH whereas the 75% RBRP+25% PJ sheets had the lowest declining pH values. Similarly, Khan *et al.* (2015) and Shakoor *et al.* (2015) found that different varieties of fruit sheets showed reduction in pH values throughout the storage. The formation of free acids, pectin hydrolysis, and ascorbic acid degradation might be the contributing factors to the declining trend of pH.

Table 2 also reveals considerable variances in TSS values of investigated sheets. All treated sheet samples had TSS levels of 63.99–67.41 Brix at zero (0) time and 65.08–68.31 Brix after 6 months of storage. Generally, 100% PJ sheets had the highest TSS values (ranging from 67.41 to 68.31 Brix), followed by 25% RBRP+75% PJ sheets (ranging from 66.64 to 67.65 Brix), 50% RBRP+50% PJ sheets (ranging from 65.68 to 67.52 Brix), 75% RBRP+25% PJ sheets (ranging from 65.11 to 66.20 Brix), and 100% RBRP sheets (ranging from 63.99 to 65.08 Brix).

The findings showed that TSS level of sheets increased from 63.99 to 68.13 Brix after storing for 6 months in ambient conditions. Increase in TSS could be because of the conversion of polysaccharides into sugars, then conversion of starch and polysaccharides back to sugars, or moisture loss, which inclined to increase TSS over a 6-month period of storage (Rani and David, 2021; Shakoor *et al.*, 2015). Out of all the prepared sheets, 100% PJ sheets had the highest TSS (67.41°Brix) value after processing (zero time), followed by the 25% RBRP+75% PJ sheets (66.64°Brix); 100% RBRP sheets had the lowest TSS (65.08°Brix) value after storing for 6 months.

Table 2 also shows the results of titratable acidity of all produced fruit sheets. At zero (0) time, fresh 100% PJ sheets recorded the greatest titratable acidity (1.90%), followed by 25% RBRP+75% PJ sheets (1.64%), 50% RBRP+50% PJ sheets (1.41%), and 75% RBRP+25% PJ sheets (1.03%). All prepared sheets showed a progressive increase in titratable acidity values if the storage duration was extended to 6 months at ambient temperatures.

Table 2. Physicochemical properties of red beetroot, pomegranate, and red beetroot–pomegranate sheets.

Parameters	Storage period (month)	Type of fruit sheets				
		100% RBRP sheet	100% PJ sheet	50% RBRP+ 50% PJ sheet	75% RBRP+ 25% PJ sheet	25% RBRP+ 75% PJ sheet
pH	0	$4.13\pm0.07^{A,a}$	$3.52\pm0.04^{B,a}$	$3.90\pm0.06^{A,a}$	3.29 ± 0.11^{Ca}	$2.80\pm0.08^{D,a}$
	3	$4.11\pm0.04^{A,a}$	$3.50\pm0.05^{C,a}$	$3.86\pm0.09^{B,a}$	3.28 ± 0.09^{Da}	$2.77\pm0.06^{E,a}$
	6	$4.09\pm0.06^{A,a}$	$3.49\pm0.05^{C,a}$	$3.84\pm0.05^{B,a}$	3.27 ± 0.08^{Da}	$2.75\pm0.05^{E,a}$
TSS (Brix)	0	$63.99\pm0.06^{b,E}$	$67.41\pm0.07^{c,A}$	$65.68\pm0.05^{c,C}$	$65.11\pm0.07^{c,D}$	$66.64\pm0.07^{c,B}$
	3	$64.97\pm0.03^{a,E}$	$68.01\pm0.05^{b,A}$	$66.22\pm0.03^{b,C}$	$65.91\pm0.09^{b,D}$	$67.34\pm0.05^{b,B}$
	6	$65.08\pm0.11^{a,E}$	$68.31\pm0.10^{a,A}$	$67.52\pm0.08^{a,C}$	$66.20\pm0.03^{a,D}$	$67.65\pm0.12^{a,B}$
Titrable acidity (% of citric acid)	0	$0.98\pm0.13^{E,a}$	$1.90\pm0.09^{A,a}$	$1.41\pm0.22^{C,a}$	1.03 ± 0.10^{Da}	$1.64\pm0.06^{B,a}$
	3	$1.0\pm0.18^{D,a}$	$1.93\pm0.11^{A,a}$	$1.43\pm0.24^{C,a}$	1.05 ± 0.13^{Da}	$1.65\pm0.08^{B,a}$
	6	$1.10\pm0.16^{D,a}$	$1.94\pm0.13^{A,a}$	$1.45\pm0.20^{C,a}$	1.07 ± 0.09^{Da}	$1.67\pm0.06^{B,a}$
Moisture content (%)	0	$14.96\pm0.06^{a,A}$	$14.75\pm0.15^{a,C}$	$14.87\pm0.13^{a,B}$	$15.01\pm0.07^{a,A}$	14.79 ± 0.09^{aC}
	3	$14.81\pm0.20^{a,b,B}$	$14.63\pm0.05^{a,b,D}$	$14.73\pm0.08^{a,b,C}$	$14.90\pm0.11^{a,b,A}$	$14.64\pm0.06^{a,D}$
	6	$14.64\pm0.11^{b,B}$	$14.49\pm0.12^{b,E}$	$14.57\pm0.05^{b,C}$	$14.76\pm0.09^{b,A}$	14.52 ± 0.31^{aD}
Water activity (a_w)	0	$0.642\pm0.07^{a,A}$	$0.630\pm0.05^{a,A}$	$0.637\pm0.09^{a,A}$	$0.652\pm0.17^{a,A}$	$0.646\pm0.10^{a,A}$
	3	$0.639\pm0.11^{a,A}$	$0.629\pm0.21^{a,A}$	$0.631\pm0.10^{a,A}$	$0.641\pm0.06^{a,A}$	$0.644\pm0.13^{a,A}$
	6	$0.638\pm0.09^{a,A}$	$0.628\pm0.08^{a,A}$	$0.629\pm0.05^{a,A}$	$0.640\pm0.12^{a,A}$	$0.634\pm0.04^{a,A}$
Total sugars	0	$59.90\pm0.09^{a,C}$	$61.72\pm0.06^{a,A}$	$60.79\pm0.06^{a,B}$	$59.29\pm0.11^{a,D}$	$60.76\pm0.02^{a,B}$
	3	$59.76\pm0.07^{b,C}$	$61.57\pm0.08^{b,A}$	$60.63\pm0.08^{a,b,B}$	$59.12\pm0.05^{b,D}$	$60.61\pm0.04^{b,B}$
	6	$59.58\pm0.04^{c,C}$	$61.42\pm0.06^{c,A}$	$60.56\pm0.12^{b,B}$	$58.97\pm0.03^{c,D}$	$60.44\pm0.08^{c,B}$
Reducing sugars (%)	0	$44.62\pm0.08^{c,C}$	$48.86\pm0.08^{c,A}$	$46.73\pm0.10^{c,B}$	$43.08\pm0.04^{c,D}$	$46.69\pm0.05^{c,B}$
	3	$45.20\pm0.05^{b,D}$	$49.42\pm0.05^{b,A}$	$47.42\pm0.07^{b,B}$	$43.65\pm0.06^{b,E}$	$47.26\pm0.03^{b,C}$
	6	$45.50\pm0.11^{a,C}$	$49.72\pm0.03^{a,A}$	$47.53\pm0.09^{a,B}$	$43.97\pm0.09^{a,D}$	$47.56\pm0.07^{a,B}$
Non-reducing sugars (%)	0	$15.28\pm0.05^{a,B}$	$12.86\pm0.03^{a,D}$	$14.06\pm0.03^{a,C}$	$16.21\pm0.05^{a,A}$	$14.07\pm0.06^{a,C}$
	3	$14.49\pm0.03^{b,B}$	$12.08\pm0.06^{b,D}$	$13.21\pm0.07^{b,C}$	$15.42\pm0.08^{b,A}$	$13.30\pm0.02^{b,C}$
	6	$13.99\pm0.06^{c,B}$	$11.57\pm0.09^{c,E}$	$13.03\pm0.02^{c,C}$	$14.93\pm0.04^{c,A}$	$12.81\pm0.05^{c,D}$
Hardness	0	$12.88\pm0.01^{C,c}$	$13.85\pm0.19^{A,c}$	$13.10\pm0.07^{B,c}$	$12.27\pm0.03^{D,c}$	$13.09\pm0.05^{B,c}$
	3	$13.32\pm0.01^{D,b}$	$14.44\pm0.17^{A,b}$	$13.65\pm0.05^{C,b}$	$12.91\pm0.04^{E,b}$	$13.78\pm0.06^{B,b}$
	6	$14.10\pm0.03^{C,a}$	$15.62\pm0.09^{A,a}$	$14.13\pm0.06^{C,a}$	$13.59\pm0.01^{D,a}$	$14.52\pm0.005^{B,a}$

Mean ± standard deviation of three values.
RBRP: red beetroot puree; PJ: pomegranate juice.
In a row, mean values having the same small superscript letter are not significantly different by Dunken's test at $p \leq 0.05$. In a column, mean values having the same capital superscript letter are not significantly different by Dunken's test at $p \leq 0.05$.

For a storage period of 6 months, 75% RBRP+25% PJ sheets had the lowest TSS (1.07%), compared to 100% RBRP sheets (1.10%). Our results were consistent with the results of Effah-Manu *et al.* (2013) and Khan *et al.* (2015), who found that fruit sheets turned more acidic over storage. Increase in acidity could be due to the addition of citric acid to fruit purees as well as concentration of fruits' inherent acidity during the drying process. Breakdown of pectin into pectenic acid could also increase acidity throughout the storage.

Moisture content and water activity

Moisture content and water activity of manufactured sheets were evaluated at 3-month intervals during a 6-month storage at room temperature. Moisture is a critical component of food items. It affects appearance, taste, and texture as well as shelf life of food items. It is typically employed as an indicator of food's shelf life.

Table 2 shows that at zero (0) time, the 75% RBRP+25% PJ sheets had the maximum moisture content (15.01), which was equal to the moisture content of 100% RBRP sheets (14.96), followed by 50% RBRP+50% PJ sheets, 25% RBRP+75% PJ sheets, and 100% PJ sheets. The 100% PJ sheets had the lowest moisture content (14.75). All examined sheets had a moisture content of 14.75–15.01% at zero time, which was within the 12–25% range noted by da Silva Simão *et al.* (2020).

In respect of storage, it was observed that during a 6-month storage period, the sheet moisture content reduced significantly in the following manner: 100% RBRP sheets (from 14.96% to 14.64%), 100% PJ sheets (from 14.75% to 14.49%), 50% RBRP+50% PJ sheets (from 14.87% to 14.57%), 75% RBRP+25% PJ sheets (from 15.01% to 14.76%), and 25% RBRP+75% PJ sheets (from 14.79% to 14.52%). One possible explanation for moisture loss could be that during storage packaging might have released moisture into the environment. Our findings were in line with those of Chavan *et al.* (2016) and Uzma Litaf *et al.* (2014). Water activity greatly influences the development and survival of microorganisms in food items. Indeed, natural process of microorganisms in the environment with condensed moisture contributed to the development of expression of water activity.

Additionally, data in Table 2 show that at zero (0) time, 75% RBRP+25% PJ sheets had the maximum water activity value (0.652), followed by 25% RBRP+75% PJ sheets (0.646), 100% RBRP sheets (0.642), 50% RBRP+50% PJ sheets (0.637), and 100% PJ sheets (0.630). The water activity levels of sheets decreased in the range of 0.3–0.7, as reported in literature (da Silva Simão *et al.*, 2020).

The water activity levels of all sheets under investigation decreased gradually and nonsignificantly during storage. Water activity levels dropped in the following sheets after 6 months of storage: 100% RBRP sheets (from 0.642 to 0.638), 100% PJ sheets (from 0.630 to 0.628), 50% RBRP+50% PJ sheets (from 0.637 to 0.629), 75% RBRP+25% PJ sheets (from 0.652 to 0.640), and 25% RBRP+75% PJ sheets (from 0.646 to 0.634). Reduced water activity might be caused by pectin, acids, and ability of sucrose to bind free water.

Total, reducing, and non-reducing sugars

Table 2 shows that 100% RBRP sheets had a lower reducing sugar percentage (ranging from 44.62% to 45.50%) and total sugar content (ranging from 59.90% to 59.58%) than 100% PJ sheets. In contrast, 100% RBRP sheets had a greater non-reducing sugar content than 100% PJ sheets (ranging from 13.99% to 15.28%). Furthermore, increasing the replacement percentage of red beetroot juice with pomegranate juice from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets) resulted in an increase in total sugar content (from 59.29% to 60.76%), reducing sugar content (from 43.08% to 46.69%), and a decrease in non-reducing sugar content (from 16.21% to 14.07%) at zero (0) time.

All sheets showed a substantial ($p \leq 0.05$) drop in both total and non-reducing sugar contents throughout 6 months of storage at ambient temperatures. According to Dhake *et al.* (2018), reduction in non-reducing sugars during storage could be due to increase in reducing sugars caused by the hydrolysis of total sugars. This decline could be due to the conversion of non-reducing sugars to reduced sugars. Conversely, throughout the 6 months of storage at room temperature, there was a substantial ($p \leq 0.05$) increase in the amount of reducing sugars. The increase in reducing sugars might be due to the hydrolysis of non-reducing sugars and conversion into reducing sugars (Dhake *et al.*, 2018).

Texture profile

Hardness establishes the amount of force needed to flex a sheet sample. Data in Table 2 indicate that 100% PJ sheets had greater hardness values (ranging from 13.85 N to 15.62 N) than 100% RBRP sheets (ranging from 12.88 N to 14.10 N). In addition, there was an increase in hardness values from 12.27 N to 13.09 N at zero time if the substituting proportion of pomegranate juice by red beetroot juice was increased from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets). Reduced moisture content could be the cause of this.

All investigated sheets had a substantial ($p \leq 0.05$) increase in hardness throughout the storage period of 6 months at room temperature. Decrease in moisture content of sheets during storage period could be the cause of increase in hardness. This result was consistent with the findings of Kamal-Eldin *et al.* (2020). Fruit sheets exhibit increased hardness due to sugar crystallization; this was consistent with the results of the research conducted by Perera (2005). All of the produced sheet samples exhibited good hardness in this regard, indicating appropriation of products to customers' satisfaction.

Color properties

Color is an important determinant of fruit sheet quality, indicating its suitability for human consumption (Sukasih and Widayanti, 2022). Figures 1A–C show the respective color parameters (L^*, a^*, and b^*) of formulated fruit sheets. The L^* value, which denotes color lightness or intensity, ranged between 21.86 and 23.64 for all formulated sheet samples at zero (0) time, with 100% RBRP sheets showing maximum values (ranging from 23.64 to 24.14). These results are shown in Figure 1A. 100% PJ sheets had lower L^* values (ranging from 21.86 to 22.28) than 100% RBRP sheets (ranging from 23.64 to 24.14).

This could be the result of the fact that 100% PJ sheets had more total and reducing sugars than 100% RBRP sheets, resulting in more incidences of Millard reaction in 100% PJ sheets than in 100% RBRP sheets. Decrease in color brightness is known to be caused by the Millard response. These findings were consistent with those of Sukasih and Widayanti (2022). Additionally, there was a decline in L^* values from 22.80 to 22.31 at zero time when the replacement proportion of pomegranate juice by red beetroot juice was increased from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets). This might

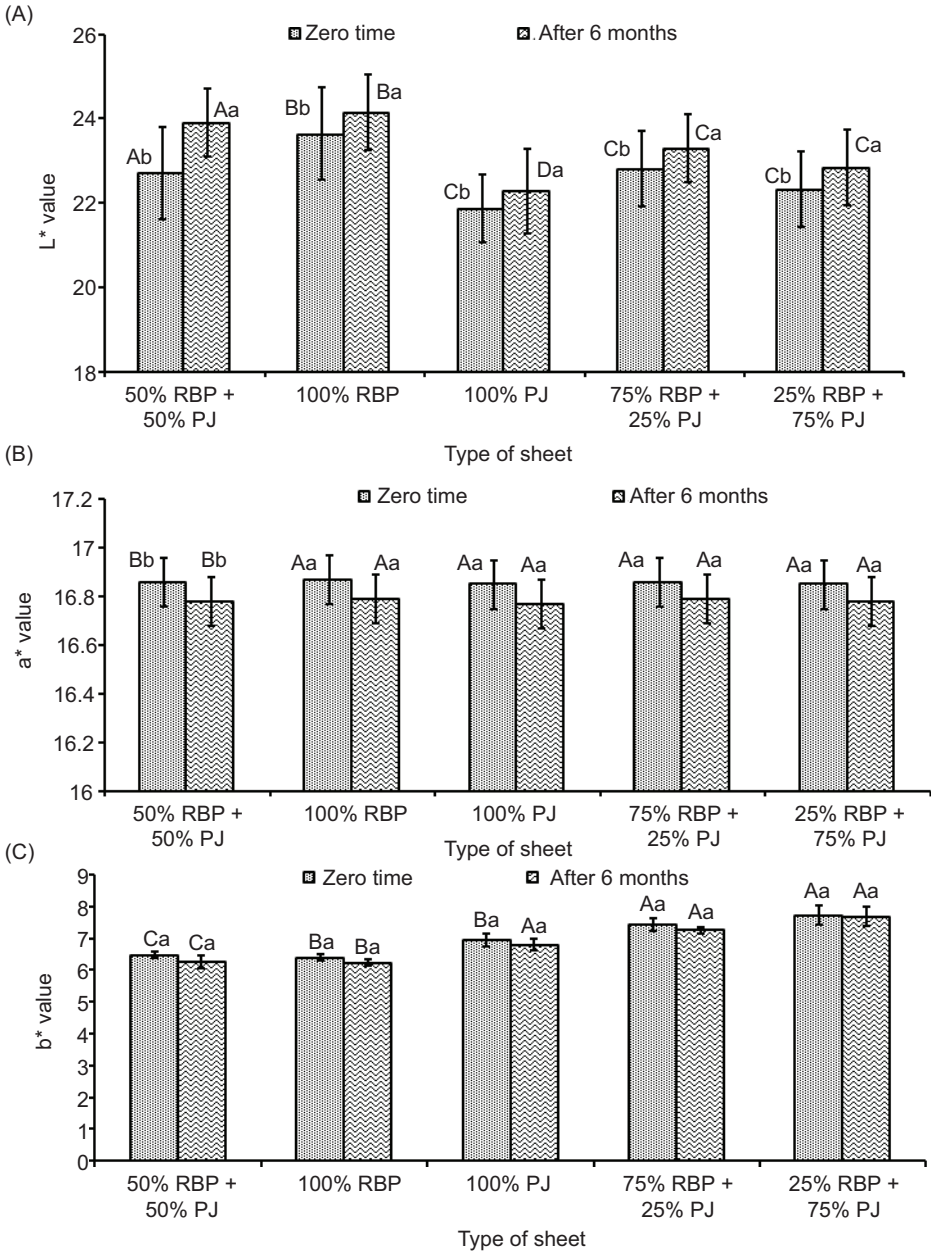

Figure 1. (A) L* value, (B) a* value, and (C) b* value of apricot, red beetroot, pomegranate, and red beetroot–pomegranate sheets. Error bars represent standard deviation (n = 5). Different superscripts lowercase letters indicate significant differences at $p \leq 0.05$ between the same treatments at different storage periods. Different superscripts uppercase letters indicate significant differences at $p \leq 0.05$ between treatments for the same storage period.

be due to the increased percentage of total and reducing sugars. All examined samples showed a notable increase in L^* values during 6 months of storage at room temperature.

Figure 1B shows that a^* values varied from 16.85 to 16.87 for all sheet samples at zero time, with 100% PJ sheets having the lowest values. Figure 1B shows that there was no significant ($p \leq 0.05$) variation in the a^* values of 100% PJ sheets (which ranged from 21.86 to 22.28) and 100% RBRP sheets (which ranged from 16.79 to 16.87).

Furthermore, when the replacement proportion of pomegranate juice for red beetroot juice was increased from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets), there was no significant ($p \leq 0.05$) difference in a^* values at zero time, which was 16.86–16.85. This could be due to an increase in both total and reducing sugars. All examined sheet samples showed a considerable increase in L^* values during 6 months of storage at room temperature. Following the 6-month storage at room temperature, all examined samples showed a non-significant ($p \leq 0.05$) drop in their a^* values; this could

be, most likely, due to pigment decomposition (Nurkaya *et al.*, 2020).

Furthermore, it is abundantly obvious from Figure 1C that the formed sheets' yellowness is indicated by positive b^* values. Maximum b^* value (ranging from 7.68 to 7.72) was observed in 25% RBRP+75% PJ sheets. This was followed by 75% RBRP+25% PJ sheets (ranging from 7.26 to 7.43), 100% PJ sheets (ranging from 6.80 to 6.94), 50% RBRP+50% PJ sheets (ranging from 6.27 to 6.47), and 100% RBRP sheets (ranging from 6.22 to 6.38). Additionally, extending the room temperature storage duration from zero to 6 months did not appreciably reduce b^* values for any of the sheet samples.

Bioactive compound and antioxidant activity

Table 3 shows bioactive component contents (total phenols and flavonoids) and antioxidant activity% of produced sheets. According to the results shown in Table 3, total phenols (19.20 mg GAE/g) and total flavonoids (16.59 mg RE/g) in 100% RBRP sheets were more than in 100% PJ sheets, which contained 17.01 mg GAE/g of total phenols and 12.97 mg RE/g of total flavonoids at zero time. Furthermore, at zero time, there was a decrease in total phenols from 18.71 to 17.63 mg GAE/g and total flavonoids from 15.74 to 13.90 mg RE/g, with an increase in the percentage substitution of pomegranate juice with red beetroot juice from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets).

Total phenol and flavonoid concentrations of all sheets decreased nonsignificantly ($p \leq 0.05$) throughout 6-month storage at room temperature. These findings were consistent with the results of Kaushal *et al.* (2017).

The antioxidant activity of each produced sheet was assessed using three assays (DPPH, ABTS, and FRAP). Fresh 100% RBRP sheets and fresh 100% PJ sheets had the ABTS scavenging activity of 52.09% and 44.28%, respectively, whereas the free radical scavenging activity of DPPH was 77.02% and 63.28%, respectively, as shown in Table 3.

Table 3 also show that fresh 100% RBRP sheets had a higher FRAP value (166.13 mg TE/100 g) than fresh 100% PJ sheets (139.54 mg TE/100 g).

This could be because RBRP sheets had greater concentrations of bioactive components, such as total phenols and flavonoids, than PJ sheets. Furthermore, at zero time, there was a significant decrease ($p \leq 0.05$) in DPPH scavenging activity from 72.19% to 68.14%, in ABTS scavenging activity from 50.86% to 48.33%, and FRAP

Table 3. Bioactive compounds and antioxidant activity of red beetroot, pomegranate, and red beetroot–pomegranate sheets.

Parameters	Storage period (month)	Types of sheets				
		100% RBRP sheets	100% PJ sheets	50% RBRP+ 50% PJ sheets	75% RBRP+ 25% PJ sheets	25% RBRP+ 75% PJ sheets
Total phenolic content (mg GAE/g)	0	$19.20\pm0.06^{a,A}$	$17.01\pm0.03^{a,E}$	$18.09\pm0.01^{a,C}$	$18.71\pm0.02^{a,B}$	$17.63\pm0.06^{a,D}$
	3	$18.97\pm0.04^{a,A}$	$16.96\pm0.06^{a,E}$	$17.98\pm0.03^{a,C}$	$18.66\pm0.03^{a,B}$	$17.57\pm0.03^{a,D}$
	6	$18.94\pm0.05^{a,A}$	$16.94\pm0.06^{a,E}$	$17.95\pm0.04^{a,C}$	$18.62\pm0.01^{a,B}$	$17.52\pm0.04^{a,D}$
Total flavonoid content (mg RE/g)	0	$16.59\pm0.04^{a,A}$	$12.97\pm0.05^{a,E}$	$14.73\pm0.03^{a,C}$	$15.74\pm0.06^{a,B}$	$13.90\pm0.01^{a,D}$
	3	$16.53\pm0.05^{a,A}$	$12.95\pm0.03^{a,E}$	$14.69\pm0.02^{a,C}$	$15.68\pm0.02^{a,B}$	$13.85\pm0.04^{a,D}$
	6	$16.50\pm0.07^{a,A}$	$12.90\pm0.03^{a,E}$	$14.65\pm0.02^{a,b,C}$	$15.63\pm0.04^{a,B}$	$13.81\pm0.03^{a,D}$
DPPH radical scavenging activity (%)	0	$77.02\pm0.69^{a,A}$	$63.28\pm1.00^{a,E}$	$69.80\pm1.07^{a,C}$	$72.19\pm0.83^{a,B}$	$68.14\pm0.99^{a,D}$
	3	$74.92\pm0.86^{b,A}$	$61.12\pm1.02^{b,D}$	$66.45\pm0.99^{b,C}$	$70.65\pm0.71^{b,B}$	$66.33\pm0.62^{b,C}$
	6	$73.66\pm0.94^{c,A}$	$59.86\pm0.79^{c,E}$	$64.66\pm1.12^{c,D}$	$70.04\pm0.92^{b,B}$	$65.80\pm0.79^{c,C}$
ABTS (%)	0	$52.09\pm0.55^{a,A}$	$44.28\pm0.42^{a,E}$	$47.31\pm0.66^{a,D}$	$50.86\pm0.50^{a,B}$	$48.33\pm0.68^{a,C}$
	3	$50.97\pm0.39^{b,A}$	$42.11\pm0.61^{b,E}$	$45.62\pm0.54^{b,D}$	$48.23\pm0.84^{b,B}$	$46.26\pm0.72^{b,C}$
	6	$50.13\pm0.62^{c,A}$	$41.\ 57\pm0.94^{c,D}$	$44.98\pm0.71^{c,E}$	$46.71\pm0.65^{c,B}$	$45.11\pm0.53^{c,C}$
FRAP (mg TE/10 0 g)	0	$166.13\pm7.09^{a,A}$	$139.54\pm6.92^{a,E}$	$151.22\pm8.51^{a,C}$	$156.85\pm6.18^{a,B}$	$145.42\pm9.63^{a,D}$
	3	$163.27\pm10.11^{b,A}$	$135.39\pm7.40^{b,E}$	$148.70\pm7.62^{b,C}$	$152.19\pm9.40^{b,B}$	$141.66\pm10.04^{b,D}$
	6	$159.86\pm8.24^{c,A}$	$132.75\pm4.33^{c,E}$	$144.97\pm8.44^{c,C}$	$149.03\pm9.23^{c,B}$	$138.82\pm8.25^{c,D}$

Mean ± standard deviation of three values.
RBRP: red beetroot puree; PJ: pomegranate juice.
In a column, mean values having the same small superscript letter are not significantly different by Dunken's test at $p \leq 0.05$. In a row, mean values having the same capital superscript letter are not significantly different by Dunken's test at $p \leq 0.05$.

values from 156.85 mg TE/100 g to 145.42 mg TE/100 g, with increased substitution percentage of pomegranate juice with red beetroot juice from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets). A minor reduction in phenolic and flavonoid contents was observed in all fruit sheets after a storage period of 6 months at room temperature. This led to a noteworthy ($p \leq 0.05$) decline in DPPH scavenging activity, ABTS scavenging activity, and FRAP value. These findings concur with those reported by Kaushal *et al.* (2017).

Identification of phenolic compounds in formulated sheets

Phenolic compounds in the five types of prepared fruit sheets at zero time and after 6 months of storage at room temperature were identified by HPLC (Table 4).

According to the obtained data, the most predominant phenolic acids in 100% RBRP sheets were B-coumaric acid (16.52 mg/g in fresh sheets and 16.28 mg/g in stored sheets), caffeic acid (0.99 mg/g in fresh sheets and 0.97 mg/g in stored sheets), and catechins (0.75 mg/g in fresh sheets and 0.74 mg/g in stored sheets). In addition, the most predominant phenolic acids in 100% PJ sheets were gallic acid (5.27 mg/g in fresh sheets and 5.24 mg/g in stored sheets), chlorogenic acid (4.78 mg/g in fresh sheets and 4.75 mg/g in stored sheets), and caffeic acid (3.13 mg/g in fresh sheets and 3.11 mg/g in stored sheets). In addition, data in Table 4 show that catechins, syringic acid, and ferulic acid were absent in 100% PJ sheets, while catechol, vanillic acid, ellagic acid, and colchicine were absent in 100% RBRP sheets.

Furthermore, increasing the substitution percentage of pomegranate juice with red beetroot juice from 25% (75% RBRP+25% PJ sheets) to 75% (25% RBRP+75% PJ sheets) caused a decrease in B-coumaric acid (from 12.73 to 5.16 mg/g), catechins (from 0.56 to 0.19 mg/g), syringic acid (from 0.03 to 0.01 mg/g), ferulic acid (from 0.11 to 0.04 mg/g), and B-OH benzoic acid (from 0.14 to 0.08 mg/g) as well as an increase in gallic acid (from 1.43 to 3.99 mg/g), catechol (from 0.23 to 0.68 mg/g), chlorogenic acid (from 1.38 to 3.65 mg/g), caffeic acid (from 1.52 to 2.59 mg/g), vanillic acid (from 0.29 to 0.87 mg/g), ellagic acid (from 0.01 to 0.03 mg/g), and colchicine (from 0.01 to 0.04 mg/g) at zero time.

In addition, data in Table 4 indicate that the storage for 6 months decreased all phenolic acids. These findings concur with those reported by Chen *et al.* (2024).

Microbiological analysis of formulated sheets

Total plate count is a commonly used indication of the microbiological activity of food items (Harandeh and Mansouripour, 2021). Table 5 demonstrates that coliform group was not discovered in all sheet samples during more than 6-month storage period at room temperature. This finding could be related to the use of inferior raw materials or to better handling and processing techniques in terms of hygiene. According to this data, the generated

Table 4. Phenolic acids (mg/g) identified in fresh and stored red beetroot, pomegranate, and red beetroot–pomegranate sheets.

Compounds	Sheet type									
	100% RBRP		100% PJ		50% RBRP+50% PJ		75% RBRP+25% PJ		25% RBRP+75% PJ	
	Fresh	Stored	Fresh	Stored	Fresh	Stored	Fresh	Stored	Fresh	Stored
Gallic acid	0.15	0.15	5.27	5.24	2.71	2.70	1.43	1.42	3.99	3.97
Catechol (pyrocatechol)	ND	ND	0.91	0.91	0.46	0.45	0.23	0.23	0.68	0.68
Chlorogenic acid	0.24	0.24	4.78	4.75	2.51	2.50	1.38	1.37	3.65	3.63
B-coumaric acid	16.52	16.28	1.37	1.36	8.94	8.82	12.73	12.55	5.16	5.09
Catechins	0.75	0.74	ND	ND	0.38	0.37	0.56	0.55	0.19	0.18
Caffeic acid	0.99	0.97	3.13	3.11	2.06	2.04	1.52	1.51	2.59	2.57
Vanillic acid	ND	ND	1.17	1.16	0.58	0.58	0.29	0.29	0.87	0.87
Ellagic acid	ND	ND	0.03	0.03	0.02	0.02	0.01	0.01	0.03	0.03
Syringic acid	0.04	0.04	ND	ND	0.02	0.02	0.03	0.03	0.01	0.01
Ferulic acid	0.15	0.15	ND	ND	0.08	0.07	0.11	0.11	0.04	0.04
B-OH benzoic acid	0.17	0.16	0.05	0.05	0.11	0.11	0.14	0.13	0.08	0.08
Colchicine	ND	ND	0.05	0.05	0.03	0.03	0.01	0.01	0.04	0.04

ND: not detected.

sheets had varying bacterial loads after 6 months of storage, ranging from 0.436 log CFU/g for 100% RBRP sheets to 0.543 log CFU/g for 100% PJ sheets.

Compared to the sheets with high pomegranate juice percentage, sheets with a high percentage of pureed red beetroot often had lower TPC. This might be explained by the fact that red beetroots include more bioactive components than pomegranates, including polyphenols, flavonoids, betalain, and anthocyanins, which are naturally occurring antioxidants and antimicrobials. Regarding the yeast and mould counts of prepared sheet samples, Table 4 shows that no microorganism was observed in any sample at any point during 6-month storage at room temperature. This might be because the drying process eliminated both yeast and mould.

This satisfied the globally recognized standards for bacteria (<1 log CFU g^{-1}) and fungus (<3 log CFU g^{-1}) (Berthold-Pluta *et al.*, 2021). According to da Silva Simão *et al.* (2020), all examined sheets could be microbiologically safe and shelf-stable for a preliminary period of 6 months, as this is the typical shelf life for fruit sheets.

Sensory evaluation of formulated sheets

Table 6 describes the sensory qualities (taste, flavor, color, texture, and general acceptability) of the prepared sheets during and after processing and up to 6 months of storage at room temperature.

According to the tabulated data, all prepared sheets had excellent scores for every sensory characteristic and showed no statistically significant changes in any of the sensory qualities other than the taste parameter. Furthermore, all examined samples showed no significant changes ($p < 0.05$) in any of the sensory metrics at zero time and after 6-month storage period, with the exception of taste score value.

Overall, all prepared sheets were approved by panellists after 6 months of storage, which could be due to primary raw ingredients—pomegranate and red beetroot—as well as sugars and citric acid.

Conclusions

Fruit sheets are a healthy alternative for junk foods, particularly for children, because of their texture and nutritive value. In this study, innovative and useful fruit sheets from RBRP and PJ were prepared and stored for 6 months in ambient conditions (25–30°C) in five different formulations (100% RBRP; 100% PJ; 50% RBRP+50% PJ; 75% RBRP+25% PJ; and 25% RBRP+75% PJ). The effect of RBRP–PJ blending ratio and storage period were studied on physicochemical parameters, bioactive component content, antioxidant activity, microbiological load, and sensory properties of the prepared sheets. The results showed that moisture content, water activity, total phenols, total flavonoids, DPPH radical scavenging activity and ABTS scavenging activity in 100% RBRP sheets

Table 5. Microbiological analysis of red beetroot, pomegranate, and red beetroot–pomegranate sheets.

Type of sheet	Storage period (month)	Total coliform group (log CFU/g)	TPC (log CFU/g)	Mould & yeast (log CFU/g)
100% RBRP sheets	Zero time	Nil	Nil	Nil
	3	Nil	Nil	Nil
	6	Nil	0.436	Nil
100% PJ sheets	Zero time	Nil	Nil	Nil
	3	Nil	Nil	Nil
	6	Nil	0.543	Nil
50% RBRP+50% PJ sheets	Zero time	Nil	Nil	Nil
	3	Nil	Nil	Nil
	6	Nil	0.482	Nil
75% RBRP+25% PJ sheets	Zero time	Nil	Nil	Nil
	3	Nil	Nil	Nil
	6	Nil	0.439	Nil
25% RBRP+75% PJ sheets	Zero time	Nil	Nil	Nil
	3	Nil	Nil	Nil
	6	Nil	0.456	Nil

RBRP: red beetroot puree; PJ: pomegranate juice.

Table 6. Sensory evaluation of red beetroot, pomegranate, and red beet root–pomegranate sheets.

Parameters	Storage period (month)	Types of sheets				
		100% RBRP sheet	100% PJ sheet	50% RBRP+ 50% PJ sheet	75% RBRP+ 25% PJ sheet	25% RBRP+ 75% PJ sheet
Taste (9)	0	8.10±0.10^{a,B,C}	7.90±0.57^{a,C}	8.71±0.12^{a,A}	8.61±0.23^{a,A,B}	8.53±0.12^{a,A,B}
	3	8.00±0.30^{a,A}	7.87±0.82^{a,A}	8.30±0.23^{a,b,A}	8.27±0.18^{a,,A}	8.17±0.35 ^{a,A}
	6	7.80±0.66^{a,A}	7.79±0.67^{a,A}	7.99±0.35^{b,A}	8.00±0.71^{a,A}	7.97±0.70^{a,A}
Flavour (9)	0	7.50±0.90^{a,A}	8.12±0.82^{a,A}	7.93±0.61^{a,A}	8.41±0.16^{a,A}	8.68±0.22^{a,A}
	3	7.48±0.58^{a,A}	8.00±0.78^{a,A}	7.55±0.88^{a,A}	8.30±0.11^{a,A}	8.41±0.41^{a,A}
	6	7.00±0.69^{a,A}	7.85±0.56^{a,A}	7.04±0.75^{a,A}	8.10±0.24^{a,A}	8.05±0.37^{a,A}
Color (9)	0	7.95±0.78^{a,A}	7.83±0.66^{a,A}	7.90±0.53^{a,A}	8.15±0.14^{a,A}	8.49±0.11^{a,A}
	3	7.78±0.69^{a,A}	7.80±0.55^{a,A}	7.82±0.71^{a,A}	7.92±0.69^{a,A}	8.01±0.13^{a,A}
	6	7.67±0.80^{a,A}	7.73±0.91^{a,A}	7.50±0.49^{a,A}	7.20±0.54^{a,A}	7.96±0.81^{a,A}
Texture (9)	0	7.92±0.58^{a,A}	8.32±0.20^{a,A}	8.11±0.38^{a,A}	8.20±0.15^{a,A}	8.07±0.10^{a,A}
	3	7.90±0.62^{a,A}	8.27±0.11^{a,A}	8.10±0.17^{a,A}	7.94±0.51^{a,b,A}	7.94±0.42^{a,A}
	6	7.83±0.77^{a,A}	7.89±0.62^{a,A}	7.80±0.81^{a,A}	7.28±0.33^{b,A}	7.52±0.51^{a,A}
Overall acceptability (9)	0	7.87±0.15^{a,A}	8.04±0.67^{a,A}	8.16±0.19^{a,A}	8.20±0.15^{a,A}	8.44±0.07^{a,A}
	3	7.79±0.10^{a,A}	7.98±0.38^{a,A}	7.94±0.43^{a,A}	8.34±0.28^{a,A}	8.13±0.30^{a,A}
	6	7.57±0.33^{a,A}	7.81±0.21^{a,A}	7.58±0.26^{a,A}	7.64±0.31^{b,A}	7.87±0.62^{a,A}

Mean ± standard deviation of three values.
RBRP: red beetroot puree; PJ: pomegranate juice.
In a row, mean values having the same small superscript letter are not significantly different by Dunken's test at $p \leq 0.05$.
In a column, mean values having the same capital superscript letter are not significantly different by Dunken's test at $p \leq 0.05$.

were more than that in 100% PJ sheets. In contrast, 100% RBRP sheets had a lower pH, TSS, total sugars, and hardness than that in 100% PJ sheets. In addition, 100% RBRP sheets had higher L^* and a^* values and lower b^* value than that in 100% PJ sheets. When the replacement percentage of PJ for RBRP increased from 25% to 100%, there was an increase in TSS, acidity, total sugars, and hardness as well as decrease in moisture, water activity, total phenol content, total flavonoid content, DPPH scavenging activity, ABTS scavenging activity, and L^* value. During storage, a significant decrease ($p \leq 0.05$) was observed in pH, moisture, water activity, total sugars, total phenol content, total flavonoid content, and antioxidant activity. All studied sheets could be considered as microbiologically safe with a stable shelf life of 6 months. In addition, these sheets were in attributed good quality and accepted by panelists after 6 months of storage. Overall, the findings indicated the potential to develop PJ and RBRP into fruit sheets rich in bioactive phenolics with stable shelf life. Fruit sheets prepared from these widely produced, extremely perishable fruits could be an excellent solution to reduce post-harvest losses.

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Data Availability

The authors confirmed that the data supporting the findings of this study are available within the article.

Conflicts of Interest

The authors declared no conflict of interest.

Author Contributions

Conceptualisation: Omar Turki Mamdoh Ershidat and Eatemad M. El-Sayed.; methodology: Omar Turki Mamdoh Ershidat and Eatemad M. El-Sayed; software: Shaymaa A. Hozifa and Marwa Fawzi Ahmed El-Farsy; validation: Omar Turki Mamdoh Ershidat, Marwa Fawzi Ahmed El-Farsy and Eatemad M. El-Sayed.; formal analysis: Omar Turki Mamdoh Ershidat, Asmaa Antar Faramawy and Dalia M. El-Mesiry.; investigation: Omar Turki Mamdoh Ershidat and Eatemad M. El-Sayed.; resources: Dalia M. El-Mesiry, Rehab A. Shehata, Shaymaa A. Hozifa, Soher Abd-Elfattah ElMeslamy, and Marwa A. Ahmed; data curation: Soher Abd-Elfattah ElMeslamy, Shaymaa A. Hozifa, Rehab A. Shehata and Marwa A. Ahmed; writing—original draft preparation:

Essam Mohamed Elsebaie and Omar Turki Mamdoh Ershidat; writing—review and editing: Essam Mohamed Elsebaie and Eatemad M. El-Sayed.; visualisation: Marwa Fawzi Ahmed El-Farsy and Asmaa Antar Faramawy; funding acquisition: Asmaa Antar Faramawy and Eatemad M. El-Sayed. All authors have read and agreed to the published version of the manuscript.

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