

Article

Physicochemical and Functional Characterization of Pear Leathers Enriched with Wild Bilberry and Blackcurrant Pomace Powders

Ana Maria Blejan ^{1,2}, Violeta Nour ^{2,*}  and Georgiana Gabriela Codină ³ 

¹ Faculty of Food Science and Engineering, Dunărea de Jos University of Galati, Domnească Street 111, 800201 Galati, Romania; ana.blejan@ugal.ro

² Department of Horticulture and Food Science, University of Craiova, 13 AI Cuza Street, 200585 Craiova, Romania

³ Faculty of Food Engineering, Stefan cel Mare University of Suceava, 720229 Suceava, Romania; codina@fia.usv.ro

* Correspondence: violeta.nour@edu.ucv.ro

Abstract: Fruit leathers are convenient, delicious and sophisticated alternatives to natural fruits as a source of nutrients, fibers and bioactive compounds. The present study was conducted to develop new fruit leathers by adding 0.5%, 1.0% and 1.5% wild bilberry (BIPP) and blackcurrant (BCPP) pomace powders in pear leather manufactured with honey (5%), pectin (1%) and lemon juice (2.5%) as additional ingredients. The CIEL*a*b* color parameters, titratable acidity, total phenolics content, total anthocyanins content and DPPH radical scavenging activity were determined in the fruit leathers. In addition, the puncturing force, flexibility and adhesiveness of the fruit leathers were measured and sensory analysis was conducted. The results showed that the addition of pomace powders significantly decreased the lightness, chroma and hue angle and increased the titratable acidity of the fruit leathers while a* values decreased in the leathers with BIPP addition. Flexibility slightly decreased while adhesiveness significantly increased with increasing BIPP and BCPP addition level, changes that were perceived as negative in the sensory analysis. The total phenolic content increased by 2.03, 3.26 and 4.45 times at 0.5, 1.0 and 1.5% BIPP addition, respectively, while only by 1.22, 1.42 and 1.60 times at the same levels of BCPP addition. The newly developed fruit leathers could be recommended as alternative snack foods with high nutritional value and functionality.

Keywords: pear leather; bilberry; blackcurrant; pomace; antioxidant activity; texture



Citation: Blejan, A.M.; Nour, V.; Codină, G.G. Physicochemical and Functional Characterization of Pear Leathers Enriched with Wild Bilberry and Blackcurrant Pomace Powders. *Agronomy* **2024**, *14*, 2048. <https://doi.org/10.3390/agronomy14092048>

Academic Editors: Pedro Javier Zapata, Maria Jose Gimenez Torres and Vicente Serna-Escolano

Received: 5 August 2024

Revised: 3 September 2024

Accepted: 5 September 2024

Published: 7 September 2024



Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Fresh fruits are prime sources of vitamins, minerals, fibers (pectic and cellulose substances), carbohydrates and bioactive compounds, such as phenolics and carotenoids. Increasing fruit consumption is one of the main trends in terms of a healthy diet. Recent epidemiological, nutritional and toxicological studies have associated fruit consumption with an improved health status and a lower incidence of chronic diseases, such as cardiovascular diseases, diabetes, cancer and neurodegenerative diseases [1–3]. A minimum recommendation of 400 g/person per day is defined by the World Health Organization for fruit and vegetable consumption level [4], while less than 50% of the global population achieved average per-capita fruit and vegetable consumption consistent with this minimum target [5].

Moreover, the global consumption of sugars and sweet snacks has increased consistently [6]. Against this background, the challenge for food scientists is to develop innovative and healthier confectioneries based on fruits, with less added sugars and increased fiber and bioactive content, to replace high-calorie and low-nutrient candies and confections [7].

Fruit leathers provide various nutrients, fibers and bioactive compounds with fewer calories, in a delicious and sophisticated form [8,9], being a valuable substitute for unhealthy

sweets and snacks. Apples, apricots, berries, grapes, jackfruits, kiwifruits, oranges, papayas, peaches and pears are among the most suitable fruits for making fruit leathers. Moreover, fruit leather manufacture can be a practical approach to recover fruit overproduction, low-grade fruits and by-products from the fruit processing industry, thus increasing the economic value of fruit production and reducing postharvest losses [8,10]. Originating from the Persian Empire [11], the fruit leather, also entitled fruit sheet, fruit roll or pestil, is a slim dried flexible sheet made through dehydration from fresh fruit pulp rich in carbohydrates and fiber or a mixture of fruit juice concentrates and other food ingredients and additives like sugar, pectin, citric acid, glucose syrup, color and, optionally, preservatives [12,13]. Apart from pectin, other hydrocolloids with gelling and stabilizing properties have been added to fruit leathers, such as gelatin, carrageenan, alginate, gums or starch [14]. Also, honey, glucose, fructose, corn syrups or intensive sweeteners have been added instead of sugar [7]. Various drying methods including hot air drying, vacuum drying, and combined convective and far infrared drying, as well as microwave, solar and sun drying, have been used to make fruit leathers [15].

Fruit leathers have a higher nutrient and bioactive density compared to fresh fruits as a result of dehydration that concentrates nutrients, antioxidant compounds and minerals. In addition, fruit leathers are more stable during storage and transportation due to their low moisture contents (12–20%) and water activity [9,11]. Their concentrated fruit flavor and chewy texture make fruit leathers a healthier alternative sweet snack compared to candies and confectioneries [16].

Previously, several studies showed that it is possible to develop mixed leathers by combining several fruits to provide desirable attributes and obtain high-quality and nutritious products [17], but only very few works proposed to add fruit by-products to enhance the functionality of fruit leathers [18].

Currently, the by-products from the fruit processing industry cause serious environmental concerns since huge quantities are generated and discarded, mostly due to ineffectual management and disposal systems [19]. These by-products, consisting of seeds, skins, peels, pomaces, husks and stems [20], have been proven to be valuable sources of nutrients, polyphenols, anthocyanins, carotenoids, dietary fibers, essential oils, fatty acids and vitamins [21,22], which may be of great interest to global food and nutrition security [19].

Berries of *Vaccinium* spp. and *Ribes* spp., such as bilberries (*Vaccinium myrtillus* L.) and blackcurrants (*Ribes nigrum* L.), have been identified as superfruits based on their high bioactive content and potential health benefits, owing to their richness in phenolic acids, flavonoids, proanthocyanidins and hydrolysable tannins [23,24]. Citric, malic and quinic acids are the main organic acids in wild bilberries while anthocyanins (mainly delphinidin-3-O-glucoside and delphinidin-3-O-galactoside), flavonoids (mostly flavan-3-ols), flavonols (predominantly kaempferol, quercetin and myricetin), hydroxycinnamic acids (mostly chlorogenic acid) and derivatives of stilbenes are the main phenolic compounds [25–27]. Consequently, several beneficial health effects have been associated with their dietary intake, like antioxidant, antibacterial, anti-inflammatory, antiproliferative, cardioprotective and hypoglycemic properties [23,26].

Wild blackcurrants are deep-pigmented berries extremely rich in bioactive compounds such as phenolic acids, polyunsaturated fatty acids, anthocyanins and other polyphenols [24,28]. Delphinidin-3-O-rutinoside and cyanidin-3-O-rutinoside are the main blackcurrant anthocyanins [29,30].

Due to their astringency, wild bilberries are seldom eaten as fresh fruits. Most often, they are processed in juices, jams, jellies and alcoholic beverages or used to synthesize dark violet pigments. After their processing in juice, high amounts of pomace are formed consisting mainly of skins and seeds. The red-to-purple-colored powders obtained after the drying and milling of bilberry and blackcurrant by-products contain oils with a unique fatty acid composition, rich in mono- and polyunsaturated fatty acids (especially n-3 PUFAs) and considerable amounts of phenolic compounds, especially anthocyanins, that make them

a good candidate as a food ingredient for augmenting the functionality of food products or as a source of biologically active compounds with colorant properties, able to replace synthetic additives [31].

The inclusion of bilberry or blackcurrant pomace powder in leathers from white pulp fruits, like apples or pears, could improve the functional properties and color of leathers as apple and pear leather tend to brown due to the enzymatic oxidation of polyphenols or even due to the non-enzymatic browning caused by heating. Previously, Diamante et al. [32] added blackcurrant concentrate to an apple fruit leather to increase the nutritional quality of the product but, as far as we know, no one has previously tested the addition of dried bilberry or blackcurrant pomaces to fruit leathers.

Considering current consumers' demand for food products with enhanced functional properties and the high bioactive content and antioxidant activity of bilberry and blackcurrant by-products, the objective of this study was to investigate the effect of adding bilberry and blackcurrant pomace powder on the physicochemical, antioxidant, texture and sensory properties of pear leathers as compared with a control pear leather, in order to obtain a delicious fruit product with improved physicochemical characteristics and functionality.

2. Materials and Methods

2.1. Materials

Pears from the cultivar “Abate Fetel” at the commercial mature stage of ripening were purchased from a local supermarket in Craiova (Romania). The fruits were selected to ensure uniformity in size and color, and transferred to the Food Technology Laboratory of the University of Craiova and stored at 4 °C until fruit leather processing and analysis.

Bilberries (*Vaccinium myrtillus* L.) and blackcurrants (*Ribes nigrum* L.) from the wild flora of Vâlcea county (South-West Oltenia Region, Romania) were industrially processed into juice without enzymatic treatment at a commercial juice processor from Vaideeni (Vâlcea county, Romania). The resulting fresh pomaces (two batches of 5 kg for each berry) comprising seeds and peels were collected and frozen (−18 °C) until further use. When needed, the frozen pomaces were thawed in the air at room temperature (20 °C) and dried at 57 °C in a convective laboratory dryer (Deca +SS Design, Profimatic, Romania). The dried pomaces were ground in a household electric grinder, sieved through a mesh of 0.5 mm size, and stored at 20 °C in the dark. The other ingredients used in fruit leather processing were polyfloral honey produced by local beekeepers from Dolj County, Romania, Sosa Fruit Pectin NH from Sosa Ingredients S.L (Moià, Barcelona, Spain) and lemon juice obtained by hand-squeezing lemons from the cultivar “Verna”.

2.2. Chemicals and Reagents

Folin–Ciocalteu's reagent, gallic acid, 2,2-diphenyl–1-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) and sodium acetate were purchased from Sigma-Aldrich (Steinheim, Germany) while anhydrous sodium carbonate, hydrochloric acid, potassium chloride and methanol were supplied by Merck (Darmstadt, Germany).

2.3. Preparation of the Fruit Leathers

Seven different formulations of fruit leather were manufactured: C (control pear leather), BI0.5, BI1.0, BI1.5, made by adding 0.5%, 1% and 1.5% bilberry pomace powder (BIPP) and BC0.5, BC1.0 and BC1.5 made by adding 0.5%, 1% and 1.5% blackcurrant pomace powder (BCPP) to the puree mixture, respectively. Two batches of 500 g pear puree were prepared for each formulation on different days. The pears were peeled, sliced, cored and blended into puree using a household blender (Bosch MS61B6170, 1000 W, Stuttgart, Germany). Honey (5%, *w/w*), pectin (1%), lemon juice (2.5%, *w/w*) and pomace powder were weighed and mixed with the pear puree. The blending process was carried out at high speed for 2 min to obtain a smooth and homogenous mixture. The blend was then spread evenly as a thin layer over carbon steel trays covered with parchment paper and dried in a cabinet type laboratory dryer (Deca +SS Design, Profimatic, Romania) set at 57 °C. The

moisture loss of the leathers was determined every 30 min during drying by weighing the tray with a 0.01 g sensitive digital scale (Radvag WLC/6/A2, Radom, Poland). The drying was stopped when the moisture content of the leather, calculated from weight loss and dry solid weight data [33], reached about 13%. After drying, fruit leather samples were pulled from the surface, packaged in a low density polyethylene film and stored at 20 °C until analysis.

2.4. Proximate Composition of Bilberry and Blackcurrant Pomace Powders

Dry matter, fat, protein, fiber and ash contents were analyzed in the pomace powders using standardized methods. The dry matter content was determined using the drying oven method at 103 °C (Memmert ULM500, Uden, The Netherlands); protein content was assayed using the Kjeldahl method in an automated nitrogen analyzer (UDK 149, Velp Scientific, Milan, Italy) while fat was assayed according to SR EN ISO 6492:2001 by using a Soxhlet automatic extraction system (SER 148/3, Velp Scientific, Usmate, Italy). The crude fiber content was determined by digestion with acid and alkali (ISO 6865:2002) in an automatic analyzer (Fibertec 2010, Tecator, Sweden) and ash according to ISO 2171:2009 by using a Caloris CL 1206 oven (Bucharest, Romania). Triplicate samples were analyzed and the average values were reported.

2.5. Titratable Acidity

The titratable acidity was determined in the extract made from 10 g of fruit leather, which was homogenized and diluted to 100 mL with distilled water. The extract was then titrated to pH 8.2 with 0.1 N NaOH solution and the results were expressed as grams of citric acid (CA) per 100 g fresh weight. Two independent extracts were prepared for each sample and each one was titrated in duplicate.

2.6. Color Analysis

The CIEL*a*b* color values (L*, a* and b* indicating lightness, redness and yellowness, respectively) of the fruit leathers were determined with a PCE-CSM1 reflectance colorimeter (PCE Instruments, Southampton, UK) calibrated against a white standard. Chroma (C) was calculated as $(a^{*2} + b^{*2})^{1/2}$ while hue angle (h) was calculated as $\arctan(b^*/a^*)$. Five readings were taken at different points on each sample.

2.7. Extraction of Phenolic Compounds

The fruit leather samples (1 g) were extracted with 10 mL methanol in a Bandelin Sonorex Digital 10P ultrasonic bath (Bandelin Electronic GmbH, Berlin, Germany) for 60 min at 20 °C. The extracts were centrifuged at $2500 \times g$ for 5 min and the supernatants were collected, filtered through filter paper (Whatman No. 1) and assayed for total phenolic content and radical scavenging activity.

2.8. Total Phenolic Content

The total phenolic content was assessed in the fruit leathers by using the Folin–Ciocalteu procedure described by Singleton et al. [34]. Aliquots of 0.1 mL extracts were combined with 5 mL of distilled water and 0.5 mL of Folin–Ciocalteu reagent. After 3 min, 1.5 mL of sodium carbonate solution (20% w/v) and 2.9 mL of distilled water were added. The mixture was vortexed and placed in the dark for 30 min at 40 °C, then the absorbance was read at 765 nm on a Varian Cary 50 UV spectrophotometer (Varian Co., Cary, NC, USA). The results were expressed as milligrams of gallic acid equivalents (GAE) per 100 g (fw). Three replicates were carried out for each sample.

2.9. Total Anthocyanin Content

Total anthocyanin content was determined by the pH differential spectrophotometric method described by Giusti and Wrolstad [35]. Anthocyanins were extracted from 2 g of fruit leather with 20 mL methanol acidified with 0.1% HCl (v/v). Aliquots of 2 mL extract

were separately diluted to 25 mL with 0.025 M KCl buffer (pH 1.0) and 0.4 M CH₃COONa buffer (pH 4.5). The resulting solutions were left at 20 °C for 15 min and the absorbance of each solution was recorded at 510 and 700 nm. The total anthocyanin content was calculated as follows:

$$\text{Total anthocyanin content (mg CGE/L)} = (A \times \text{MW} \times \text{DF} \times 1000) / \epsilon$$

where $A = (A_{510 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH 1.0}} - (A_{510 \text{ nm}} - A_{700 \text{ nm}})_{\text{pH 4.5}}$; MW (molecular weight) = 449.2 g/mol for cyanidin-3-O-glucoside; DF = dilution factor of the samples; ϵ (molar absorptivity of cyanidin-3-glucoside) = 29,600 L/(mol·cm). The results were expressed as milligrams of cyanidin 3-O-glucoside equivalents (CGE) per 100 g (fw).

2.10. DPPH Radical Scavenging Activity

The fruit leather extracts were tested for their ability to scavenge DPPH using a spectrophotometric method previously described by Oliveira et al. [36]. Briefly, aliquots of 50 µL extract were combined with 3 mL of 0.004% DPPH solution. After mixing and incubation in the dark for 30 min, the absorbance of the mixture was read at 517 nm using a Varian Cary 50 UV spectrophotometer (Varian Co., USA). The DPPH radical scavenging activity was calculated as follows:

$$\text{DPPH scavenging activity (\%)} = [1 - \text{absorbance of sample} / \text{absorbance of blank}] \times 100$$

The results were expressed as milimoles Trolox per 100 g (fw).

2.11. Texture Profile Analysis

To describe the behavior of the fruit leather samples during penetration, a texturometer (model TVT-6700, Perten Instruments, Hägersten, Sweden) was used. The penetration test was performed at 1 mm/s constant speed on the surface of the sample until it was punctured. A 5 mm diameter spherical probe was used to puncture the sample. Also, a heavy duty stand of 65 mm height with a hole of 10 mm diameter in the center was also used to support the fruit leather sheet. The experimental parameters were set as follows: compression distance, 15 mm; distance above trigger, 10 mm; initial speed, 2 mm/s; test speed, 1 mm/s; retract speed, 10 mm/s; trigger force, 5 g. The puncturing force or breaking force was the force required to puncture the sample while the flexibility or deformability was the distance at which the probe entered into the sample. The measurements were repeated 10 times at different points for each sample and the results were expressed as mean values per sample.

2.12. Sensory Analysis

A 9-point hedonic scale varying from “9 = like extremely” to “1 = dislike extremely” was used to evaluate the fruit leather samples for appearance, color, flavor, taste, texture and general acceptability. The sensory panel consisted of twelve members from the Master’s students and staff members of the Department of Food Science, University of Craiova. Sensory profile diagrams were plotted based on the statistically analyzed data.

2.13. Statistical Analysis

The results were expressed as mean values $\pm$ standard deviation. The means were compared by the analysis of variance (ANOVA) followed by the Least Significant Difference (LSD) test and differences at $p < 0.05$ were considered to be significant. Statgraphics Centurion XVI (StatPoint Technologies, Warrenton, VA, USA) was the software used to carry out the statistical analysis.

3. Results

3.1. Characterization of Wild Bilberry and Blackcurrant Pomace Powders

The bilberry and blackcurrant pomace powders were characterized concerning their proximate composition, titratable acidity, total phenolic content, total anthocyanin content and DPPH radical scavenging activity and the results are presented in Table 1.

Table 1. Proximate composition, titratable acidity, total phenolic content, total anthocyanin content and DPPH radical scavenging activity of bilberry and blackcurrant pomace powders *.

	BIPP	BCPP
Dry matter (g/100 g)	89.46 ± 0.84 a	89.71 ± 0.78 a
Crude protein (g/100 g)	8.13 ± 0.34 b	4.77 ± 0.22 a
Crude fat (g/100 g)	8.21 ± 0.23 b	4.25 ± 0.18 a
Crude fiber (g/100 g)	11.84 ± 0.48 a	15.5 ± 0.69 b
Ash (g/100 g)	1.02 ± 0.19 a	1.06 ± 0.21 a
Titratable acidity (g CA/100 g)	5.63 ± 0.24 b	4.22 ± 0.19 a
Total phenolic content (mg GAE/g)	36.7 ± 0.77 b	26.2 ± 0.45 a
Total anthocyanin content (mg CGE/g)	28.35 ± 0.52 b	3.68 ± 0.07 a
DPPH radical scavenging activity (μmol Trolox/g dw)	26.1 ± 1.07 a	25.5 ± 0.88 a

* Different lowercase letters indicate significant differences between pomace powders ($p < 0.05$).

BIPP showed significantly ($p < 0.05$) higher protein and fat content but less fiber content than BCPP. A higher titratable acidity was found in the dried bilberry pomace while no significant differences ($p < 0.05$) were found in terms of ash content.

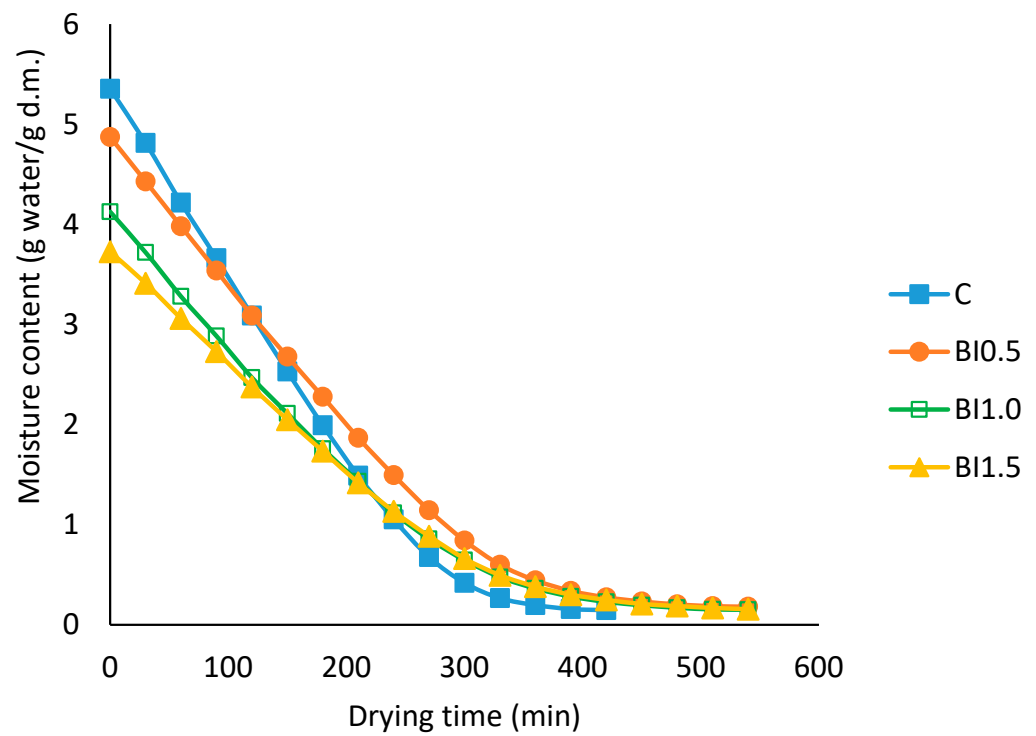
Berries contain high amounts of polyphenols and anthocyanins, which are found mainly in skins and seeds. After juice processing, skins and seeds remain in the pomace and together with them antioxidant compounds located in the cell walls [37]. Significantly higher total phenolic and total anthocyanin content ($p < 0.05$) were found in the dried bilberry pomace as compared with the dried blackcurrant pomace. However, regarding the antioxidant activity, the differences between the two pomace powders were not significant, proving that there are other antioxidant compounds besides polyphenols that contribute to the pomaces' antioxidant activity.

3.2. Drying Process

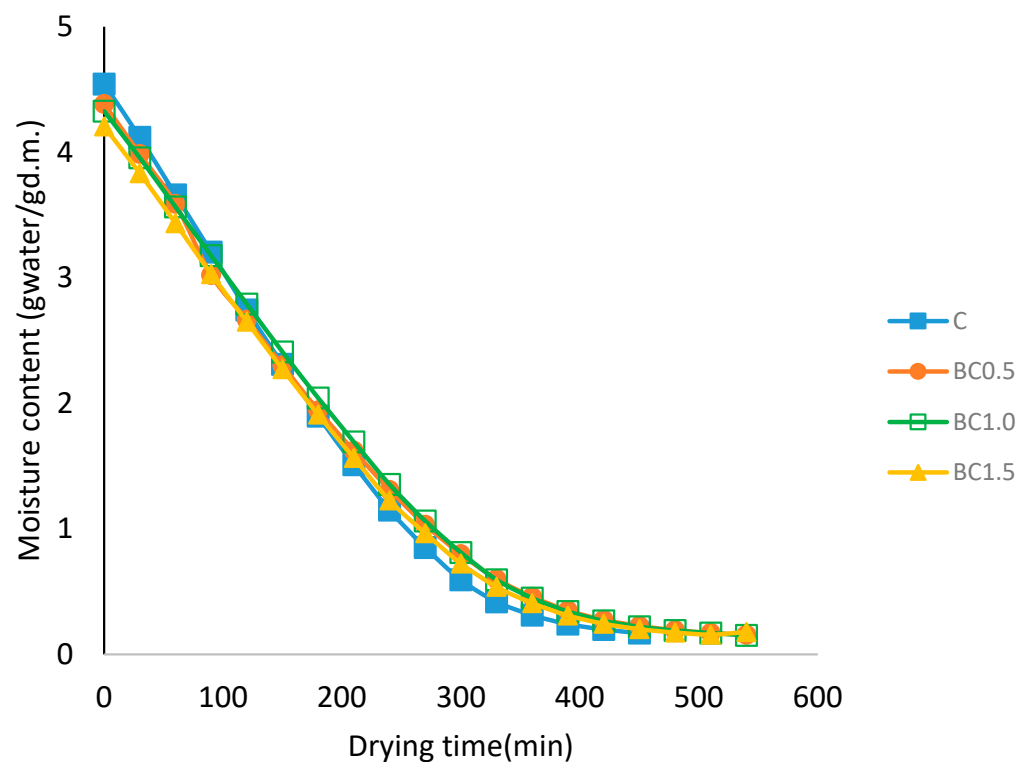
The decline in moisture content of the fruit leathers over time is presented in Figure 1. The initial moisture content of the pear pulp mixtures was affected by the addition of pomace powders; the higher the level of addition, the lower the moisture content. Slightly faster drying of the control pear leather could be noticed as compared with the fruit leathers with added pomace powders. This behavior could be attributed to the low moisture content of the pomace powders and to their high water-holding capacity, mainly as a result of their high fiber content.

3.3. Color and Titratable Acidity of Fruit Leathers

The effects of bilberry and blackcurrant pomace powder addition on color parameters and titratable acidity of pear leather are shown in Tables 2 and 3, respectively. The formulations exhibited considerable differences in terms of color as compared with the control pear leather (Figure 2).



(a)



(b)

Figure 1. Drying curves at 57 °C of the control pear leather and fruit leathers made with addition of (a) bilberry pomace powder; (b) blackcurrant pomace powder.

Table 2. Effect of bilberry pomace powder addition on color parameters and titratable acidity of pear leather *.

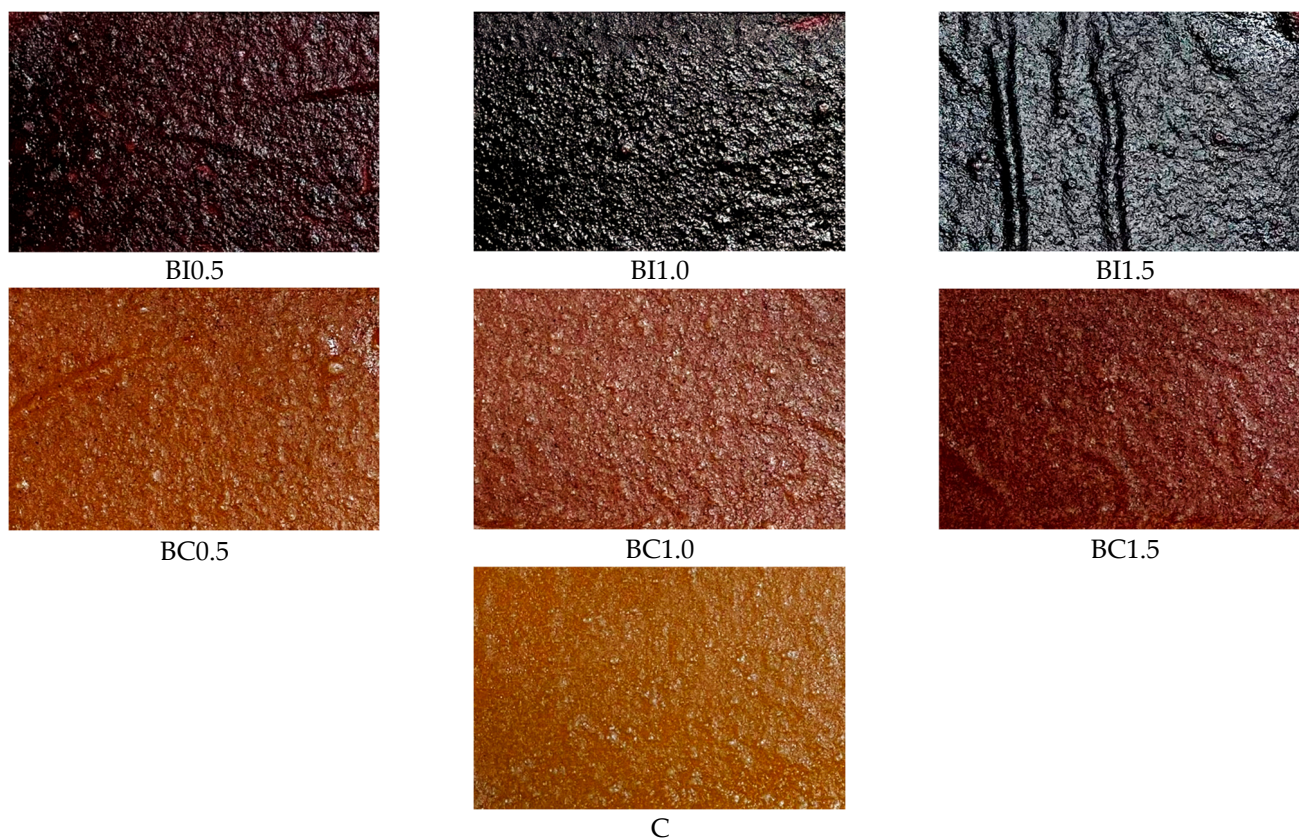
	C	BI0.5	BI1.0	BI1.5
L*	41.79 ± 0.37 ^d	23.08 ± 0.32 ^c	20.74 ± 0.35 ^b	19.75 ± 0.10 ^a
a*	17.79 ± 0.25 ^d	7.77 ± 0.32 ^c	4.91 ± 0.34 ^b	4.20 ± 0.83 ^a
b*	27.71 ± 0.40 ^d	9.41 ± 0.42 ^c	5.51 ± 0.29 ^b	3.56 ± 0.52 ^a
C	32.93 ± 0.43 ^d	12.20 ± 0.47 ^c	7.38 ± 0.44 ^b	5.51 ± 0.94 ^a
h	57.33 ± 0.36 ^d	50.45 ± 1.14 ^c	48.37 ± 0.61 ^b	40.58 ± 0.82 ^a
Titratable acidity (g CA/100 g)	1.31 ± 0.08 ^a	1.54 ± 0.14 ^b	1.68 ± 0.12 ^{bc}	1.75 ± 0.07 ^c

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

Table 3. Effect of blackcurrant pomace powder addition on color parameters and titratable acidity of pear leather *.

	C	BC0.5	BC1.0	BC1.5
L*	42.50 ± 0.62 ^d	38.86 ± 0.99 ^c	32.67 ± 0.54 ^b	30.51 ± 0.77 ^a
a*	15.21 ± 0.46 ^b	15.12 ± 0.42 ^b	14.27 ± 0.40 ^a	14.49 ± 0.39 ^a
b*	26.41 ± 0.50 ^d	22.98 ± 0.81 ^c	17.86 ± 0.30 ^b	16.97 ± 0.36 ^a
C	30.48 ± 0.63 ^c	27.51 ± 0.80 ^b	22.86 ± 0.46 ^a	22.32 ± 0.51 ^a
h	60.10 ± 0.45 ^d	56.69 ± 0.91 ^c	51.40 ± 0.50 ^b	49.53 ± 0.65 ^a
Titratable acidity (g CA/100 g)	1.26 ± 0.07 ^a	1.31 ± 0.08 ^{ab}	1.42 ± 0.04 ^b	1.63 ± 0.11 ^c

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

**Figure 2.** The appearance of the fruit leathers.

The formulations exhibited considerable differences in terms of color as compared with the control pear leather.

Lightness (L^*), redness (a^*) and yellowness (b^*) for the control pear leather were 42.50 ± 0.62 , 17.79 ± 0.25 and 27.71 ± 0.40 , respectively. Similar L^* values (40.70–56.07) were reported by Huang and Hsieh [8] in pear leathers made from different levels of pear juice concentrate, pectin and corn syrup; however, the a^* (4.98–10.15) and b^* (13.67–20.65) values were lower than those found in the present study. The addition of pomace powders caused a substantial decline in lightness (L^* values); however, for a^* values an important decrease was found only in leathers with BIPP addition as compared with the control leather. In those enriched with blackcurrant pomace powder (BCPP), the decrease in a^* values was significant ($p < 0.05$) only at an addition level of more than 1%. The lowest lightness (L^* value = 19.75) was found for BI1.5 (1.5% addition level of BIPP).

The leathers enriched with BCPP were lighter in color (higher L^* values) than the leathers enriched with BIPP. The b^* values were significantly lower in the pear leathers enriched both in BIPP and BCPP as compared with the control leathers; however, b^* values were higher in the latter ones, probably due to the lower anthocyanins content of BCPP as compared with BIPP. Lightness (L^*), redness (a^*), and yellowness (b^*) decreased with increasing level of BIPP and BCPP addition. The color parameters of the leathers are influenced by the color of the incorporated dried by-products (BIPP and BCPP), but also by the behavior of anthocyanins during drying, as it is well known that anthocyanins are highly unstable and very susceptible to degradation [38], being oxidized and heat degraded during drying. However, citric and ascorbic acids from lemon juice may protect anthocyanins from oxidation.

Chroma values between 22.32 and 27.51 were found in the pear leather enriched with blackcurrant pomace powder. Lower chroma values (3.93–19.86) have been reported by Diamante et al. [32] in fruit leathers made from apple juice concentrate, blackcurrant concentrate and pectin.

There were significant increases in the titratable acidity as a result of both bilberry and blackcurrant pomace powder addition (with 33.58% and 29.36% in BI1.5 and BC1.5 as compared with the control, respectively), which is expected to have a positive effect on fruit leather shelf life by inhibiting bacterial growth [39]. In addition, the higher levels of acidity protect the color and flavor of the fruit. Higher values of the titratable acidity were found in the pear leathers enriched with BIPP (1.75 g/100 g in BI1.5) as compared with those enriched with BCPP (1.63 g/100 g in BC1.5), which was expected considering the higher acidity found in BIPP (5.63 ± 0.24 g CA/100 g) as compared with BCPP (4.22 ± 0.19 g CA/100 g). Addai et al. [39] reported TA values between 1.48% and 1.63% in papaya leathers from different cultivars and they recommended papaya cultivars with high acidity to manufacture papaya leathers. Nizamlioglu et al. [40] found TA from 0.9 to 1.7% in fruit leathers from apple, plum and apple–plum mixture while Phuong et al. [10] reported TA between 1.29% and 1.36% in mulberry fruit leathers dried at different temperatures.

3.4. Texture Analysis

The texture features of the leather are important when corroborating the results of the sensory analysis. However, the instrumental texture analysis gives more objective results [41]. The effects of bilberry and blackcurrant pomace powder addition on the textural attributes of pear leather are displayed in Tables 4 and 5, respectively.

Significant differences were found between fruit leather samples ($p < 0.05$) in terms of puncturing force (N), flexibility (mm) and adhesiveness (J). Previous studies mainly focused on the textural attributes of fruit leathers as influenced by the addition of different ingredients (citric acid, sucrose, milk powder) and hydrocolloids (starch, gums, pectin) [42–44], while the current study was the first to report the texture properties of the new fruit leathers produced from pear pulp by adding different levels of BIPP and BCPP. The thickness of the fruit leathers was 1.11 ± 0.18 mm. The puncturing force of the fruit leathers in the present study was found to be between 33.93 and 51.70 N while Diamante

et al. [32] reported values ranging from 9.28 to 29.36 N in apple-blackcurrant fruit leathers made from different levels of apple juice concentrate, blackcurrant concentrate and pectin.

Table 4. Effect of bilberry pomace powder addition on texture properties of pear leather *.

	C	BI0.5	BI1.0	BI1.5
Puncturing force (N)	51.70 ± 1.14 ^d	36.15 ± 1.23 ^a	46.13 ± 1.65 ^b	48.29 ± 1.74 ^c
Flexibility (mm)	0.40 ± 0.02 ^d	0.38 ± 0.01 ^c	0.35 ± 0.02 ^b	0.33 ± 0.03 ^a
Adhesiveness (J)	−12.46 ± 0.49 ^a	−10.37 ± 0.49 ^b	−9.80 ± 0.71 ^c	−9.25 ± 0.42 ^d

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

Table 5. Effect of blackcurrant pomace powder addition on texture properties of pear leather *.

	C	BC0.5	BC1.0	BC1.5
Puncturing force (N)	51.54 ± 1.19 ^c	33.93 ± 1.92 ^a	48.74 ± 1.41 ^b	58.47 ± 2.15 ^d
Flexibility (mm)	0.41 ± 0.02 ^c	0.39 ± 0.02 ^b	0.37 ± 0.02 ^{ab}	0.36 ± 0.02 ^a
Adhesiveness (J)	−12.46 ± 0.49 ^a	−9.83 ± 0.65 ^b	−8.20 ± 0.75 ^c	−5.09 ± 0.40 ^d

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

The results showed that puncturing force decreased as a result of 0.5% BIPP and 0.5% BCPP addition as compared with the control pear leather; however, puncturing force further increased with increasing addition level. Previous authors considered that the texture of leathers may be influenced by water absorption and the protein content of the fruit [39]. Azeredo et al. [45] found that the puncturing force of mango leather decreased with increasing water content due to water absorption during storage. Therefore, the decrease in the puncturing force after BIPP and BCPP addition could be attributed to the water absorption capacity of these dried by-products, while the further increase in the puncturing force as the addition level increased could be attributed to the rise in protein and fiber content of the leather.

The results from Tables 4 and 5 show that flexibility slightly decreased with increasing BIPP and BCPP addition level. The highest flexibility was recorded for the control pear leather (0.41 mm) while the lowest flexibility for BI1.5 (0.33 mm). Flexibility is an important texture attribute as fruit leathers with lower flexibility can be easily fractured during handling and transportation [13].

Fruit leather adhesiveness increased significantly with increasing BIPP and BCPP addition level. The results were in line with the sensory analysis, taking into account the negative opinion of the panelists regarding the high adhesiveness of the fruit leathers. Momchilova et al. [46] reported also that the addition of raspberry pressings to plum fruit leathers increased their adhesiveness but just up to 3% concentration.

3.5. Total Phenolic Content, Total Anthocyanins Content and Antioxidant Activity

The total phenolic content (TPC), total anthocyanins content (TAC) and DPPH radical scavenging activity of control and enriched fruit leathers are presented in Tables 6 and 7.

The addition of BIPP determined the increase in the total phenolic content by 2.03, 3.26 and 4.45 times at addition levels of 0.5, 1.0 and 1.5%, respectively. Values of TPC from 69.73 mg GAE/kg to 310.64 mg GAE/kg were found in the fruit leathers in the present study. Previously, Nizamlioglu et al. [40] reported TPC from 70.9 to 267.3 mg GAE/100 g in fruit leathers from apple, plum and apple–plum mixtures while Addai et al. [39] found TPC of 104.71 and 121.4 mg GAE/100 g in fruit leathers made from two cultivars of papaya. Much higher TPC values were reported by Phuong et al. [10] in mulberry fruit leathers (866–1213 mg GAE/100 g dw) and by Yilmaz et al. [47] in pomegranate fruit leathers (742.4–868.8 mg GAE/100 g dw) manufactured with different drying methods and temperatures.

Table 6. Effect of bilberry pomace powder addition on total phenolic content, total anthocyanin content and DPPH radical scavenging activity of pear leather *.

	C	BI0.5	BI1.0	BI1.5
Total phenolic content (mg GAE/100 g)	69.73 ± 2.23 ^a	141.55 ± 4.55 ^b	227.91 ± 5.11 ^c	310.64 ± 8.89 ^d
Total anthocyanin content (mg CGE/100 g)	-	6.89 ± 0.38 ^a	25.42 ± 1.16 ^b	46.28 ± 1.89 ^c
DPPH radical scavenging activity (mmol Trolox/100 g)	0.95 ± 0.07 ^a	2.31 ± 0.13 ^b	3.27 ± 0.16 ^c	4.45 ± 0.26 ^d

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

Table 7. Effect of blackcurrant pomace powder addition on total phenolic content, total anthocyanin content and DPPH radical scavenging activity of pear leather *.

	C	BC0.5	BC1.0	BC1.5
Total phenolic content (mg GAE/100 g)	70.45 ± 2.60 ^a	86.09 ± 3.67 ^b	99.73 ± 3.98 ^c	112.45 ± 4.21 ^d
DPPH radical scavenging activity (mmol Trolox/100 g)	0.97 ± 0.06 ^a	1.27 ± 0.07 ^b	1.62 ± 0.11 ^c	1.76 ± 0.12 ^d

* Different lowercase letters indicate significant differences between fruit leather formulations ($p < 0.05$).

The addition of bilberry pomace powder came up with an important anthocyanin content that increased the TAC of the enriched fruit leathers with increasing addition levels, reaching 46.28 ± 1.89 mg CGE/100 g for 1.5% addition of BIPP. The DPPH radical scavenging activity increased also with increasing BIPP addition level (by 2.42, 3.44 and 4.68 times for addition levels of 0.5, 1.0 and 1.5%, respectively). A DPPH radical scavenging activity of 4.45 ± 0.26 mmol Trolox/100 g was found in BI1.5 samples and only 1.76 ± 0.12 mmol Trolox/100 g in BC1.5 samples. Previously, Quintero Ruiz et al. [48] reported Trolox equivalent antioxidant activity between 1.7 and 3.3 mmol TE/100 g in rose hip leathers while Chen and Martynenko [49] reported DPPH results between 5.91 and 7.19 mmol TE/100 g dw in blueberry leathers.

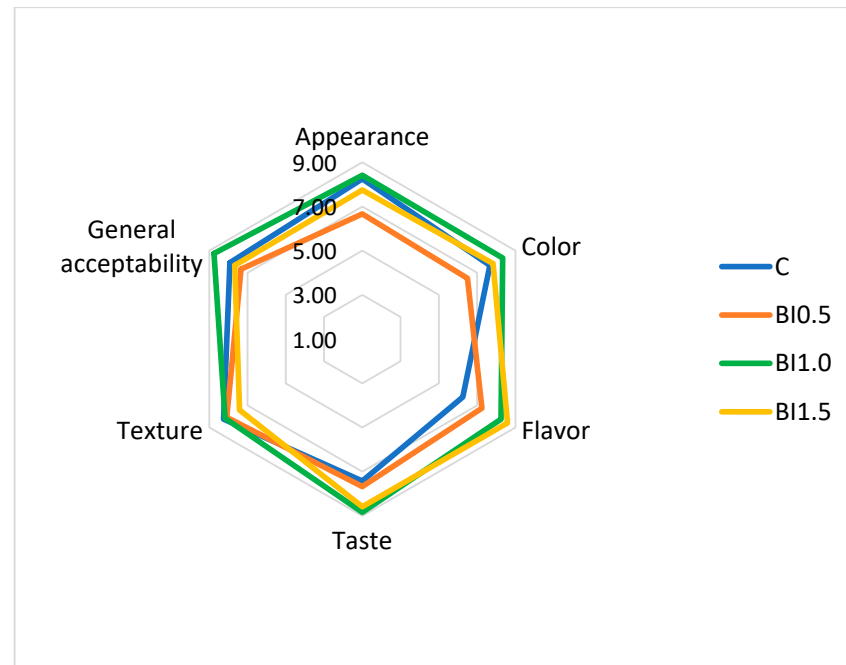
The TPC and DPPH antioxidant activity were higher in the pear leathers with BIPP addition than in the corresponding ones made with the same level of BCPP addition, predictably, considering the higher total phenolic content in BIPP (36.7 ± 0.77 mg GAE/g) as compared with BCPP (26.2 ± 0.45 mg GAE/g).

The pH differential method was unable to determine the anthocyanin content in the fruit leathers developed with BCPP addition due to the low anthocyanins content in BCPP (3.68 ± 0.07 mg CGE/g) as compared with BIPP (28.35 ± 0.52 mg CGE/g). The total phenolic content increased in these fruit leathers by 1.22, 1.42 and 1.60 times as compared with the control pear leather at BCPP addition levels of 0.5, 1.0 and 1.5%, respectively, leading to a 1.31-, 1.66- and 1.81-fold increase in the antioxidant activity of the corresponding fruit leathers. The higher rate of increase in the antioxidant activity compared to that in the phenolic content as a result of the BIPP and BCPP addition may be attributed to the composition of pomace powders in other antioxidant compounds besides phenolics such as ascorbic acid, tocopherols and carotenoids.

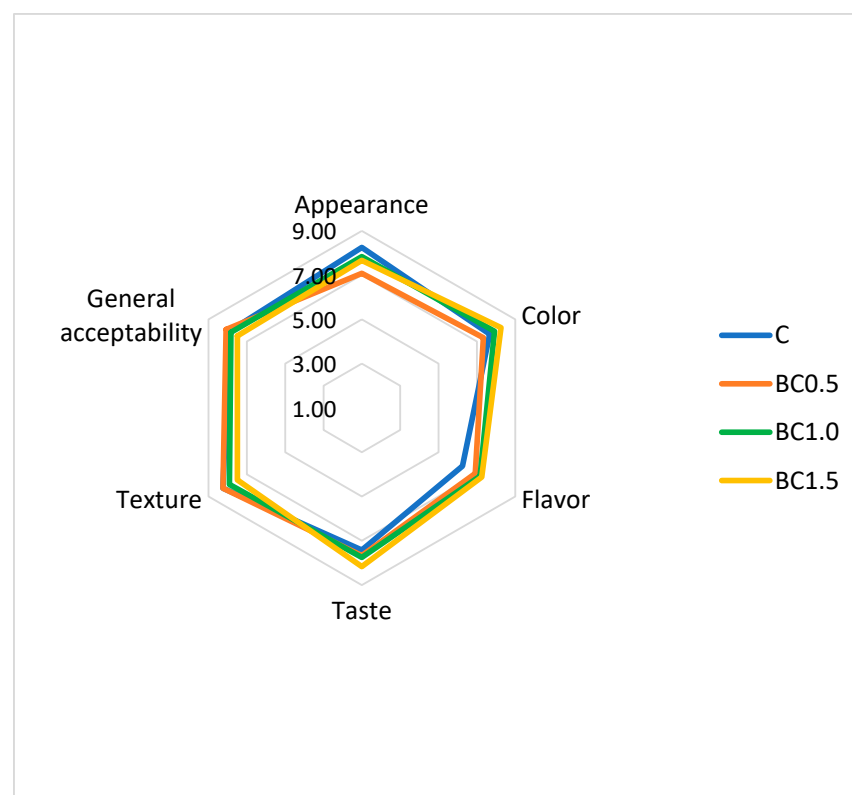
3.6. Sensory Analysis

The sensory evaluation of the developed fruit leathers was conducted on the basis of twelve responses. The average scores for the sensory properties of the fruit leathers are presented in Figure 3. The results revealed that an addition of 0.5% BIPP caused a decrease in the appearance score compared to the control, while the samples with higher addition levels scored significantly higher values. The BI1.0 sample received the highest score for appearance. The addition of 0.5% BCPP was also not favorable for appearance, but a higher addition level led to an increase in the appearance score, which was maximum for BC1.0. A similar variation was recorded for color, which was to be expected considering

that color is a determinant in the appearance of the fruit leather. The golden-yellow color of the pear leather was reduced by an addition of 0.5% BIPP or BCPP but it was improved at 1% addition level. However, 1.5% addition of BIPP led to an excessively dark color of the fruit leather and the color score dropped accordingly (Figure 2).



(a)



(b)

Figure 3. Sensory profile of control pear leather and pear leathers enriched with (a) bilberry pomace powder; (b) blackcurrant pomace powder.

The flavor improved constantly as the level of BIPP addition increased due to the intensification of the bilberry aroma. The control pear leather had a sweet aroma, without fructosity and freshness. The taste evolved in the same way as the flavor, the bilberry taste intensified with increasing BIPP addition and the acidity increased as well, giving a fruity, fresh taste to the fruit leather. The leathers enriched with BCPP achieved lower flavor scores than those with BIPP.

The addition of BIPP and BCPP caused an increase in leather adhesiveness, which was noticed by the panelists during the sensory analysis and resulted in a decrease in the texture and acceptance scores of the leathers [43]. However, no significant texture score differences were found between leather formulations up to 1% BIPP or BCPP addition level; above this level, the texture score dropped significantly. In terms of general acceptability, the formulation with 1% added BIPP (BI1.0) was the best-liked fruit leather, with a significantly higher score than the other formulations, while of the leathers enriched with BCPP, BC1.0 was the favorite.

4. Conclusions

New fruit leathers were successfully developed from pear pulp by adding wild bilberry and blackcurrant pomace powders at three 0.5%, 1.0% and 1.5% addition levels. Besides improving the taste and flavor, the addition of BIPP and BCPP significantly increased the titratable acidity, total phenolic content, total anthocyanin content and antioxidant activity of the new fruit leathers as compared with a control pear leather. Flexibility slightly decreased while adhesiveness significantly increased with increasing BIPP and BCPP addition levels, changes that were perceived as negative in the sensory analysis and led to a decrease in the scores for texture. The fruit leathers made with 1.0% BCPP or 1.0% BIPP addition were rated as the best in the sensory evaluation. Due to their attractive color, palatable flavor and high bioactive content, these newly developed fruit leathers could be recommended as alternative snack foods with a high nutritional level and functionality. Additional studies are needed to confirm the sensory findings by a larger panel and to increase the efficiency of the newly developed fruit leathers manufacturing process by optimizing the drying conditions.

Author Contributions: Conceptualization, V.N. and A.M.B.; methodology, V.N. and G.G.C.; software, V.N., A.M.B. and G.G.C.; validation, V.N. and G.G.C.; formal analysis, A.M.B., V.N. and G.G.C.; investigation, V.N. and A.M.B.; resources, V.N., G.G.C. and A.M.B.; data curation, V.N. and G.G.C.; writing—original draft preparation, V.N., A.M.B. and G.G.C.; writing—review and editing, V.N.; visualization, V.N. and G.G.C.; supervision, V.N.; project administration, V.N.; funding acquisition, V.N. and A.M.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Del Rio-Celestino, M.; Font, R. The health benefits of fruits and vegetables. *Foods* **2020**, *9*, 369. [CrossRef] [PubMed]
2. Majdan, M.; Bobrowska-Korczak, B. Active compounds in fruits and inflammation in the body. *Nutrients* **2022**, *14*, 2496. [CrossRef] [PubMed]
3. Rahaman, M.; Hossain, R.; Herrera-Bravo, J.; Islam, M.T.; Atolani, O.; Adeyemi, O.S.; Owolodun, O.A.; Kambizi, L.; Daştan, S.D.; Calina, D.; et al. Natural antioxidants from some fruits, seeds, foods, natural products, and associated health benefits: An update. *Food Sci. Nutr.* **2023**, *11*, 1657–1670. [CrossRef] [PubMed]
4. World Health Organization. *Healthy Diet. Fact Sheet No. 394*; WHO: Geneva, Switzerland, 2015.
5. FAO; IFAD; UNICEF; WFP WHO. The State of Food Security and Nutrition in the World 2018. In *Building Climate Resilience for Food Security and Nutrition*; FAO: Rome, Italy, 2018; Available online: <http://www.fao.org/3/I9553EN/i9553en.pdf> (accessed on 2 July 2024).
6. Kaufman-Shriqui, V.; Navarro, D.A.; Raz, O.; Boaz, M. Dietary changes and anxiety during the coronavirus pandemic: A multinational survey. *Eur. J. Clin. Nutr.* **2022**, *76*, 84–92. [CrossRef]

7. Vázquez-Sánchez, A.Y.; Corfield, R.; Sosa, N.; Salvatori, D.; Schebor, C. Physicochemical, functional, and sensory characterization of apple leathers enriched with acáchul (*Ardisia compressa* Kunth) powder. *LWT-Food Sci. Technol.* **2021**, *146*, 111472. [\[CrossRef\]](#)
8. Huang, X.; Hsieh, F.-H. Physical properties, sensory attributes, and consumer preference of pear fruit leather. *J. Food Sci.* **2005**, *70*, E177–E186. [\[CrossRef\]](#)
9. Diamante, L.M.; Bai, X.; Busch, J. Fruit Leathers: Method of preparation and effect of different conditions on qualities. *Int. J. Food Sci.* **2014**, *2014*, 139890. [\[CrossRef\]](#)
10. Phuong, H.M.K.; Hoa, N.D.H.; Ha, N.V.H. Effects of added pectin amounts and drying temperatures on antioxidant properties of mulberry fruit leather. *J. Biotechnol.* **2016**, *14*, 487–495.
11. Bandaru, H.; Bakshi, M. Fruit Leather: Preparation, packaging and its effect on sensorial and physico-chemical properties: A review. *J. Pharmacogn. Phytochem.* **2020**, *9*, 1699–1709. [\[CrossRef\]](#)
12. da Silva Simão, R.; de Moraes, J.O.; Carciofi, B.A.M.; Laurindo, J.B. Recent advances in the production of fruit leathers. *Food Eng. Rev.* **2020**, *12*, 68–82. [\[CrossRef\]](#)
13. Ayalew, G.M.; Emire, S.A. Formulation and characterization of fruit leather based on *Annona muricata* L. fruit and *Avena sativa* flour. *J. Food Process Preserv.* **2020**, *44*, e14284. [\[CrossRef\]](#)
14. Gómez-Pérez, L.S.; Navarrete, C.; Moraga, N.; Rodríguez, A.; Vega-Gálvez, A. Evaluation of different hydrocolloids and drying temperatures in the drying kinetics, modeling, color, and texture profile of murta (*Ugni molinae* Turcz) berry leather. *J. Food Process Eng.* **2020**, *43*, e13316. [\[CrossRef\]](#)
15. Eyiz, V.; Tontul, İ.; Türker, S. Effect of variety, drying methods and drying temperature on physical and chemical properties of hawthorn leather. *J. Food Meas. Charact.* **2020**, *14*, 3263–3269. [\[CrossRef\]](#)
16. Mphaphuli, T.; Manhivi, V.E.; Slabbert, R.; Sultanbawa, Y.; Sivakumar, D. Enrichment of mango fruit leathers with natal plum (*Carissa macrocarpa*) improves their phytochemical content and antioxidant properties. *Foods* **2020**, *9*, 431. [\[CrossRef\]](#)
17. Santos, K.L.; de Sousa, P.H.M.; Cavalcanti-Mata, M.E.R.M.; de Vasconcelos, L.B. Mixed leather of açai, banana, peanut, and guarana syrup: The effect of agar and gellan gum use on quality attributes. *Int. J. Gastron. Food Sci.* **2021**, *26*, 100407. [\[CrossRef\]](#)
18. Cappa, C.; Lavelli, V.; Mariotti, M. Fruit candies enriched with grape skin powders: Physicochemical properties. *LWT-Food Sci. Technol.* **2015**, *62*, 569–575. [\[CrossRef\]](#)
19. Teshome, E.; Teka, T.A.; Nandasiri, R.; Rout, J.R.; Harouna, D.V.; Astatkie, T.; Urugo, M.M. Fruit by-products and their industrial applications for nutritional benefits and health promotion: A comprehensive review. *Sustainability* **2023**, *15*, 7840. [\[CrossRef\]](#)
20. Pathania, S.; Kaur, N. Utilization of fruits and vegetable by-products for isolation of dietary fibers and its potential application as functional ingredients. *Bioact. Carbohydr. Diet. Fibre* **2022**, *27*, 100295. [\[CrossRef\]](#)
21. Campos, D.A.; Gómez-García, R.; Vilas-Boas, A.A.; Madureira, A.R.; Pintado, M.M. Management of fruit industrial by-products—A case study on circular economy approach. *Molecules* **2020**, *25*, 320. [\[CrossRef\]](#)
22. Mohd Basri, M.S.; Abdul Karim Shah, N.N.; Sulaiman, A.; Mohamed Amin Tawakkal, I.S.; Mohd Nor, M.Z.; Ariffin, S.H.; Abdul Ghani, N.H.; Mohd Salleh, F.S. Progress in the valorization of fruit and vegetable wastes: Active packaging, biocomposites, by-products, and innovative technologies used for bioactive compound extraction. *Polymers* **2021**, *13*, 3503. [\[CrossRef\]](#)
23. Vega, E.N.; García-Herrera, P.; Ciudad-Mulero, M.; Dias, M.I.; Matallana-González, M.C.; Cámara, M.; Tardío, J.; Molina, M.; Pinela, J.C.S.P.; Pires, T.; et al. Wild sweet cherry, strawberry and bilberry as underestimated sources of natural colorants and bioactive compounds with functional properties. *Food Chem.* **2023**, *414*, 135669. [\[CrossRef\]](#)
24. Ejaz, A.; Waliat, S.; Afzaal, M.; Saeed, F.; Ahmad, A.; Din, A.; Ateeq, H.; Asghar, A.; Shah, Y.A.; Rafi, A.; et al. Biological activities, therapeutic potential, and pharmacological aspects of blackcurrants (*Ribes nigrum* L.): A comprehensive review. *Food Sci. Nutr.* **2023**, *11*, 5799–5817. [\[CrossRef\]](#)
25. Mikulic-Petkovsek, M.; Schmitzer, V.; Slatnar, A.; Stampar, F.; Veberic, R. A comparison of fruit quality parameters of wild bilberry (*Vaccinium myrtillus* L.) growing at different locations. *J. Sci. Food Agric.* **2015**, *95*, 776–785. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Pires, T.C.S.P.; Inês Dias, M.; Calhelha, R.C.; José Alves, M.; Santos-Buelga, C.; Ferreira, I.C.F.R.; Barros, L. Development of new bilberry (*Vaccinium myrtillus* L.) based snacks: Nutritional, chemical and bioactive features. *Food Chem.* **2021**, *334*, 127511. [\[CrossRef\]](#) [\[PubMed\]](#)
27. Prencipe, F.P.; Bruni, R.; Guerrini, A.; Rossi, D.; Benvenuti, S.; Pellati, F. Metabolite profiling of polyphenols in *Vaccinium* berries and determination of their chemopreventive properties. *J. Pharm. Biomed. Anal.* **2014**, *89*, 257–267. [\[CrossRef\]](#)
28. Delazar, A.; Khodaie, L.; Afshar, J.; Nahar, L.; Sarker, S. Isolation and free-radical-scavenging properties of cyanidin 3-glycosides from the fruits of *Ribes biebersteinii* Berl. *Acta Pharm.* **2010**, *60*, 1–11. [\[CrossRef\]](#) [\[PubMed\]](#)
29. Gopalan, A.; Reuben, S.C.; Ahmed, S.; Darvesh, A.S.; Hohmann, J.; Bishayee, A. The health benefits of blackcurrants. *Food Funct.* **2012**, *3*, 795–809. [\[CrossRef\]](#) [\[PubMed\]](#)
30. Nour, V.; Stampar, F.; Veberic, R.; Jakopic, J. Anthocyanins profile, total phenolics and antioxidant activity of black currant ethanolic extracts as influenced by genotype and ethanol concentration. *Food Chem.* **2013**, *141*, 961–966. [\[CrossRef\]](#)
31. Blejan, A.M.; Nour, V.; Păcularu-Burada, B.; Popescu, S.M. Wild bilberry, blackcurrant, and blackberry by-products as a source of nutritional and bioactive compounds. *Int. J. Food Prop.* **2023**, *26*, 1579–1595. [\[CrossRef\]](#)
32. Diamante, L.M.; Li, S.; Xu, Q.; Busch, J. Effects of apple juice concentrate, blackcurrant concentrate and pectin levels on selected qualities of apple-blackcurrant fruit leather. *Foods* **2013**, *2*, 430–443. [\[CrossRef\]](#)
33. Sarma, O.; Kundlia, M.; Chutia, H.; Mahanta, C.L. Processing of encapsulated flaxseed oil-rich banana-based (Dwarf Cavendish) functional fruit leather. *J. Food Process Eng.* **2023**, *46*, e14282. [\[CrossRef\]](#)

34. Singleton, V.L.; Orthofer, R.; Lamuela-Raventos, R.M. Analysis of total phenols and other oxidation substrates and antioxidants using Folin-Ciocalteu reagent. *Methods Enzymol.* **1999**, *299*, 152–178. [[CrossRef](#)]
35. Giusti, M.M.; Wrolstad, R.E. Characterization and measurement of anthocyanins by UV-Visible spectroscopy. In *Current Protocols in Food Analytical Chemistry*; Wrolstad, R.E., Acree, T.E., An, H., Decker, E.A., Penner, M.H., Reid, D.S., Schwartz, S.J., Shoemaker, C.F., Sporns, P., Eds.; John Wiley & Sons, Inc.: New York, NY, USA, 2001; pp. F1.2.1–F1.2.13.
36. Oliveira, I.; Sousa, A.; Ferreira, I.C.F.R.; Bento, A.; Estevinho, L.; Pereira, J.A. Total phenols, antioxidant potential and antimicrobial activity of walnut (*Juglans regia* L.) green husks. *Food. Chem. Toxicol.* **2008**, *46*, 2326–2331. [[CrossRef](#)] [[PubMed](#)]
37. Struck, S.; Plaza, M.; Turner, C.; Rohm, H. Berry pomace—A review of processing and chemical analysis of its polyphenols. *Int. J. Food Sci. Technol.* **2016**, *51*, 1305–1318. [[CrossRef](#)]
38. Giusti, M.M.; Wrolstad, R.E. Acylated anthocyanins from edible sources and their applications in food systems. *Biochem. Eng. J.* **2003**, *14*, 217–225. [[CrossRef](#)]
39. Addai, Z.; Abdullah, A.; Sahilah, A.M.; Musa, K.H. Evaluation of fruit leather made from two cultivars of papaya. *Ital. J. Food Sci.* **2016**, *28*, 73–82. [[CrossRef](#)]
40. Nizamlioglu, N.M.; Yasar, S.; Bulut, Y. Chemical versus infrared spectroscopic measurements of quality attributes of sun or oven dried fruit leathers from apple, plum and apple-plum mixture. *LWT-Food Sci. Technol.* **2022**, *153*, 112420. [[CrossRef](#)]
41. Karabacak, A.Ö.; Suna, S.; Dorak, S.; Copur, Ö.U. Drying characteristics, mineral content, texture and sensorial properties of pumpkin fruit leather. *Lat. Am. Appl. Res.* **2021**, *51*, 193–201. [[CrossRef](#)]
42. Çağındı, O.; Otles, S. Comparison of some properties on the different types of pestil: A traditional product in Turkey. *Int. J. Food Sci. Technol.* **2005**, *40*, 897–901. [[CrossRef](#)]
43. Al-Hinai, K.Z.; Guizani, N.; Singh, V.; Rahman, M.S.; Al-Subhi, L. Instrumental texture profile analysis of date-tamarind fruit leather with different types of hydrocolloids. *Food Sci. Technol. Res.* **2013**, *49*, 531–538. [[CrossRef](#)]
44. Tontul, I.; Topuz, A. Effects of different drying methods on the physicochemical properties of pomegranate leather (pestil). *LWT-Food Sci. Technol.* **2017**, *80*, 294–303. [[CrossRef](#)]
45. Azeredo, H.M.C.; Brito, E.S.; Moreira, G.E.G.; Farias, V.L.; Bruno, L.M. Effect of drying and storage time on the physico-chemical properties of mango leathers. *Int. J. Food Sci. Technol.* **2006**, *41*, 635–638. [[CrossRef](#)]
46. Momchilova, M.; Zsivanovits, G.; Milkova-Tomova, I.; Buhalova, D.; Dojkova, P. Sensory and texture characterisation of plum (*Prunus domestica*) fruit leather. *Bulg. Chem. Commun.* **2016**, *48*, 428–434.
47. Yılmaz, F.M.; Yüksekaya, S.; Vardin, H.; Karaaslan, M. The effects of drying conditions on moisture transfer and quality of pomegranate fruit leather (pestil). *J. Saudi Soc. Agric. Sci.* **2017**, *16*, 33–40. [[CrossRef](#)]
48. Quintero Ruiz, N.A.; Demarchi, S.M.; Giner, S.A. Effect of hot air, vacuum and infrared drying methods on quality of rose hip (*Rosa rubiginosa*) leathers. *Int. J. Food Sci. Technol.* **2014**, *49*, 1799–1804. [[CrossRef](#)]
49. Chen, Y.; Martynenko, A. Combination of hydro-thermodynamic (HTD) processing and different drying methods for natural blueberry leather. *LWT Food Sci. Technol.* **2018**, *87*, 470–477. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.