VALORIZATION OF BERRY BY-PRODUCTS IN THE DEVELOPMENT OF NEW FUNCTIONAL FOODS

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Abstract

The paper presents ways to utilize by-products resulting from the processing of berries, especially billberry, blackcurrant and blackberry pomace, for the development of functional food products. The study aimed to evaluate the nutritional composition, the content of bioactive compounds and antioxidant activity, as well as the use of these by- products in various food matrices, such as fruit leather (pestil) and bakery products. The results highlighted the high potential of pomace powders as a functional ingredient rich in fiber, polyphenols and polyunsaturated fatty acids, contributing to the production of food products with superior nutritional and functional value.

Keywords: pomace, berries, phenolic compounds, antioxidants, functional food products;

INTRODUCTION

In the current context of sustainable development and the increased interest in the valorization of agri-food by-products, berry pomace represents a promising resource due to its rich content in bioactive compounds and essential nutrients. Pomace, defined as the residual material obtained after the extraction of fruit juice, contains significant amounts of dietary fiber, unsaturated fatty acids, polyphenols and natural pigments with antioxidant potential. Thus, its use as a functional ingredient can contribute to the reduction of agro-industrial waste and the production of food products with high added value.

Berries, such as bilberries (*Vaccinium myrtillus*), blackcurrants (*Ribes nigrum*) and blackberries (*Rubus fruticosus*), are recognized for their high concentrations of phenolic compounds and for the associated antioxidant properties. However, data on the detailed chemical composition and bioactive potential of pomace from these species are still limited. Studying these by-products can provide valuable information on the possibilities of utilization in the food and nutraceutical fields, contributing, at the same time, to the promotion of the principles of circular economy in the food industry. Berries are commonly marketed in the form of processed products, such as juices, jams, jellies and alcoholic beverages (Basegmez et al., 2017). After the processing operations of berries to obtain juice by pressing, a large amount of waste is formed in the form of pomace (Xue et al., 2022). Pomace is rich in fiber, acids, anthocyanins and other phenolic compounds (Mäkilä et al., 2014), and this has led researchers to carry out studies to valorize berry pomace, using it as a natural ingredient for the development of healthy food products (Michalska et al., 2017).

In this context, our research aimed to

evaluate the nutritional composition, lipid profile and antioxidant content of bilberry, blackcurrant and blackberry pomaces, in order to identify their potential for use as sustainable functional ingredients in the food industry. Our research also aimed at using powders from bilberry and blackcurrant processing by-products as functional additives for the development of new food products.

MATERIALS AND METHODS

A first study aimed at characterizing the main chemical components, determining the titratable acidity, color and total content of phenolic compounds, flavonoids and anthocyanins, as well as evaluating the antioxidant activity of the powders resulting from drying and grinding bilberry, blackcurrant and blackberry pomaces (Lorenzo et al., 2018). The fatty acid and polyphenol profiles were also examined by chromatographic methods (Kurek et al., 2021).

Studies were conducted to develop fruit leathers by adding 0.5%, 1.0% and 1.5% bilberry (BIPP) and blackcurrant (BCPP) pomace powder to pear leather made with the addition of 5% honey, 1% pectin and 2.5% lemon juice (Blejan et al., 2023). The CIEL*a*b* color parameters, titratable acidity, total phenolic content, antioxidant activity and textural properties of the fruit leathers were determined (Singleton et al.,1999).

Also, in order to improve the nutritional and functional value of corn puffs, studies were conducted on the effect of adding bilberry pomace powder at 2%, 4% and 6% in corn puffs, as a source of bioactive compounds and fibers.The proximal composition, total phenolic content, antioxidant activity, color, titratable acidity and textural properties of the control and supplemented puffs were determined (Blejan et al., 2023).

Another study by our research team aimed to analyze the effects of replacing wheat flour in cookies at levels of 2.5%, 5% and 10% with bilberry and blackcurrant pomace powders on the proximal composition, color, acidity, textural properties, total phenolic content, antioxidant activity and sensory properties of the cookies.

RESULTS AND DISCUSSIONS

1. Characterization of berry pomace powders

Bilberry, blackberry and blackcurrant pomaces, obtained as by-products of juice processing, represent a rich and economical source of nutrients and biologically active compounds. Due to their high seed content, berry pomace is a source of oils with a unique fatty acid profile, rich in monounsaturated and polyunsaturated fatty acids (Wajs-Bonikowska et al., 2017). Although the three studied by-products did not differ significantly in terms of total polyunsaturated fatty acid content, bilberry pomace was the richest in n-3 polyunsaturated fatty acids, followed by blackcurrant pomace (Helbig et al., 2008). The red powders obtained after drying and grinding the studied berry pomaces contain considerable amounts of anthocyanins, making them a potential source of components with coloring properties, capable of replacing synthetic additives.

Bilberry pomace powder showed higher protein, fiber and water absorption capacity compared to blackcurrant pomace, but had lower values for fat content and titratable acidity. These compositional differences can be attributed to botanical variations and the distinct content of bioactive substances in the two types of pomace.

Blackberry pomace showed higher levels of fiber, lipids and minerals compared to bilberry and blackcurrant pomace. Lipid profile analysis revealed a predominance of monounsaturated (16.7–18.7%) and polyunsaturated fatty acids (72.3–77.4%), with the lowest n−6/n−3 ratio determined in bilberry pomace (0.90). It also recorded the highest content of total phenolics (36.7 mg GAE/g dry matter) and total anthocyanins (28.35 mg CGE/g d.u.) (Varo et al., 2019**).** The phenolic profile was dominated by ellagic acid and catechin in bilberry pomace, and by epigallocatechin and catechin in blackberry and blackcurrant pomace, respectively. Significant levels of

procyanidins B1 were also quantified in bilberry and blackcurrant pomace.

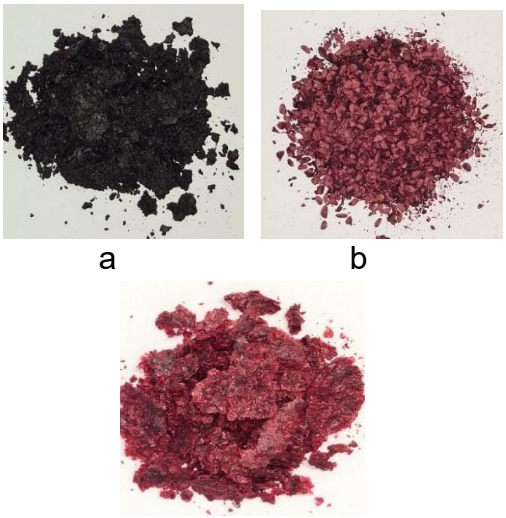

Figure 1. Fruit pomace powders: a – bilberry pomace; b – blackberry pomace; c – blackcurrant pomace.

Due to their healthy lipid profile and richness in antioxidant compounds, berry pomaces are good candidates as food ingredients to improve the functionality of food products and to contribute to the sustainable development of the food industry (Machado et al., 2015).

2. Pear pestil enriched with bilberry and blackcurrant pomace powders

The analysis of the obtained products highlighted the significant influence of the addition of wild bilberry and blackcurrant pomace powders on the physicochemical, textural and sensory properties of the “fruit leather” products (Karabacak et al., 2021). Colorimetric determinations showed that the addition of pomace powders led to a significant decrease in brightness (L*), color intensity (chroma) and hue angle, which indicated an intensification of the dark shades specific to anthocyanin pigments. The values of the parameter a* decreased especially in the samples containing additions of bilberry pomace powders, suggesting a reduction in the red components. At the same time, an increase in titratable acidity was observed, proportional to the level of powder addition, which can be explained by the presence of organic acids in the pomace.

The addition of pomace powders to the pear pestil resulted in significant increases in the total phenolic and anthocyanin content, as well as in the antioxidant activity. In the case of samples with 0.5%, 1.0% and 1.5% bilberry pomace powder, the total phenolic content increased by 2.03, 3.26 and 4.45 times, while for samples with the addition of blackcurrant pomace powder, the corresponding values were 1.22, 1.42 and 1.60 times higher compared to the control.

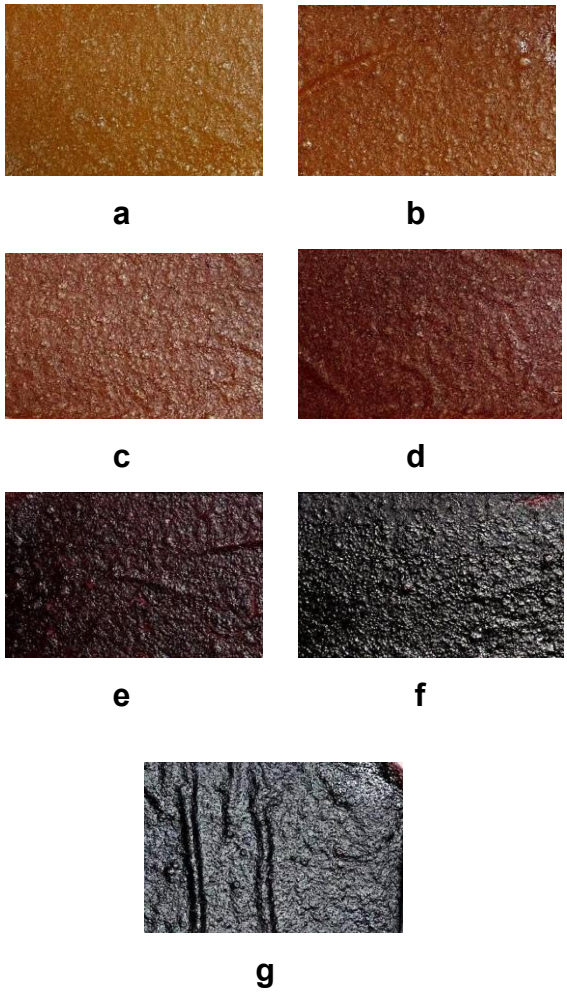

Figure 2. Appearance of fruit pestils: a – control pear pestil; b – pear pestil with 0.5% blackcurrant pomace; c – pear pestil with 1.0% blackcurrant pomace; d – pear pestil with 1.5% blackcurrant pomace; d – pear pestil with 0.5% bilberry pomace; e – pear pestil with 1.0% bilberry pomace; f – pear pestil with 1.5% bilberry pomace.

These results confirm the important role of pomace powders as concentrated sources of polyphenols, which can have positive effects on the functional properties of the finished products (Blejan et al., 2023).
Textural analysis showed that, with the increase in the addition level of bilberry and blackcurrant pomace powders, the flexibility of the products decreased slightly, while the stickiness increased significantly (Yılmaz et al., 2017). These modifications can be attributed to the interactions between phenolic compounds and the pectin network, which may influence the structure and cohesion of the gel matrix. In the sensory evaluation, these textural changes were perceived negatively by the sensory panel, by reducing the sensation of elasticity and increasing stickiness.
The observed effects indicated that the addition of pomace, although significantly influencing the visual and mechanical characteristics of the products, contributed substantially to the enrichment in bioactive compounds and the increase in antioxidant activity. Thus, the new fruit pestils enriched with pomace powders can be considered functional snacks, with superior nutritional value and high beneficial potential for human health, especially due to the increased intake of polyphenols and anthocyanins from pomace. The new reformulated products could be recommended as alternative snacks with high nutritional value and functionality.

3. Corn puffs with added bilberry pomace powder

Extruded corn-based snacks (puffs) are food products that are very popular, especially among children, appreciated for their pleasant taste and accessibility, but they are characterized by a high content of starch and fat, along with a low level of bioactive compounds. In this context, the present study aimed to improve the functional value of extruded corn snacks by supplementing them with bilberry pomace powder, at levels of 2%, 4% and 6% (Blejan și colab.,2023)

The compositional analysis revealed a significant increase in the content of proteins, fibers and ash with the increase in the addition level of bilberry pomace powder. In products with the addition of 6% bilberry pomace powder, the fiber content increased approximately 2.7 times compared to the control sample, which demonstrated the potential of bilberry pomace to improve the nutritional profile of corn puffs (Blejan et al., 2024).

Figure 3. a - control puffs; b - puffs with 2% bilberry pomace powder; c - puffs with 4% bilberry pomace powder; d - puffs with 6% bilberry pomace powder.

The physico-chemical determinations showed that the additions of 4% and 6% bilberry pomace powder did not significantly affect the expansion ratio and hardness of the puffs, but led to a notable decrease in textural parameters such as cohesiveness, gumminess, resilience, chewiness and brittleness. These changes can be explained by the interactions between the insoluble fibers from the bilberry pomace powder and the starch-protein matrix of the extruded product, which influenced its mechanical behavior

(Korkerd et al., 2016).

The addition of bilberry pomace powder determined a consistent increase in the total phenolic content, by approximately 54%, 86% and 118% for the addition levels of 2%, 4% and 6%, respectively, compared to the control sample. This enrichment was correlated with an increase in antioxidant activity, confirming the significant contribution of bioactive compounds from bilberry pomace.
The results obtained demonstrated that the supplementation of extruded corn snacks with bilberry pomace powder contributed to improving the nutritional and functional value, without significantly compromising the essential physical qualities of the product (Korkerd et al., 2016).
The addition of 6% bilberry pomace powder offered the most balanced profile between structural properties, chemical composition and antioxidant activity, leading to obtaining an innovative product, with high potential for commercial exploitation and benefits for human health and especially children.

4. Cookies with the addition of bilberry and blackcurrant pomace powders

In this study, the aim was to evaluate the effects of partially replacing wheat flour with bilberry and blackcurrant pomace powders, added at 2.5%, 5% and 10% in cookies (Blejan et al., 2025), on the rheological and textural properties of the dough, as well as on the proximal composition, color, titratable acidity, pH, total phenolic content, antioxidant activity, textural and sensory properties of the cookies.
The incorporation of pomace powders into the cookie recipe resulted in a reduction in protein content and a significant increase in fat, fiber, and mineral content, with increasing addition rates. The rheological properties of the dough were influenced by the addition of pomace, with increases in hardness, consistency, and stiffness with increasing substitution levels (Raczkowska et al., 2024).
These changes can be explained by the increased water absorption capacity of the pomace fibers, which affected the structure of the gluten matrix.

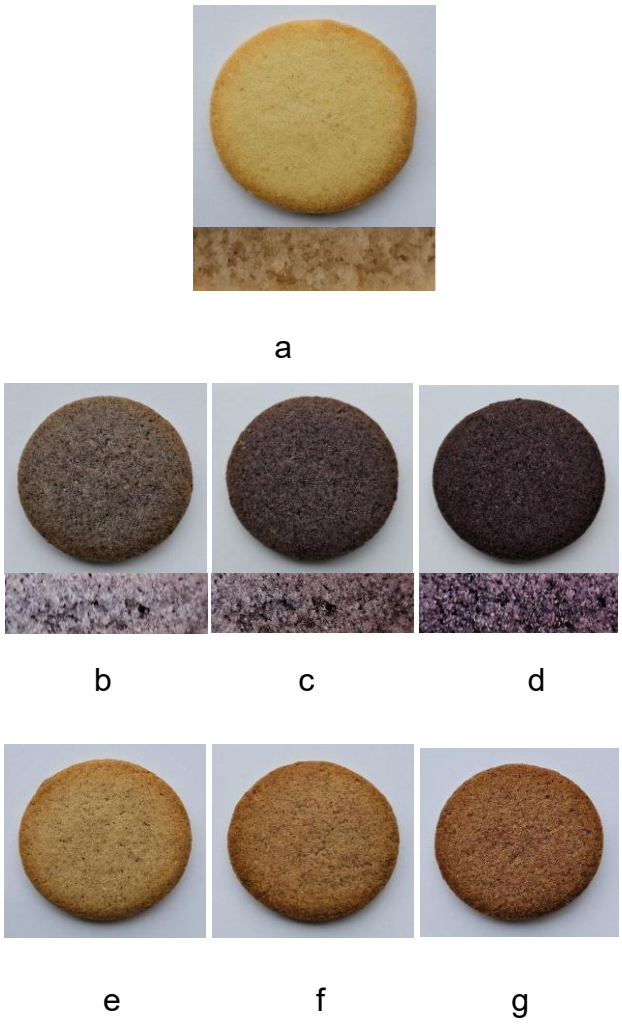

Figure 4. a - control cookie; b - cookie with 2.5% bilberry pomace powder; c - cookie with 5% bilberry pomace powder; d - cookie with 10% bilberry pomace powder; e - cookie with 2.5% blackcurrant pomace powder; f - cookie with 5% blackcurrant pomace powder; g – cookie with 10% blackcurrant pomace powder.

Regarding the finished product, a decrease in the hardness, cohesiveness and gumminess of the cookies was observed, which may indicate a more crumbly texture and a more aerated internal structure. The total phenolic content increased significantly with the level of wheat flour

replacement, especially in the samples with bilberry pomace powder. At an addition of 10% bilberry pomace powder, an increase of approximately seven times was recorded compared to the control (214.73 mg gallic acid equivalents/100 g), while for the same level of addition of blackcurrant pomace powder, the increase was approximately three times (90.18 mg gallic acid equivalents/100 g). These results confirmed the potential of bilberry pomace as a rich source of phenolic compounds and natural antioxidants.

The sensory analysis revealed a better appreciation of the cookies enriched with pomace powders compared to the control, especially for an addition level of 10%, which obtained the highest scores from the panelists. The additions contributed to an attractive colour, a pleasant taste and a balanced texture, improving the general characteristics of the product.
The results demonstrated that bilberry and blackcurrant pomace can be successfully used as a functional ingredient to obtain cookies enriched in fiber and bioactive compounds, offering nutritional, technological and sensory benefits. The addition of 10% bilberry pomace powder proved optimal, leading to a product with high antioxidant value and sensory properties appreciated by consumers (Nour, 2024).

CONCLUSIONS

The results demonstrated the high potential of bilberry and blackcurrant pomace powders as sustainable functional ingredients, able to improve the nutritional, functional and sensory value of various food products. The incorporation of these powders into products such as fruit pestils, extruded corn snacks (puffs) and wheat flour cookies led to a significant increase in the content of phenolic compounds, anthocyanins and fibers, implicitly determining an intensification of antioxidant activity and an improvement in the bioactive profile of the finished products.

In the case of pestils, the addition of 1.0% bilberry pomace powder and 1.0% blackcurrant pomace powder provided products with an attractive colour, intense aroma and high bioactive content, being the most appreciated from a sensory point of view. For extruded snacks (puffs), the addition of 6% bilberry pomace powder led to a balanced texture, an increased content of proteins, fibers and phenolic compounds, as well as a pleasant purple color, which increased the visual attractiveness and acceptability of the product.

In the case of cookies, partial replacement of wheat flour with up to 10% pomace powder (both bilberries and blackcurrants) increased the fiber, fat and mineral content, improved taste, colour and antioxidant activity, while maintaining a sensory acceptable texture.
Overall, the use of bilberry and blackcurrant pomace as a functional ingredient has demonstrated multiple benefits – from the valorization of an agri-food by-product with a positive impact on the environment, to the development of foods with superior nutritional properties and increased antioxidant potential. The optimal addition levels (1% for pestils, 6% for corn snacks and 10% for cookies) can be considered as reference points for the formulation of functional products with high commercial value. These results confirm that berry pomaces represent a promising resource for the development of innovative, healthy and sustainable foods, aligned with current trends in the food industry.

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