

THE VALORIZATION OF BERRY POMACE – OPPORTUNITIES FOR THE MOUNTAINOUS AREA

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Abstract

Berry pomace is a significant source of fiber and bioactive compounds. Its valorization for creating high-value products presents an opportunity for mountainous areas, both environmentally and economically. This review paper aims to highlight the chemical composition of pomace from various berries (raspberries, blueberries, blackberries, and cranberries), as well as identify its health benefits and applications based on studies from the specialized literature. Scientific articles from databases such as Web of Science, Scopus, and Google Scholar were reviewed. The findings indicate that berry pomace is rich in polyphenols, fat- and water-soluble vitamins, soluble and insoluble fibers, carotenoids, anthocyanins, and more, depending on the species. Dietary fiber in berry pomace contributes to proper digestive system function. Polyphenols and certain vitamins play a key role in protecting against oxidative stress. Additionally, berry pomace has demonstrated anti-inflammatory and antimicrobial effects due to its rich composition of phenolic compounds. Berry pomace can be used as an ingredient in the food industry, a substrate for microbial substance production, a fortifier for cosmetic products, and for developing pharmaceutical preparations. This highlights the potential of these by-products for higher-value utilization, which could lead to a diversification of mountain-specific product assortments and beyond.

Keywords: *berries by-products, bioactive compounds, superior valorization, nutritional value.*

INTRODUCTION

Approximately 20-30% of the processed berry weight results in pomace, which consists of skins and seeds (Struck et al. 2016). The structure of berries generally includes the skin, a soft and fleshy pericarp, intracellular juice, and seeds, though the distribution of these components varies by fruit type. For instance, blueberries consist of 19% skins and 1.5% seeds (Struck et al. 2016). These by-products are rich in dietary fiber and bioactive compounds, which can add value to basic food products. Berry pomace is typically used as animal feed, compost, or for biogas production (Rohm et al. 2015).

The high moisture content of berry pomace (approximately 50%) can lead to storage issues as it is prone to microbial contamination. Therefore, conditioning processes such as drying, grinding, and sieving are necessary, depending on its intended use. It is essential to choose appropriate drying methods, temperatures, and timeframes to minimize the loss of thermolabile bioactive compounds, such as anthocyanins (Struck et al. 2016).

The use of berry pomace in food products can involve its direct incorporation as a powder or the extraction of bioactive-rich compounds that can later serve as ingredients in various food products.

The aim of this study was to identify the main types of berry pomace and highlight their chemical composition, biological activity, and health benefits, as well as their application in different industries, based on studies from the scientific literature.

MATERIALS AND RESEARCH METHOD

Scientific papers were selected by analyzing the existing literature using the Web of Science, Scopus, and Google Scholar databases. After reviewing the abstracts, studies that did not align with the research objective were excluded based on the following criteria: type of study (only research articles were considered), language (only studies in English, Spanish, or French were included), experimental conditions (fruits from mountainous regions).

The keywords used for the search included: *raspberries, blueberries, cranberries, blackberries, berries pomace, bioactive compounds, chemical composition, valorification, health benefits*.

Berries POMACE CHEMICAL COMPOSITION

The chemical composition of berry pomace depends on several factors such as botanical origin, climatic conditions, geographical location, and processing methods. McDougall and Beames (McDougall & Beames 1994) demonstrated that raspberry pomace contains a high percentage of total dietary fiber (59.5%). The authors reported an acid-detergent fiber content of 46%, cellulose approximately 27%, crude fat about 11%, crude protein 10%, lignin 11.7%, cutin 6%, and ash 2.2%. The main sugars in raspberry pomace are glucose, fructose, and sucrose, and minerals identified include sodium, potassium, calcium, phosphorus, and magnesium (Brodowska 2017). The crude fibers contain polyphenols associated with non-starchy polysaccharides such as pectin, cellulose, β -glucans, hemicellulose, gums, and lignin. Additionally, raspberry pomace has a low content of proteins, ash, and fat (1.87%, 5.97%, and 1.38%, respectively) (Brodowska 2017). Raspberry pomace also contains small amounts of vitamins (E, C), with vitamin C present at a significant level (McDougall, Beames 1994), unsaturated fatty acids, and tocopherols. Volatile compounds found in raspberry pomace include alcohols, esters, acids, ketones, and carbonyl compounds (Oomah et al. 2000). Raspberry pomace, in particular, is a rich source of antioxidants. The biological activity of these compounds is mainly exerted by dietary fibers, tocopherols, unsaturated fatty acids, carotenoids, vitamin C, and polyphenols (Table 1), such as tannins (especially ellagitannins), anthocyanins, flavanols, flavonoids, and phenolic acids (Laroze et al. 2010).

The study conducted by Blejan et al. (Blejan et al. 2023) showed that blueberry pomace contains 8.13 g/100 g of protein, and blackberry pomace contains 7.32 g/100 g of protein, with values higher than those of whole fruits due to the higher seed content in the pomace, which is rich in proteins. According to the mentioned authors, the highest fat content was reported for blackberry pomace (9.67 g/100 g), followed by blueberry pomace (8.21 g/100 g) due to the higher percentage of seeds. The high fiber content of

blackberry pomace (44.87 g/100 g) was noted, while blueberry pomace contained 11.84 g/100 g of fiber (Blejan et al. 2023).

Berry pomace has a high seed content and, as a result, is a source of lipophilic compounds. Previous studies have reported a significant variation in the fatty acid profile, even within the same plant species. Blackberry and blueberry pomace are rich in monounsaturated fatty acids (MUFA) (18.09–18.7%), but especially in polyunsaturated fatty acids (PUFA) (72.25–72.93%) (Blejan et al. 2023). A lower content of saturated fatty acids (SFA) was reported in blueberry pomace (5.43%) compared to blackberry pomace (8.08%). The most abundant fatty acid in the oil from blueberry pomace powder was found to be linolenic acid (C18:3n-3), while linoleic acid (C18:2n-6) was the most abundant fatty acid in blackberry pomace (Blejan et al. 2023).

Table 1. Bioactive compounds content and antioxidant activity of berries pomaces

Pomace type	State	Total polyphenols (mg GAE/g)	Total flavonoids (mg QE/g)	Total anthocyanins (mg CGE/g)	Antioxidant activity			Reference
					DPPH ($\mu\text{mol TE/g}$)	FRAP ($\mu\text{mol TE/g}$)	ABTS ($\mu\text{mol TE/g}$)	
Blueberries	Oven dried (57°C)	36.70	22.35	28.35	26.10	-	32.64	(Blejan et al. 2023)
	Lyophilized	31.13	6.17	11.14	-	243.61	306.77	(Ross et al. 2017)
	Lyophilized	13.42	4.45	6.04	-	-	-	(Kithama et al. 2023)
	Lyophilized	20.53	4.20	14.11	-	126.28	146.28	(Ross et al. 2020)
	Oven dried (50°C)	19.97	4.10	12.97	-	126.10	143.34	
Cranberries	Lyophilized	24.87	3.08	4.46	-	144.12	104.51	(Ross et al. 2017)
	Lyophilized	15.16	2.98	1.47	-	69.64	96.10	(Ross et al. 2020)
	Oven dried (50°C)	14.37	2.85	1.13	-	68.68	90.56	
Raspberries	Fresh pomace	6.38	5.91	0.65	-	-	-	(Brodowska 2017)
	Lyophilized	19.74	-	-	24.10	-	180.00	(Różyło et al. 2023)
Blackberries	Oven dried (57°C)	14.40	8.55	1.86	19.20	-	26.25	(Blejan et al. 2023)
	Fresh pomace	8.04	2.45	1.49	-	-	-	(Brodowska 2017)
	Fresh pomace	7.97	-	1.14	1.91	-	-	(Dragana et al. 2017)

Blueberry pomace exhibited the highest total content of phenolic compounds (36.70 mg GAE/g dw) and anthocyanins (28.35 mg CGE/g dw). The phenolic profile of blueberry pomace was dominated by ellagic acid and catechin, while the main phenolic compounds

in blackberry pomace were epigallocatechin and catechin. High levels of procyanidin B1 were noted in blueberry pomace (Blejan et al. 2023).

The characterization of bioactive compounds in cranberry and blueberry pomace carried out by Ross et al. (Ross et al. 2017) revealed a wide range of chemical constituents, such as carbohydrates, including soluble and insoluble fibers, proteins, minerals, and phenolic compounds like flavonoids, anthocyanins, and tannins. The authors demonstrated that the lipid content of cranberry pomace (4.41%) was significantly lower than that of blueberry pomace (5.43%). The protein content of cranberry pomace (~5.8%) was significantly lower than that of blueberry pomace (~8.4%), and the carbohydrate content of cranberry and blueberry pomace was 88.78% and 84.91%, respectively (Ross et al. 2017). Analysis of the mineral elements in the pomaces showed that they are a valuable source of B, Zn, Fe, Mn, and Cu, with blueberry pomace showing increased quantities of Ca and Mn. The main anthocyanins found in blueberry pomace were peonidin 3-glucoside, malvidin 3-galactoside, malvidin 3-glucoside, and cyanidin 3-arabinoside. Peonidin 3-galactoside, cyanidin 3-galactoside, cyanidin 3-arabinoside, and peonidin 3-arabinoside were the main anthocyanins identified in cranberry pomace (Ross et al. 2017).

BIOLOGICAL ACTIVITY AND HEALTH BENEFITS

Phenolic compounds are a major group of bioactive compounds found in vegetals and their by-products. Phenolic compounds include flavonoids (such as anthocyanins and flavonols), stilbenes, tannins, and simple phenolic acids. Many of these compounds have been reported to have a wide range of biological effects, including antioxidant, antimicrobial, anti-inflammatory, and vasodilatory activities (Biswas et al. 2012; Gross 2004). Berry pomace represents a potentially valuable resource that should be explored in the development of new healthy food ingredients, dietary supplements, and pharmaceutical products (Cavanagh et al. 2003). The main health benefits of consuming berry pomace are presented in Figure 1.

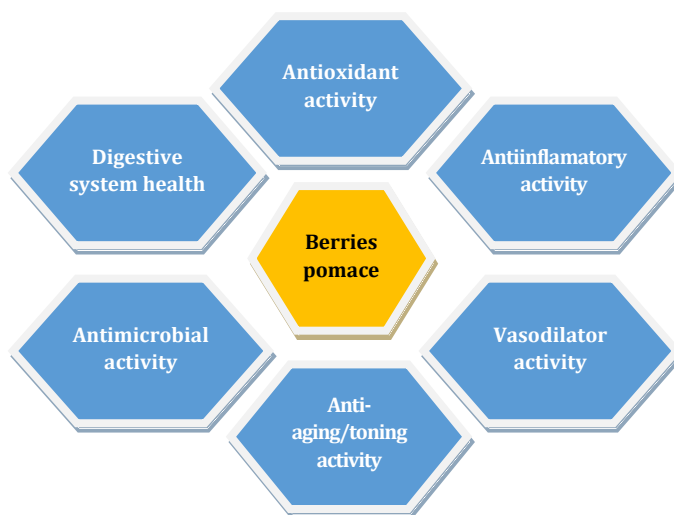


Fig. 1. Health benefits of berries pomace consumption

Consuming raspberry pomace is effective in reducing oxidative and inflammatory stress levels, which promote morphological changes in the heart, thus preventing or delaying heart disease (Różyło et al. 2023). Numerous health benefits of raspberries and their by-products have been highlighted. An increasing number of studies suggest that red raspberries may play a role in reducing the risk of chronic metabolic-related diseases. A daily intake of raspberries can reduce postprandial hyperglycemia and inflammation in diabetic adults, while also having anti-inflammatory properties (Różyło et al. 2023). A diet rich in raspberries has shown to improve immune function and phospholipid metabolism in obese patients (Franck et al. 2020). Other clinical studies have demonstrated that including fresh raspberry extract in the diet of elderly rats reduces aging indices, improves psychomotor coordination and balance, and stimulates muscle tone and endurance (Galli et al. 2016).

Since anthocyanins and most phenolic compounds are primarily found in the skins, berry pomace contains various phenolic compounds with antioxidant potential, especially high levels of anthocyanins, which possess strong antimicrobial, anti-inflammatory, and anti-mutagenic properties (Blejan et al. 2023). Previous results related to the antibacterial activity of berries showed that raspberry fruit extract inhibited the growth of *Salmonella typhimurium*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Bacillus cereus*, *Staphylococcus saprophyticus*, and *Listeria monocytogenes* (Velićanski et al. 2012). In addition to inhibiting bacterial growth, blackberry extract inhibited the early stages of replication of herpes simplex virus type 1 (HSV-1) and exhibited strong virucidal activity (Danaher et al. 2011). Antioxidant activity depend on polyphenols that have antimicrobial properties against human pathogens. More specifically, the function of these compounds is to slow down or stop cellular DNA, lipid, and protein damage caused by reactive oxygen species (ROS) (Brodowska 2017).

The chemical composition of fruit pomace is composed of great amounts of polysaccharides and phytochemicals, mostly polyphenols, which can enhance the aspect and health of the skin. Polysaccharides play the role of a natural humectant, interfering with water retention, improving hydration, and the skin's barrier function. On the other hand, polyphenols are powerful antioxidants that protect the skin from oxidative stress and premature aging (Del Rio Osorio et al. 2021). Berry pomace has important amounts of dietary fibers. Numerous studies on dietary fibers have shown that this component can prevent and treat certain diseases. Enriching the diet with fiber reduces the risk of certain types of cancer (in the colon), coronary heart disease (CHD), atherosclerosis, diabetes, and obesity. Furthermore, dietary fibers increase fecal volume and stimulate intestinal peristalsis, reducing total cholesterol and low-density lipoprotein (LDL) cholesterol levels in the blood (Brodowska 2017).

USES OF BERRY FRUIT BY-PRODUCTS

Berry pomace can be used both in the food industry as well as in various cosmetic preparations and dietary supplements.

After processing blackberry juice, the resulting pomace can be utilized as a source of bioactive compounds that can be used as potential dietary additives and natural colorants (Blejan et al. 2023). Recently, Isopencu et al. (2021) developed edible complex films incorporating blackberry pomace as a valuable source of antioxidants and antimicrobial

agents, while Tarasevičienė et al. (2022) reported that adding blackberry pomace improved the quality of beef meatballs, acting as a thickening agent, increasing fiber content, and reducing lipid oxidation. It has been demonstrated that anthocyanins in raspberries have strong effects in inhibiting the growth of *L. acidophilus*, which is important when consumed in high concentrations, as *L. acidophilus* is frequently used in fermented dairy products. It has also been reported that treating berry pomace with fungal strains can provide an innovative solution for producing a wide range of antimicrobial substances (Puupponen-Pimiä et al. 2005).

It is well known that berry pomace represents an important source of dietary fiber. Fibers are not only important for their technological properties but also for their nutritional and functional properties (Brodowska 2017). They can be used to modify texture and improve the stability of foods during production and storage, as well as enhance agricultural products and by-products for use as food ingredients (Thebaudin et al. 1997). Research conducted by Górecka et al. (2010) showed that adding raspberry pomace to short dough biscuits increased the intensity of fruity aroma and taste as well as fragility. Due to the numerous health benefits of dietary fiber, it can be used in many applications in the food and pharmaceutical industries. A wide range of foods enriched with berry by-products includes, for example, baked goods, biscuits, cereals, snacks, sauces, dairy products, meat products, and beverages (Thebaudin et al. 1997). Fibers from raspberry by-products can partially replace flour, fats, or sugar, acting as enhancers of water and oil retention and improving the stability of emulsions or oxidation (Ayala-Zavala et al. 2011).

Berry pomace has become a significant source of pigments, mainly anthocyanins and carotenoids, which exhibit high color stability, availability, high yield, and low cost. Raspberry seed oil, obtained from raspberry pomace, has applications in food, pharmaceutical, and cosmetic products. The addition of raspberry seed oil to cosmetic and pharmaceutical products has been patented. Therefore, its unique composition of fatty acids and high tocopherol content, as well as its protective effect against oxidative stress and relatively good shelf life, make raspberry pomace oil a suitable ingredient for use as a dietary supplement, in toothpaste, bath oils, shampoos, skin irritation prevention creams, aftershave creams, lipsticks, deodorants, etc. (Oomah et al. 2000).

It has been observed that fruit pomace has the potential to bind heavy metal ions. Specifically, the fiber fractions in pomace are capable of binding heavy metals (Brodowska 2017). According to the literature, hemicellulose and pectins have a better binding capacity than cellulose and lignin. Studies report that the stability of metal-dietary fiber complexes differs depending on the metal involved and the fiber source (Borycka & Zuchowski 1998). Berry pomace can also be an effective ion-binding agent due to its rich source of polyphenols. Additionally, tannins (proanthocyanidins or gallic acid esters of glucose) in berries are chelating agents for metal ions such as aluminum, iron, and copper. These polyphenols, at neutral pH, form complexes with metal ions and easily precipitate at neutral pH through the intestinal barrier (Brodowska 2017).

CONCLUSION

Berry pomace has a high potential for valorization due to the antioxidant activity generated by its polyphenol content and bioactive compounds. Moreover, it has a low

acquisition cost and can serve as an additional source of nutrients to enhance the nutritional value of staple food products. This paper highlighted the chemical composition of blackberry, blueberry, raspberry, and blackcurrant pomace, indicating a rich content of fiber and polyphenols with numerous health benefits. Berry pomace can be used in powder form to enrich the nutritional value of products, as a thickening agent, in the production of cosmetics, as a substrate for microbial cultures, etc.

AUTHOR CONTRIBUTION

Conceptualization, M.U.-I.; Data curation, M.U.-I.; Formal analysis, M.U.-I.; Funding acquisition, M.U.-I.; Investigation, M.U.-I.; Methodology, M.U.-I.; Project administration, M.U.-I.; Resources, M.U.-I.; Software, M.U.-I.; Supervision, M.U.-I.; Validation, M.U.-I.; Visualization, M.U.-I.; Roles/Writing - original draft, M.U.-I.; and Writing - review & editing, M.U.-I.

CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

DATA AVAILABILITY

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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