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Nutritional, technological, and health perspectives of blackcurrant (*Ribes nigrum* L.): A comprehensive review

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Abstract

Blackcurrant (*Ribes nigrum* L.) is a nutrient-rich berry known for its high content of vitamins, minerals, dietary fibre, and bioactive compounds. It is especially valued for its polyphenols, mainly anthocyanins, which are responsible for its deep purple colour and strong antioxidant and anti-inflammatory properties. Regular consumption of blackcurrants and their processed forms has been linked to several health benefits, including improved cardiovascular health, better blood pressure control, enhanced glucose and lipid metabolism, gut health support, and protection of skin and eye health.

This review summarizes the nutritional composition of blackcurrants, with a focus on carbohydrates, organic acids, fibre, lipids, proteins, vitamins, minerals, and phytochemicals. It also discusses modern extraction techniques used to recover bioactive compounds from blackcurrants, highlighting their advantages over conventional methods in terms of efficiency and preservation of sensitive compounds. In addition, different food formats such as juice, powder, pomace, extracts, and encapsulated products are reviewed, along with their applications in functional and value-added foods.

Overall, blackcurrants are considered a promising functional food ingredient due to their rich bioactive profile and wide range of potential health benefits. Further research and technological advancements may help improve their stability, bioavailability, and use in developing healthier food products.

Keywords: Blackcurrant (*Ribes nigrum* L.), anthocyanins, polyphenols, antioxidant activity, functional food

1. Introduction

As a species of the family *Grossulariaceae*, blackcurrant (BC; *Ribes nigrum*) is a small dark purple fruit that comes from medium-sized woody shrubs, native to colder climate areas such as northern Europe, Northern Asia, and Central Asia. The high nutrient content of BCs has given this fruit a wide range of health-promoting benefits that have been investigated *in vitro* and *in vivo*. Two key bioactive properties of BC nutrients are antioxidant and anti-inflammatory activities. Substantial research evidenced that the polyphenol-rich juice supported the prevention of cardiovascular disease, and significantly reduced systolic blood pressure (BP) in both normotensive and hypertensive subjects, with the effect being more significant in the latter group. Moreover, in older adults, intake of BC extracts led to significant decreases in systolic and diastolic BP, but there was no effect on 6-minute walk performance or cognitive function variables.

Multiple biochemical compounds, like phenolic acids, organic acids, polyunsaturated fatty acids, and polyphenols, are abundant in blackcurrants (*Ribes nigrum* L.). Flavonols and anthocyanins are a couple of the polyphenolic components called blackcurrant flavonoids. These tiny round berries with incredibly flavorful seeds are generally used in processed items such as juice, jams and preservers, pie fillings, dessert toppings, yogurt, ice cream, mineral waters, teas, confectionery, and perfumes. The anthocyanin composition of the berries gives blackcurrant its rich purplish color. The presence of carbohydrates and acids controls the sweetness and sourness which alter sensory characteristics and customer satisfaction. Phenolic components increase tartness and saltiness, which can sometimes adversely affect the sensory quality and reduce customer perception of certain commodities.

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Blackcurrants are now considered “super fruits” since they are supposed to have numerous therapeutic benefits, such as the capacity to treat chronic illnesses associated with oxidative stress (Lister *et al.*, 2002)^[8].

2. Nutritional composition of blackcurrants

Blackcurrants are nutritionally rich berries with a balanced composition of carbohydrates, dietary fibre, vitamins, minerals, and bioactive compounds.

2.1. Carbohydrates and organic acids

Blackcurrants contain relatively low amounts of sugars compared to many other fruits, with total sugars ranging from 7-10 g per 100 g of fresh fruit. The main sugars are fructose, glucose, and sucrose, with fructose being the most abundant. Blackcurrant concentrates contain higher sugar levels due to processing. In addition to sugars, blackcurrants are rich in organic acids, mainly citric acid, which gives the fruit its characteristic sharp and acidic taste. Other acids such as malic, quinic, and ascorbic acids are present in smaller amounts.

2.2. Dietary fibre

Blackcurrants are an excellent source of dietary fibre, especially in their pomace. They contain a healthy balance of soluble and insoluble fibre, including pectin, cellulose, hemicellulose, and lignin. This fibre composition supports digestive health and may contribute to antioxidant activity.

2.3. Lipids

The fat content of fresh blackcurrants is very low. However, blackcurrant pomace contains higher lipid levels, mainly made up of palmitic, oleic, and linoleic fatty acids, which are beneficial for health.

2.4. Proteins

Blackcurrants contain small amounts of protein in fresh form, while pomace shows a relatively higher protein content. The amino acid profile includes essential amino acids, with glutamic acid being the most abundant. Some functional proteins, such as arabinogalactan proteins, are also present.

2.5. Vitamins and Minerals

Blackcurrants are especially rich in vitamin C, with less than 100 g of fruit sufficient to meet daily requirements. They also provide B-complex vitamins, vitamin E, and vitamin K. Important minerals such as potassium, calcium, magnesium, iron, and zinc are present, though their levels can vary depending on cultivar and soil conditions.

2.6. Phytochemicals

Blackcurrants are highly valued for their phytochemical content, particularly polyphenols. Anthocyanins are the dominant compounds, responsible for the deep purple color and strong antioxidant activity. Other polyphenols include flavonols, flavanols, proanthocyanidins, and phenolic acids. These compounds are linked to various health benefits, although processing may reduce their concentration and bioavailability.

2.7. Absorption and metabolism

Some polyphenols, especially anthocyanins, can be absorbed directly in the intestine, while others need to be

broken down into simpler forms before absorption. Their complex metabolism influences their biological effects in the body.

3. Extraction of blackcurrant by different novel techniques

Extraction is an essential process used to obtain bioactive compounds from blackcurrant tissues. Traditional extraction methods often require long extraction times, large volumes of solvents, high temperatures, and may cause degradation of heat-sensitive compounds (Selvamuthukumaran & Shi, 2017)^[9]. To overcome these limitations, several novel extraction techniques have been developed. These advanced methods, including microwave-assisted extraction, ultrasound-assisted extraction, pulsed electric field extraction, sonication-assisted extraction, and enzyme-assisted extraction, reduce solvent use and extraction time while improving the yield and quality of bioactive compounds.

3.1. Solvent extraction method

Solvent extraction is a commonly used technique for recovering phytochemicals from blackcurrants. Ethanol and methanol are more effective than water for extracting anthocyanins (Lapornik *et al.*, 2005)^[10]. Acidified solvents further enhance extraction efficiency by releasing anthocyanins from the fruit skin and pomace (Azman *et al.*, 2020)^[11]. However, solvents such as methanol and acetone, although effective, are restricted in food applications. Hot water extraction with citric acid has also been used successfully, but strong acids may cause degradation of acylated anthocyanins.

3.2. Microwave-Assisted Extraction (MAE)

Microwave-assisted extraction is a rapid and efficient method widely used for extracting natural compounds. It offers faster extraction and reduced solvent consumption compared to traditional methods (Morales-Muñoz *et al.*, 2006)^[12]. Water and acidified aqueous solvents are commonly used due to their effective interaction with microwave energy. Pap *et al.* demonstrated that microwave power, solvent pH, extraction time, and solvent-to-solid ratio significantly influence anthocyanin recovery from blackcurrant residues.

3.3. Ultrasound-Assisted Extraction (UAE)

Ultrasound-assisted extraction improves mass transfer through acoustic cavitation, leading to higher extraction yields at lower temperatures and shorter. UAE has been shown to increase both the concentration and stability of anthocyanins in blackcurrant extracts (Wang *et al.*, 2016)^[13]. Studies using different blackcurrant matrices, including fruits, leaves, and pomace, reported enhanced extraction efficiency using ultrasound treatment.

3.4. Pulsed-Electric Field (PEF)

Pulsed-electric field extraction is a non-thermal technique that enhances cell membrane permeability, allowing easier release of intracellular compounds (Barba *et al.*, 2015)^[14]. This method minimizes thermal degradation while reducing energy consumption and processing time (Vorobiev & Lebovka, 2017)^[15]. Gagnetet *et al.* (2019)^[15, 16] reported an approximate 6% increase in monomeric anthocyanin extraction from blackcurrants using optimized PEF

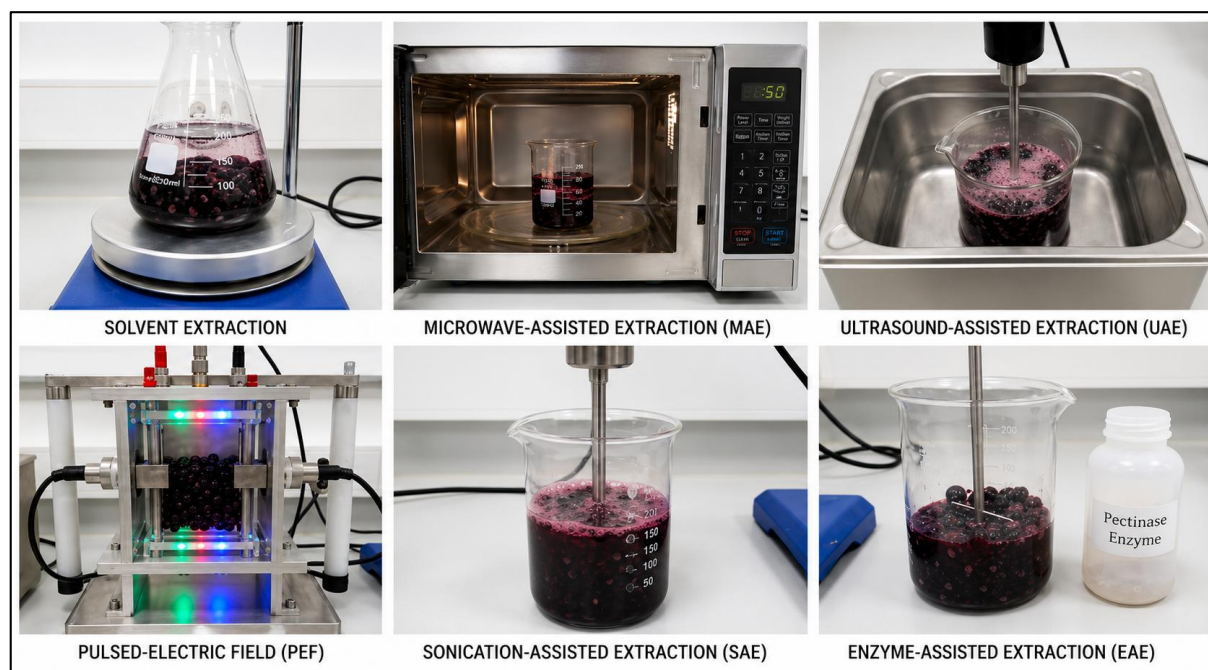
parameters. However, further studies are needed due to limited available literature.

3.5. Sonication-Assisted Extraction (SAE)

Sonication-assisted extraction is an efficient and cost-effective technique for extracting polyphenols and other bioactive compounds (Belwal *et al.*, 2020) [17]. The process relies on acoustic cavitation, which disrupts plant tissues and enhances solvent penetration. Compared conventional and sonication-assisted extractions and found that ethanol-based sonication significantly improved the recovery of bioactive compounds from blackcurrant leaves.

3.6. Enzyme-Assisted Extraction (EAE)

Enzyme-assisted extraction utilizes enzymes such as pectinase, cellulase, and protease to break down plant cell walls and release bioactive compounds (Akyüz & Ersus, 2021) [18]. Pectinase is particularly effective for blackcurrants due to the pectin-rich structure of their cell walls (Landbo & Meyer, 2004) [19]. EAE is considered environmentally friendly as it requires less energy, mild conditions, and minimal solvent use (Domínguez-Rodríguez *et al.*, 2021) [20]. González *et al.* (2022) [21] reported improved extraction of anthocyanins and polysaccharides from blackcurrants using optimized enzyme and ultrasonic-assisted conditions.



Source: Adapted from published review and research articles on conventional and emerging extraction techniques for blackcurrant (*Ribes nigrum* L.) bioactive compounds, including solvent extraction, microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), pulsed electric field (PEF), sonication-assisted extraction (SAE), and enzyme-assisted extraction (EAE) (Chemat *et al.*, 2017; Donsì & Ferrari, 2016; Putnik *et al.*, 2019; Vilkickyte *et al.*, 2020) [22-25].

4. Health benefits of bioactive compounds from blackcurrants

Blackcurrants are rich in bioactive compounds, particularly anthocyanins (ANC), which make up about 90% of the total polyphenols present. A large proportion of consumed ANC (up to 73%) reaches the colon, where they are further metabolized by gut microbiota (Parker *et al.*, 2014) [26]. These compounds are associated with multiple health-promoting effects.

4.1. Antioxidant and anti-inflammatory effects

The strong antioxidant activity of blackcurrants is mainly attributed to anthocyanins and other phenolic compounds, which neutralize free radicals and reduce oxidative stress (Blando *et al.*, 2018) [27]. A high correlation between antioxidant activity and anthocyanin concentration has been reported ($r = 0.85$) (Nour *et al.*, 2013) [28]. Blackcurrants are also rich in vitamin C (50-280 mg/100 g), which further enhances antioxidant capacity and supports collagen synthesis and hormone production (Woznicki *et al.*, 2017) [29].

Blackcurrant extracts (BCE) have demonstrated anti-inflammatory properties through the downregulation of inflammatory cytokines and enzymes, making them beneficial for asthma and airway-related conditions (Shaw *et al.*, 2017) [30].

4.2. Antimicrobial and gut health benefits

Anthocyanins from blackcurrants can inhibit the adhesion of *Salmonella enterica* serovar Typhimurium to intestinal cells by up to 39%, highlighting potential applications in food safety and gut health (Parker *et al.*, 2014) [26]. This effect was strongly linked to delphinidin-3-glucoside (D3G) and cyanidin-3-rutinoside (C3R).

4.3. Metabolic health: Cholesterol and glucose regulation

Several studies have shown hypocholesterolemic effects of BCE in animal models, possibly through increased LDL receptor activity and enhanced cholesterol transport in intestinal cells (Kim *et al.*, 2018) [31]. Blackcurrants have also been reported to lower blood glucose levels and improve glucose tolerance in animals and humans (Iizuka *et al.*, 2018) [32]. These effects are associated with increased secretion of glucagon-like peptide-1 (GLP-1) and improved glucose transporter activity.

4.4. Skin and eye health

Blackcurrant anthocyanins have shown protective effects against UV-induced skin damage. Oral intake of blackcurrant polysaccharides reduced skin dehydration and inflammatory markers in mice (Ashigai *et al.*, 2018) [33]. BCE has also demonstrated phytoestrogen-like activity, increasing collagen, elastin, and hyaluronic acid production

in human skin fibroblasts and ovariectomized rats (Nanashima *et al.*, 2018) ^[34].

Regarding eye health, anthocyanins from blackcurrants were found to cross the blood-retinal barrier and accumulate in ocular tissues, suggesting potential benefits in preventing oxidative damage and supporting retinal health (Matsumoto *et al.*, 2006) ^[35].

4.5. Athletic performance and fatigue reduction

Human studies have shown that blackcurrant consumption can reduce exercise-induced oxidative stress, muscle damage, and inflammation (Hutchison *et al.*, 2016) ^[36]. Supplementation with BCE improved endurance performance, increased fat oxidation, reduced blood pressure during exercise, and enhanced recovery in trained individuals (Strauss *et al.*, 2018) ^[37].

4.5. Enzyme inhibition and antidiabetic potential

Ultrasound-treated blackcurrant polysaccharides exhibited improved antioxidant capacity and higher inhibition of α -amylase and α -glucosidase, indicating potential antidiabetic effects (Xu *et al.*, 2018) ^[38]. These effects were attributed to partial degradation of polysaccharides without major structural changes.

5. Food formats and technology

5.1. Blackcurrant pomace

Blackcurrant pomace, a by-product of juice processing, is a rich source of dietary fibre, protein, lipids, and polyphenols, showing strong antioxidant activity. Its composition varies depending on harvest season and juice extraction methods (Sójka & Król, 2009) ^[39]. During juice processing, most sugars (~96%) transfer into the juice, leaving pomace low in sugars but rich in fibre and bioactive compounds (Kunachowicz *et al.*, 2005) ^[40]. Citric acid is the main organic acid present, followed by malic acid (Siksnianas *et al.*, 2006) ^[41]. Due to environmental concerns, pomace is increasingly explored for value-added food applications.

5.2. Blackcurrant extract

Blackcurrant extracts contain more concentrated phytochemicals than fresh juice, particularly anthocyanins and phenolics (Archaina *et al.*, 2017) ^[42]. Ethanol concentration influences extraction efficiency, with maximum anthocyanin content at 60% ethanol and highest

total phenolics at 96% ethanol (Nour *et al.*, 2013) ^[28]. However, blackcurrant extracts are acidic, bitter, and volatile, which limits their direct use in foods (Cortez & Gonzalez de Mejia, 2019) ^[7].

5.3. Blackcurrant powder

Blackcurrant powder is commonly produced by freeze-drying, preserving most nutrients of the whole fruit. Due to its high fibre content, it is poorly soluble in water, making it more suitable for solid food products. It has been successfully incorporated into bakery products and biscuits as a partial flour substitute, enhancing colour, fibre, and bioactive content.

5.4. Blackcurrant juice

Fresh blackcurrant juice is rich in anthocyanins and polyphenols (Landbo & Meyer, 2004) ^[19]. However, industrial processing steps such as heating, clarification, filtration, and pasteurization significantly reduce anthocyanin content (Koponen *et al.*, 2008) ^[43]. Due to its strong sour taste, sugar is often added during processing to improve palatability (Cortez & Gonzalez de Mejia, 2019) ^[7].

5.5. Industrial applications

Blackcurrant-derived formats such as pomace powder, fruit powder, and encapsulated extracts are increasingly used in functional foods. Blackcurrant powders have been added to bakery items, pasta, oat bran, extruded snacks, and salted snacks, improving nutritional value and fibre content. Encapsulation using whey protein or other wall materials has shown promise in protecting bioactive compounds and improving their food compatibility.

5.6. Encapsulation technology

Blackcurrant polyphenols, especially anthocyanins, are sensitive to pH, temperature, light, oxygen, and metal ions (Bąkowska *et al.*, 2003) ^[44]. Encapsulation techniques such as freeze-drying, spray-drying, emulsification, and complexation improve their stability. Materials like maltodextrin and inulin effectively protect anthocyanins, allowing their use as natural food colourants and functional ingredients (Michalska *et al.*, 2019) ^[45].



Source: Smith, K. A., Lloyd, E., & Sharp, P. (2019) ^[46], Xue, Y., Zhang, S., Du, M., & Zhu, M. (2022) ^[47], Vilckickyte, G., Motiekaityte, V., & Venskutonis, P. R. (2020) ^[48], Määttä-Riihinen, K. R., Kamal-Eldin, A., & Törrönen, A. R. (2004) ^[49].

6. Blackcurrant as a colourant

6.1. Pigment composition

Blackcurrant (*Ribes nigrum* L.) owes its intense purple hue to anthocyanins, primarily delphinidin-3-rutinoside, cyanidin-3-rutinoside, and their glucoside derivatives. These pigments account for nearly 90% of the total polyphenols in the fruit and are responsible for the characteristic red-purple coloration. The anthocyanin profile is influenced by cultivar, growing conditions, and processing, but consistently provides strong tinting strength compared to many other berries.

6.2. Colour properties and stability

- **pH-dependent colour:** Anthocyanins exhibit red tones under acidic conditions (pH 2-4), shifting to bluish-purple near neutral pH.
- **Environmental sensitivity:** Heat, light, oxygen, and metal ions can degrade anthocyanins, leading to browning or fading.
- **Co-pigmentation:** Interaction with other phenolics enhances colour intensity and stability, a phenomenon exploited in food formulations.

6.3. Applications in food industry

Blackcurrant-derived colourants are increasingly used in various sectors due to their bioactive profile and pigment stability.

- **Beverages:** Acidic drinks benefit from stable red-purple hues, as anthocyanins are most stable at low pH levels.
- **Dairy products:** Yogurts and ice creams incorporate blackcurrant pigments for natural coloration and functional benefits.
- **Bakery and confectionery:** Powders and extracts enhance colour while adding fibre and antioxidants.
- **Encapsulated formats:** Encapsulation protects anthocyanins from degradation, enabling broader application in processed foods.



Source: Adapted from published research and review articles on the incorporation of blackcurrant (*Ribes nigrum* L.) juice, powder, and extracts into functional foods such as yogurt and bakery products to enhance antioxidant capacity, colour, and nutritional quality (Vilkickyte *et al.*, 2020) ^[25].

7. Conclusion

Blackcurrant (*Ribes nigrum* L.) is a highly valuable berry with exceptional nutritional, technological, and therapeutic significance. Its rich composition of vitamins, minerals, dietary fibre, and bioactive compounds particularly anthocyanins and other polyphenols contributes to its strong antioxidant, anti-inflammatory, and disease-preventive

properties. The evidence reviewed highlights the role of blackcurrant and its derivatives in supporting cardiovascular health, metabolic regulation, gut health, skin and eye protection, and physical performance.

Advancements in extraction technologies, such as microwave-assisted, ultrasound-assisted, pulsed-electric field, sonication-assisted, and enzyme-assisted extraction, have greatly improved the efficiency and quality of bioactive compound recovery from blackcurrants. These modern approaches not only reduce solvent use and processing time but also help preserve heat-sensitive phytochemicals, making them more suitable for food and nutraceutical applications.

In addition, the utilization of blackcurrant in various food formats including juice, powder, pomace, extracts, and encapsulated products demonstrates its versatility as a functional food ingredient. The valorization of blackcurrant by-products, particularly pomace, offers sustainable solutions for waste reduction while enhancing the nutritional quality of food products. Encapsulation technologies further improve the stability, bioavailability, and sensory acceptability of blackcurrant bioactives, expanding their potential use in the food industry.

Overall, blackcurrant represents a promising natural resource for the development of health-promoting foods and nutraceuticals. Future research should focus on optimizing processing techniques, improving bioavailability, and conducting long-term human studies to better understand its health effects and support wider industrial and dietary applications.

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