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Berries as Source of Bioactive Compounds

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Abstract

Berries are rich in phenolic compounds. Phenolic compounds, secondary metabolites of plants, exhibit a wide range of biological functions, such as antihypertensive, anti-inflammatory, antioxidant and antimicrobial activities, which are beneficial for human health. Fruits peel, a waste generated during juice elaboration, comprises nearly around 30-40% portion of the fruit. Phenolic compounds are primarily concentrated in the peel portion of berries fruit. Berries and their fruit peels are an economic source of bioactive phenolic compounds having immense possibilities for future investigations related with their utilization as well as recovery. This review summarizes the reported about quantitative and qualitative data of phenolic compositions in different types of berries and its wastes during juice elaboration. Furthermore, biological activities, including antioxidant, antihypertensive, antimicrobial and anti-metabolic disorder effects, have also been discussed.

Keywords: phenolic compounds; berries; biological activity; natural preservative.

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1. INTRODUCTION

Numerous epidemiological studies have shown that a diet rich in fruits and vegetables reduces the risk of many chronic diseases, such as cardiovascular diseases and cancer [1, 2, 3]. Among different fruit species, berries have attracted a great attention for their bioactivity and they are part of human diet all over the world [4, 5]. In addition to nutritive dietary components such as vitamins, minerals, sugars or organic acids [6], berries are also a good source of different classes of phytochemicals such as flavonoids (anthocyanins, flavonols, flavanols), tannins (proanthocyanidins, ellagitannins, gallotannins), stilbenoids (e.g., resveratrol), phenolic acids (hydroxybenzoic and hydroxycinnamic acid derivates) and lignans [7, 8, 5].

Blueberries, strawberries and raspberries have health benefits associated with the high concentrations of anthocyanins. A growing number of scientific reports suggested that anthocyanin-rich berries or derived extracts exhibit a wide range of protective effects with potential benefits for human and animal health. Antioxidative, antiinflammatory, vasoprotective, neuroprotective, among others, are biological activities that have been reported for anthocyanins [9, 10, 8]. As a result of many proposed beneficial effects, berry fruits and extracts are today often used as a compound of functional foods, dietary foods or dietary supplements.

It is widely recognized that berries are rich in phenolic compounds. In addition to flavonols commonly found in berries, proanthocyanidins are the main phenolic compounds in hawthorn (Crataegus spp.), and anthocyanins are dominant in dark-skinned berries, such as black currant (*Ribes nigrum*) and bilberry (*Vaccinium myrtillus*) [11, 12, 13]. Some phenolic acids (ferulic acid and ρ-coumaric acid), usually linked to lignins or

other cell wall components, are also abundant in berries [8, 14].

2. BERRIES AS SOURCE OF BIOACTIVE COMPOUNDS

Berries are rich sources of bioactive compounds, mostly polyphenolics.

Vallejo et al., [8] studied and identified the main phenolic compounds with antifungal activity present in four cultivars of blueberries grown in Argentina (Table 2). The authors reported that the major compounds in the four blueberry cultivars were chlorogenic acid (Figure 1) and quercetin (Figure 2).

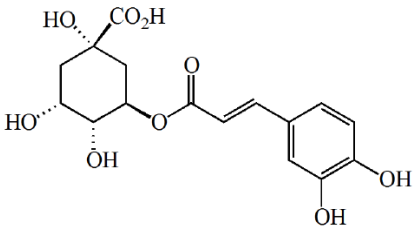

Figure 1. Chemical structure of chlorogenic acid

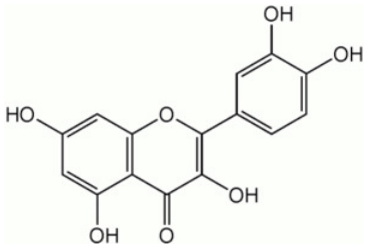

Figure 2. Chemical structure of quercetin.

Results reported by Vallejo et al., [8] (see Table 1) in relation with the phenolic profile of Argentinean blueberries are coincident with those informed by other authors, who reported chlorogenic acid as the major phenolic acid in blueberries cultivated in Spain and Greece, among other countries [16, 17, 18, 19] (Table 2). Dudonné et al., [20] reported that ρ-coumaric, caffeic and ferulic acid in all blueberry cultivars are in higher concentrations than gallic and protocatechuic acids. In addition, *Ribes nigrum*, a blueberry cultivar grown in Europe, contained mainly ρ-coumaric, ferulic and caffeic acid, with caffeoyl glucoside and flavonols such as myricetin, quercetin, isorhamnetin and kaempferol as the most important compounds [21, 22].

The berries are an important crop adaptable to a wide range of agro-climatic conditions. The berries are mainly grown in, Spain, USA, Argentina, China, India, Israel and South Africa [23].

Many berry residues have a high concentration of phenolic compounds, with beneficial properties for human, such as anti-inflammatory, antioxidant, antimicrobial, antidiabetic and anti-allergic agents [24, 25]. Blueberry peel comprises nearly around 10-30% portion of the fruit and remains as a byproduct after juice extraction [26]. Blueberry peels are rich in a variety of phenolic compounds and in last years the search for phenolic compounds in juice industry was increasing for the possible to reuse blueberry peels.

Table 1. Phenolic profile of four blueberry cultivars.

Phenolic compounds	*Blueberry*			
	Misty	***Millennium***	***Blue Crisp***	***O´Neal***
Gallic acid	-	+	-	-
Methyl gallate	-	+	+	+
Caftaric acid	+	+	+	-
Cutaric acid	+	+	+	+
Procyanidin	+	+	+	+
Catechin	-	-	+	-
Chlorogenic acid	+	+	+	+
Trans-caffeic acid	+	+	+	+
Trans-ρ-coumaric acid	+	+	+	+
Ferulic acid	+	+	+	+
Ellagic acid	+	+	+	+
Quercetin-3-glucoside	+	+	+	+
Laricitrin 3-galactoside	+	+	+	+
Isorhamnetin-3-galactoside	+	+	+	+
Kaempferol-3-glucoside	-	+	+	+
Laricitrin-3-glucoside	-	+	+	+
Isorhamnetin-3-glucoside	+	+	+	+

Source: Vallejo et al. [8].

On the other hand, the increase of residue production in modern society is an unavoidable fact, and society requires different waste management than in past decades. The worldwide food, agricultural and forestry industries produce annually large volumes of wastes, which cause a serious disposal problem [27]. Most of these residues have a nutritional potential, and therefore they are receiving greater attention in terms of quality control and have been classified as agro industrial by-products [28].

At present, fruits peels are considered to be new sources of bioactive compounds. There is an increased interest in search for beneficial phytochemicals present in fruit peels and utilized them in food, pharmaceutical and cosmetic industry.

The quest for safer food has led researchers to discover new substances that can inhibit microbial contamination [29]. Natural preservatives have been replacing chemical additives because, in addition to improving the nutritional content, they prevent microbial deterioration, thus increasing food durability in friendly conditions [8, 30, 31].

Increasing consumer demands for safe foods without any chemical preservative has generated interests in the use of natural antimicrobials. Plant products have been used since ancient times for the flavoring of foods and beverages and for medicinal purposes to cure and prevent diseases [29].

CDC estimates that each year roughly one in every six Americans (or 48 million people) gets sick, 128,000 are hospitalized, and 3000 die of foodborne diseases. *Salmonella* infection was the most common infection reported and had the largest number of hospitalizations (19,336) and deaths (378) in USA [32].

The fruits phenolic, such as those present in berries have been purported to exhibit a wide range of human health benefits due to their capacity to quench free radicals, and consequently delay oxidation stress-related diseases, including but not limited to, atherosclerosis, diabetes, and cancer [33, 34, 35]. As well, due to their radical scavenging ability, phenolic extracts of berries have the potential of extending the shelf life of food products through reducing the negative impacts of lipid oxidation on the nutritional

quality, flavour, colour, odour, texture, and appearance of foods [8].

Berries offer a potentially source of phenolic for use in food and related products. In recent years, the demand from consumers for foods/ingredients that are free from synthetic antioxidants has been increasing [36, 37].

The berries are used as a traditional medicinal plant for the treatment of bronchial calmative, cardiac diseases and nephritis; and also the treatment for embolism by preserving the fruits in rakı (a traditional Turkish alcoholic drink, 40% alcohol) for 40 days [38]. Berries have also been used as astringent, diuretic and purgative [39]. Natural products, either as pure compounds or as standardized plant extracts, provide unlimited opportunities for new drug leads because of the unmatched availability of chemical diversity [40].

The beneficial health effects of berry bioactive components have received a great deal of attention from researchers, consumers and food industries. Although most in vitro and in vivo studies show that polyphenolic compounds in berries have favourable influence on humans, this effect depends on many factors, e.g. bioavailability [41, 42, 43].

The role of phenolic compounds as bioactive components of berries is the subject of numerous studies [43, 44]. Most polyphenols are naturally stored as glycosylated forms. However, they need intestinal bio-conversion through the polyphenols-gut microbiota interplay to transform into more absorbable forms [45].

There is strong evidence supporting the role of berry phenolic in human health. Their mechanism of action involves antioxidative activity, antimicrobial activity, antihypertensive activity and interactions with proteins such as those in bacterial cell walls and fimbria, as well as participation in enzyme reactions [8, 10, 46].

Infectious diseases have been an important cause of morbidity and mortality over the years [47], which makes the study of bioactive metabolites an interesting alternative. Recently, there is a growing demand for new antibacterial and antifungal compounds due to the increased resistance of bacterial and fungal pathogens [48]. Natural products from berry are considered an important source for novel antibacterial and antifungal compounds [8, 48].

The challenges to be faced currently are the emergency of resistant pathogens, a decrease in the discovery of new active principles and legal requirements to use substances that generate a lower impact on the environment [49].

The antimicrobial activities of the naturally occurring phenolic from berries such as cloudberry, raspberry, strawberry, lingonberry, blueberry, cranberry, sea buckthorn berry and blackcurrant have been studied [8, 50]. Lacombe et al., [51] suggested that the addition of blueberry phenolic may enhance the body's ability to defend itself against food borne infection by targeting the surface structures of pathogen bacteria preventing adhesion of the mucosa.

Cavanagh et al, [52] investigated antimicrobial activity of raspberry, blackcurrant, cranberry and blackberry cordials (100% fruit) as well as fresh berries against 12 different bacteria and suggested that these berries may be used in water purification of suspected water supplies or to enhance shelf life of food products.

The antibacterial properties of blueberry juice have been well studied [8, 53, 54, 55].

Elderberry and blackcurrant juices inhibited the growth of *Escherichia coli* and *Staphylococcus aureus*. Maximum reduction of *S. aureus* was obtained with blackcurrant juice at 37 °C [56].

The knowledge of antimicrobial effect is important for the development of health promoting functional foods and in food preservative purposes [50; 8]. The dried plum mixtures were able to increase the microbial shelf life of ground beef by at least 8 days and ground chicken by 4 days at 7 °C [57]. In another study, antimicrobial activities of plum were observed on *E. coli*, *Salmonella enteritidis* and *Bacillus cereus* by using disk diffusion method [58].

Vallejo et al., [8] (see Table 2) investigated antifungal activity of polyphenols present in four blueberry cultivars and use these blueberry extracts in the control of *Starmerella bacillaris* and *Hanseniaspora osmophila*. Then, the authors demonstrated that all blueberries phenolic extracts and several individual phenolic compounds present in blueberry inhibited the growth of two spoiled yeast, *Hanseniaspora osmophila* and *Starmerella bacillaris* (Table 2). Quercetin, kaempferol and ρ-coumaric, ellagic and chlorogenic acid showed highest antifungal activity, and they are probably responsible for the antifungal activity of blueberries.

Table 2. Antifungal activity of blueberry extracts and individual phenolic compounds

Antifungal activity of LMPF extracts of four blueberry cultivars and individual phenolic compounds.

LMPF	*Starmerella bacillaris*	*Hanseniaspora osmophila*
Misty	w	+
Millennium	+	+
Blue Crisp	+	++
O'Neal	w	+
Gallic acid	+	+
p-coumaric acid	++	++
Ferulic acid	+	+
Caffeic acid	+	+
Chlorogenic acid	++	++
Ellagic acid	++	++
Catechin	+	+
Quercetin	++	++
Kaempferol	++	++
Control (+)	+++	+++
Control (−)	-	-

Antifungal activity: Inhibition zone < 1 mm, nil (−); Inhibition zone 1–5 mm, weak (w); Inhibition zone 6–11 mm, moderate (+); Inhibition zone 12–19 mm, high (++); inhibition zone > 19 mm, strong (+++).
Standard deviation ± 0.5 mm.

Source: Vallejo et al., [8].

The antioxidant potential of phenolic compounds can act to prevent chronic diseases and oxidative reactions in pharmaceuticals, cosmetic products and food [59].

Recently, many epidemiological studies have suggested that the consumption of natural antioxidants such as polyphenol-rich food, fresh fruits, vegetables or teas has protective effects against the aforesaid diseases and this protection has been partly ascribed to the presence of several components, such as vitamins, flavonoids, anthocyanins and other phenolic compounds [10, 60, 61, 62].

Fruits, especially berries can prevent health problems such as cardiovascular and neurodegenerative diseases, diabetes, cancer and obesity [62, 63, 64, 65]. Their health-promoting properties result in part from high content of phenolic compounds, which exhibit antioxidant properties [66]. The natural antioxidants are also of interest in the cosmetic, pharmaceutical and especially in the food industries, since they can also be used as substitutes for synthetic antioxidants [67]. Blueberry is reported as a fruit with one of the highest antioxidant capacities [62, 68, 69, 70].

Hypertension is a major health issue, affecting approximately 20% of the adult population worldwide; it leads to serious chronic health problems, including heart attack and stroke [71]. The suppression of ACE is considered a useful approach for the regulation of blood pressure.

Angiotensin I-converting enzyme (ACE) is a peptidyldipeptide hydrolase that plays an important physiological role in both the regulation of blood pressure and cardiovascular function. Therefore, ACE inhibitors are used extensively as pharmaceutical drugs or components of functional foods for the treatment of cardiovascular diseases.

3. CONCLUSIONS

A large number of polyphenols including phenolic acids [72, 73] have been assessed for their antihypertensive and angiotensin I-converting enzyme (ACE) inhibitor potential. Vallejo et al., [10] demonstrated the ACE inhibitor potential of various phenolic from strawberry acids including gallic acid, chlorogenic acid and caffeic acid.

The cytotoxicity assay demonstrated that berries were not toxic to humans and that they did not modify the sensorial qualities of strawberry juice [8]. The authors reported that berry extracts could be a good natural and non-toxic alternative to prevent growth of spoilage yeasts of juice strawberry. Others authors reported similar results [74, 75].

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