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Review Article

Raspberry pomace - composition, properties and application

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ABSTRACT

Raspberry pomace can be valorised due to its nutritionally favourable effect on human health. It is an important source of polyphenols, ellagic acid, ellagitannins, tocopherols, unsaturated fatty acids, and dietary fibre. Thus, raspberry pomace can be considered as a potential raw material to receive products rich in polyphenols or dietary fibre, which can provide healthy properties to food when used as an additive. This review presents the chemical composition and antioxidant properties of raspberry pomace. The possibilities of its usage in industry are also briefly reviewed.

Keywords: Raspberry; Pomace; Fruit; Antioxidant activities; Bioactive substances; Waste disposal.

1. INTRODUCTION

Nowadays, because of the rising interest in functional food, especially bioactive compounds, food producers are looking for new sources and carriers of those substances. Due to their health properties, consumers search for products that allow them to maintain a proper physical and mental fitness and also well-being [1]. Raspberry pomace is the residue that remains after the extraction of juice from raspberry. Dried raspberry pomace, a fruit industry by-product, is considered as a potential food ingredient. Its pomace contains plenty of valuable components such as carbohydrates, proteins, fats, fibre, flavours, pectins, vitamins, similar to the composition of whole raspberries [2]. Moreover, raspberry pomace is rich in a large group of various phenolics especially ellagitannins, proanthocyanidins, anthocyanins, flavonols, and phenolic acids (especially, ellagic acid) which are also predominant in berries [3]. It has been reported [4] that these compounds have beneficial properties for human like antioxidant and antimicrobial activities and a wide range of physiological properties, such as anti-allergenic, anti-atherogenic, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, cardioprotective and vasodilatory effects. The antioxidant activity of phenolics is provided by the hydroxyl groups and phenolic hydrogen for donation [3].

The aim of this review is to collect recent data on chemical composition and antioxidant properties of raspberry pomace and to present a great potential of usage of raspberry pomace in various fields of industry.

2. CHEMICAL COMPOSITION

Raspberry pomace, a fruit waste, received during pressing raspberries during juice production consists, mainly of seeds and pulps. On average, raspberry pomace is characterized by a high content of total dietary fibre 59.5%, acid detergent fibre 46%, cellulose about 27%, crude fat about 11%, crude protein 10%, lignin 11.7%, cutin 6%, acid detergent ash 2.2% (Table 1) [5].

Table 1. Approximate composition of raspberry pomace (dry matter basis).

Parameters	(%)
Crude fat	11.1
Crude protein	10.0
Total dietary fiber (TDF)	59.5
Acid detergent fiber	46.0
Lignin	11.7
Cutin	6.0
Acid detergent ash	2.2
Cellulose	26.9

On the other hand, results obtained by Laroze et al. (2010) show that raspberry residue composition consists mainly of crude fibre (59.76%) and nitrogen free extract (31.02%). The high content of crude fibre suggests that raspberry pomace is a source of antioxidants. Crude fibre contains polyphenols which are associated with non starch polysaccharides such as pectin, cellulose, β-glucans, hemicellulose, gums, and lignin. Moreover, raspberry residue shows low protein, ash and oil content (1.87%; 5.97%; 1.38%, respectively). Due to the fact that raspberry residue ash contains a low percentage of minerals and heavy metals, from which it is known that it can act as pro-oxidants like iron, a positive impact on the antioxidant capacity of raspberry waste is likely [6].

Furthermore, raspberry pomace contains small amounts of vitamins (E, C), but only vitamin C is presented at a significant level and responsible for anti-inflammatory activity [7, 8]. In addition, a lot of volatile compounds are found in raspberry pomace (Fig. 1) such as alcohols, esters, acids, ketones and carbonyls [9]. Additionally, raspberry pomace is an important source of unsaturated fatty acids and tocopherols. Besides, the main sugars in raspberry pomace are glucose, fructose and sucrose. Raspberry pomace is also a source of sodium, potassium, calcium, phosphorus and magnesium [7].

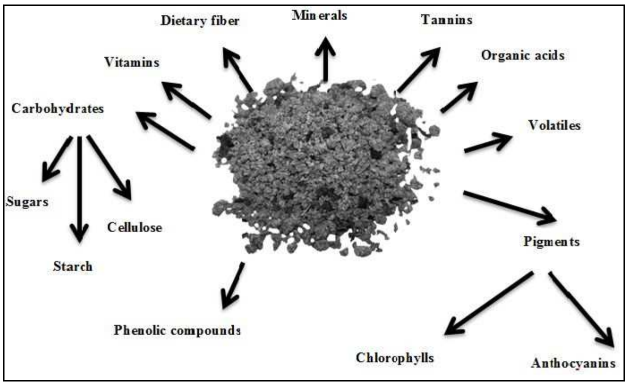

Figure 1. Simplified schematic representation of the remarkable components of raspberry pomace.

3. OCCURRENCE OF BIOACTIVE COMPONENTS IN RASPBERRY POMACE

Bioactive compounds (often called antioxidants) are defined as chemical substances which in small quantities have an ability to prevent or reduce the oxidation of easily oxidisable molecules [10].

Antioxidant activity is closely associated with antioxidants which have antimicrobial activities against human pathogens [11]. More specific, the function of these compounds is to slow down or to stop damaging cellular DNA, lipids, and proteins caused by reactive oxygen species (ROS) [12].

Raspberry pomace, in particular, is a rich source of antioxidants. The biological activity of those compounds is mainly exercised by dietary fibre, tocopherols, unsaturated fatty acids, carotenoids, vitamin C and polyphenols such as tannins (especially ellagitannins), anthocyanins, flavanols, flavonols and phenolic acids [13, 14].

3.1. Dietary fibre

The chemical composition of raspberry pomace makes that it belongs to a valuable group of fruit by-products [15]. By-products from raspberry processing contain prominent amounts of bioactive components including dietary fibre which is highly desirable for dietary purposes [16]. The content of total dietary fibre (TDF) in raspberry pomace is very high, about 60% [5]. Its composition demonstrates the high content of lignin (63.16%), which means a presence of phenolics. There are also other components, but in less amounts, namely pectin (15.38%), hemicellulose (14.89%) and cellulose (5.36%) [6].

Due to the nutritional benefits of dietary fibre, producers are keen on using by-products as food ingredients. For instance, enriched cookies with 50% of a non-crumbled raspberry pomace resulted in the desired high content of dietary fibre. It has been noticed that differences in a flavour in such kind of cookies depend on the quantity and form of pomace used [17].

The addition of raspberry pomace to shortcrust cookies caused an increase of their fruity smell and taste, as well as an increased sour taste while the sweet taste was less perceptible (Fig. 2). It was confirmed that the more raspberry pomace is added, the stronger the fruity smell, fruity taste and sour taste. An increased crumbliness of cookies was reported after adding a 50% of whole seed raspberry pomace [1].

3.2. Fatty acids and tocopherols

Raspberry seed oil from raspberry by-product has a unique fatty acid profile [18, 19]. Dimić et al. reported that the oil content of raspberry pomace was about 14% on dry basis. It had a dark yellowish-orange colour due to lower chlorophyll content (about 200 mg/kg). The total content of carotenoids was around 40 mg/kg [20].

Oil from raspberry seeds possesses an important nutritional profile. It is a rich source of fatty acids, vitamin A, vitamin E and α-, γ-, σ-tocopherols. Raspberry seed oil is abundant in unsaturated fatty acids such as linoleic, α-linolenic, and oleic acid (96% of the total fatty acids). The extraction of raspberry seed oil with chloroform resulted in a fatty acid composition as follows: C16:0, 2.7%; C18:0, 0.2%; C18:1, 18.7%; C18:2, 55.5%; and C18:3, 32.6%. Oomah et al. investigated that raspberry seed oil contains neutral lipids, free fatty acids, and phospholipids with 93.8, 3.5, 2.7%, respectively. Additionally, raspberry seed oil is a superior source of tocopherols, mainly γ-tocopherol (137-272 mg/100 g). The ratio of the tocopherol isomers (α, γ, σ) in raspberry seed oil was 20:75:5. The high γ-tocopherol content can indicate the prevention of degenerative diseases [9].

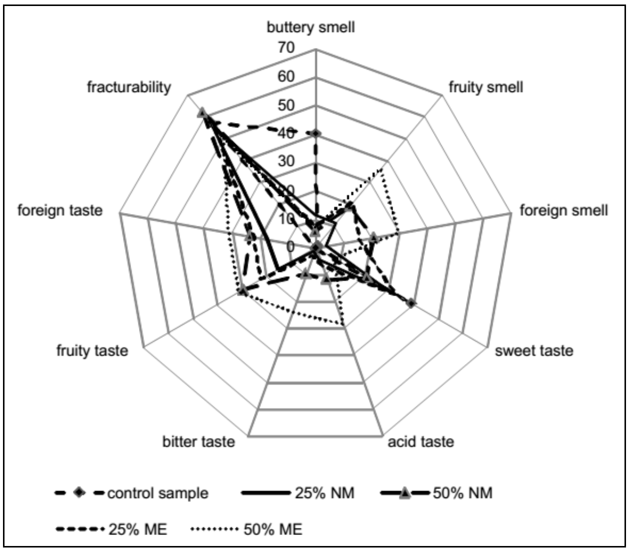

Figure 2. The influence of adding crumbled (ME) and non-crumbled (NM) raspberry pomace on the sensory qualities of shortcrust cookies (based on [1]).

3.3. Carotenoids

Carotenoids belong to the class of natural pigments, occurring in plant materials including fruits and vegetables. They are responsible for the yellow to red colour of those plants. Some of them demonstrate provitamin A activity. Carotenoids are polyenoicterpenoids having conjugated trans double bonds, including carotenes (*β*-carotene, lycopene). These compounds are polyene hydrocarbons, and xanthophylls (lutein, zeaxanthin, capsanthin, canthaxanthin, astaxanthin, and violaxanthin) which means that they have oxygen in the form of hydroxyl-, oxo-, and epoxy groups [16]. Carotenoids have a great potential to human health. It was proved that they occur as biological antioxidants, protectors of cells and tissues against free radicals and inhibitors of the proliferation of the cells [16, 21].

3.4. Vitamin C

Vitamin C, also known as ascorbic acid and dehydroascorbic acid, is widely used as a food additive for humans and other animal species. The deficiency of vitamin C causes the disease called scurvy in human organisms. Dehydroascorbic acid is the minor part of vitamin C content and the oxidised form of ascorbic acid. Ascorbic acid possesses antioxidant activity and prevents oxidative stress-related diseases. Thus, it can be considered as a scavenger of reactive oxygen species. However, humans are not able to synthesise ascorbic acid because of the lack of enzyme L-gluconolactone oxidase. Therefore, plants appear to be able to synthesise ascorbic acid from D-glucose or D-galactose [22].

3.5. Phenolic compounds

Numerous studies show that raspberry pomace is a superior source of phenolics. The results of the quantitative analysis of antioxidant components are shown in Table 2.

The study conducted by Vulić et al. (2011) indicates that raspberry pomace extracts contain a high amount of total flavonoids: 591.65 mg per 100 g of fresh pomace. Besides, the total anthocyanin content appeared to be 65.21 mg per 100 g of fresh pomace [23]. Regarding another study, the total phenolic content of raspberry was higher (234 ± 5.1 mg gallic acid per 100 g of fresh fruit) [24]. It has also been reported that the total anthocyanin content of raspberry pomace extract is 68.0 mg per 100 g fresh fruit [23].

The antioxidant composition commonly occurring in raspberry pomace is presented in Table 3.

3.5.1. Flavonoids

Flavonoids represent the largest group of plant phenolics, accounting for over half of the eight thousand naturally occurring phenolic compounds. Flavonoids consist of classes like: anthocyanins, flavones, flavanols, flavanones, flavans, isoflavones and flavonols. Furthermore, flavonoid compounds are classified in bioflavonoids, chalcones, flavono-lignans, prenylflavonoids, glycoflavons, aurones [25]. In raspberry pomace was noticed the dominant presence of flavonol glycosides, namely quercetin and kaempferol glycosides [12].

Table 2. Total anthocyanins, flavonoids and poly-phenolics in berry pomace extracts [based on Vulić et al. 2011].

Berrypomace extracts	Antioxidant compounds content (mg/100 g fresh pomace)		
	Total anthocyanins	Total flavonoids	Total polyphenolics
Raspberry	65.21	591.65	637.77
Blackberry	149.12	245.48	804.50
Strawberry	19.48	296.11	488.12
Bilberry	1279.49	1047.39	1116.24

Table 3. Antioxidant compounds identified in raspberry pomace.

Antioxidative compounds	Major compounds	References
Anthocyanins	cyanidin-3-sophoroside*, cyanidin-3-glucoside, cyanidin-3-glucorutinoside, cyanidin-3-rutinoside, pelargonidin-3-sophoroside, pelargonidin-3-glucoside	47
Flavonols (flavonol glycosides)	quercetin glycosides, kaempferol glycosides	12
Flavanols	catechin, epicatechin	10
Polymeric tannins	ellagitannins, proanthocyanidins	7, 48
Phenolic acids	hydroxycinnamic acid, chlorogenic acid	3

*Anthocyanin dominant

The flavonoids are formed in the condensation reaction of a phenylpropanoid (C6-C3) compound with malonyl coenzyme A. Flavonoids have the basic skeleton of diphenylpropanes (C6-C3-C6) [3]. The broad range of functions of flavonoids gives wide prospects for applications, not only in prevention but also in therapy of many diseases, for instance: cancers, atherosclerosis, cardiovascular disease, diabetes, and so on [25]. Flavonoids as ubiquitous compounds in plants constitute an important element in the human diet. It is estimated that on average one person eats in a day about 1 g flavonoid compounds [26].

3.5.2. Anthocyanins

Anthocyanins, which are classified as pigment compounds in the tissues of berries, constitute one of the major groups of polyphenols in berry pomaces [23, 27]. The basic structures of anthocyanins are the anthocyanidins (or aglycons). When anthocyanidins are bound to sugar molecules, anthocyanins are obtained. The most common sugar substitutes on the anthocyanidins are glucose, fructose, galactose, rhamnose, xylose, and arabinose [22, 28].

Anthocyanins are usually presented in coloured flavylium cation form, which depends on the pH [3]. Therefore, at pH 1, the flavylium cation (red colour) is the predominant species and contributes to the purple and red colours of raspberries.

Anthocyanins belong to compounds which are easy to oxidise, thus they are usually the best antioxidants. Several studies have suggested that the anthocyanin content and their corresponding antioxidant activity, contribute to the fruits protective effect against degenerative and chronic diseases [28]. It has also been reported that they characterize anticarcinogenic activity. It has been proven that the antioxidant activity of berries is directly proportional (linear correlation) to the anthocyanins content [29]. The results received by Soto Rodriguez Gil demonstrated that the main anthocyanins found in black raspberry pomace extract were cyanidins (95% of the anthocyanins), namely cyanidin-3-rutinoside (68.8%), cyanidin-3-sambubioside-5-rhamnoside (18.2%), cyanidin-3-glucoside (7.1%) and pelargonidin-3-glucoside (6%). In addition, in the study by Soto Rodriguez Gil anthocyanin content was 3800 mg per kg of black raspberry pomace [30].

3.5.3. Polymeric tannins

Proanthocyanidins, regarded as condensed tannins, are dimers, oligomers, and polymers of catechins which are bound together by C-C links. Catechins are monomer form of flavan-3-ols and proanthocyanidins are the polymer form of those compounds [22, 31, 32]. Proanthocyanidins have, similar as flavan-3-ols, the C6-C3-C6 flavonoid skeleton and give a characteristic bitter taste to many berries. Flavan-3-ols commonly occurring include: (+)-catechin, (-)-epicatechin, gallocatechin, and epigallocatechin. Procyanidins and prodelphinidins are made of epicatechin units and epigallocatechins, respectively [33]. There were found prominent amounts of proanthocyanidins in berries [3]. In raspberry residue proanthocyanidins are formed of procyanidins and propelargonidins [13].

Ellagitannins with gallotannins form the group of hydrolyzable tannins. Ellagitannins are presented especially in the family *Rosaceae*, genus *Rubus*, namely raspberries, cloudberries, and blackberries [34]. These berries as well as its pomace produce ellagitannins based on stable glucose conformation [11]. The ellagitannin monomers often form dimers, trimers and even higher oligomers via phenolic oxidative coupling reactions [34, 35].

The major ellagitannins which have been identified in raspberries (*Rubus idaeus* L.) and raspberry pomace are the dimeric sanguiin H-6 and the trimeric lambertianin C (Fig. 3) and comprising 81% of the total ellagitannins in raspberries. Also, raspberries contain ellagitannins such as monomeric casuarictin, potentillin, pedunculagin, sanguiin H-10, dimeric nobotanin A, and tetrameric lambertianin D [3, 11, 34].

Moreover, ellagitannins are complex derivatives of ellagic acid. They contain one or more hexahydroxydiphenic acid (HHDP) moieties esterified usually to glucose. Hydrolysis of ellagitannins with acids or bases yields that HHDP is lactonized to ellagic acid (Fig. 4) [36].

It has been reported that free ellagic acid was detected in berries. The highest level was found in cloudberries and wild red raspberries, whereas ellagic acid glycosides were detected only in raspberries, of which wild raspberries contained the highest level [36].

3.5.4. Phenolic acids

Phenolic acids in raspberry pomace are represented mainly by cinnamic acids and benzoic acid derivatives. Hydroxybenzoic acids, occurring in raspberry pomace, consist of salicylic acid, p-hydroxybenzoic acid, gallic acid, and ellagic acid. The last one, ellagic acid, is predominant in raspberry pomace and is presented in the free form or esterified to glucose. Hydroxycinnamic acids, which are widely distributed in berry pomaces, include p-coumaric, caffeic, sinapic, and ferulic acids. Hydroxycinnamic acids are commonly found as derivatives of caffeic acid. Chlorogenic acid, which is an ester of caffeic and quinic acid (5-O-caffeoylquinic acid), belongs to the one of the main hydroxycinnamates found in plants [22, 37].

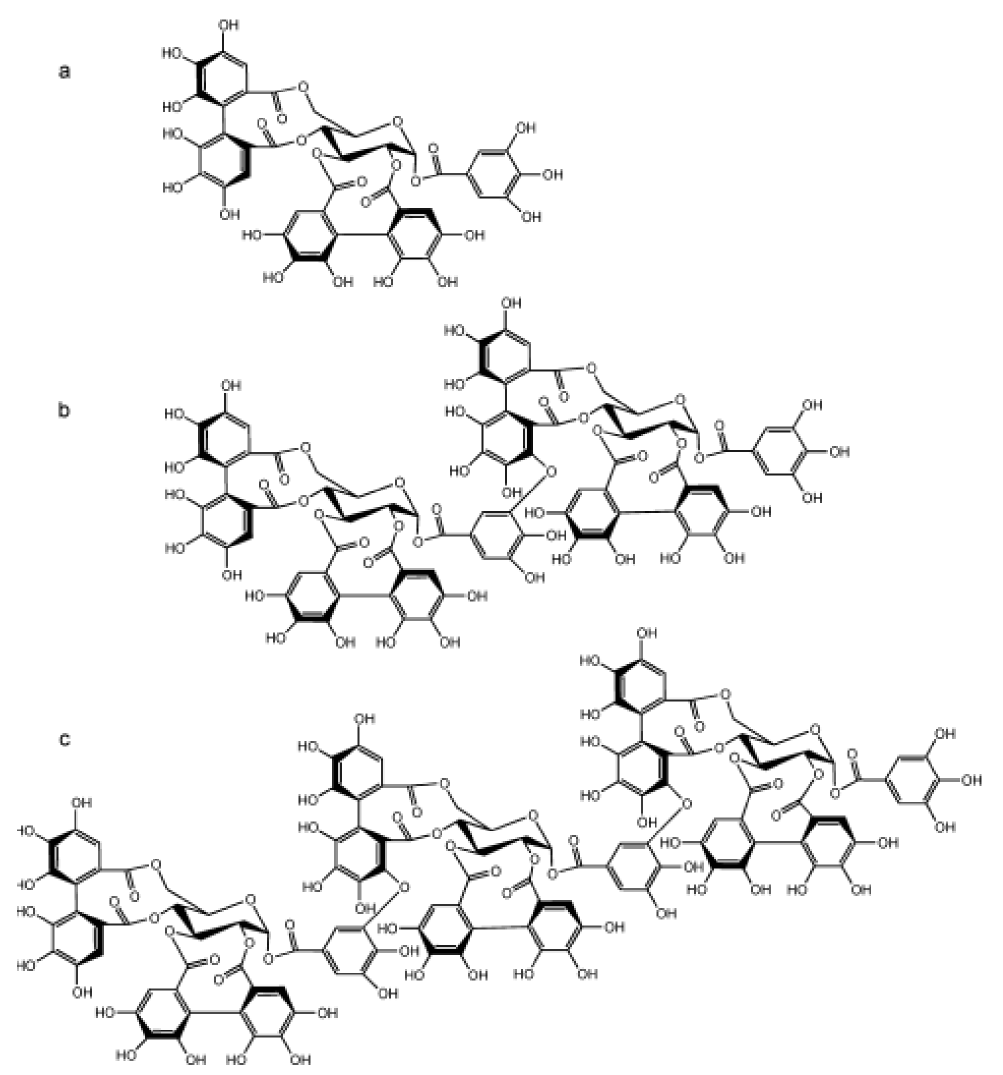

Figure 3. Structures of the major ellagitannins in raspberries and raspberries pomace: casuarictin (a), sanguiin H-6 (b), lambertianin C (c).

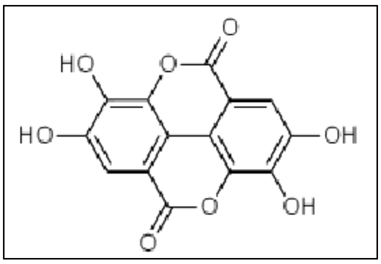

Figure 4. Ellagic acid - the hydrolysis product of ellagitannins.

4. ANTIOXIDANT ACTIVITY

Bioactive compounds, described above, display potential health-promoting effects such as antioxidant, anticancer, anti-inflammatory, and anti-neurodegenerative biological properties. Therefore, the identification of antioxidant activity of raspberry pomace is necessary. Vulić et al. determined the berry pomace extracts (bilberry, strawberry, raspberry and blackberry) using methods such as DPPH free radical scavenging assay and reducing power. The IC_{50} values were determined using the RSC_{DPPH}. The IC_{50} value is a parameter used to measure the free radical scavenging activity, and can be defined as the extract concentration required for 50% inhibition of DPPH radicals under experimental conditions. The results show that the IC_{50} of the obtained raspberry pomace extract was 0.040 mg/ml. Also, there was observed a high linear correlation between the IC_{50} and the content of anthocyanins, polyphenols and flavonoids. Thus, there is a great importance of phenolic compounds in the radical scavenging activities [23]. The results obtained by Vulić et al. indicate that the reducing power of berry pomace extracts increased with increasing concentration. Berry fruits pomaces are a good source of antioxidant compounds and can be used as a potential value-added ingredient in the food, cosmetic and pharmaceutical industry [23].

4. GENERATION OF RASPBERRY POMACE

In the horticulture, there has been observed a growth in acreage as well as in agricultural production to fulfill the requirements of global food demand. It is estimated that the average worldwide production of fresh fruits and vegetables is 800,000 tons per year [21, 38]. However, in Poland annually about 1.5 million tons of fruit are being produced. Most of them (around 60%) is used for wine, juice and beverage production, 15% for frozen products, and around 15% for marmalade and jams production [39].

During processing of plant materials basic products and by-products are obtained. The latter can be divided into wastes generated during storage, production and manufacturing. A disposal of raspberry pomace, as well as other fruit pomaces, usually represent a serious ecological and environmental problem due to the low pH value. Other emergingproblems are the legal waste stream restrictions which must not be exceeded. Wastes can impede the proper conduct of production due to spoilage, which has to be avoided because of the possibility of microbiological contamination of the process. In the processing of raspberry juice or wines, the pomace becomes a by-product which is currently underexploited. Raspberry waste is prone to microbial spoilage; therefore, drying is necessary before further exploitation. However, the cost of drying, storage, and transport posses-ses additional economical limitations to waste utilization. Thus, agroindustrial waste is very often utilized as feed or fertilizer [5]. However, there appears some new aspects concerning the use of berry wastes.

5. POSSIBLE USES OF RASPBERRY POMACE IN THE VARIOUS FIELDS OF INDUSTRY

Several potential uses can be considered for raspberry by-products, covering various fields of industry: food, pharmaceutical, medical, cosmetic, composting as well as chemical industry [21].

5.1. Raspberry pomace as antimicrobial agent

In the past few years, due to concerns regarding the safety of synthetic antimicrobial agents, an increase in consumer demand for naturally processed food is observed. It has resulted in a huge increase in the use of naturally derived compounds such as plant extracts as antimicrobials in food. What is more, natural antimicrobial compounds can be an alternative to food preser-vation [21]. Studies confirmed that phenolics (ellagitannins) which occur in berry pomace, including raspberry, display a very effective role in inhibiting the growth of the pathogenic bacteria: *Clostridium*, *Enterococcus*, *Escherichia*, *Mycobac-terium, Salmonella* and *Staphylococcus* species as well as some Gram-positive and Gram-negative bacteria [22, 40]. Puupponen-Pimiä et al. reported that isolated ellagitannin fractions from raspberry were highly efficient against Gram-negative bacteria such as *Staphylococcus aureus* and *Salmonella*, but with no effect on Gram-positive lactic acid bacteria. Raspberry anthocyanins were found to exhibit the strong inhibiting effects on the growth of *L. acidophilus*, a Gram-positive bacterium. It can be important when raspberry anthocyanins are consumed in high concentrations because *L. acidophilusis* is commonly used in fermented milk products [11]. In addition, raspberry can inhibit the growth of *Bacillus subtilis* and *Micrococcus luteus* [41].

Also, it has been reported that solidstate bioprocessing of cranberry pomace, using food-grade fungus results in an enrichment of the total soluble phenolics and of ellagic acid. Also, it has been confirmed that bioprocessing improved the antimicrobial activities of the extracts against important foodborne pathogens *L. monocytogenes*, *Vibrio parahaemolyticus* and *E. coli* O157:H7. Microorganisms, used in studies, showed different sensitivities to various functional properties of the extracts, which may indicate that different mechanisms of action in the antimicrobial activity exist. Therefore, bioprocessing of berry pomace may offer an innovative solution to produce a broad spectrum of antimicrobials against important pathogens [11].

In this context, raspberry by-products are promising new sources of phenolic antimicrobial compounds [21].

5.2. Raspberry pomace as dietary fibre additive

Until recently, people believed that non-digestible components of plant products belonged to ballast substances. Nowadays beneficial physiological properties of these substances on human health are appreciated. Numerous studies on dietary fibre proved that this component can prevent and treat some diseases. Diet enrichment in fibre reduces risk of certain cancers (large intestine), coronary heart disease (CHD), atherosclerosis, diabetes and obesity. Additionally, dietary fibre increases the faecal bulk, and stimulates intestinal peristalsis, lowers the levels of total cholesterol and low-density lipoprotein cholesterol in the serum. Due to that fact the addition of dietary fibres to food becomes more and more popular [17]. It is well-known that fruit processing waste (raspberry pomace) represents an important source of dietary fibre [42]. Dietary fibre is not only desirable for its technological properties, but also for its nutritional and functional properties. It can be used in order to modify the texture and enhance the stability of the food during production and storage, and to upgrade agricultural products and by-products for the use as a food ingredient [17]. The investigations by Górecka et al. show that the addition of raspberry pomace to shortcrust cookies increase their fruity smell and taste, as well as crumbliness [1].

Due to numerous health benefits of dietary fibre, it can be used for many applications in food and pharmaceutical industry. Dietary fibre fractions from raspberry processing waste can create functional food products. A wide range of fibre-enriched foods included, for instance bakery products, biscuits, cereals, snacks, sauces, dairy products, meat products, drinks [17].

Moreover, it may supplement the daily diet as a prebiotic which is defined as a non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, and thus improves host health [43]. There are dietary fibre supplements available on the market, both fruit- and vegetable-based, but these mostly contain apple, peach or carrot fibre rather than raspberry fibre. Raspberry pomace fibre may be of a great interest to food technologists. According to literature the exotic fruits such as guava, carambola, mamey, mango, sapodilla and raspberries possess a significant dietary fibre content. Besides, fibre from raspberry waste can be incorporated into food products as inexpensive, non-caloric bulking agents for partial replacement of flour, fat or sugar, as enhancers of water and oil retention and to improve emulsion or oxidative stabilities [21].

5.3. Raspberry pomace as a source of natural colorants

The colour of a food has a major impact on the consumer's behaviour. It influences the priority of purchase and is therefore of great economic value. Increasing consciousness of consumers about healthy lifestyle causes that they prefer natural colorants isolated from fruits, vegetables, herbs and spices rather than unwholesome synthetic ones.

Raspberry pomace has become a significant source of those pigments and colours, mainly anthocyanins and carotenoids which demonstrate high colour stability, good availability, high yield and low price. Currently, natural colorants are received from wastes such as chokeberry, cherry, elderberry, blackberry, red cabbage, red radish, black carrot, and purple sweet potato [21].

5.4. Raspberry pomace as cosmetic and pharmaceutical component

Raspberry seed oil from raspberry by-product is very important for its potential application in food, pharmaceutical as well as cosmetic products. The addition of raspberry seed oil in cosmetics and pharmaceutical products has been patented. Therefore, the unique fatty acid composition and the high tocopherol content, as well as the protective effect against oxidative stress and relatively good shelf life makes oil of raspberry pomace desirable for uses as dietary supplements, in toothpastes, bath oil, shampoos, creams for prevention of skin irritations, aftershave cream, lipsticks, antiper-spirants, etc. [9].

5.5. Raspberry pomace as metal-binding agent

It has been noticed that fruit pomaces have the potential for binding heavy metal ions. In particular, fractions from dietary fibre of pomace are able to bind heavy metals [42, 44]. According to literature, hemicellulose and pectins have better binding capacity than cellulose and lignin. Studies report that the stability of metal-dietary fibre complexes differs according to the metal involved and fibre source [45, 46]. In the study conducted by Nawirska pectins were found to be the most effective metal ion binders, and lignins the least effective metal ion binders. As it has been mentioned before, dietary fibre of raspberry pomace consists of 63.16% of lignins, thus has a smaller binding ability. However, it has been noticed that polyphenols bind considerable amounts of lead ions in chokeberry, pear, apple, and rosehip pomace (34.8, 34.0, 35.2, and 26.5%, respectively) [44]. Therefore, raspberry pomace may also be an effective ion binder due to the rich source of polyphenols. It was also reported that tannin compounds (proanthocyanidins or the galloyl ester of glucose) of *Rubus* berries are chelating agents for metal ions such as alumi-nium, iron, and cooper. These polyphenols at neutral pH form complexes with metal ions and precipitate easily at neutral pH through the gut barrier [22].

6. CONCLUSIONS

To conclude this review, raspberry pomace represents a potential source of natural food ingredients. No major exploitation of this source is happening today, although there is a great opportunity for the food industry in this area.

The exploitation of raspberry pomace during fruit processing as a source of functional compounds and their application in food is a promising field which requires interdisciplinary research. Due to the high nutritional value of raspberry by-products, it can be exploited as food additives or supplements providing the high-valuable products which may be economically attractive for consumers. Raspberry pomace has a great potential as a source of antioxidants and may have important applications in the future. By presenting antibacterial activity, it can be used as a natural antimicrobial agent in the future. Some components of raspberry pomace can be isolated and may be the goal of prospective findings in medicine (therapy) as well as in the food industry.

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TRANSPARENCY DECLARATION

The author declares no conflicts of interest.

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