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# The effects of strawberry, black currant, and chokeberry extracts in a grain dietary fiber matrix on intestinal fermentation in rats

Monika Kosmala [a,*], Zenon Zduńczyk [b], Elżbieta Karlińska [a], Jerzy Juśkiewicz [b]

[a] Institute of Chemical Technology of Food, Lodz University of Technology, Stefanowskiego Str. 4/10, 90-924 Lodz, Poland
[b] Institute of Animal Reproduction and Food Research of the Polish Academy of Sciences, Tuwima Str. 10, 10-747 Olsztyn, Poland

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ABSTRACT

The objective of this work was to study the composition, hydration properties and oil holding capacity, antioxidant properties and the physiological effects on the digestive system of dietary preparations containing wheat or oat fiber enriched with polyphenol extracts from strawberry, chokeberry, and black currant pomace. By the addition of black currant, strawberry and chokeberry polyphenol extracts to grain fibers preparations with corresponding polyphenol content of 0.7%–0.8%, 1.1%–1.2%, and 2.5%–2.9% were obtained. The preparations were used as part (8%) of a modified AIN-93 diet given to growing Wistar rats (8 animals per group) over a period of 4 weeks. The highest antioxidant potential had grain–chokeberry preparations with the greatest polyphenol content, while grain–black currant preparations exhibited the lowest antioxidant potential with the smallest polyphenol content. The addition of strawberry and chokeberry extracts caused a decrease in the activity of bacterial β-glucosidase and α-galactosidase, while black currant extract led to increased activity of β-galactosidase and β-glucuronidase. The production of short chain fatty acids (SCFAs) in the caecum of rats fed the grain–strawberry preparation, rich in ellagitannins, was considerably higher than the grain–black currant preparation, rich in proanthocyanidins and anthocyans, or the grain–chokeberry preparation with the highest polyphenol content (78.3 *vs.* 64.7 *vs.* 56.3 μmol/100 g body weight, $p = 0.012$). In comparison to preparations without polyphenols only chokeberry extract significantly decreased SCFA concentration. The grain–strawberry preparations were characterized by a higher antioxidant potential per unit of polyphenol content and exhibited a more beneficial influence on the fermentation processes in the caecum of rats than the grain–black currant and grain–chokeberry preparations.



## 1. Introduction

The results of many population studies indicate that the composition of one's diet as well as eating habits are important risk factors in the development of so-called diseases of modern civilization, that is, arteriosclerosis, cardiac ischemia, myocardial infarction, hypertension, obesity, osteoporosis, various kinds of cancer, and diabetes (Kaczmarczyk, Miller, & Freund, 2012; Li & Uppal, 2010).

One of the important components of a balanced diet is dietary fiber (Gray, 1995; Sierra et al., 2002). Sources of dietary fiber include cereals and grains (especially whole meal), legumes and vegetables, nuts and seeds, fruits, mushrooms, and seaweeds (Lee, Lee, Lee, Jang, & Kim, 2008). In spite of considerable efforts to promote increased consumption of vegetables and fruits, in Europe, the United States, and Canada the average consumption of fiber is equal to about 15–18 g, which is much less than the amount of 25–38 g (14 g of dietary fiber per 1000 kcal) recommended for health reasons (Hauner et al., 2012; King, Mainous, & Lambourne, 2012; Li & Uppal, 2010). This justifies the idea of increasing fiber consumption by dietary supplementation with appropriately prepared fiber preparations (Larrauri, 1999; O'Shea, Arendt, & Gallagher, 2012).

The beneficial health effects of dietary fiber on the human organism are due to the positive influence of this substance on large intestine function, as it facilitates the passage of intestinal digesta, increases stool weight, and inhibits the development of pathogenic microflora, mainly by decreasing the pH of digesta rich in short chain fatty acids (Chen, Haack, Janecky, Vollendorf, & Marlett, 1998; Kaczmarczyk et al., 2012). The increased production of short chain fatty acids has a positive effect on lipid metabolism in the

*Abbreviations:* IDF, insoluble dietary fiber; O, oat fiber preparation without supplementation; OBC, oat fiber with black currant extract; OC, oat fiber with chokeberry extract; OS, oat fiber with strawberry extract; SCFAs, short chain fatty acids; SDF, soluble dietary fiber; TDF, total dietary fiber; W, wheat fiber preparation without supplementation; WBC, wheat fiber with black currant extract; WC, wheat fiber with chokeberry extract; WS, wheat fiber with strawberry extract.

* Corresponding author. Tel.: +48 42 631 34 65; fax: +48 42 636 74 88.
*E-mail address:* monika.kosmala@p.lodz.pl (M. Kosmala).

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liver, decreases the level of total and/or LDL cholesterol in the blood, and reduces postprandial blood glucose and/or insulin levels (Kaczmarczyk et al., 2012; Kosmala, Kołodziejczyk, Zduńczyk, Juśkiewicz, & Boros, 2011).

The physiological activity of fiber depends to a great degree on the distribution of its fractions, and in particular the relative content of the soluble fraction, mostly consisting of pectins and some hemicelluloses, which most effectively decrease the levels of LDL cholesterol and blood glucose (Drozdowski et al., 2010; Isken, Klaus, Osterhoff, Pfeiffer, & Weickert, 2010). Insoluble fiber stimulates intestine function and increases stool weight, which prevents constipation and the development of hemorrhoids (Brownlee, 2011; Sierra et al., 2002), and in addition decreases the risk of cancer of the large intestine (Karagianni & Triantafillidis, 2009). In contrast, soluble fiber usually increases the viscosity of intestinal contents and is more prone to fermentation (Li & Uppal, 2010).

Technological changes implemented in the production of fruit juices, including the techniques of separation of water-insoluble fruit components from juice, have made it possible to obtain fruit pomace of considerable dry weight, often above 40% (Rój & Dobrzyńska-Inger, 2009). The principal component of fruit pomace is dietary fiber (Jaroslawska et al., 2011; Sójka & Król, 2009). However, specific harvesting methods can cause some contamination, such as sand in the case of strawberries, or twig fragments in the case of mechanically picked black currants or chokeberries. Being the side product of fruit processing in juice production, pomace is still an underestimated source of beneficial health substances, both fiber and polyphenols (Kołodziejczyk, Markowski, Kosmala, Król, & Płocharski, 2007; Kosmala et al., 2011; Schieber, Stintzing, & Carle, 2001; Sójka & Król, 2009). Depending on their source and composition, polyphenols exhibit anticancer activity (Bishayee et al., 2011; Heber, 2008), particularly as regards colorectal cancer (McDougall, Ross, Ikeji, & Stewart, 2008; Theodoratou et al., 2007), antibacterial and antiviral activity (Ooi, Wang, He, & Ooi, 2006) as well as anti-inflammatory activity (Zapolska-Downar, Hajdukiewicz, Bryk, Sitkiewicz, & Malecki, 2012), in addition, they strengthen blood vessels and have a positive influence on heart function (Giampieri et al., 2012). Polyphenol-rich fruit pomace obtained from modern juice manufacturing plants can be used as a raw material for the production of polyphenol preparations with potentially beneficial physiological effects on the human organism.

Vitaglione, Napolitano, and Fogliano (2008) and Saura-Calixto (2011) put forward the hypothesis that grain fiber contains polyphenols which are gradually released in the digestive system and then absorbed into the blood stream. Many researchers have claimed that polyphenols are more effective when they are combined with digestive fiber. Aprikian et al. (2003) stated that apple polyphenols combined in a diet with apple pectins exhibit a positive synergic effect on caecal fermentation and plasma lipids in rats. Zduńczyk, Juśkiewicz, and Estrella (2006) reported that a 5% addition of inulin together with a 0.3% addition of grapefruit polyphenols protects caecal parameters without causing either an excessive increase in digesta weight or caecal wall enlargement. Saura-Calixto (2011) concluded that the transportation of dietary antioxidants through the gastrointestinal tract may be an essential function of dietary fiber. In this context, it was considered appropriate to study the physiological effects of the simultaneous consumption of polyphenol extracts and fiber preparations of various compositions.

The objective of this work was to study the chemical composition, the composition, hydration properties and oil holding capacity, antioxidant properties and, above all, the physiological effect on the digestive system of rats of dietary preparations composed of grain fiber (wheat or oat) and aqueous polyphenol extracts from various fruits (strawberries, chokeberries, and black currants). *In vivo* experiment final body weight and caecal function parameters as well as activity of microbial enzymes and short chain fatty acid concentration in caecal digesta were measured. The dietary fiber preparations with increased polyphenol content were obtained in technologically simple way. Preparations were standardized mostly on similar dietary fiber content. As strawberry polyphenols are known for their beneficial influence on fermentation parameters (Kosmala et al., 2014) and we wanted to check if obtained in the same simple technological way fiber–polyphenol preparations from black currant and chokeberry pomaces have similar effects. Sensory analysis of preparations (not presented in the article) showed that all the preparations were attractive in the sense of color and taste.

## 2. Materials and methods

### 2.1. Materials

#### 2.1.1. Fruit extracts

Aqueous fruit extracts were obtained by extraction of the fruit pomace (from strawberries *Fragaria ananassa*, black currants *Ribes nigrum* L., and chokeberries *Aronia melanocarpa*) obtained during the industrial processing of fruits into juice in a modern production plant (ALPEX, Łęczeszyce, 2011 season). The fruit processing procedure involved the application of some commonly used enzymes with the aim of softening fruit tissue and increasing the yield of fruit juice. Fruit pomace was dried in a laboratory convection drier. Each time three 1.5 kg portions of pomace were extracted (4.5 kg total weight). Each extraction was carried out by immersing 1.5 kg of pomace in 7 L of water at 70 °C for 0.5 h. Then the liquid was removed through pressing in a hand-press, and the remaining wet pomace was immersed in another portion of water at 70 °C. The decanted extracts were condensed to 20°Bx. Aqueous black currant extract with 20°Bx was obtained in a yield of 464 g/kg of dried pomace, or 94 g of dried extract/kg. Aqueous strawberry extract with 20°Bx was obtained in a yield of 400 g/kg of dried pomace (81 g of dried extract/kg). Aqueous chokeberry extract with 20°Bx was obtained in a yield of 350 g/kg of dried pomace (73 g dried extract/kg).

#### 2.1.2. Grain fiber

Three wheat fibers (WF 200R, WF 600R, WF 600-30) and 2 oat fibers (HF 600 and HF 401) acquired from Rettenmaier Polska Ltd. were selected for preliminary evaluation. WF 200R and HF 600 were chosen for further studies among wheat and oat fibers, respectively, owing to the best hydration properties (swelling, water binding capacity, and oil holding capacity) and the highest content of dietary fiber.

#### 2.1.3. Grain–fruit preparations

Taking into consideration relatively high hydration properties, technological ease of preparation, as well as high antioxidant value, the ration of 2:1 was chosen as the best for combining fruit extracts and grain fibers (WF and HF). Fruit extracts (strawberry, black currant, chokeberry) with 20°Bx were mixed with fiber preparations at a ratio of 2:1. For homogenization they were sifted through a sieve with a 2 mm mesh and dried in a convection drier at 60 °C. Then, the preparation was pressed through a sieve with a 0.8 mm mesh for obtaining fine products.

The process allowed obtaining preparations with an interesting color (light pink for strawberry, pink for black currant and amaranth for chokeberry).

### 2.2. Chemical analysis

#### 2.2.1. The chemical composition of preparations

The composition of preparations was determined using AOAC methods (Horwitz & Latimer, 2007) by means of the following procedures: AOAC 920.152 for crude protein, AOAC 930.09 for crude fat, AOAC 940.26 for dry matter and ash, AOAC 985.29 for total dietary fiber (TDF), and AOAC 991.42 for insoluble dietary fiber (IDF). Soluble dietary fiber (SDF) was calculated from the difference between TDF and IDF.