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Dietary fibre fractions from fruit and vegetable processing waste

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Abstract

Until recently, dietary fibre and its components were regarded as balast substances from vegetal food. These days, they are given increasing attention because of the beneficial physiological effects they may exert on human and animal organisms. Dietary fibre includes a number of components, and each of them displays specific properties. The components of major importance are cellulose, hemicellulose, lignin and pectins. The objective of this study was to determine the amounts of particular dietary fibre fractions in samples containing apple, black currant, chokeberry, pear, cherry and carrot pomace. The results revealed the following pattern: in each pomace sample, pectins occurred in the smallest amounts, and the content of lignin was very high (black currant and cherry pomace) or comparatively high (pear, chokeberry, apple and carrot pomace). The other dietary fibre components were difficult to form into clearly defined groups. Their proportions varied from one pomace type to another.

Keywords: Fruit and vegetable pomace; Non-starch polysaccharides

1. Introduction

Until the 1980s, the nondigestible components of vegetal foods were regarded as ballast substances (Asp, 1985) but, since then, increasing attention has been given to their beneficial physiological effects on humans and animals. In the natural state, dietary fibre (DF) is a conglomeration of different ingredients. Few of them have yet been chemically defined . Of the physiological definitions proposed for DF, the one developed by Trowell has found the widest acceptance (Trowell, 1974). According to this definition, the term “dietary fibre” is used to denote plant substances (edible parts of plants) that are resistant to hydrolysis by digestive enzymes in humans, and contain membrane components, as well as endocellular polysaccharides. In 1981, over 100 scientists took part in a discussion on the definition of DF and on methods for its quantification. It was agreed that DF in foods should be quantified according to the definition of Trowell. Despite this, in the European Union, and also in many other countries, scientific committees have been working on a suitable definition. The one proposed in 1999 differed from Trowell’s definition only in that a physiological description of how DF acts in the human organism was included (Prosky, 1999).

In chemical terms, the definition of the DF refers mainly to the sum of non-starch polysaccharides and lignin (Cummings, 1991; Asp, 1987, 1996; Englyst & Hudson, 1996). But there are also non-structural components (gums and mucilages), as well as industrial additives (modified cellulose, modified pectin, commercial gums and algal polysaccharides) (Davidson & McDdonald, 1998; Grigelmo-Miguel, Gorinstein, & Martín-Belloso, 1999).

Although these species are not biologically active as, for example, vitamins or mineral components, they noticeably affect the metabolic and physiological processes that occur in human organisms.

DF exerts a buffering effect and binds excess hydrochloric acid in the stomach, increases the fecal bulk and stimulates intestinal peristaltis, as well as provides a favourable environment for the growth of the desired intestinal flora. It is in the digestive tract that the DF components bind a number of substances, including cholesterol and gastric juices (Veldman et al., 1997; Jenkins, Kendall, & Ransom, 1998; Jiménez-Escrig &

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Sánchez-Muniz, 2000). Owing to these specific properties, DF plays an important role in both prevention and treatment of obesity, atherosclerosis, coronary heart diseases, large intestine cancer and diabetes (Schweizer & Würsch, 1986; Topping, 1991; Davidson & McDdonald, 1998; Schneeman, 1998; Terry et al., 2001; Wang, Rosell, & de Barber, 2002; Ferguson & Harris, 2003; Peters et al., 2003; Bingham et al., 2003). Hemicellulose and pectins share a remarkable ability to bind heavy metal compounds, which is promising and gives good hope for the promotion of health via fibre-containing food. Also, cellulose and lignin are able to bind heavy metals (though to a smaller extent than hemicellulose and pectins), and their binding ability varies with the source of origin of relevant fractions (Casterline & Yuoh, 1993; Borycka, Borycki, & Żuchowski, 1996; Davidson & McDdonald, 1998; Nawirska & Oszmiański, 2001; Sangnark & Noomhorm, 2003). With the results of epidemiological investigations, it was possible to relate the incidence of civilization-induced diseases to insufficient DF intake from fruit and vegetables (Burkitt & Trowell, 1975; Cummings, 1978; Grigelmo-Miguel et al., 1999; Grigelmo-Miguel & Martín-Belloso, 1999; Jiménez-Escrig & Sánchez-Muniz, 2000).

DF components are usually grouped into two major classes: water-soluble (pectins, gums) and water-insoluble (cellulose, lignin, some of the hemicellulose) (Thebaudin & Lefebvre, 1997; Grigelmo-Miguel et al., 1999). The sorbing properties of the DF depend on the chemical structure and mass fraction of the components. Thus, hemicellulose and pectins are amongst those with a remarkable ability to bind heavy metals. The sorbing capacity of the preparations was found to be influenced by the DF origin (fractional composition), experimental conditions (pH, temperature), and the type of the metal being investigated (Borycka & Żuchowski, 1998; Nawirska & Oszmiański, 2001).

DF is a combination of many compounds differing in physical and chemical properties. In the organism, DF displays the ability to sorb many harmful substances by reducing their levels (e.g. cholesterol), as well as to bind mineral components and heavy metals (Thebaudin & Lefebvre, 1997; Borycka & Żuchowski, 1998; Sangnark & Noomhorm, 2003).

When used for the filtering of heavy metals, DF from pomace may noticeably upgrade the health-promoting properties of a food (Larrauri, 1999). This holds particularly for the preparations from black currant pomace (Borycka et al., 1996).

Pomace constitutes a major part of the wastes from fresh fruit processing for wine, juice and soft beverage production, and accounts for 25% of the volume of the raw material processed (Fronc & Nawirska, 1994). According to statistics, the annual volume of fruit and vegetables processed by Poland's food industries averages two million tons (Statistical data, 2002).

Published data indicate that approximately 12% of the pomace obtained from fruit processing in Poland is sent to landfills for storage, where the total pomace volume is irreparably lost, although it could have been reused because of its health-promoting components and other valuable ingredients (e.g., carbohydrates, proteins, mineral substances and flavours). Pomace may also become a cheap raw material for food and fodder production (Fronc & Nawirska, 1994). An appropriate management of the wastes from fruit and vegetable processing might considerably reduce the cost of transport and utilization. Another advantage, in economic terms, is the potential reuse of pomace as a raw material for the manufacture of new products, thus making it possible to reduce the troublesome seasonal pattern from which some industries suffer.

The objective of our study was to compare the amounts of particular DF fractions in the wastes from fruit and vegetable processing.

2. Materials and methods

2.1. Samples

The materials to be studied included pomace from apple, cherry, chokeberry, black currant, pear and carrot processing. Apple, cherry and pear pomaces were supplied by the Fruit Processing Plant of Prusice (Poland); black currant and chokeberry pomaces came from the fruit processed at the laboratory of the Department of Fruit, Vegetables and Cereals Technology, Agricultural University of Wroc*error*aw (Poland). The carrot material was obtained from the Fruit and Vegetables Processing Plant Agros-Fortuna, Łowicz (Poland).

2.2. Analysis

The investigations were carried out at the laboratory of the Department of Fruit, Vegetables and Cereals Technology, Agricultural University of Wroc*error*aw. Immediately upon arrival in a wet state at the laboratory, the material was frozen. Prior to physical and chemical determinations, it was defrosted, dried and ground. The samples prepared via the above route were analyzed for contents of dry matter (AOAC), non-starch polysaccharides (NSP) and lignin, using the method developed by Jaswal, as well as by Dever, Bandurski, and Kiviliaan (1968) method, modified by the staff of the Department of Agricultural and Storing Technology, Wroc*error*aw University of Agriculture (Kita, 2002). Non-starch polysaccharides are a group of polysaccharides differing in particle size, composition and physicochemical properties. Polysaccharides were classified according to their solubility in a variety of media. The procedure involved enzymic hydrolysis of the starch, precipitation of NSP in ethanol and acid hydrolysis of the NSP. With this procedure, fractions of pectins, hemicellulose, cellulose and lignin were obtained. It must be noted, though, that the fractions determined in this way may not be very clearly defined.

2.3. Statistical analysis

Each sample was analyzed in triplicate and the figures were then averaged. Data were assessed by analysis of variance. The Duncan multiple range test was used to separate means. Significance was accepted at $\rho \leqslant 0.05$.

3. Results and discussion

As may be inferred from investigations into the two types of pomace, the DF content ranged between 54.2% and 98.8% DM. In our study, dry matter content in the apple pomace averaged 93.23%. DF content accounted for 98.74% and was rich in cellulose; hemicellulose was approximately half the cellulose fraction. The pectin fraction of the DF was the smallest (Table 1). By comparison, in apples the total DF content amounted to 60.1/100 g DM and that of lignin was 12.5/100 g DM (Grigelmo-Miguel & Martín-Belloso, 1999).

The dry matter content in the cherry pomace accounted for 91.37% and was characterized by a high quantity of lignin. The remaining components of the DF determined in the cherry pomace amounted to 13.13/100 g DM, 7.66/100 g DM and only 1.08/100 g DM for cellulose, hemicellulose and pectins, respectively (Fig. 1). The total DF content in the investigated pomace accounted for 71.44%. The amounts of lignin and cellulose accounted for 87% of the DF components determined in the pomace.

The chokeberry pomace had a dry matter content of 90.83%. The DF components, altogether, determined in the pomace, amounted to 95.77%. Cellulose and hemicellulose occurred in the largest amounts. Lignin content was lower and pectin content was much lower than that of cellulose or hemicellulose (Table 1).

The black currant pomace was characterized by a DF content of 90.8%. The DF fractions determined followed a pattern similar to that in the cherry pomace (in descending order): lignins, hemicellulose, cellulose and pectins. The amounts of lignin and hemicellulose accounted for 84% of the DF components determined in the pomace.

In the pear pomace, dry matter content averaged 94%. Compared to the other fruit pomace samples under study, the DF content was the highest, totalling

Table 1
Proportion of DF in pomace

Pomace	Apple	Cherry	Chokeberry	Black currant	Pear	Carrot
Pectins	11.7^{a}	1.51^{a}	7.85^{a}	2.73^{a}	13.4^{a}	3.88^{a}
Hemicellulose	24.4^{c}	10.7^{b}	33.5^{c}	25.3^{c}	18.6^{b}	12.3^{b}
Cellulose	43.6^{d}	18.4^{c}	34.6^{d}	12.0^{b}	34.5^{d}	51.6^{d}
Lignin	20.4^{b}	69.4^{d}	24.1^{b}	59.3^{d}	33.5^{c}	32.2^{c}

Means (of three replications), within a column with different letters are significantly different at $\alpha \leqslant 0.05$.

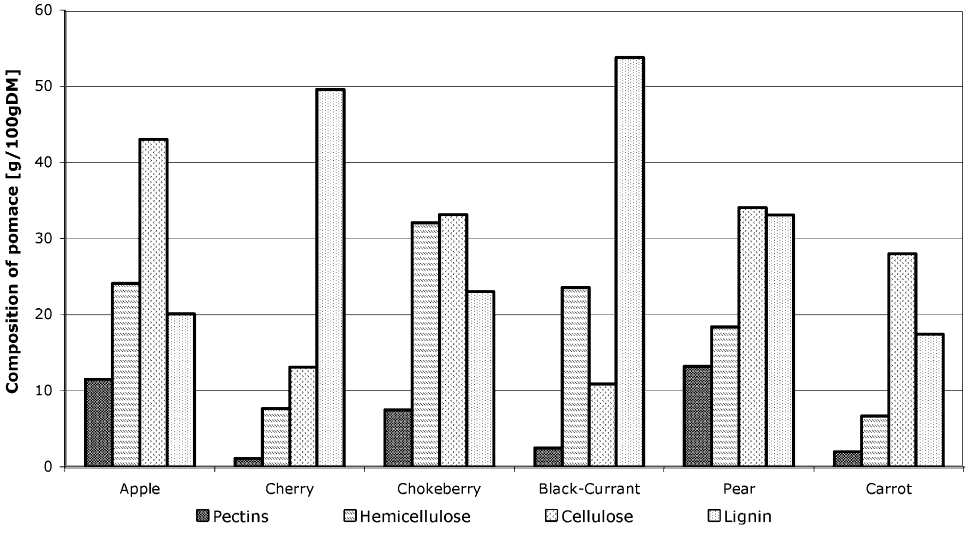

Fig. 1. DF fractions determined in the pomace samples.

as much as 98.8%. In the study reported by Grigelmo-Miguel and Martín-Belloso (1999), the total DF content and that of lignin in pears amounted to 36.1/100 g DM and 8.4/100 g DM, respectively. Of the DF fractions determined in our study, cellulose and lignin occurred in the largest amounts. Hemicellulose was approximately half the amount of cellulose or lignin. Pectins were detected in the lowest amounts. It is noteworthy, however, that in absolute values, the pectin fraction determined in the pear pomace was higher than that of the pectin fractions determined in the other fruit pomace samples under study (Table 1).

Our study also included pomace obtained from vegetables, namely carrots. The pomace generally displayed low contents of the investigated fractions – which means a low amount of the DF (54.2%) – but the dry matter content was very high. Amounting to 95%, it was higher than any of the dry matter values detected in the investigated pomace samples. The amounts of cellulose (28.0/100 g DM) and lignin (17.5/100 g DM) accounted for 51% and 32% of the DF components determined in the pomace, respectively. The quantity of pectins (2.10/100 g DM) was comparable with that detected in the black currant pomace (Fig. 1).

Of the analyzed DF fractions, pectins occurred in the smallest amounts in all of the samples, ranging from 13.2/100 g DM in the pear pomace to 1.08/100 g DM in the cherry pomace (Fig. 1). The pectin fraction was found to be comparatively high (11.8/100 g DM) in the apple pomace, which is known to be pectin-rich and is widely used for pectin recovery.

However, the other fibre components were difficult to form into clearly defined groups; their proportions varied from one pomace type to another. Thus, the highest hemicellulose content was detected in the chokeberry pomace (32.1/100 g DM) (Fig. 1). Small amounts of hemicellulose were detected in the cherry (7.66/100 g DM) and carrot (6.66/100 g DM) pomace.

Cellulose fails to show promising ion-exchange properties and it does not bind bile acids or their salts (Story & Kritchevsky, 1976). Although cellulose fibres are not digested in the alimentary tract, they are able to noticeably support peristaltic motion. The highest cellulose content (43.2/100 g DM) was that in the apple pomace. The cellulose fractions in the pear and chokeberry pomace were comparable (Fig. 1).

The lignin fraction occurred in large amounts in each of the investigated samples, ranging from 73.8/100 g DM in the black currant pomace to 17.5/100 g DM in the carrot pomace. The fractions are able to noticeably support peristaltic motion, like cellulose. The lignin fraction does not show ion-exchange properties and it does not bind heavy-metal ions (Nawirska & Oszmiański, 2001).

4. Conclusions

As demonstrated earlier, both hemicellulose and pectins are best for binding heavy-metal ions. Comparison of the contents of hemicellulose and pectins in the investigated pomace showed that the highest contents of these species were in chokeberry pomace (41%) and the lowest in apple pomace (36%). It can therefore be anticipated that the chokeberry and apple pomaces, which have the highest concentrations of these two species, will be equally good sorbents for heavy metals.

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