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Use of blackcurrant and chokeberry press residue in snack products

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Fruit and vegetable processing by-products, undervalued until recently, are rich sources of nutrients. This study investigated properties of extruded corn puffs with addition (5–20%) of blackcurrant or chokeberry pressings. We assessed expansion rate, water absorption index (WAI) and water solubility index (WSI) of the produced extrudates, the concentration of polyphenols, and antioxidant activity measured by FRAP method and ABTS method. The puffs with addition of chokeberry pressings had higher WSI values, higher phenolic acids, flavonols, and anthocyanins content, and higher antioxidant activity than puffcorn with addition of blackcurrant pressings. The corn puffs with addition of fruit pressings contained much higher concentrations of phenolic compounds and were characterized by much higher antioxidant activity than pure puffcorn. This confirms the usefulness of addition of such fruit processing by-products in order to manufacture functional food.

Keywords: fruit press resid ues, black chokeberry, blackcurrant, extrusion, extruded snacks.

INTRODUCTION

Poland is a leader in fruit growing and fruit processing in the European Union. Simultaneously, Poland ranks first worldwide in both blackcurrant and chokeberry production. About half of the fruit is used to manufacture juices, nectars, and wines. The press residues (pomace) are by-products that are sources of very valuable nutrients. They include large amounts of polyphenols and anthocyanins[1, 2]. Anthocyanin compounds contained in blackcurrants are located mostly in the skin, so they remain in the press residue. Moreover, research has proved that phenolic compounds are much more abundant in the chokeberry pressings than in the juice. According to Oszmański and Wojdyło[3], the mean concentration of phenolic compounds in chokeberry pressings is nearly 3-fold higher than in the juice. Chokeberry pressings also have an about 2.5-fold higher antioxidant activity, as compared to the juice. The press residue contains also other highly valuable nutrients: saccharides, proteins, minerals, pectins, lipids, organic acids, vitamins, aldehydes, alcohols, pigments, aromatic compounds, and fibre[4, 5].

Because of the numerous valuable characteristics of fruit and vegetable press residues, food manufacturers more and more often search for new possibilities of making use of such by-products. Some authors have noted the possibility of using food processing by-products as an addition to snack products[6, 7, 8]. Snack products account for a large proportion of the everyday diet, especially of children and adolescents. Most of the products are results of extrusion. This process enables very easy application of various raw materials and additives. Most often, snack products are made on the basis of cereal flours or starch, which contain small amounts of fibre, vitamins or other biologically active ingredients. Because of the low nutritional value of extruded snacks, many studies have been undertaken to enrich them in more nutritional and functional ingredients. There are many scientific publications on production of extruded snacks with addition of components increasing their nutritional value, e.g. elevating the concentration of phenolic compounds and the antioxidant activity or fibre content[9, 10]. Also blackcurrant press residue has been used to enrich snack product. The mixture of blackcurrant pressing and different flours have been used to obtain extruded snacks[11] as well as breakfast cereals[12]. However, neither of these studies determine the composition of polyphenols and changes of these compounds occurring during the extrusion cooking. Furthermore there is scanty of literature on the application of chokecerry pressing as a component extruded snacks.

That is why in this study we have investigated the possibility of using blackcurrant and chokeberry press residues as sources of phenolic compounds in extruded corn puffs (puffcorn). The content of bioactive compounds and antioxidant activity has been determined depending on proportion of pressing and type of pressing in obtained extrudates. In addition, the expansion rate and functional properties of puffcorn were also characterised.

MATERIAL AND METHODS

Plant materials

In the experiment, we used coarse cornmeal manufactured by Sante A. Kowalski Co. (Warsaw, Poland) and press residues of blackcurrant (*Ribes nigrum*) and black chokeberry (*Aronia melanocarpa*), resulting from juice pressing in the laboratory (Department of Fruit, Vegetable, and Plant Nutraceutical Technology, Wrocław University of Environmental and Life Sciences, Wrocław, Poland). Immediately after the pressing process, the press residue was frozen and stored at –18°C. Next, the press residue was thawed, dried in an air flow drier at 30°C and ground in the FRITSCH Universal Cutting Mill PULVERISETTE 19. The powder was passed through a sieve (mesh size 1 mm) and stored in plastic bags at 4°C. For extrusion, we mixed the coarse cornmeal and ground blackcurrant and chokeberry pressings. The pressings accounted for 5–20% of the mixture.

Extrusion process

Extrusion was conducted in a single-screw laboratory extruder (Brabender 20DN) with 3 heating zones: 120–130–150°C. The screw had a compression ratio of 2:1 and screw speed of 180/s, with feeder speed of 45/s, and a rounded die of 3 mm in diameter. The produced extrudates were kept in an air flow drier at 25°C for 48 h. Some of the extrudates were used for expansion measurements, whereas the remaining part of each sample was ground in a Brabender Rotary Mill to grain size of 1.5 mm, and stored in plastic bags for further analyses.

Expansion rate measurements

The expansion rate was calculated as the ratio of the extrudate diameter to the diameter of the die. The extrudate diameter was measured with a digital caliper to the nearest 0.01 mm, with 15 replications.

Assessment of water absorption index (WAI) and water solubility index (WSI)

In a sample tube, 1 g of the examined sample was placed and overtopped with 10 ml of distilled water. The mixture was shaken in a vortex mixer and next left for 10 min. The procedure was repeated 7 times and next the tubes were moved to a centrifuge (Rotofix 32 a) and rotated at 4000 rpm for 10 min at room temperature (20°C). The supernatant was removed and its dry weight was determined. The gel left in the tube was weighed. WSI was calculated as a ratio of the dry weight of the supernatant to sample weight, expressed as a percentage. WAI was calculated as the weight of the produced gel per unit of sample weight.

Quantification of polyphenols by liquid chromatography–mass spectrometry (LC-MS)

The extraction of obtained extrudates for quantification of their polyphenols was performed as described previously by Wojdyło, Oszmiański, & Bielicki[13]. The samples were analyzed by using an Acquity UPLC system (Waters, Milford, MA) with PDA (photodiode detector (UPLC) with binary solvent manager (Waters Corpora-tion; Milford, USA) series with a mass detector G2 QTof Micro mass spectrometer (Waters; Manchester, UK) equipped with an electrospray ionization (ESI) source operating in negative and positive mode.

An Acquity UPLC BEH C18 column (2.1 x 100 mm, 1.7 μm; Waters Corporation, Milford, USA) was used to perform the chromatographic separation of 5 μl of each sample injected into a gradient system at a flow rate of 0.42 ml/min. The column and sample managers were maintained at 30°C and 10°C, respectively. The mobile phase consisted of 4.5% formic acid in deionized water (A) or acetonitrile (B). Samples were eluted according to a linear gradient: 0−12 min, 1−25% B; 12−12.5 min, 100% B; 12.5−13.5 min, 1% B. Quantification was achieved by injection of solutions of known concentrations ranging from 0.05 to 5 mg/ml ($R^2 \leq 0.9998$) of (-)-epicatechin, (+)-catechin, procyanidin B2, quercetin, and kaempferol 3-*O*-glucoside, -galactoside, and –rutinoside, with cyanidin-3-glucoside, neochlorogenic, and chlorogenic acid as standards. Quercetin and kaempferol derivatives were expressed as quercetin- and kaempferol-3-*O*-glucoside, respectively, and quercetin-3-*O*-rutinoside. Anthocyanins, flavonols, phenolic acids, and flavan-3-ols were monitored at the following wavelengths: 520, 360, 320, and 280 nm. The results were expressed as mg per kg dry matter (dm).

Antioxidant activity assessment by the ABTS assay

Antioxidant activity was assessed by the method involving reduction of the ABTS radical cation, as described by Re et al.[14]. The extract from extruded corn puffs was prepared by soaking about 0.5 g of sample in 10 ml of 80% methanol with addition of acetic acid (1%), and by ultrasonic extraction twice for 15 min during 24 h. Next the samples were centrifuged and analysed. To 3 ml of a properly diluted ABTS reagent, we added 0.03 ml of the sample, and after 6 min the absorbance was measured at a wavelength of 734 nm in the UV–2401 PC spectrophotometer (Shimadzu, Kyoto, Japan). Results of the analysis were expressed as mM Trolox Equivalents (TE) per 100 g of the sample.

Assessment of ferric ion reducing antioxidant power

Ferric ion reducing antioxidant power was assessed by the ferric reducing antioxidant power (FRAP) method. The extract from extruded corn puffs was prepared by soaking about 0.5 g of sample in 10 ml of 80% methanol with addition of acetic acid (1%), and by ultrasonic extraction twice for 15 min during 24 h. To a cuvette with 0.1 ml of the analysed extract, 1 ml of distilled water was added, and next 3 ml of the FRAP reagent. Absorbance of the mixture was measured at a wavelength of 593 nm after 10 min of the initiated reaction in a UV–2401 PC spectrophotometer. Results of the analysis were expressed as mM TE per 100 g of the sample.

Statistical analysis

The collected data were analysed statistically with the use of STATISTICA 12 software.5. One-way analysis of variance (ANOVA) was performed for many factors. Homogenous groups and least significant difference (LSD) values were denoted using Duncan's multiple comparison test at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The expansion rate of the produced extrudates (Fig. 1.) shows that expansion rate decreased with increasing proportion of the pressings in the produced extrudates. The lowering of the expansion rate with increasing proportion of pressings in the extrudates was probably associated with the rising fibre content, which is high in the pressings[15]. Similarly, Yanniotis, Petrarki & Soumpasi[16] noted that the expansion rate of puffcorn declined with growing fibre content. Dietary fibre causes early breaking of air bubbles, which obviously lowers the expansion rate of extrudates. Moreover, the expansion rate depends on the degree of starch gelatinization, which takes place in the presence of water, while non-starch polysaccharides (contained in the dietary fibre) are capable of hydration. Consequently, during extrusion of ingredients containing starch and fibre, they can compete for access to water and hence the process of starch gelatinization can be limited[17]. Also the monosaccharides present in the press residues (mostly glucose, fructose, and sucrose) may have a negative effect on the expansion rate of extrudates, as they are characterized by high acidity, which can additionally cause starch degradation. This may lead to a decline in viscosity of the mixture in the extruder, which in turn decreases the forces and pressure, which are insufficient for adequate expansion of the product[18].

Blackcurrant pressings contain more sugars in comparison to chokeberry pressings[19]. This property had probably an influence on the level of expansion of crisps depending on kind of added pressings – samples containing chokeburry pressings were marked by a higher level of expansion in comparison to samples containing blackcurrant pressings what could influence on differences between the level of expansion of crisps with addition of blackcurrant or chokeberry pressings.

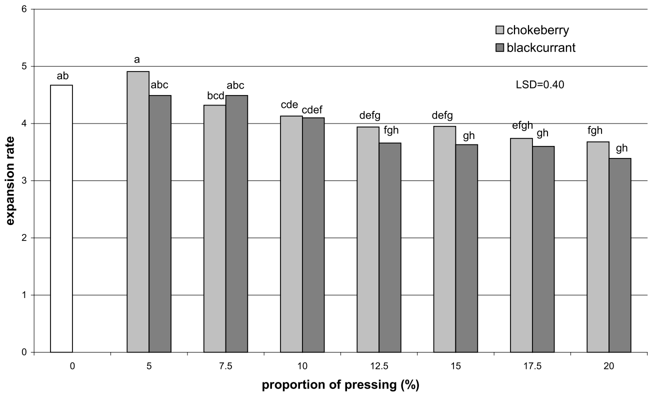

Figure 1. Effect of the type of berry pressings and the proportion of pressings in the sample on the expansion rate of extrudates (LSD- least significant difference)

Water absorption index (WAI) and water solubility index (WSI) are parameters describing the functional properties of extruded products. WAI reflects the amount of water absorbed by starch and can be used as a measure of starch gelatinization. WAI of the control equalled 6.5 g/g, while in puffs with berry pressings it varied from 6.4 to 4.6 g/g, and declined with increasing proportion of pressings in the puffs (Fig. 2). We observed only slight differences between samples with addition of chokeberry pressings and samples with addition of blackcurrant pressings. WSI of puffcorn declined with increasing proportion of pressings in the puffs (Fig. 3). WSI is a measure of soluble components resulting from extrusion and is often used as a parameter of starch degradation. As a result of the addition of berry pressings, and thus large amounts of fibre, the starch content of the product declines. Research has shown that during extrusion, the soluble fibre content increases[20, 21]. A decrease in WSI can be due to the rising proportion of this component, as it tends to form bonds with starch chains and to limit starch dextrinization, influencing the solubility of extrudates[22]. A decline in WSI with increasing fibre content was also observed by authors studying the properties of extrudates with brewers spent grain addition[23], pineapple pomace[24], and carrot pomace[25]. Samples with addition of chokeberry pressings had higher WSI values than samples with addition of blackcurrant pressings. This difference could be caused by a various composition of fibre fractions in these two plants. The lover solubility of puffs with blackcurrant pressings addition could be influenced by higher content of insoluble fibre including insoluble lignins whose blackcurrant pressings contain three times more than chokberry pressings[19].

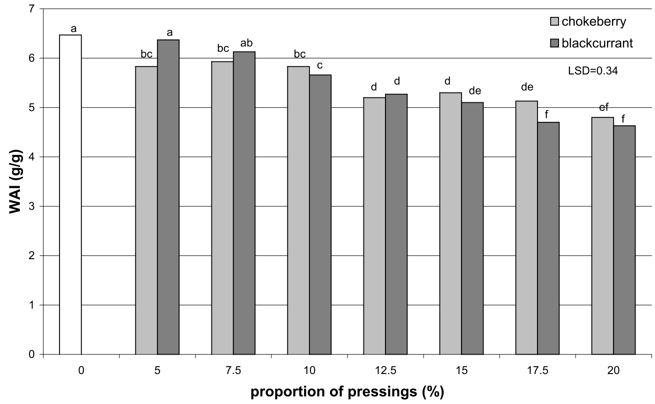

Figure 2. Effect of the type of berry pressings and the proportion of pressings in the sample on the water absorption index (WAI) of extrudates (LSD- least significant difference)

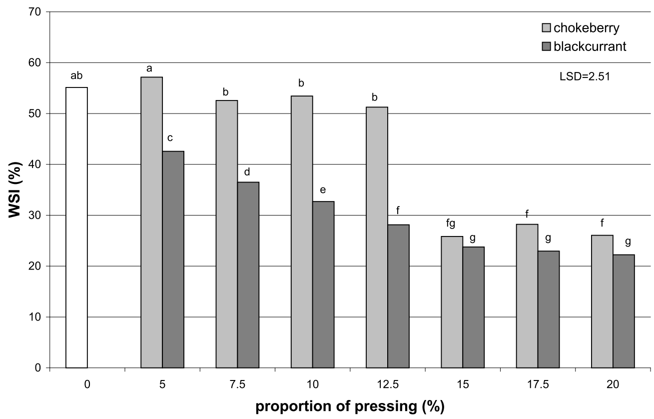

Figure 3. Effect of the type of berry pressings and the proportion of pressings in the sample on the water solubility index (WSI) of extrudates (LSD- least significant difference)

The total polyphenol content of the control sample and of extrudates with addition of berry pressings (Tab. 1) indicate that the introduction of by-products to corn puffs increased the concentration of polyphenolic compounds from the initial value of 4.15 mg/kg (control sample) to 351.46 mg/kg and 739.69 mg/kg in the puffs with the highest addition of blackcurrant and chokeberry pressings respectively. This means that the total polyphenols content of corn puffs with the addition of pressings was 85-fold to 178-fold higher than in the control. The content of total polyphenols in all as well as particular compounds coming in the composition of total polyphenols in extrudates has increased with the increasing proportion of pressings. During extrusion, however, losses of total polyphenol content can be noticed in comparison with the amount introduced with the pressings, depending on the proportion and on type of added pressings. Many phenolic compounds are easily hydrolysed and oxidized. High temperature facilitates the oxidation of polyphenols, which results in lowering of their efficiency and antioxidant activity[26]. In extrudates with chokeberry pressing, in the case of the samples with 5% to 12.5% of pressing, destruction of polyphenols compounds was

		neochlorogenic acid	chlorogenic acid	3-caffeoylglucoside acid	derivative of p-coumaroyl-quinic acid	quercetin -3-O-glucoside	other quercetin derivatives	myricetin-3-O-galactoside	delphinidin-3-O-rutinoside	cyanidin -3-O-glucoside	cyanidin -3-O-rutinoside	petunidin-3-O-rutinoside	delphinidin-3-O-(6''-p-coumaroyl)-glucoside	cyanidin-3 -O- (6''-p-coumaroyl)-glucoside	quercetin -3-O-rutinoside	quercetin -3-O-galactoside	quercetin -3-O-arabinoside	cyanidin-3-O-galactoside	cyanidin -3-O-arabinoside	cyanidin -3-O-xyloside	total polyphenolic compounds
corn grits		16.64	27.26	nd	nd	2.43	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	46,33
chokeberry pressing		596.28	654.77	102.47	nd	nd	152.21	nd	nd	135.20	nd	nd	nd	nd	150.21	176.20	387.82	2357.31	973.46	136.39	5822.31
blackcurrant pressing		30.12	0.00	126.00	65.59	3.46	174.55	218.46	498.08	195.60	1358.73	969.88	3.54	10.91	nd	nd	nd	nd	nd	nd	3654.92
control sample*		2.89	0.58	nd	nd	0,69	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	4.15
proportion of pressing in extrudates (%)																					
chokeberry	5	17.92^{b}	19.15^{a}	nd	nd	4.97^{b}	6.62^{b}	nd	nd	1.07^{a}	nd	nd	nd	nd	6.11^{a}	7.87^{a}	18.31^{a}	21.20^{a}	5.73^{a}	0.53^{a}	109.47^{b}
	7.5	27.56^{g}	30.30^{e}	nd	nd	7.24^{d}	9.20^{d}	nd	nd	0.86^{a}	nd	nd	nd	nd	8.86^{b}	11.59^{b}	24.73^{b}	15.22^{b}	3.30^{b}	0.30^{b}	139.15^{c}
	10	35.47^{h}	45.06^{f}	nd	nd	9.95^{g}	13.10^{g}	nd	nd	0.85^{a}	nd	nd	nd	nd	11.89^{c}	16.21^{c}	35.00^{c}	12.20^{c}	2.52^{b}	0.20^{b}	182.44^{d}
	12.5	42.85^{i}	54.62^{g}	nd	nd	12.04^{h}	15.64^{h}	nd	nd	0.90^{a}	nd	nd	nd	nd	13.71^{d}	19.07^{d}	40.73^{d}	15.68^{b}	3.36^{b}	0.31^{b}	218.91^{e}
	15	60.65^{j}	59.07^{h}	nd	nd	14.30^{k}	19.11^{k}	nd	nd	8.75^{d}	nd	nd	nd	nd	16.37^{e}	22.27^{e}	49.81^{e}	182.59^{d}	60.87^{c}	6.83^{c}	500.62^{i}
	17.5	87.88^{k}	87.39^{i}	nd	nd	21.28^{m}	27.69^{m}	nd	nd	11.12^{e}	nd	nd	nd	nd	24.28^{f}	32.89^{f}	73.85^{f}	244.45^{e}	79.08^{d}	8.93^{d}	698.80^{j}
	20	90.47^{l}	89.23^{j}	nd	nd	22.43^{n}	28.83^{n}	nd	nd	12.68^{f}	nd	nd	nd	nd	25.53^{g}	34.63^{g}	76.53^{g}	264.41^{f}	85.05^{e}	9.88^{e}	739.69^{k}
blackcurrant	5	19.34^{de}	23.92^{cd}	1.15^{a}	5.85^{a}	3.03^{a}	4.65^{a}	4.27^{a}	4.85^{a}	1.96^{a}	15.92^{a}	10.80^{a}	0.26^{a}	0.11^{a}	nd	nd	nd	nd	nd	nd	96.10^{a}
	7.5	18.92^{cd}	22.89^{bc}	2.39^{b}	5.77^{a}	5.91^{c}	7.69^{c}	8.55^{b}	11.00^{b}	4.14^{b}	30.95^{b}	22.18^{b}	0.58^{b}	0.37^{b}	nd	nd	nd	nd	nd	nd	141.35^{c}
	10	19.01^{cd}	22.86^{b}	3.13^{c}	5.75^{a}	7.99^{e}	9.78^{e}	10.41^{c}	15.98^{c}	6.24^{c}	44.46^{c}	32.18^{c}	0.73^{c}	0.55^{c}	nd	nd	nd	nd	nd	nd	179.07^{d}
	12.5	17.26^{a}	22.64^{b}	3.89^{d}	5.28^{b}	9.05^{f}	12.24^{f}	14.23^{d}	22.38^{d}	8.44^{d}	59.49^{d}	42.72^{d}	0.95^{d}	0.62^{d}	nd	nd	nd	nd	nd	nd	219.18^{e}
	15	19.85^{ef}	24.89^{d}	5.44^{e}	5.56^{c}	12.45^{i}	16.42^{i}	18.43^{e}	31.47^{e}	11.83^{e}	81.41^{e}	59.36^{e}	1.19^{e}	0.97^{e}	nd	nd	nd	nd	nd	nd	289.28^{f}
	17.5	20.08^{f}	23.12^{bc}	6.18^{f}	5.30^{b}	13.73^{j}	18.04^{j}	19.87^{f}	37.33^{f}	13.94^{f}	96.26^{f}	69.13^{f}	1.45^{f}	0.95^{e}	nd	nd	nd	nd	nd	nd	325.38^{g}
	20	18.29^{bc}	22.72^{b}	6.61^{g}	4.72^{d}	14.70^{l}	19.51^{l}	22.45^{g}	40.80^{g}	15.48^{g}	106.31^{g}	77.09^{g}	1.60^{g}	1.07^{f}	nd	nd	nd	nd	nd	nd	351.46^{h}

*extrudat was made from corn grits only (without pressing)

Table 1. Content of phenolic compounds (mg/kg dm) in corn grits, pressing and extrudates (values followed by the same letter, within the same column, were not significantly different ($p \leq 0.05$))

higher (loss of approximately 70%) than in the samples with 15% to 20% of pressing (loss of 31%–43%). The conternt of total polyphenols in extrudates containing blackcurrant pressing totalled about 50% for all samples independing on proportion of pressing. Research shows, that samples with 7.5–12.5% of pressing addition did not vary statistically between themselves in terms of total polyphenols content. Extrudates with chokeberry pressing in amount 15–20% proved significantly higher content of total polyphenols in comparison to extrudates with blackcurrant pressing addition. This phenomenon was influenced by the type and amount of compounds entering in the composition of total polyphenols in two different type of pressings used in the experiment. Total phenolics content was determined as the sum of phenolic acids, flavonols, and anthocyanins. The content of phenolic acids in chokeberry press residue totalled 1251,05 mg/kg (neochlorogenic acid and chlorogenic acid) which reached 21,5% of total phenolic, whereas blackcurrant press residue contained only 99,17 mg/kg phenolic acids (neochlorogenic acid and derivative of p--coumaroyl-quinic acid), 2,7% of total phenolics. During the extrusion cooking we could notice a decrease of the content of phenolic acids in samples with chokeberry pressing from 30% to 50% depending on the proportion of pressing.

Although blackcurarat pressingdid not contain chlorogenic acid we can observe its presence in extrudates with this pressing addition. This compound as well as neochlorogenic acid and derivative of p-coumaroyl-quinic acid, was identified in corn grits used for obtained puffs,hence probably presence of this compound in samples with blackcurant pressing. The amount of neochlorogenic acid and chlorogenic acid in puff with blackcurrant pressing was at the same level independently of the proportion of pressing in extrudates and represented 90–100% of the amount of these compounds incorporated into samples with pressing and corn grits. Phenolic acids are the most common phenolic compounds in cereals. H. Ti et al. investigated the increase in chlorogenic acid content in extruded black rice bran[27]. Zeng et al. determined a higher content of phenolic acids in extruded brown rice flour than in unprocessed flour[28]. The modest amount of phenolic acids has been marked in the control sample, however their content in samples with pressing was significantly higher. It was probably caused by the presence of sugars in pressing. It was reported that reducing sugars might protect phenolics acid during extrusion[29, 30, 31].

Chekeberry press residue and blackcurrant press residue varied in content and composition of flavonols, except quercetin -3-O-glucoside and quercetin derivatives, whose presence has been recognized in both type of pressing. In addition, except these flavons, in chokeberry pressing 3 quercetin: -3-O-rutinoside, quercetin -3-O-galactoside and quercetin -3-O-arabinoside has been identified. The amount of flavons present in chokeberry pressing totalled 16.6% of total phenolics, and they were the least compounds in total phenolics content. However there were observed the smallest loss of this compounds in samples with chokeberry pressing addition (less than 20%). The main compounds of total phenolics in pressing constitued anthocyanins (61.9% for chokeberry press residue, and 83.0% for blackcurrant press residue). Cyanidin-3-O-glucoside was found in both type of pressing. Moreover the anthocyanins of chekeberry press residue consisted of -3-O-galactoside, -3-O-arabinoside, -3-O-glucoside, -3-O-xyloside of cyanidin. Similarly Jakobek at al have detected the same anthocyanins characterizing three chokeberry cultivars and wild chokeberries[32]. In chokeberry pressing using in this work two of identified anthocyanins: cyanidin--3-O-galactoside and cyanidin-3-O-arabinoside accounted for more than half (57.2%) of total phenolics. Hirth et al. have investigated stability of cyanidin-3-O-galactoside and cyanidin-3-O-arabinoside during extrusion of native maize starch with chokeberry extract addition[33]. They reported that both anthocyanins were diminished between 42–90% depending on extrusion conditions. In this study we observed loss of anthocyanins about 90% in samples with 5–12.5% chokeberry pressing and 45–75% in case of sample with 15–20% of chokeberry pressing.

The anthocyanins found in blackcurrant press residue were delphinidin-3-O-rutinoside, cyanidin -3-O-rutinoside, cyanidin -3-O-glucoside, petunidin-3-O-rutinoside, delphinidin-3-O-(6''-p-coumaroyl)-glucoside, cyanidin-3 -O- (6''-p-coumaroyl)-glucoside, and they were the main compounds in total phenolics content. Three of them (delphinidin-3-O-rutinoside, cyanidin -3-O-rutinoside, cyanidin -3-O-glucoside) were indicated by others in seedless blackcurrant pomace[34] and fresh fruit of blackcurrant[35, 36]. Extrusion cooking caused losses in all anthocyanins of about 60–80% in puffs with blackcurrant pressing excluding delphinidin-3-O-(6''-p-coumaroyl)--glucoside its amount has decreased. These observations

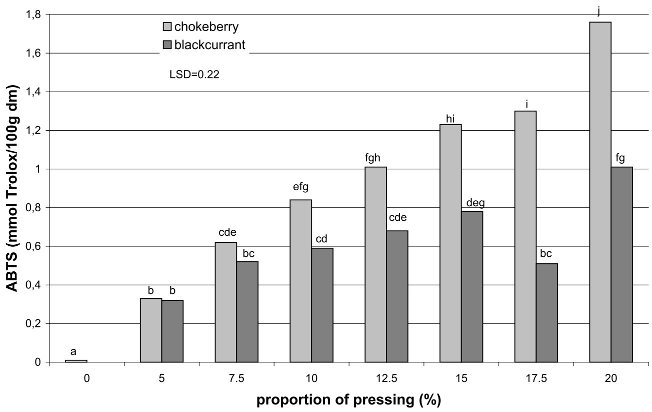

Figure 4. Effect of the type of berry pressings and the proportion of pressings in the sample on ABTS of extrudates (LSD- least significant difference)

prove that conditions (high temperature, high pleasure, shear force) had a destructive effect on anthocyanins.

The antioxidant activity of extrudates with addition of blackcurrant and chokeberry pressings and without the addition was measured as the ability to inactivate the ABTS radical cation and as ferric reducing antioxidant power (FRAP). The higher the proportion of pressings in the puffs, the higher the antioxidant activity of the analysed samples (Fig. 4, Fig. 5). The antioxidant activity in the ABTS test of corn puffs with the highest proportion of berry pressings was over 175-fold higher for sample with chokeberry pressing than that of puffs

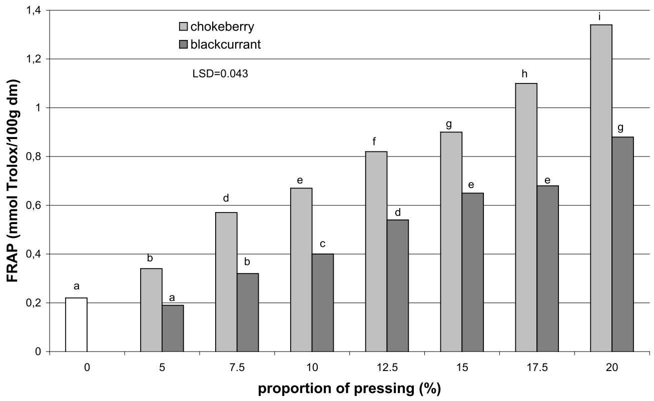

Figure 5. Effect of the type of berry pressings and the proportion of pressings in the sample on FRAP of extrudates (LSD- least significant difference)

without the addition of pressings and over 100-fold higher for sample with blackcurrant pressing. A similar relationship was observed in case of FRAP test. Puffs with 20% of chokeberry or blackcurrant pressing had over 6-fold higher over 4-fold higher respectively, than puffs without press residue. The type of berry pressings significantly affected the antioxidant activity of the analysed samples: the activity was higher in corn puffs with the addition of chokeberry pressings. This is due to the antioxidant activity of the pressings themselves, which in the case of chokeberry pressings reached 8.27 (ABTS) and 5.72 (FRAP) mmol TE/100g of the product, compared to 4.15 mmol TE/100g and 3.31 mmol TE/100g in blackcurrant pressings, respectively. Chokeberry is known as the plant having the highest antioxidant activity and it is superior over blueberries, cranberries, black and red currants, raspberries, elderberries and strawberries[37] Similarly, Zheng and Wang observed that chokeberry has a significantly higher polyphenol content and antioxidant activity as compared to other berries, such as blackcurrants, redcurrants, blueberries, cranberries, raspberries, elderberries, and strawberries[38].

CONCLUSIONS

Corn puffs with addition of berry pressings were characterized by lower expansion rate, lower water absorption and solubility indices, but higher polyphenols compounds content and higher antioxidant activity, as compared to pure corn puffs. The changes were enhanced by increasing proportion of pressings in the puffs. The puffs with the addition of chokeberry pressings had higher WSI values as well as higher polyphenols compound content and higher antioxidant activity than puffcorn with addition of blackcurrant pressings. Extruded snacks with addition of fruit pressings can be a new kind of functional food thanks to the high concentration of phenolic compounds, which have a positive influence on human health.

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