Acta Sci. Pol. Technol. Aliment. 18(4) 2019, 463–471
www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2019.0686

ORIGINAL PAPER

Received: 14.07.2019
Accepted: 18.10.2019

QUALITY ASSESSMENT OF EXPERIMENTAL COOKIES ENRICHED WITH FREEZE-DRIED BLACK CHOKEBERRY

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ABSTRACT

Background. The present work was designed to evaluate the influence of incorporating freeze-dried black chokeberry powder on the chemical composition, antioxidant activity and sensory properties of cookies.

Material and methods. The content of fat, water, total ash, protein and directly reducing sugars, total phenolic content (TPC), DPPH radical scavenging activity, and reducing power (FRAP) was determined in cookies containing a 5, 10 and 15% freeze-dried black chokeberry and control sample. Enriched cookies were prepared by replacing the dough with freeze-dried black chokeberry powder on a weight basis. The samples were subjected to Qualitative Descriptive Analysis and consumer hedonic test.

Results. The incorporation a growing amount of black chokeberry resulted in an increase in the water, total ash and directly reducing sugar content and to a decrease in the fat content of the cookies. TPC increased from 14.1 mg GAE per 100 g control sample to 481.1 mg GAE per 100 g cookies with 15% black chokeberry. The multiple increment in DPPH radical scavenging activity and reducing power FRAP was observed in cookies with the additive in comparison to the control sample, which was due to the high antioxidant capacity of black chokeberry. The addition of black chokeberry influenced the sensory profile of cookies, resulting in their darkening, in turn strengthening the intensity of sour taste, chokeberry flavour and astringency and at the same time decreasing the intensity of sweet aroma, sweet taste and crumbliness of the cookies. The sample with 10% of black chokeberry showed a balanced sensory profile with high consumer liking.

Conclusion. The consumer acceptance and high antioxidant activity of experimental cookies suggest that freeze-dried black chokeberry could be considered as a nutritive additive to cookies and other bakery products.

Keywords: black chokeberry, freeze-drying, antioxidant activity, sensory quality, consumer acceptance, cookies

INTRODUCTION

In the last few years, the significant growth of consumers' interest in healthy lifestyles and the quality of everyday diets has been widely observed. As food manufactures search for products that combine high nutritional and dietary values with the desired sensory properties, attempts are often made to enrich well-known and highly liked food products. Aronia, also known as chokeberry, has strong health-promoting properties. Chokeberry is extensively cultivated in Poland (Wilczyński et al., 2017). Black chokeberry (*Aronia melanocarpa* [Michx.] Elliot) is the most widespread and popular species among chokeberries

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(Kulling and Rawel, 2008). Aronia fruits are a rich source of micro-, macroelements and vitamins, including vitamin C (Andrzejewska et al., 2015). Furthermore, chokeberries have been proved to be one of the richest sources of many anthocyanins, flavonoids, phenolic acids and quercetins (Kulling and Rawel, 2008; Lee et al., 2014). Antioxidant compounds present in chokeberries play an important role in supporting the proper function of the cardiovascular system and in preventing civilization diseases (Lin et al., 2016). Fresh chokeberry fruits have a characteristic tart and bitter taste, because of their high of tannin and polyphenol content (Białek et al., 2012). Due to their astringency, they are not consumed raw as often as other berries, but are rather used for juices, wines and tea production. Because of the high water content and possible microbiological changes of chokeberry fruits, drying must be done to preserve valuable material. Even though freeze-drying is a high-cost and energy-consuming process, it was proved by Thi and Hwang (2016) to be the optimal method for maintaining high levels of bioactive compounds in chokeberries.

The application of freeze-dried chokeberries to various food products seems to fit into current trends concerning consumers' willingness to have a healthy diet. In this study, cookies were selected as a model food, as no attempt to enrich cookies with freeze--dried black chokeberry had been made previously. The results of various studies showed significant potential in increasing both the physical and nutritional values of confectionary products through the addition of functional ingredients (Davidov-Pardo et al., 2012; Hossain et al., 2017). On the other hand, concerns about lower sensory quality may arise. The study of Tańska et al. (2016) showed that cookies with the addition of fruit pomaces exhibited acceptable sensory properties parallel to increased content of dietary fibre and higher antioxidant potential. Nevertheless, the amount of the additive incorporated might be a limiting factor (Ajila et al., 2008; Mildner-Szkudlarz et al., 2013).

The aim of the study was to evaluate the impact of adding freeze-dried black chokeberry on the chemical composition and antioxidant properties of cookies and to assess the changes in sensory quality, depending on the amount of this additive.

MATERIAL AND METHODS

Plant material

Plant material consisting of fresh and undamaged black chokeberry fruits was purchased in retail. The chokeberries were washed by hand, dried and then frozen at –18°C in a refrigerator until lyophilization. These frozen fruits were then freeze-dried in two stages: freezing (at –45°C) and drying (from 12°C to 48°C). The entire freeze-drying process lasted 4 days. The dry matter of freeze-dried chokeberries was 22.7%. Afterwards, the freeze-dried material was ground.

Reagents

The Folin-Ciocalteu reagent, 3,4,5-trihydroxybenzoic acid (Gallic acid, GAE), Iron(III) chloride hexahydrate, 2,2-diphenyl-1-picrylhydrazyl (DPPH), and 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) were purchased from Sigma-Aldrich (USA). 2,4,6-tri(2-pirydyl)-stiazine (TPTZ) was purchased from Fluka (Germany) and all other chemical analytical reagents were acquired from POCH (Gliwice, Poland).

Preparation of cookies

The dough was prepared according to an original recipe based on the ingredients weight percentages as follows: wheat flour (40%), margarine (27%), cream pudding powder (13%), powdered sugar (13%) and raw egg yolks (7%). After preparing the dough, 5%, 10% and 15% of its weight was replaced with the same amount of freeze-dried black chokeberry powder (BC). BC-enriched cookies and cookies without BC (control sample) were baked in a preheated oven for 10 minutes at 180°C.

Analysis of chemical composition

Baked and cooled cookies were analysed to determine their fat, water, total ash, protein and directly reducing sugar content. All results were reported as g per 100 g of the cookies (g/100 g). Fat content was determined on a solvent extractor SER 148/3 (VELP Scientifica) based on the Randall technique (Guidotti et al., 2013). The water content in the cookies was evaluated by thermal drying, in accordance with BN-80/8133-03. Total ash content was measured in a muffle furnace at 580°C according to PN-59/A-88022. The protein content in the cookies was determined by the Kjeldahl method, according to Jung et al.'s method (2003). The directly reducing sugar content in the cookies was assessed by the Lane-Eynon method (Chandraju et al., 2014).

Sample preparation for analysis of antioxidant properties

In order to determine the antioxidant properties of cookies, ethanolic extracts from defatted cookies were prepared. 2 g of each ground and defatted sample was extracted three times with 30 mL ethanol (80%, v/v). Each extraction was performed in a water bath at 60°C for 1 h with hand shaking for 2 min every 20 min. The solvent from the combined extract was evaporated under reduced pressure using a rotary vacuum-evaporator at 40°C. The concentrated extracts were placed in 25 mL volumetric flasks, filled with 80% ethanol and then stored at –20°C until analysis. Two extracts were prepared from each sample. The same procedure was applied to extracts from freeze-dried black chokeberry. The extracts were diluted before further analysis.

Analysis of antioxidant properties

Total phenolic content (TPC) was determined by the Folin-Ciocalteu spectrophotometric method (Singleton and Rossi, 1965), with modifications described in the study by Sielicka and Małecka (2017). A standard curve was prepared using various gallic acid (GAE) concentrations. The results were reported as milligram of GAE per 100 g of cookie (mg GAE/100 g).

The reducing power of cookies was measured by the spectrophotometric FRAP method originally developed by Benzie and Strain (1996) with a modification consisting of 8-minute incubation of the reaction mixture at room temperature. Trolox was used as a standard and the results were expressed in mmol of Trolox per 100 g of the sample (mmol Trolox/100 g).

Assessment of DPPH radical scavenging activity of extracts was based on Sánchez-Moreno et al.'s method (1998) with a slight modification using 2,2-diphenyl-1-picrylhydrazyl dissolved in 96% ethanol at a concentration of 2.5 mg/100 mL. The decrease in absorbance was measured at 515 nm for 10 min with 30-second intervals and 96% ethanol was used as a blank. The reduction in DPPH radicals after 10 min of incubating the sample was calculated as the percentage inhibited.

Sensory panel evaluation

The sensory panel members (11 women) were recruited based on their ability to discriminate between samples during the sensory acuity screening. Qualitative Descriptive Analysis (QDA) was used as a suitable method (Stone and Sidel, 2004). Ten sensory attributes were selected and defined: colour, colour on cutaway, sweet aroma, creamy aroma, earthy aroma (aroma similar to dry soil), sweet taste, sour taste, chokeberry flavour, astringency and crumbliness. Moreover, the overall quality of each cookie was assessed. 10-centimeter structured line scales with labelled ends ("very light" – "very dark" or "not detectable" – "strongly detectable") were applied. To facilitate the assessment, the control sample was presented to the assessors at the beginning of each evaluation session. It was agreed that colour and colour on cutaway of the control cookie was 0 (= "very light"), earthen aroma, sour taste, chokeberry flavour and astringency was 0 (= "not detectable") and sweet and creamy aroma, sweet taste, crumbliness was 10 (= "strongly detectable").

Consumer hedonic test

A consumer sensory testing was carried out on 104 people (81 women and 23 men) aged 18 to 35. The degree of liking the cookies' colour, colour on cutaway, aroma, crumbliness, taste and overall acceptance was assessed on a 9-point hedonic scale, ranging from 1 = "extremely dislike" to 9 = "extremely like" (Peryam and Girardot, 1952). Each consumer received 3 samples with a different BC additive amount and a control sample, which was not evaluated.

Statistical analysis

The data obtained were analysed using Statistica 12.0 PL software (StatSoft, Poland) and XL Stat software connected to Microsoft Excel. Analysis of variance (ANOVA) with Tukey's test as post hoc ($p < 0.05$) was conducted to assess the significant differences between the mean values for all tests. The Pearson's correlation coefficient was calculated to measure the strength of the linear associations between the results from antioxidant assays. Principal Component Analysis was employed to display the pattern of similarity of observations and variables as points on maps based on the results given by sensory panel members. A significance level of 0.05 was used.

RESULTS AND DISCUSSION

Impact of black chokeberry addition on chemical composition of cookies

The addition of freeze-dried black chokeberry to cookies resulted in a significant change in the chemical composition (Table 1), except for the protein content, which insignificantly amounted to 6.3 and 6.4 g/100 g of cookies. The highest fat content was determined in the control sample (20.5 g/100 g cookie), while the lowest was in the 15% BC sample (16.6 g/100 g cookie). The fat content in the 5% and 10% BC samples was on a moderate level (from 19.0 to 19.1 g/100 g cookie). A decrease in the amount of fat in the cookies with an increased additive percentage might result from the low fat content measured by the authors in freeze-dried chokeberry powder – 3.2 g/100 g fruits (data not published). The water content ranged from 4.7 to 5.8 g/100 g cookie, with the lowest value obtained for the 5% BC sample, and the highest for the 15% BC sample. Higher amounts of freeze-dried chokeberry powder could retain some amounts of water in food products. Total ash content was highest in the cookie with 15% black chokeberry. The results concerning fat, water and ash content are in accordance with those found by Varastegani et al. (2015), who reported that greater addition of papaya pulp flour resulted in increased water and ash content in cookies and a decreased amount of fat.

Directly reducing sugars were not found in the control sample. Adding BC significantly influenced the content of directly reducing sugars, which gradually increased with the growing amount of BC added. The reason for such a significant increase is a high content of reducing sugars in black chokeberry itself which, according to the research by Białek et al. (2012), ranged from 13.0 to 17.6 g/100 g fresh matter.

Impact of black chokeberry addition on the antioxidant properties of cookies

Total phenolic content (TPC) and antioxidant activity of the cookies was influenced by adding black chokeberry as presented in Table 2. TPC was significantly different ($p < 0.05$) and increased proportionally when BC increased in formulation. The cookie with 5% BC contained 176.1 mg GAE per 100 g of cookie, while the sample with 10% BC had 335.7 mg GAE/100 g cookie. The highest amount of extractable phenolics were exhibited by the cookie with 15% BC – 481.1 mg GAE/100 g cookie. The control sample showed the lowest amount of extractable phenolic compounds. Higher content of TPC in cookies enriched with black chokeberry than in the control sample results from the high polyphenol content in freeze-dried black chokeberry (6473.3 mg GAE/100 g DW). In other authors' studies, the TPC of black chokeberry powders was lower and ranged from 2494.4 to 3009.0 mg GAE/100 g DW (Szopa et al., 2017) for various samples and 4951.0 mg GAE/100 g DW for commercial black chokeberry fruit powder (Tolić et al., 2015).

The impact of fruit additive on the TPC of bakery products was also evident in other authors' studies. The addition of powdered papaya (15%) to cookies increased the total phenolic content from 0.01 to

Table 1. Chemical composition of cookies with freeze-dried black chokeberry powder and control sample, g/100 g

Sample	Fat	Water	Total ash	Protein	Directly reducing sugars
CS	20.5 ±0.1[a]	5.2 ±0.0[b]	0.8 ±0.0[c]	6.4 ±0.1[a]	n.d.
5% BC	19.1 ±0.0[b]	4.7 ±0.0[c]	0.7 ±0.0[d]	6.3 ±0.1[a]	7.8 ±0.1[c]
10% BC	19.0 ±0.1[b]	5.2 ±0.1[b]	1.0 ±0.0[b]	6.3 ±0.1[a]	8.6 ±0.0[b]
15% BC	16.6 ±0.0[c]	5.8 ±0.0[a]	1.2 ±0.0[a]	6.4 ±0.1[a]	10.3 ±0.4[a]

CS – control sample, BC – freeze-dried black chokeberry powder, n.d. – not detected.
Values are reported as mean ±standard deviation, $n = 6$. Different letters in the same column indicate significant difference ($p < 0.05$).

Table 2. Total phenolic content (TPC) and antioxidant activity of cookies and freeze-dried black chokeberry powder

Sample	TPC mg GAE/100 g sample	FRAP mmol Tr/100 g sample	DPPH % inhibited
	per 100 g of cookies		
CS	14.1 ±1.6[d]	0.1 ±0.0[d]	5.0 ±1.3[d]
5% BC	176.1 ±13.0[c]	0.8 ±0.0[c]	51.3 ±2.0[c]
10% BC	335.7 ±11.8[b]	1.5 ±0.1[b]	68.5 ±0.1[b]
15% BC	481.1 ±12.7[a]	2.5 ±0.1[a]	85.9 ±0.3[a]

Values are reported as mean ±standard deviation, $n = 6$. Different letters in the same column indicate significant difference ($p < 0.05$).

0.6 mg/g in comparison to the cookie without this additive (Varastegani et al., 2015). Similarly, the results of the experiment conducted by Bhaduri and Navder (2014) showed an increase in the total phenolic content of cookies fortified with freeze dried blueberry powder by 41 to 49% (depending on flour applied) in comparison to the control sample.

The FRAP assay (Table 2) revealed the highest value for the cookie with 15% additive, which equalled 2.5 mmol Trolox/100 g of cookies and was the lowest for the control sample (0.1 mmol Trolox/100 g of cookies). The cookie with 10% freeze-dried chokeberry showed a two-fold higher reducing power than the cookie with 5% additive. The FRAP assay amounted to 34.5 mmol Trolox/100 g DW for BC, which was slightly higher than value obtained by Samoticha et al. (2016) – 26.3 mmol Trolox/100 g DW, who also proved that freeze-drying allows the closest TPC and antioxidant activity values to be achieved comparing to fresh fruit values.

The study showed that the amount of black chokeberry powder added significantly affected DPPH radical scavenging activity (Table 2). The highest antiradical potential was demonstrated by the cookie with 15% additive, which reduced DPPH radical by 85.9% after 10 min of incubation with the radical. Lower properties were observed for the cookie with 10% and 5% BC, in which the reduction in radical concentration was 68.5% and 51.3%, respectively. The control sample revealed very low DPPH radical scavenging activity (5.0% inhibition). The antiradical activity of black chokeberry powder was more than 10 times higher than that of cookies.

Adding freeze-dried chokeberry to cookies had a similar effect on DPPH radical scavenging activity as adding powdered papaya to cookies (Varastegani et al., 2015), as a multiple increment in radical inhibition in comparison to the control sample was reported. Likewise, the bigger the amount of the additive, the higher the radical scavenging activity observed.

In this study, radical scavenging activity was highly correlated ($p < 0.05$) with TPC. Similarly, a positive linear correlation was exhibited between TPC and two antioxidant capacity (DPPH and ORAC) assays in the work by Hossain et al. (2017), where the incorporation of blackcurrant powder in cookies up to 15% considerably increased their antioxidant capacity.

Impact of black chokeberry addition on sensory quality and consumer liking of cookies

The sensory profile of enriched cookies was evaluated by rating the intensities of ten selected attributes and the overall quality of products. The ANOVA analysis (Table 3) showed that attributes such as a creamy and earthy aroma were not significant for the cookies ($p > 0.05$), so they were discounted in further analysis. The incorporation of black chokeberry powder resulted in a significant ($p < 0.05$) change in the surface colour and colour on cutaway of the enriched cookies (Table 4), which differ considerably from the control sample. The cookies became darker with the higher amount of additive, which is probably due to

Table 3. Results of ANOVA analysis* for sensory attributes as dependent variables

Descriptors	*F*	Pr > *F*
Colour	54.7	<0.0001
Colour on cutaway	70.3	<0.0001
Sweet aroma	13.0	0.000
Creamy aroma	2.7	0.089
Earthy aroma	0.3	0.735
Sweet taste	25.4	<0.0001
Sour taste	21.6	<0.0001
Chokeberry flavour	73.3	<0.0001
Astringency	25.7	<0.0001
Crumbliness	20.7	<0.0001
Overall quality	4.0	0.035

*Model: $Y = P + J + P{\cdot}J$, significance level = 0.05, filter out non discriminating descriptors / Threshold *p*-value = 0.05.

Table 4. Sensory profile of cookies with freeze-dried black chokeberry

Sample	Cookie sample		
	5% BC	10% BC	15% BC
Colour	5.4 ±1.6[b]	6.7 ±1.6[b]	8.6 ±1.0[a]
Colour on cutaway	5.0 ±1.5[c]	6.6 ±1.7[b]	8.5 ±1.3[a]
Sweet aroma	6.6 ±1.4[a]	4.1 ±1.4[b]	2.9 ±0.7[b]
Sweet taste	7.3 ±1.2[a]	5.9 ±1.1[ab]	4.5 ±1.8[b]
Sour taste	1.2 ±0.7[b]	2.8 ±1.3[ab]	4.4 ±1.5[a]
Chokeberry flavour	2.8 ±1.3[b]	4.5 ±1.0[b]	7.1 ±2.0[a]
Astringency	0.8 ±0.4[b]	1.7 ±0.8[b]	4.0 ±1.5[a]
Crumbliness	7.7 ±1.1[a]	7.0 ±0.7[a]	4.5 ±1.1[b]
Overall quality	7.4 ±1.5[ab]	8.3 ±1.7[a]	6.3 ±1.1[b]

Intensity scale from 0 to 10.
Values are reported as mean ±standard deviation. Different letters in the same row indicate significant difference ($p < 0.05$).

the higher level of anthocyanins present in the sample. These results are in accordance with those of Šaponjac et al. (2016), who reported a significant increase in the surface colour scores of cookies in line with the higher addition of sour cherry pomace extract encapsulated in soy and whey protein. In other studies, the addition of grape seed extract in bulk and microencapsulated also resulted in the cookies having a darker colour (Davidov-Pardo et al., 2012).

The intensities of sweet aroma and taste in the enriched cookies were lower than in the control sample. The sweet taste was distinctly sensed in cookies with 5% BC, while in the sample with 15% BC was on a moderate level (4.5). In contrast, applying black chokeberry powder strengthened the detection of sour taste, chokeberry flavour and astringency in the cookies, which was 3.5 times, 2.5 times, and 5 times higher, respectively, in cookies with 15% BC in comparison to cookies with 5% BC. The high values of these attributes could be connected with the drying technique applied to the material. The study by Calin-Sanchez et al. (2015) showed that freeze-drying the black chokeberry resulted in a product with the highest values of sourness, bitterness and astringency among various drying methods. From the sensory point of view, vacuum microwave drying seemed to be a useful technique, as it led to significant and simultaneous reductions in the undesirable intensities of attributes typical for chokeberry. The addition of BC below 10% kept the crumbliness of cookies on a high level close to the scores for the control sample. The drop was observed for the sample with 15% BC. It could be correlated with the amount of fat in certain samples. The lower fat content in cookies with 15% BC might decrease the crumbliness perceived by panellists. The overall quality of the cookies was evaluated positively by experts and was 6.3 for the 15% BC sample, 7.4 for the 5% BC sample and 8.3 for the 10% BC sample.

PCA allowed the conclusion that attributes such as colour, colour on cutaway, sour taste, chokeberry and astringency were positively correlated with the first factor, while sweet aroma, sweet taste and crumbliness were negatively correlated (Fig. 1). The sample with 5% BC might be described as crumbly, sweet in taste and aroma with a slightly detectable astringency and sour taste. The sample with 10% BC balanced all the attributes with high overall quality. The sample

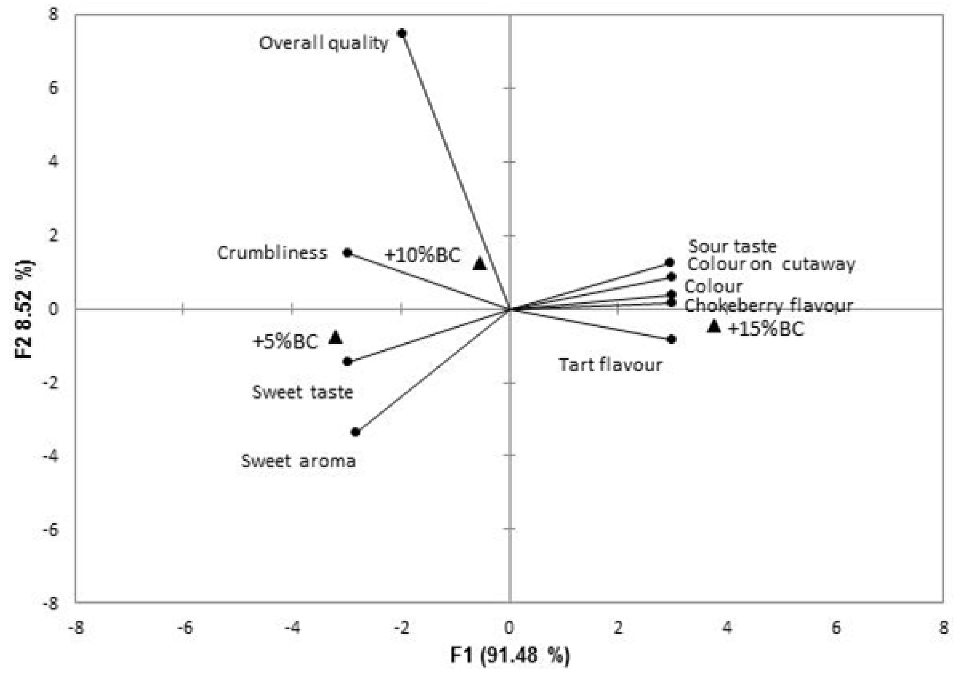

Fig. 1. PCA biplot of sensory profile of cookies with freeze-dried black chokeberry. Vectors represent sensory attributes. Samples are marked

containing 15% BC was the darkest, with moderate astringency and a sour taste, intense chokeberry flavour.

Consumers accepted all attributes of the cookies, as the average degrees were above 5 points on the 9-point hedonic scale (Table 5). The study showed that liking the cookies' colour depended on the amount of additive and was stronger for samples with 10% and 15% BC. On the contrary, the aroma and taste of the sample with 5% BC were significantly more desired (7.0 and 6.7, respectively) than in the 15% BC sample (6.4 and 5.9, respectively). The liking for cookies' crumbliness was graded higher with less of the additive in the sample. All cookies were evaluated positively by consumers, receiving comparable notes between 6.2 and 6.5 on a 9-point scale.

Taking into consideration both experts' and consumers' opinions, it might be assumed that darker cookies were more desired by consumers. The aroma liked by consumers was marked by panellists as intensively sweet. Higher amounts of the additive resulted in sourer, more astringent and less sweet cookies, which in turn caused the drop in consumer acceptance of the cookies. Crumbliness was highly desired by consumers. In general, the cookies exhibited high sensory quality in the panel's opinion and were accepted by consumers. The experts evaluated cookies with 5% and 10% BC higher than cookies with 15% BC, while

Table 5. Consumer liking of cookies with freeze-dried black chokeberry (n = 104)

Liking of	Cookie sample		
	5% BC	10% BC	15% BC
Colour	5.4 ±1.8^{b}	6.2 ±1.8^{a}	6.5 ±1.8^{a}
Colour on cutaway	5.1 ±1.8^{b}	6.1 ±1.7^{a}	6.3 ±1.8^{a}
Aroma	7.0 ±1.4^{a}	6.9 ±1.5^{ab}	6.4 ±1.6^{b}
Taste	6.7 ±1.6^{a}	6.3 ±1.6^{ab}	5.9 ±1.9^{b}
Crumbliness	6.9 ±1.6^{a}	6.3 ±1.5^{b}	5.5 ±1.8^{c}
Overall acceptance	6.5 ±1.6^{a}	6.5 ±1.4^{a}	6.2 ±1.7^{a}

Hedonic scale from 1 = "extremely dislike" to 9 = "extremely like".
Values are reported as mean ±standard deviation. Different letters in the same row indicate significant difference ($p < 0.05$).

in the consumer hedonic test, no difference in overall acceptance between samples was found.

CONCLUSIONS

The study demonstrated that the chemical composition, antioxidant activity and sensory properties of cookies were influenced by the addition of freeze-dried black chokeberry powder. The additive exhibited high TPC, reducing power and strong DPPH radical scavenging activity. The consumers evaluated all cookies positively, despite the characteristic sour taste and astringency found in black chokeberry. Consumers preferred darker, rather sweet, less sour cookies with balanced chokeberry flavour, so 10% addition seemed to be the most suitable. Some improvement in the colour of cookies containing lower levels of additive could be implemented in further developments to attract more consumers.

The results of the present study indicate that freeze-dried black chokeberry might be an interesting additive for enhancing the antioxidant potential, sensory quality and consumer acceptance of traditional cookies. It may be beneficial to broaden the application of freeze-dried chokeberry to other bakery products.

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