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Freeze-dried elderberry and chokeberry as natural colorants for gluten-free wafer sheets

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A b s t r a c t. Freeze-dried elderberry and chokeberry were proposed as natural colorants for gluten-free wafers. In addition to colour, other physical and sensorial properties of wafer sheets were also evaluated. The elderberry powder was significantly darker (L* equal 37.61) than the chokeberry powder (L* equal 41.01), and it was characterized by a considerably lower a* value (4.21 in comparison with 12.32). These powdered fruits were added in the range from 0 to 5 %. A new indicator of wafer batter delamination was developed, which can also be proposed for other liquids. Significant and favourable changes were noted in the colour of both batter and wafers, with an increased content of fruits from 1 to 5%. Gluten-free wafers with a 5% addition of fruits were characterized by L*, a*, b* values, respectively, equalling 35.73, 6.05 and 3.24 for elderberry, and 39.74, 7.15 and 5.05 for chokeberry. Wafers with a 5% addition of chokeberry and elderberry, in comparison to control wafers, had significantly higher contents of minerals, including iron, potassium, calcium, magnesium and sodium. The freeze-dried elderberry powder, as compared to the chokeberry powder, was found to significantly increase the content of these minerals. In addition, the total flavonoids content was higher in the wafers containing elderberry. Freeze-dried chokeberry and elderberry can be proposed as natural colorants and valuable functional components for wafers.

K e y w o r d s: natural colorant, elderberry, chokeberry, gluten-free, wafer

INTRODUCTION

Colour is a significant indicator of food quality, which appears particularly important for consumer preferences. Increasing attention has been recently paid to the toxicity of food additives such as synthetic colorants. Some researchers have shown potentially detrimental effects of colorant mixes on children's behaviour (Amchova *et al.,* 2015). Knowledgeable consumers are increasingly looking for functional foods containing natural colorants. Natural colorants present in foods have attracted interest because of their safety, and potential nutritional and therapeutic effects. Different kinds of fruit can be viewed as constituting the natural source of such colouring matters.

The beneficial health effect of fruit is mainly attributable to the high content of natural antioxidants, such as polyphenols and carotenoids. Thus, regular fruit consumption may significantly reduce the risk of many chronic diseases, like cancer, cardiovascular heart diseases and diabetes (Saikia *et al.,* 2015) .

Among the fruit types that are worth mentioning, small berries, like elderberry and chokeberry, have particularly valuable chemical compositions and are rich sources of pigments.

Elderberry fruit contains valuable components, such as anthocyanins (Vlachojannis *et al.,* 2015), vitamins A, C, B6, calcium and iron, as well as sterols, tannins and essential oils (Charlebois, 2007). Elderberry fruit and its products are not only rich sources of phenolics, boosting their antioxidant activity, but also contain harmful cyanogenic glycosides. Moreover, elderberry fruit shows many health benefits. It is especially used to cure stomach and intestine inflammation, and it exhibits anti-diarrheal, diuretic and diaphoretic properties (Piątkowska *et al.,* 2011).

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Therefore, it has been widely utilized in medicine, or as a source of dietary supplements and foods (Jakobek and Seruga, 2012).

Chokeberry is known as one of the plants that are rich in flavonoids, including anthocyanins exhibiting a strong antioxidant effect (Sidor and Gramza-Michałowska, 2015). The possible health benefits of consuming chokeberry include the prevention of blood vessel diseases, a positive effect on the digestive system, the strengthening of the immune system, and the prevention of cell proliferation under some cancer conditions (Pozderović *et al.,* 2016).

Evaluation of the colouring ability of elderberry varieties, as potential sources of natural food colorants, was attempted in the study by Szalóki-Dorkó *et al.* (2015). The authors performed a profiling and quantitative analysis of anthocyanins in five elderberry varieties. In an earlier study, other authors (Jakobek and Seruga, 2012) explained that elderberry might be a source of natural food colorants because of its high anthocyanin content. The relationship between colour parameters, phenolic content and sensory changes of commercially-processed elderberry juices were studied by Casati *et al.* (2012).

Espin *et al.* (2000) prepared natural extracts combining black chokeberry, black-thorn and strawberry, and demonstrated the usefulness of these extracts as potential colorants and antiradicals. The optimum operating conditions for the extraction of phenolic compounds from elderberry were investigated by Vatai *et al.* (2009). The aim was to obtain extracts with a high anthocyanin content, which would be potentially interesting for commercial applications as natural colorants.

As indicated above, the extraction procedure was used for the preparation of natural colorants but there have been no studies involving the use of freeze-dried powders. Freeze-drying has proven to constitute the optimum drying method for maintaining high levels of bioactive compounds in the 80% ethanol extracts of dried black chokeberries (Thi and Hwang, 2016). Lyophilization (freeze-drying), in turn, has been suggested for drying materials including heat-sensitive antioxidant components, such as carotenoids, ascorbic acid, tocopherols and plant phenolics (Rudy *et al.,* 2015). Freeze drying could also prevent deterioration and microbiological reactions, as well as give rise to high-quality food (Tu *et al.,* 2017).

Freeze-dried powders could act as natural colorants for cereal products. Recently. more attention has been given to gluten-free cereal products (Różyło *et al.,* 2015a, 2015b). Among these products, wafers have already been the subject of some studies (Huber and Schoenlechner, 2016; Mert *et al.,* 2015; Dogan, 2006; Dogan *et al.,* 2016).

In the literature, there are no reports concerning the production of gluten-free wafers containing freeze-dried fruits as natural colorants.

The objective of this study was to determine changes in colour as well as other physical and sensorial parameters of gluten-free wafer sheets, caused by the addition of freeze-dried elderberry and chokeberry. An essential task was to verify whether freeze-dried chokeberry and elderberry could be used as functional additives, acting as natural colorants for gluten-free wafers.

MATERIALS AND METHODS

Raw materials for making gluten-free wafers included white rice flour (Melvit, Warsaw, Poland), rapeseed oil, salt and baking soda. Rice flour was characterised by a protein content of 6.0±0.29%, a carbohydrate content of 78.0±3.7%, a fibre content of 1.4±0.08%, and a fat content of 1.0±0.04%. Lyophilisedelderberry and black chokeberry were derived from WPPH "Elena" (Żelazków, Poland). The baking soda (Gellwe, FoodCareGroup, Zabierzów, Poland) rapeseed oil (Kujawski, Kruszwica, Poland) and salt were purchased on the local market.

Fruit powders were prepared by grinding (with a knife grinder, Optimum RK-0150, Expo-service Warsaw, Poland) whole freeze-dried fruits, following which the desirable colour parameters were measured. The colour measurements were performed using a colorimeter (4Wave CR30-16) (Planeta, Tychy, Poland). The powders were built up into a 1-cm-thick layer using a special vessel which was fixed into a probe. The colorimeter settings were as follows: light – D65, space – LAB, diameter – 16 mm, style – 8/d. The colour was recorded using a CIE-$L^*a^*b^*$ uniform colour space, where L^* indicates lightness. The redness+/greenness- and the yellowness+/blueness- are denoted by a^* and b^* values, respectively.

Gluten-free wafer sheets were obtained through a testing procedure, based on an individually-developed recipe, and were made of rice flour (100%), rapeseed oil (2.5%), salt (0.3%), baking soda (0.5%) and water (170%). In line with the baking practice, the amount of flour was given as 100%, and the ratios of other components were converted into the weight of the flour. The control wafers were obtained from rice flour (100%). The lyophilized chokeberry and elderberry powders were added in the amounts of 1, 2, 3, 4 and 5% to the control wafer recipe. The gluten-free wafers were prepared after mixing all the ingredients with a 5-speed mixer (Kitchen Aid, St. Joseph, MI, USA) for 1 min. After mixing, the batter (an equal mass of 20 g) was immediately transferred into a wafer machine, type MD 13211 (LifeTec, Germany), and baked for 4-5 min in a temperature of 180-190°C. After baking, the obtained wafer sheets were dried (40°C, 5 min) and cooled to room temperature.

Baking tests were performed in eight replicates, based on which the average values were determined. The gluten-free wafer sheets were wrapped into polyethylene bags after both baking and cooling.

Gluten-free wafer batter properties were measured immediately after mixing all ingredients. The colour measurements of the resultant wafer batter were performed using a colorimeter (4Wave CR30-16) (Planeta, Tychy, Poland) by means of a liquid measuring device. The colorimeter settings were as shown above, and the colour was recorded using a CIE-$L^*a^*b^*$ uniform colour space. Colour differences (ΔL, Δa, Δb) were measured with a colorimeter following the type input (control wafer batter – without additives). The ΔE was determined as follows:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}. \quad (1)$$

Because of the observed delamination tendency of wafer batter, a new indicator of batter delamination was developed.

Measurements of batter delamination were performed using a device adopted to measuring Zeleny's sedimentation index (Sadkiewicz Instruments, Bydgoszcz, Poland). The batter was poured into a 50 cm^3 measuring cylinder with a capacity of 100 cm^3, and then placed in a desktop. The volume of the laminated batter was subsequently recorded after 0, 15, 30, 45 and 60 min. Lamination was inspected throughout the measurement process (after a certain time, a clear solution was noted on the batter surface). Immediately after mixing (t = 0 min), the indicator of batter delamination equalled 0%. The indicator of batter delamination (I_d) was calculated and determined in percentage terms, based on the following formula:

$$I_d = \left(1 - \frac{V_t}{V_0}\right) \cdot 100\%, \quad (2)$$

where: I_d – the indicator of batter delamination, V_t – the volume of batter at a certain measuring time (0, 15, 30, 45, 60 min), V_0 – the starting volume of batter (50 cm^3), Measurements of wafer batter delamination were performed in triplicate.

The colour measurements were performed after applying the probe of a colorimeter (4Wave CR30-16) (Planeta, Tychy, Poland) to whole wafer sheets (discs). The colour was recorded using the CIE - $L^*a^*b^*$ uniform colour space, as shown above. All the settings and records were used as shown above for both the powders and batter.

For mechanical measurements, the sheets (discs) of wafers were broken using a strength tester (ZWICK Z020/TN2S), with a 500 N measuring capital equipped with a blade with a width of 100 mm and a thickness of 3 mm. Before testing, the wafer discs (2 mm in thickness and 80± 5 mm in diameter) were placed on the base with two parallel arms set at a distance of 35 mm from each other. The test consisted of breaking a single wafer disc with a blade positioned parallel and equidistant from the arms of the base. The blade was moving at a speed of 1 mm s^{-1} until breaking the wafer. The force of wafer breaking was then determined, and the breaking tests were performed in eight replicates.

For sensory evaluation, the wafer discs divided into eight parts were presented on plastic dishes coded and served in a randomized order. The sensory evaluation panel consisted of 52 untrained consumers (aged 22-51, including 27 women and 25 men) who were habitual consumers of wafers, and who evaluated the wafer's appearance, taste, texture and the overall acceptability. The wafers were evaluated using a nine-point hedonic scale (1: extremely dislike, 5: neither like nor dislike, 9: extremely like) (Lim *et al.,* 2011).

Following the sensory analysis, the wafers with the best rating were separated. These samples were additionally analysed for the content of trace elements and flavonoids. These analyses were also made for freeze-dried powders of elderberry and chokeberry.

Quantitative analyses of the elements found in both fruit powders and wafers were performed by means of the flame atomic absorption spectrometry (FAAS) (SpektrAA 280 FS, autosampler SPS-3, diluter SIPS, Varian) specifying the content of zinc, copper and iron (EN 14084:2003), as well as sodium and magnesium (EN 15505:2008), using SpectraAA software. Analyses were performed upon the prior mineralisation (Mars Xpress, CEM) of each sample. The mineralisation process was one-stage with the use of nitric acid (V) in the amount of 10 cm^3 per 0.5 g of the sample. The magnetron power was 800W, and the 25 min temperature build up to 210°C was used, which was then maintained for 15 min.

The flavonoid content was determined spectrophotometrically for both fruit powders and wafers after extraction (Polish Pharmacopoeia, 2002). The extraction was carried out using acetone, hydrochloric acid and a methenamine solution. A basic and comparative solution was prepared after extraction. To obtain a stock solution of up to 10ml of the extract, 2 ml of aluminium chloride solution was added and supplemented (1:19) with a mixture of acetic acid and methanol. The comparative solution was prepared in a similar manner, but no aluminium chloride solution was added. After 45 min, the absorbance of the solutions at 425 nm was measured using a reference solution. The flavonoid content based on quercetin was determined using the following formula:

$$x = \frac{\mathrm{A} \;\; k}{\mathrm{m}}, \quad (3)$$

where: A – the absorbance of the test solution, k – the conversion factor for quercitin k = 0.875, m the weight of raw material (g).

Statistical analysis was performed at a significance level α = 0.05 using Statistica by Statsoft. Measurement scores were subjected to the analysis of variance (ANOVA). When significant differences in ANOVA were detected, the means were compared using the Tukey`s test.

RESULTS AND DISCUSSION

Freeze-dried fruit powders were characterized by different colour parameters (Table 1). The elderberry powder was significantly darker. The L^* value (lightness) of the elderberry powder was equal to about 37.6, and this parameter for the chokeberry powder was equal to about 41.0. Fresh elderberry, in comparison with chokeberry, contains more dark pigments which may impact on the powder colour after the freeze-drying process. The freeze-dried elderberry powder was characterized by a considerably lower a^* value (4.2) than the freeze-dried chokeberry powder (12.3). Such a result could be expected because fresh chokeberry has more red colour than elderberry. More blueness, in turn, was found in the case of the elderberry powder, as compared to the chokeberry powder.

Lyophilized elderberry fruits were characterized by a protein content of 3.0±0.11%, a carbohydrate content of 53.0±2.11%, a fibre content of 33.0±0.12 and a fat content of 2.3±0.12%. Lyophilized black ch okeberry fruits were characterized by a protein content of 6.6±0.31, a carbohydrate content of 58.0±0.32 and a fibre content of 25.1±0.13. The freeze-dried elderberry powder, as compared to the chokeberry content, had a significantly higher content of minerals, including iron, potassium, calcium, magnesium and sodium (Table 2). In addition, freeze-dried elderberry, as compared to chokeberry, had a higher content of flavonoids (Table 3). Several studies have confirmed that elderberry is a valuable raw material with many nutrients and bioactive substances (Petrut *et al.,* 2017). Elderberry displays a high concentration of compounds with antioxidative activity, especially anthocyanins, flavonoids and vitamins (Matejicek *et al.,* 2015). Ksonzekova *et al.* (2016) found that the chokeberry and elderberry extracts exhibit better antioxidant and anticytotoxic activ ities than blueberry or bilberry extracts with complex anthocyanin profile. Among the most common fruit and vegetables, elderberry is one of the richest in anthocyanins (Salamon *et al.*, 2015)

Table 1. Colour parameters of freeze-dried elderberry and chokeberry powders

Kind of fruit powder	L^*	a^*	b^*
Freeze-dried elderberry	37.61±0.14[a]	4.21±0.04[a]	-4.53±0.16[a]
Freeze-dried chokeberry	41.01±0.09[b]	12.32±0.02[b]	-1.81±0.09[b]

Means with different letter in the same column are significantly different ($p < 0.05$).

Table 3. Total flavonoids content in elderberry and chokeberry freeze-dried powders and wafers

Kind of material	Total flavonoids (calculated as quertistin) (mg QE 100 g^{-1})
Elderberry powder	80±4.3[a]
Chokeberry powder	51±3.1[c]
Wafer with elderberry	37±2.2[b]
Wafer with chokeberry	5.0±0.2[d]
Wafer without fruits (Control)	2.3±0.1[e]

Means with different letter are significantly different ($p < 0.05$).

After preparation, the highest indicator of batter delamination was observed for the batter with no addition of fruit powders. With an increased content of chokeberry and elderberry powder in the wafer recipe, significant changes were noted in batter delamination (Fig. 1a, b). The indicator of batter delamination decreased significantly as more freeze-dried elderberry and chokeberry powder was added (ranging from 0 to 5%), as compared to the control wafer. This trend was observed at almost all measuring times (15, 30, 45 and 60 min). Furthermore, the wafer batter containing chokeberry was characterized by a significantly lower indicator of batter delamination than the batter with an addition of the elderberry powder. A lower indicator of batter delamination appears desirable as it facilitates the preparation of wafers. The phenomenon of reducing the delamination of batter under the influence of fruit powders can be explained by the presence of pectin which, in combination with the water itself, are subjected to gelation.

Table 2. Mineral composition of elderberry and chokeberry freeze-dried powders and wafers

Kind of material	K	Na	Ca	Mg	Fe
	(mg kg^{-1})				
Elderberry powder	13500±832[a]	23.4±1.1[a]	1770±125[a]	2190±131[a]	47.8±2.1[a]
Chokeberry powder	10600±621[b]	20.5±1.2[b]	932±71[b]	704±42[b]	22.9±1.0[b]
Wafer with elderberry	1230±69[c]	1810±110[c]	268±17[c]	452±24[c]	15.5±0.7[c]
Wafer with chokeberry	1000±61[d]	1510±73[d]	211±14[d]	364±18[d]	11.8±0.6[d]
Wafer without fruits (Control)	807±52[e]	1440±104[d]	181±9[e]	340±19[d]	9.92±0.4[e]

Explanations as in Table 1.

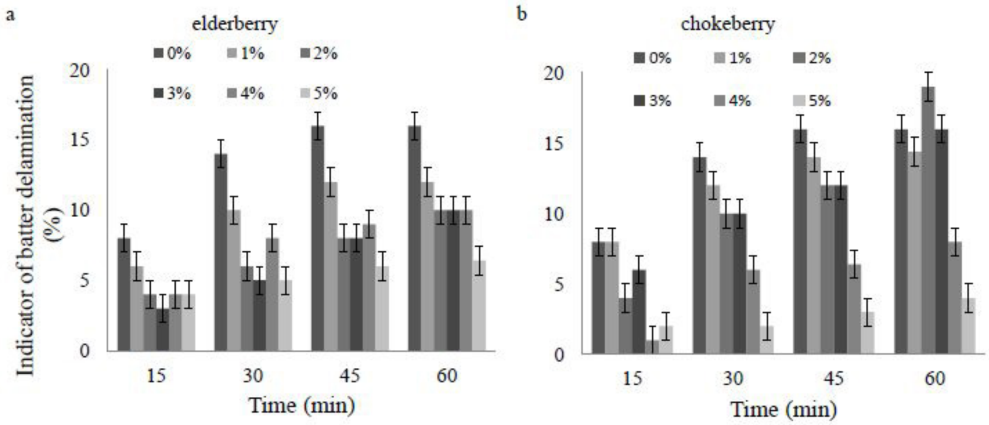

Fig. 1. An indicator of gluten-free wafer batter delamination with different amounts of freeze-dried fruit additives: a – elderberry addition, b – chokeberry addition ($p < 0.05$, $n = 72$).

Pectic substances were extracted from red currant, black currant, raspberry, blackberry and elderberry press residues using hot water (Cserjési *et al*., 2011). The rheological behaviour of the pectins extracted from berries was studied by Bélafi-Bakó *et al*. (2012). The authors found that the gels of pectins from berry press residues are stronger than those of the commercially-available apple pectin. For example, the red currant pectin was found to possess outstanding values regarding the gel-forming capacity and the thickening effect.

With an increased content of elderberry and chokeberry powders, significant changes were noted in the colour of batter (Fig. 2a-c) (Table 4). The lightness component L^* (Fig. 2a) decreased with an addition of elderberry and chokeberry in the range from 0 to 5%. Similar values of the batter L^* components were obtained for both the elderberry and chokeberry in the range from 1 to 2%. The changes described by ΔL showed that elderberry addition caused a significant darkening, in comparison with chokeberry, in the range from 3 to 5%. Parameters a^* (Fig. 2b) increased

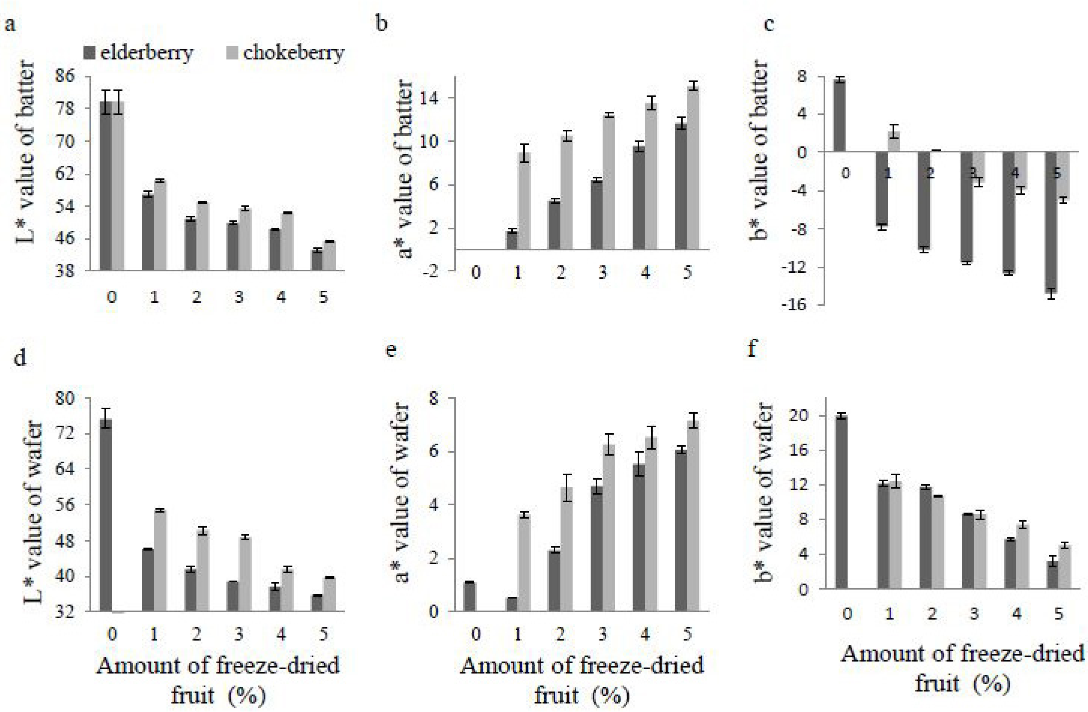

Fig. 2. Colour $L^*a^*b^*$ values of gluten-free wafer batter and wafer sheets with an addition of freeze-dried elderberry and chokeberry powders, a, d – colour L^* value of batter and wafer, b, e – colour a^* value of batter and wafer, c, f – colour b^* value of batter and wafer ($p < 0.05$, $n = 96$).

with an addition of chokeberry, and decreased with an addition of elderberry, in the range from 0 to 5%. The highest redness (a^*) of batter was achieved with a 5% content of chokeberry. Changes in redness showed that any amount of the chokeberry powder resulted in larger changes than an addition of the elderberry powder. Such results could be expected because of the colour of the fruit powder used as an additive. As shown above, the freeze-dried elderberry powder was characterized by a considerably lower a^* value than the freeze-dried chokeberry powder (Table 1). The colour b^* value of batter (yellowness) (Fig. 2c) decreased with the increasing content (from 0 to 5%) of elderberry and chokeberry powders. In comparison with chokeberry, significantly lower values of b^* parameters were obtained for batter with a 2, 3, 4 and 5% addition of the elderberry powder. As regards changes relating to all the colour parameters described by ΔE (Table 2), more significant changes were observed in the range from 3 to 5% of the elderberry powder, as compared to the chokeberry powder.

With an increased content of elderberry and chokeberry powders, significant changes were noted in the colour of wafers (Fig. 2d-f) (Table 4). The lightness component L^* (Fig. 2d) decreased with an addition of elderberry and chokeberry in the range from 0 to 5%. Lower values of the wafer L^* components were obtained with a 2, 3, 4 and 5% addition of elderberry. As shown above, the freeze-dried elderberry powder used in the wafer recipe was characterized by a significantly lower L^* value than the freeze-dried chokeberry powder. Parameters a^* (Fig. 2e) increased with an addition of chokeberry, and decreased with an addition of elderberry, in the range from 0 to 5%. The higher redness (a^*) of wafers was achieved with a 1-5% content of chokeberry. Such results could be expected because of the colour of the fruit powder used as an additive. As shown above, the freeze-dried chokeberry powder was characterized by a considerably higher a^* value than the freeze-dried elderberry powder. In other studies presented by Mert *et al.* (2015), the effects of the natural colour of flour were clearly observed in the colour analyses of wafer sheets. The colour b^* value of gluten-free wafers (yellowness) (Fig. 2f) decreased with an increasing content (from 0% to 5%) of elderberry and chokeberry powders. In comparison with chokeberry, significantly lower values of b^* parameters were obtained for wafers with a 2, 3, 4 and 5% addition of the elderberry powder. It is clear that the elderberry powder contains more blue pigments which impact on the wafer colour after baking.

Table 4. Changes in color parameters ΔE of wafer's batter caused by different amount of fruit addition

Kind of freeze-dried fruit addition	Amount of fruit addition (%)	ΔE
	Wafer's batter	
	1	27.59±0.66^{g}
	2	34.14±0.99^{d}
Elderberry	3	36.11±0.87^{c}
	4	38.59±0.92^{b}
	5	44.45±1.23^{a}
	1	22.09±0.73^{j}
	2	28.01±0.74^{gh}
Chokeberry	3	31.06±1.18^{fg}
	4	32.76±1.04^{ef}
	5	39.56±1.13^{b}
	Wafer's sheet	
Elderberry	1	30.23±0.96^{fg}
	2	34.70±0.89^{cd}
	3	38.32±1.16^{b}
	4	40.10±1.27^{b}
	5	42.59±1.11^{a}
	1	22.02±0.97^{j}
	2	26.94±0.84^{hi}
Chokeberry	3	29.28±0.90^{g}
	4	36.34±0.71^{i}
	5	38.99±1.02^{b}

Means with different letters are significantly different ($p < 0.05$).

The colour difference formula ΔE of wafer sheets, in comparison with wafer batter (Table 4), was considerably higher for the freeze-dried elderberry powder. It could be expected that the pigments available in elderberry are

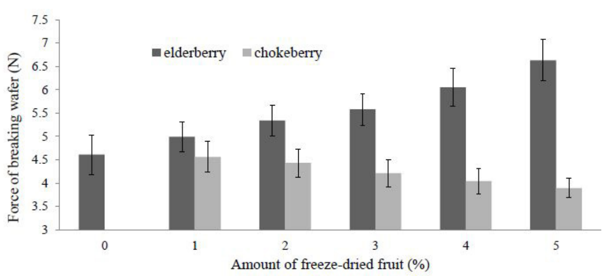

Fig. 3. The force of breaking wafer sheets with different amounts of freeze-dried elderberry and chokeberry ($p < 0.05$, $n = 96$).

more stable than those found in chokeberry. In addition, the Maillard reaction during baking (Delgado-Andrade *et al.,* 2010) could be more intense in the case of the elderberry powder. As shown earlier (Mazza and Minitiani, 1993), the stability of pigments depends on the structure and concentration of pigment s, as well as on pH, temperature and the presence of metal ions, enzymes, oxygen, ascorbic acid, sugar and metabolites and sulphur oxide.

The force of wafer breaking was found to change with an addition of elderberry and chokeberry (Fig. 3). This parameter significantly increased with the growing content (from 0 to 5%) of elderberry, and slightly decreased with an addition of the chokeberry powder. There were no significant differences in the force of wafer breaking with a 0 and 1, 2, 3 and 4% share of chokeberry in the wafer formulation process. In other studies, the force of wafer breaking, following the fruit addition, was not determined. In this study, the force of wafer breaking, following an addition of elderberry, was higher in comparison with chokeberry. The exact reason is hard to identify but it could be due to the higher fibre content in elderberry. Fibre-containing formulations of bread were found to affect crumb texture, inducing an increase in hardness (Rosell and Santos, 2010). Fibre-enriched gluten-free cakes also resulted in increased hardness (Gularte *et al*., 2012). Aydogdu *et al*. (2018), having analysed the microstructure of dough containing insoluble fibre, concluded that the insoluble fibre remained unchanged and became more rounded by starch granules which had formed irregular structures than the control dough. Therefore, insoluble fibre increased dough consistency , and a more consistent dough gave rise to products of higher hardness (Sudha *et al*., 2007).

Sensory evaluation showed that control gluten-free wafers and wafers with a 5% addition of chokeberry were characterised with the highest scores for appearance and taste, and the highest overall scores (Fig. 4). The scores obtained for appearance decreased with a smaller addition of freeze-dried fruits. The least acceptable wafer was obtained with an addition of 1 to 2% of freeze-dried elderberry and chokeberry powders. Greater levels of fruits (3-5%) caused an acceptable appearance and taste of wafers. More acceptable wafer sheets were obtained with an addition of the chokeberry powder, as compared to the elderberry powder. Finally, it was concluded that the most acceptable gluten-free wafers could be obtained by adding from 4 to 5% of freeze-dried elderberry and chokeberry powders. Dogan (2006) showed that, for a high-quality wafer sheet, the level and quality of ingredients proved very important.

Wafers with the maximum (5%) amount of black elderberry and chokeberry were selected for further analysis.

In comparison to control wafers, wafers with a 5% addition of black elderberry and chokeberry had significantly higher contents of minerals, including iron, potassium, calcium, magnesium and sodium (Table 2). The addition of elderberry to wafers increased the iron content by 56%, potassium by 52%, calcium by 48%, and magnesium by 32%. However, the addition of chokeberry increased the amount of potassium by 23%, iron by 18.9%, calcium

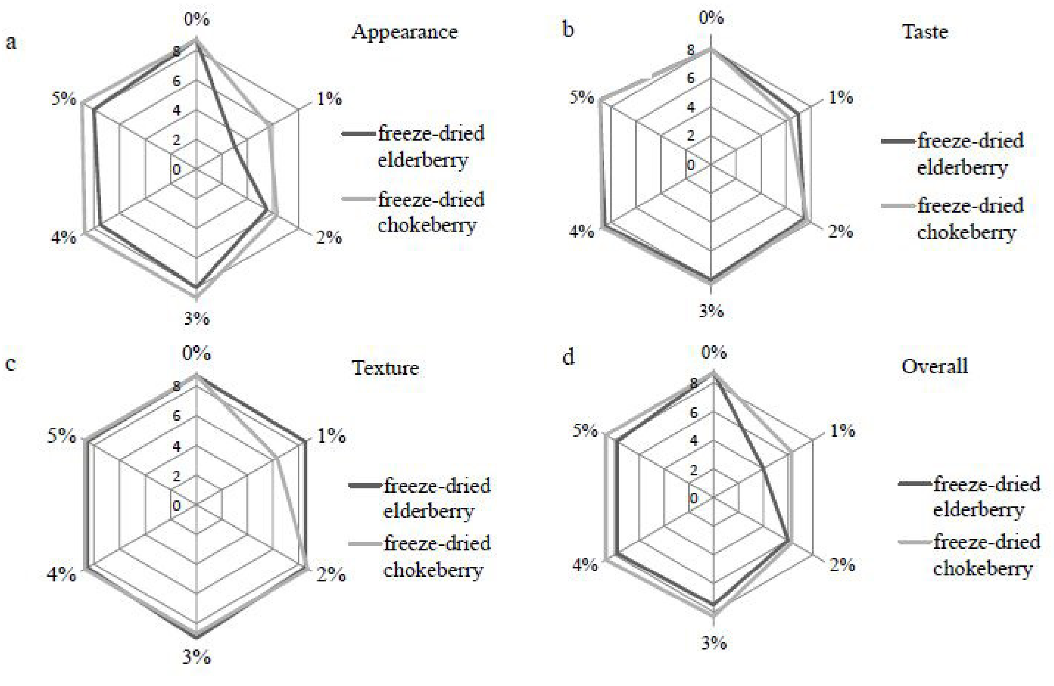

Fig. 4. Sensory evaluation of wafer sheets with different amounts of freeze-dried elderberry and chokeberry additives: a – wafer appearance, b – wafer taste, c – wafer texture, d – overall assessment of the wafer.

by 16.6%, and magnesium by 7%. In the study presented by Martins *et al.* (2017), wheat bread was fortified with elderberry skin, pulp and seeds (fibre-enriched extracts recovered from agri-industrial by-products). The impact of this fortification on the total and bio-accessible mineral composition of wheat breads was estimated by means of the daily mineral intake.

Freeze-dried elderberry, as compared to chokeberry, caused a higher increase in the flavonoid content (Table 3). As shown before, this was related to the higher content of flavonoids in freeze-dried elderberry, as compared to chokeberry. Control wafers had a low content of flavonoids, while the addition of elderberry caused a significant increase in this parameter. Other authors have proven that flavonoids are heat-sensitive (Franke *et al*., 2004; Sharma and Gujral, 2014) and react differently to various temperatures (Bhatt and Gupta, 2015; Go *et al*., 2017). Sharma and Gujral (2014) proved that baking leads to a significant decrease in the total flavonoid content in barley cookies.

CONCLUSIONS

1. In comparison with freeze-dried chokeberry, a darker powder with more blue and less red pigments was obtained from freeze-dried elderberry.

2. The indicator of batter delamination decreased significantly with the increasing content of freeze-dried elderberry and chokeberry powders.

3. The force of breaking wafer sheets significantly increased with the growing content (from 0 to 5%) of elderberry, and slightly decreased with an addition of the chokeberry powder.

4. The colour and sensory evaluation revealed that gluten-free wafers with a 4-5% addition of chokeberry and elderberry were characterised by higher scores for colour, appearance and taste, and higher overall scores.

Conflicts of interest. The authors declare that they have no conflicts of interest pertaining to this study.

REFERENCES

Amchova P., Kotolova H., and Ruda-Kucerova J., 2015. Health safety issues of synthetic food colorants. Regulatory Toxicology and Pharmacology, 73(3), 914-922. https://doi.org/10.1016/j.yrtph.2015.09.026

Aydogdu A., Sumnu G., and Sahin S., 2018. Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes. J. Food Sci. Technol., 55(2), 667-677.

Bélafi-Bakó K., Cserjési P., Beszédes S., Csanádi Z., and Hodúr C., 2012. Berry Pectins: Microwave-Assisted Extraction and Rheological Properties. Food and Bioprocess Technol., 5(3), 1100-1105.

Bhatt S.M., and Gupta R.K., 2015. Bread (composite flour) formulation and study of its nutritive, phytochemical and functional properties. J. Pharmacognosy Phytochemistry, 4(2), 254-268.

Casati C.B., Sánchez V., Baeza R., Magnani N., Evelson P., and Zamora M.C., 2012. Relationships between colour parameters, phenolic content and sensory changes of processed blueberry, elderberry and blackcurrant commercial juices. Int. J. Food Sci. Technol., 47, 1728-1736. https://doi.org/10.1111/j.1365-2621.2012.03027.x

Charlebois D., 2007. Elderberry as a Medicinal Plant. In Issues in New Crops and New Uses (Eds J. Janick, A. Whipket). ASHS Press, Alexandr'ıa, Va.

Cserjési P., Bélafi-Bakó K., Csanádi Z., Beszédes S., and Hodúr C., 2011. Simultaneous recovery of pectin and colorants from solid agro-wastes formed in processing of colorful berries. Progress in Agric. Eng. Sci., 7(8), 65-80. https://doi.org/10.1556/Progress.7.2011.5

Delgado-Andrade C., Conde-Aguilera J.A., Haro A., de la Cueva S.P., and Rufian-Henares J.A., 2010. A combined procedure to evaluate the global antioxidant response of bread. J. Cereal Sci., 52(2), 239-246. https://doi.org/10.1016/j.jcs.2010.05.013

Dogan I.S., 2006. Factors affecting wafer sheet quality. Int. J. Food Sci. Technol., 41, 569-576. https://doi.org/10.1111/j.1365-2621.2005.01117.x

Dogan I.S., Yildiz O., and Meral R., 2016. Optimization of corn, rice and buckwheat formulations for gluten-free wafer production. Food Sci. Technol. Int., 22, 5, 410-419.

EN standards (EN 13804:2003; EN 15505:2008). Foodstuffs – Determination of trace elements. European Committee for Standardization, B-1050 Brussels.

Espín J.C., Soler-Rivas C., Wichers H ., and García-Viguera C., 2000. Anthocyanin-based natural colorants: A new source of antiradical activity for foodstuff. J Agric. Food Chem., 48, 1588-1592, https://doi:10.1021/jf9911390

Franke A.A., Custer L.J., Arakaki C., and Murphy S.P., 2004. Vitamin C and flavonoid levels of fruits and vegetables consumed in Hawaii. J. Food Composition and Analysis, 17(1), 1-35. https://doi.org/10.1016/S0889-1575(03)00066-8

Go S.K., Chia S.L., Tan C.P., and Chong G.H., 2017. Effects of multi-stage dehumidified-air drying on the polyphenol content of *Hydrocotyle bonariensis*. Int. Food Res. J., 24(2), 589-593.

Gularte M.A., de la Hera E., Gómez M., and Rosell C.M., 2012. Effect of different fibers on batter and gluten-free layer cake properties. LWT – Food Sci. Technol., 48(2), 209-214. https://doi.org/10.1016/j.lwt.2012.03.015

Huber R. and Schoenlechner R., 2016. Waffle production: influence of batter ingredients on sticking of fresh egg waffles at baking plates – Part I: effect of starch and sugar components. Food Sci.d Nutrition, 5(3), 504-512. https://doi.org/10.1002/fsn3.424

Jakobek L., and Seruga M., 2012. Influence of anthocyanins, flavonols and phenolic acids on the antiradical activity of berries and small fruits. Int. J. Food Properties, 15,122-133. https://doi.org/10.1080/10942911003754684

Ksonzekova P., Mariychuk R., Eliasova A., Mudronova D., Csank T., Kiraly J., Marcincakova D., Pistl J., and Tkacikova L., 2016. In vitro study of biological activities of anthocyanin-rich berry extracts on porcine intestinal epithelial cells. J. Sci. Food Agric., 96(4), 1093-1100. https://doi.org/10.1002/jsfa.7181

Lim H.S., Park S.H., Ghafoor K., Hwang S.Y. and Park J., 2011. Quality and antioxidant property of bread containing turmeric. *Curcuma longa* L. cultivated in South Korea. Food Chemistry, 112, 1577-1582. https://doi.org/10.1016/j.foodchem.2010.08.016

Martins Z.E. Pinto E., Almeida A.A., Pinho O., Ferreira I.M.P.L.V.O., 2017. Fibre fortification of wheat bread: impact on mineral composition and bioaccessibility. Food and Function, 8(5): 1979-1987. https://doi.org/10.1039/C7FO00382J

Matejicek A., Kaplan J., Matejickova J., Vespalcova M., and Cetkovska J., 2015. Comparison of substances in elderberry cultivars and wild elderberry. Acta Horticulturae, (1074), 105-109. https://doi.org/10.17660/ActaHortic.2015.1074.15

Mazza G. and Minitiati E., 1993. Introduction. In Anthocyanin in Fruits, vegetables, and grains. Boca raton, FL: CRC Press (Chapter 1).

Mert S., Sahin S., and Sumnu G., 2015. Development of gluten-free wafer sheet formulations. LWT - Food Sci. Technol., (63)2, 1121-1127. https://doi.org/10.1016/j.lwt.2015.04.035

Petrut G.S., Muste S., Mureşan C., Păucean A., Mureşan A.E., and Nagy M., 2017. Chemical profiles and antioxidant activity of black elder (*Sambucus nigra* L.) - A Review. Bulletin UASVM Food Science and Technology, 74(1), 9-16. https://doi.org/10.15835/buasvmcn-fst:11591

Piątkowska E., Kopeć A., and Leszczyńska T., 2011. Anthocyanins – their profile, occurrence, and impact on human organism (in Polish). Żywność. Nauka. Technologia Jakość, 4(77), 24-35.

Polish Pharmacopoeia, **2002.** Edition VI. Polish Pharmaceutical Society. Warsaw, Poland.

Pozderović A., Popović K., Pichler A., and Jakobek L., 2016. Influence of processing parameters on permeate flow and retention of aroma and phenolic compounds in chokeberry juice concentrated by reverse osmosis. Cyta – J. Food, 14(3), 382-390.

Rosell C.M., and Santos E., 2010. Impact of fibers on physical characteristics of fresh and staled bake off bread. J. Food Eng., 98(2), 283-291. https://doi.org/10.1016/j.jfoodeng.2010.01.008

Różyło R., Rudy S., Krzykowski A., and Dziki D., 2015a. Novel application of freeze-dried amaranth sourdough in gluten-free bread production. J. Food Process Eng., 38, 135-143. https://doi.org/10.1111/jfpe.12152

Różyło R., Dziki D., Gawlik-Dziki U., Cacak-Pietrzak G., Miś A. and Rudy S., 2015b. Physical properties of gluten-free bread caused by water addition. Int. Agrophys., 29, 353-364. https://doi.org/10.1515/intag-2015-0042

Rudy S., Dziki D., Krzykowski A., Gawlik-Dziki U., Polak R., Różyło R., and Kulig R., 2015. Influence of pre-treatments and freeze-drying temperature on the process kinetics and selected physico-chemical properties of cranberries (Vaccinium macrocarpon Ait.). LWT - Food Sci. Technol., 63, 497-503. https://doi.org/10.1016/j.lwt.2015.03.067

Saikia S., Mahnot N. K., and Lata Mahanta C.L., 2015. Optimisation of phenolic extraction from Averrhoa carambola pomace by response surface methodology and its microencapsulation by spray and freeze drying. Food Chemistry, 171, 144-152. https://doi.org/10.1016/j.foodchem.2014.08.064

Salamon I., Mariychuk R., Grulov D., 2015. Optimal extraction of pure anthocyanins from fruits of *Sambucus nigra*. Acta Horticulturae, (1061),73-78. https://doi.org/10.17660/ActaHortic.2015.1061.6

Sharma P., and Gujral H.S., 2014. Cookie making behavior of wheat-barley flour blends and effects on antioxidant properties. LWT - Food Sci. Technol., 55(1), 301-307. https://doi.org/10.1016/j.lwt.2013.08.019

Sidor A. and Gramza-Michałowska A., 2015. Advanced research on the antioxidant and health benefit of elderberry (Sambucus nigra) in food – a review. J. Functional Foods, 18, 941-958. https://doi.org/10.1016/j.jff.2014.07.012

Sudha M.L., Srivastava A.K., Vetrimani R., and Leelavathi K., 2007. Fat replacement in soft dough biscuits: Its implications on dough rheology and biscuit quality. J. Food Eng., 80(3), 922-930. https://doi.org/10.1016/j.jfoodeng.2006.08.006

Szalóki-Dorkó L., Stéger-Máté M., and Abrankó L., 2015. Evaluation of colouring ability of main European elderberry (*Sambucus nigra* L.) varieties as potential resources of natural food colourants. Int. J. Food Sci. Technol., 50, 1317-1323. https://doi.org/10.1111/ijfs.12773

Thi N.D. and Hwang E-S., 2016. Effects of drying methods on contents of bioactive compounds and antioxidant activities of black chokeberries (*Aronia melanocarpa*). Food Sci. Biotechnol., 25(1), 55-61. https://doi.org/10.1007/s10068-016-0008-8

Tu Z-C., Zhang B-Z., and Wang H., 2017. Identification of glycated sites in ovalbumin under freeze-drying processing by liquid chromatography high-resolution mass spectrometry. Food Chemistry, 226, 1-7. https://doi.org/10.1016/j.foodchem.2017.01.038

Vatai T., Škerget M., and Knez Z., 2009. Extraction of phenolic compounds from elder berry and different grape marc varieties using organic solvents and/or supercritical carbon dioxide. J. Food Eng., 90(2), 246-254. https://doi.org/10.1016/j.jfoodeng.2008.06.028

Vlachojannis C., Zimmermann B.F., and Chrubasik-Hausmann S., 2015. Quantification of anthocyanins in elderberry and chokeberry dietary supplements. Phytotherapy Res., 29, 561-565. https://doi.org/10.1002/ptr.5284