Scientific Papers. Series B, Horticulture. Vol. LXII, 2018
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

BAKERY PRODUCTS FORTIFIED WITH DRIED FRUITS OF *ARONIA MELANOCARPA*

Monica CATANĂ[1], Luminița CATANĂ[1], Enuța IORGA[1], Adrian Constantin ASĂNICĂ[2], Nastasia BELC[1]

[1]National Research and Development Institute for Food Bioresources, IBA Bucharest, 6 Dinu Vintilă, District 2, 021102, Bucharest, Romania
[2]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Horticulture, 59 Mărăşti Blvd, District 1, 011464, Bucharest, Romania

Corresponding author email: mcatana1965@gmail.com

Abstract

Aronia (Aronia melanocarpa) has gained a huge interest due to its complex biochemical composition that gives it various beneficial effects on health. Polyphenols (anthocyanins and procyanidins, especially), represent the most important group of biologically active compounds, which give to these fruits their therapeutical properties and antioxidant potential. In this study it was evaluated the quality of bakery (bread, minibaguette and biscuits) products fortified with dried fruits of Aronia melanocarpa. Products made have superior sensory quality, high nutritional value and antioxidant potential. Thus, products are characterized by the content in polyphenols (193.34 ... 263.22 mg GAE/100g), proteins (11.92 ... 12.95%), fibres (9.13 ... 16.60%) and mineral elements (potassium, calcium, magnesium, iron and zinc). Antioxidant capacity of the achieved products varied in the range 1.91 ... 3.42 mg Trolox Equivalents/g. Biscuits with Aronia and ginger recorded the highest value of antioxidant capacity, and Bread with Aronia had the minimum value. Shelf-life of products studied is quite long, possibly due to the antioxidant and antibacterial properties of fruits of Aronia melanocarpa. In addition, in case of bread and minibaguette, lactic acid bacteria from sourdough used for fermentation have an important role to ensure the preservation of these products. This study has practical value; dried fruits of Aronia melanocarpa can be a functional ingredient to increase the nutritional value and antioxidant capacity of bakery products.

Key words*: Aronia melanocarpa, polyphenols, antioxidant capacity, bakery products.*

INTRODUCTION

There are scientific evidences that a diet rich in fruits and vegetables may reduce the risk to have different chronic diseases (Borges et al., 2010). Berries are recommended in a healthy diet as it provides protection against degenerative diseases, cardiovascular diseases and cancer (Howard et al., 2012). This protective role is given by some biologically active compounds they contain, like: phenolic acids, anthocyanins and flavonoids (De Pascual-Teresa et al., 2008). Among berries, fruits of *Aronia melanocarpa*, they have gaine recently attention due to the health claims associated with their consumption (Chrubasik et al., 2010; Kokotkiewicz et al., 2010).

Fruits of *Aronia melanocarpa* (Michx.) Elliott are rich sources of biologically active compounds, polyphenols (anthocyanins and procyanidins, especially) representing the most important group. Polyphenols are the main substances which give the antioxidant potential of black chokeberry fruits (Kokotkiewicz et al., 2010). Total polyphenolic content varies in the range 2-8 mg/100 d.m. and depends on the cultivar, growing conditions and harvesting time (Kähkönen et al., 1999; Hudec et al., 2006; Oszmiański and Wojdyło, 2005; Benvenuti et al., 2004; Sueiro et al., 2006; Hakkinen et al., 1999). Jakobek et al. (2012) determined total polyphenolic content in case of three cultivars ('Viking', 'Nero', 'Galicianka') of fruits of chokeberry (*Aronia melanocarpa*) and wild chokeberries, in Croatia, region Slavonia during two consecutive years (2010 and 2011). Cultivars 'Viking', 'Nero' and wild chokeberries had a similar total polyphenolic content (9012–10,804 mg kg^{-1} in the first year, 9361–12,055 mg GAE/ kg FW in the second year). Cultivar 'Galicianka' had a lower total polyphenolic content (8564 mg GAE/kg^{-}FW first year, 8600 mg GAE/kg FW second year).

Besides polyphenols, fruits of *Aronia melanocarpa* are sources of sugar (10-18%), pectins (0.6-0.7%), the sugar alcohol sorbitol, and parasorboside (Wolski et al., 2007; Niedworok and Brzozowski, 2001; Weinges et al., 1998; Kulling and Rawel, 2008).

Fresh fruits of *Aronia melanocarpa* can be consumed a short period time and thus to benefit by their nutritional qualities and antioxidant potential these fruits are processed under various forms: dried fruits, puree, juice, liqueur, syrup, jam, wine, compote, tea, powder (Chrubasik et al., 2010; Ochmian et al., 2012; Kapci et al., 2013; Šnebergrová et al., 2014). On the other side, fresh fruits of *Aronia melanocarpa*, have sour and astringent taste and therefore consumers prefer juice of *Aronia melanocarpa*, in combination with other fruits, such as, apples, pears and blackcurrant (Lehmann, 1990; Ara, 2002).

Kapci et al. (2013) investigated the antioxidant potential of fruits of *Aronia melanocarpa* and of their derivate products (Chokeberry juice, Chokeberry pomace, Chokeberry concentrate, Chokeberry syrup, Chokeberry compote, Chokeberry jam, Raspberry-chokeberry syrup, Sour cherry-chokeberry syrup). Total polyphenolic content varied in the range: 0.78 ± 0.02 g GAE/kg ... 63.1 ± 0.5 g GAE/kg (minimum value was recorded by Raspberry-chokeberry syrup and the maximum one by Chokeberry pomace, due to the fact that it contains skin and seeds of chokeberry). It should be noted that dried chokeberry have a high total polyphenolic content (39.9 ± 0.3 g GAE/kg, respectively, 50.1 ± 0.4 g GAE/kg). Antioxidant capacity of chokeberry fruit determined by ABTS, DPPH, and CUPRAC were 10.9 $g \cdot kg^{-1}$, 11.3 $g \cdot kg^{-1}$ and 67.7 $g \cdot kg^{-1}$, respectively. By all methods, the highest antioxidant capacity was recorded in case of dried chokeberries (54.4 ± 1 $g \cdot kg^{-1}$ by ABTS, 30.5 ± 1 $g \cdot kg^{-1}$ by DPPH and 233.2 ± 1.3 $g \cdot kg^{-1}$ by CUPRAC). The lowest antioxidant capacity was recorded in case of Raspberry-chokeberry syrup (0.7-1.2 $g \cdot kg^{-1}$), the obtained results correlated with content in total polyphenols, total flavonoids, total anthocyanins.

Taking into account the high content of biologically active compounds and antioxidant capacity of dried fruits of *Aronia melanocarpa,* their use to fortify food products has a real interest.

In this paper are presented bakery products („Bread with *Aronia*", „Minibaguette with *Aronia*", „Biscuits with *Aronia* and cinnamon", „Biscuits with *Aronia* and ginger") fortified with dried fruits of *Aronia melanocarpa.* Products quality was evaluated through sensory, physico-chemical and microbiological analyses. Also the antioxidant potential was evaluated by determination of total polyphenolic content and of antioxidant capacity.

MATERIALS AND METHODS

Materials

Dried fruits of *Aronia melanocarpa* used within experiments were obtained from organic culture (Figure 1). These fruits were ground with a Retsch mill within the performed experiments. The raw materials and materials used for making bakery products were purchased from the market.

Figure 1. Dried fruits of *Aronia melanocarpa*

Methods

Sensory analysis

Sensory evaluation of the bakery products fortified with dried fruits of *Aronia melanocarpa* was performed 12 hours after baking, using *„Comparison method with unitary score scales"*. Sensory quality of the fortified product was established based on the total average score by comparison with a scale from 0 to 20 points (18.1 ... 20 - qualyfing „very good"; 15.1 ... 18 - qualyfing „good"; 11.1 ... 15 - „satisfactory"; 7.1 ... 11 - „unsatisfactory"; 0 ... 7 - „inadequate").

For measurement of colour parameters dried fruits of *Aronia melanocarpa* were ground with Retsch mill, and bakery products fortified were liophylised and then grounded with a Retsch mill. Measurement of the colour parameters of samples was performed at room temperature, using a HunterLab colorimeter, equipped with Universal Software V4.01 Miniscan XE Plus

programme, to register CIELab parameters (the Commission Internationale de l'Eclairage - CIE), *L**, *a** and *b**: *L** - colour luminance (0= black, 100 = white); *a** - red-green coordinate (-a = green, +a = red); *b** - yellow-blue coordinate (-b = blue, +b = yellow).
The texture properties of the bakery products fortified with dried fruits of *Aronia melanocarpa* were measured through a compression test using an Instron Texture Analyzer (model 5944, Illinois Tool Works Inc., USA).

Physic-chemical analysis
The moisture content was determined according to the AACC 44-15A method. Protein content was determined by the Kjeldahl method with a conversion factor of nitrogen to protein of 6.25 (AOAC Method 979.09, 2005). Fat content was determined according to AOAC Method 963.15, and ash content according to AOAC Method 923.03 (AOAC, 2005). Mineral elements content was determined by atomic absorption spectrophotometer (type *AAnalyst* 400, Perkin-Elmer, Waltham, MA, USA) from HCl mineralized sample.
Total dietary fiber (TDF) was determined by enzymatic method using the assay kits: K-TDFR „Total dietary fiber" (AOAC Method 991.43).
Total sugar and reducing sugar content was determined according to Schoorl method. For total sugar, the method is applied after an acid hydrolysis (20% HCl solution) at 70ºC, for 27 minutes.
Calorie contents were calculated using the following conversion factors: 9 for fat, 4 for carbohydrates, 4 for protein and 2 for fibre, according to the Commission Regulation no. 1169/2011 (European Commission, 2011).
Joule contents were calculated using the following conversion factors: 37 for fat, 17 for carbohydrates, 17 for protein and 8 for fibre, according to the Commission regulation no. 1169/2011 (European Commission, 2011).
Total polyphenol content
Total polyphenol content was conducted according to Horszwald and Andlauer (2011) with some modifications (concerning extract volumes of the used sample and reagents, using UV-VIS Jasco V 550 spectrophotometer), based on calibration curve of gallic acid achieved in the concentration range 0 to 0.20 mg/mL. The extraction of phenolic compounds was performed in methanol: water = 50:50 and the absorbance of the extracts were determined at a wavelenght λ = 755 nm. Results were expressed as mg of Gallic Acid Equivalents (GAE) per g product.

Antioxidant capacity
The DPPH scavenging radical assay was conducted according to Horszwald and Andlauer (2011) with some modifications (concerning extract volumes of the used sample and reagents, using UV-VIS Jasco V 550 spectrophotometer). The reaction was performed in dark for 30 min (at ambient temperature) and after this time the absorbance was read at 517 nm. It was achieved the calibration curve Absorbance = f (Trolox concentration), in the concentration range 0-0.4375 mmol/L and the results were expressed as mg Trolox Equivalents per g product.

Microbiological analysis
The water activity (*A*w) was determined by an instrument Aquaspector AQS-2-TC, Nagy. The measurements were performed at 25ºC. Yeasts and molds were determined by the method SR ISO 21527-1: 2009. *Enterobacteriaceae* were determined according to the SR ISO 21528-2: 2008 method and *Escherichia coli* by SR ISO 16649-2: 2007 method. *Salmonella* was determined by the method SR EN ISO 6579:2003/AC: 2006.

RESULTS AND DISCUSSIONS

Sensory analysis
Sensory analysis plays an important role in characterizing the quality of food products. Results of sensory analysis of bakery products showed that the addition of powder of *Aronia melanocarpa,* in their composition, has not a negative effect on sensory characteristics (Figure 2).
So, the analyzed products were tested by an expert panel receiving qualifying „very good", with scores in the range 19.44-19.92, as follows: Biscuits with *Aronia* and cinnamon-19.44; Biscuits with *Aronia* and ginger-19.52; Bread with *Aronia* and seeds-19.76; Minibaguette with *Aronia* and seeds-19.92 (Figure 3).

Using of sourdough for fermentation and final proofing, in case of bread and minibaguette, give them an elastic and dense crumb, proper texture and in the same time intense and pleasant flavour.

Figure 2. Bakery products fortified with *Aronia*

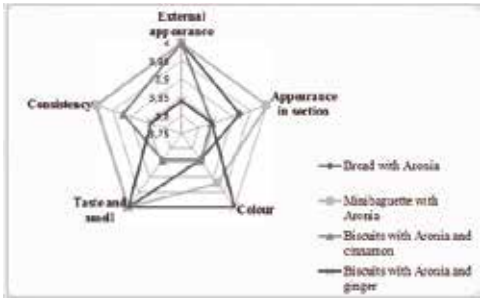

Figure 3. Sensory evaluation of bakery products fortified with *Aronia*

According to the results obtained, the darkest colour was recorded for the product „Biscuits with *Aronia* and ginger" (L* = 29.6), and the least intense for the product „Bread with *Aronia*" (L* = 40.18). In comparison with the achieved products, *Aronia* fruits have the most intense colour (L* = 18.55) (Figure 4).

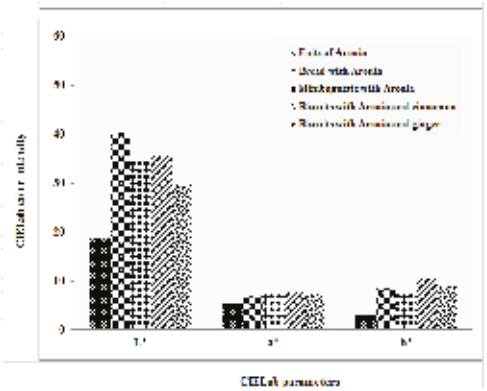

Figure 4. Colour parameters of *Aronia* fruits and bakery products fortified with *Aronia*

In the case of the four bakery products, the colour parameter *a** recorded close values (7.10 ... 7.84), while the colour parameter *b** varied in the range 7.45 ... 10.58 (the minimum value was recorded for the product „Minibaguette with *Aronia*" and the maximum one for the product „Biscuits with *Aronia* and cinnamon").

Texture properties of bakery products fortified with dried fruits of *Aronia melanocarpa,* during the shelf-life, packed in polypropylene film are presented in Tables 1 and 2.

Table 1. Texture properties of products Bread with *Aronia* and Minibaguette with *Aronia*

Product	Period, days	Firmness, N	Elasticity	Cohesiveness	Gumminess, N
Bread with *Aronia*	1	4.23 ± 0.27	0.91 ± 0.01	0.57 ± 0.07	2.41 ± 0.15
	2	5.11 ± 0.32	0.89 ± 0.04	0.48 ± 0.05	2.45 ± 0.16
	3	6.09 ± 0.59	0.85 ± 0.04	0.40 ± 0.05	2.44 ± 0.16
	4	7.08 ± 0.80	0.80 ± 0.04	0.35 ± 0.05	2.48 ± 0.19
	5	7.96 ± 1.07	1.00 ± 0.06	0.30 ± 0.02	2.35 ± 0.43
	6	8.83 ± 1.37	0.77 ± 0.23	0.25 ± 0.05	2.35 ± 0.74
	7	10.38 ± 2.29	0.76 ± 0.14	0.29 ± 0.03	2.96 ± 0.67
Minibaguette with *Aronia*	1	9.08 ± 0.88	0.91 ± 0.01	0.59 ± 0.03	5.90 ± 0.64
	2	15.46 ± 0.72	0.71 ± 0.15	0.36 ± 0.01	5.55 ± 0.15
	3	17.5 ± 0.75	0.65 ± 0.05	0.31 ± 0.03	5.43 ± 0.15
	4	20.73 ± 0.77	0.62 ± 0.02	0.29 ± 0.03	6.01 ± 0.17
	5	23.97 ± 0.80	0.59 ± 0.04	0.26 ± 0.03	6.23 ± 0.17
	6	27.2 ± 0.82	0.58 ± 0.01	0.28 ± 0.05	7.62 ± 0.19
	7	30.44 ± 0.84	0.56 ± 0.01	0.25 ± 0.03	7.61 ± 0.19

Table 2. *Texture* properties of products Biscuits fortified with *Aronia*

Biscuits with *Aronia* and cinnamon			Biscuits with *Aronia* and ginger		
Period, days	Firmness, N	Brittleness, MPa	Period, days	Firmness, N	Brittleness, MPa
1	11.26 ± 5.31	27.29 ± 6.09	1	14.91 ± 3.97	28.47 ± 8.08
8	20.48 ± 9.70	95.09 ± 11.06	8	32.91 ± 3.49	72.11 ± 16.94
16	27.49 ± 9.41	55.12 ± 24.89	16	36.06 ± 3.25	69.57 ± 4.21
23	28.43 ± 2.19	56.58 ± 9.35	23	41.87 ± 1.43	52.06 ± 4.92
29	29.60 ± 4.58	60.42 ± 6.87	29	47.81 ± 0.92	85.51 ± 12.81
36	32.35 ± 1.28	105.73 ± 9.43	36	55.10 ± 2.73	101.74 ± 4.27
43	35.71 ± 4.31	125.02 ± 49.36	43	62.36 ± 3.08	95.86 ± 9.22
51	35.83 ± 2.02	82.97 ± 4.58	51	71.37 ± 1.16	155.61 ± 22.26
58	37.20 ± 2.68	113.72 ± 27.20	58	74.78 ± 5.48	139.63 ± 6.83
65	41.13 ± 0.70	117.74 ± 34.33	65	78.10 ± 6.23	158.62 ± 12.99
72	45.25 ± 0.85	122.66 ± 19.46	72	85.22 ± 6.90	157.31 ± 0.63

Bread with *Aronia* had the lowest firmness, in comparison with those of Minibaguette with *Aronia*, due to the highest moisture content (41.69 ± 0.30%). During the 7 days firmness varied in the range 4.23 ... 10.38 N, in case of Bread with *Aronia*, and, respectively, 9.98 ... 30.44 N, in case of Minibaguette with *Aronia*. Elasticity and, respectively, cohesiveness, have values relatively close in case of those two bakery products. Although initially those two assortments of biscuits with *Aronia* have close values of firmness and brittleness, after 72 days of storage, Biscuits with *Aronia* and ginger have firmness of 1.84 times higher in comparison with Biscuits with *Aronia* and cinnamon, and brittleness of 1.28 times. This can be explained by difference in lipid content, water content and, in the same time, by difference in composition between those two biscuit assortments.

Physic-chemical analysis

Dried fruits of *Aronia melanocarpa,* used to fortify bakery and pastry products, have a complex biochemical composition, by total polyphenolic content, mineral elements and fibre content, especially. Their total polyphenolic content was 3180.90 ± 84.67 mg GAE/100 g, comparable with those reported by Kapci et al. (2013): 3990 ± 30 mg GAE/100 g, 5010 ± 50mg GAE/100 g, respectively. Also, fruits used within experiments had antioxidant capacity of 67.29 ± 2.82 mg Trolox/g, higher than those reported by Kapci et al. (2013): 36.3 ± 1.2 mg Trolox/g, respectively, 30.5 ± 1.0 mg Trolox/g. In the same time, dried fruits of *Aronia* are an important source of potassium (9693.3 ± 1095.34 mg/kg), calcium (1563.7 ± 161.22 mg/kg), magnesium (694.1 ± 109.95 mg/kg), iron (36.8 ± 1.10 mg/kg), zinc (6.36 ± 0.36 mg/kg) and fibres (16.50 g/100 g). Moisture of *Aronia* fruits was 10.2%, and total sugar content 30.25%.

Chemical composition of bakery products fortified with *Aronia* is presented in Table 3.

It is noteworthy that these products have high protein content (11.92 ... 12.95%), fibres (9.13 ... 16.60%) and mineral elements, ash varying between 1.51 ... 2.03%.

Due to the high fibres content and low sugar content (4.33 ... 5.79%), bakery products with *Aronia* can be beneficial in diet of peoples with type 2 diabetes and obesity.

Table 3. Chemical composition (%) of bakery products fortified with *Aronia*

Component	Bread with Aronia	Minibaguette with Aronia	Biscuits with Aronia and cinnamon	Biscuits with Aronia and ginger
Moisture	41.69±0.30	30.49±0.30	14.26±0.30	12.7±0.30
Protein	11.92±0.11	12.95±0.11	12.42±0.11	12.30±0.11
Fat	8.85±0.10	6.91±0.10	18.23±0.10	17.95±0.10
Total sugar	5.70±0.11	4.52±0.11	4.33±0.11	5.79±0.11
Reducing sugar	5.01±0.08	3.35±0.08	3.37±0.08	4.56±0.08
Carbohydrates	26.81±0.14	38.9*±0.14	38.60±0.14	39.44±0.14
Ash	1.60±0.01	1.51±0.01	2.03±0.01	1.91±0.01
Total dietary fiber	9.13±0.17	9.17±0.17	14.46±0.17	16.60±0.17
Energy[a]	252.83	268.21	397.07	393.61
Energy[b]	1058.90	1211.45	1665.85	1648.23

[a] Expressed as kcal/100 g product.
[b] Expressed as kJ/100 g product.

Also biscuits can have a beneficial effect on diabetes because they contain ingredients with hypoglicemiant effect: fruits of *Aronia melanocarpa,* ginger and cinnamon (Simeonov et al., 2002; Valcheva-Kuzmanova et al., 2007; Li et al., 2012; Lu et al., 2012).

Due to the used raw materials, the bakery products fortified with *Aronia* have high mineral element content (Table 4). The most abundant among investigated elements was potassium, its concentration varying in the range 4784,60 … 10547 mg/kg (maximum concentration was recorded for Minibaguette with *Aronia*).

Table 4. Mineral element content of bakery products fortified with *Aronia*

Component	Bread with Aronia	Minibaguette with Aronia	Biscuits with Aronia and cinnamon	Biscuits with Aronia and ginger
K, mg/kg	4784.60±540.07	10547.0±1191.81	5921.6±669.14	6513.7±735.91
Ca, mg/kg	1100.29±113.44	1598.57±164.81	1504.3±155.14	1691.4±174.38
Mg, mg/kg	839.2±112.91	1088.6±172.62	1020.3±162.99	1196.6±189.53
Fe, mg/kg	10.9*±0.33	16.1±0.42	57.29±1.75	65.27±1.96

Also, the achieved products have high calcium content, which varied between 1100.29 mg/kg (for Bread with *Aronia)* and 1691.4 mg/kg (for Biscuits with *Aronia* and ginger), being significantly higher than those obtained by Ajibola et al. (2015) in case of biscuits prepared from different blends of whole-wheat flour, *Moringa oleifera* leaves and cocoa powder (291.7 … 524.7 mg/kg) and, respectively, Mahmoud et al. (2012), in case of fenugreek supplemented biscuits (465.10 mg/kg d.w., respectively, 561.7 mg/kg d.w.). Magnesium content of products varied in the range 839.20 ... 1196.6 mg/kg, being comparable with those of the achieved biscuits by Vitali et al. (2009) with inulin added and one of the following raw materials: soy flour, amaranth, carob, apple fibre or oat fibre. The higher iron content was recorded for Biscuits with *Aronia* and ginger (65.27 mg/kg, higher than those reported by Vitali et al., 2009), and the lower, in case of Bread with *Aronia* (10.97 mg/kg).

Total polyphenol content

Fortification of bakery products with dried fruits of *Aronia melanocarpa* had a positive effect on total polyphenol content and their antioxidant properties. The biscuits present the highest total polyphenol content: 263.22 mg GAE/100g in case of Biscuits with *Aronia* and ginger and 221.58 mg GAE/100 g, respectively, in case of Biscuits with *Aronia* and cinnamon (Figure 5).

Total polyphenol content is higher than those reported by Mildner-Szkudlarz et al. (2013), in case of biscuits made from wheat flour and addition of 10% white grape pomace (211 mg GAE/100 g). Also, total polyphenol content of biscuits with *Aronia* exceeds those of biscuits supplemented with 10% germinated fenugreek (*Trigonella Foenum Graecum*) seeds flour: 196.58 mg GAE /100 g (Mahmoud et al., 2012).

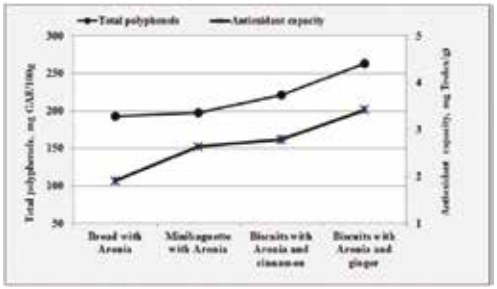

Figure 5. Total polyphenol content and antioxidant capacity of bakery products fortified with *Aronia*

Bread with *Aronia* and Minibaguette with *Aronia* had close values of total polyphenol content (193.34 mg GAE/100 g, respectively, 197.91 mg GAE/100 g), but small in comparison with biscuits. This fact can be explained by difference in composition (lower percentage of powder obtained from dried fruits of *Aronia melanocarpa*) and by higher value of moisture.

Total polyphenol content of those two bakery products is superior to those recorded in case of bread prepared with 10% of grape pomace powder (89.43 mg GAE/100 g; Hayta et al., 2014). Grape pomace presents high antioxidant capacity, due to high content in phenolic compounds, such as proanthocyanidins (Özkan et al., 2004).

It should be noted that bread prepared with sourdough mixed rye and four different levels: 4%, 6%, 8% and 10% of grape by-products has a significantly higher polyphenol content (334.32 ... 613.77 mg GAE/100 g d.m.), in comparison with bread assortments with *Aronia* (Mildner-Szkudlarz et al., 2011). These results were achieved mainly due to the high content of polyphenols of grape by-products (5895 ± 150 mg GAE/100 g d.m.), in comparison with those of the dried fruits of *Aronia*, and the difference in composition of products.

Bread with *Aronia* and Minibaguette with *Aronia* have a higher content of polyphenols than those recorded for bread with adding of 15% amaranth flour (173 ± 9 mg GAE/100 g d.m.) and of 15% quinoa flour (188 ± 7 mg GAE/100 g d.m.), respectively, and increase of dose of these pseudocereal flours, to 30%, determines an increase of total polyphenol content of the achieved breads: 261 ± 4 mg GAE/100 g d.m. in case of amaranth flour and 254 ± 10mg GAE/100 g d.m. in case of quinoa flour (Chlopicka et al., 2012). Also, in case of bakery with *Aronia*, there is an inversion relationship between total polyphenol content and colour parameter L*, demonstrating that presence of these compounds in composition of products determines dark colour of them (Figure 6).

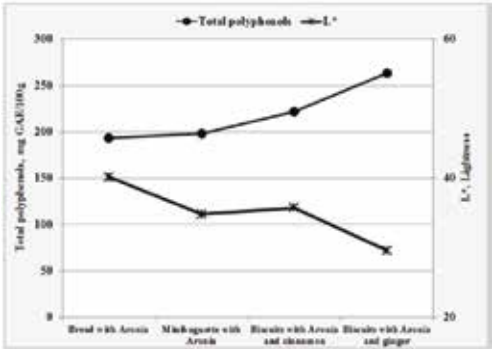

Figure 6. Correlation between total polyphenols and colour parameter L* in case of bakery products fortified with *Aronia*

Antioxidant capacity

Due, mainly, to phenolic compounds contained in powder of *Aronia*, bakery products fortified with it have antioxidant capacity which varied in the range: 1.91 ... 3.42 mg Trolox Equivalents/g (minimum value was recorded for Bread with *Aronia*, and the maximum one in case of Biscuits with *Aronia* and ginger).

Between total polyphenol content and antioxidant capacity there is a directly proportional relationship. The obtained results are consistent with those obtained by Zheng and Wang (2003), mentioning that content of polyphenols of fruits of *Aronia* was strongly correlates with their antioxidant capacity. In case of bakery products fortified with *Aronia* in this study, between total polyphenol content and antioxidant capacity there is a linear correlation, $R^2 = 0.8126$. Antioxidant capacity of biscuits with *Aronia* is higher than those recorded in case of biscuits enriched with grape marc extract: 0.79 ± 0.045 µmol Trolox/g (Pasqualone et al., 2014). Antioxidant capacity of those two assortments bread with *Aronia* (7.64 ± 0.73 µmol Trolox/g for bread and 11.16 ± 0.45 µmol Trolox/g, respectively, for minibaguette) is superior to bread which contains 2.5 ... 7.5% grape seed and has antioxidant capacity in the range 4.15 ... 6.28 µmol Trolox/g d.m. (Meral and Dogăn, 2013).

Microbiological analysis

Based on microbiological, sensory and peroxide index analyses it was established shelf-life of products with *Aronia*, as follows: Bread with *Aronia* - 7 days; Minibaguette with *Aronia* - 7 days; Biscuits with *Aronia* and cinnamon - 72 days; Biscuits with *Aronia* and ginger - 72 days.

Microbiological analysis of bakery and pastry products fortified with *Aronia*, at the end of shelf-life is presented in Table 5.

Table 5. Microbiological analysis of bakery products fortified with *Aronia*

Microbiological indicator	Bread with Aronia	Minibaguette with Aronia	Biscuits with Aronia and cinnamon	Biscuits with Aronia and ginger
Yeasts and molds, CFU/g	< 10	< 10	< 10	< 10
Enterobacteriaceae, CFU/g	< 10	< 10	< 10	< 10
Escherichia coli, CFU/g	< 10	< 10	< 10	< 10
Salmonella	absent/25 g	absent/25 g	absent/25 g	absent/25 g

Microbiological indicators determined come under provisions of the Commission Regulation (EC) No. 2073/2005 on microbiological criteria for foodstuffs.

During shelf-life water activity varied differentiated depending on product, as follows: Bread with *Aronia* - 0.938 ... 0.945; Minibaguette with *Aronia* - 0.926 ... 0.938; Biscuits with *Aronia* and cinnamon - 0.615 ... 0.834; Biscuits with *Aronia* and ginger - 0.694 ... 0.849.

Shelf-life relative high of bakery products fortified with *Aronia* can be explained mainly by antioxidant and antibacterial potential of fruits of *Aronia melanocarpa*. Bräunlich et al. (2013) have shown that *Aronia melanocarpa* extracts can inhibit bacterial growth of *Escherichia coli* and *Bacillus cereus in vitro*. Also, Liepiņa et al. (2013) have shown that extracts from fruits of *Aronia melanocarpa* and wild rowan (*Sorbus aucuparia* L.) inhibited the growth of Gram-negative bacterium *Pseudomonas aeruginosa* but did not have influence on *Escherichia coli.* However, in case of bread and minibaguette, lactic acid bacteria from sourdough used for fermentation and final proofing, act as a natural antibiotic, thereby increasing the shelf-life of these products.

CONCLUSIONS

This study showed that dried fruits of *Aronia melanocarpa* are an important source for fortification of bakery products. Bakery products achieved with adding of powder of dried fruits of *Aronia melanocarpa* have a complex biochemical composition and antioxidant potential.

Bakery products fortified with dried fruits of *Aronia melanocarpa* have a high polyphenol content (193.34 ... 263.22 mg GAE/100 g), proteins (11.92 ... 12.95%), fibres (9.13 … 16.60%), potassium (4784,60 … 10547 mg/kg), calcium (1100.2 ... 1691.4 mg/kg), magnesium (839.20 ... 1196.6 mg/kg) and iron (10.97 ... 65.27 mg/kg). Due to high content of fibres and low content of sugars (4.33 ... 5.79%), bakery products with *Aronia* can be included in diet of people with type 2 diabetes and obesity. Also, noteworthy is that those two assortments of biscuits with *Aronia*, contain ingredients with hypoglicemiant effect (fruits of *Aronia melanocarpa,* ginger and cinnamon) could have beneficial effects on glycemic equilibrium of consumers with type 2 diabetes.

Antioxidant capacity of bakery products fortified with dried fruits of *Aronia melanocarpa* varied in the range 1.91 to 3.42 mg Trolox Equivalents/g. Biscuits with *Aronia* and ginger recorded the higher value of

antioxidant capacity and Bread with *Aronia* had the minimum value.

Products achieved with *Aronia* received qualifying „very good" at sensory analysis, recording scores in the range: 19.44-19.92. Due to use of sourdough in composition, bread and minibaguette have crumb elastic and dense, proper texture and, in the same time, pleasant and intense flavour. Colour of products with *Aronia* was apreciated by expert panel receiving 4 or 5 points after evaluation. Biscuits with *Aronia* and ginger had the darker colour (L* = 29.6),

ACKNOWLEDGEMENTS

This study was achieved through Core Programme (PN 12 48), supported by the Ministry of Education and Scientific Research, contract 48 N/2012, project no. PN 12 48 01 03.

REFERENCES

Ajibola C.F., Oyerinde V.O., Adeniyan O.S., 2015. Physicochemical and Antioxidant Properties of Whole-Wheat Biscuits Incorporated with *Moringa oleifera* Leaves and Cocoa Powder. Journal of Scientific Research & Reports, 7 (3), 195-206.

Ara V., 2002. Schwarzfruchtige Aronia: Gesund - und bald „in aller Munde"?. Flüssiges Obst, 10, 653-658.

Benvenuti S., Pellati F., Melegari M., Bertelli D., 2004. Polyphenols, anthocyanins, ascorbic acid, and radicals scavenging activity of *Rubus*, *Ribes*, and *Aronia*. J Food Sci, 69, 164-169.

Borges G., Mullen W., Crozier A., 2010. Comparison of the polyphenolic composition and antioxidant activity of European commercial fruit juices. Food & Function, 1 (1), 73-83.

Bräunlich M., Økstad O.A., Slimestad R., Wangensteen H., Malterud K.E., Barsett H., 2013. Effects of *Aronia melanocarpa* Constituents on Biofilm Formation of *Escherichia coli* and *Bacillus cereus.* Molecules, 18, 14989-14999.

Chlopicka J., Pasko P., Gorinstein S., Jedryas A., Zagrodzki P., 2012. Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. LWT - Food Science and Technology, 46, 548-555.

Chrubasik C., Li G., Chrubasik S., 2010. The clinical effectiveness of chokeberry: A systematic review. Phytotherapy Research, 24, 1107-1114.

De Pascual-Teresa S., Sanchez-Ballesta M.T., 2008. Anthocyanins: from plant to health. Phytochemistry Review, 7, 281-299.

Hakkinen S., Heinonen M., Karenlampi S., Mykkanen H., Ruuskanen J., Torronen R., 1999. Screening of selected flavonoids and phenolic acids in 19 berries. Food Res Int, 32, 345-353.

Hayta M., Özuğur G., Etgü H., Şeker I.T., 2014. Effect of grape (*Vitis vinifera* L.) pomace on the quality, total phenolic content and anti-radical activity of bread**.** Journal of Food Processing and Preservation, 38, 980-986.

Horszwald A., Andlauer W., 2011. Characterisation of bioactive compounds in berry juices by traditional photometric and modern microplate methods. Journal of Berry Research, 1, 189-199.

Howard L.R., Prior R.L., Liyanage R., Lay J.O., 2012. Processing and storage effect on berry polyphenols: challenges and implications for bioactive properties. Journal of Agricultural and Food Chemistry, 60, 6678-6693.

Hudec J., Bakoš D., Mravec D., Kobida L., Burdova M., Turianica I., Hlušek J., 2006. Content of phenolic compounds and free polyamines in black chokeberry *(Aronia melanocarpa*) after application of polyamine biosynthesis regulators. J Agric Food Chem, 54, 3625-3628.

Jakobek L., Drenjančević M., Jukić V., Šeruga M., 2012. Phenolic acids, flavonols, anthocyanins and antiradical activity of 'Nero', 'Viking', 'Galicianka' and wild chokeberries. Scientia Horticulturae, 147, 56-63.

Kapci B., Neradová E., Čížková H., Voldřich M., Rajchl A., Capanoglu E., 2013. Investigating the antioxidant potential of chokeberry (*Aronia melanocarpa*) products. Journal of Food and Nutrition Research, Published online 23 October 2013.

Kähkönen M.P., Hopia A.I., Vuorela H.J., Rauha J., Pihlaja K., Kujala T.S., Heinonen M., 1999. Antioxidant activity of plant extracts containing phenolic compounds. J Agric Food Chem, 47, 3954-3962.

Kokotkiewicz A., Jaremicz Z., Luczkiewicz M., 2010. Aronia plants. A Review of traditional use, biological activities, and perspectives for modern medicine. Journal of Medicinal Food, 13, 255-269.

Kulling S.E., Rawel H.M., 2008. Chokeberry (*Aronia melanocarpa*) - a review on the characteristic components and potential health effects. Planta Medica, 74, 1625-1634.

Lehmann H., 1990. Die Aroniabeere und ihre Verarbeitung. Flüssiges Obst, 57, 340-345.

Li Y., Tran V.H., Duke C.C., Roufogalis B.D., 2012. Preventive and Protective Properties of *Zingiber officinale* (Ginger) in Diabetes Mellitus, Diabetic complications, and Associated Lipid and Other Metabolic Disorders: A Brief Review. Evidence-Based Complementary and Alternative Medicine, Volume 2012, Article ID 516870, 10 pages.

Liepiņa I., Nikolajeva V., Jākobsone I., 2013. Antimicrobial activity of extracts from fruits of *Aronia melanocarpa* and *Sorbus aucuparia.* Environmental and Experimental Biology, 11, 195-199.

Lu T., Sheng H., Wu J., Cheng Y., Zhu J., Chen Y., 2012. Cinnamon extract improves fasting blood glucose and glycosylated hemoglobin level in Chinese patients with type 2 diabetes. Nutr Res., 32 (6), 408-12.

Mahmoud N.Y., Salem R.H., Mater A.A., 2012. Nutritional and Biological Assessment of Wheat

Biscuits Supplemented by Fenugreek Plant to Improve Diet of Anemic Rats. Academic Journal of Nutrition, 1 (1), 01-09.

Meral R., Dogăn I.S., 2013. Grape seed as a functional food ingredient in bread-making. International Journal of Food Sciences and Nutrition, 64 (3), 372-379.

Mildner-Szkudlarz S., Zawirska-Wojtasiak R., Szwengiel A., Pacyński M., 2011. Use of grape by-product as a source of dietary fibre and phenoliccompounds in sourdough mixed rye bread. International Journal of Food Science and Technology, 46, 1485-1493.

Mildner-Szkudlarz S., Bajerska J., Zawirska-Wojtasiaka R., Górecka D., 2013. White grape pomace as a source of dietary fibre and polyphenols and its effect on physical and nutraceutical characteristics of wheat biscuits. Journal of the Science of Food and Agriculture, 93, 389-395.

Niedworok J., Brzozowski F., 2001. The investigation of a biological and phytotherapeutical properties of the *Aronia melanocarpa* E anthocyanins [in Polish]. Post Fitoter, 1, 20-24.

Ochmian I., Grajkowski J., Smolik M., 2012. Comparison of some morphological features, quality and chemical content of four cultivars of choke berry fruits (*Aronia melanocarpa*). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 40, 253-260.

Oszmiański J., Wojdyło A., 2005. *Aronia melanocarpa* phenolics and their antioxidant activity. Eur Food Res Technol, 221, 809-813.

Özkan G., Sagdic O., Baydar N.G., Kurumahmutoglu Z., 2004. Antibacterial activities and total phenolic contents of grape pomace extracts. J. Sci. Food Agric., 84, 1807-1811.

Pasqualone A., Bianco A.M., Paradiso V.M., Summo C., Gambacorta G., Caponio F., 2014. Food Research International, 65, 385-393.

Simeonov S.B., Botushanov N.P., Karahanian E.B., Pavlova M.B., Husianitis H.K., Troev D.M., 2002. Effects of *Aronia melanocarpa* juice as part of the dietary regimen in patients with diabetes mellitus. Folia Med (Plovdiv), 44, 20-3.

Sueiro L., Yousef G.G., Seigler D., De Mejia E.G., Grace M.H., Lila M.A., 2006. Chemopreventive potential of flavonoid extracts from plantation-bred and wild *Aronia melanocarpa* (black chokeberry) fruits. J Food Sci, 71, 480-488.

Šnebergrová J., Čížková H., Neradová E., Kapci B., Rajchl A., Voldřich M., 2014. Variability of characteristic components of Aronia. Czech J. Food Sci., 32, 25-30.

Valcheva-Kuzmanova S., Kuzmanov K., Tancheva S., Belcheva A., 2007. Hypoglycemic and hypolipidemic effects of *Aronia melanocarpa* fruit juice in streptozotocin-induced diabetic rats. Methods Find Exp Clin Pharmacol, 29, 101-5.

Vitali D., Vedrina Dragojević I., Šebečić B., 2009. Effects of incorporation of integral raw materials and dietary fibre on the selected nutritional and functional properties of biscuits. Food Chemistry, 114, 1462-1469.

Weinges K., Schick H., Schilling G., Irngartinger H., Oeser T., 1998. Composition of an anthocyan concentrate from *Aronia melanocarpa* Elliot-X-ray analysis of tetraacetyl parasorboside. Eur J Org Chem, 1, 189-192.

Wolski T., Kalisz O., Prasał M., Rolski A., 2007. Black chokeberry - *Aronia melanocarpa* (Michx.) Elliot-the rich source of antioxidants [in Polish]. Post Fitoter, 3, 145-154.

Zheng W., Wang S.Y., 2003. Oxygen radical absorbing capacity of phenolics in blueberries, cranberries, chokeberries, and lingonberries. Journal of Agricultural and Food Chemistry, 51 (2), 502-509.


EX·TERRA·AVRVM