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Changes in the nutritional value of breakfast cereals containing germinated spring grain flakes during storage

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Abstract. The aim of current research was to assess the nutritional value of breakfast cereals containing germinated spring grain flakes and its changes after 6 month storage. Three types of breakfast cereals were prepared and packaged in two types of Standup pouches – Pap50g/Alu7/Pe60 (AL), Pap40g/PELD20/PE40 (PE). For the accelerated shelf life test the samples were stored at 35 ± 2 °C and dietary fibre, protein, fat, B-group vitamins, sugars, total phenol content and DPPH, ABTS+ radical scavenging activity were determined. Developed breakfast cereals have high nutritional value and all are high in fibre and thiamine. Additionally, sample S2 is source of protein, riboflavin, niacin, and S3 – is source of riboflavin and high in niacin. Comparing total phenolic content and antioxidant capacity of tested samples S3 showed the highest values. Storage and selected packaging influenced stability of nutrients, and for S1 and S2 AL showed better results whereas for S3 – PE.

Key words: breakfast cereals, nutritional value, germination, spring cereals, packaging, storage.

INTRODUCTION

Breakfast cereals are popular food product and different approaches are developed to improve their nutrition quality by use of whole grain cereals, cereals not widely used in similar products like germinated cereals, triticale (further – non-traditional cereals), specific ingredients or processes with beneficial effect to final product. Whole grain products are increasingly being used in food, due to their beneficial composition – increased content of fibre, vitamins, minerals and phytochemicals, including phenolics, carotenoids, vitamin E, lignans, β-glucan, inulin, resistant starch, sterols, and phytates (Lafiandra et al., 2014; Oliveira et al., 2015; Sumczynski et al., 2015; Bucsella et al., 2016). Non-traditional types of cereals contain significant amounts of biologically active compounds and can be assumed that breakfast flakes and muesli products made from non-traditional cereals will have higher nutritional properties (Sumczynski et al., 2015).

Cereal consumption as part of a healthy lifestyle may play a role in maintaining adequate nutrient intake all day long and the study about selection of breakfast cereals in diet, showed that the main parameters determining the beneficial effects in the body is increased amount of fibre, protein, calcium and reduced fat content (Barton et al., 2005; Albertson et al., 2008). Dietary fibre is important for a healthy diet and can lower risk factors for cardiovascular disease and type 2 diabetes mellitus (Lafiandra et al., 2014). Also, cereals contain various essential nutrients including B-group vitamins (Capozzi et al., 2012). Human body does not accumulate B-group vitamins and that is why, in order to comply with daily recommended intake, products enriched in B-group vitamins should be included in every meal (Lebiedzińska & Szefer, 2006).

For development of breakfast cereals it is important to combine different raw materials to obtain products with the target composition. Barley is a desirable food ingredient, with health benefits provided by a β-glucan fibre fraction (Škrbić et al., 2009). Hull-less barley flakes have better nutritional value than hulled ones and they contain more proteins, lipids and soluble dietary fibre (Soares et al., 2007). Oat flakes are the main commercial oat products around the world (Hu et al., 2014). β-glucan is the major form of soluble dietary fibre in oat, and it is known for its effectiveness in lowering blood cholesterol (Kapica, 2001). Rye grain contributes significant quantities of energy, protein, selected micronutrients and non-nutrients to a human diet (Edge et al., 2005) Wheat is one of the oldest food crops, which has achieved a central role as a staple food and contains different classes of bioactive compounds as phenolic acids, carotenoids, tocopherols, alkylresorcinols, etc. (Luthria et al., 2015). Triticale is a hybrid crop developed by crossing wheat (Triticum) and rye (Secale cereale). Comparing to wheat triticale has similar content of protein (Fraś et al., 2016), with a slightly higher amount of lysine (0.33–0.71%) and also similar content of fibre, but with a higher amount of soluble fraction, especially water-extractable arabinoxylans (Rakha et al., 2011).

Germination is a complex process causing physical, chemical, and structural changes in grains, and has been identified as an inexpensive and effective technology for improving cereal quality (Wu et al., 2013). During the germination process a significant changes in the biochemical, nutritional, and sensory characteristics of cereals occur due to degradation of reserve materials used for respiration and synthesis of new cell constituents for developing embryo in the seed. As compared to un-germinated seed, germinated seeds contain high protein, vitamin, low unsaturated fatty acids, low carbohydrate content (Sharma et al., 2016).

For preserving quality of food products an optimum package design should balance the packaging material properties, product protection requirements, environmental and transport conditions, and cost (Macedo et al., 2013). Breakfast cereals are traditionally packed in different paper pouches, and for packaging of breakfast cereal products a paper or polymer package, with particular emphasis on the moisture permeability must be selected.

Development of breakfast cereals should result in high fibres and B group vitamins, formulation made using hull-less grains and germinated samples from barley, oat, rye and wheat to prepare nutritionally enriched breakfast cereals.

The aim of current research was to assess the nutritional value of breakfast cereals containing germinated spring grain flakes and its changes after 6 month storage.

MATERIALS AND METHODS

Raw materials

The grains of hull-less barley (cv 'Irbe'), hull-less oat (cv 'Lizete'), rye (cv 'Kaupo'), and wheat (cv 'Elvis') conventionally grown at Institute of Agricultural Resources and Economics (Latvia) in 2015, and triticale (cv 'Tulus') cultivated at Norwegian Institute for Agricultural and Environmental Research (Norway) in 2015 were used in the study. Varieties for breakfast cereals were selected based on their nutritional composition. The following experiments were carried out in the scientific laboratories of the Faculty of Food Technology, Latvia University of Agriculture. Cereal germination, flaking and drying was done according to methodology described by Kince et al. (2017).

Preparation of breakfast cereals

Three types of breakfast cereals with increased nutritional value were developed selecting raw materials (germinated and ungerminated cereals) based on their chemical composition (Fig. 1). Sample S1 was developed from the cereals with higher content of fibre (triticale, germinated triticale, rye, germinated hull-less oats, and germinated hull-less barley (germinated cereals – 40%)). Sample S2 was developed from the cereals with increased content of proteins (triticale, oats, germinated wheat, germinated triticale, and germinated hull-less barley (germinated cereals – 30%)). Sample S3 was developed from the cereals with high B group vitamin content (rye, triticale, germinated rye, germinated hull-less barley, germinated hull-less oats, and wheat (germinated cereals – 50%)).

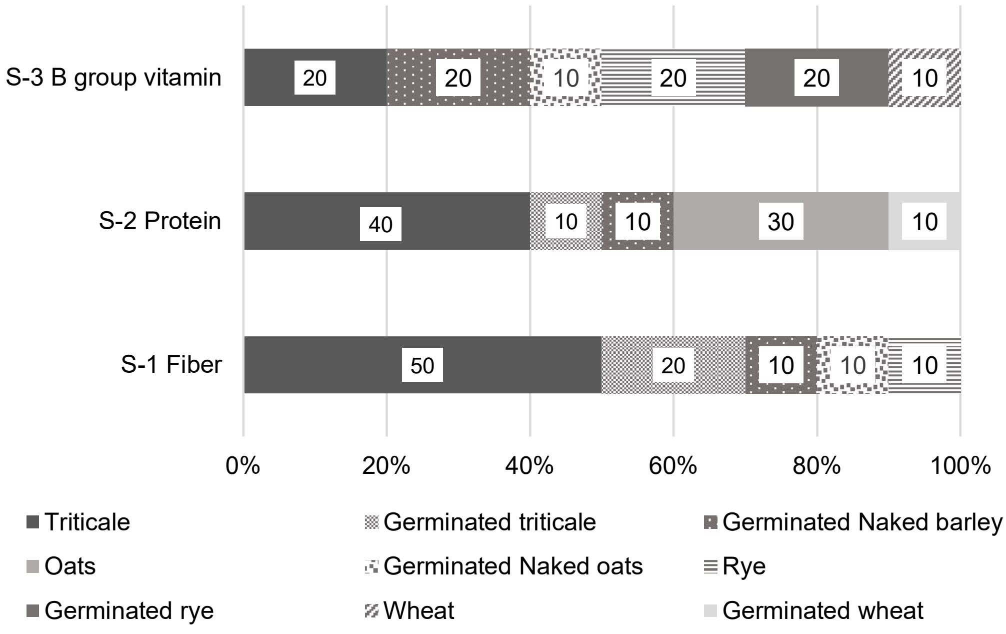

Figure 1. Recipes of developed breakfast cereals.

Packaging and storage of breakfast cereals

Breakfast cereals samples were packaged in *Doypack* (stand up pouches) made from Pap50g/Alu7/Pe60 (Pap/Alu/PE) and stand up pouches Fibrecote® HB MG 40/60 (PE/EvOH/Pap). The size of Doypack was 110 × 65 × 185 mm, volume – 250 mL, the amount of breakfast cereals in each package was 200 ± 5 g. Samples were stored for 6 months at temperature t = 35 ± 2 °C and relative air humidity φ = 55 ± 3%. Abbreviations of the samples stored for 6 month in *Doypack* made from Pap/Alu/PE are as follows: S1-Pap/Alu/PE, S2- Pap/Alu/PE, S3- Pap/Alu/PE, and for samples stored in PE/EvOH/Pap: S1- PE/EvOH/Pap, S2- PE/EvOH/Pap, S3- PE/EvOH/Pap.

Analytical methods

Total protein content was determined by Kjeldahl; standard method AACC 46-20. Total fat content was determined by the standard method ISO 6492. Dietary fibre was determined according to the standard method AOAC No 985.29 using Fibertec E System (Foss, Sweden). Sugars were determined by HPLC as described by Senhofa et al. (2016). *B-group vitamins* were determined by the following methods: vitamin B_1 (thiamine) – AOAC Official Method 986.27, vitamin B_2 (riboflavin) – AOAC Official Method 970.65, vitamin B_3 (niacin) – AOAC Official Method 961.14., vitamin B_5 (pantothenic acid) – AOAC Official Method 992.07, vitamin B_6 – AOAC Official Method 985.32.

Total phenol content and antioxidant activity

Extraction for determination of total phenol content and antioxidant activity of breakfast cereals were performed as described in previous experiments about germinated grains (Kruma et al., 2016). The total phenolic content (TPC) of the grain extracts was determined according to the Folin-Ciocalteu spectrophotometric method (Singleton et al., 1999). Total phenols were expressed as the gallic acid equivalents (GAE) 100 g^{-1} dry weight (DW) of grain material. Antioxidant activity of the breakfast cereal extracts was measured on the basis of scavenging activities of the stable 2,2-diphenyl-1-picrylhydraziyl (DPPH) radical as outlined by (Yu et al., 2003). The absorbance was measured at 517 nm. The cation scavenging activity of extract was measured by 2,2′-azino-bis(3-ethylbenz-thiazoline-6-sulfonic) acid ($ABTS^+$) radical cation assay (Re et al., 1999). The radical scavenging activity was expressed as Trolox equivalents (TE) 100 g^{-1} DW of plant material.

Statistical analysis

Experimental results are presented as means of three parallel measurements and were analysed by Microsoft Excel 2010 and SPSS 17.00. Analysis of variance (ANOVA) and Tukey test were used to determine differences among samples. A linear correlation analysis was performed in order to determine relationship between TPC, antioxidant activity such as DPPH˙, ABTS+. Differences were considered as significant at $P < 0.05$.

RESULTS AND DISCUSSION

Nutritional composition of breakfast cereals

Data on the nutritional composition and energy value of three developed breakfast cereal types is shown in Table 1. The highest content of fats was in the sample S2.

Fat content of various cereals differs significantly and the highest content is in oats (Koletta et al., 2014). The sample S2 contained the highest proportion of oats (30%), comparing to S1 (10%) and S3 (10%), thus it had the highest fat content.

The parameters presented in Table 1 indicates that the main compounds providing beneficial nutritional value of breakfast cereal are proteins and fibre. In regulation (Regulation (EC) No 1924/2006) it is determined that product can be labelled as source of protein if at least 12% of energy value is provided by proteins. Comparing the analysed samples, only in S2 it exceeds the required value, reaching 12.23%.

Breakfast cereals were made from whole grains. Wholegrain wheat flour has lower protein content comparing to bread wheat flour (Bucsella et al., 2016). In non-traditional wheat flakes crude protein content ranged between 11.9% and 16.1% (Sumczynski et al., 2015). Analysed breakfast cereal samples contained raw materials that differed in protein content. Rye whole grain flours has significantly lower protein content comparing to whole grain wheat flour (Bucsella et al., 2016). Comparing different grains the lowest protein content was observed for oat flakes (13.58%) whereas the highest was for rye wholegrain flour (Koletta et al., 2014). In whole grain oat flours protein content is 13 g per 100 g whereas proteins in whole grain triticale flours were 11.5% (Fraś et al., 2016). As part of raw materials are germinated also it is necessary to take into account transformations of proteins during germination process. Comparing raw materials wheat and oats contain more proteins, and it could explain higher content of proteins in S2 because these cereals contained the highest (40%) ratio of these cereals, comparing to S1 (10%) and S3 (20%).

Table 1. Nutritional composition and energy value of breakfast cereals

Parameters per 100 g	Samples [A]		
	S1	S2	S3
Fats, g	1.87 ± 0.06[a*]	2.72 ± 0.03[b]	1.87 ± 0.08[a]
Carbohydrates, g	61.44 ± 1.62[b]	57.84 ± 0.94[a]	57.52 ± 1.9[a]
Protein, g	8.82 ± 0.11[a]	10.05 ± 0.22[c]**	9.04 ± 0.11[b]
Fibre, g	15.12 ± 0.16[a]*	16.27 ± 0.02[b]*	18.08 ± 0.26[c]*
Ash, g	1.21 ± 0.03[a]	1.50 ± 0.07[b]	1.77 ± 0.05[c]
Energy value, kcal	328[b]	329[b]	319[a]
Energy value, kJ	1,385[b]	1,385[b]	1,345[a]
Energy value provided by proteins, %	10.75[a]	12.23[c]**	11.33[b]

[A] Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the row are not significantly different ($P < 0.05$).

* According to regulation (EC) No 1924/2006 product can bear nutrition claim High Fibre.

Breakfast cereals were developed using whole grain flakes, as a result all three samples had high fibre content – 15.12 g 100 g^{-1}, 16.27 g 100 g^{-1}, 18.08 g 100 g^{-1} in samples S1, S2, S3, respectively. Based on the Regulation all three samples can be labelled with nutritional claim high fibre. A claim that a food is high in fibre, may be made only where the product contains at least 6 g of fibre per 100 g of product. Cereal dietary fibre contributes to the health benefits associated with the consumption of whole grain cereal products, including reduced risk of obesity, type 2 diabetes, cardiovascular disease and colorectal cancer (Lafiandra et al., 2014).

Energy value of the sample S3 was lower, comparing to S1 and S2 due to the lower content of carbohydrates and higher content of fibre.

The analysed breakfast cereals were characterised by a variable content of B-group vitamins and the Table 2 demonstrates percentages of significant values provided by 100 grams of breakfast cereals relative to nutrient reference value (NRV). The highest content of thiamine was determined in the sample S3 and sample S2, which contains 61% and 53% of NRV per 100 grams of product, respectively. Riboflavin content was similar in sample S2 (27% of NRV) and sample S3 (26% of NRV). The highest niacin content was determined in sample S3 (6.39 mg 100 g^{-1}, providing 40% of NRV). Panthotenic acid and vitamin B_6 content was relatively low in all the analysed products. Cereals contain B-group vitamins, but during processing as milling, cooking etc. their content is reduced (Capozzi et al., 2012) whilst in the current technology minimal thermal treatment of cereals was applied and it resulted in relatively high content of B-group vitamins in new breakfast cereals. Also whole grain products and seeds, are better sources of the B-group vitamins than technologically processed products, and therefore more nutritionally efficacious (Lebiedzińska & Szefer, 2006).

Table 2. Content of B-vitamins in breakfast cereals (mg 100 g^{-1}) and nutrient reference values

Vitamin	Samples [A]			Source of vitamin	High vitamin
	S1	S2	S3		
Thiamine (B_1)	0.35 ± 0.01^{a}*	0.58 ± 0.02^{b}**	0.67 ± 0.01^{c}**	0.165	0.33
Riboflavin (B_2)	0.18 ± 0.00^{a}	0.38 ± 0.02^{b}*	0.36 ± 0.01^{b}*	0.21	0.42
Niacin (B_3)	3.85 ± 0.10^{a}*	4.5 ± 0.16^{b}*	6.39 ± 0.17^{c}**	2.4	4.8
Pantothenic acid (B_5)	0.35 ± 0.02^{b}	0.26 ± 0.01^{a}	0.25 ± 0.02^{a}	0.9	1.8
Vitamin B_6	0.07 ± 0.01^{b}	0.06 ± 0.00^{a}	0.08 ± 0.01^{b}	0.21	0.42

[A] Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the row are not significantly different ($P < 0.05$).

* According to regulation (EC) No 1924/2006 and Regulation (EU) No 1169/2011 product can bear nutrition claim Source of Vitamin (Name) if it provides more than 15% of NRV, and NRV for riboflavin is 1.4 mg 100 g^{-1}, niacin 16 mg 100 g^{-1}, pantothenic acid 6 mg 100 g^{-1}, vitamin B_6 1.4 mg 100 g^{-1}.

** According to regulation (EC) No 1924/2006 product can bear nutrition claim High Vitamin (Name) if it contains at least double value specified for source of vitamin.

In general addition of germinated flakes for nutritive value improvement is beneficial because germination increases protein and carbohydrate digestibility, increases vitamin bioavailability, and antioxidants activity (Donkor et al., 2012).

Changes of nutritional value after 6 month storage

During storage significant decrease in content of fats was observed but tendencies was influenced by both sample and packaging material (Table 3). Reduction of fat content most probably is the result of oxidation. Breakfast cereals were prepared by avoiding thermal treatment to maintain biologically active substances, but in unheated samples due to lipase activity in oat, hydrolysis of lipids to free fatty acids starts, which furthermore may promote lipid oxidation during storage (Lampi et al., 2015). No significant changes in total protein content during storage were observed.

Table 3. Content of total fat and protein content of breakfast cereals

Samples	Fats, g 100 g^{-1} DW ^{A}	Proteins, g 100 g^{-1} DW ^{A}
S1	2.11 ± 0.07^{c}	9.99 ± 0.12^{a}
S1-Pap/Alu/PE	1.68 ± 0.01^{b}	10.23 ± 0.15^{a}
S1-PE/EvOH/Pap	1.23 ± 0.05^{a}	10.05 ± 0.13^{a}
S2	3.08 ± 0.03^{b}	11.37 ± 0.25^{a}
S2-Pap/Alu/PE	3.04 ± 0.08^{b}	11.35 ± 0.03^{a}
S2-PE/EvOH/Pap	2.42 ± 0.06^{a}	11.38 ± 0.08^{a}
S3	2.12 ± 0.09^{b}	10.24 ± 0.12^{a}
S3-Pap/Alu/PE	0.88 ± 0.04^{a}	10.26 ± 0.06^{a}
S3-PE/EvOH/Pap	2.05 ± 0.07^{b}	10.21 ± 0.08^{a}

^{A} Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

Changes of fibre content during storage was significant and decrease of insoluble and soluble fibre was observed. Insoluble fibre content decreased less, reaching 13% in S3-PE/EvOH/Pap, whereas soluble fibre was more unstable and the highest decrease reached 65% in S2-PE/EvOH/Pap (Table 4).

Table 4. Fibre in breakfast cereals (g 100 g^{-1} DW) ^{A}

Samples	Insoluble fibre	Soluble fibre	Ratio soluble: insoluble	Total fibre
S1	13.92 ± 0.33^{a}	3.18 ± 0.13^{b}	1:4	17.09 ± 0.18^{b}
S1-Pap/Alu/PE	13.74 ± 0.62^{a}	2.46 ± 0.10^{a}	1:6	16.19 ± 0.05^{a}
S1-PE/EvOH/Pap	15.21 ± 0.17^{a}	2.69 ± 0.18^{a}	1:5	17.91 ± 0.15^{c}
S2	16.28 ± 0.35^{b}	2.13 ± 0.16^{c}	1:8	18.41 ± 0.03^{c}
S2-Pap/Alu/PE	14.51 ± 0.53^{a}	1.42 ± 0.14^{b}	1:10	15.93 ± 0.02^{a}
S2-PE/EvOH/Pap	16.28 ± 0.26^{b}	0.73 ± 0.08^{a}	1:22	17.01 ± 0.03^{b}
S3	17.19 ± 0.78^{c}	4.43 ± 0.33^{b}	1:4	20.48 ± 0.30^{c}
S3-Pap/Alu/PE	16.22 ± 0.09^{b}	2.02 ± 0.26^{a}	1:8	18.24 ± 0.03^{a}
S3-PE/EvOH/Pap	14.91 ± 0.14^{a}	4.12 ± 0.14^{b}	1:4	19.03 ± 0.06^{b}

^{A} Results are expressed as mean values ($n = 3$) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different ($P < 0.05$).

For tested samples the lowest proportion of soluble fibre was found in S2 and during storage it decreased significantly, reaching ratio 1:22 in S2-PE/EvOH/Pap. In this sample was the highest proportion of oats (30%), and oat grain is rich in dietary fibre (10–12%) with the soluble component accounting for about 55% of the total fibre (Singh et al., 2013).

Sugars during storage also changed significantly and for monosaccharides as fructose and glucose significant increase was observed, whereas content of disaccharide – sucrose decreased significantly, and maltose was not detected in any of the samples after storage (Table 5).

Table 5. Sugars in breakfast cereals (g 100 g^{-1} DW) ^{A}

Sample	Fructose	Glycose	Sucrose	Maltose	Sum of identified sugars
S1	0.08 ± 0.00^{a}	0.15 ± 0.00^{a}	0.55 ± 0.02^{b}	0.75 ± 0.03	1.53
S1-Pap/Alu/PE	0.55 ± 0.02^{b}	0.92 ± 0.02^{b}	0.24 ± 0.01^{a}	n.d.	1.71
S1-PE/EvOH/Pap	0.64 ± 0.02^{c}	0.87 ± 0.02^{b}	0.22 ± 0.01^{a}	n.d.	1.73
S2	0.28 ± 0.02^{a}	0.15 ± 0.01^{a}	0.73 ± 0.02^{c}	0.54 ± 0.04	1.7
S2-Pap/Alu/PE	0.68 ± 0.02^{b}	0.80 ± 0.02^{b}	0.24 ± 0.01^{b}	n.d.	1.72
S2-PE/EvOH/Pap	0.89 ± 0.02^{c}	0.84 ± 0.02^{b}	0.16 ± 0.01^{a}	n.d.	1.89
S3	0.10 ± 0.00^{a}	0.19 ± 0.01^{a}	0.77 ± 0.04^{c}	1.18 ± 0.02	2.24
S3-Pap/Alu/PE	0.36 ± 0.02^{b}	1.07 ± 0.03^{b}	0.07 ± 0.01^{a}	n.d.	2.2
S3- PE/EvOH/Pap	0.70 ± 0.02^{c}	1.20 ± 0.04^{b}	0.26 ± 0.02^{b}	n.d.	2.16

^{A} Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different (P < 0.05).

One of the reasons for increase of simple sugars could be breakage of starch by enzymes that are activated during germination. During the germination, the most significant changes occur in starch, which is broken to simpler sugars by amylases. Starch degradation changes during the sprouting process directly affects grain germination temperature, germination time, relative humidity, moisture content, culture media, steeping time and light (López-Amorós et al., 2006; Kruma et al., 2016).

TPC in breakfast cereals differed significantly and the highest content was observed in sample S3 (Table 6).

Table 6. Phenolic compounds and antioxidant activity

Samples	TPC, mg 100 g^{-1} DW ^{A}	DPPH, mM 100 g^{-1} DW ^{A}	ABTS, mM 100 g^{-1} DW ^{A}
S1	47.79 ± 1.79^{c}	2.63 ± 0.05^{a}	4.40 ± 0.15^{a}
S1-Pap/Alu/PE	43.01 ± 0.81^{a}	3.76 ± 0.07^{b}	5.57 ± 0.27^{b}
S1-PE/EvOH/Pap	45.11 ± 0.54^{b}	3.6 ± 0.17^{b}	5.69 ± 0.18^{b}
S2	47.02 ± 0.48^{b}	2.74 ± 0.03^{a}	5.98 ± 0.13^{a}
S2-Pap/Alu/PE	35.38 ± 0.56^{a}	3.28 ± 0.09^{b}	6.27 ± 0.14^{b}
S2-PE/EvOH/Pap	35.63 ± 2.12^{a}	3.38 ± 0.05^{b}	6.62 ± 0.23^{b}
S3	57.01 ± 2.17^{c}	3.42 ± 0.13^{a}	6.23 ± 0.18^{b}
S3-Pap/Alu/PE	48.40 ± 0.54^{b}	3.96 ± 0.16^{b}	7.27 ± 0.43^{c}
S3-PE/EvOH/Pap	41.29 ± 1.88^{a}	3.79 ± 0.16^{b}	5.28 ± 0.08^{a}

^{A} Results are expressed as mean values (n = 3) ± standard deviation. Mean values followed by the same letter within the column for the each sample group separately are not significantly different (P < 0.05).

This sample contained the highest proportion of hull-less barley, followed by rye and wheat and previous results showed that these cereals has higher TPC (Kruma et al., 2016). During storage TPC significantly decreased in all tested samples. The highest decrease was detected in sample S2, and it was similar for both S2- Pap/Alu/PE and S2- PE/EvOH/Pap, 24.75%, 24.22%, respectively. Packaging material influenced TPC in sample S3.

DPPH and ABTS scavenging activity during storage significantly increased, except sample S3- PE/EvOH/Pap. The highest increase of 29.32% was observed in S1- PE/EvOH/Pap. For S3 sample contrary results were found, in S3- Pap/Alu/PE increase for 16.7% whereas for S3-PE/EvOH/Pap 15.2% decrease was observed. Radical scavenging activity, analysed by both assays in S1 and S2 was significantly higher. Contrary to phenolic compounds, scavenging activity during storage increased in all three tested samples.

To understand the role of phenolic compounds in antioxidant activity of flakes, correlation analyses were performed. No correlation between TPC and DPPH scavenging activity (r = 0.08) and TPC and ABTS scavenging activity (r = 0.05) was observed. Only between both tested antioxidant assays moderate correlation (r = 0.47) was determined. The cereals with high TPC are not efficient for DPPH inhibition and it could be explained by ferulic acid, the main phenolic acid in cereal grains, which showed a weak antiradical effect in experiments with the DPPH radical, which may explain the discrepancies (Đorđević et al., 2010). Also it could be explained by the contribution of other compounds to antioxidant activity.

Phenolic compounds have been investigated due to their diverse health benefits as antioxidants both in food and in human body. Thereby for selection of packaging material it is also important to select material for the best presevation of phenolic compounds. In current experiment accelerated storage test was performed, and it could also influence changes of phenolic compounds and antioxidant acitivity. But results about processing of sorghum with dry heat did not affect the total phenolic compounds and antioxidant activity, whereas the wet heat decreased total phenolic compounds and antioxidant activity (Cardoso et al*.,* 2014). Also in the sorghum TPC reduced after storage for 180 days at a temperature of 40°C, the retentions of these compounds were high, 87.6% in flour and 93% in grains (Oliveira et al., 2017).

The permeability of packaging materials to water vapour and oxygen as well as light transmittance are critical factors determining the quality and bio-chemical stability of dried products during storage. Aluminum polyethylene pouches, with a greater protective barrier, better preserved TPC and the antioxidant compared to polyamide/polyethylene pouches (Udomkun et al., 2016). Our results showed that breakfast cereal composition also is critical factor and in the current research the highest decrease of TPC in S3 was detected and it could be explained by the highest proportion of germinated grains. These samples were microwave vacuum dried at low temperature and still some enzymatic activity may remain resulting in oxidation of phenolic compounds.

As different whole grains have different composition and health benefits, technologies should be developed to allow the use of versatile grain raw materials, also multigrain products and new product concepts. More varied use of raw materials and ingredients would also diversify the taste of cereal foods' (Poutanen et al., 2014). Developed breakfast cereals are multigrain products, with additional value of germinated cereals, but it also can cause problems in stability of product during its storage.

CONCLUSIONS

Breakfast cereals containing germinated grains has high nutritional value. All developed samples are high in fibre and thiamine (vitamin B1). Additionally S2 is a source of protein, riboflavin (vitamin B2) and niacin (vitamin B3); S3 – is a source of riboflavin (vitamin B2) and high in niacin (vitamin B3). Comparing TPC and antioxidant capacity of tested samples S3 showed the highest values. Storage and selected packaging material influenced stability of nutrients, except proteins. During storage fat content and TPC reduced, whereas antioxidant activity increased. For better preserving of samples nutrition value for S1 and S2 Pap50g/Alu7/Pe60 (AL) but for S3 Pap40g/PELD20/PE40 (PE) should be selected.

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