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EFFECT OF BARLEY β-GLUCAN ADDITION AS A FAT REPLACER ON MUFFIN QUALITY

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ABSTRACT

Background. The aim of this study was to perform the partial replacement of bakery fat with barley β-glucan in muffins and to determine its effect on the physical properties of products. Most shortenings used in the industry are solid fats rich in saturated fatty acids and often *trans* fatty isomers, which are nutritionally unfavorable.
Material and methods. Dough and baked muffins were used as the research material. Five muffin recipes were prepared: control (K0%) with 16% fat content in the total dough weight, with fat content decreased by 10% (PG10%), 15% (PG15%), 20% (PG20%) and 25% (PG25%). β-glucan was used as a fat replacer in the 1:4 ratio. The parameters determining the physical characteristics and sensory attributes were measured, compared and statistically analyzed using a principal component analysis (PCA) method.
Results. Although the partial replacement of shortening with barley β-glucan is possible, it may negatively influence the physical properties of dough (aeration) and baked products (volume, density). It has been observed that increasing the content of this fat replacer enlarges the pores of the crumb. The textural properties of muffins with a fat content decreased by 20% are most similar to the control. Moreover, it has been shown that the overall sensory quality goes down when the amount of fat replacer in the muffin recipe is increased. However, adding β-glucan to products in which fat content was decreased by 10% did not influence significantly the typical taste.
Conclusion. Despite the adverse effect of β-glucan on the physical and sensorial properties, it was found to be reasonable to use it even in small amounts (up to 10%) to increase the nutritional value of products.

Key words: texture analysis, β-glucan, porosity, PCA, fat replacer, nutrition value

INTRODUCTION

Snacks such as bakery and confectionary products are becoming more popular among consumers. However, these products might be a source of nutritionally unfavorable fats. Most shortenings used in the industry are solid fats rich in saturated fatty acids and often *trans* fatty isomers, which are nutritionally unfavorable (Onacik-Gür et al., 2014; Ribeiro et al., 2009).

Fat is a very important ingredient in bakery and confectionary products because it gives the proper taste and texture. As regards the fat used in the production of such products, it is mostly vegetable margarines and vegetable fats like palm and coconut fat (Kanagaratnam et al., 2013). Vegetable solid fat can also be obtained by modifying vegetable oils, whether

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this is physical – fractionation, or chemical – hydrogenation. Nowadays, food producers tend to avoid hydrogenating fat, as during this process harmful *trans* fatty isomers are developed (Żbikowska, 2010). Moreover, saturated fatty acids contained in solid vegetable fats, which make them solid, exert an adverse influence on humans' cardiovascular system. According to the EFSA, FDA and WHO recommendations, the consumption of these food compounds and fat itself should be limited. Fat is high-energetic (1 gram of fat – 9 kcal), which is why its increased consumption may lead to obesity (EFSA, 2010; WHO, 2014).

In order to reduce the fat content in food, fat replacers can be used. These are mainly carbohydrate components that have the ability to bind water and give a sensory effect similar to fat. Dietary fibers and their fractions are often used as fat replacers. Their consumption may have a positive impact on overall health as it improves intestinal peristalsis, lowers blood cholesterol etc. (Davidson and Maki, 1999; Piñero et al., 2008).

To increase the nutritional value and reduce the caloric content of bakery products, scientists have proposed additives such as inulin (Żbikowska and Rutkowska, 2008), maltodextrin (Baixauli et al., 2008), oat, wheat, barley (Zahn et al., 2013), cocoa (Martinez-Cervera et al., 2011), apple (Żbikowska et al., 2015), citrus, pea fiber, and apricot kernel powder (Özboy-Özbaş et al., 2010). Nowadays, β-glucan is becoming more and more popular. It is a fraction of dietary fiber soluble in water, which can be found in wheat, oats and barley as well as in certain kinds of yeast and mushrooms (Augustín et al., 2007; Gibiński, 2008). β-glucan is similar to cellulose and is made of ~250 000 β-D-glucose particles. β-glucan is able to stabilize oil in water emulsions. This component is extremely beneficial: an intake of 3 grams of β-glucan per day lowers LDL cholesterol and, in consequence, it reduces the risk of a cardiovascular disease (EFSA, 2010). In addition, it is recommended for people suffering from type II diabetes, since it has a low glycemic index (Zheng et al., 2013).

β-glucan has been used as a fat replacer in mayonnaise sauces (Worrasinchai et al., 2006), meat products (Álarez and Barbut, 2013) and biscuits (Kalinga and Mishra, 2009; Onacik-Gür et al., 2015).

Muffins are one of the most popular breakfast cereal snacks. However, muffins are a high-calorie product. By adding pro-health ingredients they can be a great carrier of nutritious compounds (Bajerska et al., 2015). For example, other authors have made these bakery products with fruit pomaces as a source of antioxidants (Górnaś et al., 2016; Mildner-Szkudlasz et al., 2015) or dietary fibers (Zahn et al., 2013).

The aim of this study was to partially replace shortening with barley dietary fiber with a high content of β-glucan and to compare the products obtained with full-fat muffins.

MATERIAL AND METHODS

Dough and baked muffins were used as the research material. The ingredients used for muffin production were as follows: wheat flour type 480 (Polskie Młyny S.A.), sugar (Pfeifer & Langen Poland), shortening Acofect LT M53 (AKK, Sweden) with the following profile of the main groups of fatty acids (FA): 54.41 g/100 g (SFA), 1.96 g/100 g (TFA), 38.28 g/100 g monounsaturated FA, 5.35 g/100 g PUFA, 3.2% fat milk (Mlekpol, Poland), eggs (size L, from the local market), baking powder (Winiary, Nestle Poland) and barley β-glucan preparation (β-glucan > 23%, VITACEL® BG 300, Sancel, Germany; fiber content – 54%, carbohydrates – 19%, protein – 18%; length of fiber < 600 μm; water holding capacity – 8–12 g).

Five muffin recipes were prepared: control (K0%) with a 16% vegetable shortening content in the total dough weight, with a fat content decreased by 10% (PG10%), 15% (PG15%), 20% (PG20%) and 25% (PG25%). β-glucan was used as a fat replacer in a 1:4 ratio. In the control sample, except for the 16% addition of shortening, other ingredients were used in the following amounts: flour – 33%, sugar – 19%, milk – 18%, eggs – 13%, and baking powder – 1%. 58 grams of dough were put into cups and baked for 25 minutes at 175°C in aUNOX type XBC convection oven (Vie Dell Ariginato, Padowa, Italy). 3 batches of muffins were made and analyzed 24 h after baking. The muffins were stored at room temperature (22 ±2°C) in polyethylene bags.

Physical properties of dough and baked muffins

The density of dough was measured with a bottle of closely determined capacity and weight. The volume of the baked products was determined in rapeseed

(Rahmati and Tehrani, 2014). The crumb density was calculated by cutting a cube of 2×2×2 cm from the inside of the muffin and weighing it. This analysis was carried out in 3 repetitions.

Porosity

The muffins were cut parallel 1.5 cm above the bottom and the cut sections were scanned using a Canon iR1024A scanner. The area and diameter of the pores (measured in μm) were determined by using the Multi Scan Base computer program (Computer Scanning System).

Texture analysis

The texture properties of muffins were determined using a Brookfield model CT3 texture analyzer (USA). Cubes of 2×2×2 cm were cut out from the inside of the muffins (crumb) and then immediately evaluated by a two-bite test (TPA) with a constant 50% deformation of the probe height. Using this test, the following texture features were calculated individually for each probe: hardness, gumminess, cohesiveness, adhesion, chewiness. Hardness and gumminess were expressed in Newton's [N]. The analysis was run in 3 repetitions.

Sensory analysis

Sensory analysis was conducted using the profile method according to the norms (PN-ISO 11036:1999, PN-ISO 6564:1999). This evaluation was carried out by twelve trained panelists, who had graduated from the Faculty of Food Science and passed the sweet taste threshold test. On the hedonic scale, the group of experts marked the intensity of feelings related to: appearance of muffins and crumb, aroma, texture and taste. The line was unscaled with a length of 10 cm.

Statistic analysis

The analysis was done using Statistica 10.0. For all the data, normality was determined using the Shapiro-Wilk test. For distributions, in which $p \geq 0.05$, Tukey's test was used to determine statistically significant differences among probes of $p \leq 0.05$. The physical properties of muffins were compared using the principal components analysis (PCA).

RESULTS AND DISCUSSION

Physical properties of dough and muffins

Solid fat in bakery products has a very important effect on cakes' properties. Bakery fats have a high content of solid phase. Thanks to its capacity to hold air in its structure, it has a positive impact on dough and baked product volume. The fluffiness of the dough has an impact on the properties of the final product (Manohar and Rao, 1999), which is why shortening was used in the present work. The reduction in fat content and the increase in barley β-glucan had a statistically significant effect ($p < 0.05$) on dough density. The lowest density (989.55 g/cm^3), and thus the best aeration, was observed in a control sample with the highest content of fat and without fat replacer. The dough density increased gradually as the fat content in the recipes decreased. The highest dough density was observed in muffins with a reduced fat content and the highest content of barley preparation (PG25%) 1149.55 g/cm^3, which shows that these products had the lowest aeration of dough (Table 1).

It was observed that the addition of a fat replacer increased product moisture. Muffins PG25% had the highest moisture content, while the control sample (K0%) had the lowest (Table 1). Martinez-Cervera et al. (2011) used cocoa fiber as a fat replacer and obtained similar results. Zahn et al. (2013) also observed that the addition of barley fiber significantly increased the moisture content in products.

The increasing content of the fat replacer was followed by a decrease in the volume of the muffins. A similar tendency was shown in the study by Zahn et al. (2010), where inulin was used as a fat replacer in cakes. Moreover, in another study it was found that the addition of barley fiber cause a decrease in the volume of the muffins (Zahn et al., 2013).

It was observed that with the increased barley β-glucan content the density of the products and crumb rose as well. K0% had the lowest density (651.25 g/dm^3), while the highest density was observed in muffins with the biggest content of β-glucan (725.63 g/dm^3) (Table 1). In turn, a study by Chung et al. (2010) showed that the addition of maltodextrin and OSA (octenyl succinic anhydride)-type modified starch caused a decrease in the density of the muffins.

Table 1. Muffins properties

Parameter	Type of sample				
	K0%	PG10%	PG15%	PG20%	PG25%
Dough density, g/cm³ Ā ±SD	989.55[a] ±1.19	1 044.1[b] ±1.11	1 094.53[c] ±3.94	1 113.5[d] ±3.09	1 149.55[e] ±6.61
Baked product density, g/cm³ Ā ±SD	470.88[a] ±3.56	476.68[ab] ±9.77	477.75[ab] ±3.20	485.68[b] ±1.71	525.43[b] ±2.67
Crumb density, g/cm³ Ā ±SD	651.28[a] ±8.51	666.9[a] ±33.52	676.9[ab] ±7.51	675.33[ab] ±21.20	725.68[b] ±21.96
Average volume of a muffin, cm³ Ā ±SD	113.8[c] ±0.87	111.7[bc] ±1.50	110.5[bc] ±0.50	108.5[b] ±0.50	100.0[a] ±0.00
Moisture content, % Ā ±SD	23.31[a] ±11.66	24.14[b] ±12.73	29.70[c] ±1.21	29.14[cd] ±0.73	36.86[d] ±13.47
Total pores area, µm	475 909.6	1 016 904.0	1 844 700.0	2 000 586.0	890 829.9
Average pore size, µm	369.50	716.13	797.88	981.16	327.39

[a–e]Different letters indicate statistically significant differences ($p \leq 0.05$).
Data are presented as the mean ±SD of three determinations.

Products with a higher barley β-glucan content had a lower volume. The enrichment of β-glucan up to 20% increased the size of the pores in muffins (Table 1). Substituting 25% of the fat with barley β-glucan caused a decrease in the size of their pores. This could have resulted from high moisture content and dough density. Moreover, the addition of a fat replacer led to big differences in the size of pores in comparison with the control sample (Fig. 1). The opposite effect was noticed in noticed in the case of a muffin with cocoa fiber, which showed a decrease in porosity with the increasing addition of fat replacer (Martinez-Cervera et al., 2011).

Texture analysis

The hardness (F_{max}) of a product in the TPA test is measured during the first bite of the sample. PG15% had the lowest hardness value (3.0 N), while PG25% had the highest (6.5 N). The control sample (4.9 N) and PG20% (4.4 N) belonged to the same homogenous group (Fig. 2). The hardness of bakery products is mostly attributed to amylopectin and amylose matrix (Feili et al., 2013). Gómez et al. (2013) reported that hardness was due to interactions between gluten and fibrous materials. Similar results were published by Martinez-Cervera et al. (2011), where the addition of a fat replacer (cocoa fiber) on a low and medium level decreased the hardness of the products compared to the control, while the highest substitution of fat increased the hardness. In the studies by Chung et al. (2010), it was observed that the addition of starch fat replacers to muffins caused a significant increase in hardness.

Cohesiveness is a mechanical feature of texture related to the level to which it is possible to deform the sample without breaking it (PN-ISO 11036: 1999). This texture depends on the crumb network of all homogenized ingredients inside the product, which together keep it in one piece (Shyu and Sung, 2010). The control sample and PG25% had the highest cohesiveness value (Fig. 2). In the studies by Martinez-Cervera et al. (2011) it was shown that the lowest cohesiveness was observed in the samples with cocoa fiber in comparison with the control sample. However, in research by Zahn et al. (2013), no significant differences were found between the control and the sample with the addition of 6% barley fiber. Moreover, Zahn et al. (2013) showed that products with OSA type starch were significantly more cohesive than the control sample.

Springiness is a level of sample deformation. In conducted study, PG25% had the highest springiness value as well as hardness, whereas PG15% had the

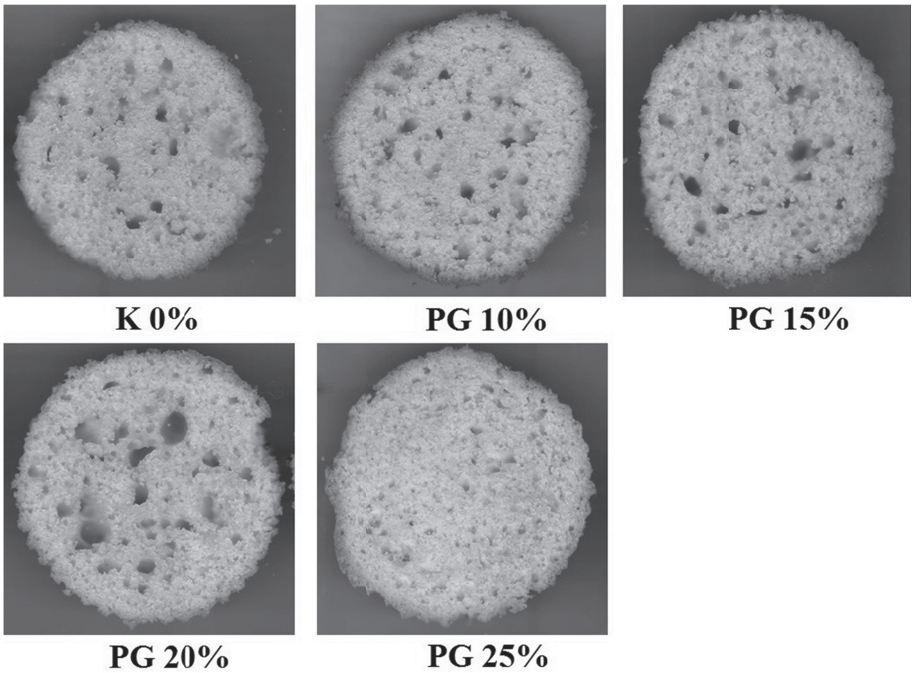

Fig. 1. Pictures of muffins cut in half

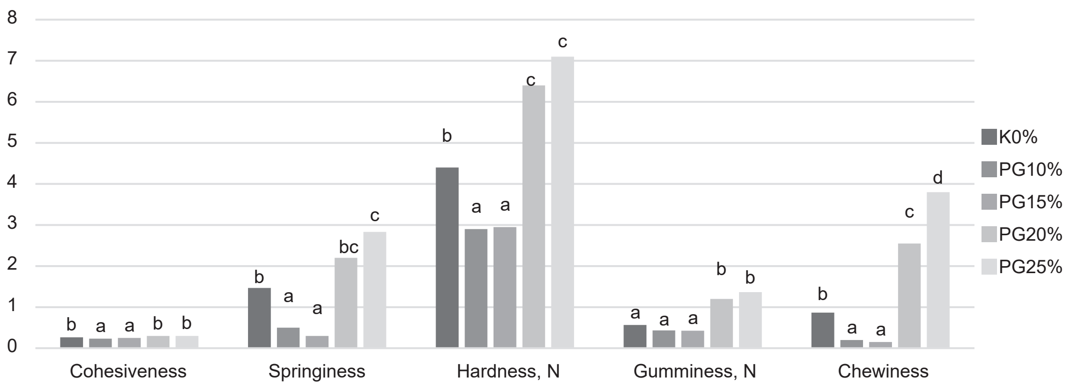

Fig. 2. Textural properties of muffins obtained from TPA test: a–e – different letters indicate statistically significant differences ($p \leq 0.05$)

lowest (Fig. 2). Zahn et al. (2013) observed that the addition of barley fiber at a level of 6% did not change the springiness of muffin crumb significantly in comparison to the control sample.

Gumminess is an energy needed to make a product easy to swallow (Pons and Fiszman, 2007). PG15% had the lowest gumminess value (0.42 N), while PG25% had the highest. In the study by Chung et al. (2010), it was shown that starch fat replacers increased the gumminess of products significantly compared with the control sample.

Chewiness is a mechanical feature and it measures the force needed to chew a bite of food. It is defined as a product of hardness, cohesiveness and springiness

(Shyu and Sung, 2010). PG15% had the lowest chewiness value – 0.15 N, while PG25% had the highest – 3.1 N (Fig. 2). Martinez-Cervera et al. (2011) observed that the addition of cocoa fiber caused a decrease in chewiness compared to the control sample.

The principal component analysis (PCA) method, based on analysis of the results average, was used to analyze the data. The first two components defined 91.85% of variable (loadings). The first principal component (PC1) explained 63.81%: springiness, F_{max}, chewiness, gumminess, product density (D_p), crumb density (D_c) and moisture (Fig. 3, Table 2). The second component (PC2) explained 28.04%: dough density (D_s) and pore area (Fig. 3, Table 2). Based on the principal component plot (Fig. 3), it was observed that cohesiveness, springiness and F_{max} were negatively correlated to the size and area of pores. In the plot (Fig. 3), it was observed that samples PG10%, PG15% and PG20% were the most similar to each other. Sample

Table 2. Loadings coordinates of first two principal components

	PC 1	PC 2
Pore size	0.654875	–0.656509
Pore area	0.400181	<u>–0.858631</u>
Moisture	<u>–0.787077</u>	–0.593076
D_c	<u>–0.831927</u>	–0.498728
D_p	<u>–0.931980</u>	–0.349022
D_s	–0.529072	<u>–0.841028</u>
F_{max}	<u>–0.950460</u>	0.223096
Cohesiveness	–0.736552	0.585525
Gumminess	<u>–0.854840</u>	–0.054769
Chewiness	<u>–0.982574</u>	0.008262
Springiness	<u>–0.910097</u>	0.300842

D_c – crumb density, D_p – product density, D_s – dough density, F_{max} – hardness.

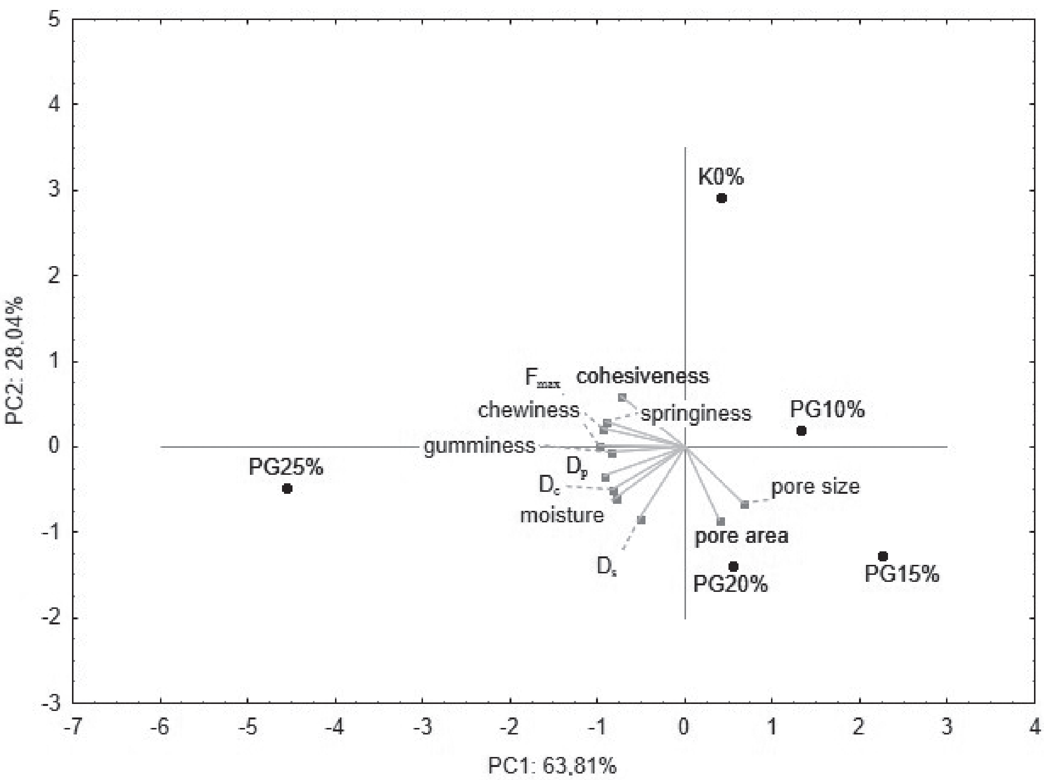

Fig. 3. Biplot of PCA

K0% was different by PC2, which are the variables D_s and pore area. The point defining PG25% is located on the very left side of the plot. It shows that the features explained by variables correlated to PC1 were different for muffins with a fat content reduced by 25% than for other products.

Sensory analysis

At the beginning the panelists evaluated the aroma of the muffins, then the appearance of the whole product and crumb. The evaluation of texture and taste attributes was the next level. At the end of the research the panelists evaluated overall quality. During consumption, the texture is checked first while biting, then after the bite, it moves to the mouth and soaks all substances related to the product taste are relived with saliva (Laguna et al., 2013).

It was observed that the addition of β-glucan had a negative effect on the characteristic aroma of muffins. K0% was evaluated as the most typical, with P25% as the least typical. It was observed that by increasing the content of β-glucan and decreasing the fat content, the cereal smell became more intense (Table 3). The cereal smell was defined as the aroma of barley cereal flakes.

The control sample (K0%) had the most uniform browning color of the crust and crumb. Higher β-glucan content decreased the uniformity of the

Table 3. Average results of sensory analysis

Attributes		Type of sample				
		K	PG10%	PG15%	PG20%	PG25%
Aroma	typical	8.03[d] ±0.69	6.41[c] ±0.85	5.91[c] ±0.90	4.40[b] ±1.08	2.05[a] ±0.79
	cereal	1.06[a] ±0.45	1.20[a] ±0.75	1.38[a] ±0.51	3.20[b] ±0.62	4.93[c] ±0.43
Appearance of the muffin	uniformity of browning colour	5.56[c] ±0.39	4.65[b] ±0.62	4.94[bc] ±0.73	3.81[a] ±0.72	3.81[ab] ±1.02
	cracks on the surface	3.75[a] ±0.80	4.91[b] ±0.51	5.28[b] ±0.61	5.94[bc] ±1.02	7.63[d] ±0.44
Appearance of crumb	color uniformity	7.14[d] ±0.75	6.04[c] ±0.65	5.09[b] ±0.34	5.24[b] ±0.79	3.73[a] ±0.93
	porosity	6.51[d] ±0.80	6.24[cd] ±0.49	5.51[c] ±0.41	4.40[b] ±0.73	2.26[a] ±0.61
Texture	hardness	4.18[a] ±0.32	4.94[b] ±0.44	5.59[c] ±0.58	6.29[d] ±0.71	7.28[e] ±1.32
	springiness	6.49[e] ±0.61	5.89[d] ±0.21	5.45[c] ±0.45	3.99[b] ±0.18	2.59[a] ±0.62
Taste	typical	6.99[d] ±1.02	6.54[d] ±0.92	5.49[c] ±1.2	4.38[b] ±0.95	2.65[a] ±1.15
	cereal	0.93[a] ±0.82	1.43[ab] ±1.27	2.90[c] ±0.75	3.95[d] ±1.35	4.96[e] ±1.24
Overall quality		7.15[d] ±1.35	6.10[c] ±1.25	5.46[c] ±0.56	3.66[b] ±1.05	1.99[a] ±1.2

Data are presented as the mean ±SD of twelve determinations.

product color. Water-soluble dietary fiber fractions (β-glucan, pectin) used in the present formulations may reduce the availability of starch degrading enzymes to their substrates by creating a gel matrix (Khanna and Tester, 2006). Dietary fiber, which is characterized by high water absorption can compete with starch in the suspension of the water available, and thus cause a reduction in the gelatinization of starch (Collar et al., 2006). It is assumed that fewer sugar particles were involved in non-enzymatic browning – a Maillard reaction in muffins with β-glucan addition. The addition of a fat replacer increased cracking on the muffin surface. Once the β-glucan content was increased, the pores became less uniform. Research by Baixauli et al. (2008) showed that muffins made of wheat flour looked better than products made of whole grain flour and the addition of resistant starch with a high content of dietary fiber.

The hardness of products increased along with the addition of β-glucan. Their springiness, on the contrary decreased. Martinez-Cervera et al. (2011) obtained similar results in their research. They observed that once the amount of fat replacer (cocoa fiber) increased, the springiness decreased and chewing and swallowing the muffins was harder.

The addition of β-glucan had a negative effect on the typical taste of the products. It also increased the sensation of a cereal taste (the taste of barley flakes). The control sample had the best overall quality. According to the sensory panelists, increased addition of barley β-glucan had a negative impact on the overall quality of the muffins.

Based on the research by Baixauli et al. (2008), whole grain muffins rich in dietary fiber were evaluated lower by consumers than products made of flour with a low fiber content. However, when they repeated the study and informed the evaluators about the ingredients used in the muffins, it was observed that consumers rated products with whole grain flour higher because of the information they had been given.

CONCLUSION

The partial replacement of shortening with barley β-glucan is possible in muffins, but it adversely affects the rheological properties of the dough (aeration) and the resulting products (eg. size, density). It was observed that by increasing the content of a fat replacer, the pores in the crumb became bigger in comparison to the control sample, which has a negative impact on quality. In terms of texture properties, the muffins most similar to the control (without addition of barley β-glucan) were those with a fat content reduced by 20%. Moreover, it was shown that a higher barley β-glucan content in the muffin recipe decreased sensorial overall quality. However, the addition of β-glucan to products in which fat was reduced by 10% did not affect the typical taste of muffins significantly. Despite the adverse effect of β-glucan on the physical and sensory properties, it seems to be appropriate to use it even in small amounts (≤10%) in order to increase the nutritional value of these products.

REFERENCES

Augustín, J., Jaworska, G., Dandár, A., Cejpek, K. (2007). Boczniak ostrygowaty (*Pleurotus ostreatus*) jako źródło β-D-glukanów [*Pleurotus ostreatus* as a source of beta--D-glucanes]. Żywn. Nauka Techn. Jakość, 6(55), 170–176 [in Polish].

Álarez, D., Barbut, S. (2013). Effect of inulin, β-glucan and their mixtures on emulsion stability, color and textural parameters of cooked meat batters. Meat Sci., 94, 320–327.

Baixauli, R., Salvador, A., Hough, G., Fiszman, S. M. (2008). How information about fiber (traditional and resistant starch) influences consumer acceptance of muffins. Food Qual. Pref., 19, 628–635.

Bajerska, A., Mildner-Szkudlarz, S., Górnaś, P., Seglina, D. (2015). The effect of muffins enriched with sour cherry pomace on acceptability, glycemic response, satiety and energy intake: a randomized crossover trial. J. Sci. Food Agric., 96, 2486–2493.

Chung, H.-J., Lee, S.-E., Han, J.-A., Lim, S.-T. (2010). Physical properties of dry-heated ocetenyl succinylated waxy corn starches and its application in fat-reduced muffin. J. Cereal Sci., 52, 496–501.

Collar, C., Santos, E., Rosell, C. M. (2006). Significance of dietary fiber on the viscometric pattern of pasted and gelled flour-fiber blends. Cereal Chem., 83, 370–376.

Davidson, M. H., Maki, K. C. (1999). Effects of dietary inulin on serum lipids. J. Nutr., 129(7), 1474–1477.

EFSA (2010). Scientific opinion on the substantiation of health claim related to oat beta-glucan and lowering blood cholesterol and reduced risk of (coronary) heart disease pursuant to Article 14 of Regulation (EC) no 1924/2006. EFSA J., 8(12), 1885, 1–15.

Feili, R., Wahidu, Z., Wan, N. W. A., Tajul, A. Y. (2013). Physical and sensory analysis of high fiber bread incorporated with jackfruit rind flour. Food Sci. Technol., 1(2), 30–36.

Gibiński, M. (2008). β-glukany owsa jako składnik żywności funkcjonalnej [Oat's β-glucans as functional food compound]. Żywn. Nauka Techn. Jakość, 2(57), 15–29 [in Polish].

Gómez, M., Ronda, F., Blanco, C. A., Caballero, P. A., Apesteguia, A. (2003). Effect of dietary fiber on dough rheology and bread quality. Eur. Food Res. Technol., 216, 51–56.

Górnaś P., Juhņeviča-Radenkova, K., Radenkovs, V., Mišina, I., Pugajeva, I., Soliven, A., Segliņa, D. (2016). The impact of different baking conditions on the stability of the extractable polyphenols in muffins enriched by strawberry, sour cherry, raspberry or black currant pomace. LWT – Food Sci. Technol., 65, 946–953.

Kalinga, D., Mishra, V. K. (2009). Rheological and physical properties of low fat cakes produced by addition of cereal β-glucan concentrates. J. Food Proc. Preser., 33, 384–400.

Kanagaratnam, S., Hoque, E. M., Sahri, M. M., Spowage, A. (2013). Investigating the effect of deforming temperature on the oil-binding capacity of palm oil based shortening. J. Food Eng., 118, 90–99.

Khanna, S., Tester, R. F. (2006). Influence of purified konjac glucomannan on the gelatinisation and retrogradation properties of maize and potato starches. Food Hydrocoll., 20, 567–576.

Laguna, L., Varela, P., Salvador, A., Fiszman, S. (2013). A new sensory tool to analyse the oral trajectory of biscuits with different fat and fibre contents. Food Res. Int., 51, 544–553.

Manohar, R. S., Rao, P. H. (1999). Effect of emulsifiers, fat level and type on the rheological characteristic of biscuit dough and quality of biscuits. J. Food Comp. Anal., 5(79), 1223–1231.

Martinez-Cervera, S., Salvador, A., Muguerza, B., Moulay, L., Fiszman, S. M. (2011). Cocoa fibre its application as a fat replacer in chocolate muffins. Food Sci. Technol., 44, 729–736.

Mildner-Szkudlarz, S., Siger, A., Szwengiel, A., Bajerska, J. (2015). Natural compounds from grape by-products enhance nutritive value and reduce formation of CML in model muffins. Food Chem., 172, 78–85.

Onacik-Gür, S., Żbikowska, A., Jaroszewska, A. (2015). Effect of high-oleic sunflower oil and other pro-health ingredients on physical and sensory properties of biscuits. CyTA J. Food, 13(4), 621–628.

Onacik-Gür, S., Żbikowska, A., Kowalska, M. (2014). Źródła izomerów *trans* kwasów tłuszczowych na polskim rynku [Sources of trans fatty acids on the Polish market]. PHiE, 95(1), 120–124 [in Polish].

Özboy-Özbaş, Ö., Seker, I. T., Gökbuly, I. (2010). Effects of resistant starch, apricot karnel flour and fiber-rich fruit powders on low-fat cookie quality. Food Sci. Biotechn., 19(4), 979–986.

Piñero, M. P., Parra, K., Huerta-Leidenz, N., Arenas de Moreno, L., Ferrer, M., Araujo, S., Barboza, Y. (2008). Effect of oat's soluble fibre (β-glucan) as a fat replacer on physical, chemical, microbiological and sensory properties of low-fat beef patties. Meat Sci., 80(3), 675–680.

PN-ISO 11036:1999. Analiza sensoryczna. Metodologia. Profilowanie tekstury [Sensory analysis. Methodology. Profiling texture].

PN-ISO 6564:1999. Analiza sensoryczna. Metodologia. Metody profilowania smakowitości [Sensory analysis. Methodology. Flavour profile methods].

Pons, M., Fiszman, S. M. (2007). Instrumental texture profile analysis particular reference to gelled systems. J. Tex. Stud., 27(6), 597–624.

Rahmati, N. F., Tehrani, M. M. (2014). Influence of different emulsifiers on characteristics of eggless cake containing soy milk: Modeling of physical and sensory properties by mixture experimental design. J. Food Sci. Technol., 51(9), 1697–1710.

Ribeiro, A. P. B., Grimaldi, R., Gioielli, L. A., Goncaves, L. A. G. (2009). Zero *trans* fats from soybean oil and fully hydrogenated soybean oil: Physico-chemical properties and food applications. Food Res. Int., 42(3), 401–410.

Shyu, Y. S., Sung, W. C. (2010). Improving the emulsion stability of sponge cake by the addition of γ-poluglutamic acid. J. Mar. Sci. Tech.-Taiw., 18(6), 895–900.

WHO (2014). Global strategy on diet, physical activity and health. Retrieved from www.who.int/dietphysicalactivity/strategy/eb11344/strategy_english_web.pdf

Worrasinchai, S., Suphantharika, M., Pinjai, S., Jamnong, P. (2006). β-Glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. Food Hydrocoll., 20(1), 68–78.

Zahn, S., Forker, A., Krügel, L., Rohm, H. (2013). Combined use of rebaudioside A and fibers for partial sucrose replacement in muffins. Food Sci. Technol., 50, 695–701.

Zahn, S., Pepke, F., Rohm, H. (2010). Effect of inulin as a fat replacer on the texture and sensory properties of muffins. Food Sci. Technol., 45, 2351–2537.

Zheng, J., Shen, N., Wang, S., Zhao, G. (2013). Oat beta-glucan meliorates insulin resistance in mice fed on high-fat and high-fructose diet. J. Food Nutr. Res., 57, 22754.

Żbikowska, A. (2010). Formation and properties of *trans* fatty acids – a review. Pol. J. Food Nutr. Sci., 2, 107–114.

Żbikowska, A., Rutkowska, J. (2008). Possibility of partial replacement of fat by inuline in cookies in order to decrease their caloric value. Pol. J. Food Nutr. Sci., 1, 58, 113–117.

Żbikowska, A., Kowalska, M., Onacik-Gür, S. (2015). Wpływ błonnika jabłkowego na jakość fizyczną i sensoryczną wyrobów biszkoptowo-tłuszczowych [Impact of apple fiber on the physical and sensory quality of sponge-fat products]. Post. Techn. Przetw. Spoż., 1, 67–73 [in Polish].