Effect of fiber sources on fatty acids profile, glycemic index, and phenolic compound content of in vitro digested fortified wheat bread

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Abstract In this study, some dietary fiber (DF) sources were investigated as fortifiers of wheat bread: oat (OB), flax (FB), and apple (AB). Adding oat and flax fibers to bread significantly changed the fatty acid profiles. OB was highest in oleic acid (33.83% of lipids) and linoleic acid (24.31% of lipids). Only in FB, γ -linolenic fatty acid was present in a significant amount—18.32%. The bioaccessibility trials revealed that the DF slow down the intake of saturated fatty acids. PUFA were least bioaccessible from all fatty acids groups in the range of (72% in OB to 87% in FB). The control bread had the greatest value (80.5) and was significantly higher than values for OB, FB, and AB in terms of glycemic index. OB, FB and AB addition led to obtain low glycemic index. AB had a significant highest value of total phenolic (897.2 mg/kg) with the lowest values in FB (541.2 mg/kg). The only significant lowering of caloric values in this study was observed in AB. The study could address the gap in the area of research about taking into consideration glycemic index, fatty acid profile and phenolic content in parallel in terms of DF application in breads.

Keywords Dietary fiber · Fatty acids · GC · Wheat bread

Introduction

Consumers are becoming more aware of the relationship between diet and health. At the same time, there is a decreased intake of dietary fiber (DF) in typical diets. One of the main sources of DF is bread.

In general, DF plays an important role in preventing several diseases like obesity, coronary heart disease, and diabetes, and is associated with decreasing the risk of cancer. The recommended daily intake of DF is 25–30 g (Chareonthaikij et al. 2016). Various sources of DF have been studied in bakery products such as cereal fiber—oat, flax—and agricultural by-products—apple pomace, or sugar beet (Sabanis et al. 2009; Filipovic et al. 2007; Moraes et al. 2010). Wheat bread is known to contain a high glycemic index (GI), due to its high content of rapidly digestible starch (Sui et al. 2016). Because of this, the substances that could be used for fortifying bread and lowering GI are sought in technological practices. Apart from fortifying the bread with DF to reap the health benefits of additional fiber, the added ingredients could deliver other substances that are nutritive, like fatty acids or lowering the glycemic index. Moreover, the additional DF could lower the caloric value of the food.

Oat DF is well known for its beneficial effects. Generally, oat DF consists of insoluble and soluble fibers, like β -glucan. Consuming food fortified with β -glucan may have positive health influences, since it decreases low density cholesterol (LDL) levels, leading to a reduced risk of coronary heart disease and hypertension (Chen and Raymond 2008). Furthermore, β -glucan creates a viscous layer on the surface of intestinal villi, which might lead to reduced absorption of cholesterol and bile acids, and also, the increased intestinal lumen viscosity due to β -glucan leads to positive hypoglycemic effects (Tabesh et al. 2014).

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β -glucan also affects the brain's satiety center, which might combat obesity (Panahi et al. 2014). Moreover, oat DF is known for being a natural replacement for fat in meat products due to its thickening properties (Yilmaz and Dağlıoğlu 2003). Nonetheless, even though oat fiber is also known for lowering GI, its fiber application in bread, according to fatty acid composition, has not been investigated. (Regand et al. 2011).

The other cereal source of DF is flax (*Linum usitatissimum*). There have been documented evidence of flaxseed anti-carcinogenic impacts on the human organism (Lowcock et al. 2013). Anti-carcinogenic impacts could be caused by the high content of polyunsaturated fatty acids in flax, which could directly influence the high content of omega-3 and omega-6 fatty acids (Calderelli et al. 2010). Breads and other baked goods appear to be useful vehicles for flax incorporation. However, because of the low-gluten content of flaxseed meal, incorporation into baked goods may result in a low-quality bread product. Therefore, there is a need to further examine and evaluate the usage of flax DF in bread production (Conforti and Davis 2006).

Because of the increasing demands in the market for a wider selection of fiber rich breads, more attention is being focused on the use of fruit. However, due to the pectin content in apple DF, wheat flour and apple DF blends were shown to have poor bread baking qualities (Sudha et al. 2007). However, if the DF is used in an optimal preparation composition, it is possible to fortify bread with sufficient quality. DF from apples is known for having a high amount of bioactive compounds, such as polyphenolic extracts (Jung et al. 2015).

There were several researches about application of oat DF in bread production and its influence on different physiologically important constituents like vitamins B (Kurek et al. 2017), lowering cholesterol level (Whitehead et al. 2014) or general influence on metabolomes present in human plasma (Nielsen et al. 2014). The impact of most in vitro studies of oat fibers is focused on the behavior of beta-glucan during digestion (Gamel et al. 2014). In our study, we wanted to focus more on the glycemic index of white bread with DF application, even though there were studies about gluten-free bread made out of oat flour (Wolter et al. 2013). Recent studies have shown that there is a positive impact on the fortification of bread with flaxseed. These researches have been mainly focused on the phenolic content and glycemic index or α -linolenic acid (Marpalle et al. 2015; Sęczyk et al. 2017). Nevertheless, it is valuable to examine application of flaxseed DF in terms of physiologically important constituents of fortified breads. In fact, there is a need for more researches in the area of application of apple DF in bread because fortification of wheat bread with the DF of non-cereal origin is still not popular. According to available information, there

were only researches performed on white bread with apple fiber which were focused on physical properties of bread and dough (Bchir et al. 2014). Due to its novelty, our study could fill the gap in the area of research about taking into consideration glycemic index, fatty acid profile and phenolic content in parallel in terms of DF application in breads.

All the nutrients present in food have a bioaccessibility level, which is the measure of how well they can be absorbed in the digestive tract. To the best of our knowledge, no research has taken the effect of four different DF bread enrichment on fatty acid profiles, glycemic index, and phenolic content into consideration. Therefore, we examined the content of DF, fatty acid composition, and polyphenol content in bread with oat (OB), flax (FB), and apple (AB) DF. Then, an in vitro digestion was performed to assess the bioaccessibility of fatty acids, and to establish the glycemic index of bread.

Materials and methods

Raw materials

The main component of bread used in the study was wheat flour that was provided by a local supplier, with the composition examined with NIR-Flex (Buchi, Switzerland) as follows for 100 g: 364 kcal, 10 g proteins, 76 g carbohydrates, 1 g fat, 2.7 g of DF (2.4 g insoluble fractions and 0.3 g soluble fractions). Three different DF preparations were used in our study to fortify the bread. The DF preparations were flax, apple, and oat fiber (Microstructure Inc., Warsaw, Poland). The DF content in the above preparations was examined with the total DF determination method (AOAC 2009.01). The bread was baked using dried yeast (Dr. Oetker, Gdańsk, Poland) and salt. The nutritional composition of dietary fiber preparations is presented in Table 1.

Bread production

Bread production was conducted in a one-phase process. The wheat flour, DF, dry yeast, and salt were mixed together, then, the water was added gradually within the first minute of mixing to achieve the desired consistency with 500 Brabender Units (based on a preliminary study). The composition of the dough was calculated in the preliminary study to achieve the final product, which could be considered as high-fiber content according to Commission Regulation (EU) No 1047/2012, where any claim that a food is high in fiber, and any claim likely to have the same meaning for the consumer, may only be made when the product contains at least 6 g of fiber per 100 g. The

Table 1 The composition of DF preparations used in the study

	Energy (kcal)	Protein (%)	Carbohydrates (%)	Fat (%)	Dietary fibre (%)	Insoluble (%)	Soluble (%)
Oat	220.0 ± 8.78 ^b	16.0 ± 2.21 ^b	23.1 ± 2.14 ^c	7.1 ± 0.45 ^b	44.0 ± 2.14 ^a	22.9 ± 2.14 ^a	21.1 ± 2.14 ^c
Flax	205.7 ± 4.47 ^b	29.1 ± 4.15 ^c	0.7 ± 0.12 ^a	10.0 ± 1.14 ^c	50.0 ± 2.17 ^b	32.9 ± 2.17 ^b	17.1 ± 2.19 ^b
Apple	122.9 ± 1.14 ^a	5.4 ± 0.42 ^a	16.9 ± 1.45 ^b	3.7 ± 0.18 ^a	72.3 ± 2.74 ^c	55.4 ± 3.14 ^c	11.7 ± 2.14 ^a

a, b, c, d: different letters indicate the statistical differences within the columns ($p \leq 0.05$)

amounts of yeast and salt used were 2% w/w and 1.5% w/w, respectively. The DF contents were as follow: the control was without DF, the FL (flax DF preparation) was added to 10.8%, the AP (apple DF preparation) to 8.1%, and OT (oat DF preparation) to 12.1% w/weight of flour.

The mixing took 5 additional minutes and the whole mass was placed in the fermentation chamber for 15 min (37 °C, 80% relative humidity). The dividing and kneading were conducted and 560 g of dough was placed in metal pans where they were proofed for an optimal time (37 °C, 80% relative humidity). The optimal time of proofing was assessed with the pressure test. When the loaf was pressed lightly and the indentation remained, the baking process started. The baking was carried out at 220 °C for 20 min and then the loaves were left to cool down.

Chemicals

The inorganic and organic chemicals for in vitro digestion—KCl (potassium chloride), Na₂HPO₄ (disodium phosphate), NaHCO₃ (sodium bicarbonate), NaCl (sodium chloride), MgCl₂·6H₂O (magnesium chloride hexahydrate), CaCl₂·2H₂O (calcium chloride dehydrate), NaOH (sodium hydroxide) or HCl (hydrochloric acid)—were supplied by Avantor Performance Materials, Poland. The enzymes—alpha-amylase from human saliva (A0521), mucin from porcine stomach (M1778), bovine serum albumin (BSA-A2153), pepsin from porcine gastric mucosa (P7000), pancreatin from porcine pancreas (P7545), lipase from porcine pancreas (L3126) and bovine bile (B3883)—were provided by Sigma-Aldrich.

The chemicals for fatty acids determination were as follows: petroleum ether, acetone, methanol, and hexane (all HPLC grade) and clean KOH (potassium hydroxide), all supplied by Avantor Performance Materials, Poland. The fatty acids reference was Supelco 37 Component FAME Mix (Sigma Aldrich).

The chemical used for testing the glycemic index were similar to chemicals for in vitro digestion. The free glucose was established using the GOPOD Reagent Kit (Megazyme, Ireland).

In vitro digestion

The breads were digested under in vitro conditions based on Minekus et al. (2014) and Zhang et al. (2011). The composition of each digestive liquid is presented in Table 2.

The 5 g of the DF and bread sample were gently homogenized with 6.7 ml of saline solution, after that, 13.3 ml of stomach solution was added. After 1 h, the pH was adjusted to 2. An hour later, 20 ml of intestine solution was added, and the pH was adjusted to 7 in similar time as in stomach stage. The whole digestion time was 245 min—5 min homogenization, 120 min stomach stage, 120 min

Table 2 The components in saliva, gastric and intestine in vitro digestion model

Component	g/l	Saliva ml	Gastric	Intestine
Inorganic				
KCl	37.3	30.2	13.8	13.6
Na ₂ HPO ₄	68	7.4	1.8	1.6
NaHCO ₃	84	13.6	25	85
NaCl	117	0	23.6	19.2
MgCl ₂ ·6H ₂ O	30.5	1	0.8	2.2
CaCl ₂ ·2H ₂ O	44	0	36	38
Organic				
Urea	25	16	6.8	28
Dissolve in 900 ml of distilled water				
pH adjustment with NaOH (1 M) or HCl (0.2 M)		7	2	7
Enzymes				
	g			
Alpha-amylase	0.29			
Mucin	0.10		6.0	
BSA			2.1	5.6
Pepsin			2.1	
Pancreatin				6.1
Lipase				1.4
Bile				12.0
Make to volume up to 1000 ml				

intestine stage. Next, the digested bread was centrifuged at 5000 rpm and the digestive activity of enzymes was stopped by putting chyme in dry ice (-78.5°C). The chyme was collected prior to subsequent examinations.

Dietary fiber content

The DF determination was made using modified methods AOAC 2009.01 and soluble and insoluble AOAC 2011.25 with FOSS Fibertec E 1023 (McCleary 2014). The DF content was determined in the DF preparations and in the breads.

Fatty acid composition

The fatty acid (FA) composition was performed in dietary fiber preparations, bread loaves, and chyme after in vitro digestion with the modified method of Zhou et al. (2012). The initial mass of the matrix subjected to extraction was 5 g for the DF preparation and bread, and 5 ml for the chyme from the in vitro digestion. FA was extracted with petroleum ether and acetone, and subsequently methylated to fatty acid methyl esters (FAME) with 1 M KOH in methanol solution. The FAME were analyzed by GC-2010 gas chromatograph (GC) (Shimadzu) fitted with an automatic injector (AOC 2), a Restek (19091N-213) column (100 m length $\times$ 0.32 mm i.d., and 0.5 μm film thickness), and a flame ionization detector (FID). The GC was operated under the following conditions: the temperature programming consisted of an initial temperature of 220°C held for 10 min, then programmed at a $10^{\circ}\text{C}/\text{min}$ rate to 250°C and held for 5 min; the inlet temperature was kept at 250°C , with the split ratio being 20:1; the FID temperature was maintained at 280°C ; gas flows were carrier nitrogen at 3.0 ml/min, hydrogen at 40 ml/min, and air at 450 ml/min. The injection volume was 1 μl . FAME were identified according to their retention times, and quantified against a certified reference material (Supelco 37 FAME Mix). The detection limit was 5 mg/kg. The fatty acids were presented as the quantity of 11 mostly present in bakery product fatty acids (i.e. myristic, pentadecanoic, palmitic, palmitoleic, stearic, elaidic, oleic, linolelaidic, linoleic, α -linolenic, *cis*-13,16-docosadienoic) and as the sum of SFA (saturated fatty acids), MUFA (monounsaturated fatty acids), PUFA (polyunsaturated fatty acids) and trans (trans fatty acids) as per 100 g of fat.

Glycemic index

To evaluate whether the modification of ingredients in breads reduces their glycemic index, we measured free glucose during in vitro digestion, whereby 0.2 ml aliquot samples were taken from the digestive flask after 0, 30, 60,

90, 120 and 180 min and analyzed for the glucose content using the GOPOD Reagent with glucose standard as a reference. The glucose was converted into starch by multiplying it by 0.9 (Ferrer-Mairal et al. 2012).

The starch hydrolysis model was established as in previous work (Goñi et al. 1997). Summarily, the area under the hydrolysis curve (AC) was calculated from the model:

$$AC = C_{\infty}(t_f - t_0) - \left(\frac{C_{\infty}}{k}\right)\left(1 - e^{-k(t_f - t_0)}\right),$$

C_{∞} corresponds to the concentration at equilibrium (t_{180}), t_f is the final time (180 min), t_0 is the initial time (0 min), and k is the kinetic constant. White wheat bread was used as the control sample, so the AC from the samples were divided by the AC from white bread and considered as the calcHI. Then, the expected glycemic index (GI) was calculated as follows:

$$GI = 0.862 \times \text{calcHI} + 8.198.$$

Polyphenol content

Total polyphenolic content was determined by the Folin–Ciocalteu method. The results were calculated as mg of gallic acid per 100 g (mg GA/100 g of dw). Measurements were made using a Shimadzu UV-1800 UV–VIS spectrophotometer. All determinations were performed in duplicate.

Caloric value

Caloric value was estimated by Atwater coefficients: 4 kcal g^{-1} for proteins, 4 kcal g^{-1} for carbohydrates, and 9 kcal g^{-1} for lipids. The proximate composition was based on the manufacturer's data for DF and the whole composition was calculated, taking into account the cooking yield.

Statistical analysis

All analyses were done in triplicate, and data were presented as means and standard deviations (SD). The analysis of variance (ANOVA) and the Tukey test, at a 95% significance level, were carried out to determine statistical differences between DF composition, fatty acid profiles, and the glycemic index between the breads.

Results and discussion

Composition of dietary fiber

The composition of DF preparations used in the study is presented in Table 1. The energy value of the preparations

was different to each other with the lowest (122.9 kcal/100 g) for apple DF and the highest for oat DF (220.0 kcal/100 g). The highest protein content was observed in flax DF preparations (29.1%), while this preparation was the lowest in carbohydrates (0.7%). The DF fractions were different in the preparations used in the study. The oat fiber preparation fraction ratio was the most aligned. The higher amount of soluble DF is present in the preparation the more viscous solution is formed after hydration (Ibrügger et al. 2012).

Fatty acids composition

The fatty acid profiles in various breads are presented in Fig. 1. The fatty acids that were determined in significantly high amounts in all breads were palmitic, stearic, oleic, and linoleic which is consistent with the results obtained by Giarretta et al. (2017) for wheat breads. The CB was highest in palmitic acid (27.01% of lipids) and linoleic acid (24.50% of lipids). The OB was highest in oleic acid (33.83% of lipids) and linoleic acid (24.31% of lipids). A different situation occurred in the FB, where the highest present fatty acids were similar to CB and OB. However, only γ -linolenic fatty acid was present in a significant amount—18.32% of lipids that corresponds to the values obtained by Aro et al. (2013). In AB samples, this fatty acid was 9.81% of lipids. Therefore, the observation was

that SFA was highest in CB (44.2%), while the lowest percentage was observed in the AB sample (31.2%), where the PUFA content was highest (40.8%). PUFA content in obtained bread could be assessed as satisfactory even if the fatty acids are easily oxidized at extreme temperatures (Gökmen et al. 2011). The richest in MUFA was the OB (36.5%). The trans fatty acids were calculated, and the lowest values were observed in the OB samples (0.5%). The obtained results are mainly the effects of presence of particular fatty acids in oat, apples and flaxseed.

The digested chyme (the simulation of the substance accessible by the intestine) was analyzed in terms of fatty acids in the same way as the bread samples. CBD was highest in the palmitic (27.55% of total lipids) and oleic (25.30% of total lipids) fatty acids. OBD was highest in the oleic (36.63% of total lipids) and palmitic (23.73%) fatty acids. FBD was the sample with high content of γ -linolenic (11.84%), but ABD had this fatty acid in a more accessible amount (13.02%), which corresponds to the results obtained by Ribeiro et al. (2013). All the samples with DF had significantly lower bioaccessible SFA than CB. MUFA content was highest in the OB sample even after digestion. What is vital is the observation that the PUFA content was highest in two samples: FBD (33.1%) and ABD (31.5%).

Even more important are the results from the nominal bioaccessibility of fatty acids (Fig. 2). It was calculated to show the impact of DF on fatty acid composition and

Fig. 1 The profile of fatty acids present in breads before and after digestion. The CB control bread, OB oat fiber bread, FB flax fibre bread, AB apple fibre bread, after digestion: CBD control bread, OBD oat fiber bread, FBD flax fibre bread, ABD apple fibre bread. Different letters on the chart indicates the statistical differences between bread with different dietary fibres within the same fatty acids group ($p \leq 0.05$)

Fig. 2 The profile of fatty acids bioaccessibility in breads before. The *CB* control bread, *OB* oat fiber bread, *FB* flax fibre bread, *AB* apple fibre bread. Different letters on the chart indicates the statistical differences between bread with different dietary fibres within the same fatty acids group ($p \leq 0.05$)

parameters known as oil holding capacity on changes of fatty acids. Moreover, Chain length is an important factor determining fatty acid digestibility. Short—and medium—chain saturated fatty acids are believed to be absorbed more efficiently in the digestive tract than long-chain saturated fatty acids (Gervais et al. 2009). We observed that the bioaccessibility of fatty acids in the control sample were in the same range in all groups (79% for PUFA; 98% for trans). The differences were observed in OB, FB, and AB samples. It is imperative to state that the SFA bioaccessibility was lower in the samples with DF than the CB and the bioaccessibility of MUFA is lower in the CB and OB. However, PUFA are least bioaccessible from all fatty acids groups in the range of 72% in OB to 87% in FB. The results lead to the statement that the addition of DF to bread does not only changes the fatty acid profiles in the bread itself, but also the oil holding capability influences its bioaccessibility because some of the fatty acids are connected to the insoluble fractions of DF and were centrifuged as the simulation of human bolus. So far, data concerning the effect of fortification with DF on fatty acids and its digestibility have been limited.

Starch hydrolization

The glycemic index factor is mainly influenced by the hydrolization of starch during digestion. The dynamic changes connected to the starch hydrolysis are mainly connected the structural traits and its physical stage. Therefore, some of the DF could interfere with starch digestion process. The results for the glycemic index are

presented in Table 3. The value (C) is the parameter that shows the start value of the digestion in the first minutes. The CB had the greatest value (80.5) and was significantly higher than values for OB, FB, and AB. A similar result considering the impact of flax on the glycemic index was observed in in vitro tests performed by Dahl et al. (2005). The addition of flaxseed flour was also responsible for decreasing the starch digestibility (Rendón-Villalobos et al. 2009). The k value is the component of the equation that provides information about the slope and pace of starch hydrolysis (De Angelis et al. 2009). This component was highest in CB. The area under the line in the chart was calculated as calcHI and the lowest value was observed in FB and the highest in CB. The general observation was that the CB had the highest GI and FB had the lowest. However, all breads with DF addition in the study were considered as products with low a glycemic index (Wolter et al. 2013). The addition of DF preparations could lead to increase of resistant starch content which is responsible for lowering digestibility of the whole starch matrix (Reshmi et al. 2017).

Phenolic compounds

The phenolic compounds in bread and chyme after digestion are presented in the Table 4. We observed that AB had a significant high value of total phenolic (897.2 mg/kg in gallic acid equivalents) with the lowest values in FB (541.2 mg/kg in gallic acid equivalents). Although FB had the lowest total phenolic content, they were the most bioaccessible. Flax in known source of the phenolic acids

Table 3 The glycemic index factors from the starch digestion of bread with dietary fibres

	C	k	calcHI	eGI
Control	80.5 ± 2.14 ^c	0.24 ± 0.02 ^b	79.1 ± 2.17 ^d	76.38 ± 3.14 ^c
OB	61.1 ± 1.89 ^a	0.18 ± 0.04 ^a	35.2 ± 2.19 ^c	38.58 ± 2.14 ^b
FB	64.3 ± 2.14 ^a	0.15 ± 0.06 ^a	19.6 ± 2.14 ^a	25.06 ± 1.74 ^a
AB	69.4 ± 2.17 ^b	0.14 ± 0.06 ^a	28.5 ± 2.16 ^b	32.80 ± 1.14 ^b

CB control bread, *OB* oat fibre bread, *FB* flax fibre bread, *AB* apple fibre bread

a, b, c, d: different letters indicate the statistical differences within the columns ($p \leq 0.05$)

Table 4 The phenolic content and their bioaccessibility; dietary fibre content and caloric value of the bread with different dietary fibres addition

Type of bread	Total phenolic content (gallic acid equivalents) (mg/kg)	Bioaccessible phenolic content	Phenolic bioaccessibility (%)	Dietary fiber	Calories
CB	674.1 ± 12.1 ^{bc}	350.5 ± 10.4 ^b	52.1	2.47 ± 0.54 ^a	266.1 ± 14.2 ^c
OB	623.1 ± 14.2 ^b	267.9 ± 14.2 ^a	43.4	6.14 ± 0.12 ^b	236.2 ± 12.7 ^c
FB	541.2 ± 14.4 ^a	362.6 ± 13.7 ^b	67.7	5.98 ± 0.18 ^b	214.1 ± 13.4 ^b
AB	897.2 ± 12.3 ^c	403.7 ± 14.7 ^c	45.3	6.14 ± 0.19 ^b	165.4 ± 11.4 ^a

CB control bread, OB oat fibre bread, FB flax fibre bread, AB apple fibre bread

a, b, c, d: different letters indicate the statistical differences within the columns ($p \leq 0.05$)

like p-coumaric, vanillic, sinapic and ferulic, and are present as glycosides with ester, ether bonds and flavonoids. According to the results obtained by Meral and Dogan (2013), flaxseed increased phenolics content, antiradical activity against ABTS and DPPH free radicals (compared to control) of breads by about 49, 75 and 28%, respectively (Meral and Dogan 2013). This could be explained by the fact that the phenolic are not a homogenous group, and the phenolics that were responsible for creating the highest amount in AB were the most easily changed. Moreover, in a recent research of Sęczyk et al. (2017) the addition of phenolic-rich ingredients was not as bioaccessible as those already present in bread. This is connected with the complexity of these substances, which play important role in its biological activity. The change of bioaccessibility could be caused because the fact that polyphenolic and antioxidants could be changed not only during storage time but during in vitro digestion as well (Altunkaya et al. 2013).

DF and caloric value

The DF was significantly highest in the samples with DF, which was the aim of the study. According to European regulations, all breads could be considered products that are high in fiber. The addition of DF is the main constituent responsible for lowering the caloric value of products. In this study, the only significant lowering of the caloric value was observed when AB was considered. Apple DF is known for the high content of pectin which is the part of soluble fraction of DF and has anti-obesity effects (Samout et al. 2016). The higher caloric value could be explained by the fact that oat and flax fiber preparations were high in fat (7.1 and 10.0, respectively). However, the higher caloric value of bread with oat does not imply negative effects on the human organism due to presence of beta-glucan known for its various health-promoting benefits (Piwińska et al. 2015). The lower caloric value leads to lower energy intake in general (Morris et al. 2015).

On the basis of obtained results, it could be stated that oat, flax and apple DF could be perceived as valuable ingredients to enrich nutritional value of fortified white

bread. Especially valuable in terms of fatty acid profile was bread with apple DF addition because its high content even they are easily degraded during thermal processing like baking. The oat DF influenced high content of γ -linolenic fatty acid in bread. This could lead the food manufacturers to include oat DF as ingredient in white bread. The obtained values estimated glycemic index were very promising because the application of oat, flax and apple DF in bread led to its lower glycemic index which could be valuable information for consumers with diabetes or other problems with carbohydrates digestion processes. In terms of phenolic compounds, the most bioaccessible phenolics were observed in the bread with flaxseed DF addition. The current study provides evidence that bread may be suitable for fortification with different DF sources. The performed work could give sufficient knowledge about taking into consideration glycemic index, fatty acid profile and phenolic content in parallel in terms of DF application in breads. We have shown the potential of developing fiber-rich breads in order to increase their added value. Therefore, DF which are by-products of some technological processes could be introduced in many other bakery branches.

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