***In vitro* glycaemic index and antioxidative properties of par -
baked wheat - flour rolls with an addition of dietary fiber**

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Abbreviations: DF-dietary fiber; GI – glycaemic index; RDS- rapidly digestible starch; SDI- starch digestion index; SDS- slowly digestible starch; TS- total starch

Key words: wheat, glycaemia, antioxidant, freezing

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Abstract

The aim of this study was to evaluate the impact of the bake-off technology with freezing process of wheat – flour rolls and the inclusion of the dietary fiber on the glycaemic index measured by in vitro method. In addition, the content of the total polyphenols and an ability to quench the free ABTS radical was determined.

Research material consisted of four kinds of wheat rolls, baked conventionally and by the bake-off technology, without and with 10 % addition of fiber (oat fiber and inulin). The following parameters were measured: content of the slowly digestible starch (SDS), rapidly digestible starch (RDS) and starch digestion index (SDI).

There was a significant effect of freezing process and frozen storage and the addition of dietary fiber on the reduction of the starch digestibility. There was found also the impact of freezing process on the value of glycaemic index, measured by in vitro method ($P<0.05$). The addition of the fiber and the use of the freezing and the frozen storage led to the significant increase in the content of the total polyphenols in the tested rolls ($P<0.05$), while the antioxidant activity was increased upon an addition of fiber into conventionally baked rolls ($P<0.05$).

1. Introduction

There has been a significant increase in the consumption of highly processed, high-fat, high-calorie foods, which over consumption may finally lead to the development of some chronic non-communicable diseases, such as: diabetes type 2, obesity, cardiovascular diseases and cancers [1]. In this situation, WHO [2] has recommended a decreased intake of easily digestible sugars, fat, alcohol and enhanced consumption of cereals, fruits and vegetables, which are essential sources of many bioactive compounds: vitamins, minerals, antioxidants and dietary fiber [3]. The latter should be consumed at the level of 25 – 40 g per day. A review of the literature has proven potential nutritional benefits of a moderate - high dietary fiber intake [4-8]. Hence, the dietary fiber should form a crucial part of a balanced nutritional diet. The amount of the antioxidant compounds in the daily diet is thus of the great importance. Its consumption may prevent against diseases associated with oxidative stress, such as cardiovascular disease, cancer and diabetes [9]. Polyphenols belong to the most popular antioxidants and their daily intake has been estimated at the level of 100 mg or more [9].

Cereals are a good source of complex carbohydrates and a poor source of fat. Nevertheless, the mostly popular white wheat products, such as: pasta or bread, are simultaneously scarce in dietary fiber, being averagely below 3% and low in biologically active compounds [1, 3, 8]. However, there are papers suggesting the possibility to enrich these products with dietary fiber for benefits such as reduced calorie intake by the manipulation of starch degradation and the enhancement of antioxidative properties [6, 8, 10-11].

The traditional baking technology, in the presence of water and high temperature, results in the total gelatinization of the wheat starch in the bread. In such form, starch is rapidly digestible and after ingestion lead to considerable increase in the concentration of

66 blood glucose and insulin. At the same time, polyphenols content are significantly affected by
67 thermal processing, leading to a reduction of these components [9]. A frequent consumption
68 of traditionally baked wheat - flour bread may develop chronic diseases, including obesity,
69 cardiovascular disease, diabetes and insulin resistance [5]. In order to reduce the amount of
70 easily digestible starch in white wheat bread and to enhance the amount of polyphenols, an
71 addition of dietary fiber has been recently proposed [7-8, 10-12] and the modification of the
72 traditional method of baking by the application of so - called “bake-off” technology, in which
73 freezing and frozen storage have been used [8,13]. The modification of the traditional baking
74 technology by the use of freezing and frozen storage contributes to the considerable
75 production of resistant starch type 3, exhibiting properties similar to the soluble fiber,
76 lowering the glycaemic index of bread [8, 13].

77 The application of dietary fiber and freezing at the same time in order to lower the
78 glycaemic index of wheat-flour rolls has been proposed by Borczak et al., [8]. The glycaemic
79 index was measured by *in vivo* method on human volunteers. This study was however long
80 lasting and quite expensive. The *in vitro* starch hydrolysis of foods has been suggested by
81 several authors [14-16] as an easily accessible alternative to predict the glycaemic index that
82 foods will produce *in vivo*. Currently, some efforts are taken to produce functional and pro-
83 healthy wheat- flour bread, still the most popular baked good among consumers. Such bread
84 should be characterized by optimal content of nutrients, rich in dietary fiber, bioactive
85 compounds and scarce in digestible starch.

86 Up to authors knowledge, the impact of bake-off technology alone and with dietary
87 fiber supplementation on the content of polyphenols and antioxidant activity has not been
88 tested in the case of white wheat flour rolls.

89 The aim of this study was to evaluate the impact of bake-off technology with freezing
90 process of wheat – flour rolls and the inclusion of dietary fiber on the glycaemic index

measured by *in vitro* method as well as on the content of total polyphenols and the ability to quench free ABTS radicals.

2. Materials and methods

2.1. Wheat rolls

Four types of wheat rolls were tested: (1) traditionally baked used as control (Conv.); (2) traditionally baked with 10% dietary fiber addition (Conv. with DF); (3) partially baked and frozen and (4) partially baked and frozen with 10% dietary fiber addition (Partially baked with DF).

The dough for the wheat rolls was prepared using the following ingredients: wheat flour type 55 - 900 g of flour was used in the case of Conv. with DF and Partially baked with DF and 1000 g for the rest of the tested rolls (Moulins Soufflet, Pornic, France)-, salt (18 g) (Janikosoda S.A., Janikowo, Poland), yeast (10 g) (SAF – Instant red – Lesaffre Group, Strasbourg, France), mix of dietary fibers (100 g) in which 75 g of insoluble fiber were delivered from oat fiber 300 (SunOpta, Bedford MA, USA) and 25 g of soluble fiber – inulin, (Raftiline® HP, Orafiti, Tienen, Belgium), Freshbake improver (10 g) (Puratos, Belgium) and the required tap water for each formulation - 580 g in Conv. and partially baked rolls, 590 g in the case of Conv. with DF and 540g in the case of Partially baked with DF. The method of baking was previously described in the study by Borczak et al., (2012).

In short, control rolls were baked conventionally (20 min., 230 °C). The partially baked rolls were firstly baked (190 °C, 30 sec.; 180 °C, 16 min. and 30 sec.), frozen in a blast freezer (30 min., -30 °C), and stored for 14 days (-18 °C). Before analyses, the rolls were defrosted at room temperature (10 min.), and finally baked (8 min. at 220 °C).

After baking, the rolls were dried at room temperature for 3 days, then grinded and packed in foil bags. In such material, the contents of protein, fat, total polyphenols and antioxidant activity were examined.

The amount of dry matter and starch nutritional fractions, as well as glycaemic index *in vitro* were designated in freshly baked rolls, which were grinded in a mincer in order to receive a representative laboratory sample.

2.2. Chemical analyses of fresh and frozen stored wheat rolls

Chemical analyses (dry matter, protein, lipid and ash content) of wheat rolls were performed using AOAC [17] standard methods. In order to obtain a mean laboratory sample, the tested rolls were ground in the kitchen mincing machine (MM1000.88, Zelmer, Rogoźnica 300, Głogów Małopolski, Poland). All values were calculated on dry matter basis (g/100 g d.m.).

2.3. *In vitro* glycaemic index determination

The nutritionally important starch fractions (SDS, RDS) and free glucose (FG) were determined by method described by Englyst et al., [14] with respect to its latest modification by Chung et al., [18].

In short, the freshly baked wheat-flour rolls underwent control enzymatic hydrolysis at 37°C by the action of pancreatic α -amylase (P-7545, Sigma-Aldrich, St.Louis, MO, USA), amyloglucosidase (3300 U/ml, A Megazyme International, Ireland Ltd., Bray, Ireland), invertase (300 U/mg, Sigma-Aldrich, St.Louis, MO, USA) and the measurement of glucose released from the tested rolls after 20 min ($RDS = (G_{20} - FG) \times 0,9$) and after 120 min ($SDS = (G_{120} - G_{20}) \times 0,9$). The glucose was measured by colorimetric method with the use of GOPOD reagent containing glucose oxidase and peroxidase at 510 nm (K-GLOX 09/12, Megazyme International Ireland, Bray Business Park, Bray, Co. Wicklow, Ireland). The

content of total starch (TS) in the tested wheat rolls was calculated as the sum of resistant starch and soluble starch determined by commercial kits (K-RSTAR 08/11, Megazyme International Ireland, Bray Business Park, Bray, Co. Wicklow, Ireland). At the end, starch digestion index (SDI) was calculated ($SDI = RDS/TS \times 0,9$).

2.4. Total polyphenols

The principle of the method was based on colorful determination of dye compounds resulting from the reaction between phenolic constituents contained in the tested rolls and Folin-Ciocalteu reagent (Sigma-Aldrich, St. Louis, MO, USA) [19].

2.5. Antioxidant activity

The principle of the method was based on determination of free radical ABTS in the solution of colorful compound, which was not reduced by the antioxidants presented in the examined product [20].

2.6. Statistical analysis

The results were presented as ranges with one standard deviation around the mean. Multivariate analysis of variance was applied in order to assess the interaction between baking technology and dietary fiber addition. Duncan test was used in order to test the significance of differences at a significance level of $P < 0.05$. All the calculations were carried out using Statistica, v.8 software (Statsoft, Inc., Tulsa, OK, USA).

3. Results and discussion

Dry matter contents (%) of the tested rolls were as follows: Conv. (73.9 ± 1.3), Conv. with DF (74.5 ± 0.2), Partially baked (67.7 ± 0.2) and Partially baked with DF (67.2 ± 0.3), while the amount of total starch (% d.m.) was at the following levels: Conv. (64.9 ± 0.2), Conv. with DF (58.7 ± 0.8); Partially baked (59.2 ± 0.9), Partially baked with DF (58.0 ± 2.3).

The content of the nutritional starch fractions and the glycaemic index *in vitro* (SDI index) is presented in Table 1. Breadmaking process and fiber incorporation in the rolls significantly affected the content of the starch fractions. The highest amount of SDS content (% d.m.) was obtained in Par - baked with DF rolls (21.8 ± 1.2) ($P < 0.05$), in the absence of fiber the SDS content was 18.3 ± 0.8 ($P < 0.05$). In the conventionally baked rolls (Conv., Conv. with DF), the amount of SDS was significantly lower, in comparison to par-baked rolls - 9.9 ± 1.0 and 7.6 ± 1.8 , respectively. On the other hand, the highest content of RDS fraction (% d.m.) was found in Conv. rolls (42.3 ± 2.2). The addition of dietary fiber led to decreased RDS contents: Conv. rolls with DF (37.7 ± 1.3), Par - baked with DF rolls (34.5 ± 1.3) ($P < 0.05$). The calculated glycemic index *in vitro* expressed as SDI index (%) was the lowest in the Partially baked with DF rolls. It was 5.8% and 4.8%, respectively lower compared with Conv. (65.2 ± 3.4) and Conv. with DF (64.2 ± 2.3) rolls ($P < 0.05$), (Table 1). The SDI index of partially baked rolls (60.4 ± 2.8) was 4.8% and 3.8%, respectively reduced compared with Conv. and Conv. with DF ($P < 0.05$). The application of the freezing treatment led to the significant decline of the glycemic index *in vitro* compared with traditionally baked rolls ($P < 0.05$), while fiber addition did not have any significant effect.

Rapidly digestible starch (RDS) consists mainly of amorphous and dispersed starch and is found in high amounts in gelatinized starchy foods, such as bread and potatoes. It is measured as the starch, which is converted to the constituent glucose molecules within 20 min upon enzyme digestion [21]. At the same time, slowly digestible starch (SDS) is expected to

be completely digested in the small intestine but for some reasons it is digested more slowly. This category consists of physically inaccessible amorphous starch, crystalline structure of either raw starch type A (cereals) or type C (peas and beans) or type B (raw potato and banana), as well as to this category the granular or retrograded form of the cooked starch is included. It can be determined chemically as a starch converted to glucose after the further 100 min of the enzyme digestion [21]. The term "resistant starch" (RS) was described as a small fraction of dietary starch, which is not digested in the small intestine. According to Englyst et al., [14], the RS is the fraction that was not hydrolyzed after 120 min of enzyme incubation.

In the available literature, the amounts of RDS and SDS fractions were in the range of 40 – 94 % and 4 – 43.48 %, respectively [14-15, 21-23], while the glycemic index *in vitro* (SDI index) of white wheat bread was found in the range of 67 – 100 % [15, 22-23]. The results obtained in this study are consistent with the above mentioned data.

Freezing process and frozen storage applied in the frame of bake-off technology had a significant reducing effect on the content of RDS and glycaemic index *in vitro* (SDI index), while SDS was significantly higher in the frozen stored rolls, compared with the control rolls (Conv.), ($P<0.05$) (Table 1). This phenomenon has been already confirmed in the literature concerning the different starchy foods, including wheat bread [14-15, 22-23]. In the research conducted by Rosin et al., [22], white wheat bread stored at -20 °C for 30 days was characterized by 12 % lower RDS fraction and 27 % reduced starch hydrolysis index (HI index) as compared with freshly baked sample ($P<0.05$). Similarly, Ronda et al., [23] found a significant 10 % decline of the RDS amount, 11 % rise of the SDS fraction and 12 % decrease of the SDI index upon frozen storage of white wheat bread for 63 days at -18°C ($P<0.05$). In the other starchy foods (spaghetti, potatoes), a similar correlation was found [14, 22].

The *in vitro* starch hydrolysis has been indicated as an important way to predict the glycaemic index *in vivo* [14-16]. Taking into account the above mentioned, the correlation between the SDI and rapidly digestible starch (RDS) was calculated. In the tested rolls, enriched with dietary fiber and prepared by bake-off technology, a significant positive correlation was observed between the SDI and the RDS values expressed on dry weight basis ($y = 0.895x - 18.044$, $r = 0.9$, $P < 0.05$, $n = 23$) (Fig.1). It can be assumed that the factors that will lower or enhance the digestibility of starch, would also have an impact on the value of SDI index.

The digestibility of starch might be affected by several factors, including: crystallinity of starch granular structure, amylose to amylopectin ratio, retrogradation of amylose, amylose chain length and linearization of amylopectin, which occurred during long low - temperature baking process and in the presence of organic acids (i.e. lactic acids) [16, 21]. Other factor that might impact the starch digestibility is the action of heat and moisture [21]. Repeated heat/moisture treatment was associated with a decrease in the hydrolysis of pancreatic α - amylase and increased formation of RS [12, 23]. The digestibility of starch could be also influenced by the interaction with the other food components, such as: protein, dietary fiber, enzyme inhibitors (i.e. polyphenols, phytic acid), ions (calcium and potassium), sugars (glucose, maltose, sucrose and ribose), lipids and emulsifiers [24]. Processing techniques affect both the gelatinization and retrogradation processes, influencing starch digestibility. Baking, pasta production, extrusion cooking, autoclaving are known to influence the yield of RS in foods [25].

The reduction of the glycaemic response as a result of freezing and frozen storage of different food products, including wheat bread was also confirmed by *in vivo* studies in healthy volunteers [8,13]. Traditional breadmaking process, at high temperatures and in the presence of water, lead to the gelatinization of the starch granules [25]. This process produces

a fraction of rapidly digestible starch. Upon cooling, a slowly digestible starch fraction is created, which undergoes a slow but complete hydrolysis in the small intestine [14, 23]. What is more, resistant starch might be also formed in the process known as a retrogradation [15, 25].

The benefits arising from the consumption of the SDS and the RS include prevention and treatment of diabetes type 2 [2, 4, 12, 14-15].

An addition of the oat fiber and the inulin to the wheat rolls contributed to the reduced RDS content compared with the control rolls ($P<0.05$). In turn, the SDS fraction was significantly increased in the rolls baked by the bake-off technology (Partially baked with DF), as compared to the conventionally baked rolls (Conv.) and the partially baked ($P<0.05$). An addition of fiber did not affect the glycaemic index *in vitro* (SDI index) ($P>0.05$).

The effect of the inulin and the oat fiber addition on the blood glucose level was repeatedly tested using both the methods *in vitro* [6, 11] and *in vivo* [4-5, 7-8].

In the *in vitro* study, Brennan et al. [6] has shown reduced rate of glucose release during digestion of pasta with the addition of inulin in various concentrations. This would correspond to the decrease of the glycaemic index in the range of 2.3 – 15 %. The larger the addition of inulin to the pasta, the significant reduction of the swollen starch and the water absorption capacity, as compared to pasta without any addition of inulin. It has been shown that the starch had been encapsulated in the inulin molecule, which in turn had reduced the water accessibility for the starch granules. Thus, higher concentrations of inulin, inhibited probably starch gelatinization, thereby reducing the digestibility as well as limited access to the amylolytic enzymes of the gastrointestinal tract [6]. In contrast, in the study by Raggæe et al., [11], there was no significant effect of the addition of the oat wholegrain flours to wheat bread on the content of RDS and SDS.

Viscosity of the soluble fiber fraction (i.e., the presence of the β -glucan, the soluble pectin, inulin) might affect the absorption of the glucose in the small intestine via several mechanisms: the delaying of the gastric emptying, the formation of the surface layer in the small intestine which prevents the rapid absorption of glucose, and reducing the availability of digestive enzymes to the starch [4-7], which has been confirmed with *in vitro* starch hydrolysis [26]. On the other hand, the insoluble fractions, such as: cellulose, hemicellulose, lignin and resistant starch, had a significant impact on the proper functioning of the colon, as well as had the ability to surround the starch granules, thereby limiting the degree of starch gelatinization by creating a physical barrier to amylolytic enzymes [4].

In this study, there was no significant effect of the addition of the oat fiber and the inulin on the glycaemic index *in vitro* (SDI index) independently on the applied method of baking ($P>0.05$). A similar relationship was observed in the previous studies by Borczak et al. [8]. Only the use of two agents at the same time, freezing and the oat fiber and the inulin addition, resulted in the reduction of the glycaemic index below 55 %.

The antioxidant properties of the tested rolls were shown in Table 2. Significantly high content of the total polyphenols was present in fiber enriched rolls (Conv. with DF; Partially baked with DF) ($P<0.05$). The freezing process carried out in the frame of bake-off technology led to increase content of the analyzed parameter compared with the control rolls ($P<0.05$).

The content of total polyphenols (mg gallic acid per 100 g d.m.) was the highest in rolls enriched with inulin and oat fiber: Par-baked rolls with DF (74.4 ± 0.2), and Conv. with DF (82.3 ± 2.2), ($P<0.05$). In the conventionally baked rolls (59.7 ± 2.0), the content of those compounds was significantly lower in contrast to par-baked rolls (68.3 ± 0.7) ($P<0.05$). The ability to quench free ABTS $\cdot^+$ radical ($\mu\text{mol Trolox/ 1 g d.m.}$) was higher in the Conv. with

DF (1.2 ± 0.1) ($P < 0.05$). In the other rolls, the ABTS values did not differ significantly ($P > 0.05$).

According to the literature data, the total polyphenols content of the wheat flour bread and wheat flour was claimed in the range of 28.3 - 344 mg / 100 g dry matter, calculated as gallic acid [9, 27]. The results obtained in this study were consistent to the above mentioned range. Phenolic compounds occur in cereals mainly in the form of phenolic acids: either free, or soluble fractions, and soluble, but coupled through an ester linkage with sugars and with the other low molecular weight components of the plant. The fourth type of phenolic compounds occurrence is the insoluble fraction of phenolic acids associated with the cell wall components, such as: polysaccharides, proteins, lignins, cutin or suberin [28]. The overall share of phenolic acids in cereal kernels consist of phenolic acids (p-hydroxybenzoic, salicylic, protocatechic, vanillin, gallic acid and ellagic acid) and phenylpropanoic acids (caffeic, p-coumaric, ferulic, synapic). In cereal grains, the predominant phenolic acid is trans-ferulic acid (Matilla et al., 2005). In wheat kernel, the most abundant are insoluble fractions (77%), then bound soluble acids (22%), and finally free and soluble fractions are presented (0.5-1%) [29]. Apart from phenolic acids in wheat, the alkylresorcinols stable during processing of grain were determined in considerable quantities [29]. The effect of the fiber addition to the wheat bread on the increase of polyphenols content and antioxidant activity was confirmed by the literature [11]. An enhancement of polyphenols content (59.2 mg/100 g) and antiradical activity in bread enriched with oat wholegrain flour (30 g/100 g flour) was observed by Raggae et al. [11]. On the other hand, Angioloni and Collar [10] observed the decrease of these compounds in the bread enriched with oat. The authors obtained a significant decrease of the antioxidants from 68.5 mg/100 g in the wheat bread, to the level of 64.3 mg/100 g in the oat-enriched bread ($P < 0.05$). The authors explained that during determination of polyphenols enzymatic extraction was applied with pepsin, α -

amylase and amyloglucosidase. These enzymes hydrolyzed the glycosidic linkages in the carbohydrate structures with fibers and thus they might have contributed to the degradation of polyphenols contained therein. The increase in the antioxidant activity in the present study was likely to be associated with significantly higher content of total polyphenols in Conv. with DF rolls ($P<0.05$). The dietary fiber could bind minerals, acting pro-oxidatively (i.e. iron, copper), thereby preventing Fenton reaction as reported by Tunland and Meyer [30].

The process of freezing and frozen storage has contributed to the significant increase in the content of total polyphenols in the tested rolls ($P<0.05$). In the available literature, there is no data concerning the impact of the freezing process on the total polyphenol content in wheat bread.

Research conducted by Kolniak [31] referred the total polyphenols content in the frozen stored strawberries. It ranged from 157.1 to 178.3 mg/100 g depending on the variety, while in the samples subjected to freezing, this content has increased and ranged from 183.7 to 211.3 mg /100 g, depending on the variety of the fruits. This phenomenon was explained by the liberation of polyphenolic compounds from damaged cells of fruit, or by the presence of cryoprotective compounds such as starch and pectin [23].

In the present work, the applied freezing process and frozen storage of wheat rolls might have contributed to the release of polyphenols fractions associated with the structures of cell walls ($P<0.05$). Another explanation might be the formation of the Maillard reaction products that formed during baking of the dough. Maillard reaction products have proven antioxidant activity, together with some chemopreventive effects [32].

The main compounds with antioxidative properties present in cereal grains and cereal products include phenolic acids and their esters and glycosides, avenamides, flavonoids, phytoestrogens, tocopherols and tocotrienols, carotenoids, melatonin, inositol phosphates, glutathione and certain trace elements such as iron, selenium, copper [9, 28-29].

The process of freezing and frozen storage contributed significantly to the reduction of antioxidant activity of Partially baked rolls and Partially baked with DF compared to the Conv. with DF rolls ($P<0.05$) (Table 2). The effect of freezing temperatures on the antioxidant activity of wheat rolls has not been studied and described before in the literature.

Conversely, the effect of heat treatment on the antioxidative activity of cereals has been previously documented [33]. The studies by Worobiej et al. [33] in spelt products, showed a decrease of antioxidant activity due to the high temperatures and the drying of pasta (0.68 mg Trolox/g d.m.), as compared to unprocessed products (not dried) seeds (3.23 mg Trolox/g d.m.) and bran (3.82 mg Trolox/g d.m.). The rolls obtained from bake-off technology in this study have been subjected to high temperature twice, what could contribute to the significant reduction in their antioxidant activity. Reduction of the antioxidative properties might be also caused by the decreased amount of the other bioactive compounds. One of them might be the vitamin E. Major source of this vitamin are cereal products, especially those derived from wheat. Vitamin E is an essential natural antioxidant of human body contributing to the detoxification of free radicals produced in metabolic processes, and it protects vitamin A and polyunsaturated fatty acids from the oxidative decomposition. Tocopherols (Vitamin E) are particularly sensitive to the heating and oxidation at the temperatures above 200 °C. The conventional cooking (100 °C) causes 10 % losses of the vitamin E, and they are even greater during frying and baking [34]). Thus, double treatment of the rolls by high temperature during partial baking and final baking, could result in a significant loss of this vitamin. Wheat is also an important source of selenium, an essential element exhibiting antioxidant, anticarcinogenic and antiviral activities [3]. The reduction of ash content, resulting from the application of low temperatures is confirmed by the literature. The widespread availability of oxygen in the frozen stored foods caused oxidation of the micronutrients, which determined the sensory and nutritional quality [3, 12, 24]. Hence,

probably less antioxidant activity of rolls obtained by postponed method of baking (Table 2). Further research is needed however on the effects of freezing and frozen storage of wheat bakery on the content of polyphenols and antioxidant activity, especially on the vitamin E and the selenium content, etc.

4. Conclusions

1. There was a significant effect of freezing process and frozen storage on the reduction of RDS fraction and SDI index of partially baked and partially baked with DF, compared with control rolls ($P<0.05$). At the same time, SDS fraction was significantly higher in rolls obtained by bake-off technology ($P<0.05$).
2. The addition of dietary fiber from the oat and the inulin to the wheat rolls reduced RDS content compared with the controls ($P<0.05$). In turn, the SDS fraction was significantly increased in partially baked rolls with an addition of fiber, compared with rolls without this ingredient ($P<0.05$). The inclusion of fiber did not affect SDI index value independently on the baking method ($P>0.05$).
3. An addition of the fiber and an application of the freezing and frozen storage increased significantly the content of the total polyphenols in the tested rolls ($P<0.05$).
4. An addition of the fiber increased significantly the antioxidant activity of the rolls baked conventionally. On the other hand, the process of freezing and frozen storage reduced significantly the antioxidant activity of the partially baked and partially baked with DF compared with Conv. with DF rolls ($P<0.05$).

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Figure captions

Figure 1. Relationship between Starch Digestion Index (SDI) and RDS (20 min.) of 4 rolls (with and without dietary fiber, baked conventionally and by using bake-off technology).

Table 1. Nutritional starch fractions and the glycaemic index *in vitro* measured as the starch digestion index.

Analyzed Parameter [% d. m.]	Conv.	Conv. with DF	Partially baked	Partially baked with DF
RDS	42.3± 2.2 ^a	37.7 ± 1.3 ^b	35.8 ± 1.7 ^{bc}	34.5 ± 1.3 ^c
SDS	9.9 ± 1.0 ^a	7.6 ± 1.8 ^b	18.3 ± 0.8 ^c	21.8 ± 1.2 ^d
SDI	65.2 ± 3.4 ^a	64.2 ± 2.3 ^a	60.4 ± 2.8 ^b	59.4 ± 2.2 ^b

Values with varied letters in rows are statistically different at $P<0.05$

Table 2. Antioxidant properties of the tested rolls

Analyzed Parameter	Conv.	Conv. with DF	Partially baked	Partially baked with DF
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Total Polyphenols	59.7 ± 2.0^a	82.3 ± 2.2^b	68.3 ± 0.7^c	74.4 ± 0.2^d
[mg/ 100 g d.m.]				
Antioxidant activity	1.1 ± 0.1^{ab}	1.2 ± 0.1^a	1.0 ± 0.0^b	0.9 ± 0.0^b
[μ mol/ g d.m.]				

522 *Values with varied letters in rows are statistically different at $P < 0.05$*

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