Polish Journal of Agronomy
2018, 34, 44–51

doi: 10.26114/pja.iung.360.2018.34.05

Effect of addition of barley wholemeal with different dietary fibre content on wheat bread quality

Anna Wirkijowska, Aldona Sobota, Piotr Zarzycki, Emilia Sykut-Domańska, Dorota Teterycz

Division of Engineering and Cereals Technology, Department of Plant Food Technology and Gastronomy,
University of Life Sciences in Lublin, POLAND

Abstract. Nowadays, interest of consumers in nutrition aspect of daily eaten foods arose; therefore, there is a demand for bakery products with a high dietary fibre content. The objective of the study was to determine the effect of an addition of wholemeal husked and naked barley with varied content of dietary fibre on the bread quality. The bread produced was examined for bread yield, total oven loss, volume of 100 g of the bread and the moisture of fresh crumb, and also consumer sensory assessment was performed. Analysis of the content of β-D-glucans, total dietary fibre with division into the soluble and insoluble fractions was made. The addition of barley wholemeal, at the rate of 7.5%, allows a significantly higher content of dietary fibre fractions to be obtained, compared to the control bread, with sensory quality characteristic of wheat bread. At the same time, barley component caused a small reduction of baking loss and increased of crumb moisture, compared to the wheat bread. It was demonstrated that wholemeal barley flour can be a highly valuable component enhancing the quality and nutritional value of white bread.

Keywords: wheat bread, barley bread, dietary fibre, functional bread, high-fibre bread

INTRODUCTION

In spite of the significant drop in bread consumption, it is still a cereal product that enjoys the greatest demand among the consumers. At present its consumption is estimated at about 50 kg/person per year (GUS, 2016). The market offers a very wide assortment of bread, both traditional and enriched in e.g. legumes, non-bread cereals or spices (Korus et al., 2002). In spite of the extensive variety to choose from, the consumers still prefer white bread, i.e. bread with a lower content of dietary fibre. That trend in consumer behaviour, with simultaneous increase in the number of people suffering from overweight, obesity and other diet-related diseases, generates the necessity of producing bread with enhanced dietary values (e.g. increased content of dietary fibre). At the same time, the product should be characterised by sensory features similar to those of traditional wheat bread.

Barley and its products cannot be the basic raw material for bread production, due to the specific fractional composition of proteins and carbohydrates. They can be introduced as substitutes for bread flour. Bread produced in this manner, enriched in valuable prebiotic fractions of dietary fibre, acquires the features of functional food (Sánchez-Muniz, 2012; Sudha et al., 2007; Topping, 2007).

Production of wheat-barley bread with high quality requires that a large number of variables is taken into account, e.g. degree of fragmentation of the percentage shares of the components, method of application to the dough, as well as the method of dough preparation (Škrbić et al., 2009). Barley proteins do not display the properties of wheat gluten, and in addition the high content of β-glucans and pentosans generates the need of introduction of modifications to the traditional recipes. The introduction of high-fibre components, barley as well as oat, has a significant effect on dough yield and acidity, on the volume and acidity of bread, and on the structure, taste and flavour of the crumb (Alu'datt et al., 2012; Andersson et al., 2004; Karolini-Skaradzińska et al., 2006).

Barley components, increasing the water absorption of wheat dough, limit the access of water to starch granules during their gelatinisation (Brennan, Celary, 2007; Karolini-Skaradzińska et al., 2006). The kind of barley components used has an effect on the bread yield of wheat-barley dough and on the time of its fermentation (Škrbić et al., 2009).

The effect of barley components on bread volume is not clearly defined. Probably, the reduced ability to retain gases within the dough is caused by the presence of β-glucans

Corresponding author:
Anna Wirkijowska
e-mail: anna.wirkijowska@up.lublin.pl
phone +48 81 4623315; fax +48 81 4623313

and arabinoxylans in the dough mass, that cause a weakening of the viscoelastic properties of gluten. Bread volume is also decreased as a result of an increase in the content of soluble proteins and a reduction of the content of the fraction of prolamins and glutelins in the dough (Kawka et al., 2005).

An addition of barley material has also an effect on the sensory values of bread crumb. In wheat-barley bread the crumb is elastic, slightly moist, with colour somewhat darker than in traditional wheat bread (Czubaszek et al., 2005).

Literature data indicate a possibility of producing wheat-barley bread with satisfactory quality even at a high level of barley wholemeal flour content, through the addition of vital gluten (3%), sodium stearoyl-2-lactate (0.25%) or xylanase (Trogh et al., 2004). Substitution of 2–6% of wheat flour with hot water treated flour causes an increase of wheat-barley bread volume and extends its shelf life (Hopek et al., 2006).

Fermentation of dough has a negative effect on the soluble fractions of dietary fibre. The process causes partial depolymerisation of (1-3)(1-4)-β-D-glucans and a reduction of their molecular mass, thus resulting in dough with lower viscosity (Åman et al., 2004; Andersson et al., 2004; Jacobs et al., 2008; Trogh et al., 2004). Depolymerisation of β-glucans is an effect of endogenic activity of β-glucanase contained in flour and in yeasts. Researchers indicate a reduction of molecular mass of β-glucans during dough mixing and fermentation, especially after the initial few minutes of the process (Andersson et al., 2004; Andersson et al., 2008). Therefore, to preserve the health-promoting properties of (1-3)(1-4)-β-D-glucans it is recommended to shorten the duration of those two processes as much as possible. The molecular mass of that fraction of fibre, lowered through the technological processes, has a direct effect on the decrease of its hypocholesterolemic and hypoglycaemic properties (Castro et al., 2007; Östman et al., 2006). Therefore, to preserve the functional potential of the barley material in bread it is required to optimise such processes as dough preparation, baking, quality of barley component applied, and its varietal origin.

The objective of the study was to determine the possibility of application of barley wholemeal from various barley cultivars as a substitute for wheat flour in the technology of baking of wheat-barley bread preserving the traits of traditional white wheat bread. In addition, the effect of varied content of fibre fractions in barley components on quality characteristics of bread was determined.

MATERIAL AND METHOD

The experimental material consisted of commercial wheat flour type 650 (falling number 253s) and wholemeal barley flour (grinding level 0.28 mm) obtained from naked (Rastik and STH 4561) and husked (Stratus) barley cultivars. The barley component was varied in terms of the content of dietary fibre and (1-3)(1-4)-β-D-glucans (Table 1). Such a choice of experimental material should allow to demonstrate the effect of the content of (1-3)(1-4)-β-D-glucans on the quality of bread and its acceptability. The barley grain originated from the IHAR experimental station, group Strzelce Sp. z o.o.

Dough was prepared with the single-stage method (Horubałowa, Haber, 1985). The barley component was applied as a substituent for wheat flour in quantities: 2.5; 5.0; 7.5; 10; 12.5%. Dough was prepared of wheat flour, barley component, yeast (3.0%), salt (1.5%) and water (450 ml) using dough mixer (Kenwood, KM240). To emphasise the effect of the level of the barley component, a constant addition of water was adopted, ensuring the obtainment of dough yield at the level of 157%. The doughs were mixed (7 min.), fermented for 30 min. (proofing chamber PL-10, temp. 28 ^{o}C), then dough pieces (250 g) were hand-divided and moulded. The baking of loaves with mass of 250g were conducted in a laboratory oven PL-10 at temperature of 230 ^{o}C for 30 minutes. The baking procedure was carried out twice and each time three loaves of bread were baked for each test. The estimation of bread quality comprised the determination of bread yield, total oven loss (Horubałowa, Haber, 1985), volume of 100g of bread (using the Sa-Wy apparatus), moisture of fresh crumb (AACC -Method 08-01). In addition, consumer sensory quality (taste, aroma, texture, shape, colour of skin and crumb) was conducted, using a one to nine hedonic scale, where nine means extreme satisfaction and one extreme dissatisfaction (9=perfect, optimal; 8=typical, without defects; 7=typical, with slight deviations; 6=noticeable deviations; 5=noticeable detractions, slight defects; 4=distinct defects; 3=strong defects; 2=very strong defects; 1=completely changed). Sensory evaluations of

Table 1. Fractional composition of dietary fibre of wholemeal barley flour [% d.m.].

Barley cultivars	TDF		IDF		SDF		(1-3)(1-4)-β-D-glucans	
STH 4561	21.01±0.27	c	13.33±0.30	c	7.68^{a}±0.03	c	5.25±0.19	a
Rastik	22.05±0.42	b	14.23±0.19	b	7.81^{a}±0.61	b	4.57±0.03	b
Stratus	25.10±0.34	a	19.88±0.15	a	5.21^{b}±0.19	a	4.39±0.10	b

TDF – total dietary fibre; IDF – insoluble dietary fibre; SDF – soluble dietary fibre bread were conducted by 10 panellists (5 men, 5 women). The content of (1-3)(1-4)-β-D-glucans (AACC 32-23, AOAC 999.16) and dietary fibre was assayed with the enzymatic method (AOAC 991.43, AACC 32-07, AACC 32-21, AOAC 985.29, AACC 32-05) permitting the determination of the dietary fibre fraction insoluble in water solution of enzymes (IDF), fraction soluble in water solution of enzymes (SDF), and total dietary fibre (TDF). The analyses were made using the enzyme set and the procedures of the company Megazyme (Bray, Ireland). The content of total dietary fibre (TDF) was adopted as the sum of fractions IDF and SDF.

The results were analysed statistically using the software SAS ver. 9.1. Mean values and standard deviations were calculated, and the significance of differences was tested (Duncan's test, $p \leq 0.05$). Also, linear correlation (Pearson) between dietary fibre fractions content and physical properties of bread was analysed.

RESULTS AND DISCUSSION

The incorporation of the barley component as a substituent for wheat flour contributed to a change in the sensory features, physical properties and chemical composition of the bread produced. The extent of the changes depended both on the percentage content of the barley component and on its kind.

The bread yield of the wheat-barley bread varied within the range from 137 to 145 %. The study did not reveal any negative effect of the addition of the barley component on bread yield. A slight increase in bread yield was noted with increasing of barley flour content. The highest bread yield was obtained for cv. Stratus at barley flour level of 7.5% (145%), increase of the flour level above 7.5% caused a slight decrease on bread yield, but the change was not statistically significant (Table 2). For the other cultivars the changes were slightly smaller. Bread yield is determined by numerous factors, including flour quality, method of dough preparation and its fermentation, dough moisture, technological additives, and kind of bread. The value of that parameter for wheat bread may fall within the broad range from 131% to 149,5% (Kasprzak, Rzedzicki, 2010; Wirkijowska et al., 2015). The increase in the bread yield of the barley bread, noted in this study, could have been caused by increased of dietary fibre content, especially IDF fraction, that have a strong effect on the amount of absorbed water and its retention during baking. A high linear correlation (Pearson) between dietary fibre content and bread yield was noted (Table 4). A similar position is presented also by Skendi et al. (2010).

The application of barley flour did not cause significant increase of total baking loss that fell within the range from 5.0 to 10.2 % (Table 2). The baking loss was inversely correlated to the bread yield and to the dietary fibre content (Table 4). Outstanding in this respect was cultivar Stratus, for which already the addition of 5% of the barley component caused a 33% decrease of the baking loss relative to the control bread (Table 2). The value of the total baking loss results primarily from the evaporation of water from dough, approximately 3% is related with the loss of CO_2, and 1.5% is accounted for by the evaporation of alcohol and volatile substances (Gąsiorowski, 2004). The amount of evaporated water depends primarily on the relative humidity in the oven, crumb structure and crust porosity. The

Table 2. Physical properties of bread and overall sensory quality.

Cultivars	Share of barley flour [%]	Bread yield [%]		Total baking loss [%]		Crumb moisture [%]		Volume of 100 g bread [cm^3]		Overall sensory quality
Control	0	139±1	bcdef	8.8±0.5	abcd	43.6±0.5	d	308±14	abcde	9.00
STH 4561	2.5	137±1	f	10.2±0.9	a	45.0±0.6	bc	339±10	a	8.50
	5.0	140±0	bcdef	9.3±0.3	abc	45.8±0.2	ab	311±5	abcd	8.75
	7.5	139±0	def	9.1±0.2	abcd	46.4±0.2	a	299±13	bcdef	8.63
	10.0	141±0	abcde	7.4±0.3	bcde	46.3±0.1	a	279±2	def	8.13
	12.5	142±0	abcd	7.1±0.2	bcde	46.8±0.5	a	272±3	f	7.86
RASTIK	2.5	138±1	ef	10.1±0.7	a	44.0±0.3	cd	326±17	ab	8.88
	5.0	139±1	cdef	9.4±1.1	ab	44.0±0.3	cd	324±8	ab	8.86
	7.5	142±1	abcd	7.2±1,0	bcde	43.9±0.2	cd	299±5	bcdef	8.63
	10.0	143±1	abc	6.9±0.5	cde	44.0±0.4	cd	270±24	f	8.50
	12.5	141±2	abcde	7.3±1.3	bcde	43.5±0.2	d	271±15	f	8.25
STRATUS	2.5	140±2	bcdef	8.6±0.8	abcd	44.3±0.1	cd	314±12	abc	8.88
	5.0	144±3	a	5.9±1.7	e	44.4±0.2	cd	288±13	cdef	8.88
	7.5	145±1	a	5.6±0.7	e	44.3±0.6	d	280±3	cdef	8.63
	10.0	143±1	ab	6.7±1	de	44.6±0.6	cd	277±4	ef	8.50
	12.5	144±1	a	5.0 ±1	de	44.9±0.1	bc	277±6	ef	8.00

Means in the same column with the same letters (a-f) aren't significantly different (Duncan; $p \leq 0.05$)

low values of the loss in the analysed wheat-barley bread are a very good recommendation for the industrial practice. Barley additives, similarly to oat component, will not cause a decrease in bread mass (Kasprzak et al., 2011).

Bread volume is a fundamental criterion of estimation of its quality by the consumers at the moment of purchase. According to literature, the volume of wheat bread can vary within a broad range from 246 to 563 cm^3/100 g of bread (Kasprzak, Rzedzicki, 2009; Skendi et al., 2010; Škrbić et al., 2009). In this study, the volume of the wheat-barley bread range from 270 to 339 cm^3/100 g. For the control bread that value was 308 cm^3/100g. Barley flour addition at rates from 2.5% to 5% may cause a slight increase of bread volume. In the case of barley STH 4561, at 2.5% addition a 10% increase of volume was obtained, relative to control bread. However, the changes were not statistically significant, while increase of the barley component level above 10 to 12,5% may lead to a significant decrease of bread volume, relative to the control. Such a relation was noted for bread with 12.5% content of wholemeal flour of barley cultivars STH 4561 and 10 and 12.5% for Rastik (Table 2). Barley cultivars STH 4561 and Rastik were characterised by a high content of dietary fibre fraction SDF and β-glucans (Table 1). The effect of barley components on bread volume is not clearly defined. In numerous studies (Karolini-Skaradzińska et al., 2006; Kawka, Konieczna, 2002; Škrbić et al., 2009) it was demonstrated that barley products added at rates of up to 10% do not cause a decrease of bread volume and do not change the characteristics of its crumb. In fact, at a 5% addition even an increase of the volume of loaves was noted (Karolini-Skaradzińska et al., 2006). An addition of over 10% of barley components caused a reduction of bread volume that was related to what kind of barley product was used. A study (Cavallero et al., 2002; Symons, Brennan, 2004) showed a decrease of bread volume irrespective of the level of addition of barley component. The negative effect of the barley component and β-glucans on bread volume is attributed to the dilution of gluten and weakening of the gluten lattice (Izydorczyk, Dexter, 2008; Skendi et al., 2010).

Barley component addition caused small changes in crumb moisture. Crumb moisture levels were within the range from 43.5 to 46.8%. Only in the case of bread with an addition of wholemeal of STH 4561 and 12.5% of Stratus a small, though statistically significant, increase was noted in crumb moisture compared to the control sample (Table 3). Crumb moisture of the analysed wheat bread was 43.6 and it was comparable to literature data (Kasprzak et al., 2011; Kawka, Konieczna, 2002).

The analysed assortment of bread was subjected to sensory assessment, adopting wheat bread as the control. The extent of changes in the sensory features of the bread was dependent on the percentage share of the barley component. The tested wheat-barley bread obtained a very high score between 8-9 points, which corresponds to the typical of bread without defects. Only bread with an addition of wholemeal of STH 4561 (12.5% share of barley) scored 7.86 corresponding to typical products with slight deviations (Table 2). Highly rated were the colour, surface of the crust and its thickness, external appearance (Fig. 1 a,b,c). No significant deterioration of the sensory features relative to the control bread was noted.

In the estimation of crumb porosity, bread with small, thin-walled and uniformly distributed pores achieved the

Table 3. Content of dietary fibre fractions [% d.m.] in bread.

Cultivars	Share of barley flour [%]	TDF		IDF		SDF		(1-3)(1-4)-β-D-glucan	
Control	0	4.37±0.13	i	2.07±0.17	i	2.30±0.04	h	0.22±0.03	i
STH 4561	2.5	4.79±0.03	hi	2.39±0.07	h	2.39±0.04	gh	0.32±0.01	h
	5.0	5.58±0.12	efg	2.91±0.05	fg	2.67±0.07	def	0.43±0.01	g
	7.5	5.96±0.08	ef	3.14±0.06	ef	2.81±0.02	cde	0.62±0.03	de
	10.0	6.23±0.06	e	3.34±0.01	de	2.89±0.05	cd	0.74±0.01	bc
	12.5	6.84±0.07	bc	3.70±0.15	bc	3.13±0.08	ab	0.92±0.04	a
RASTIK	2.5	4.79±0.08	hi	2.35±0.12	hi	2.44±0.04	fgh	0.38±0.05	gh
	5.0	5.58±0.67	fg	2.89±0.35	fg	2.69±0.32	def	0.47±0.04	fg
	7.5	6.12±0.02	e	3.09±0.09	ef	3.02±0.10	bc	0.52±0.06	f
	10.0	6.70±0.16	cd	3.54±0.08	cd	3.17±0.08	ab	0.66±0.01	cd
	12.5	7.16±0.02	ab	3.78±0.24	bc	3.38±0.22	a	0.77±0.02	b
STRATUS	2.5	4.98±0.03	h	2.64±0.01	gh	2.34±0.05	gh	0.32±0.02	h
	5.0	5.44±0.10	g	3.03±0.15	ef	2.40±0.05	gh	0.46±0.03	fg
	7.5	6.31±0.02	de	3.70±0.04	bc	2.60±0.02	efg	0.53±0.00	ef
	10.0	6.64±0.01	cd	4.01±0.06	b	2.64±0.05	defg	0.62±0.08	d
	12.5	7.32±0.06	a	4.59±0.00	a	2.73±0.05	de	0.77±0.01	b

Means in the same column with the same letters (a-f) aren't significantly different (Duncan; p≤0.05); TDF – Total dietary fiber, SDF – Soluble dietary fiber, IDF – Insoluble dietary fiber

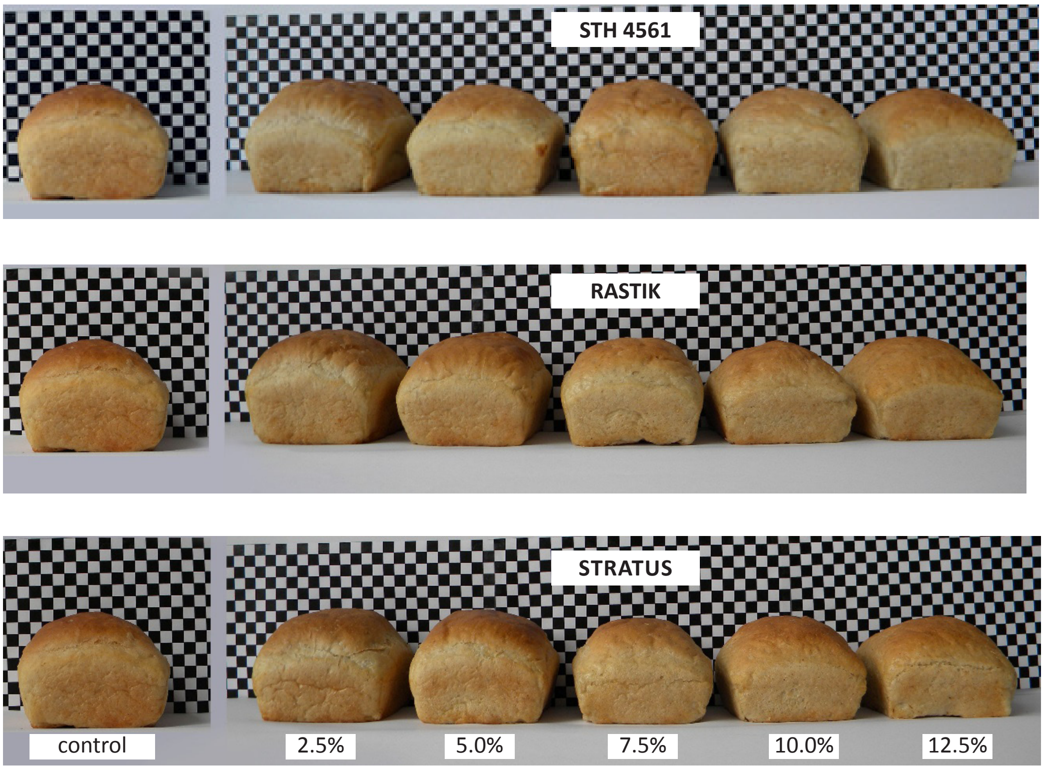

Figure 1. Wheat bread with an addition of barley wholemeal.

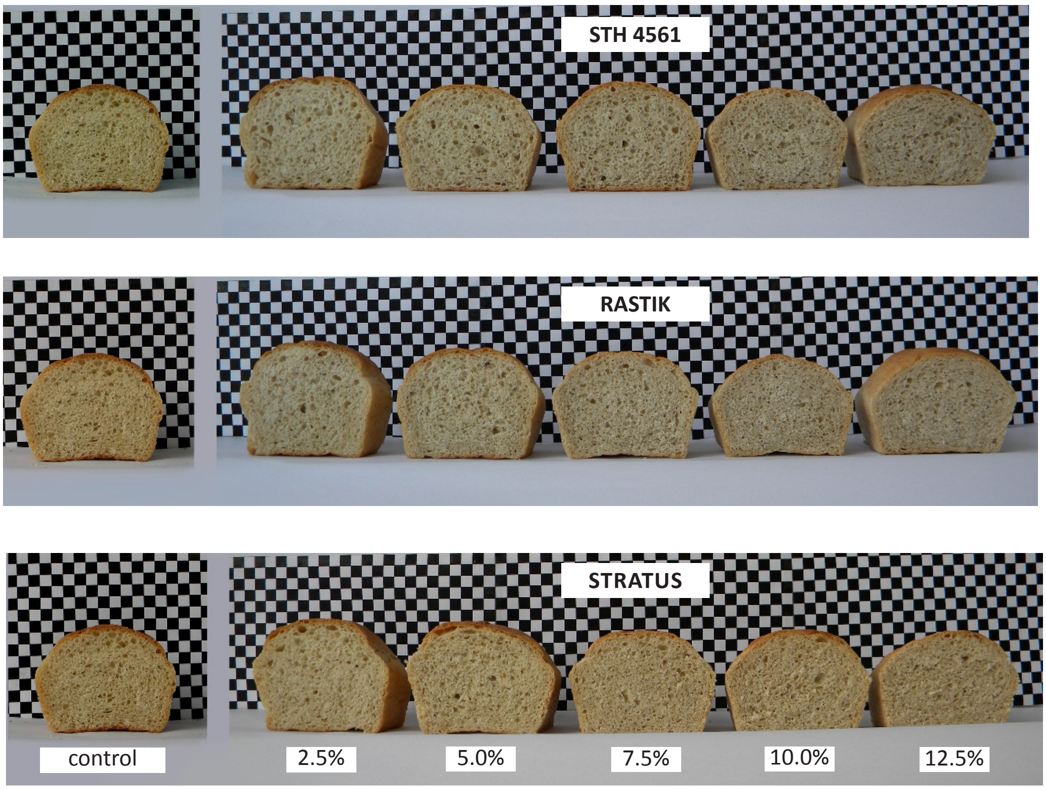

Figure 2. Section through wheat bread with an addition of barley wholemeal.

highest note. Apart from the control wheat bread, such properties were found in breads with an addition of barley cv. Rastik (Fig. 2b). In the case of the remaining assortment of wheat-barley breads, small, thin-walled and uniformly distributed pores were observed at a maximum 7.5% level of barley (Fig. 2 a,c). With an increased content of the barley component a breakdown of that features was observed, and the appearance of large pores or of compacted structure. Kawka (2004) reports that it is possible to obtain bread of good quality with as much as a 30% addition of a high-fibre barley product. This study does not support such a claim. Bread with a higher content of wholemeal barley flour is different from traditional white wheat bread. It will, therefore, require an extensive promotion campaign and consumer acceptance. Studies have shown that the addition of wholemeal barley flour to 12.5% allows obtaining bread that is fully accepted by consumers.

The inclusion of high-fibre barley component in the bread recipe distinctly improved its chemical composition. It was observed that, at the share of barley flour above 2,5%, the content of total dietary fibre (TDF) was higher in every sample of the wheat-barley bread compared to the control bread, and increased with share of wholemeal barley flour (Table 3). White bread, with total dietary fibre content at the level of 4.37% d.m. cannot be the main source of dietary fibre in the diet. Whereas, already a 5% addition of the barley component significantly increased the content of TDF in the analysed mixed bread.

The application of barley components permitted the modification of the fractional composition of dietary fibre in the final product. The content of soluble dietary fibre (SDF) in the analysed wheat-barley bread varied from 2.34 to 3.38% d.m., respectively, with fibre component addition at the rates of 2.5 and 12.5% (Table 3). These values are comparable with literature data (Knuckles et al., 1997).

The addition of the barley component caused a significant increase in the content of insoluble dietary fibre (IDF) in the bread (Table 3). According to literature data, white wheat bread contains from 2.42% d.m. to as much as 6.55% d.m. of the insoluble fibre fraction (Kasprzak, Rzedzicki, 2009; Knuckles et al., 1997; Paczkowska, Kunachowicz, 2003). The broad range of those values is an effect of using various types of wheat flour for baking, and of the application of various parameters of the baking process.

From the viewpoint of nutrition, one of the more important components of dietary fibre are (1-3)(1-4)-β-D-glucans. The content of those polysaccharides in the control bread was 0.22% d.m. and it fell within the range specified in the literature (Knuckles et al., 1997; Škrbić et al., 2009; Trogh et al., 2004). Every addition of the barley component caused a significant increase in the content of (1-3)(1-4)-β-D-glucans (Table 3). Their content in the analysed assortment of wheat-barley bread varied from 0.32 to 0.92% d.m., respectively, for 2.5 and 12.5% rates of addition of the barley component. The assayed levels of β-glucans are comparable with the results obtained by Škrbić et al. (2009) who, in bread with 15% content of wholemeal barley flour, noted 1.15% d.m. of those polysaccharides.

The addition of barley components was correlated with the bread yield (0.72 to 0.95) and moisture content of fresh crumb (0.78 to 0.98) and negatively correlated with the total baking loss (-0.70 to -0.95) (Table 4). A negative effect of the high-fibre components on the bread volume was noted. Stronger correlations were observed in the case of naked barley line (Rasik and STH 4561) vs. the hulled cultivar.

Table 4. Correlation matrix between dietary fibre content and bread physical properties.

	Volume of 100 g bread	Total baking loss	Crumb moisture	Bread yield
TDF				
STH 4561	-0.98	-0.94	0.98	0.94
RASTIK	-0.94	-0.90	0.94	0.83
STRATUS	-0.86	-0.73	0.84	0.75
IDF				
STH 4561	-0.98	-0.94	0.97	0.95
RASTIK	-0.94	-0.87	0.91	0.80
STRATUS	-0.85	-0.73	0.85	0.85
SDF				
STH 4561	-0.97	-0.93	0.98	0.94
RASTIK	-0.95	-0.92	0.96	0.86
STRATUS	-0.86	-0.70	0.78	0.81
(1-3)(1-4)-β-D-glucan				
STH 4561	-0.96	-0.95	0.93	0.90
RASTIK	-0.94	-0.81	0.93	0.72
STRATUS	-0.86	-0.77	0.89	0.87

TDF – total dietary fibre; IDF – insoluble dietary fibre; SDF – soluble dietary fibre

CONCLUSION

1. The addition of the barley component, at any rate from 2.5 to 12.5%, to wheat bread results in a product with a significantly higher content of total dietary fibre and its fractions, compared to the control bread (wheat bread) with an added benefit of greater consumer acceptability.

2. Barley's cultivar Stratus, with the lowest content of SDF fibre and (1-3)(1-4)β-D-glucans, showed the lowest correlation between the barley flour concentration and physical properties of bread.

3. The recommended barley variety to be used is Rastik. The addition of 12.5% barley's wholemeal flour makes it possible to obtain bread with 3.38% d.m. and 0.77% d.m SDF and (1-3)(1-4)β-D-glucans contents respectively, an increase of bread yield of 141% and a high overall sensory quality of the product.

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Author	ORCID
Anna Wirkijowska	0000-0002-1647-2921
Aldona Sobota	0000-0001-6526-6764
Piotr Zarzycki	0000-0003-1462-6146
Emilia Sykut-Domańska	0000-0002-2741-2772
Dorota Teterycz	0000-0002-8714-9814

received – 25 September 2018
revised – 23 November 2018
accepted – 26 November 2018