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EFFECT OF NAKED BARLEY ENRICHMENT ON THE QUALITY AND NUTRITIONAL CHARACTERISTICS OF BREAD – PART I. THE EFFECT ON WHEAT BREAD

WPŁYW WZBOGACANIA JĘCZMIENIEM NAGIM NA JAKOŚĆ I WARTOŚĆ ŻYWIENIOWĄ PIECZYWA – CZĘŚĆ I. WPŁYW NA PIECZYWO PSZENNE

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Summary: Barley is gaining more interest due to its nutritional value, especially because of the dietary fibre content and the presence of non-starch polysaccharides Hull-less barley is a rich source of soluble and insoluble dietary fibre providing beneficial non-starch polysaccharides, especially β-glucans. The effects of different barley wholemeal share in wheat bread and different dough preparation methods on the quality of bread and its nutritional composition were investigated. Barley incorporation to wheat bread improved its nutritional quality by increasing the dietary fibre, β-glucans and arabinoxylans content. However, high barley concentration led to decrease in loaf volume and overall acceptability and changes in bread's crumb and crust colour. Bread production method strongly influenced its quality and nutritional composition. Barley sourdough fermentation comparing to direct barley wholemeal incorporation allowed to obtain more acceptable products of higher nutritional quality.

Keywords: hull-less barley, wheat bread, sourdough, dietary fibre, β-glucans, non-starch polysaccharides.

Streszczenie: Zainteresowanie jęczmieniem rośnie ze względu na jego wartość żywieniową, zwłaszcza zawartość w nim błonnika pokarmowego i obecność polisacharydów nieskrobiowych. Jęczmień nagoziarnowy jest bogatym źródłem zarówno rozpuszczalnego, jak i nierozpuszczalnego błonnika pokarmowego, dostarczając korzystnych polisacharydów nieskrobiowych, szczególnie β-glukanów. Zbadano wpływ różnych udziałów całoziarnowej mąki jęczmiennej i różnych metod prowadzenia ciasta na jakość pieczywa i jego skład. Dodatek jęczmienia do mąki pszennej przyczynił się do poprawy jego jakości żywieniowej poprzez zwiększenie zawartości błonnika pokarmowego, β-glukanów i arabinoksylanów. Wysoki udział jęczmienia spowodował jednak zmniejszenie objętości pieczywa i jego akceptacji oraz zmianę barwy miękiszu i skórki. Metoda wytwarzania ciasta silnie wpłynęła na jakość chleba i jego skład. Dodatek jęczmienia w postaci zakwasu, w porównaniu z metodą bezpośrednią, pozwolił na uzyskanie lepiej ocenionych produktów o wyższej wartości żywieniowej.

Słowa kluczowe: jęczmień nagoziarnowy, pieczywo pszenne, zakwas, błonnik pokarmowy, β-glukany, polisacharydy nieskrobiowe.

1. Introduction

Improving the nutritional value of food products is gaining interest due to the increasing awareness of consumers. Supplementing wheat flour by addition flours of different origin aims to improve mineral, vitamin, protein or dietary fibre content and composition of bread [Škrbić et al. 2009]. Barley has become less popular for bakery products due to its poor baking performance and lower sensory quality of the products [Jacobs et al. 2008; Skendi et al. 2010]. Nowadays, barley is gaining more interest due to its nutritional value, especially because of the dietary fibre content and the presence of non-starch polysaccharides [Baik, Ullrich 2008; Holtekjølen et al. 2008b; Izydorczyk, Dexter 2008]. Therefore, there have been numerous studies on the applicability of barley in bread making [Collar, Angioloni 2014; Holtekjølen et al. 2008b; Izydorczyk et al. 2008; Jacobs et al. 2008; Skendi et al. 2010].

Hull-less barley cultivars compared to hulled have increased nutritional value through higher content of proteins, lipids and dietary fibre [Kinner et al. 2011; Škrbić et al. 2009]. Naked (hull-less) barley is a rich source of soluble (SDF) and insoluble (IDF) dietary fibre. It was proven that high content of dietary fibre in whole grain plays a significant role in the health promoting effect of cereal based products and there is a strong connection between chronic diseases and obesity and the intake of dietary fibre [Izydorczyk, Dexter 2008].

Strong interest is focused on a mixed-linkage (1→3), (1→4)-β-D-glucans present in naked barley in high amounts. This parts of the soluble dietary fibre are known for their ability to lower plasma cholesterol, reduce glycemic index, improve lipid metabolism, boost the immune system and reduce the risk of colon cancer. The physiological effect of β-glucans is resulted by their ability to form solutions of high viscosity [Dickin et al. 2011; Izydorczyk et al. 2008; Kinner et al. 2011; Rieder et al. 2012; Skendi et al. 2010; Škrbić et al. 2009; Wood 2007]. It is presumed that other non-starch polysaccharides present in barley- arabinoxylans may have similar physiological effects to β-glucans due to their ability to form viscous solutions [Izydorczyk, Dexter 2008; Storsley et al. 2003]. Water soluble arabinoxylans from other cereals are demonstrated to have a positive impact on cecal fermentation and production of short-chain fatty acids and reduction of serum cholesterol [Izydorczyk, Dexter 2008]. It is also envisaged that β-glucans from barley in combination with arabinoxylans may improve the shelf life of bread [Holtekjølen et al. 2008b].

Sourdough fermentation affecs bread's both sensory and nutritional quality. Except the flavour compounds formation, sourdough fermentation results in increase of arabinoxylans solubility [Gänzle 2014]. It has been demonstrated that sourdough improved the dough structure and bread quality of breads containing whole grain barley, which may be related to a softening effect on bran particles during fermentation [Rieder et al. 2012].

The incorporation of naked barley to wheat bread formula and different bread production methods strongly affect the quality of bread and its nutritional composition. Therefore, the aim of the study was to analyze the effects of different naked barley wholemeal share and dough preparation methods on the wheat-barley bread quality and the dietary fibre content and composition.

2. Materials and methods

2.1. Materials

Experimental genotype of hull-less barley (STH 4933) supplied from Plant Breeding Strzelce Ltd. IHAR Group, Poland) was used in the study. Wholemeal barley flour was obtained by milling grain using Hagberg Perten's Mill (Lab Mill type 120). For dough formulations wheat flour type 750 obtained from Good Mills Poland (Stradunia mill) was used. Compressed yeast and commercial freeze-dried Saf Levain LV1 starter cultures were supplied by Lesaffre Bio-Corporation Inc. (Łódź, Poland).

2.2. Dough formulations and bread baking

0/100, 20/80, 30/70, 40/60 barley and wheat flour blends were used in laboratory breadbaking. Doughs were prepared by using two methods in which wholemeal barley flours were added directly and as a barley sourdough fermented by starter cultures. Doughs were prepared using 250 grams of wheat flour or wheat-barley (flour or sourdough) blend, yeast – 3g/100g of flour, salt – 1.5g/100g of flour and water in amounts allowing to obtain 300 FU consistency. After 3 minutes of mixing in Brabender farinograph (Duisburg, Germany) dough portions were placed in a baking tin and fermented in a temperature of 30-35°C and 85% relative humidity in fermentation chamber Eka KL 864 (Eka, Padova, Italy).

In direct method doughs were kneaded three times during fermentation: after 60, 90 and 120 minutes and then left to final fermentation. In the other method barley wholemeal flour was fermented by LV1 starter cultures (performance of sourdough: 200, temperature: 30°C, fermentation time: 18 hours). Barley sourdough was added to the doughs in amounts allowing to obtain 20/80, 30/70 and 40/60 barley and wheat flour proportions, the dough was kneaded after 30 minutes of fermentation and left to final fermentation.

The loaves were baked in a laboratory oven (Brabender, Duisburg, Germany) for 30 minutes in 240°C in both dough preparation methods. Baking experiments were performed twice and their averages were reported in the study. Breads' properties were evaluated after 24 hours and the samples of each bread was freeze-dried and milled for non-starch polysaccharides content analysis.

2.3. Characteristics of bread

Bread was evaluated in terms of specific loaf volume, crust and crumb colour and sensory properties. Bread volume was assessed by millet displacement method using the SA-WY device (ZBPP, Bydgoszcz, Poland), and expressed in cm^3 per 100 g of flour. For bread's crust and crumb colour five different points of the slice (crumb) and loaf surface (crust) were measured with L*, a* and b* values using Minolta Colorimeter (CR-400/410, Konica Minolta, Japan). Bread was subjected to sensory analysis by ten panelists using 9-point hedonic scale. The overall acceptability of breads was expressed as the average rating of breads' external appearance, crumb colour, porosity, flavor and taste.

2.4. Dietary fibre and non-starch polysaccharides content

Total, soluble and insoluble dietary fibre content were determined by the enzymatic-gravimetric AOAC method [AOAC, Method 991.43 2006]. Colorometric method described previously [Pejcz et al. 2015] was used for the determination of total, soluble and insoluble arabinoxylans content. Total β-glucan content was determined with the use of mixed linkage β-glucan assay kit (Megazyme International, Bray, Ireland) following the ICC Standard Method No. 166. All determinations were performed in duplicate and their averages were reported in the study.

2.5. Statistical analysis

The results were statistically analysed with Statistica 12.0 software package (StatSoft, Tulsa, USA). One-way ANOVA at $p = 0.95$ was calculated and homogeneous groups according to Duncan test were estimated.

3. Results and discussion

3.1. Characteristics of bread

Wholemeal barley incorporation to wheat bread as well as dough preparation method strongly influenced breads' quality (Table 1). With increasing barley share the volume of breads decreased significantly. The results of other researchers have shown that barley products addition to wheat dough contributed to bread quality deterioration, especially its volume reduction [Blandino et al. 2015; Collar, Angioloni 2014;

Holtekjølen et al. 2008b; Jacobs et al. 2008]. The negative changes of breads' volume are the result of an increased amount of dietary fibre and the presence of non-starch polysaccharides effecting in gluten network weakening and lower gas retention in the dough in consequence. It was demonstrated that high content of both β-glucans and insoluble arabinoxylans present in naked barley leads to the bread quality deterioration [Collar, Angioloni 2014; Courtin, Delcour 2002; Holtekjølen et al. 2008b; Izydorczyk, Dexter 2008]. Sourdough fermentation of barley wholemeal resulted in significantly higher volume of breads comparing to direct method obtained breads. The positive impact on bread volume by lactic acid bacteria fermentation had been reported by Tamani et al. [2013].

Table 1. The volume, colour and acceptability of wheat-barley bread depending on the share of barley and the bread making method
Tabela 1. Objętość, barwa i akceptacja pieczywa pszenno-jęczmiennego w zależności od udziału jęczmienia i metody wytwarzania

		Loaf volume [cm^3]	Crust colour			Crumb colour			Overall acceptability
			L*	a*	b*	L*	a*	b*	
Barley share	0%	593 a	51.57 a	14.41 a	22.34 a	66.91 a	2.68 d	16.63 a	6.7 a
	20%	547 b	48.70 b	13.45 b	18.29 b	58.05 b	3.55 c	12.31 b	6.6 a
	30%	528 c	47.84 c	12.58 c	17.05 c	54.88 c	4.01 b	11.55 c	6.4 ab
	40%	507 d	46.96 d	12.23 d	15.61 d	53.74 d	4.52 a	11.35 c	6.1 b
Bread making method	direct	530 b	46.11 b	14.11 a	16.69 b	59.57 a	3.44 b	12.59 b	5.8 b
	sourdough	557 a	51.43 a	12.22 b	19.96 a	57.22 b	3.94 a	13.33 a	7.1 a

Data represent the mean of two (loaf volume), five (colour parameters) or ten (sensory analysis) replicates. Small letters denote significant groups according to Duncan's test, $p = 0.95$.

Source: own work.
Źródło: opracowanie własne.

Barley wholemeal addition to wheat bread affected the breads' crust and crumb colour. Any increase of barley share contributed to obtain significantly darker (lower L* value) and less saturated crust colour (lower a* and b* values). Increasing barley wholemeal substitution level contributed to obtain darker crumb (lower L*), higher red saturation (a*) and lower yellow saturation (b*). The results of other researchers confirmed that bread with the addition of barley grain external parts was darker than pure wheat bread [Blandino et al. 2015; Gill et al. 2002; Holtekjølen et al. 2008a; Izydorczyk et al. 2008; Trogh et al. 2004], similar effect was obtained by the addition of an isolated barley β-glucan [Skendi et al. 2010]. Higher a* values caused by barley incorporation were also reported by Blandino et al. [2015] and Holtekjølen et al. [2008a]. The crust of breads containing barley sourdough was brighter (higher L*), less red (lower a*) and more yellow (higher b*) and the crumb of barley sourdough breads had more favourable colour (higher L*, a* and b*).

Barley wholemeal addition and different bread production methods influenced the overall acceptability of breads. Barley share at 30% and 40% level resulted in lower sensory evaluation. Izydorczyk et al. [2008] reported that 20% barley fibre-rich fractions share in wheat bread was scored similarly to control wheat bread. The results of Collar and Angioloni [2014] show that wheat bread with addition of high β-glucan barley flour were characterized by worse crumb quality but it was scored higher in taste intensity and overall acceptability comparing to control bread. Breads containing barley sourdough were scored significantly higher comparing to breads obtained by direct method.

3.2. Dietary fibre and non-starch polysaccharides content

With raising barley wholemeal share in wheat breads there was a significant increase in the content of both soluble and insoluble dietary fibre, total and insoluble arabinoxylans and β-glucans, while barley products addition lead to decrease in soluble arabinoxylans concentration (Table 2). A significant increase of soluble and insoluble dietary fibre was observed with the addition of wholemeal barley flour in other reports [Collar, Angioloni 2014; Gill et al. 2002; Škrbić et al. 2009] as well as with the incorporation of external fibre-rich barley fractions [Blandino et al. 2015; Izydorczyk et al. 2008]. Low solubility of barley arabinoxylans were also reported by Izydorczyk et al. (2008). The predicted increase of β-glucans concentration in naked barley enriched wheat bread was also reported by Blandino et al. [2015], Collar and Angioloni [2014] and Izydorczyk et al. [2008].

Table 2. The content of dietary fibre, arabinoxylans and β-glucans depending on the barley share and bread making method [% d.m.]
Tabela 2. Zawartości błonnika pokarmowego, arabinoksylanów i β-glukanów w zależności od udziału jęczmienia i metody wytwarzania pieczywa [s.m.]

		Dietary fibre			Arabinoxylans			β-glucans
		total	insoluble	soluble	total	insoluble	soluble	
Barley share	0%	7.59 d	6.94 d	0.65 d	2.24 d	1.55 d	0.69 a	0.32 d
	20%	9.56 c	8.76 c	0.80 c	2.89 c	2.20 c	0.64 a	0.89 c
	30%	10.30 b	9.41 b	0.89 b	3.23 b	2.73 b	0.50 b	1.29 b
	40%	11.02 a	10.03 a	0.99 a	4.30 a	3.92 a	0.38 c	1.86 a
Bread making method	direct	9.38 b	8.70 b	0.68 b	3.21 a	2.72 a	0.49 b	1.07 a
	sourdough	9.87 a	8.97 a	0.90 a	3.12 a	2.48 b	0.64 a	1.09 a

Data represent the mean of two replicates. Small letters denote significant groups according to Duncan's test, $p = 0.95$.

Source: own work.
Źródło: opracowanie własne.

Barley sourdough incorporation comparing to barley wholemeal resulted in higher concentration of both fractions of dietary fibre and soluble arabinoxylans and lower insoluble arabinoxylans content. The production method did not influenced the β-glucans content in breads. Higher soluble arabinoxylans concentration improves the dough rheological properties, bread's crumb quality and loaf volume [Buksa et al. 2013]. The report of Jacobs et al. [2008] showed that extension of the initial fermentation resulted in improving the bread quality by improvement of arabinoxylans solubility.

4. Conclusion

Naked barley incorporation to wheat bread had a beneficial impact on its nutritional quality by increasing the concentration of dietary fibre fractions, valuable β-glucans and arabinoxylans. However, barley arabinoxylans were less soluble than those from wheat. High barley wholemeal share also lead to changes in bread's crumb and crust colour, decrease in loaf volume and overall acceptability. The bread production method used had a major impact on its quality. Favorable results were obtained using barley sourdough.

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