Effect of whole-grain flour addition on bread sensory quality

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Abstract

Regarding the consumption of whole grains and fiber, the majority of the population falls short of the recommendations of health organizations. The aim of the study was to evaluate the effect of the type and content of whole-grain flour on the sensory properties of breads. A total of sixteen experimental bread samples were prepared, containing varying proportions of different types of whole-grain flours. Both quantitative descriptive analysis and hedonic analysis were carried out by using categorical ordinal scales. Differences in the graininess of the individual samples were sensorially well discernible. In addition, slightly reduced chewability was described for samples with a higher addition of whole-grain flour. No problems with cohesiveness, increased hardness or unpleasant taste were perceived in the experimental samples. More significant differences were perceived in terms of color intensity. Hedonic ratings for taste, aroma and texture were within narrow ranges and in all cases reached values corresponding to a rather positive evaluation. All experimental samples of breads containing whole-grain flour were rated better from a hedonic point of view compared to the control made from conventional low-milled wheat flour. The addition of 30% whole-grain flour appears to be the most optimal.

Introduction

Cereals are a source of a number of bioactive substances, which, however, are mainly found in the seed coats or the germ. The degree of grinding significantly affects their content in the flour. Whole-grain flours increase the nutritional value of products, mainly due to the higher content of polyphenols and fiber. They also contribute to increased antioxidant capacity of the products (Ragaee et al., 2011). Whole-grain foods are also an important source of iron, zinc, copper and selenium (Zong et al., 2016). A higher intake of whole grains is associated with, for example, a reduced risk of cardiovascular disease and diabetes, as well as cancer, which is related to inflammation, and may also contribute to a reduced risk of other diseases in which inflammation or oxidative stress is a pathophysiological factor (Sawicki, 2023). Although there is an abundance of evidence for the health benefits of whole grains and fiber, the consumption of the majority of the population falls short of the recommendations of experts and health organizations (Dammann et al., 2013). However, we can observe an increasing demand for healthier food options. In both Latin America and the United States, a significant increase was recorded in the consumption of products containing whole grains (Sluyter et al., 2022). Bakery products are among the foods that are rich sources of fiber. Whole-grain bakery products at the present time are more available in most market chains, but still only to a limited extent. There are several reasons - established habits, different organoleptic properties, availability only in certain formats of food stores and, last but not least, their higher selling price (Barrett et al., 2020).

In the Western Diet, low-milled wheat flour became the standard ingredient for the baking industry (Parenti et al., 2020; Heiniö et al., 2016). However, there are a number of wheat species that are potentially usable for bread production and may differ in their nutritional and technological parameters (Kulathunga et al., 2020; Geisslitz et al., 2018; Shewry and Hay, 2015). Two types are traditionally available on the Czech market - common

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wheat and spelt, and in two milling variants of whole-grain flour: classic whole-grain and graham flour. Graham flour contains a more coarsely ground bran fraction and, according to the legislation in the Czech Republic, is defined as whole-grain wheat flour or wheat flour obtained by grinding degerminated wheat, but containing other components of the grain in the same proportion as the original degerminated grain (Decree No. 18/2020 Sb.).

Spelt is known for its easy digestibility, high nutritional value and palatability. For gluten-allergic individuals, consumption of spelt shows lower toxicity and spelt is better tolerated by consumers with non-celiac gluten sensitivity (Békés et al., 2017; Koenig et al., 2015). Spelt is characterized by a higher content of gluten-forming proteins, around 35-45%. Its low swelling and greater elasticity are considered disadvantages. In addition, spelt contains more fat with a suitable fatty acids profile and other nutrients compared to wheat. Spelt bread is characterized by a lower volume, a darker color of the crust and crumb, and a higher strength (Frakolaki et al., 2018; Konvalina et al., 2012). Thus, possible differences in the sensory quality of bread depending on the type of wheat have been partially described, but in the case of using whole-grain flour, a comparison of the influence of individual types of wheat and milling type on the sensory quality of bread is lacking.

From the perspective of sensory quality, key elements for baked goods include appearance, color, flavor, and aroma, as well as textural parameters like chewiness and crumbliness. The main reported difference between conventional and whole-grain products is the resulting cohesiveness of the bread, also its negatively rated, often mentioned bitter taste (Heiniö et al., 2016; Dammann et al., 2013). This is because low-milled flour contains small amounts of volatile substances and flavour precursors. In whole-grain flour, the amount of volatile compounds and amino acids is significantly higher (Czerny and Schieberle, 2002).

The first aim of the study was to evaluate the effect of content of whole-grain flour on the sensory properties of breads. Second aim was to examine and evaluate the effect of whole-grain flour type on the perceived sensory quality of experimental breads. To achieve this, a total of 14 descriptors focused on both intensity and pleasantness of individual characteristics were evaluated. This study provides a unique insight into the comparison of different types of whole-grain wheat flour in terms of their effect on the sensory characteristics and acceptability of breads.

Material and Methods

Preparation of experimental bread samples

A total of sixteen experimental bread samples were prepared, containing varying proportions (30%, 50%, 80%, and 100%) of different types of whole-grain flours. Additionally, a control sample was prepared using only fine ground wheat flour without any whole-grain flour. A total of 4 whole-grain flour variants were used, namely whole-grain wheat flour (GoodMills Česko s.r.o., Kyjov, Czech Republic), graham wheat flour (Zdraví z přírody s.r.o., Dřevnovice, Czech Republic), whole-grain spelt flour (GoodMills Česko s.r.o., Kyjov, Czech Republic) and graham spelt flour (Biomila spol. s r.o., Rudník, Slovak Republic). Conventional low-milled wheat flour was produced by GoodMills Česko s.r.o. (Kyjov, Czech Republic) and all the other raw materials were sourced from the local market.

The list of samples with their designation is given in Table 1.

Table 1. Labeling of samples according to the type and content of whole-grain flour used

Flour type/Flour ratio	30%	50%	80%	100%
Plain wheat flour				Ctrl
Whole-grain wheat flour	WW_30	WW_50	WW_80	WW_100
Graham wheat flour	GW_30	GW_50	GW_80	GW_100
Whole-grain spelt flour	WS_30	WS_50	WS_80	WS_100
Graham spelt flour	GS_30	GS_50	GS_80	GS_100

The control sample was prepared according to the following recipe: plain flour (1 kg), lukewarm water (6 dl), salt (2 tsp), cumin (2 tbsp), yeast (42 g), oil (2 tbsp), sugar (1 cube). In experimental samples, plain flour was partially replaced by individual type of whole-grain flour in selected percentages. The procedure was as follows: The yeast was activated in a mixing bowl with sugar and lukewarm water. Flour, salt and cumin were mixed together in a separate bowl. Oil and activated yeast were added. The prepared dough was left to rise for 45 minutes. Afterwards, loaves were shaped and left to rise another 30 minutes. The oven was preheated to 225 °C and loaves were baked for 5 minutes, then the temperature was decreased to 200 °C and bread was baked for additional 15 minutes.

Sensory analysis

The sensory analysis was performed by a panel of trained evaluators (n = 13) consisting of students and academic staff of the Veterinary University Brno, Czech Republic. Sample preparation and evaluation was divided into several blocks. In one block 4 to 5 samples were evaluated. The evaluators always had half of a bread slice approximately 1.5 cm thick, marked with a numerical code available for analysis. Still water was used as a neutraliser. Within each block, a quantitative descriptive analysis was carried out, followed by a hedonic analysis; ratings were made using categorical ordinal scales with described extreme values, where 7 corresponded to the highest intensity/pleasantness in a given descriptor.

Statistical analysis

The results of the sensory analysis were evaluated using the statistical software R version 3.3.3 (The R Foundation for Statistical Computing, Austria) by principal component analysis (PCA). Statistical significance of differences between samples was evaluated using Hotelling's T2 test at a significance level of $\alpha = 0.05$.

Results and discussion

A total of 16 experimentally produced bread samples containing whole-grain wheat flour and one control sample containing only conventional low-milled wheat flour were evaluated by sensory analysis. For all samples, a total of nine descriptors were assessed using quantitative descriptive analysis, along with five hedonic descriptors. The influence of the content and the type of whole-grain flour on the sensory characteristics of individual samples was investigated. Subsequently, the influence of the content and the type of whole-grain flour on the sample groups was also evaluated depending on the selected factor.

Results of quantitative descriptive analysis of individual samples

The results of the quantitative descriptive analysis of individual samples are shown in Fig. 1.

A plot of the results of the principal component analysis focusing on individual whole-grain bread samples explains 67.06% of the variability, with the first component explaining 41.51% and the second component explaining 25.55% of the variability. The evaluators observed the most statistically significant differences ($p < 0.05$) within the descriptor graininess, where they focused on the amount of small particles recognizable in a chewed bite. As expected, the control sample had the lowest grain size followed by the experimental samples with a lower proportion of whole-grain flour. Thus, the difference in grain size was well distinguishable sensorially. Dammann et al. (2013) stated that whole-grain bakery products can be characterized by a coarser and more grainy texture associated with the presence of seed coats as well as a more pronounced bitter taste, which, together with the aspect of a less familiar product, can contribute most significantly to negative consumer reactions. Similarly, Khalid et al. (2017) stated that the presence of seed coats can pose a problem in achieving optimal cohesiveness of whole-grain bakery products. This is because bran contains both soluble and insoluble fiber, which takes away part of the water, making it less available for proteins and starches, which subsequently affects the formation of the dough texture.

In the case of our samples, a statistically significantly lower cohesiveness was observed only in the case of a single sample GW_80 (4.308); the values of the other samples ranged from 4.538 to 5.769, which corresponds rather to higher cohesiveness. Furthermore, more

statistically significant differences were observed within the chewability descriptor, where samples with the highest proportions of whole-grain flour were characterized by more difficult chewability (≥4). A certain stratification of the samples also occurred within the surface color descriptor. The samples WS_100 and WW_80 (5.462 and 4.846) were characterized by statistically significantly higher ($p < 0.05$) surface color values, on the other hand, the control sample (2.231) together with the sample WW_30 (3.231) were characterized by a statistically significantly lighter color. A higher addition of fiber can negatively affect the hardness of the product (Heinio, 2009), however, in the case of our samples, although there were some statistically significant differences, the hardness values were in a narrow range (2.615-3.385), which corresponded to a rather softer character. No statistically significant difference was observed in the intensity of the typical flavour.

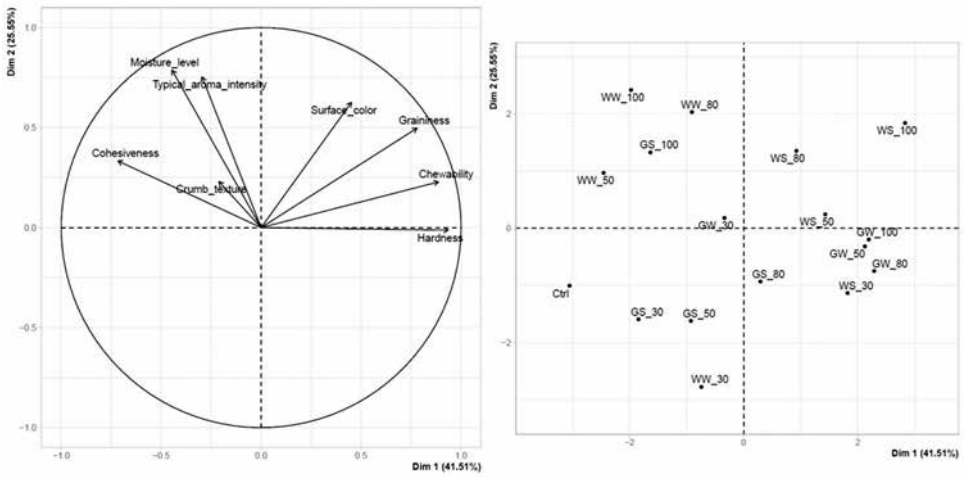


Figure 1. The results of PCA of quantitative descriptive analysis of individual experimental bread samples: (a) Variables factor map. (b) Score plot for the mean points. Ctrl = bread sample without the addition of whole-grain flour; WW_30 = bread sample with added 30% of whole-grain wheat flour; WW_50 = bread sample with added 50% of whole-grain wheat flour; WW_80 = bread sample with added 80% of whole-grain wheat flour; WW_100 = bread sample with 100% of whole-grain wheat flour; GW_30 = bread sample with added 30% of graham wheat flour; GW_50 = bread sample with added 50% of graham wheat flour; GW_80 = bread sample with added 80% of graham wheat flour; GW_100 = bread sample with 100% of graham wheat flour; WS_30 = bread sample with added 30% of whole-grain spelt flour; WS_50 = bread sample with added 50% of whole-grain spelt flour; WS_80 = bread sample with added 80% of whole-grain spelt flour; WS_100 = bread sample with 100% of whole-grain spelt flour; GS_30 = bread sample with added 30% of graham spelt flour; GS_50 = bread sample with added 50% of graham spelt flour; GS_80 = bread sample with added 80% of graham spelt flour; GS_100 = bread sample with 100% of graham spelt flour.

Results of hedonic evaluation of individual samples

The results of the hedonic analysis of individual samples are shown in Fig. 2.

A plot of the results of the principal component analysis focusing on hedonic evaluation of individual whole-grain bread samples explains 78.67% of the variability, with the first component explaining 53.60% and the second component explaining 25.07% of the variability. A number of statistically significant differences were observed between the samples. The values of the hedonic ratings for taste, aroma and texture ranged in narrow intervals and in all cases were higher than 4.231, corresponding to a rather positive

assessment. In general, the samples achieved higher scores also within the descriptor pleasantness of appearance. The overall evaluation of the samples ranged from 4,154 to 5,385, while the control sample surprisingly achieved a statistically significantly lower scores, and the samples with 100% spelt graham flour and whole-grain wheat flour (GS_100, WW_100) achieved statistically significantly higher overall scores. At the same time, the last mentioned sample WW_100 achieved a statistically significantly higher rating in aroma pleasantness. According to Torbica et al. (2022) the addition of fiber in whole-grain flour generally has a negative impact on the textural and sensory properties of whole-grain bakery products. Also Heiniö et al. (2016) state that sensory characteristics are believed to be the limiting factor for the consumption of whole-grain bakery products. However, the author also state that there are relatively few scientific studies focusing on factors affecting the sensory quality of whole-grain products. Our results showed that whole-grain wheat breads were sensory rated better than the control made from conventional wheat flour.

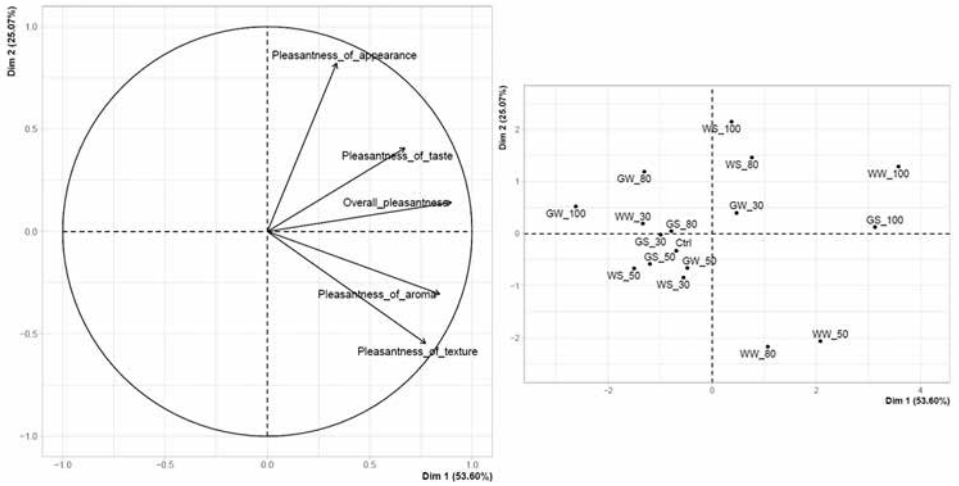


Figure 2. The results of PCA of hedonic analysis of individual experimental bread samples: (a) Variables factor map. (b) Score plot for the mean points. Ctrl = bread sample without the addition of wholegrain flour; WW_30 = bread sample with added 30% of whole-grain wheat flour; WW_50 = bread sample with added 50% of whole-grain wheat flour; WW_80 = bread sample with added 80% of whole-grain wheat flour; WW_100 = bread sample with 100% of whole-grain wheat flour; GW_30 = bread sample with ad ed 30% of graham wheat flour; GW_50 = bread sample with added 50% of graham wheat flour; GW_80 = bread sample with added 80% of graham wheat flour; GW_100 = bread sample with 100% of graham wheat flour; WS_30 = bread sample with added 30% of whole-grain spelt flour; WS 50 = bread sample with added 50% of whole-grain spelt flour; WS_80 = bread sample with added 80% of whole-grain spelt flour; WS_100 = bread sample with 100% of whole-grain spelt flour; GS_30 = bread sample with added 30% of graham spelt flour; GS_50 = bread sample with added 50% of graham spelt flour; GS_80 = bread sample with added 80% of graham spelt flour; GS_100 = bread sample with 100% of gr ham spelt flour.

Results of hedonic evaluation according to the percentage of whole-grain flour

The results of the hedonic evaluation of the sample groups with respect to the proportion of the used whole-grain flour are shown in Fig. 3.

A plot of the results of the principal component analysis focusing on hedonic evaluation of individual whole-grain bread samples explains 99.55% of the total variability, with the first component explaining 74.08% and the second component explaining 25.47% of the variability. Several statistically significant differences were observed between sample groups according to whole-grain flour content, as shown in Table 2. The control sample achieved a statistically significantly lower overall pleasantness (4.154); groups of experimental samples achieved values of 4.577-4.904, while the group of samples containing 30% whole-grain flour achieved statistically significantly higher values. This group also achieved statistically significantly higher values in aroma pleasantness and texture pleasantness. However, the groups of samples containing 50%, 80% and 100% whole-grain flour content also scored higher than 4 (out of a total of 7 points), indicating a positive rating. Similar to our study, Koletta et al. (2014) reported that when evaluating samples of bread enriched with whole grain, but in their case, pseudocereal flour, all experimental samples scored higherer in pleasantness of taste compared to the control sample made from conventional low-milled wheat flour. Similarly, their experimental samples scored higher than 5.5 (out of 9 points) in the overall evaluation, even for samples containing 60% whole-grain flour.

Table 2. Results of Hotelling T2 test for hedonic evaluation of group of bread samples according to the percentage of whole-grain flour addition irrespective of flour type.

	Ctrl	WG_100	WG_30	WG_50	WG_80
Ctrl	1	0.07475	0.01821	0.06823	0.1021
WG_100	0.07475	1	0.2282	0.6046	0.871
WG_30	0.01821	0.2282	1	0.02019	0.03346
WG_50	0.06823	0.6046	0.02019	1	0.6301
WG_80	0.1021	0.871	0.03346	0.6301	1

*Ctrl = bread sample without the addition of whole-grain flour; WG_30 = group of bread samples with added 30% of whole-grain flour irrespective of flour type; WG_50 = group of bread samples with added 50% of whole-grain flour; WG_80 = group of bread samples with added 80% of whole-grain flour; WG_100 = group of bread samples containing 100% of whole-grain flour.

Statistically significant differences between the groups are emphasized with grey colour.

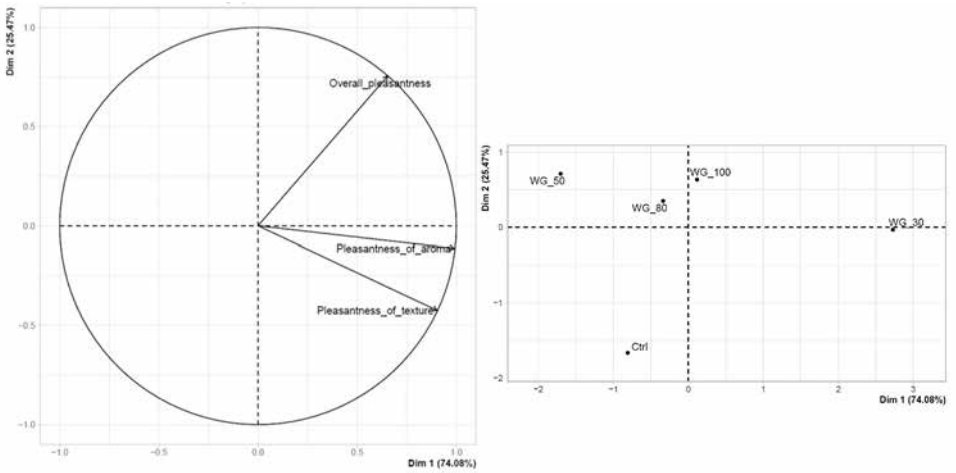


Figure 3. The results of PCA of hedonic analysis of groups of experimental bread samples with regard to the percentage of the wholegrain flour addition: (a) Variables factor map. (b) Score plot for the mean points. Ctrl = bread sample without the addition of wholegrain flour; WG_30 = group of bread samples with added 30% of wholegrain flour irrespective of flour type; WG_50 = group of bread samples with added 50% of wholegrain flour; WG_80 = group of bread samples with added 80% of wholegrain flour; WG_100 = group of bread samples containing 100% of wholegrain flour.

Results of quantitative descriptive analysis by type of whole-grain flour

The results of the quantitative descriptive analysis of the sample groups with regard to the type of used flour are shown in Fig. 4.

A plot of the results of the principal component analysis focusing on groups of whole-grain bread samples depending on the type of whole-grain flour explains 82.55% of the variability, with the first component explaining 63.06% and the second component explaining 19.49% of the variability. Based on these results, it can be said that all sample groups were statistically significantly different from the control sample, furthermore, the group of samples containing wheat graham flour (GW) was similar to the group of samples containing whole-grain spelt flour (WS), and this pair was also statistically significantly different from the pair of similar samples WW and GS, i.e. groups containing whole-grain wheat and graham spelt flour. The control sample was characterized by statistically significantly higher porosity (crumb texture), statistically significantly lighter crust color, easier chewability and lower graininess. Samples containing whole-grain wheat flour were characterized by statistically significantly higher moisture and surface color and at the same time statistically significantly lower hardness. Samples containing graham wheat flour were distinguished by statistically significantly lower cohesiveness and porosity and statistically significantly higher hardness, graininess and more difficult chewability. This is because the outer layers of the grain contain lignocellulose layers, large particles and insoluble fiber, which can cause a hard and rough texture of the product (Gostin, 2019). Samples containing whole-grain spelt flour were similarly characterized by statistically significantly higher graininess and more difficult chewability, along with a darker crust color. In contrast to white bread, whole-grain wheat breads are denser and have a firmer crust and give the impression of dryness, due to the presence of bran particles (Cauvain

and Witney, 2014). Surprisingly, the last group of samples containing graham spelt flour was characterized by statistically significantly lower perceived graininess and intensity of typical aroma. Comparison of the sensory characteristics of breads containing wheat (*Triticum aestivum* ssp. *vulgare* L.) and spelt (*Triticum aestivum* ssp. *spelta* L.) flour was also addressed by Callejo et al. (2015), who described differences in the aroma and flavour of the breads, with spelt contributing to the roasted aroma of the crust and being characterized by the highest intensity of flavour of both crumb and crust. However, the specific cultivar and other aspects also play an important role. No statistically significant differences were observed between our sample groups with regard to the type of flour used.

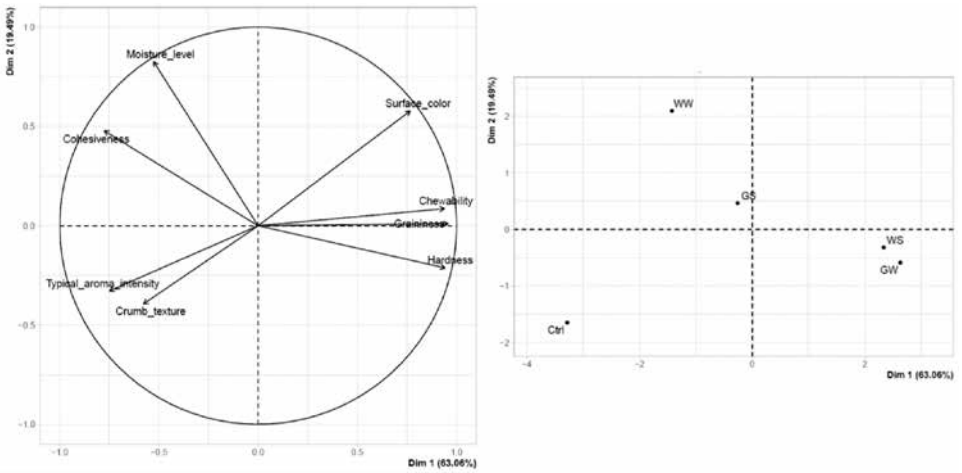


Figure 4. The results of PCA of quantitative descriptive analysis of groups of experimental bread samples with regard to the type of whole-grain flour addition: (a) Variables factor map. (b) Score plot for the mean points. Ctrl = bread sample without the addition of whole-grain flour; WW = group of bread samples with the addition of whole-grain wheat flour irrespective of quantity; WS = group of bread samples with the addition of whole-grain spelt flour irrespective of quantity; GW = group of bread samples with the addition of graham wheat flour irrespective of quantity; GS = group of bread samples containing the addition of graham spelt flour irrespective of quantity.

Results of hedonic analysis by type of whole-grain flour

The results of the hedonic analysis of the sample groups with regard to the type of flour used are shown in Fig. 5.

A plot of the results of the principal component analysis focusing on groups of whole-grain wheat bread samples depending on the type of whole-grain wheat flour explains 99.55% of the variability, with the first component explaining 74.08% and the second component explaining 25.47% of the variability. Within the principal component analysis, only the group containing whole-grain wheat flour (WW) was statistically significantly different from all other groups, including the control sample, with the exception of the sample containing graham spelt flour (GS). The group of breads containing whole grain wheat flour was characterized by a statistically significantly higher pleasantness of aroma, texture and overall pleasantness. It is worth noting that the control sample was characterized by a statistically significantly lower overall pleasantness. There is a general perception that whole-grain bakery products may be less well accepted by consumers due to their

different characteristics related to bitter taste, darker color or coarser texture (Heiniö et al., 2016; Dammann et al., 2013). Therefore, ways to improve the sensory characteristics of whole-grain bakery products are being developed. Noort et al. (2017), for example, proposed the addition of improving enzymes or vital gluten to increase bread volume and its textural parameters. However, our results show a high level of acceptability of breads containing whole-grain flour, even without the use of improving ingredients. Also, Bakke and Vickers (2007) point out the ambiguity in the results of studies investigating the degree of sensory acceptability of whole-grain bakery products. According to Sluyter et al. (2022), between 2008 and 2020, the average whole grain content in marketed products increased by 36% on a global scale. In the United States, a change in consumer purchasing behavior and a shift in favor of more frequent purchases of whole-grain products was already described in 2010 (Arndt, 2010), which seems to be related both to the growing awareness of the higher nutritional value and health benefits of whole-grain products, and also to the gradual adaptation to whole-grain products, which are becoming more available.

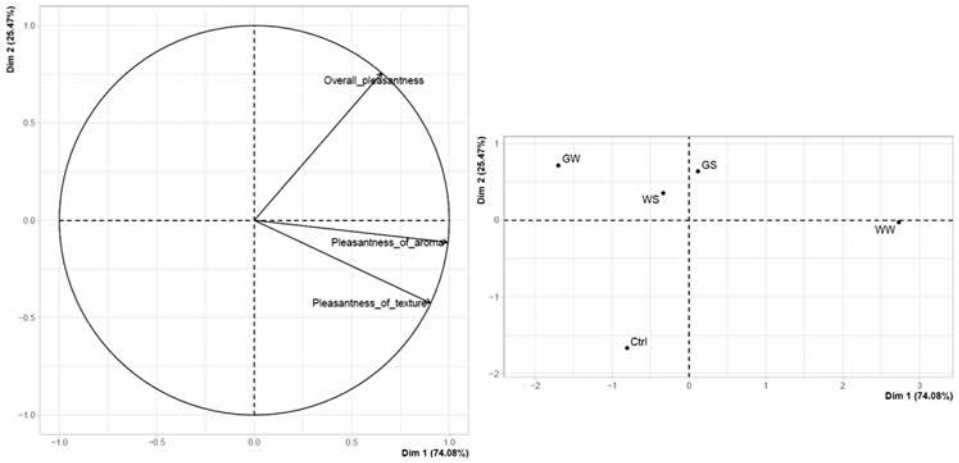


Figure 5. The results of PCA of hedonic analysis of groups of experimental bread samples with regard to the type of wholegrain flour addition: (a) Variables factor map. (b) Score plot for the mean points. Ctrl = bread sample without the addition of wholegrain flour; WW = group of bread samples with the addition of whole-grain wheat flour irrespective of quantity; WS = group of bread samples with the addition of whole-grain spelt flour irrespective of quantity; GW = group of bread samples with the addition of graham wheat flour irrespective of quantity; GS = group of bread samples containing the addition of graham spelt flour irrespective of quantity.

Conclusion

All experimental samples of breads containing whole-grain flour were rated better from a hedonic point of view compared to the control made from conventional low-milled wheat flour. In terms of whole-grain flour content, regardless of its type, the addition of 30% whole-grain flour appears to be the most optimal. However, even groups of samples with a higher content of whole-grain flour were positively evaluated.

Regarding the type of whole-grain flour, regardless of its content, samples containing whole-grain wheat flour were rated the best. However, all types of whole-grain flour were rated better compared to the control.

Our results did not support the common notion that different sensory characteristics of whole-grain bakery products may lead to lower acceptability. On the contrary, the control sample of white bread was characterized by significantly lower overall acceptability. This may be due to a gradual change in consumer taste preferences. The inclusion of breads with different proportions of whole-grain flour, regardless of the type of wheat, in the production range of the bakery can therefore be considered an advantageous option to increase the nutritional value of the products available on the market, thus contributing to improving public health and at the same time meeting the sensory requirements of today's consumers.

References

Arndt E 2010: Functionality and health aspects of whole grains for product development. Institute of Food Technologists Annual Meeting , Chicago, IL .

Bakke A, Vickers Z 2007: Consumer liking of refined and whole wheat breads. J. Food Sci. **72**: S473-480

Barrett EM, Foster SI, Beck EJ 2020: Whole grain and high-fibre grain foods: How do knowledge, perceptions and attitudes affect food choice? Appetite **149**: 104630

Békés F, Ács K, Gell G, Lantos C, Kovács AM, Birinyi Z, Pauk J 2017: Towards breeding less allergenic spelt-wheat with low fodmap content—A review. Acta Aliment. **46**: 246-258

Callejo MJ, Vargas-Kostiuk ME, Rodríguez-Quijano M 2015: Selection, training and validation process of a sensory panel for bread analysis: Influence of cultivar on the quality of breads made from common wheat and spelt wheat. J. Cereal Sci. **61**: 55-62

Cauvain SP, Witney UK 2014: Getting More from Whole Grains. Cereal Foods World **59**: 260

Czech Republic. Decree No. 18/2020 on requirements for flour-milling cereal products, pasta, bakery products and confectionary products and doughs. Sbírka zákonů 2020: 8

Czerny M, Schieberle P 2002: Important aroma compounds in freshly ground wholemeal and white wheat flour identification and quantitative changes during sourdough fermentation. J. Agric. Food Chem. **50**: 6835-6840

Dammann KW, Hauge D, Rosen RA, Schroeder N, Marquart L 2013: Consumption and consumer challenges of wholegrain foods. Fibre-rich and wholegrain foods: improving quality, Woodhead Publishing Series in Food Science, Technology and Nutrition, pp.120-149

Frakolaki G, Giannou V, Topakas E, Tzia C 2018: Chemical Characterization and Breadmaking Potential of Spelt versus Wheat Flour. J. Cereal Sci. **79**: 50-56

Geisslitz S, Wieser H, Scherf KA, Koehler P 2018: Gluten protein composition and aggregation properties as predictors for bread volume of common wheat, spelt, durum wheat, emmer and einkorn. J. Cereal Sci. **83**: 204-212

Gostin AI 2019: Effects of substituting refined wheat flour with wholemeal and quinoa flour on the technological and sensory characteristics of salt-reduced breads. LWT **114**: 108412

Heiniö RL, Noort MW, Katina K, Alam SA, Sozer N, De Kock HL, Hersleth M, Poutanen K 2016: Sensory characteristics of wholegrain and bran-rich cereal foods–a review. Trends Food Sci. Technol. **47**: 25-38

Khalid KH., Ohm JB, Simsek S 2017: Whole wheat bread: Effect of bran fractions on dough and end-product quality. J. Cereal Sci. **78**: 48-56

Koenig A, Konitzer K, Wieser H, Koehler P 2015: Classification of spelt cultivars based on differences in storage protein compositions from wheat. Food Chem. **168**:176-182

Koletta P, Irakli M, Papageorgiou M, Skendi A 2014: Physicochemical and technological properties of highly enriched wheat breads with wholegrain non wheat flours. J. Cereal Sci. **60**: 561-568

Konvalina P, Capouchová I, Stehno Z 2012: Genetic resources of hulled wheat species in

Czech organic farming. 62. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2011, Lehr- und Forschungszentrum für Landwirtschaft, Raumberg-Gumpenstein, Austria, pp. 81-86

Kulathunga J, Reuhs BL, Simsek S 2020: Novel trends in hulled wheat processing for value addition. Trends Food Sci. Technol. **106**: 232-241

Noort MW, Mattila O, Katina K, van der Kamp JW 2017: HealthBread: Wholegrain and high fibre breads with optimised textural quality. J. Cereal Sci. **78**:57-65

Parenti O, Guerrini L, Zanoni B 2020: Techniques and technologies for the breadmaking process with unrefined wheat flours. Trends Food Sci. Technol. **99**: 152-166

Ragaee S, Guzar I, Dhull N, Seetharaman K 2011: Effects of fiber addition on antioxidant capacity and nutritional quality of wheat bread. LWT-Food Sci. Technol. **44**: 2147-2153

Sawicki CM, McKeown NM, Goon S, Bhupathiraju SN 2023: Whole grains and chronic disease risk. Encyclopedia of Human Nutrition (Fourth Edition), Academic Press, pp. 675-689

Shewry PR, Hey S 2015: Do "ancient" wheat species differ from modern bread wheat in their contents of bioactive components? J. Cereal Sci. **65**:236-243

Sluyter C, LeBlanc K, Hicks-Roof K 2022: Boosting Whole-Grain Utilization in the Consumer Market: A Case Study of the Oldways Whole Grains Council's Stamped Product Database. Nutrients **14**: 713

Torbica A, Radosavljević M, Belović M, Tamilselvan T, Prabhasankar P 2022: Biotechnological tools for cereal and pseudocereal dietary fibre modification in the bakery products creation–Advantages, disadvantages and challenges. Trends Food Sci. Technol. **129**: 194-209

Zong G, Gao A, Hu FB, Sun Q 2016: Whole Grain Intake and Mortality From All Causes,
Cardiovascular Disease, and Cancer. A Meta-Analysis of Prospective Cohort Studies. Circulation **133**: 2370-2380