

Case study of commercially available gluten-free bread products: Texture changes during storage and sensory analysis

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ORIGINAL RESEARCH PAPER

Received: November 30, 2021 • Accepted: February 22, 2022

Published online: March 29, 2022

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ABSTRACT

Gluten-free (GF) breads are often described with low quality, rapidly staling, dry mouthfeel and crumbling texture attributes. In lack of recent texture profile data on commercially available, preservative-free, freshly-baked GF bread, this study aimed to compare different types of GF products with their wheat-based counterparts during a 4-day-long storage test. Texture analysis data showed that GF loaves performed better than or comparable to the wheat-based ones in hardness, springiness and cohesiveness. Among sensorial properties mouth-feel, softness and aroma were evaluated as significantly better or similar for GF versus wheat-based products. GF cob had a saltier taste, which reduced the flavour experience. Both the texture results of the storage test and sensory data showed that the quality of GF bread products improved in recent years; they stayed comparable with their wheat-based counterparts even during a 4-day-long storage period.

KEYWORDS

gluten-free bread, texture change during shelf-life, commercial reality, quality and sensory comparison

INTRODUCTION

Nowadays more and more people get diagnosed with gluten-related disorders (GRD): Coeliac disease (CD), non-celiac gluten sensitivity (NCGS), gluten ataxia (GA) or dermatitis

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herpetiformis (DH) (Khoury et al., 2018). In these individuals, consumption of gluten leads to mucosal damage in the small intestine, the nutritional imbalance caused by malabsorption and other related health issues (Ortiz et al., 2017). Currently, the only known and effective treatment is a lifelong, strict gluten-free diet (GFD) (Khoury et al., 2018). The absence of gluten (found in wheat (gliadin), barley (hordein) and rye (secalin), including all their subtypes and genus) in the gluten-free (GF) bread formulations ends up with much weaker gas-holding properties, therefore low loaf volume (Elgeti et al., 2015), crumbling texture, poor colour (Torbica et al., 2010), choky dry mouth-feel and shorter shelf life (Gambus et al., 2007).

According to consumer survey studies the quality of GF sweets, biscuits and pasta are satisfying, but further improvement is needed in GF breads and cakes to meet the consumers' expectations (Roman et al., 2019; Ozola and Straumite, 2014; Potter et al., 2014). Although in the last decades, several approaches were studied to achieve the desired elevation of the quality of GF breads quality, only a few publications deal with commercially available products. The majority of the numerous articles in this topic focus on self-made prototypes using different raw materials and measurement methods.

Roman et al. (2019) made an important step by publishing results regarding the gap between research and commercial reality. By examining 228 commercial GF flours from a compositional and nutritional standpoint, they noticed that some ingredients (e.g. pseudocereals) which have emphasized scientific attention are hardly used in the commercial products. It was found in their detailed analysis that commercial breads do not tend to contain one single starch, but a combination of several ingredients (like hydrocolloids, acidifiers, emulsifiers, leavening agents, preservatives, and aromas or flavourings) with the aim to optimize and improve quality of the GF bread.

The higher consumer price and nutritional imbalance seems to be a common attribute of the GF flours and breads, based on studies from UK, Spain and Italy (Fry et al., 2018; Foschia et al., 2016; Cornicelli et al., 2018; Tres et al., 2020; Melini and Melini, 2019; Missbach et al., 2015; Jamieson and Gougeon, 2017).

The studies referred above provide valuable information about commercial actuality. Despite the fact that the gap is already identified and communicated from a nutritional aspect and regarding ingredients, up-to-date texture profile studies are hardly available dealing with commercially available products (Table 1).

It would be useful to examine the texture profile properties of the commercially available GF bread products, as the market is developing and changing rapidly in ingredients and technologies. Following this mindset, this study aims to compare GF commercial bread products with their gluten-containing wheat flour-based counterparts, focusing on the texture and sensorial properties.

MATERIALS AND METHODS

Bread samples

Wheat-based products (Ceres Zrt., Győr, Hungary) were purchased in a supermarket, while the GF breads were from a specialized GF bakery shop (Táplálékallergia Centrum, Budapest, Hungary). All the samples were baked on the same day, were manufactured without any preservatives and without protective gas or modified atmosphere in the packaging. The closure and



Table 1. The most relevant published articles regarding commercial GF breads

| Year | Scope |
|------|---|
| 2003 | Commercial wheat starch containing GF flour supplemented with different dairy powders (Gallagher et al., 2003) |
| 2004 | Comparison of newly developed GF bread samples and GF bread products made from commercially available GF flour mix (Moore et al., 2004) |
| 2012 | The bread-making potential of seven commercial GF flours, wheat and wholemeal wheat flour was compared (Hager et al., 2012) |
| 2012 | Characterizes diverse GF breads in order to discriminate them and to establish possible correlations among descriptive parameters of GF bread features determined by instrumental methods and sensory analysis (Matos and Rosell, 2012) |
| 2013 | Investigation of 2 commercial GF flour mixtures with HPMC and buckwheat addition (Mariotti et al., 2013) |
| 2014 | Analyzing the in vitro starch digestibility of five GF breads and commercial GF sample (Wolter et al., 2014) |
| 2014 | Investigating the visual and taste liking of 3 commercial GF foods in a group of celiac children (Mazzeo et al., 2014) |
| 2016 | 2 commercial GF mixtures were enriched with 10 or 20 g/100 g of chestnut flour, and compared to commercial GF breads, and monitored during three days storage (Paciulli et al., 2016) |
| 2018 | Sensory, digestion and texture quality of commercial GF bread were analysed using rice flour derived from different cultivars (Feizollah et al., 2018) |
| 2020 | Study of the bolus properties of commercial GF and regular breads in relation to the dynamics of sensations perceived during its consumption (Puerta et al., 2020) |

material of the packaging were not air-tight. All the samples were sliced with 12 mm thickness, and ready to eat, without prior heating requirement. In this study three different types of bread were analysed: cob (artisan, round shape bread), white and wholegrain loaves (baked in loaf tin). From each bread type two samples (GF and wheat-based products) were selected and compared (Table 2), thus all together involving six different samples in this study.

Ingredients and nutrition values of the samples are presented in Table 3.

Texture measurement

Texture profile analysis (TPA) was performed at room temperature using Stable Micro Systems TA.XT2 instrument. Samples were taken and measured from the first, middle and last third of

Table 2. The selected bread samples used in the study

| Type | Sign |
|-----------------|---|
| cob | Wheat based Gluten free CW CGF |
| white loaf | Wheat based Gluten free WLW WLGf |
| wholegrain loaf | Wheat based Gluten free WGW WGGF |



Table 3. Ingredients and nutrition values of the bread samples (HPMC: Hydroxypropyl-methyl cellulose)

| Product | Ingredients | Energy (kcal) | Fat (g) | Carb. (g) | Fibre (g) | Protein (g) | Salt (g) |
|---------|---|---------------|---------|-----------|-----------|-------------|----------|
| CW | Wheat flour, water, yeast, salt, pork fat, vegetable oil (palm, rapeseed), acidity regulator, emulsifiers, ascorbic acid | 257 | 2.2 | 49 | 2.0 | 9.1 | 1.3 |
| CGF | Corn starch, modified starch, tapioca starch, rice flour, psyllium fibre, guar gum, HPMC, potato and apple fibre, pea protein, buckwheat flour, amaranth flour, water, sunflower oil, yeast, salt, sugar, coconut oil | 285 | 6.0 | 48 | 11.0 | 1.9 | 2.1 |
| WLW | Wheat flour, water, butter, yeast, sugar, salt, dried sourdough, soy flour, milk powder, rye flour, emulsifiers, ascorbic acid | 272 | 4.7 | 48 | 1.8 | 8.5 | 1.2 |
| WLGf | GF flour mix (corn starch, modified starch, potato fibre, HPMC, psyllium fibre, guar gum, apple fibre, amaranth flour, sugar, pea protein), water, sunflower oil, yeast, salt, sugar, coconut oil | 221 | 1.9 | 46 | 8.5 | 0.8 | 2.0 |
| WGW | Whole grain wheat flour, water, sunflower oil, yeast, salt, wheat gluten, sugar | 258 | 4.7 | 42 | 6.2 | 8.9 | 1.3 |
| WGGF | GF flour mix (corn starch, modified starch, apple fibre, seeds/sunflower, flex, sesame, pumpkin/, apple fibre, HPMC, buckwheat flour, psyllium fibre, guar gum, baking soda, amaranth flour, sugar, pea protein), water, vegetable oil, yeast, salt, sugar, coconut oil | 232 | 3.3 | 44 | 11.0 | 1.0 | 2.0 |

the sliced bread products, covering 7 different measurements on different slices of the same sample. The measurement was always conducted in the middle of the slices, paying attention to avoid the region near the crust. Each slice had the same 12 mm thickness. The applied settings were the same for all types of samples: Ø35 mm acryl cylindrical probe, 50% strain, 5 mm s⁻¹ crosshead speed and 5 s of waiting time between the two measurements. Hardness, cohesiveness and springiness were determined as the main representative parameters of the crumb texture. Results obtained from the GF and wheat bread samples were compared and followed up.

Sensory evaluation

In the sensory evaluation, 15 individuals (13 female and 2 male, aged between 22 and 47 years) were involved to test the bread samples. All participants acknowledged consuming wheat-based bread at least once per day. Participants confirmed not having any known gluten, rye, milk protein or lactose consumption related disorder. During the evaluation, the assessors received 1



full slice of the sample without any spreading on a white plate. Samples were randomized and signed with 3 digit codes. Participants were asked to evaluate the intensity of 17 sensory attributes, which were described as relevant ones for GF bread by [Pagliarini et al. \(2010\)](#) to cover appearance, colour, taste and texture. For every attribute a continuous, unstructured 100 mm long line scale was used with extremes at the ends (absolutely not intense and immensely intense).

Data analysis

IBM SPSS Statistics 25.0.2.2 software was used to evaluate the data. A significant difference between the measured groups was determined by one-way analysis of variance (ANOVA) with 95% confidence level. Tukey HSD test was used after normality and standard deviation homogeneity test. Linear discriminant analysis (LDA) was performed to examine the separability of each bread type. Sensory test data were compared by group means through ANOVA. When a significant difference was found, the Tukey test was applied using a level of 5% of significance.

RESULTS AND DISCUSSION

Nutritional values of the bread samples

According to the ingredient list of the examined GF samples, all of them contained different starches, hydrocolloids, fibres and protein supplements at the same time, being in line with the previously published data. The type of starches (corn, tapioca, rice) and hydrocolloids (HPMC, guar gum) found in these samples were the most commonly used ingredients among commercial GF breads ([Roman et al., 2019](#); [Foschia et al., 2016](#)). The fibre and salt content were higher while the protein content was lower in all GF bread samples than in their wheat-based counterparts. The energy and carbohydrate values were similar among the GF and wheat-based samples, notable difference was not discovered. Lower protein level was previously reported in GF breads ([Roman et al., 2019](#)), as a negative nutritional attribute. In this case, according to the statement on the manufacturer's website, keeping the protein level low was a conscious decision. With this low value these products can be recommended for people diagnosed with phenylketonuria (PKU) as well. The treatment for people with PKU is to strictly follow a lifelong low protein and phenylalanine intake diet ([Parlak and Dundar, 2021](#)). Traditional cereal products are not allowed to be consumed due to their high protein content ([MacDonald et al., 2020](#)), but these GF breads are suitable not just for celiac people but in the PKU diet as well.

Texture profile changes

Results of the TPA measurements during the shelf-life test are presented in [Fig. 1](#).

As expected, the hardness values increased during shelf-life in all samples. The hardness of WLGF and WGGF samples was significantly lower compared to the wheat-based counterparts throughout the whole storage test. The change of hardness in the GF loaf samples was slower and lesser over the measured shelf-life. Out of the cob samples, CGF showed higher values from the second day onwards versus CW, but a significantly different value was experienced only on the last day ($P < 0.05$). In general, CW had the highest value among the GF samples, but no significant difference was detected among the GF samples from the second day onwards.



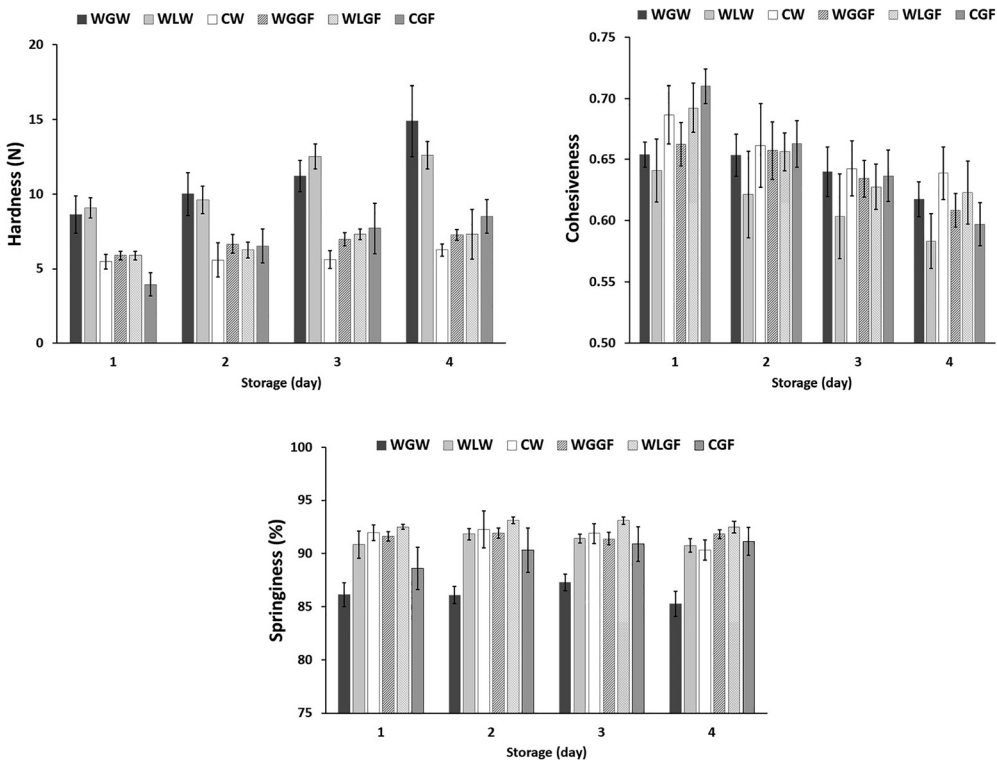


Fig. 1. TPA results of sample hardness, cohesiveness and springiness during storage test

High cohesiveness leads to no disintegration during mastication, in case of low cohesiveness the bread crumbles (Onyango et al., 2011). The crumbling texture of GF bread during storage test was reported in the last decades, raising awareness as a general quality issue of these products (Naqash et al., 2017). Moore et al. (2004) experienced a decrease in cohesiveness ($P < 0.01$) in GF bread samples after 2 days storage. In this study, the measured GF samples stayed comparable with the wheat-based products during the storage period. On day 2 and 3 hardly any significant difference was detected among the samples. WLGF and WGGF showed no significant difference compared to CW during 4 days, although CW was the artisan wheat-based sample, assumed to be of higher quality.

Between WGGF and WGB no significant difference was detected during the whole storage test. Cohesiveness of CGF decreased faster than CW, but until the fourth day it was better or comparable.

In bread, springiness is associated with freshness, and products with low values are linked with crumb brittleness (Matos and Rosell, 2012), therefore having high springiness values during the shelf-life is desired. Both of the GF loaves had significantly higher values from the second day compared to WLW and WGW. Despite the fact that hardness increased during storage in case of CGF, continuous improvement was detected in the springiness values. On the last day of the storage test, all the GF samples had higher values than their wheat-based counterparts, in the



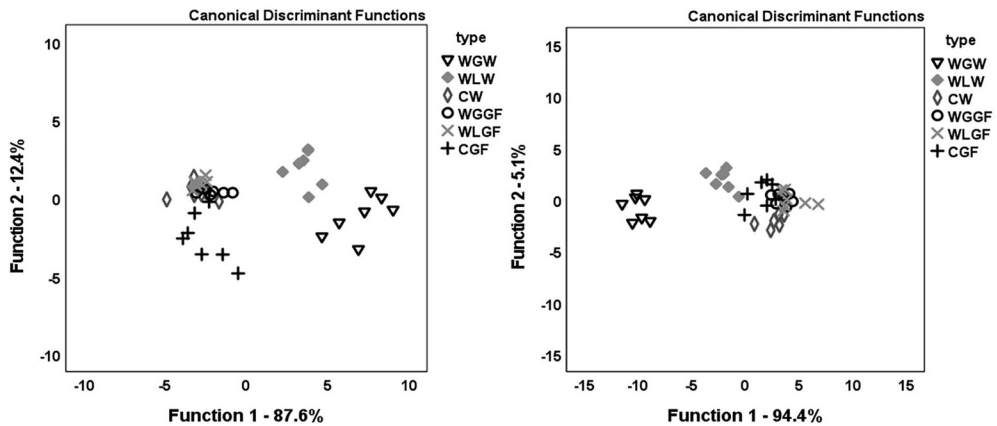


Fig. 2. LDA results of bread samples by their TPA results at day 1 (left) and day 4 (right)

case of WGGF and WLGF significantly ($P < 0.05$). According to the results, GF bread samples in general had low hardness and high springiness values, therefore can be described as soft and spongy (Puerta et al., 2020).

LDA results showed that all the GF samples were categorized the same as CW (Fig. 2). On day 1, the first discriminant variable described 87.5% of the variance, while on day 4, this value increased to 94.4%. This result clearly showed that the quality and texture profile attribute (hardness, cohesiveness, springiness) changes of the GF samples during the 4-day-long storage test were as good as those of the highest quality wheat-based product (considered to be artisan).

The result of the cross-validation showed that the established classification model was able to classify 78.57% based on the results of day 1, while according to the results of day 4 it was able to classify 71.43%.

The data proved that among hand-made GF and wheat-based products the initial and final quality was not different; therefore, the GF market was able to present a product, which lacks the inferior properties that were claimed before.

WLW and WGW samples were classified by the LDA test as groups different from the others during the whole storage test. Both products showed significantly worse results in hardness from the other samples through the whole study, and WGW was significantly worse in springiness from the other samples from the second day onwards. The significant difference of these two attributes presents these samples as different product groups.

Sensory evaluation

High starch and low protein content had an effect on the textural attributes, ending up in less homogeneous crumb porosity (Onyango et al., 2011; Pruska-Kedzior et al., 2008). Uniform crumb porosity of commercial GF bread samples was found with higher protein content (Pagliarini et al., 2010). Although GF samples in this study had lower protein content according to their nutrition table versus the ones in the study by Pagliarini et al. (2010), crumb homogeneity perception received as high values as their wheat-based counterparts. The reason for that



Table 4. Mean ratings for the sensory attributes of the bread samples. Values marked with different letters among the same row were significantly different ($P < 0.05$)

| Sensory descriptors | Samples | | | | | |
|------------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| | CW | CGF | WLW | WLGF | WGW | WGGF |
| Appearance | | | | | | |
| Porosity | 7.3 ^a | 7.4 ^a | 8.6 ^b | 8.5 ^b | 7.3 ^a | 7.2 ^a |
| Crumb colour | 7.8 ^d | 7.7 ^d | 5.9 ^b | 8.2 ^e | 5.1 ^a | 6.4 ^c |
| Crust colour | 7.9 ^e | 7.4 ^d | 5.2 ^a | 6.8 ^c | 6.4 ^b | 7.5 ^d |
| Touch (by hand) | | | | | | |
| Soft | 7.6 ^d | 7.1 ^c | 5.2 ^b | 7.3 ^c | 4.9 ^a | 7.3 ^c |
| Aroma | | | | | | |
| Corn | 0.8 ^a | 0.7 ^a | 0.9 ^a | 0.8 ^a | 1.6 ^b | 1.8 ^b |
| Yeast | 2.2 ^c | 1.7 ^b | 2.4 ^c | 0.9 ^a | 2.8 ^d | 2.9 ^d |
| Cheese | 0.8 ^a | 0.7 ^a | 0.8 ^a | 0.6 ^a | 0.8 ^a | 0.7 ^a |
| Fermented | 1.5 ^b | 0.6 ^a | 5.2 ^e | 0.6 ^a | 2.6 ^d | 1.8 ^c |
| Taste | | | | | | |
| Sweet | 2.3 ^d | 0.8 ^a | 2.4 ^d | 1.6 ^c | 6.1 ^e | 1.1 ^b |
| Salty | 2.1 ^c | 3.8 ^d | 1.9 ^c | 2.1 ^c | 1.1 ^a | 1.5 ^b |
| Flavour | | | | | | |
| Corn | 0.8 ^a | 0.8 ^a | 0.8 ^a | 0.7 ^a | 0.9 ^a | 0.8 ^a |
| Yeast | 1.1 ^a | 1.2 ^a | 1.2 ^a | 1.3 ^a | 2.2 ^c | 1.8 ^b |
| Cheese | 0.8 ^a | 0.7 ^a | 0.8 ^a | 0.6 ^a | 0.6 ^a | 0.7 ^a |
| Fermented | 0.9 ^a | 0.8 ^a | 4.3 ^d | 1.9 ^b | 2.4 ^c | 2.3 ^c |
| Texture | | | | | | |
| Adhesive | 4.2 ^b | 4.4 ^b | 5.3 ^c | 5.2 ^c | 3.3 ^a | 3.5 ^a |
| Rubbery | 2.1 ^b | 2.3 ^b | 2.2 ^b | 2.1 ^b | 3.8 ^c | 1.4 ^a |
| Soft | 7.9 ^c | 8.1 ^c | 6.8 ^b | 7.9 ^c | 5.2 ^a | 8.1 ^c |

could be linked to more effective protein supplements and/or better starch-protein-hydrocolloid interactions. Mean ratings for the 17 sensory descriptors of the 6 bread samples are presented in Table 4.

From crust and crumb colour of the GF loaves were found more intense and preferable for the participants. In the case of CW and CGF the crumb colour was not significantly different, while the crust colour was perceived as less intense, more pale brown. Although the exact ratio of the ingredients could not be determined by the ingredient list, the result of the GF loaves showed that with the optimal combination of included ingredients (like starches, pseudocereals and fibres) creating favourable crumb and crust colour for GF breads was possible.

Taste and mouthfeel had always been one of the biggest struggles with GF bread formulations. GF bread products were often described as having dry, cardboard-like, tasteless or unpleasantly strong corn taste (Capelli et al., 2020; Foschia et al., 2016; Matos and Rosell, 2012; Pagliarini et al., 2010). In this study, participants did not feel any intense corn and/or cheese flavour and odour, although all of the GF bread samples contained a higher amount of corn starch (Fig. 3). In case of WGW and WGGF the significantly higher level of yeasty smell



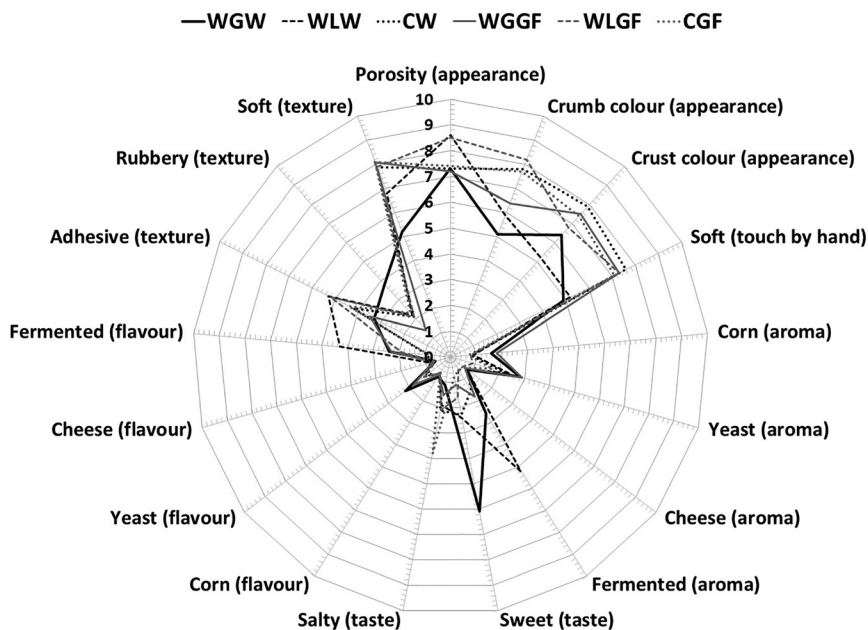


Fig. 3. Sensory test results of the different samples

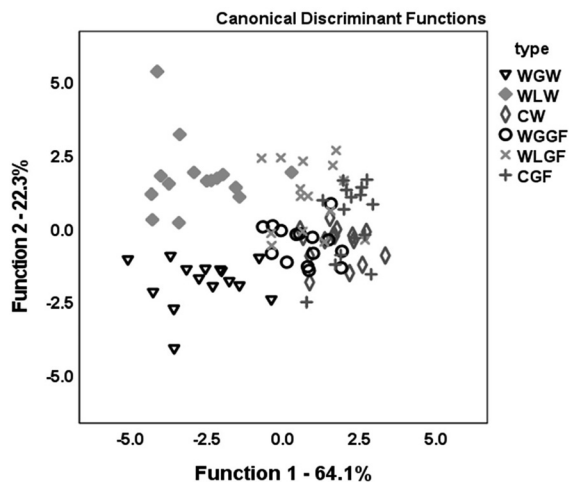


Fig. 4. LDA results of sensory evaluation, based on bread type and the most relevant sensorial attributes

was linked with the higher amount of seed content. WLW was characterized with the most intense fermented taste and smell, which was probably due to the presence of sourdough. GF samples were all characterized with more intense salty taste, in the case of CGF and WGGF



significantly. This was confirmed with the nutritional data presented on the product labels, as GF products contained higher level of salt by design. From sweetness point of view, WGW showed outstandingly more intense perception, but in general, all the wheat-based samples were significantly sweeter than their GF counterparts. Sweeter taste of wheat-based products can be caused by their lower salt-content compared with GF-breads. This result showed that the nutritional imbalance of higher sugar level intake was not true with these included GF breads.

Sensory results were in line with the instrumental measurements. WLW and WGW samples showed the highest values of hardness during the storage test, which was reflected in the sensory test as well with the least intense softness value. WGW was perceived as the hardest both by instrumental and sensory assessment. Adhesive and rubbery texture attributes were in line with the cohesiveness values.

The LDA results (Fig. 4) considering porosity, softness (touch by hand and mouthfeel by tasting), smell, adhesiveness, sweet and salty taste perception were noted as the most significant variables in discriminating samples (Pagliarini et al., 2010). Overlap was found between the GF loaves, CGF and CW, while WLW and WGW stood as separate groups. 66.67% of cross-validated grouped cases were correctly classified, strengthening the texture measurement and sensory evaluation results, namely the similarity between GF loaves, CGF and CW.

CONCLUSION

This study aims to provide up to date data regarding the so far neglected topic of texture and sensory aspects of commercially available GF bread products. Results show that the included samples had the capability to be preservative-free, ready to eat bread products with comparable texture properties and attributes to their wheat-based counterparts during storage at room temperature. The hardness, springiness and cohesiveness data of the storage test showed that the quality of GF products has improved during the last few years, and samples being comparable with the wheat-based bakery products are already present on the market. The previously published gap in the nutritional differences between GF and wheat-based products was decreased, as the GF samples had higher fibre and comparable or even lower energy and carbohydrates values. In the future, it would be important that publications put more focus on shelf-life studies aiming to evaluate the texture and sensory qualities of commercially available GF bread samples. The outcome of those researches could be used as reference for the GF product development strategies.

Funding: The Project is supported by the European Union and co-financed by the European Social Fund (grant agreement no. EFOP-3.6.3-VEKOP-16-2017-00005).

ACKNOWLEDGEMENT

The authors acknowledge the Hungarian University of Agriculture and Life Sciences' Doctoral School of Food Science for the support in this study.



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