Effects of ingredients on sensory attributes of gluten-free breads available in the UK

Type: Research paper

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Abstract

Purpose: This study aims to evaluate the effects of alternative ingredients in three different gluten-free (GF) breads available on the UK market with regards to their quality attributes and consumer preference.

Methodology: Three different GF bread samples purchased from a UK retailer were visually assessed. Their quality attributes and consumer acceptability were analysed via an untrained taste panel (n=35) on day 1. Texture was compared using a texture analyser on day 1 and 8, to examine the differences between samples and the effects of ingredients towards staling.

Findings: Results from visual inspection showed that ingredients affected the appearance of samples, in terms of crumb structure, and both crumb and crust colour. Firmness and springiness were significantly different ($p<0.05$, $p=0.007$) between samples on day 1 and 8 although no significant difference existed within each individual sample. Sensory analysis showed no significant differences between samples with respect to denseness, chewiness, crumbliness, dryness and overall preference.

Research limitations: The ingredient combination in each bread differed and thus it is not clear if the results are due to the incorporation of individual ingredients or a combination of them.

Originality/Value: Overall, the study showed that the use of different ingredients affected the appearance, firmness and springiness of three GF breads available on the UK market. However, it did not affect denseness, chewiness, crumbliness, dryness or consumer preference. This indicates a number of ingredient combinations are possible in the manufacture of acceptable GF bread.

Keywords: Gluten-free, Gluten-Free Bread, Gluten-Free Ingredients, Texture, Sensory, consumer preference.

Paper Category: Research Paper

Introduction

Bread, a major staple food, is one of the most commonly consumed products in the world (Robinson, 2001). One of the most important ingredients required in bread making is flour (Cauvain, 2015). In traditional bread making wheat is commonly used, due to the presence of its gluten protein fractions (Robinson, 2001; Hager *et al*., 2012; Pagliarini *et al*., 2010). These fractions possess unique viscoelastic properties responsible for providing wheat with the technological properties required to produce good quality bread (Hager *et al*., 2012; Pagliarini *et al*., 2010). During the kneading process, these fractions combine to form a gluten network, which is crucial in bread making to provide structure to bread dough by trapping carbon dioxide (CO_2) produced by yeast or natural fermentation. Gluten is also responsible in forming the final structure of bread by forming a matrix with other ingredients (Cauvain, 2015; Shewry *et al*., 2002).

Although gluten is crucial in bread making, its existence can give rise to adverse health effects or conditions that are centred around the digestive system in people with gluten intolerance (Hager *et al*., 2012). Gluten intolerance is a term used to describe people with the inability to handle gluten and this condition can be classified into three distinct related categories; coeliac disease, non-coeliac gluten insensitivity and wheat allergy (Hager *et al*., 2012; McAneney, 2014).

Coeliac disease is characterised by chronic inflammation and villous atrophy, where the immune system is triggered by gluten to attack itself, causing damage to the small intestine's absorptive surface (Coeliac UK, 2017; Morais *et al*., 2014). Non-coeliac gluten insensitivity has similar symptoms to coeliac disease, however it is not associated with the reaction of the immune system damaging the wall of the small intestine (Coeliac UK, 2017). Furthermore, wheat allergy is an allergic reaction caused by histamine's response to wheat, much like peanut allergy (Coeliac UK, 2017; Mullani, 2012).

Due to the presence of these conditions, gluten intolerance sufferers are unable to consume gluten-containing products and are restricted to a gluten-free (GF) diet. Over the years, there has been an increase in the number of people suffering from, or self-diagnosing gluten intolerance (Gallagher *et al.,* 2004). This gives rise to an increased need, interest and demand for alternative ingredients suitable for GF products, such as, gluten free bread (GFB) (Hager *et al*., 2012; Sciarini *et al*., 2008; Thompson, 2003; Torbica *et al*., 2010).

Quality characteristics of GFBs are highly influenced by the ingredients used (Rodrigo & Pena, 2014). Improvements have been made in the quality of GFBs commonly utilising various GF flours, starches, hydrocolloids, fibres, non-gluten proteins, humectants in various combinations providing the same functional properties of gluten (Hager *et al*., 2012; Pagliarini *et al*., 2010; Torbica *et al*., 2010).

GF flours and starches have low protein and high starch content that increases the firmness, toughness and staling rate of GFBs. The use of rice and corn flour resulted in firmer, denser, lower volume, more compact structure and higher staling rate GFB's (Gujral and Rosell, 2004; Sabanis and Tzia, 2009).

Hydrocolloids have been used in GFB formulations to improve quality characteristics and mimic the viscoelastic properties provided by gluten (Cauvain, 2012). In the production of GFBs the hydrocolloids Hydroxy Propyl Methyl Cellulose (HPMC) and xanthan gum are commonly used (Cauvain, 2012). Guarda *et al.* (2004) found that both HPMC and xanthan gum have really good potential as anti-staling agents and bread improvers in GFBs. HPMC however was found to provide greater effects in improving the quality characteristics of GFBs due to its ability to bind water and retard amylopectin retrogradation.

The addition of fibre in the formulation of GFBs have been shown to increase nutritional value and provide technological properties, by forming gels, binding water, imitating fat, and thickening to modify and improve sensory properties and shelf-life (Sabanis *et al*., 2009). Psyllium husk is commonly used in GFBs producing a good quality GFB due to its anti-staling effect, film forming and water binding ability (Cappa *et al.,* 2013).

Non-gluten proteins in GFB formulations replace and mimic the functional properties of gluten proteins, but their addition have also been found to also increase colour and flavour and elastic modulus, thereby improving the structure, of GFBs (Arendt & Bello, 2008). Gallagher *et al.* (2003) indicated milk protein isolate, when used with rice powder improved the acceptability and quality characteristics of GFB including volume, colour, crust and crumb structure.

Humectants are added in GFB formulations to control water activity, prolong shelf- life, retain moisture and retard staling. In certain cases, it can also improve quality characteristics of baked products (Cauvain & Young, 2008; Devahastin, 2011). Karimi *et al.* (2013) investigated the functional properties of humectants in baking and concluded that this ingredient controls water activity and thus improves the volume and texture of the GFB.

However, despite extensive research on alternative ingredients, Pagliarini *et al.* (2010), Torbica *et al.* (2010) and Arendt & Bello (2011) express dissatisfaction in the quality of GFBs available on the market, compared to their traditional counterparts. This indicates the effects of different alternative ingredients on the quality attributes and consumer preference of GFBs needs further study.

Therefore, the aim of this study was to evaluate the effects of different ingredients used towards selected quality attributes and consumer preference of three different GFBs available on the UK market using different objective and subjective sensory assessments.

Methodology

Study Design

The University departmental ethics committee gave approval prior to data collection. Three different brands of GFBs were purchased from a UK retailer a day before data collection was undertaken. Samples were stored in ambient temperature (20^{o}C) before use. Data collection occurred during day 1, after purchase and day 8.

Materials

The GFBs were purposively selected to represent different manufacturers, utilising different ingredients. All samples were sliced ready-to-eat breads, available on the UK market and thus easily accessible by UK consumers. Samples were anonymised using letter codes (Sample A, B, C).

Figure 1 near here

Visual Analysis

Pictures of a single sample GFB slice, taken with an iPhone camera (Apple, California, USA) allowed for visual comparison of the appearance of the individual samples.

Texture Analysis

Triplicates of each GFB sample (Sample A, B, C) were analysed on day 1 and day 8 of data collection using a Texture Analyser (Stable Micro Systems Ltd, Surrey, UK), to determine firmness and springiness using a American Association of Cereal Chemists 36mm radius cylinder probe using a 5kg load cell for all measurements. Following the texture analysers guidelines all measurements were taken on a thickness of 2cm of bread sample (for all samples this was 2 slices of bread). Torbica *et al.* (2010) also used this method to assess the effects of ingredients in GFB formulations on the texture of samples.

The texture of samples were also assessed on day 8, a typical shelf life of bread at ambient temperature (Forsythe, 2011), to examine the effect of staling. This analysis on the effect of staling was done because staling is a particular interest in the development of GFBs, as faster staling is commonly reported in GFBs compared to traditional breads due to their high starch content (Horstmann *et al.*, 2017).

Sensory Analysis

Sensory analysis was undertaken to assess the consumer acceptability of the GFBs, similar to research conducted by Hager *et al.* (2012) and Torbica *et al.* (2010).

An untrained consumer sensory taste panel, using BSI standard rating and ranking methods in BSI standard sensory booths at the University (British Standards Institute (BSI), 2007).

Recruitment was aided by posters and social media accounts used within the University. All participants were made aware of allergens contained within the samples using information stated on the posters, participant information/ consent sheet and questionnaire.

Samples of 5x5cm GFB, without crusts were presented using three-digit random code Participants tasted the samples in the random order listed on the questionnaire. Water was available to rinse their mouth between samples. Rating test was conducted by participants circling a value from 1 to 9 for 4 attributes; denseness, chewiness, crumbliness and dryness. 1 being extremely weak and 9 being extremely strong (BSI, 2015). The same participants were then asked to rank the samples from 1 to 3. 1 being most liked and 3 being least liked, giving reasons for choice (BSI, 2006).

Data Analysis

Differences between the texture analysis of the three individual GFB samples (A,B,C) on day 1 and day 8 were analysed by comparing the results of the three samples individually on day 1 (between day 1 sample A, B, C) and individually on day 8 (between day 8 sample A, B, C) using One-way ANOVA, followed by Tukey's HSD (Honest Significant Difference) test (Statistical Package for Social Sciences v25.0 for Mac, IBM Corporations, New York). Wilcoxon Signed Ranked Test using SPSS was used to ascertain any statistically significant differences between the texture of the three samples by comparing day 1 samples to their day 8 counterparts (Sample A to A, B to B, C to C).

One-Way ANOVA tests were performed on the sensory analysis results for denseness, chewiness, crumbliness and dryness between samples (A, B, C). Friedman's ANOVA were used to look at the presence of statistical significance in consumer preference between samples

(Kemp *et al*, 2009), $p<0.05$ was taken as the presence of statistically significant in all cases (Rumsey, 2011).

Results

The ingredients used in each of the selected GFB samples are reported in Table 1 and their nutritional information in Table 2.

Table 1 and 2 near here.

Slices from each loaf of the three GFB samples were taken on day 1 of data collection (Figure 2). Clear differences in crumb structure are visible. Sample A is more compact with a closer pore structure, followed by sample B and then C. Sample A had lighter crust with white crumb, sample B had darker crust with yellowish crumb, and sample C had similar lighter colour crust as A, with greyish crumb.

Figure 2 near here.

Texture Analysis of GFB Samples

The three GFB samples were subjected to texture analysis on day 1 and day 8 of data collection. The average force (g) required to compress the GFB samples on day 1 and day 8 can be seen in Figure 3. It is clear that on both day 1 and day 8, sample A had the lowest average force (399g), followed by sample B (409g) and then sample C (492g). Sample C was significantly firmer than samples B and C ($p<0.05$, $p=0.007$) on day 1 and 8.

The average force to compress all GFB samples had increased by Day 8. The increases were to 399g for Sample A (a 7% increase), 431g for Sample B (a 5% increase) and 682g for sample C (a 39% increase). No significant differences were observed within the breads of at day 1 compared to day 8.

Figure 3 near here.

Sensory Analysis of GFB Samples

Figure 4 indicates negligible difference between the mean value of the chewiness of every sample, while slight differences were seen on the denseness, crumbliness, dryness and preference of samples, there were no statistically significant differences between all samples for all attributes or in consumer preference.

Figure 4 near here.

Discussion

Visual Analysis

The cause of the denser and more closed crumb structure of sample A may be due to the presence of quinoa and maize flour (Table 1). This agrees with Hager *et al.* (2012) who found that the addition of quinoa and maize flour produces bread with increased density resulting in denser bread with firmer crumb. This occurs because both ingredients have high starch content; 40 to 50% in quinoa (Eliasson, 2004; Turkut *et al*., 2016) and 70% in maize (Yang *et al*., 2013), which when added to bread, increases the starch content of the GFB batter causing an increase in viscosity (Gallagher, 2009). In bread making, when viscosity is too high, the development of air pockets are retarded, resulting in bread with denser and more closed crumb structure (Cauvain & Young, 2008).

Another possible cause of the closed crumb structure of sample A is the presence of bamboo fibre. The addition of fibre into bread has been found to increase density (Martinez *et al.,* 2014) who found that the addition of coarse insoluble fibre, such as, bamboo, lowers the volume and increase the denseness of bread. This is caused by the slow hydration of fibre, which causes the increase in dough viscosity during the moulding stage and results in damaging the delicate bubble structure in the dough, subsequently reducing gas retention and air pockets, producing bread with a more closed crumb structure (Cauvain & Young, 2008).

Furthermore, the different quantities of HPMC used in sample A, B and C could also cause differences in crumb structure, as the addition of HPMC were found by Nishita *et al.* (1976) to provide a suitable viscosity to trap gasses and help produce bread with better pore structure. Therefore, consideration of the level of incorporation of HPMC may improve the crumb structure of both sample A and C.

Emulsifiers are used in GFB to improve crumb porosity Nour *et al.* (2017). Sample A (table 1) is the only GFB in this study that contains emulsifiers (mono- and di-glycerides of fatty acids), which does appear to improve crumb porosity in sample A compared to B and C (figure 2).

The greyish crumb colour of sample C (figure 2) may result from the addition of ground flaxseed, which was not present in sample A & B (table 1). Codina *et al.,* (2016) indicate the addition of flaxseed in bread decreases the yellowness and lightness of the product, which was concluded out of the results of this study.

Sample B was more yellow than sample A (figure 2), which could be caused by the higher level of maize starch used in sample B, the level indicated by its earlier presence in the QUID ingredients declaration (figure 1) (Goodburn, 2001). GFB made with entirely maize starch normally has a strong yellow colour (Hager *et al.,* 2012).

In terms of crust colour, sample B was darker compared to A and C (figure 2). Crust colour is related to the presence of sugar and proteins in the bread via caramelisation and Maillard reaction (Cauvain, 2017). Sample B had the highest protein content (6.8g, Table 2) between samples and the second highest sugar content (1.4g, Table 2). High protein ingredients in sample B were pea protein and egg white powder, the former of which increases crust darkness in bread (Marchais *et al.,* 2011).

Texture Analysis

The results suggest that on both day 1 and 8, sample A was the softest, followed by sample B and then C, sample C was statistically significantly ($p<0.05$, $p=0.007$) firmer than the other samples (figure 3). The soft texture of sample A may be the result of the presence of bamboo fibres producing bread with lower hardness (Martinez *et al.,* 2014) and emulsifiers producing bread with a softer texture a result of retarding the staling effect (Azizi *et al.,* 2002).

Sample C was the firmest sample (figure 3), possibly due to the inclusion of ground flaxseed, GF flours or starches and psyllium fibres (table 1) which are known to increase bread density

(Arendt & Bello, 2011; Cappa *et al*., 2013; Codina *et al.,* 2016). The low protein and high starch content of GF flours or starches, and the thickening and binding ability of fibres are the main cause of the increase in the density of bread when they are used (Arendt & Bello, 2011; Cappa *et al*., 2013; Sabanis *et al.*, 2009).

Figure 3 reveals the staling of all samples increased, non-significantly after a week of storage, although statistical analysis showed no significant difference, sample C had the highest increase, followed by sample A and then B.

The highest level of staling of sample C may relate to its high carbohydrate content (47%, table 2) contributed by the GF flours and starches used (table 1). The higher the concentration of starch, the higher the concentration of retrograded starch, the faster the staling rate (Eliasson & Larsson, 1993; Kong & Singh, 2011). The presence of calcium propionate in sample A and B may contribute to the lower rate of staling, due to a reduction in water activity in the GFBs (Belz *et al.,* 2012; Kosseva & Webb, 2013). An additional ingredient which may contribute to a lower staling rate in sample A is the emulsifier, which retains crumb softness by slowing down amylose retrogradation (Norn, 2015).

Sensory Analysis

Figure 4 indicates that there were no significant differences in any of the attributes examined in the sensory analysis panel, or the overall preferences of the GFBs. However, the sensory results do reflect the texture analysis (figure 3) in that participants found sample C to be the most dense. Sample C was also the crumbliest sample possibly due to the low level of protein (2.4g, table 2) reducing the development of the gluten-like network required in bread, as indicated by Crockett *et al.,* (2011).

Conclusion and recommendations

To conclude different GF ingredients appear to have an effect on the visual appearance of bread in terms of crumb structure, and crumb and crust colour.

In addition, the ingredients affected the texture of the breads with sample A being the softest throughout the 8 days studied. Samples A and B were similar in terms of texture. Sample C was significantly firmer throughout the study. In terms of ingredients calcium propionate and emulsifier seem to be useful inclusions to soften the texture of GFBs and lower the rate of staling.

Sensory analysis indicated that the GF ingredients used did not affect the attributes investigated. However, the sensory panel was small in number and untrained, so there is a possibility of error.

Overall, this research as a whole suggests that when developing GFBs, the bakery industry can use any GF ingredients to produce GFBs that meets consumer preference. However, they need to carefully formulate the recipe as the ingredients do have an effect on the visual appearances and the texture of the products.

*F*uture research needs to investigate the effects of each individual ingredient on the quality attributes and consumer preference of GFBs using a substitution of ingredients approach, for instance bamboo fibre vs HPMC.

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