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Different formulations in gluten-free bread production: A review

Başak Sungur[1,*]

[1]Department of Food Engineering, Faculty of Engineering, University of Near East, Near East Boulevard, 99138 Nicosia, Mersin 10 – Turkey

[*]Corresponding Author: basaksungur@hotmail.com

Abstract

Studies in recent years have shown that the market demand for gluten-free products is considerably increasing to fulfill celiac patients' needs. Celiac disease is a food allergenic disease in humans induced by gluten in wheat, barley, rye, kamut, spelt and hybrids like triticale. For individuals with this disease, the one and only cure is to keep away from gluten-containing foods for perpetuity. Because of this reason, production and development of gluten-free bakery products, particularly bread because it is a basic food consumed daily in the world, have become popular and have been improved by the addition of different cereals, flours and starches, dough treatment or changing processing conditions and the method of baking. It needs to improve gluten-free bakery products' quality because the absence of gluten is a big problem for the quality of dough and bread. For example, a bread made from gluten free flour has lower volume, weaker texture and aroma than the traditionally ones . However the increase of gluten-free market, there are still some problems such as their high prices, limited variety, and availability and low nutritional quality. This review focuses on the finding suitable alternatives for gluten free bread to improve their baking and sensory quality and nutritional properties.

Keywords: Celiac, hydrocolloids, gluten-free bread, bread quality

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Introduction

Celiac disease is a lifelong intolerance to gluten disease, caused by the intake of gluten-containing cereals such as wheat, rye, barley, oat, kamut, spelt and their products. (Korus et al. 2009; Padalino et al. 2016; Wang et al. 2017). Celiac disease can appear in the early childhood and people with the Celiac disease have some symptoms such as chronic diarrhea, failure to thrive, fatigue and weight loss when consumed gluten-containing foods (Korus et al. 2009; Demirkesen et al. 2010; Foschia et al. 2016). Nowadays, the only and effective treatment for people with Celiac disease is strict keep to a gluten-free (GF) diet, which means a permanent withdrawal of all types of bread and food prepared with wheat flours and similar proteins including kamut, spelt, triticale, barley and rye from daily food (Mariotti et al. 2013; Lamacchia et al. 2014; Foschia et al. 2016).

Gluten, the protein present in wheat which contains glutenin and gliadin fractions, is a major protein component which is responsible for water absorption capacity, cohesivity, viscosity elasticity and gas holding ability of bread dough and producing high quality baked goods with desired volume and texture (Gallagher et al. 2004; Demirkesen et al. 2010; Janawali et al. 2016; Tsatsaragkou et al. 2016). The production of bread using gluten-free flours is a major problem for bakers and researchers. Because, it can't be produced desirable bread which has some quality properties such as taste, texture, specific volume, flavour, colour and nutritional value without gluten (Matos and Rosell 2014; Tsatsaragkou et al. 2016).

Nowadays, numerous studies have been investigated on GF to eleminate these problems which means manufacturing GF breads with similar quality properties to wheat breads such as the use of rice flour (Demirkesen et al. 2010; Torbica et al. 2010; Hager and Arendt 2013; Mohammadi et al. 2014; Nicolae et al. 2016), corn flour (Sanchez et al. 2002), soybean flour (Sciarini et al. 2012), patato flour (Liu et al. 2018), buckwheat flour; (Torbica et al. 2010; Hager and Arendt 2013; Mariotti et al. 2013; Buresova et al. 2016), chestnut flour (Demirkesen et al. 2013; Moreira et al. 2013a;b;), corn starch (Lazaridou et al. 2007; Korus et al. 2009; Aguilar et al. 2015), quinoa white flour (Elgeti et al. 2014), hydrocolloids (Lazaridou et al. 2007; Demirkesen et al. 2010; Hager and Arendt 2013; Mariotti et al. 2013; Mohammadi et al. 2014; Nicolae et al. 2016; Mir SA et al. 2016; Ferrero 2017; Liu et al. 2018;), emulsifiers (Demirkesen et al. 2010; Houben et al. 2012; Sciarini et al. 2012), enzymes (Gujral and Rosell 2004a,b; Moore et al. 2006; Renzetti et al. 2008; Buresova et al. 2016), water-soluble dietary fibres (Tsatsaragkou et al. 2016; Capriles et al. 2016), dairy ingredients (Buresova et al. 2016) as alternatives to gluten, to development of properties of GF bakery products.

Effect of some different flours and starches on the quality of GF breads and batters

Cereal flours such as rice, corn, millet species, sorghum, finger millet and foxtail millet are widely used for GF bakery products due to they don't contain gluten forming proteins (Houben et al. 2012; Foschia et al. 2016; Padalino et al. 2016). These flours are used for enhancing the texture of several bakery products such as tarhana, cookies, bread, pasta, tagliatelle, cake and spaghetti (Jnawali et al. 2016).

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In addition general applications used to improve GF pasta and bread such as adding different GF flours, hydrocolloids, proteins, and enzymes was investigated by Padalino et al. (2016). These researchers also explained that dough heating and cooling practices are more important than starch gelatinization and starch retrogradation for GF products technology. Foschia et al. (2016) reported that rice flour 59.3%, maize flour 40.7%, buckwheat flour 22.2%, whole grain maize flour 18.5%, tapioca flour 11.1%, potato flour 7.4%, millet flour 7.4% and quinoa flour 3.7% were used in commercial GF bread formulations. Among these flours, rice flour is especially interesting because of its hypoallergenic properties, bland taste, white color, digestibility and easy availability (Sanchez et al. 2002; Torbica et al. 2010; Foschia et al. 2016).The use of rice flour, corn, and cassava starch to replace wheat flour in the production of free-gluten white bread has been produced (Lopez et al. 2004). Evaluating the physical parameters (crumb appearance, specific volume, and moisture) and the sensorial parameters (flavor, appearance, crumb texture, crust color and satisfaction) they reported that rice flour bread presented the best parameters, followed by corn starch bread and cassava starch bread. They also optimized a mixture of flours that composed of 45% rice flour, 35% corn starch and 20% cassava starch.

Similar results were obtained from GF bread containing some different flours such as rice, husked buckwheat or unhusked buckwheat flour by Torbica et al. (2010). They have explained that the rheological properties of GF bread formulations containing mixtures of these flours by using Mixolab. They have also investigated textural and sensory properties of GF bread formulations. They found that GF products with unhusked buckwheat flour had highest water absorption values, lowest stability, and weakest protein network structure in consisted of husked buckwheat flour.

Addition of starch in GF products is one of the used methods as a replacement for gluten. Starch and its derivates (chemically modified, resistant starches, maltodextrins etc.) are very important for bread making because of their ability to gelatinize, positively affects on bread volume and crumb softness (Naqash et al. 2017). In a study by Sanchez et al. (2002), rice flour, corn starch, and cassava starch were used in GF breadmaking to statistically establish optimal amounts of each ingredient by using a central composite design. According to the obtained results, the optimal GF bread can be prepared from 74.2% corn starch, 17.2% rice flour, and 8.6% cassava starch. In the same study, it was also found that addition of soy flour improved crumb-structure quality of bread. In another study, Korus et al. (2009) showed that the addition of corn resistant starch preparations gave GF bread with less hard crumb than bread without resistant starch addition.

Impact of dietary fibre and pseudocereals on the quality of GF breads and batters

Dietary fibres have a significant role in improving GF bread quality because of it increases the nutritional value of bread and also uses for improving rheological, texture characteristics of dough and sensory properties of final baked products (Gomez et al. 2003; Tsatsaragkou et al. 2016). Saturni et al. (2010) reported that their use in GF diet can help to increase fibre intake in celiac disease patients. Moreover, some researchers have investigated the addition of dietary fibres in GF bakery products formulations. For example, Talens et al. (2017) applied two different orange fibres; one obtained by hot air coupled with microwave drying of orange peels and the other commercially available to effect on texture and sensory properties of GF muffins. With the application of hot air coupled with microwave drying of orange peels, total dietary fibre, water retention capacity, viscosity and viscoelastic properties were higher and resulted in a new alternative for citrus by-products valorisation and transformation into a fibre ingredient suitable for GF baking. In a previous study, some different cereal fibres based on wheat, maize, oat and barley were used to improve the quality, sensory and nutritional properties of GF dough and bread by Sabanis et al. (2009). Results showed that among the dietary fibres maize and oat fibres had significantly affect the loaf volume and crumb softness of GF bread. In the same study, researchers have also found that the addition of wheat fibre resulted in decreased bread volume and a much firmer crumb texture than the control due to the high water binding capacity of this fibre. Similar results were explained in a review by Tsatsaragkou et al. (2016) and they indicated that the each category of dietary fibres such as flours/seeds, isolated fibres/commercial formulations (insoluble and soluble fibres), fruit/vegetable fibres and products alternative flours etc. can be positively affected the final quality of GF product due to their ability to increase bread volume, improve water and gas holding capacity of dough.

In addition, the pseudocereals, which are considered as protein supplementation on GF products, such as amaranth, yellowpea, chickpea and lentil flour, psyllium flour, teff flour (fermented), quinoa flour, dehulled buckwheat flour, and puffed buckwheat flour are often used for GF bakery products because of increasing batter volume, elasticity and shelf life; improving essential amino acids, dietary fiber, fatty acids, mineral and ash content, and baking properties of GF bakery products (Alvarez-Jubete et al. 2010; Houben et al. 2012; Elgeti et al. 2014; Lamacchia et al. 2014; Alencar et al. 2015; Naqash et al. 2017). Because many GF bakery products are made using GF flours or starch and in this way, they do not contain the same levels of B-vitamins, iron and fibre as their gluten-containing counterparts (Alvarez-Jubete et al. 2010). Among these pseudocereals, buckwheat flour was investigated due to it has high nutritional value and health benefits for humans by Mariotti et al. (2013). They have been also used hydroxypropylmethylcellulose (HPMC) on the breadmaking properties of commercial GF bread mixtures and found that the combination of both 0.5% HPMC and 40% dehulled buckwheat flour increased in bread height and specific volume and also decreased significantly crumb hardness of GF bread.

Elgeti et al. (2014) indicated that the addition of quinoa white flour gave GF bread with significantly higher specific volume and homogeneous and finely distributed gas bubbles crumb compared to the typical GF control recipe based on rice and corn flour. Similarly, Alverez-Jubete et al. (2010) pointed out that the quinoa, amaranth and buckwheat flours have been extensively used in formulations of GF products due to their high nutritional properties such as high protein, fiber and mineral content and health-promoting effects. In a study by Alencar et al. (2015) evaluated the temporal profile and instrumental analysis of different GF bread's formulations containing amaranth and quinoa flours and sweeteners. The researchers found that the addition of pseudocereals and sweeteners was shown to be similar effects on sensory and physicochemical properties of GF bread, compared to starch-based formulations which consisting of potato, cassava and sour tapioca starches.

Application of hydrocolloids and emulsifiers in GF bread

Hydrocolloids, also known as water-soluble gums, are one of the food additives with the intention of improving dough handling properties and resulting on positive effects of crumb structure, taste, acceptability and staling of GF breads due to their ability to increase water retention capacity, rheology, viscosity and texture of dough (Anton and Artfield 2008; Padalino et al. 2016; SAMir et al. 2016; Wang et al. 2017). The GF bread quality is influenced by the presence of hydrocolloids which increase dough rheology and quality of final bread (Houben et al. 2012; Nicalae et al. 2016; Liu et al. 2018).

Among hydrocolloids, cellulose derivates such as carboxymethylcellulose (CMC) and HPMC; guar gum and xanthan gum are extensively used in recipes of GF bakery products (Wang et al. 2017). For example, Sciarini et al. (2010) showed that hydrocolloids such as carrageenan, alginate, xanthan gum, CMC and gelatine increased batter consistencies of GF bread made from rice, corn and soy flours and 158% water. Similarly, Liu et al. (2018) reported that hydrocolloids such as HPMC, CMC, xanthan gum and apple pectin improved the mixing and thermal behaviour of GF potato dough. In particular, they also suggested that the addition of hydrocolloids in the GF potato steamed bread was improved the specific volume, hardness and porosity of the crumb.

GF dough structure is highly affected by the addition of hydrocolloids, such as CMC. Lazaridou et al. (2007) used different hydrocolloids into GF bread made from rice flour, corn starch and sodium caseinate and studied their effect on dough rheology and bread quality. Among the hydrocolloids, they found that CMC and pectin seemed to be the best hydrocolloid improvers of GF bread, at 1% for CMC and 2% for pectin, resulted in bread with significantly increased volumes and high values of crumb porosity and elasticity and also the addition of these hydrocolloids did not alter the firmness of the crumb, and the supplemented bread had high acceptability ratings by consumer panel. Likewise, Buresova et al. (2016) examined that the effect of calcium and sodium caseinate was compared to the effect of xanthan gum and CMC on the behaviour of rice-buckwheat dough and bread quality. At the end of the study, they found that the incorporation of calcium and sodium caseinate could be used as an alternative supplement positively effected of the both rheological properties of rice-buckwheat dough and bread quality.

Hager and Arendt (2013) studied the effects of different gums such as HPMC and xanthan gum and their combination on GF model systems consisting of rice, maize, teff and buckwheat flours using response surface methodology. They showed that with the addition of HPMC and xanthan gum at very low levels contributed to improve bread properties, but might also deteriorate loaf quality. Moreover, Sabanis and Tzia (2011) suggested that 1% and 1.5 % addition of HPMC promoted to increase loaf volume and color than control GF bread and also bread containing 1.5% HPMC was preferred by a trained panel for sensory evaluation. These positive impacts of HPMC on GF bread quality can be explained by because of its moisture absorption ability, gas binding capacity (Houben et al. 2012). In another study, McCarthy et al. (2005) optimized formulation for GF bread based on rice flour containing different levels of HPMC (0.5-2.5% flour/starch base) and the water levels (70-95% flour/starch base) using response surface methodology. They found that the optimized formulation was at the level of 2.2% HPMC and 79% water. They also determined that the increasing water addition considerably effected on bread quality properties and HPMC and water showed significant interactions in their effect on crumb grain structure.

Mohammadi et al. (2014) determined the effects of xanthan gum and CMC on the development of GF flatbread. Evaluating the moisture, firmness, elasticity, crumb and crust color, sensory evaluation, porosity appearance, dough, bread yield and weight loss, they reported that the xanthan gum showed the best bread quality properties as compared to all the samples.

The effects of hydrocolloid addition on rheological properties and breadmaking performance of rice-buckwheat batter at different water levels have been reported (Peressini et al. 2011). In their study, xanthan gum and propylene glycol alginate were added to rice-buckwheat blend (60:40) at levels of 0.5-1.5%. The researchers showed that propylene glycol alginate provided higher quality bread regarding specific volume, crumb mechanical properties and crumb structure than xanthan gum and also it gave promising results for the production of high quality to rice-buckwheat bread.

Another hydrocolloid like Sodium Carboxymethylcellulose (NaCMC) has been tested for rheological properties of GF dough (Nicolae et al. 2016). They found that the addition of 1% NaCMC was the most appropriate dose for a good quality GF product comparable as structure and volume with a standard wheat bread. Contrary to common opinion, Sciarini et al. (2012) explained that additives used in GF bread like emulsifiers, enzymes and hydrocolloids did not improve final bread technological quality and they also showed that the presence of additives is not essential for GF bread production.

Bourekoua et al. (2018) investigated the effect of agar-agar, gum arabic, locust bean gum, tapioca starch and corn starch and their combinations on the quality of GF bread. GF bread was made from rice semolina supplemented with field bean semolina and thermal properties of additives and GF bread were evaluated using differential scanning calorimeter (DSC). According to results, they reported that gum arabic was found to be the best additive for producing optimum GF rice-based bread (with 1.5% of gum arabic and 71.5 g/100 g of water).

Morreale et al. (2018) studied with HPMC to understand the role of hydrocolloids viscosity and hydration in developing GF bread. They confirmed that the role of the HPMC in effecting the viscoelastic behaviour of the GF batter and influencing the rheology characteristics of bread by the inclusion of a 2.2% of HPMC 15000 cP with hydration level to 110%. And finally they obtained desirable GF bread regarding crumb hardness, cohesiveness and resilience.

Additives such as emulsifiers have also been used in GF bread for improving bread structure and staling (Houben et al. 2012; Selomulyo and Zhou 2007). DATEM is anionic oil-in-water emulsifiers that are used for improving dough and bread quality by improving mixing tolerance, gas retention and resistance of the dough to collapse (Selomulyo and Zhou 2007).

Demirkesen et al. (2010) conducted studies to show the effect of different gums and emulsifiers on GF bread made from rice flour. In their study, they found that emulsifiers in addition to gums were necessary to obtain the desired physical properties in dough formulations. In another study by the same researchers, they evaluated that the GF bread formulated with different chestnut/rice flour ratio with/without gum blend and emulsifier DATEM using rheological, baking and sensory measurements. They found that the bread containing chestnut/rice ratio 30/70 with an addition of the blends of xanthan-guar and emulsifier had the best quality parameters.

Onyango et al. (2009) studied that the effect of cellulose-derivatives and emulsifiers on creep-recovery and crumb properties of GF bread made from sorghum and gelatinised cassava starch. At the end of their study, they found that emulsifiers strengthened the doughs and decreased crumb firmness and staling rate when compared the control. These effects were most pronounced at 2.4% w/w fwb concentration. Similarly, the effects of some emulsifiers such as lecithin, DATEM, distilled monoglycerides or sodium stearoyl lactylate were studied by Nunes et al. (2009). It was found from their study that emulsifiers have a positive effect on the GF bread. For example, they suggested that the bread containing with distilled monoglycerides at high levels the specific volume reached a maximum improvement as well as reducing significantly the staling rate of the crumb.

Conclusions

The primary focus of this review is to discuss the current approaches used to develop the rheological and baking properties of GF bread. Because people suffering from celiac disease consists in a lifelong GF diet. With this aim different kinds of additives such as different flours, starch, dietary fibre, pseudocereals, hydrocolloids, enzymes, diary ingredients, and emulsifiers have been commonly used for as alternatives to gluten and to improve the properties of GF bakery products. They have been used for diverse purposes like to make GF bread with good bread quality, sensory and nutritional properties available to consumers with celiac disease patients and also to increase the variety of these products. The obtained results have been showed that more research is needed in this area, in particular improving nutritional quality and increasing variety of GF products.

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