Journal of Food Quality and Hazards Control 2 (2015) 81-85

Gluten-Free Bread Quality: A Review of the Improving Factors

N. Mollakhalili Meybodi[1, 2], M.A. Mohammadifar[2*], E. Feizollahi[2]

1. Research Center for Molecular Identification of Food Hazards, Shahid Sadoughi University of Medical Sciences, Yazd, Iran
2. Department of Food Science and Technology, National Nutrition and Food Technology Research Institute, Faculty of Nutrition Sciences and Technology, Shahid Beheshti University of Medical Sciences, Tehran, Iran

Article type
Review article

Keywords
Diet
Gluten-Free
Bread
Food Quality
Celiac Disease

Received: 23 Jan 2015
Revised: 7 Mar 2015
Accepted: 29 Mar 2015

Abstract

Celiac disease is the inability of the small intestine to tolerate some cereal prolamin with sequence specific oligopeptide. Wheat gliadin, rye secalins and barley hordenine are the main proteins involved in the disease mechanisms and may provoke an inflammatory process to damage the small intestine. There are different methods to overcome the problems for such patients; one of them is using gluten-free diet. Bread has the main role in the human diet and gluten is its main structure forming component. Gluten-free breads are produced by either cereals like wheat, barley and rye with removed prolamin or no prolamin containing ingredients. Considering the fact that gluten is the main protein in the formation of dough viscoelastic network, which is necessary to create the high quality bread, the aim of this review article is studying different factors with ability to improve quality of gluten-free bread produced for consumption of the vulnerable persons.

Introduction

Celiac disease is a chronic disease with the inability to tolerate some cereal prolamin, containing sequence specific oligopeptide (Arentz-Hansen et al., 2004; Ludvigsson et al., 2013; Sturgess et al., 1994). It is induced by consumption of gluten proteins from commonly prevailing food sources like wheat, rye, barley, and probably oats (Dicke et al., 1953; Hardy et al., 2015; Londono et al., 2013). The intake of gluten provokes an inflammatory process which damages the villous structure of the small intestine (Shan et al., 2002). Currently about 1% of the world's population are encountered with the celiac disease and the only useful way to its treatment is the strict constant abandonment of gluten containing foods (Feighery, 1999; Ronda and Roos, 2011).

Gluten network is a key structure to keep gas and acquire the pleasing volume and texture in a bread dough system (Abbasi et al., 2012). It is important not only for bread appearance, but also for its structure formation in dough systems (Gallagher et al., 2004). Glutenin and gliadin are two main fractions of gluten (Abbasi et al., 2012). Whereas glutenin is necessary to make an elastic and consistent structure in dough, gliadin is responsible for viscosity and extensibility of a dough system (Abbasi et al., 2015; Gujral and Rosell, 2004).

Considering that cereal products, particularly breads, are the main components of the diet in different countries, there are increasing demands for gluten-free breads. In view of the fact that gluten-free breads have poor quality compared to complete one, in this review article the

*Corresponding author
E-mail: mohamdif@ut.ac.ir

ingredients used to improve the quality of gluten-free bread are discussed.

Gluten-free bread

Gluten-free breads are technologically poor with low specific volume (SV); crumb softness and higher staling rate compared to complete breads owing to the lack of gluten structure (Arendt et al., 2007; Gallagher et al., 2003). Various non-gluten components have been incorporated in gluten-free breads to supply their structure. They are also involved in mimicking gluten network and improve their nutritional quality (Mariotti et al., 2009) which is discussed in the next.

Non-gluten components used to improve the quality of gluten-free bread

Starch and gums/hydrocolloid

Gums and thickening agents are mainly used in gluten-free breads for different reasons, including gelling, thickening, and texture expansion (Balaghi et al., 2011). They are in the form of polysaccharides and/or protein which are originating from different sources of seeds, fruits, plant extracts, seaweeds and microorganisms (Mollakhalili Meybodi et al., 2014). Starches and hydrocolloids are two main groups which are extensively used in bakery products formulation to improve their texture and appearance properties (Anton and Artfield, 2008; Demirkesen et al., 2010; Kohajdová et al., 2009). Different studies have investigated the possibility of a wide range of starches with gums/hydrocolloids to make high quality gluten-free breads (Kohajdová et al., 2009; Lamacchia et al., 2014; Linlaud et al., 2009).

Comparison wheat starch with non-wheat starches, for gluten-free bread making, showed that the latter is more pleasing since some celiac patients cannot endure even wheat starch (Chartrand et al., 1997; Ribotta et al., 2004). Rice starches are usually accessible and potentially applicable as replacement in the formulation of gluten-free baked goods (Hoover et al., 1996). However, lack of gluten in rice creates problems in bread making. It has been noted that some gums including hydroxyl propyl methyl cellulose (HPMC), locust bean gum (LBG), guar gum, xanthan gum and agar can be used to form rice bread and HPMC create the optimum volume development (Demirkesen et al., 2010; Hager and Arendt, 2013). Previous studies revealed that the substitution of rice flour instead of wheat flour in amount as high as 30% makes the most acceptable gluten-free bread quality.

Effect of binding factors (xanthan, guar gum, LBG and tragacanth) as a replacement agent of gluten in gluten-free bread formulations containing corn starch have been also studied (Acs et al., 1996). Results indicated that binding agents are significantly able to increase loaf volume and decrease the crumb structure. Investigation of gluten-free breads showed that the replacement of 10% and 20% soy flour increased the batter consistency 2 and 4 times, respectively compared to batters completely made of rice flour. However, it has recently been anticipated that lower consistency pleasurably increases the batter development (Nunes et al., 2009a). Different gluten-free formulations including hydrocolloids have been studied to imitate the viscoelastic properties of gluten.

Dietary fiber

Diets which have average amounts of cereal grains, fruits and vegetables are likely to supply enough fiber (Buttriss and Stokes, 2008). Considering the fact that gluten-free breads are usually not fortified, and prepared from refined flour or starch, they will not have the same amounts of nutrients as the gluten containing ones. So, doubt still exists about the nutritionally balanced diet of celiac patients received a gluten-free diet. In a study investigated the intake of nutrients by 49 adults with celiac disease receiving a gluten-free diet, the results indicated that their fiber intake was lower compared to a control group with a normal diet (Grehn et al., 2001). The fortification of gluten-free baked goods with dietary fibers has consequently been investigated by different teams of technologists. Inulin, as a non-digestible polysaccharide and prebiotic component, is able to develop loaf volume and slice ability, to increase dough stability and to produce an even and finely grained crumb texture (Korus et al., 2006). In a similar work carried out by Gallagher et al. (2004) to encompass inulin (at 8% level) into a wheat gluten-free formulation, it was revealed that the dietary fiber amount of the bread increased from 1.4 (gluten-free bread) to 7.5% (inulin containing gluten-free bread). Results also designated the higher browning color of inulin containing sample which can be attributed to its hydrolyzing by yeast enzyme, resulting in the creation of fructose that is more prone to crust browning (Gallagher et al., 2004). The fortification of gluten-free products with dietary fibers has been verified to be required, regarding the lower intake of fibers ascribed to their gluten-free diet (Korus et al., 2006).

Whey protein

The first studies to find an appropriate alternative for gluten in gluten-free baked goods come back to 1960. In gluten-free products, batter is used instead of dough (Gallagher et al., 2004; Torbica et al., 2010). Therefore, the gas produced during the bread formation is not stable due to the lack of viscoelastic structure of gluten network. Special characteristic of wheat flour in bread making is mainly derived from its ability to create a mesoscopic structure (Fessas et al., 2008). This structure retards the water movement in bread structure and creates a softer crumb. In the absence of gluten, water diffusion is facilitated in a way to create a harder crumb with softer crust (Lazaridou et al., 2007).

Whey proteins are also able to create mesoscopic structure in batter and cause appropriate characteristic like strain hardening which is necessary to have a dough-like mixture, too (van Riemsdijk et al., 2011c; van Riemsdijk et al., 2011b). Previous studies revealed that the addition of 6% whey protein powder in gluten-free bread is able to enhance its protein content two times but have no effect on its dietary fiber amounts (Gallagher et al., 2003).

Whey protein is a functioning agent which is added to bread to enhance its water absorption, and nutritional value (Kenny et al., 2000). Gluten-free breads supplemented by whey protein have a preferred brown color compared to gluten-free bread which this matter is mainly due to higher maillard browning reaction and caramelization (Nunes et al., 2009b). Whey protein replacement also improves the gluten-free breads tissue characteristic like its kneading properties, size and volume of loaf. In other word, it is a suitable substitute of gluten to improve gluten-free breads appearance and retard its rate of staling. The mixing tolerance of dough supplemented by whey is not as much as those containing gluten; while the mixing tolerance of complete wheat dough is about 96%, it is about 83% in the case of whey protein is used instead of gluten (Indrani et al., 2007). The rheological properties like spread ability and viscoelasticity (of structure formed in dough) are weakened in the case of using whey protein. The structure formed by whey protein is more rigid compared to gluten containing one which can be attributed to the number of disulfide bands, higher in whey protein supplemented dough.

According another research conducted to investigate the effect of N-ethyl maleimide (NEM) as thiol blocking agent in whey protein added dough, it was revealed that the blocking treatment will enhance the bread loaf volume almost eight times and improve its rheological properties. The increase observed in bread loaf volume could be attributed to its higher swelling rate and weaker protein networks. So, the higher swelling rate is not the only reason for whey proteins higher ability to improve gluten-free bread quality, in the presence of NEM (van Riemsdijk and van der Goot, 2011; van Riemsdijk et al., 2011a). Finally, the addition of NEM to whey protein makes it a suitable replacement of gluten. Considering that NEM is not food grade, using other blocking agent like ovalbumin or heating treatment is suggested. It is worthy to consider that gluten-free bread enrichment by dairy powders containing lactose is not suitable for celiac patient, since their intolerance induced a villous atrophy. So, they are exposed to lack of lactase enzyme and finally lactose intolerance.

Sourdough

Considering the fact that gluten-free breads are highly poor in vitamins, iron, folate as well as dietary fiber (Hallert et al., 2002), and the growing demand for producing high quality, natural and affordable gluten-free breads, the addition of sourdough is suggested to be a good solution (Di Cagno et al., 2008; Moore et al., 2008; Moroni et al., 2009). Sourdough is a combination of flour, water, and/or other components which is fermented by naturally occurring starter culture containing lactic acid bacteria (LAB) and yeasts (Gobbetti, 1998). The sourdough supplementation creates different positive effects on appearance, texture, nutritional quality, and shelf life of gluten-free breads which is mainly resulted from the metabolic activity of LAB. Acidification, exopolysaccharide production, proteolytic, lipolytic and phytase enzyme activity are some examples of these organisms performance (Ravyts et al., 2012) which are discussed in the next.

Gluten network is responsible for slowing down the water transfer and maintaining of gas produced during yeast fermentation and oven-rise (Demirkesen et al., 2010). Using sourdough fermentation postpones the starch retrogradation and staling of gluten-free bread (Rojas et al., 1999). Biological acidification, amylolytic and proteolytic activities of sourdough starter culture are the main mechanisms involved in retardation of retro-gradation. It is notable that some LAB have no amylolytic activity. So, in order to create an appropriate condition to produce gluten-free bread with longer shelf life, using of sprouted grains is suggested (Tabassum and Rajoka, 2000). Sourdough containing yeast and LAB is also able to produce phytase to reduce phytic acid and boost the mineral bioavailability and thus lead to improvement of the nutritional value (Poutanen et al., 2009).

Sourdough starter culture addition to gluten-free bread is also able to enhance the immune system of celiac patients by producing prolin/glycin-rich peptide via proteolytic activity (Rollan et al., 2005). It is also proved that the addition of sourdough to gluten-free bread make it prone to be a functional food. This function is mainly due to the ability of LAB to produce exopolysaccharide especially fructooligosaccharide (Schwab et al., 2008). It is worthy to note that the ability of LAB to produce exopolysaccharide is type and species dependant. It is known that sourdough is the foremost fermentation used for baking purposes and it has been proven to be ideal for improving the texture, palatability, aroma and shelf life of different types of bread. Also, regarding the fact that lactic acid and acetic acid are two main flavoring agents in final aroma of bread, it is possible to achieve the same flavor in gluten-free bread by adding LAB.

Conclusion

Celiac disease is a common intestinal disorder with only treatment the constant adherence to a gluten-free diet. However, gluten is a major component of wheat and rye flours, and its replacement in bakery products remains a significant technological challenge. Using starches, gums, and hydrocolloids are the most prevalent method to imitate gluten structure in the manufacture of gluten-free bakery products. Novel attitudes as well as applying the dietary fibers, other protein sources and additives which enhance the gluten-free breads nutritional value are also promising. However, regarding the current increasing awareness of celiac disease due to superior diagnostic methods, more comprehensive researches in the field of gluten-free cereal-based products are necessary.

Conflicts of interest

None declared.

Acknowledgements

We would like to acknowledge our colleagues in Department of Food Science and Technology, National Nutrition and Food Technology Research Institute, Tehran, Iran for their scientific help.

References

Abbasi H., Ardabili S., Seyedain M., Emam-Djomeh Z., Mohammadifar M.A., Zekri M., Aghagholizadeh R. (2012). Prediction of extensograph properties of wheat-flour dough: artificial neural networks and a genetic algorithm approach. *Journal of Texture Studies*. 43: 326-337.

Abbasi H., Seyedain Ardabili S.M., Mohammadifar M.A., Emam-Djomeh Z. (2015). Comparison of trial and error and genetic algorithm in neural network development for estimating farinograph properties of wheat-flour dough. *Nutrition and Food Sciences Research*. 2: 29-38.

Acs E., Kovacs Z., Matuz J. (1996). Bread from corn starch for dietetic purposes. I. Structure formation. *Cereal Research Communications*. 36: 441-449.

Anton A.A., Artfield S.D. (2008). Hydrocolloids in gluten free breads: a review. *International Journal of Food Sciences and Nutrition*. 59: 11-23.

Arendt E.K., Ryan L.A., Dal Bello F. (2007). Impact of sourdough on the texture of bread. *Food Microbiology*. 24: 165-174.

Arentz-Hansen H., Fleckenstein B., Molberg O., Scott H., Koning F., Jung G., Roepstorff P., Lundin K.E., Sollid L.M. (2004). The molecular basis for oat intolerance in patients with celiac disease. *PLoS Medicine*. 1: 84-92.

Balaghi S., Mohammadifar M.A., Zargaraan A., Gavlighi H.A., Mohammadi M. (2011). Compositional analysis and rheological characterization of gum tragacanth exudates from six species of Iranian *Astragalus*. *Food Hydrocolloids*. 25: 1775-1784.

Buttriss J., Stokes C. (2008). Dietary fibre and health: an overview. *Nutrition Bulletin*. 33: 186-200.

Chartrand L.J., Russo P.A., Duhaime A.G., Seidman E.G. (1997). Wheat starch intolerance in patients with celiac disease. *Journal of the American Dietetic Association*. 97: 612-618.

Demirkesen I., Mert B., Sumnu G., Sahin S. (2010). Rheological properties of gluten free bread formulations. *Journal of Food Engineering*. 96: 295-303.

Di Cagno R., Rizzello C.G., De Angelis M., Cassone A., Giuliani G., Benedusi A., Limitone A., Surico R.F., Gobbetti M. (2008). Use of selected sourdough strains of *Lactobacillus* for removing gluten and enhancing the nutritional properties of gluten free bread. *Journal of Food Protection*. 71: 1491-1495.

Dicke W.K., Weijers H.A., Kamer J.H.v.D. (1953). Coeliac disease the presence in wheat of a factor having a deleterious effect in cases of coeliac disease. *Acta Paediatrica*. 42: 34-42.

Feighery C. (1999). Fortnightly review: coeliac disease. *British Medical Journal*. 319: 236-239.

Fessas D., Signorelli M., Pagani A., Mariotti M., Iametti S., Schiraldi A. (2008). Guidelines for buckwheat enriched bread: thermal analysis approach. *Journal of Thermal Analysis and Calorimetry*. 91: 9-16.

Gallagher E., Gormley T., Arendt E. (2003). Crust and crumb characteristics of gluten free breads. *Journal of Food Engineering*. 56: 153-161.

Gallagher E., Gormley T., Arendt E. (2004). Recent advances in the formulation of gluten free cereal-based products. *Trends in Food Science and Technology*. 15: 143-152.

Gobbetti M. (1998). The sourdough microflora: interactions of lactic acid bacteria and yeasts. *Trends in Food Science and Technology*. 9: 267-274.

Grehn S., Fridell K., Lilliecreutz M., Hallert C. (2001). Dietary habits of Swedish adult coeliac patients treated by a gluten free diet for 10 years. *Scandinavian Journal of Nutrition/Naringsforskning*. 45: 178-182.

Gujral H.S., Rosell C.M. (2004). Functionality of rice flour modified with a microbial transglutaminase. *Journal of Cereal Science*. 39: 225-230.

Hager A.S., Arendt E.K. (2013). Influence of hydroxylpropylmethylcellulose (HPMC), xanthan gum and their combination on loaf specific volume, crumb hardness and crumb grain characteristics of gluten free breads based on rice, maize, teff and buckwheat. *Food Hydrocolloids*. 32: 195-203.

Hallert C., Grant C., Grehn S., Grännö C., Hulten S., Midhagen G., Ström M., Svensson H., Valdimarsson T. (2002). Evidence of poor vitamin status in coeliac patients on a gluten-free diet for 10 years. *Alimentary Pharmacology and Therapeutics*. 16: 1333-1339.

Hardy M.Y., Tye-Din J.A., Stewart J.A., Schmitz F., Dudek N.L., Hanchapola I., Purcell A.W., Anderson R.P. (2015). Ingestion of oats and barley in patients with celiac disease mobilizes cross-reactive T cells activated by avenin peptides and immuno-dominant hordein peptides. *Journal of Autoimmunity*. 56: 56-65.

Hoover R., Sailaja Y., Sosulski F. (1996). Characterization of starches from wild and long grain brown rice. *Food Research International*. 29: 99-107.

Indrani D., Prabhasankar P., Rajiv J., Rao G.V. (2007). Influence of whey protein concentrate on the rheological characteristics of dough, microstructure and quality of unleavened flat bread (parotta). *Food Research International*. 40: 1254-1260.

Kenny S., Wehrle K., Stanton C., Arendt E.K. (2000). Incorporation of dairy ingredients into wheat bread: effects on dough rheology and bread quality. *European Food Research and Technology*. 210: 391-396.

Kohajdová Z., Karovičová J., Schmidt Š. (2009). Significance of emulsifiers and hydrocolloids in bakery industry. *Acta Chimica Slovaca*. 2: 46-61.

Korus J., Grzelak K., Achremowicz K., Sabat R. (2006). Influence of prebiotic additions on the quality of gluten free bread and on the content of inulin and fructooligosaccharides. *Food Science and Technology International*. 12: 489-495.

Lamacchia C., Camarca A., Picascia S., Di Luccia A., Gianfrani C. (2014). Cereal-based gluten free food: how to reconcile nutritional and technological properties of wheat proteins with safety for celiac disease patients. *Nutrients*. 6: 575-590.

Lazaridou A., Duta D., Papageorgiou M., Belc N., Biliaderis C. (2007). Effects of hydrocolloids on dough rheology and bread quality parameters in gluten free formulations. *Journal of Food Engineering*. 79: 1033-1047.

Linlaud N., Puppo M., Ferrero C. (2009). Effect of hydrocolloids on water absorption of wheat flour and farinograph and textural characteristics of dough. *Cereal Chemistry*. 86: 376-382.

Londono D., Van't Westende W., Goryunova S., Salentijn E., Van Den Broeck H., Van Der Meer I., Visser R., Gilissen L., Smulders M. (2013). Avenin diversity analysis of the genus *Avena* (oat). Relevance for people with celiac disease. *Journal of Cereal Science*. 58: 170-177.

Ludvigsson J.F., Leffler D.A., Bai J.C., Biagi F., Fasano A., Green P.H., Hadjivassiliou M., Kaukinen K., Kelly C.P., Leonard J.N. (2013). The Oslo definitions for coeliac disease and related terms. *Gut*. 62: 43-52.

Mariotti M., Lucisano M., Pagani M.A., Ng P.K. (2009). The role of corn starch, amaranth flour, pea isolate, and *Psyllium* flour on the rheological properties and the ultrastructure of gluten free doughs. *Food Research International*. 42: 963-975.

Mollakhalili Meybodi N., Mohammadifar M.A., Abdolmaleki KH. (2014). Effect of dispersed phase volume fraction on physical stability of oil-in-water emulsion in the presence of gum tragacanth. *Journal of Food Quality and Hazards Control*. 1: 102-107.

Moore M., Dal Bello F., Arendt E. (2008). Sourdough fermented by *Lactobacillus plantarum* FST 1.7 improves the quality and shelf life of gluten free bread. *European Food Research and Technology*. 226: 1309-1316.

Moroni A.V., Dal Bello F., Arendt E.K. (2009). Sourdough in gluten free bread-making: an ancient technology to solve a novel issue? *Food Microbiology*. 26: 676-684.

Nunes M.H.B., Moore M.M., Ryan L.A., Arendt E.K. (2009a). Impact of emulsifiers on the quality and rheological properties of gluten free breads and batters. *European Food Research and Technology*. 228: 633-642.

Nunes M.H.B., Ryan L., Arendt E.K. (2009b). Effect of low lactose dairy powder addition on the properties of gluten free batters and bread quality. *European Food Research and Technology*. 229: 31-41.

Poutanen K., Flander L., Katina K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology*. 26: 693-699.

Ravyts F., Vuyst L.D., Leroy F. (2012). Bacterial diversity and functionalities in food fermentations. *Engineering in Life Sciences*. 12: 356-367.

Ribotta P.D., Ausar S.F., Morcillo M.H., Perez G.T., Beltramo D.M., León A.E. (2004). Production of gluten-free bread using soybean flour. *Journal of the Science of Food and Agriculture*. 84: 1969-1974.

van Riemsdijk L., van der Goot A. (2011). Colloidal Protein particles can be used to develop a gluten free bread. *Cereal Foods World*. 56: 201-203.

van Riemsdijk L.E., van der Goot A.J., Hamer R.J. (2011a). The use of whey protein particles in gluten free bread production, the effect of particle stability. *Food Hydrocolloids*. 25: 1744-1750.

van Riemsdijk L.E., van der Goot A.J., Hamer R.J., Boom R.M. (2011b). Preparation of gluten free bread using a meso-structured whey protein particle system. *Journal of Cereal Science*. 53: 355-361.

van Riemsdijk L.E., Pelgrom P.J., van der Goot A.J., Boom R.M., Hamer R.J. (2011c). A novel method to prepare gluten free dough using a meso-structured whey protein particle system. *Journal of Cereal Science*. 53: 133-138.

Rojas J., Rosell C., De Barber C.B. (1999). Pasting properties of different wheat flour-hydrocolloid systems. *Food Hydrocolloids*. 13: 27-33.

Rollan G., De Angelis M., Gobbetti M., De Valdez G.F. (2005). Proteolytic activity and reduction of gliadin-like fractions by sourdough lactobacilli. *Journal of Applied Microbiology*. 99: 1495-1502.

Ronda F., Roos Y.H. (2011). Staling of fresh and frozen gluten free bread. *Journal of Cereal Science*. 53: 340-346.

Schwab C., Mastrangelo M., Corsetti A., Gänzle M. (2008). Formation of oligosaccharides and polysaccharides by *Lactobacillus reuteri* LTH5448 and *Weissella cibaria* 10M in sorghum sourdoughs. *Cereal Chemistry*. 85: 679-684.

Shan L., Molberg Ø., Parrot I., Hausch F., Filiz F., Gray G.M., Sollid L.M., Khosla C. (2002). Structural basis for gluten intolerance in celiac sprue. *Science*. 297: 2275-2279.

Sturgess R., Day P., Ellis H., Kontakou M., Ciclitira P., Lundin K., Gjertsen H. (1994). Wheat peptide challenge in coeliac disease. *The Lancet*. 343: 758-761.

Tabassum R., Rajoka M.I. (2000). Methanogenesis of carbohydrates and their fermentation products by syntrophic methane producing bacteria isolated from freshwater sediments. *Bioresource Technology*. 72: 199-205.

Torbica A., Hadnađev M., Dapčević T. (2010). Rheological, textural and sensory properties of gluten free bread formulations based on rice and buckwheat flour. *Food Hydrocolloids*. 24: 626-632.