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Review

Gluten-free baking: Combating the challenges - A review

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ABSTRACT

Background: Gluten-free products are finding an increased demand since the incidence of celiac disease or other gluten-associated allergies. The replacement of gluten becomes a necessity to avoid the occurrence of any such disorder. Eliminating gluten however appears in the face of a technological challenge as it aims to minimize the prevalence of any disease causing condition on the one hand, and gives rise to products with compromised quality on the other hand. Attempts are thus made to adopt methods that could produce cereal based gluten-free products with technological properties comparable to their gluten containing counterparts and minimum compromises with quality.
Scope and approach: This paper reviews the approaches adopted to combat the commonly encountered problems associated with the elimination of gluten. Composition directed approaches and technologies involved are discussed, and a brief mention of the defects with gluten-free products is also included.
Key findings and conclusions: It is possible to reduce technological inadequacies in gluten-free bread and related products by the incorporation of functional ingredients in the formulations and adopting technologies like high pressure, improving aeration, sourdough fermentation, and extrusion. Defects commonly encountered are considerably reduced furnishing an improved product for gluten-free consumers. More research is however required in extending the use of high pressure, ultrasound aeration, hydrothermal treatments and the applicability of different mixing systems in the production of gluten-free products.

1. Introduction

Celiac disorder characterized by the life-long intolerance to gluten is increasingly being recognized as an autoimmune enteropathy (Newinski, 2008). It is a disorder of the gastrointestinal tract in which the ingestion of gluten leads to damage of the small intestinal mucosa by an immune mediated mechanism, in individuals that have genetic susceptibility towards gluten (Tye-Din & Anderson, 2008). In response to the ingestion of gluten, such patients show self perpetuating inflammation of the mucosa characterized by the loss of absorptive villi and hyperplasia of the crypts (Curiel et al., 2014).

The symptoms of gluten sensitivity disappear after gluten is withdrawn from the diet (Di Sabatino & Corazza, 2012). Removal of the immunological trigger forms thus, the basis for treatment of all diagnosed manifestations. In this connection, enzyme breakdown targeting the uptake of toxic gluten peptides and sequestering gluten has been developed at the clinical level. Thermal and enzyme treatments to produce low gluten wheat flours have been proposed for meeting the needs of gluten susceptible individuals (Rizello et al., 2014; Sapone et al., 2012). Use of microbial transglutaminase (mTGase) reduces gluten concentrations in flour (Mazzeo et al., 2013). Sourdough lactobacilli have also been incorporated for the hydrolysis of wheat flour proteins during fermentation. Sourdough lactobacilli along with fungal proteases have reduced the gluten concentration to less than 20 ppm (Rizello et al., 2007).

In the prevailing scenario, the treatment available for celiac disease is a strictly gluten free diet for life. Under administration of a gluten free diet, taxonomically similar species such as rye and barley are also avoided. The International Food Authority demands complete absence of gluten for qualifying to be gluten free, whereas Codex Alimentarius allows a limit of 200 ppm of gluten per food. However, addressing the need to produce a completely gluten free diet makes way for other challenges. Gluten is the abundant structural protein complex found in wheat, exhibiting functional properties that confer a unique status to it in the wheat flour and

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the products made from it (Sapone et al., 2012). Gluten containing products also form a staple diet for a large proportion of the world population. Hence, the development of gluten free products for celiac patients is not only a pressing need but also a demanding job for food scientists. It is unrealistic to achieve a complete elimination of gluten owing to cross-contamination, the ubiquitous nature of the protein itself and social constraints. The dietary compliance also being poor necessitates the adoption of alternate methodologies to treat celiac disorders (Mazzeo et al., 2013).

Gluten free breads are characterized by a heterogeneous recipe, being a combination of rice and corn (Brites, Trigo, Santos, Collar, & Rosell, 2010), starch and flour, as well as proteins, fibers, fats, hydrocolloids, and specific enzymes. Commercially available gluten free breads are incompetent with their gluten containing counterparts in terms of quality and acceptability. Gluten free breads show poor crumb and crust characteristics as well as poor mouth feel and flavor. Since gluten free breads mainly contain starch, they lack other nutrients and undergo fast staling (Moroni, Dal Bello, & Arendt, 2009). Commonly encountered defects with gluten-free bread arise due to inefficient gas expansion and retention during leavening, resulting in reduced volume bread with low crumb softness (Mariotti, Lucisano, Pagani, & Ng, 2009). Such products also do not exhibit the rheological, textural properties and baking quality that are unique to gluten based products (Mazzeo et al., 2013).

Cereal technologists worldwide have tried to overcome the issues emanating with exclusion of gluten from breads and other products, and at the same time cater to the expectations of the celiac patients. To improve the gluten-free bread quality, incorporation of additives and nutritive ingredients is done. The nutritional value of these breads has been increased by adding whole grains such as amaranth, buck-wheat, millet, quinoa, brown rice, sorghum and teff (Alvarez-Jubete, Arendt, & Gallagher, 2009; Moroni et al., 2009). The viscoelastic properties of gluten free breads have been improved by the addition of hydrocolloids (Kittisuban, Ritthiruangdej, & Suphantharika, 2014; Ronda, Perez-Quirce, Lazaridou, & Biliaderis, 2015). Milk proteins result in gluten like matrix in the gluten free bread, resulting in the improvement in crumb texture and delayed staling (Moroni et al., 2009). Use of microbial proteases such as that from *Aspergillus oryzae* (Hamada, Suzuki, Aoki, & Suzuki, 2013) and *Bacillus stearothermophilus* (Kawamura-Konishi, Shoda, Koga, & Honda, 2013) in gluten free rice bread improved their quality. Transglutaminase improves the bread making potential of gluten free flours which in turn promotes network formation (Mohammadi, Azizi, Neyestani, Hosseini, & Mortazavian, 2015; Pongjaruvat, Methacanon, Seetapan, Fuongfuchat, & Gamonpilas, 2014; Renzetti, Dal Bello, & Arendt, 2008). Other than altering formulations, processing methods like high pressure, extrusion, sourdough fermentation, etc. acting directly on the base material of the product also bring promising results. Various methodologies have thus been adopted to meet the challenge of producing gluten free products, while minimizing the issues arising consequently. This review highlights the approaches, recipe based and technological, adopted for producing gluten free products comparable to those containing gluten.

2. Defects associated with gluten-free products

The elimination of gluten is translated into the defects that appear in the product in terms of quality attributes, nutritional characteristics, and consumer acceptance. In the production of gluten-free bread deficient gas retention and the resulting low loaf volume are the major challenges encountered. The lack of gluten also leads to a liquid batter instead of dough, which in turn results in baked bread with a crumbling texture, poor color and post-baking quality defects (Hager et al., 2012; Matos & Rosell, 2012; Onyango, Mutungi, Unbehend, & Lindhauer, 2009). Commercially available gluten free products such as those based on rice have lower protein content and are deficient in lysine. The carbohydrate and fat content of the gluten-free bread is high while as the protein content is low. The protein content in gluten-free breads analyzed ranged from 0.90 to 15.5 g/100 g, fat ranged from 2.00 to 26.1 g/100 g, and carbohydrate 68.4–92.9 g/100 g, contributing little to the recommended protein intake therefore. *In vitro* hydrolysis of starch of the gluten-free breads showed rapidly digested starch to be the major starch fraction followed by solely digested starch and resistant starch, pointing towards high starch digestibility. The most predominant starch fraction ranged from 75.6 to 92.5 g/100 g and the glycaemic index ranged from 83 to 96 (Matos & Rosell, 2011). So far, only one study reports the comparative nutritional composition of 206 gluten-free and 289 gluten-containing products (Table 1). Gluten-free products provided twice as much fat, mainly saturated, compared to gluten-containing equivalents. Breads were poor contributors of protein and bakery contained less energy due to lower carbohydrate and protein content (Miranda, Lasa, Bustamante, Churruca, & Simon, 2014; Pellegrini & Agostoni, 2015). Glycaemic index of different rice breads was also reported to be high ranging from 87 to 93. However, less hydrated flours produced breads with lower glycaemic index, due to limited gelatinization of starch granules and lower susceptibility to enzymatic hydrolysis (de la Hera, Rosell, & Gomez, 2014). Gluten-free breads prepared with single flours (buckwheat, oat, quinoa, sorghum, or teff) were evaluated for *in vitro* starch digestibility and their predicted glycaemic index and glycaemic load (pGI and pGL) was calculated. Highest pGI was exhibited by quinoa bread (91), followed by buckwheat (80), teff (74), sorghum (74), and oat (71). Sorghum bread presented the highest pGL followed by quinoa (9), oat (9), and teff (8). The breads were classified as high GI and low GL (Wolter, Hager, Zannini, & Arendt, 2013).

The elimination of gluten further translates into a poor supply of fibers, minerals, vitamins, and calories in the diet and poor sensory properties. Levels of some B vitamins, iron, and folate are reduced in gluten free products (Moroni et al., 2009; Yazynina, Johansson, Jägerstad, & Jastrebova, 2008). A study reported the assessment of the nutritional composition of a range of gluten-free products. The folate, iron, and dietary fiber contents of gluten-free cereal products were assessed and compared with gluten-containing counterparts. The findings indicated lower amounts of folate and iron in gluten-free breads, pastas and cold cereals (Thompson, 2000). Lower mineral content was observed in different types of gluten-free products and their bioavailability ranged from 10 to 70% (Suliburska, Krejpcio, Reguła, & Grochowicz, 2013).

The gluten-free bread based on rice, millet, corn and buckwheat, as well as those from which natural gluten is removed does not match the gluten containing bread in terms of the unique taste and aroma contributed by distinct volatile compounds. In the production of gluten-free bread, it has remained a challenge to replicate the aroma, texture and taste similar to those of bread made with gluten-containing components, since these are devoid of the inherent texture forming events and aroma compounds produced in gluten-based products (Pacynski, Wojtasiak, & Szkudlarz, 2015). However, research directed with this aim is increasingly involving alternative formulations and methods like high-pressure and sourdough fermentation, to strike the best possible replication as discussed in the subsequent sections.

3. Meeting challenges: gluten-free product improvement

Since the gluten-free products do not match gluten containing counterparts in terms of technological attributes and quality, it is a