Chapter 8
Novel Approaches in Gluten-Free Bread Making: Case Study

E. J. Rifna, Madhuresh Dwivedi, and Rewa Kulshrestha

Abstract Celiac disease is the most commonly reported human chronic gastrointestinal disease. The unique effectual therapy for victims with celiac disease is to pursue a diet free of gluten strictly. Currently, the rising occurrence of celiac diseases encourages global attentiveness for diverse favored gluten-free products. Therefore, the increasing requirement for high-quality gluten-free bread from natural compounds is increasing the want for novel approaches in gluten-free bread-making. Nevertheless, baking devoid of gluten, the chief component for bread texture, quality, and structure, is a great confront for every confectioner and cereal researchers. Various methods have been used to comprehend and develop a gluten-free bread system by monitoring various starch properties, flour sources, additives, and the use of technology or synergistic effect of these elements. Few works intended to evaluate or progress gluten-free bread technical or dietary attributes, whereas others aimed at manifold objectives. Some studies applied food science elements to develop the sensory property of gluten-free bread, mutually with nutritional aspects. Henceforth, the important focus of this book chapter is to confer the new approaches for gluten-free bread improvements in the past few years, including sourdough, the role of hydrocolloids, innovative techniques, and nutritional enhancement.

Keywords Celiac disease · Bread · Nutritional quality · Hydrocolloids · Prebiotics

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8.1 Introduction

Celiac disease is a dreadful autoimmune disease spotted by enduring intolerance to compounds says gliadin, hordein, secalin, and avidins in wheat, barley, rye, and oats respectively, owing to genetic characteristics (Mohammadi et al., 2014). Celiac disease leads to immunologically related inflammatory damage of the mucosa layer in the small intestine that results in malabsorption of essential food ingredients and gastrointestinal problems (Kagnoff, 2005). Presently, works have revealed that celiac disease attacks mostly half percent of the global populace. The sole present remedy is a lifetime complete elimination of gluten and other associated prolamines from a daily diet. In before years, European Union formulated a guideline explaining that gluten-free foods that are composed of naturally gluten-free compounds should only hold gluten in an amount less than 20 ppm (Demirkesen et al., 2010; Deora et al., 2014). Gluten is the chief structure forming compound in wheat bread that gives out the dough its distinctive rheological properties and baking quality.

Contrast to bread dough with gluten compound, in gluten-free bread dough the stereoscopic structured protein-starch complex is absent, and they are majorly prepared from refined flour or unadulterated starches (e.g. corn starch, rice flour). To permit the starch-rich compounds to completely gelatinize through baking and to enhance the viscosity and thus improve the gas-holding property, significantly greater water contents are essential in gluten-free formulations. This considerably alters the dough consistency towards a batter which negatively modifies the production parameters and the final bread quality. Henceforth owing to its inimitable functionality, the substitution of gluten stands to be challenging. Furthermore, the distinctive attributes of wheat gluten make it cumbersome to discover raw ingredients, or additives, which could completely substitute it and currently, many gluten products accessible in the market have reduced dietary properties, penurious taste, and poor quality (Mustalahti et al., 2010; Tripathi et al., 2017). Various approaches have been used to assist in processing and improve gluten-free bread attributes. The majority of been these was based on applying multifaceted formulations comprising of a grouping of various additives and ingredients, so as to imitate the gluten structure. Regardless through various works, no single baking additive was significantly found capable to replicate the gluten network to its full potential yet (Niewinski, 2008; Mishra et al., 2020).

During the last few years, the addition of new substitutive ingredients involving starches, fibers, proteins, emulsifiers, enzymes, and gluten-free flours (López-Tenorio et al., 2015; Tsatsaragkou et al., 2014; Wronkowska et al., 2013; Ziobro et al., 2016), was found promising in improving dough rheological characteristics, aiding processing parameters and improving the nutritional profile. More lately, novel approaches say sourdough fermentation, physical treatments, prebiotic gluten-free bread, and partial baking technology (Basso et al., 2015; Stefańska et al., 2016; Jerome et al., 2019) have been demonstrated to be a favorable alternative substitute to develop gluten-free bread of significant quality. This chapter focuses on the novel approaches that have been undertaken towards the development of high-quality gluten-free bread.

8.2 Sourdough in Gluten-Free Bread Baking

Sourdough is a blend of flour and water agitated with yeast and lactic acid bacteria (LAB), that decide its properties with respect to aroma and production of acids. The application of sourdough has an extended tradition in the baking of rye and wheat bread (Gänzle et al., 2008). In particular, fermentation developed by lactic acid bacteria is a precondition for rye bread preparation, as it enhances the dissolution of rye pentosans, which decide the rye bread texture, structure, and this also ceases the activity of amylase (Alvarez-Jubete et al., 2009). When added in measured proportions, sourdough improves texture, volume, and health aspects by enhancing the shelf life of bread by protecting it from mold spoilage. These affirmative effects are related to the metabolic behavior of sourdough-resident microbes, like exopolysaccharides (EPS) production and release of antimicrobial compounds (De Vuyst & Vancanneyt, 2007).

The use of sourdough is an old method that has been applied for a long time and is achieving attention over again. Few judges it therefore to be a “novel” methodology (Moroni et al., 2009). In recent days consumers who insist on clean labels have rerouted the center of study in identifying alternative tools that permit the development of elevated quality of gluten-free bread without the use of additives. Decreasing food additives quantity could decrease extreme ingredient price and eliminate the occurrence of few allergens in the final baked product. Current investigations revealed that when applied in the correct ratio, sourdough can be used to tackle the majority of the issues related to the baking of low-quality gluten-free bread, whilst being and echo friendly and cost effectual (Cappa et al., 2016). The positive property is related to the occurrence of few by-products produced from LAB, say antimicrobial molecules, EPS, volatiles, and lactic acid which are formed at the process of fermentation. Dough acidification could also trigger few endogenous flour chemical molecules such as enzymes which can later makes bread crumb softer. The ratio among acids is necessary, as it determines the texture and structure of bread (Arendt et al., 2007). The acetic acid and lactic acid also increase the shelf life of bread, as it prolongs staling by disturbing retrogradation of starch.

With respect to the microbial constituents, works emphasized the significance of choosing suitable starter strains for the preparation of gluten-free sourdoughs, as every microorganism cannot adjust evenly to the identical raw compound. Microbial growth can also get affected by the accessibility of carbohydrates, lipids, nitrogen content, and percentage of free fatty acids, in addition to the buffer capacity and enzymatic activity in the substrate (Moroni et al., 2010). Nevertheless, the property and superiority of the raw ingredient are not the sole properties that assess the sourdough microbiota. Parameters such as dough yield, fermentation temperature, time and autochthonous culture also influence the end constituents of the sourdough

(Arendt et al., 2007; Rifna et al., 2019). *L. Plantarum* and *Lactobacillus fermentum*, strain commonly separated from gluten-free sourdoughs from, rice, amaranth, and teff (Moroni et al., 2009). Between LAB used, *Lactobacillus plantarum* is the main reported in gluten-free sourdoughs prepared from quinoa, rice, and amaranth (Moroni et al., 2010). The authors identified that the above strain released organic acids (lactic acid) which were antifungal (Moore et al., 2008), and enhanced firmness of crumb and staling level of gluten-free bread prepared with the refined flour (Moore et al., 2007). The use of sourdough was identified to enhance the textural properties as studied by (Houben et al., 2010). Likewise, (Jekle et al., 2010) reported that the incorporation of amaranth sourdough appreciably affected the rheological characteristics of amaranth batters and these effects were reliant on the quantity of sourdough added used in fermentation process.

Another work explained that sorghum sourdough fermented with *most lactobacillus strain* improved final bread nutritional value by depressing the polyphenolic activity (Svensson et al., 2010). As aforementioned, the microbiota in sourdough will assess the dough attributes regards to the aroma, acidification, and leavening. Few LAB strains release EPS that increase the elastic characteristic of batter, but also enhance the structure and bread shelf-life. The major general EPS employed are fructan, levan, and dextran. Sourdough is an important assuring technique to be used at the time of gluten-free bread preparation as it enhances concurrently nutritional and sensorial final bread attributes. Important is the assortment of suitable starter strains that should be cautiously selected for every particular raw ingredient. Notably, four important parameters are dependable for the supremacy of lactic acid bacillus strains: the compliance of sugar metabolism, pH, fermentation temperature, and the release of the antimicrobial molecule. These parameters will donate to the perseverance of the superior cultures and could make certain a reproducible and restricted ratio of sourdough microbiota and guarantee an even final bread quality.

8.3 Aeration Strategies

To evaluate different aeration methods the level of gas entrapment has to be defined which is often challenging. The different methods and formulas which have been employed to describe the amount of air in the dough will be discussed below about their applicability for gluten-free dough. Various methods have been demonstrated to identify the gas entrapment of bread. The chief objective of these techniques is to know how the gas is dispersed among the continuous phase. It has been reported that two different dough samples holding equal gas content can possess dissimilar crumb textures, owing to the dissimilarity regarding the size distribution and their primary bubble sizes (Chin & Campbell, 2005). The dullness and volatility of dough create complications to identify the arrangement and the characteristics of formed gas bubbles. As the gluten-free dough is regularly more flowing and less elastic when compared to dough out of wheat, disproportionation and buoyancy could play a greater part in its foam constancy. Henceforth, appropriate technologies for assessing gas bubbles all through processing in the gluten-free dough are mandatory. However various aeration methods, applied for gluten-free bread are described below.

8.4 Biological Aeration

To attain a fine crumb grain structure with a large volume, the bubble amount and size added at the process of mixing have to enhance uniformly in the succeeding processing steps. For this reason, biological aeration using microorganisms, say yeast, is suitable, as it constantly releases carbon dioxide until the neighboring circumstances are positive. The amount of carbon dioxide developed relies on the viability of the chosen microorganism, ionic strength, pH, temperature, substrate, humidity, and the availability of the nutrients. The ensuing development of bubbles at the process of proofing and baking can be modeled (Chiotellis & Campbell, 2003). To produce an accurate computation of the dispersion of carbon dioxide into air bubbles it seems demanding to monitor its quantity in the liquid dough state. From the outcomes, it was estimated that the end bubble dimension relies on the original size at the commencement of the fermentation process (Chiotellis & Campbell, 2003). This explains the significance of the primary mixing methods for creating minute nuclei with a fine size distribution. An appropriate model valid to gluten-free dough might be beneficial for understanding the correct option of baking and fermentation process.

8.5 Chemical Aeration

Another strategy for better aeration of gluten-free bread is the application of chemical raising compounds as a substitute or in couple to baker's yeast. Alike to biological leavening, the aeration using chemical agents relies on the amount of carbon dioxide generated and the capability of the gluten-free dough to hold the gas. In the case of wheat bread, the use of chemical raising agents is very limited, they are used for numerous gluten-free foodstuffs in addition to added microbes. Segura and Rosell (2011) evaluated gluten-free bread procured from the market which integrated chemical raising agents. Confirmative, (Sinelli et al., 2008) demonstrated that added chemical agents are frequent in wheat and gluten-free bread composition. It is noteworthy to cautiously select the kind, combination baking powder with the precise characteristics and necessities of the product in mind. Henceforth, it is startling that to date no valid research works concerning the correct alternative of chemical leavening substitutes are developed.

8.6 Physical Aeration

Chemical and biological aeration are generally followed by an agitating process that pretends a particular role for the ensuing bubble distribution. With respect to the quantity and arrangement of original gas nuclei, the rate of the successive bubble development and constancy at the period of baking gets affected. This could be the major significant objective for an alteration of conventional processing steps to the necessities of gluten-free dough. In early 1962, a substitute for conventional kneading was introduced, by coupling elevated speed mixing using the addition of vacuum (Cauvain & Young, 2006). As this method permits for an indirect inflection of bubble sizes by altering the head pressure, there could be possible for an amendment to the necessities of gluten-free dough. Massey et al. (2001) identified that an augment of the vacuum at the process of mixing boosted aeration and decreased the bubble dimensions. In this work though, the enhanced gas volume was owing to the development of the bubbles after pressure release and not owing to improved gas retentiveness. Usually, pressure development creates fine bubbles that enlarge as fast as the pressure is set free which could retain ingredients and process time. Cheng (1992) demonstrated a patented technique to join a mixer and an ultrasonic bath for an enhancement of cake batter aeration using acoustic cavitation. The aeration with aid of ultrasound was studied as a superior technique for aeration of batter at the laboratory level, whereas its incorporation at the industrial level could strongly increase operating expenses (Chin et al., 2015). In general, the adaption of the aeration strategies discussed for gluten-free bread seems to be a potential tool. However, future experiments that evaluate the effect of mixing and the gas volume fraction non-destructively on gluten-free dough need to be developed.

The most used tool for evaluating aeration strategies in food molecules is the application of the image analysis technique. With respect to the cake batter, a charge-coupled device camera was coupled with microscopy for monitoring gas bubbles (Hicsasmaz et al., 2003). Through another work, researchers examined physically divide samples of gluten-free frozen dough under cryo-scanning electron microscopy for better resolution (Trinh et al., 2013). Authors found that freezing affected the density of dough and also cell arrangement was reported to be distorted (Campbell & Mougeot, 1999). Later, (Trinh et al., 2013) demonstrated that starch granules could have been misplaced at the period of fracturing operation and their remaining could be misguided for air bubbles. A synopsis involving works applying microscopy has been provided by (Campbell & Martin, 2012), who explained significant variations regards to the bubble sizes (35–112 μm), gas volume fraction (3.5–10%), and a robust correlation on the experiential slice thickness of gluten-free products. Confocal scanning microscopy aids a three-dimensional revelation of the grain structure of bread dough after streaking particular ingredients (Jekle & Becker, 2011). For the gas bubble assessment, the ingredients of the neighboring medium have to be examined. Inadequately colored samples result in producing smaller bubbles, which can forge the outcome (Richardson et al., 2002). Similarly, interactions among dyes, gluten-free dough, and normal dough molecules could have an impact on the observable texture. Gas bubbles of bigger size (500–2000 μm) are complicated to observe through computer scanning microscopy as they hold the majority or the entirety of the visible region.

8.7 Nutritional Enhancement

Dietary fibers have been extensively considered for their functional properties in gluten-free bread composition, with regards to their water fastening property, fat mimetic properties, gel-forming capacity, and textural effects (Wang et al., 2017). Researches were performed to study the impacts of insoluble fibers on the sensorial property of gluten-free bread (Utrilla-Coello et al., 2013). Dough consistency and pasting characteristics of starch were also found to be affected fractionally by incorporation of fiber (oat bran) (Aprodu & Banu, 2015), due to their significant water-binding ability to present dough rheology and gelatinization of starch for gluten-free bread making (Demirkesen et al., 2010).

The addition of starch and soluble fiber compounds may lower the glycemic response of gluten-free bread that is significantly advantageous for folks with concurrent celiac disease and diabetes. Preparing composition with functional fibers for example psyllium and β-glucan have been researched widely as a remedy to aid regulation of gut and reduce serum low-density lipoprotein cholesterol values (Gunness & Gidley, 2010).

Prebiotics says oligofructose, resistant starch, and inulin are the most commonly studied functional dietary fibers for gluten-free bread preparation. As per (Capriles & Arêas, 2013), gluten-free bread with a high percentage (4–12%) of inulin-type fructans (ITFs) exhibited specific volume less than 10%, whilst noticing a turn down higher than 10%. The authors recommended that ITFs could develop a gel arrangement and hold carbon dioxide similar to few hydrocolloids. Various degrees of polymerization of inulin also produce a significant impact on the bread quality. Usually, a reduced degree of polymerization of inulin has robust effects compared to superior ones (Ziobro et al., 2013). Resistant starch develops numerous functional properties and could not only lower the food energy but also improves digestive properties and final bread properties (Witczak et al., 2016). Furthermore, resistant starch does not affect the bread crumb firmness whereas enhances its rheological properties particularly, porosity and elasticity (Tsatsaragkou et al., 2014).

8.8 Changing Flour Functionality Through Physical Treatments

Gluten-free flour could be physically altered using various particle size categorization and milling techniques. On one side these physical treatments are used to stabilize gluten-free flour and enhance shelf life whereas on the other side novel functionalities are developed. Henceforth, the flour developed after these physical treatments varies in its properties, say thickening capacity, water binding ability, pasting properties, emulsifying characteristics, and chemical activity towards proteins, enzymes, and others.

8.8.1 Particle Size Classification

In this approach, (Kadan et al., 2008) and (Araki et al., 2009) demonstrated that the milling process affected the broken starch and particles of refined flour and henceforth the bread volume was greatly affected. Through the above work, the authors observed a significant negative trend among broken starch and a specific volume of the final bread. On the other hand, the authors must incorporate wheat gluten into the bread recipe, so that outcomes cannot be entirely extrapolated. Whereas, (de la Hera et al., 2013b) observed that as there was a decrease in particle size of refined flour the specific volume also decreased for gluten-free flour. This impact was credited to the characteristics of dough at the fermentation process, as dough prepared with flours were barely capable of preserving gas released, which could be owing to the structural variations demonstrated among various doughs. Nevertheless, variations in the broken starch between the flours categorized through sieving were diminutive and, contrary to the outcome expected, the best portion was that which exhibited a reduced percentage of damaged starch (de la Hera et al., 2013a). Henceforth, the starch damaged itself could not elucidate these variations on gluten-free bread volume.

By working on semi-dry milled refined flours accessed through air classification, (Park et al., 2014) demonstrated that the superior portions produced bread of reduced volume, though a reduced starch percentage (<5%) was existing. In general, it has been demonstrated with rice flour that, finer flours baked bread of reduced specific volume (de la Hera et al., 2013c). Also, regards to oat bread, oat flours possessing coarse particles, restricted damage to starch and ended up producing superior quality oat bread (Hüttner et al., 2010). Henceforth it can be concluded that there is an obvious impact of refined rice flour particle size on the baking of gluten-free bread. On the other hand, further studies applying various kinds of gluten-free flours and various milling techniques are obligatory to confirm the above findings. From a nutritional viewpoint, the suitable combination could be incorporating a reduced volume and increased hardness of bread (De La Hera et al., 2014). Henceforth, apart to particle dimensions, hydrations of dough also have to be considered for modulating the hydrolysis of gluten-free breads and other similar foods.

8.8.2 Grinding and Air Classification

Once refined gluten-free flour is obtained, this could be exposed to various physical treatments to attain flours with diverse functionality and dietary formulation. The most exciting physical treatments are fine grinding (micronization) followed by air classification. This physical treatment involves decreasing the particle dimensions of flour significantly, that would alter flour functionality and formulate them highly appropriate for diverse processes.

Oat flours allow preparing breads of greater volume, reduced hardness and better sensory properties regards to breads baked by numerous other gluten-free flours (Hager et al., 2012). The superiority of oat breads may be enhanced if those flours are selected with better particle dimensions, decreased broken starch and protein percentage (Hager et al., 2012). The enzymatic alteration of their organic compounds could also be positive (Flander et al., 2011). Contrasting other gluten-free flours, oat flours possesses an elevated protein percentage, warranting studies for air-classification in future works. In this regards, oat cereal holding various protein percentage and particle dimensions could be accessed using fine grinding and air-classification, being the premium fractions that possess increased protein percentage (Wu & Stringfellow, 1995). β-glucan percentage in this part is also varied. Henceforth these portions should have a varying attribute in making of gluten-free bread, a phase that should be proceeded in detail as no present works regards to this exist. A numerous works on application of micronization and air classification in pea flours and legume flours have also been performed (Patel et al., 1980; Tyler et al., 1981). However, most of these works are chiefly based on the functional characteristics of these portions. Works on the addition of gluten-free flours to products are also very limited or void. On contrary, the integration of starches and protein is frequent in bread or cookie preparation, thus aforementioned flours can be an appealing alternative owing to their attribute of not involving artificial chemicals and ingredients.

8.8.3 Role of Hydrocolloids in Gluten-Free Breads

Additives for example hydrocolloids, enzymes and proteins are most commonly used in preparation of gluten-free bread with the objective of enhancing the visco-elastic attributes and end bread quality. Hydrocolloids are recently applied to enhance the rheological characteristics of gluten-free doughs and batters (Lazaridou et al., 2007), as they possess enormous prospective to structure three-dimensional polymer complex in solutions (Arendt et al., 2008). Various works have been conducted on the utilization of numerous hydrocolloids; say cellulose, guar gum, locust bean, hydroxypropril-methyl-cellulose and xanthan in gluten-free bread composition (Ahlborn et al., 2005; McCarthy et al., 2005; Moore et al., 2008). Respect to the other additives and refined flours used, particular hydrocolloids could affect to great percentage the bread volume and crumb texture of the baked bread, in which methyl celluloses was identified to be the most effectual amongst all (Lazaridou et al., 2007; Schober et al., 2007). Hydrocolloids are also significantly applied to enhance binding water capacity, dough viscosity, textural property, volume and end quality of bread (Mir et al., 2016). Methyl cellulose and xanthan gum are the widely applied hydrocolloids in gluten-free flour formulation owing to their their capability to advance the product quality (Hager & Arendt, 2013). Other hydrocolloids say CMC, guar gum, and locus bean gum are also most commonly applied in gluten-free bread dough preparation. However presently, numerous other hydrocolloids namely sodium carboxymethyl cellulose, cress see gum and (NaCMC) (Raeder et al., 2008) have also been recommended as novel gluten replacements that ensured promising baked bread quality. However, it was also observed that half-baked breads showed decreased volumes and increased crumb appearances, and elevated hardness. The incorporation of hydrocolloids, in peculiar CMC, partly mitigated the produced negative effect.

8.8.4 Prebiotic Gluten-Free Bread

The rising consumer insist for foodstuffs which are not only delicious and healthful but also offer health aspects have encouraged studies on prebiotics. The enormous application of inulin in the food industries is regards on its functional properties. Inulin is of enormous concern for the progress of healthy food products as it concomitantly communicates to an wide array of consumer necessities (Stephen et al., 2017). Inulin is the most commonly researched functional components in gluten-free breads (GFB) affecting constructively the sensorial and characteristics of final bread and prolonging the shelf life (Capriles & Arêas, 2013). Nevertheless, as the proteins present in gluten-free refined rice flours are usually incapable to hold gases at process of fermentation and baking henceforth, the enzymes were widely used to enhance the superiority of gluten-free breads by encouraging protein complex and elastic nature by protein cross-linking. The most widely employed prebiotics in gluten-free bread preparation is microbial transglutaminase – TG which aids in protein-connecting (Lee et al., 2005; Ziobro et al., 2016).

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8.9 Conclusion

In answer to a global growing occurrence of celiac disease in individuals, the requirement to propose celiac disease patients with significant quality and extensive multiplicity of gluten-free baking food products is a plight. Nevertheless, the non-existence of gluten, whose existence decides the comprehensive appearance and textural attributes of bread making products, makes it a scientific dispute. This book chapter discusses numerous alternative resources, functional components (incorporated independently or in combination), and technologies that can produce gluten-free bread of enviable quality. Literature demonstrates that an imperative objective is to mimic the gluten-network by conjunction numerous components, from which hydrocolloids possess a decisive part. As well crosslinking enzymes have been progressively studied. In the future, additional research and investigations warrants to be focused on the detection and relevance of further novel gluten replacements and the development and popularization of the coeliac-safe wheat. Study on amalgamation of these outlooks must be performed to remark the impending synthetic impacts and produce gluten-free bread and other products with attributes resembling those of wheat breads. Conversely, elementary understanding about these baking substitutes on product superiority, consumer approval and shelf life has yet to be considered in more detail.

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