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Review

A Systematic Review of Gluten-Free Dough and Bread: Dough Rheology, Bread Characteristics, and Improvement Strategies

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Abstract: High-quality, gluten-free doughs and bakery products are clearly more difficult to produce than wheat flour-based products. The poor quality of the breads that are currently available demonstrates that manufacturing remains a significant technological problem. This is mainly due to the absence of gluten, which has a huge negative impact on dough rheology and bread characteristics. Gluten replacement is still the major challenge in the development of doughs and baked goods. The literature documents various improvement strategies. The most active approach seeks to identify alternative ingredients that can mimic the viscoelastic properties of the gluten network, notably hydrocolloids, enzymes, emulsifiers, and alternative sources of protein. However, other innovative strategies, such as high pressure, using heat to dry flour, and sourdough fermentation, have been investigated. In this context, the first aim of this review is to summarize current knowledge regarding gluten-free doughs, breads, and bakery products. Secondly, as it is clear that the manufacture of gluten-free products remains a key challenge, it suggests some improvement strategies that can boost their nutritional, technological, and sensorial characteristics.

Keywords: gluten-free; advances in gluten-free; gluten-free batters; innovative gluten-free products; gluten-free breadmaking; celiac disease

1. Introduction

Most conventional doughs and breads are produced using wheat flour, water, salt and yeast (brewer's yeast or sourdough starter) [1]. Breads rely on the unique ability of hydrated gluten to develop a viscoelastic network [2], which traps gas, and produces bread with higher loaf volume [3]. After baking, gluten contributes to moisture control [3]. Factors such as: the correct management of agronomical treatments in the field [4,5], the milling method [6–8]; conditioning wheat to optimal moisture content before milling [9,10]; and optimizing dough kneading [11,12] all influence wheat flour quality, dough rheology, and bread characteristics and, at the same time, gluten quality, quantity, and strength. However, gluten is not the only important contributor to wheat dough and bread: starch also plays an important role. Starch granules are dispersed within a continuous network made up of gluten proteins [11,12]. Nonetheless, it should be noted that, although starch dominates in quantity, the gluten network is mainly responsible for the overall, viscoelastic properties of dough [11].

Gluten intolerance, which leads to celiac disease and other health issues [3,13], has become a worldwide problem. Consequently, interest in gluten-free products has grown among both researchers and consumers [3]. At the same time, so-called 'free-from' products (lactose-free, sugar-free, etc.) have become a global indicator of healthy lifestyle choices, which has expanded the market for gluten-free products [3]. These trends have led to a significant increase in demand, which the food industry has struggled to respond to. The main problem is that it is impossible to produce gluten-free doughs, breads, and bakery products with the same technological and sensorial performance as wheat-based products. In practice, making bread without gluten is a major challenge for researchers, bakers, and the food industry.

The absence of gluten has a significant effect on both dough rheology and the quality of the final product [13–15]. Gluten-free doughs are characterized by lower cohesiveness and elasticity compared to wheat dough [13–15]. Moreover, the lack of gluten results in bread with a poor texture and color, characterized by lower specific volume [13–15]. Other problems are a shorter shelf life, dry mouth feeling, unsatisfying taste, and other unwanted features [13–15]. Gluten-free doughs and breads are not only consumed by those who are gluten intolerant, or people with celiac disease, they are also part of a market towards environmental sustainability [16]. Notwithstanding the efforts made by bakers, scientists, and the food industry, the manufacture of gluten-free baked products continues to present a significant technological challenge. This point is illustrated by the gluten-free breads that are currently available. Although demand is constantly growing, the majority of commercial, gluten-free products are of very poor technological and sensorial quality [3,13–15,17].

The literature proposes various improvement strategies. Most focus on ingredients, additives, enzymes, and other substances (or combinations of them) that are able to reproduce the viscoelastic properties of the gluten network, and improve the final product from a technological and sensorial point of view. Starch is one of the most important constituents, highlighted by the copious number of articles on this topic. Other essential elements are water addition and the capacity to absorb water [3]. Water content is critical, as it influences loaf quality, texture, taste, smell, volume, flavor, and mouthfeel, and various studies have highlighted the influence of water mobility and distribution on dough rheology and baking performance [3,14,15,17].

However, there is a lack of an overview that summarizes the characteristics of gluten-free products, and the most interesting improvement approaches. Therefore, the first aim of this paper is to review current knowledge regarding gluten-free doughs, breads, and bakery products. Moreover, since production remains a key challenge, the second aim is to identify strategies that can boost their nutritional, technological, and sensorial characteristics.

2. Search Strategy

Three databases (ScienceDirect, PubMed, and the Web of Science) were explored using the following research string:

"Gluten free" AND dough AND rheology.

No restrictions regarding language, time, or publication status were imposed. Initial results were screened by reading the title and abstract (articles that only consisted of an abstract and/or index were excluded at this point), and then by a full-text reading. Finally, any duplicates were excluded. All articles about gluten-free dough rheology and breadmaking were included, while other, not pertinent papers were discarded. For each database, a flow chart was produced to summarize the obtained results (Figure 1).

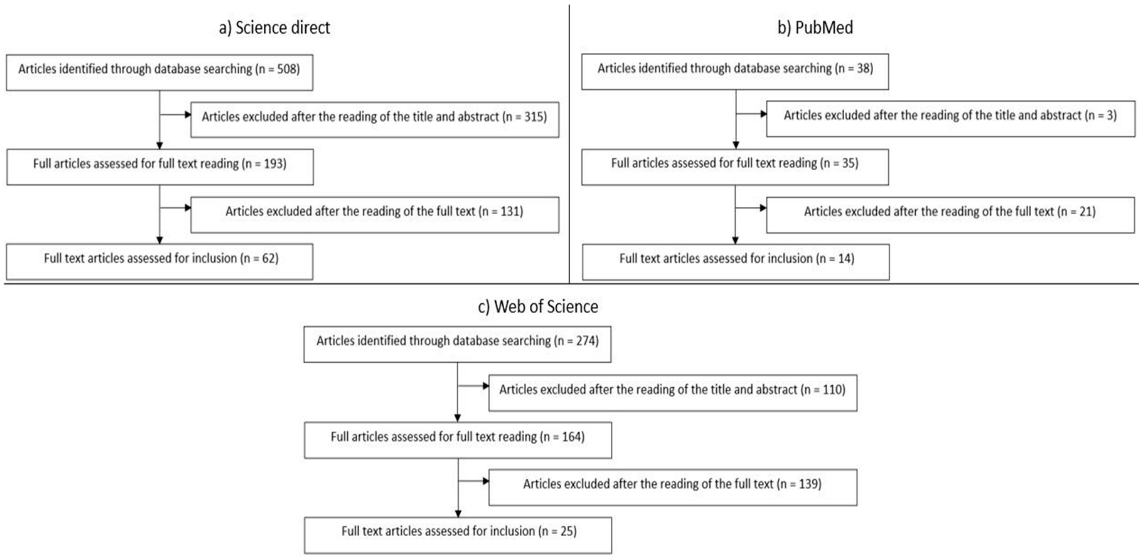

Figure 1. Flow charts pertaining to the selection process of papers on ScienceDirect (**a**), PubMed (**b**), and the Web of Science (**c**), summarizing the obtained results of the systematic literature review.

3. Main Findings

3.1. Results of the Systematic Literature Review

The initial dataset consisted of 820 items. After screening, 101 texts were selected. The removal of duplicates left a final total of 72 items: eight book chapters, 14 reviews, and 50 research papers. Figure 1 summarizes the selection process, which is consistent with the PRISMA statement. Figure 1a–c show results for ScienceDirect, PubMed, and the Web of Science, respectively.

3.2. Technological Effects Related to the Absence of Gluten, and Differences in Breadmaking

As highlighted in the introduction, breadmaking and the quality of bakery products depend on both the quantity and quality of gluten [14,15,17]. When wheat flour is kneaded with water, gluten proteins enable the formation of a cohesive viscoelastic dough that is able to hold the gases that are produced during proofing, resulting in high-quality, structured products. Bread (in particular), and other leavened goods, have higher loaf volume and other desirable characteristics [1,6,7,12,14,15]. The absence of gluten in dough has a major impact on rheology, and gluten-free doughs are much less cohesive and elastic than wheat doughs [13–15,17].

This unique structure and function of gluten makes the search for an alternative ingredient very challenging [14,15,17]. Gluten-free bread often has a poor color, mediocre texture, and other problems related to volume and crumb texture [14,15,17]. Although various novel ingredients, such as dairy powders, sorghum, rice, starches, pseudo-cereals, etc. have been tested, in combination with hydrocolloids, the literature reports little success [15]. The absence of gluten often results in excessively fluid doughs, which are closer in viscosity to cake batters, with a lower gas holding capacity than wheat flour doughs [14,15,17].

Although the fundamental breadmaking steps (kneading, proofing, and baking) must be followed, Duodu and Taylor (2012) [17] summarizes three important differences between gluten-free and wheat flour breadmaking processes. First, gluten-free bread formulations often include ingredients (hydrocolloids, and other sources of starch and protein) that improve dough structure, increase its gas retention capacity, and improve bread volume. Second, more water is usually added, leading to doughs with a consistency that is more similar to batter [14,15,17]—with the aim to increase starch hydration and subsequent swelling. Third, gluten-free breads usually require shorter mixing, proofing, and baking times than wheat breads [13,15,17].

3.3. Ingredients and Their Effects on Gluten-Free Dough Rheology and Bread Quality

The majority of gluten-free products described in the literature are made from native and modified starches blended with different hydrocolloids or other improvers, with the aim of improving dough rheological properties, bread appearance and volume, and crumb structure [13]. Recently, a significant increase in demand for better-quality products has increased research into their development [14,15]. The most noteworthy approaches are based on: the use of gluten-free flours (pseudo-cereals, maize, rice, etc.), and naturally gluten-free sources of starch (potato, maize, rice, etc.); the addition of protein from other production chains (egg, dairy ingredients, soya, etc.); the use of alternative sources of protein to strengthen doughs (insects and legumes); and the addition of gums, hydrocolloids, emulsifiers, and enzymes as improvers. The following sections examine these approaches in depth.

Various methods and instruments have been used to assess the rheological properties of gluten-free doughs. The most widely used are the Chopin alveograph, the farinograph, the mixograph, the Visco Analyzer, and different types of rheometer. Although initially developed for wheat flour doughs, they are also effective in characterizing gluten-free dough rheology. Similarly, a wide variety of methods have been used to characterize gluten-free breads. Some are based on manual, physical measurements (e.g., the standard millet displacement method for volume, or loaf height measured with a caliper), others use instruments such as a texturometer (for crumb texture characterization), or sensorial analyses can be run with consumers. The most widely investigated parameters are specific volume, crumb and crust moisture, crumb and crust texture, loaf and slice color, and water activity.

3.3.1. Naturally Gluten-Free Flour

Several alternatives to wheat flour can be used in gluten-free breadmaking. The review found that the most widely-used are rice flour, corn flour, teff flours, and several others that can be obtained from pseudo-cereals such as amaranth and buckwheat. Several authors observed that rice flour has received the most attention, due to its neutral taste, white color, low sodium content, easily-digested carbohydrates, and hypoallergenic properties [3,15,17]. Choosing the correct type of rice flour is essential, since different flours can have different impacts on the final quality of products [14,15,17]. Corn is another interesting alternative, illustrated by the wide range of gluten-free corn products on the market. Ground corn is used in products such as corn pasta, corn meal, corn starch, masa farina and corn flour, tortillas, pancake mixes, cornbread mixes, corn chips, and cereal [15].

Teff seems to be another promising substitute. Teff contains 11% protein, 80% complex carbohydrates, and 3% fat [15,17]. It is an excellent source of essential amino acids, especially lysine, which is most deficient in wheat [15]. Pseudo-cereals, such as amaranth and buckwheat, are other interesting alternatives due to their nutritional profile, and the increasing number of papers on the topic suggest growing interest. In particular, these pseudo-cereals are characterized by higher phenol and dietary fiber content, which significantly increased the interest and their use in breadmaking. Despite both phenolic compounds and dietary fiber have positive effects on consumer health, the increase of dietary fiber content could have detrimental effects on gluten-free dough rheology and gluten-free bread volume. Finally, flours have been obtained from legumes such as chickpeas, lupins, beans, etc., although they tend to be blended with the above-mentioned base flours.

In conclusion, gluten-free doughs and bread formulations based on alternative flours could be improved by hydrocolloids, emulsifiers, enzymes, and other approaches. In this context, choosing the most suitable base flour is essential, and further details of this important aspect are reported in Section 4.1.1.

3.3.2. Naturally Gluten-Free Sources of Starch

Starch is the most important reserve polysaccharide, and the most abundant constituent in many plants [14]. It is a unique vegetal carbohydrate, as it is naturally present in the form of dense, and relatively-insoluble semi-crystalline granules [13–15,17]. It plays multiple roles in food applications.

In baked products, it influences dough rheology and extensibility, bread texture, and overall acceptance [13–15,17].

As reported in Arendt et al. (2008) [14], most starch granules are a mixture of amylose and amylopectin, and there are clear differences between the two. Amylose is a linear molecule, consisting of c~(1,4)-linked D-glucopyranosyl units with a degree of polymerization in the range of 500–600 glucose residues [14]. In contrast, amylopectin is a very large, highly-branched polysaccharide with a degree of polymerization ranging from 3×10^5 to 3×10^6 glucose units, and is composed of chains of o~(1,4)-linked D-glucopyranosyl residues, which are interlinked by oL(1,6)-bonds [14]. The ratio between amylose and amylopectin differs significantly between different types of starches, ranging from 25–28% to 72–75%, respectively [13–15]. Botanically, starch takes the form of intracellular, water-insoluble granules of different sizes and shapes [13–15,17].

Many studies highlight that, during milling, a significant amount of starch is damaged [6–8,10,14,17]. This mechanical damage has a significant impact on its properties; in particular, damaged starch has higher water absorption capacity, and is more susceptible to enzymatic hydrolysis [6,7,14]. Heating starch suspensions in water that is above a specific temperature leads to disruption at the molecular level, with a consequent loss of crystallinity, and irreversible granule swelling [14]. This process, called gelatinization, facilitates molecular mobility, the dissociation of amylopectin double helices, and the melting of crystallites [14,15]. Gelatinization is also related to a reduction in starch solubilization (mainly amylose leaching) that determines an increase in the viscosity of the starch suspension [13–15,17]. This phenomenon continues with further heating and, above the gelatinization temperature, a continuous phase of solubilized macromolecules (mainly amylose), and a discontinuous phase of swollen, amorphous starch granules (remnants) are formed [14].

When starch is cooled after heating, another phenomenon, called retrogradation, occurs. Here, starch polysaccharides re-associate to form a more ordered, crystalline state [13,14]. Significant differences in the kinetics of starch retrogradation have been reported for amylose and amylopectin [13–15,17]. The re-crystallization of short amylopectin side-chains is significantly slower than amylose retrogradation, which is faster and determines, to a greater extent, the initial firmness of the starch gel [14,15,17]. Several factors have been found to influence retrogradation. The most noteworthy are related to the presence of other molecules, such as sugars, salts, lipids (in particular polar lipids), and pH [13,14].

There are several, naturally gluten-free sources of starch. They include rice, potatoes, tapioca, and cornstarch [14,15]. Potato starch seems to be the most promising option, as it has desirable characteristics that differ significantly from the other sources. It has been reported that small amounts of potato solids help to maintain the freshness of bread, and impart a distinctive, pleasing flavor, improving tasting qualities [15]. However, the latter authors observe that dough made with potato starch is highly viscous, and susceptible to shear; moreover, big potato granules are susceptible to breakage. The study also notes that high-molecular-weight amylose, and phosphate groups esterified to amylopectin, contribute to the high transparency, swelling power, water binding capacity, and freeze–thaw stability of potato starches.

3.3.3. Conventional and Alternative Sources of Protein

Several studies have examined the addition of alternative protein sources. The first distinction relates to the type of protein, which can be divided into "conventional" (egg, dairy, soy, etc.) and "alternative" (insects and legumes). The latter, in addition to any technological improvements, reduces environmental pressure, and meets increasing demand for sustainable protein. Like other improvers, the aim of protein addition is to reinforce the dough structure, with the help of cross-linking enzymes. An additional benefit is improved nutritional content [13].

Generally, protein addition decreases dough peak viscosity, final viscosity, and setback, due to starch dilution [13–15,17]. Soybean protein isolates and solid egg whites have been found to significantly increase the storage modulus of rice-based, gluten-free doughs [13]. However, the latter authors report that although loaf specific volume and crumb hardness were better when using solid egg white, its addition did not modify the elastic modulus. At the same time, while the addition of soybean protein did increase the elastic modulus, crumb hardness was poorer. These findings were supported by Arendt et al. (2008) [14], who highlighted that the addition of soy protein to gluten-free formulations enhanced crumb grain, bread volume, and the overall bread score. Consistent with Matos and Rosell (2015) [13], the latter study found that the addition of egg protein resulted in the formation of a film-like continuous structure (similar to wheat gluten); the effect was enhanced by the addition of transglutaminase, which catalyzed cross-linking.

A very interesting development is reported by Duodu and Taylor (2012) [17], who tested the use of processed storage proteins from tropical cereals such as maize and sorghum. The latter authors report that zein, the maize prolamin protein, and kafirin, the sorghum prolamin, exhibit viscoelastic (gluten-like) properties if suitably plasticized with a lipid, such as oleic acid. However, at normal kneading temperature, these proteins exist in a glassy state, and must be mixed at a higher temperature to be effective. In other work, Arendt et al. (2008) [14] highlighted that the addition of dairy ingredients such as demineralized whey powder, a powdered skimmed milk substitute, skimmed milk powder, sodium caseinate, and milk protein isolate significantly improved the nutritional content, volume, appearance, and sensory properties of breads, due to their ability to form stable networks. However, the use of dairy ingredients as an improver is not recommended, as approximately 50% of people with celiac disease are also lactose intolerant.

From an environmental point of view, alternative protein sources are more sustainable than those mentioned above. The literature reports several studies that test the suitability and effectiveness of flour made from different insects. The first critical issue relates to safety. An early study (Cappelli et al. (2020)) [18] examined the potential microbial, chemical, physical, and allergenic risks related to the breeding, transformation, and consumption of insects. Regarding microbial risk, the authors noted that, although neither *Salmonella* spp. nor *Listeria monocytogenes* have been detected, particular attention needs to be paid to this aspect [18]. Chemical and allergenic risks are also worrying, and they observed that care needs to be given with respect to breeding (chemical risk), and food labeling (allergenic risk) [18]. Nevertheless, although insects are still not globally accepted as food—the European Community has only recently recognized them as a novel food [19]—it seems that, if due precautions are taken during production, the use of insect flours is very promising [18,20].

The latter observation is confirmed by Cappelli et al. (2020) [20], who investigated the effects of the partial substitution of wheat flour with cricket, mealworm, and chickpea flours (5%, 10%, and 15%) on nutritional quality, dough rheology, and bread characteristics. The results highlighted that both chickpea and insect proteins were able to significantly improve nutritional content (in particular protein). Furthermore, the same study showed that substitution with 15% cricket flour significantly increased dough stability (assessed with a farinograph), and significantly reduced dough softening compared to the control (100% wheat flour). However, the authors found that the most promising source of protein, from a technological point of view, was chickpea. A 5% substitution with chickpea flour in ancient wheat flour notably improved dough stability and bread volume, compared to the control.

The results reported in [18,19], and [20] suggest that insect and legume flours could be valid candidates for the improvement of gluten-free doughs and breads. Thus, Section 4.1.7 examines the use of alternative sources of protein, and suggests a specific improvement strategy.

3.3.4. Improvers for Gluten-Free Doughs and Baked Products

Hydrocolloids have been widely investigated as additives and improvers [14]. The most noteworthy applications are: to improve food texture and viscoelasticity [13–15,17]; act as water binders [13–15,17]; extend the overall quality of products during storage [14]; slow down starch retrogradation [14]; and act as a gluten substitute [13,14]. Usually, they are added to dough as a structuring agent, with the aim of imitating gluten network properties [13,14,17]. Their high water retention capacity, among other characteristics, means that they are able to give stability to products that undergo successive freeze–thaw cycles. Moreover, they are a good fat substitute in many products, especially as, at concentrations below 1%, they have been found to have a significant influence on dough rheology and bread characteristics [14,15].

The review highlighted that carboxymethyl cellulose (CMC), guar gum, sodium alginate, κ-carrageenan, xanthan gum, and hydroxypropyl methylcellulose (HPMC) are effective improvers [3,13–15,17]. These agents are extensively used to modify starch gelatinization, and improve pasting properties and gelling. Moreover, they have been found to improve dough development and gas retention capacity, through an increase in viscosity, with a subsequent increase in loaf volume [13–15,17]. In particular, Arendt et al. (2008) [14] highlighted that hydrocolloid addition can increase elasticity and deformation resistance.

The literature reports a high degree of variation in functionality. The type and extent of the improvement depends on the origin and chemical structure of the hydrocolloid, and its concentration. Cellulose derivatives are obtained by chemical modification, which ensures uniformity. These agents have high water holding capacity (due to their hydrophilic groups), and other desirable properties, such as interfacial activity within the system during proofing, and the formation of gel networks during breadmaking [14]. They have been found to increase viscosity and gas retention capacity, with a consequent increase in loaf volume [14,15]. Moreover, the hydrophobic–hydrophilic balance in HPMC has been reported to strengthen crumb grain and increase moisture content [14]. CMC interacts preferentially with protein, and HPMC with starch [14]. The latter study reported that CMC and pectin significantly increased loaf volume, porosity, and elasticity. Xanthan and pectin increased cooking stability, while κ-carrageenan mainly affected the formation of the amylase-lipid complex.

In conclusion, the effects of the most widely used hydrocolloids depends on their source, chemical structure, extraction process, chemical modification, and dosage. Moreover, the most suitable hydrocolloid, and the optimal dosage, are a function of the selected base flour, and the desired characteristics of the final product.

Similarly, emulsifiers appear to be a promising way to stabilize and structure gluten-free dough. In particular, Matos and Rosell (2015) [13] highlighted that they are able to stabilize gas bubbles during proofing and, consequently, improve crumb texture. With respect to dough rheology, the latter study highlighted that the addition of xanthan gum resulted in the highest increase in viscoelastic moduli, and lowest hardness in bread. Diacetyl tartaric acid ester of mono- and diglycerides (DATEM), is another emulsifier that has been found to increase viscoelastic moduli and loaf specific volume, and decrease crumb firmness [13–15,17]. This is due to the ability of emulsifiers to improve dough consistency and pasting properties. On the other hand, Matos and Rosell (2015) [13] highlighted that the addition of inulin decreased dough viscoelasticity. This decrease was higher for inulin with shorter chains, due to inulin-inulin interactions.

Last but not least, enzymes have been found to improve both doughs and products. Various types are widely used in the baking industry, to enhance the formation of protein networks [17]. Amylases, proteases, cyclodextrinase, hemicellulases, lipases, and oxidases have been investigated by several authors. The effect of starch-hydrolyzing enzymes from the genus *Bacillus* was reported in [14,15,17]. The latter studies note decreased amylopectin retrogradation, a significant anti-staling effect, and an increase in loaf specific volume. Transglutaminase (TGase) seems to be another promising option. TGases have been reported to catalyze acyl-transfer reactions, which can induce covalent cross-linking between proteins, peptides, and various primary amines, mimicking the gluten network [15]. Moreover, they can link proteins of different origin, such as casein and albumin from milk, animal proteins from eggs and meat, etc. [14,15]. Typically, TGases used in baking applications are microbial aminotransferases that are able to create a network-like structure, with significant benefits for the quality of the final product [14,15].

The effect of cyclodextrinase addition to rice flour was reported in Duodu and Taylor (2012) [17]. The final product had good specific volume and very soft crumb texture, due to, among other effects, hydrolysis and cyclization [17]. Cyclization, in particular, produced cyclodextrins that formed complex molecules with rice proteins, increasing their solubility [17]. Cyclodextrins can also form inclusion complexes with lipids, creating films with the ability to retain gases, with a consequent increase in bread volume and better crumb texture [17]. The addition of glucose oxidase has been found to have a positive effect on dough rheology. In particular, Duodu and Taylor (2012) [17] highlighted that it increased the viscous and elastic moduli of rice flour dough. The authors suggested that this might be related to its ability to catalyze the oxidation of glucose to gluconic acid and hydrogen peroxide, which, in turn, induces the gelation of water-soluble pentosans in rice flour [17]. The authors noted that this could promote protein cross-linking, increasing bread volume.

4. Discussion

Section 3 summarized current knowledge regarding gluten-free dough rheology and breadmaking, and highlighted that production remains a challenge. Therefore, the second part of this review examines the most interesting improvement strategies reported in the literature. It is important to note that this section only considers the most innovative options, as Section 3 summarized some of the most widely adopted approaches. In particular, the use of hydrocolloids, enzymes, and alternative sources of protein are examined in depth, in the following sub-sections.

4.1. Strategies to Improve Gluten-Free Dough Rheology and Bread Characteristics

4.1.1. Careful Selection of the Base Flour

A key issue is to select the most suitable replacement for wheat flour. The substitute must have adequate nutritional content, dough rheology, technological characteristics, and taste.

Several authors have highlighted the potential of rice flour, due to its neutral taste, white color, low sodium content, easily digested carbohydrates, hypoallergenic properties [3], and low level of prolamins [15]. However, its starch granules can significantly influence dough rheology and bread texture, especially when present in large amounts (>10%) [14,15,17]. It is important, therefore, to carefully select the type of flour as a function of the desired final product, as different flours have different impacts on quality [14,15,17]. This observation is supported by Feizollahi et al. (2018) [21], who highlighted significant differences in amylose content, damaged starch, water absorption, starch granule dimensions, dough rheological properties, and loaf volume. Many authors have found it to be particularly suitable when blended with other sources of starch (such as potato or corn), and in combination with a suitable hydrocolloid [13–15,17].

Another interesting alternative is corn. It is important to highlight that corn and legumes are already widely-used in pasta production. Gluten-free doughs and bread formulations based on cornstarch have been improved with binding agents such as xanthan gum, guar gum, and locust bean gum, which substitute the gluten network [15]. Their addition has been found to significantly increase loaf volume [14,15,17]. Ground corn is already used in products such as corn meal, corn starch, masa farina and corn flour. Corn flour is used in the manufacture of food products such as tortillas, corn pasta, pancake mixes, cornbread mixes, corn chips, and cereal, as well as in home cooking for stews, soups, and casseroles [15].

Teff is another promising substitute. Teff contains 11% protein, 80% complex carbohydrates, and 3% fat [15]. It is an excellent source of essential amino acids, especially lysine, which is most often deficient in grain [15]. Furthermore, it is an excellent source of fiber and iron, and contains far more calcium, potassium, and other essential minerals than other grains [14,15,17]. It is widely used in products such as fermented flat bread (injera), and is mixed with sorghum and pearl millet to produce another flat bread (kisra) in Sudan and Eritrea [15]. Teff is an adjunct in homemade beverages and beer, and is used to make waffles, chocolate cake, muffins, biscuits, cookies, soups, stews, and puddings [15].

Finally, pseudo-cereals such as amaranth and buckwheat are another interesting alternative, as their protein structure and aminoacidic composition make them a very valuable addition to food [14,15,17]. Combined with hydrocolloids and emulsifiers, they have been found to produce high-quality gluten-free doughs (with increased water absorption), and bread with increased volume, lower staling, and a better nutritional profile [15].

4.1.2. Correct Management of Kneading and Total Water Content

Kneading, water absorption, and total water content significantly affect both wheat and gluten-free doughs [12]. In particular, water is an essential ingredient, and must be dosed wisely. The amount of water determines dough consistency, and affects its fermentation [13,14,17]. In dough, it has been reported to have the biggest impact on rheological properties [2], influencing the conformational state of biopolymers, interactions between constituents, and contributing to dough structure [13–15]. In bread, water content and its distribution determine textural properties such as crumb softness and crispness, and shelf life [14,15,17]. It plays a key role in starch gelatinization and, consequently, has a significant impact on the performance of the final product [13,14]. The water/starch ratio (along with other parameters, such as temperature, the amylose/amylopectin ratio, granule size distribution, and the presence of sugars, salt, protein, and lipids) has been reported to be involved in the most significant changes to starch structure, notably melting, gelatinization, and fragmentation [13–15,17]. Given the important plasticizer effect of water, most gluten-free breads tend to contain higher water levels, and have a more fluid-like structure [14].

Furthermore, wheat dough formulations typically adjust water content using a farinograph, following the ICC-Standard No 115/1 method [22]. This method is widely used to determine the exact amount of water necessary to hydrate the dough to the optimal consistency of 500 BU [1,8,10,20,22]. Although the method has also been applied to predict water absorption in gluten-free bread formulations, it has been found to be of limited use in the analysis of starch-based formulations containing hydrocolloids. These limitations are reported to be due to the lack of gluten, notably its network-forming properties [22].

Therefore, Horstmann et al. (2018) [22] developed a simple method to predict the optimal water content in gluten-free formulations containing hydrocolloids. It considers the water absorption properties of the base flour and the hydrocolloid (based on the amount added to the formulation) to determine the optimal amount of water to be added. The latter authors found that the water holding capacity (WHC) of the tested hydrocolloids was significantly different. WHC was highest for xanthan gum and guar gum, indicating cold swelling properties. On the other hand, sodium alginate and pectin had almost no swelling power, demonstrating high solubility and hot swelling. These characteristics are linked to the source, chain length, molecular weight, distribution, and polar charge of the hydrocolloid. The authors propose an improvement strategy that considers the WHC of single hydrocolloids, and carefully optimizes water content. They reported that sodium alginate at 2%, together with optimal total water content, significantly improved gluten-free doughs and bread quality parameters.

Mixing parameters, such as the type of mixing arm, kneading time, and method, have been found to significantly influence dough rheological properties and bread characteristics. The correct management of mixing parameters may significantly improve dough aeration, and its capacity to retain gases. Specifically, Matos & Rosell, (2015) [13] highlighted that the type of mixing arm had no significant effect on aeration, but longer kneading increased specific volume. Conversely, both the mixing arm and the mixing speed had a significant effect on bread volume and texture. Specific volume was higher and bread was softer when prepared with a wire whip, at a low mixing speed, and kneaded for longer. The same study found that less-hydrated gluten-free doughs tended to lack the ability to retain gases released during proofing, while highly hydrated doughs could be fermented for longer, improving specific volume [13]. Regarding mixing methods, Lammers et al. (2018) [23] suggested a strategy based on continuous preparation with a twin-screw extruder, which combined mixing, kneading, and molding in a single unit. Although this result is interesting, further investigation is needed to assess the effects of this continuous approach on bread quality parameters.

4.1.3. Improve and Increase Starch Gelatinization and Protein Cross-Linking

As gluten-free breads are mainly starchy matrixes, the gelatinization of starch significantly influences bread quality. Starch gelatinization can only be ensured if enough water is present, and when gelatinized starch is present in the initial stages of breadmaking it can significantly improve dough consistency [13]. Wheat dough development relies on maintaining a low temperature to improve the gluten network [24]; however, non-wheat doughs traditionally rely on blanching, boiling water, and other strategies to induce or increase starch gelatinization. In a novel approach, Matos and Rosell (2015) [13] suggested that high hydrostatic pressure could be a way to increase starch gelatinization. Although the strategy was initially developed for gluten breads, results for gluten-free breadmaking are reported to be very promising. The authors found that pressures of 200–600 MPa, particularly above 300 MPa, increased dough consistency due to the pressure-induced gelatinization of starch.

The potential use of high pressure (HP) to improve gluten-free doughs and bakery products was confirmed by Vallons et al. (2011) [25], who investigated the effects of HP treatments (200, 400, and 600 MPa for 10 min.) on starch gelatinization, protein cross-linking, and rheology, in dough made with buckwheat, rice, and teff flour. With respect to starch gelatinization, starch granules in white rice samples were most sensitive to heat, with gelatinization occurring between 47.7 and 77.9 °C [25]. Buckwheat starch gelatinized between 50.9 and 81.9 °C, while teff starch was most resistant to heat, as granule melting started at 54.4 °C [25]. HP pre-treatment of the batter led to a significant change in the gelatinization temperature. Exposure to 400 MPa for 10 min significantly increased the initial gelatinization temperature in rice and teff samples, while buckwheat also increased, but not significantly [25]. The authors attributed these changes to modifications in the granule structure and crystallinity.

The same study of Vallons et al. (2011) [25] found that HP treatment increased dough viscosity in all tested samples. For all flours, and all pressures, G′ was higher than G″ in the whole range of frequencies. Furthermore, the complex modulus (G*) increased in white rice and buckwheat batters as pressure increased, while the damping factor decreased, indicating the increased contribution of the elastic compound (G′) [25]. On the other hand, teff batters responded differently. At pressures up to 200 MPa, the structure weakened, while at >200 MPa it became increasingly elastic and resistant to deformation (higher G*) [25]. The authors suggested that this unusual behavior might be due to the cleavage of disulfide bonds, proteolytic activities, or decreased intrinsic viscosity due to changes in secondary structure [25]. Furthermore, the study used Lab-on-a-Chip capillary gel electrophoresis to reveal protein polymerization by thiol/disulfide-interchange reactions in white rice and teff batters [25]. No such mechanism was observed for buckwheat proteins, which the authors suggested was due to the absence of free sulfhydryl groups [25].

The results presented above were confirmed by Cappa et al. (2016) [26], who treated both corn starch and rice flour with HP (600 MPa for 5 min at 40 °C). In particular, Cappa et al. (2016) [26] highlighted a significant increase in water binding capacity that improved dough consistency and workability, despite the higher amount of water required for formation. Moreover, Cappa et al. (2016) [26] found that the HP treatment and higher water content resulted in well-leavened breads, characterized by higher specific volume, and good crumb softness. Like Vallons et al. (2011) [25], Cappa et al. (2016) [26] reported that pressure was consistent with a significant modification in starch functionality, in particular, gel samples had slower hardening kinetics. Finally, the latter authors reported that HP appeared to be a promising way to improve bread shelf life. Breads containing treated corn starch and rice flour were characterized, after 72 h storage, by higher moisture and lower water activity, and slower hardening kinetics compared to the control bread.

4.1.4. Dry Heat Treatment of Gluten-Free Flours

An interesting strategy is reported in Collar (2019) [27], where the authors tested the use of dry heat to improve gluten-free doughs, bread, and cake, particularly those made with weak, substandard flours. The treatment led to protein denaturation and the partial gelatinization of starch granules, which induced an increase in gas retention capacity and dough expansion. A change in dough viscosity in cake-making was connected to the ability to transform from foam to sponge form, and reduced shrinkage during baking. In particular, the authors highlighted an increase in the volume of *kasutera* cake by dry heating at 120 °C for 30 min. The same study found that heat-treated flour had increased resistance, viscosity, and stiffness. These factors increased dough elasticity, with positive effects on oven spring and loaf volume. The authors also investigated the effects of the treatment on sorghum flour, and found that heating produced bread with the highest specific volume, and the most cells per slice area. Improvements in structure, strength, and volume were related to the increased viscosity of sorghum flour. Additionally, cakes and bread made with dry-heated flours were more acceptable than controls in consumer testing.

These findings are supported by Padalino et al. (2016) [28], who, additionally, highlighted that the pre-processing treatment seemed to be a particularly suitable way to improve the technological properties of gluten-free pasta produced with corn flour. Pasta produced with dry-heated corn flour had higher firmness, improved texture, and increased flavor after cooking, compared to pasta obtained by a conventional extruder.

In conclusion, dry heat treatment seems to be a viable way to improve sorghum flour and sorghum-base doughs and products, with no pungent off-notes. Furthermore, in-depth studies of its effects on the structural behavior of flours are needed to better explain how heat alters flour and dough functionality, and how it may improve the quality of sorghum-based bakery products.

4.1.5. Hydrocolloids

Section 3.3.4 highlights that hydrocolloids are widely used to improve dough rheology. Moreover, they seem to be an essential element in the production of high-quality products. In Mir et al. (2016) [29], the authors reviewed the influence of hydrocolloids on gluten-free dough rheology and bread characteristics, and confirmed their role as structuring agents, imitating gluten network properties [13,14,17]. Moreover, Mir et al. (2016) [29] confirmed their ability to improve food texture and viscoelastic characteristics. As reported in [13–15,17], they act as water binders, extending the overall quality of products during storage, and delaying starch retrogradation [14]. However, although the benefits appear relatively clear, some questions remain. Which hydrocolloids perform best? At what dosage? Using what addition modality? How can we optimize any improvements?

We begin with the first question—which hydrocolloids perform best? Here, it is important to highlight that the magnitude of the effect on dough and bread properties is a function of their chemical structure, the amount used, interactions with other ingredients, and process parameters [14,15,17,29]. Nevertheless, HPMC and xanthan gum are the most commonly used, due to their superior effects on dough rheology and the quality of the final product [29]. They have been found to increase dough elastic and viscous moduli, increase dough viscosity, consistency and strength, increase the strength of gas cells, increase rheofermentographic indexes, and increase elasticity in doughs produced with rice, corn, and buckwheat flours [29]. Bread is reported to have higher specific volume (and the loaf resembles wheat bread), reduced crumb hardness, improved color, bigger gas cells and improved crumb porosity, increased moisture content, reduced water loss, reduced crumb firmness, slower staling kinetics, improved sensory properties, and higher consumer preference in panel tests [29]. These findings are supported by [22,30–35].

Turning to the second question—what is the correct dosage? In the context of HPMC and xanthan gum, it is very hard to determine the correct percentage, as it depends on several factors. The first is the optimum water content of the formulation (made up of flour, hydrocolloids, and other ingredients). As noted in Section 4.1.2 and by Horstmann et al. (2018) [22], the optimum percentage must be evaluated by considering the WHC of individual ingredients (including the selected hydrocolloid). This observation is supported by Morreale et al. (2018) [30], who tested three HPMC levels (1%, 2%, 3%) and three hydration level (90%, 100%, 110%) to find the best HPMC percentage, and optimal water content for doughs and bread produced with rice flour. The analysis found that 2.2% HPMC, and optimum dough hydration of 110% was the best formulation to improve both dough rheology and bread characteristics. Finally, the authors highlighted that hydrocolloid viscosity and dough hydration played a key role in product quality. Other authors have examined the effect of HPMC on gluten-free doughs and bread. In Baldino et al. (2018) [31], the authors confirmed that HPMC improved dough rheology and bread characteristics in formulations based on rice and buckwheat flours. Unlike Morreale et al. (2018) [30], best performance was obtained with 1% HPMC and 100% water. This difference could be due to different flour characteristics (no buckwheat in Morreale et al. (2018) [30]), different water content (100% vs. 110%), and other breadmaking factors.

With respect to xanthan gum, Sciarini et al. (2010) [32] compared the effects of the addition of different hydrocolloids on batter properties and bread quality. Breads were made of rice, corn, and soy flours, with 158% water. The study tested several hydrocolloids (0.5%), such as carrageenan, alginate, xanthan gum, and carboxy methylcellulose. The results showed that xanthan gum improved batter consistency the most (double the control), and resulted in the highest increase in bread volume (+18.30% compared to the control). Moreover, the addition of 0.5% xanthan gum increased average cell size, lowered crumb firmness, and slowed staling.

Other authors have highlighted that xanthan gum may have a promising effect on dough rheology. In Lazaridou et al. (2007) [33], the authors assessed the effect of hydrocolloids on dough rheology and bread quality parameters, in formulations based on rice flour, corn starch, and sodium caseinate, using pectin, CMC, agarose, xanthan gum, and oat b-glucan (1% and 2% *w*/*w* rice flour basis). The analysis evaluated the rheological behavior of dough with a farinograph and a rheometer, and highlighted that xanthan gum had the most pronounced effect on viscoelastic properties, producing strengthened doughs. The formulation resulted in a farinograph curve typical of wheat flour doughs. Moreover, the addition of xanthan gum was consistent with the highest increase in dough elasticity and resistance to deformation. Despite these impressive results regarding dough rheology, no improvement was observed with respect to bread, which was characterized by low loaf volume and high crumb firmness. It should be noted that these results conflict with those reported in Sciarini et al. (2010) [32]. It is possible that the lack of improvement is due to the formulation. In Lazaridou et al. (2007) [33], the authors highlighted a decreasing trend with an increasing level of hydrocolloids (from 1% to 2%), but did not test the specific case of 0.5% xanthan gum.

Similar observations were reported by Sabanis and Tzia (2011) [34], who assessed the effects on dough rheology and bread characteristics related to the addition of HPMC, xanthan gum, κ-carrageenan, and guar gum at 1%, 1.5% and 2% (*w*/*w*) in formulations based on corn starch and rice flour. Like Lazaridou et al. (2007) [33], Sabanis and Tzia (2011) [34] highlighted an improvement in dough rheology and consistency, but not bread characteristics. The best results were obtained with HPMC, and guar gum performed better than xanthan gum. Different results were reported for millet-based pasta, where the addition of 2% xanthan gum was consistent with the highest increase in elasticity, and network strengthening [35]. Hydrocolloids have been widely studied in gluten-free formulations, and this literature review suggests that HPMC is the most promising option; nevertheless, further studies are needed to understand the topic in greater depth.

4.1.6. Enzymes

Like hydrocolloids, enzymes are widely used in both gluten-free doughs and to improve bread, and they have been widely investigated in the literature (see Section 3.3.4). The most comprehensive study, by Renzetti and Rosell (2016) [36], summarized the role of enzymes in improving the functionality of gluten-free doughs, bread, and bakery products. The authors noted that the main purpose of the addition of enzymes is to create protein aggregates that mimic (or try to mimic) gluten functionality, and to modify proteins, with the aim of changing their functionality. They highlighted that transglutaminase (TGase), oxidases, and proteases are the most interesting options.

As reported in Renzetti and Rosell (2016) [36], TGase is a protein-glutamine γ-glutamyl-transferase, which catalyzes an acyl-transfer reaction between the γ-carboxamide group of peptide-bound glutamine residues, and a variety of primary amines. Its use could significantly improve gluten-free doughs. The results of their batter rheological analysis and bread quality evaluation confirmed the improving effect of TGase on buckwheat and brown rice doughs and breads [36]. The authors argued that this finding was due to protein cross-linking, and the formation of large protein complexes in both breads [36]. Conversely, TGase had a detrimental effect on the elastic-like behavior of corn batters, but increased specific volume and lowered crumb hardness in corn breads [36]. The latter study also found that it was not effective in improving gluten-free doughs and breads made from oat, sorghum, and teff.

With respect to oxidases, Renzetti and Rosell (2016) [36] and Gujral and Rosell (2004) [37] evaluated several types (lipoxygenase, sulfhydryl oxidase, glucose oxidase, and peroxidase). Improvements were related to their dough strengthening and stabilization effect, and their activity as bleaching agents. Another interesting enzyme is glucose oxidase [36,37]. When added to gluten-free dough formulations based on rice flour, it increased bread specific volume and reduced crumb hardness [36]. The authors of the latter studies suggested that this was due to an increase in dough consistency related to protein cross-linking, connected to the ability of hydrogen peroxide to form disulfide bonds, and gelation of water-soluble pentosans in rice flours.

Last but not least, we turn to the proteases. Proteinases and peptidases hydrolyze peptide bonds in proteins. Proteases are reported to significantly improve gluten-free dough rheology and bread characteristics, and induce changes in protein-protein and protein–starch interactions in rice batters, due to the creation of interlinked protein–starch aggregates after protein degradation [36,38,39]. Moreover, protease treatments are reported to decrease peak viscosity, and the breakdown of starchy-based gluten-free doughs, independent of the type of base flour used [36,38,39].

The findings reported above are widely supported by other authors. In particular, Gujral and Rosell (2004) [37] tested the efficacy of glucose oxidase in the improvement of gluten-free dough rheology and bread characteristics. The results showed that it was able to modify proteins in rice flour, by lowering thiol and amino group concentrations. Furthermore, its addition increased both the elastic and viscous moduli of gluten-free doughs [37]. Finally, its addition to rice flour resulted in bread with increased specific volume and improved texture, minimizing the addition of HPMC [37]. Similarly, the addition of protease (0.01%), in Renzetti and Arendt (2009) [38], improved the rheological properties of gluten-free doughs made with brown rice flour, notably a decrease in viscosity and breakdown. The same study highlighted an increase in loaf specific volume, and a decrease in crumb hardness and chewiness. The effectiveness of protease was confirmed by Hamada et al. (2013) [39], who tested pre-fermented (with *Aspergillus oryzae*) rice flour.

The efficacy of TGase in promoting protein cross-linking and improving dough rheology and bread characteristics was evaluated in Renzetti et al. (2008) [40]. The authors tested six, gluten-free flours (brown rice, buckwheat, corn, oat, sorghum, and teff) and three TGase levels (0, 1, or 10 U/g). Rheological analyses highlighted a significant increase in the pseudoplastic behavior of buckwheat and brown rice doughs when the maximum level of TGase was added (10 U/g) [40]. The obtained buckwheat and brown rice breads showed increased specific volume, decreased crumb hardness, and lower chewiness [40]. However, minimal improvement was observed for breads made from oat, sorghum, or teff [40]. In conclusion, enzymatic treatments to improve gluten-free doughs, bread, and bakery products, seem to be a very promising strategy that merits further investigation.

4.1.7. Alternative Sources of Protein, and Functionalized Zein

As noted in Section 3.3.3, several authors have tested the addition of conventional protein from vegetal (soya, potato, etc.) and animal (egg albumen, dairy products, etc.) sources to improve dough rheology and bread characteristics, with interesting results [41–44]. Three studies have reported that best results are obtained for egg albumen proteins [42–44]. Legumes are another interesting source of protein that has been widely examined in the literature. One study highlighted that the addition of lupin and pea protein isolates improved dough rheology, increased loaf volume, cell pores, and led to a softer crumb [45]. Lupine protein was assessed in Matos and Rosell (2015) [13], and was found to decrease crumb hardness and slightly increase the storage modulus.

However, it seems that chickpea is the best improver. An early study found that the addition of 5% chickpea flour significantly improved ancient wheat flour, notably with respect to increased dough stability and bread volume [20]. Chickpeas have also proven to be able to improve gluten-free doughs and bread. In Miñarro et al. (2012) [46], the authors compared the effects of the addition of chickpea flour, pea isolate, carob germ flour, and soya flour, and found that chickpea bread had the highest volume (3.26 cm^3/g), and the softest crumb. These findings are in accordance with Kahraman et al. (2018) [47], who tested the effects of raw, roasted, and dehulled chickpea flours on gluten-free formulations based on rice flour (75%) and chickpea (25%). Doughs containing chickpea flours had higher protein and fat content, reduced retrogradation tendency, higher foaming capacity, superior dough stability, and higher CO_2 retention capacity (≥98%). At the same time, chickpea roasting decreased foaming capacity, and stability.

Both the food industry and consumers are increasingly sensitive to environmental impacts. This has led to an ongoing search for alternative, cheaper and more sustainable sources of protein. In this context, insects seem to be one of the best opportunities [18,20]. A recent study by Kowalczewski et al. (2019) [48] tested gluten-free formulations substituted with cricket flour at 2%, 6% and 10%. Although little change was observed for dough rheology, breads were characterized by significantly reduced hardness, and improved consistency and texture. The authors also suggested that its use could significantly improve the nutritional content of gluten-free products.

Another interesting approach is to functionalize non-gluten proteins, in particular, zein. Zein is an alcohol-soluble protein made from corn. It is classified as a prolamin, and composed of a combination of peptide chains linked by disulfide bonds [49]. Above its glass transition temperature (35–40 °C), and combined with other dough components, its molecular structures are able to form doughs with viscoelastic properties comparable to those of gluten. It has been commercially available for about 60 years, and already has several applications, including the production of fibers, adhesives, buttons, binders, and coatings [49]. As the United States Food and Drug Administration has recently confirmed that it is suitable for use in the food industry, there has been an explosion of interest in its unique characteristics and functionalities (which are similar to those of gluten) [49]. In a detailed study, Erickson et al. (2012) [50] suggested that the properties of functionalized zein are the result of developing fibrous, b-sheet-rich protein networks.

A later study investigated the optimal extrusion temperature for zein in rice-based formulations [51]. The authors highlighted that the correct temperature resulted in doughs with viscoelastic properties similar to those of doughs prepared with wheat flours. Extrusion conditions also influenced dough elasticity, with the greatest effect seen at 160 °C [51]. Finally, gel electrophoresis of zein extruded at 160 °C increased protein aggregates and the presence of smaller peptides, compared to samples subjected to lower temperatures. Furthermore, Schober et al. (2010) [52] highlighted that zein defatting improved specific volume (4.5 mL/g vs. 3.3 mL/g), but had a limited effect on lipid content reduction, which decreased from 8.0% to 6.6%. Moreover, laser scanning confocal microscopy with zein-starch dough confirmed that zein particles aggregated more easily when a defatting treatment was applied. In conclusion, although zein appears to be an interesting strategy to improve gluten-free dough rheology and baked products, further investigations are needed.

4.1.8. Sourdough Fermentation

Several authors have investigated the effects of sourdough fermentation on gluten-free dough rheology and bread characteristics. For example, Matos and Rosell (2015) [13] highlighted that sourdough fermentation positively influenced all aspects of bread quality: texture, aroma, nutritional properties, and shelf life. However, improvement was strictly dependent on the used microbiota. Moreover, the possibility of obtaining natural products with a reduced use of additives or even clean labels is appealing. The acidification of gluten-free doughs by sourdough fermentation can partially replace the function of gluten, and enhance polysaccharide swelling [14]. In particular, Arendt and Dal Bello (2008) [15] highlighted that sourdough fermentation increased dough elasticity over the initial 24 h of fermentation, and delayed the onset of bread staling. Furthermore, Duodu and Taylor (2012) [17] highlighted that it increased loaf specific volume, and improved the texture of bread produced with oat flour.

The findings outlined above are supported by other work [53]. The latter study investigated the effect of sourdough made from combinations of four *Lactobacillus* spp. on the physicochemical properties, consumer acceptability, and shelf life of formulations made with pearl millet flour. The authors found that sourdough fermentation increased the elasticity, and reduced the stiffness of doughs [53]. Doughs fermented with *L. brevis* had the greatest increase in loaf height, specific volume, porosity, and moisture content. Loaves had higher moisture content, the development of mold during storage was suppressed for a longer period, and breads were more palatable than either conventional or chemically acidified ones [53]. The authors suggest that *L. brevis* and *L. paralimentarius* are the two most promising species for the production of high-quality, gluten-free doughs and breads made using millet flour [53].

The results reported in Nami et al. (2019) [53] are supported by Falade et al. (2014) [54]. The latter study investigated the effects of sourdough fermentation on doughs and breads obtained with maize flour. The rheological analysis found that it shortened relaxation time, and resulted in the lowest elastic modulus, indicating a softer and less elastic dough. Fermentation also increased loaf volume by 25–26%, and improved texture and larger cells were observed. However, Moroni et al. (2011) [55] tested the effect of sourdough fermentation on dough and bread produced with buckwheat flour, with conflicting results.

Although sourdough fermentation seems to be an interesting improvement strategy, both from a nutritional and technological point of view, like Arendt et al. (2008) [14], we believe that further studies are necessary. In particular, close attention should be paid to a very interesting secondary advantage related to sourdough fermentation—the ability of some lactic acid bacteria to produce techno-functionalized exopolysaccharides. This topic was extensively examined in Lynch et al. (2018) [56]. The authors noted that, typically, exopolysaccharides produced by lactic acid bacteria are high molecular weight polymers with physiochemical properties that are similar to commercial hydrocolloids or gums, and could be considered as a potential (natural) improver for gluten-free formulations. Although these molecules are able to mimic gluten network behavior, the authors observe that several factors can influence their impact. Flour composition, acidification potential, the type of exopolysaccharide, and many other factors must be carefully considered. However, since their in-situ production has no labeling requirements, increases shelf life, and improves nutritional content, further investigations are urgently needed.

5. Conclusions and Future Trends

This review highlighted significant differences in dough rheology and the characteristics of baked goods for wheat flour and gluten-free products. Notwithstanding the efforts of bakers, scientists, and the food industry, manufacturing still presents significant technological problems, illustrated by the poor quality of gluten-free breads currently available on the market [3,13,14,17]. The absence of gluten has a huge, negative impact on dough rheology and bread characteristics, generating doughs that are much less cohesive and elastic, and bread with lower volume and poorer texture, compared to wheat-based products [13–15,17]. The unique structure and function of gluten makes the search for alternative ingredients that can mimic the gluten network extremely challenging.

This review has highlighted the importance of selecting the optimal improvement strategy (or combination of strategies), as a function of the desired product. The most promising results seem to rely on the correct management of total water content and kneading, the use of hydrocolloids (in particular HPMC), the use of enzymes (in particular glucose oxidase and TGase), and the use of alternative sources of protein. Moreover, this review highlighted other, encouraging innovative strategies. These include: increasing starch gelatinization with HP treatments; dry heat treatment of gluten-free flours; and sourdough fermentation, particularly with lactic acid bacteria that produce functionalized exopolysaccharides able to (naturally) replace commercial hydrocolloids or gums.

In conclusion, several strategies could be adopted to improve gluten-free dough rheology and baked products. Although the literature is rich, further investigations are needed, particularly with respect to the most innovative, recent strategies. Moreover, the gluten-free industry should embrace current trends in the wheat-bakery industry, which seek to reduce environmental pressure. This could be done using local, alternative sources of protein (such as native legumes, or protein sources that are the by-product of other production chains), provincial gluten-free flours, and zero km ingredients. The COVID-19 pandemic has led us to reconsider the relevance of short supply chains, and local production [57], and this latter recommendation could be considered as an additional improvement strategy, as consumer interest in the environmental impacts of food production will only increase in future.

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