

Review

The Clean Label Concept: Novel Approaches in Gluten-Free Breadmaking

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Abstract: The commonly used term of “clean label” refers to food products that do not contain additives (E numbers). Although there is not always a scientific reason for believing that additive-free products are healthier, clean label products are becoming more popular. The growing market for gluten-free foods represents an important target group of consumers, who could be interested in products meeting clean label standards. However, manufacturing gluten-free baked goods according to the clean label concept is extremely difficult, as gluten-free raw materials demonstrate poor baking properties. Additives are required to simulate the texturing properties of gluten, few of are suitable for clean label products. This paper discusses the possibility of replacing the hydrocolloids most commonly used in gluten-free baked goods with β -glucan, psyllium, or transglutaminase.

Keywords: gluten-free bread; clean label; beta glucan; psyllium; transglutaminase; gluten-free diet



Citation: Kajzer, M.; Diowksz, A. The Clean Label Concept: Novel Approaches in Gluten-Free Breadmaking. *Appl. Sci.* **2021**, *11*, 6129. <https://doi.org/10.3390/app11136129>

Academic Editors:
Urszula Krupa-Kozak and
Vanessa Capriles

Received: 24 May 2021
Accepted: 28 June 2021
Published: 30 June 2021

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1. Introduction

In recent years, consumers have taken a more active interest in the source, quality and nutritional value of food. This is reflected not only in the rising sales of organic products from certified crops, but also in calls from both consumers and consumer organizations to reduce or even avoid the use of additives in processed food. As a result, “free-from” statements have started appearing on products, which have been reformulated to make them closer to home-made or traditional recipes, with fewer ingredients.

2. Clean Label Definition

“Clean label” is an evolving concept that has shifted in its meaning and significance over the years. This term is not regulated by food laws. However, it may be considered by manufacturers and consumers to be indicative of products that are, for example, organic, UTZ, Fair Trade, Halal, Kosher, vegetarian, vegan, and/or free from. The clean label is most strongly associated with “natural” ingredients that are easily recognizable and considered safe by consumers. Cleaner formulations are associated with shorter ingredient lists, as fewer ingredients appear to signify more natural and higher quality products. However, additives are often important for extending shelf life and improving the consistency and sensory qualities of food. Moreover, ingredients may be made from entirely natural source materials, but still not be considered suitable for use in clean label products. The term “natural” has no clear legal definition, and there are many non-synthetic additives on the food additives list that have been assigned E numbers. In the EU, a product labeled “no” (colors, preservatives, etc.) must not contain any of the substances covered by EU regulation no 1333/2008 [1].

3. Consumer Attitudes

The word “clean” is itself hardly ever used on food packaging. The perception of “clean label” products varies depends on individual differences, culture, the type of

product and its positioning [2]. Consumers link to “clean” foods such features as minimal processing and no preservatives, artificial sweeteners or artificial colors, or as being GMO-free. In recent times, the idea of clean label has evolved to also include sustainability and health. Table 1 provides figures showing the growth of new food and beverage products launched with clean label claims. Clean claims can be divided into three categories: “no added”, “natural/natural additives/organic” and “real”. “Real” seems to be a top claim only in the MEA (Middle East-Africa) region. Five out of the six fastest growing claims in North America belong to the “no added” category. In Latin America, that figure is six out of six. In Europe, the fastest-growing claim refers to “no stabilizers”.

Table 1. Growth of new food and beverage products launched with clean label claims, by region (CAGR 2017–2019) [2].

North America	Europe	Asia	Latin America	MEA (Middle East Africa)	Australasia
No stabilizers (+48%)	No stabilizer (+116%)	No stabilizer (+56%)	No sweeteners (+22%)	No artificial color (+25%)	Nothing artificial (+42%)
No artificial sweetener (+30%)	No sweeteners (+24%)	No additives (+44%)	No flavors (+15%)	Real ingredients (+24%)	Only natural (+13%)
No sweeteners (+16%)	No colors (+18%)	No flavors (+33%)	No artificial additives (+13%)	No artificial flavor (+23%)	No artificial sweeteners (+9%)
GMO free (+15%)	Natural ingredients (+17%)	Natural sweeteners (+31%)	No artificial preservatives (+11%)	Natural colors (+18%)	Natural sweeteners (+9%)
No artificial preservatives (+12%)	No flavors (+17%)	No artificial preservatives (+30%)	No colors (+10%)	No artificial preservatives (+11%)	
Natural flavors (+10%)	Organic (+13%)	No artificial sweeteners (+26%)	No artificial flavors (+5%)		

Food products containing ingredients of natural origin seem to be especially attractive to consumers. In many countries, consumer behavior is strongly influenced by health considerations [3]. According to a 2014 study by the American non-profit organization Consumer Reports [4], almost 60 percent of buyers look for the claim “natural” on packaging, believing that products labeled in this way are healthier than products without such a statement. Similar data can be found in a report prepared by Innova [2]. More than 50% of consumers surveyed in the United Kingdom considered natural products to be healthier. The same opinion was held by the vast majority of consumers in Mexico (above 80%). In the USA, 70% of consumers shared the same perception. Although the belief that additive-free products and unprocessed food are healthier does not always have a scientific basis, the clean label trend has spurred efforts to find acceptable alternatives to ingredients that are viewed negatively by consumers, which can provide the same processing functionalities, taste and texture.

3.1. Clean Label for Gluten-Free Baked Goods

The gluten-free baked goods currently available to buy are to a large extent based on starch blends or alternative wheat-free grains. These ingredients have different organoleptic values from those used in traditional wheat bread, and their taste is often considered unpalatable. Moreover, gluten-free baked goods have a lower nutritional value and the staling process is quicker than in traditional wheat bread. Gluten-free products are one of the most challenging food categories to formulate for clean label. Such aspects as availability of proper clean label raw materials, repeatability of recipes and processes as well as the economical focus of the solution need to be taken into consideration. Additionally, choosing ingredients that will imitate all the technological properties of gluten is a complex process. Gluten-free raw ingredients also exhibit poor baking properties, requiring the use of technological additives that mimic the texturing properties of gluten. At the same time, the target consumers are particularly conscious of the health and nutritional aspects of food. People on a gluten-free diet due to medical reasons are accustomed to paying more

attention to food labelling. They need to check whether a given product may contain even minimal amounts of gluten, which may have an adverse effect on their health. Additionally, various manifestations of the disease make such people more aware consumers.

3.2. Health Premises for Gluten-Free Diet

Celiac disease is a lifelong autoimmune disease caused by a reaction to gluten. Symptoms of gluten intolerance include bloating, diarrhea, mouth ulcers, tiredness, anemia, osteoporosis, neurological or psychiatric problems and infertility. Occasionally, it can also manifest itself as a skin condition known as dermatitis herpetiformis [5,6], which causes a red, raised rash, often with blisters. As the spectrum of symptoms is very broad, the diagnosis of celiac disease is not easy and involves a number of procedures. In 1969, the European Society for Pediatric Gastroenterology established diagnostic criteria, which have been widely followed since by adult as well as pediatric gastroenterologists worldwide [7]. These guidelines are updated on a regular basis and a new version of the protocol was published in 2020 [8].

The only current treatment option for celiac disease is to adopt a gluten-free diet, avoiding cereals such as wheat, barley, rye, triticale, and in some cases oats (generally due to impurities containing gluten). While celiac disease is a well defined illness, there is perhaps less understanding of gluten sensitivity, which affects many people—who are said to suffer from non-celiac gluten sensitivity (NCGS) [6,9–11] or non-celiac wheat sensitivity [12]. Some consumers are also allergic to the proteins found in wheat. Many proteins are implicated in causing such allergies. The up-to-date version of the WHO/IUIS Allergen Nomenclature Database describes 21 well classified wheat allergens. Symptoms are triggered by the immune system a short time after ingestion of wheat. Some of the most common symptoms are similar to those associated with other common allergies, such as hay fever or pet allergies, but can also include stomach problems (diarrhea, bloating) and in serious cases anaphylaxis [6,13].

However, it has to be noted that strict gluten-free diet may not provide the recommended amount of essential vitamins and minerals. According to Grace-Farfaglia [14] an investigation of newly diagnosed Australian patients revealed that following a gluten-free diet after just a year can lead to a deficiency of such ingredients. This may cause further illnesses such as i.e., anemia or cardiovascular disease. Due to the fact that gluten-free breads present on the market, to a large extent, are based on starch blends, patients may also be more prone to obesity (exceeded body mass index). Another consequence of the diet is the change in diversity and composition of the intestinal microbiota (reduction in *Lactobacillus* and *Bifidobacterium* species) [14,15]. However, Melini et al. [15] observed that there is no worldwide nutritional profile of gluten-free goods. Differences between products manufactured in various countries are observed. Between brands and food categories the same phenomenon is being noticed. Products with a similar nutritional profile to that of conventional baked goods (containing gluten) are also available on the market.

Following a gluten-free diet is challenging for a number of reasons. Here, economic aspects (higher prices than gluten-containing breads), organoleptic aspects, less product choice both in shops and restaurants as well as time consumption, etc., should be mentioned. However, people who decide to follow the gluten-free diet for a variety of reasons, not always medical ones, find their symptoms, which most often include digestive problems, feeling unwell, and fatigue, to be alleviated.

3.3. Scale of the Problem

The incidence of celiac disease has increased several-fold in recent decades and is now estimated to affect around 1% of the world's population—1.4% based on serologic test results, 0.7% based on biopsy results. The frequency of this disorder varies with sex, age, and location [16–19]. In Europe, although some areas have a similar distribution of causal factors (Sweden, Finland, Germany), significant differences in the incidence of the disease have been observed, at between 2–3% and 0.2% of the total population [17].

Several factors are believed to influence the prevalence of celiac disease. The list of agents includes but is not limited to: population genetics, gluten exposure, feeding patterns, other environmental risk factors, increased wheat ingestion and infections early in life. However, the evidence is not yet conclusive. Increased disease awareness among both patients and physicians and advances in diagnosis may also be factors [5,20,21]. Between 0.5% and 6% of the population is estimated to suffer from non celiac gluten sensitivity. However, the definitions of the disease used in different reports vary widely and the data are unreliable [10]. The prevalence of wheat allergies varies from 0.1% to 4%, depending on the analytical method used, age, and region. It is usually estimated at around 1% [22,23].

The vast majority of people struggling with celiac disease are undiagnosed. For example, Coeliac Australia, the national organization supporting Australians suffering from coeliac disease, estimates that around 80% of local people having this disease remain undiagnosed [24].

4. Market for Gluten-Free Products

The number of consumers adopting gluten-free diets is increasing constantly. This may be attributed to various reasons, including improved diagnosis of celiac disease, the availability of information about the disease and the belief of some consumers that the gluten-free diet is healthier than a conventional diet. A 2017 survey of USA consumers who eat gluten-free bread found that 31% do so as a lifestyle choice [25]. As a result of increased demand for gluten-free options, more and more products are appearing on shelves with the Crossed Grain symbol (Figure 1) [26], including in the bakery market segment (Figure 2) [26]. It is noteworthy that the total number of gluten-free products launched in all food categories, including in baked goods, has been growing year on year for the past decade. In 2020, a slight decrease was observed, most likely due to the COVID-19 pandemic.

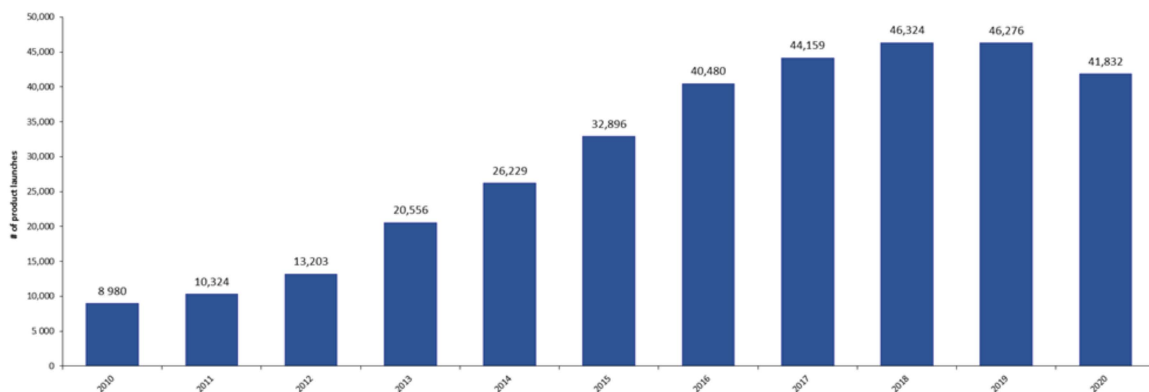


Figure 1. Total number of gluten-free products launched in all food categories worldwide [26].

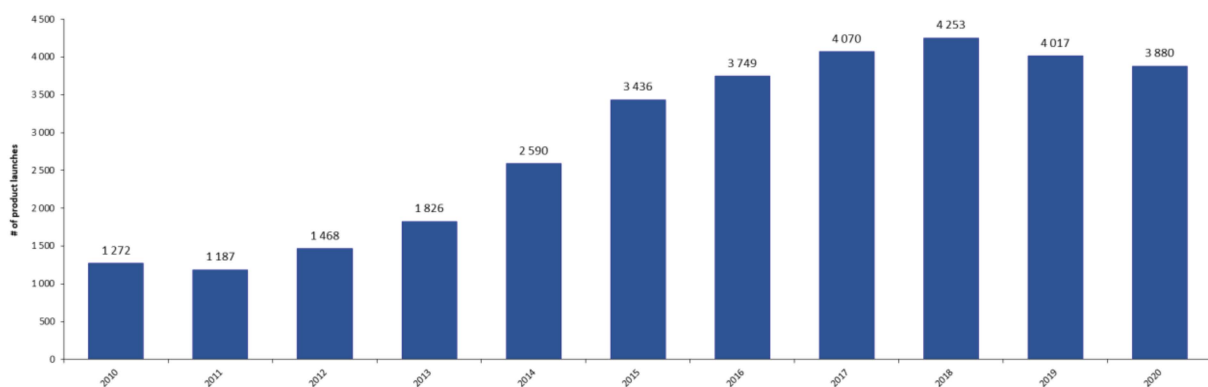


Figure 2. Total number of gluten-free baked goods launched worldwide [26].

A new phenomenon is the rising interest in gluten-free food among healthy people who are convinced of its beneficial effects and consciously choose gluten-free products. With numerous stories about food allergies in the popular media, descriptions of reactions to wheat consumption, and reports of celebrities who spontaneously adopt a gluten-free diet, the size of the gluten-free market has grown significantly. The gluten-free market was valued at \$4.3 billion in 2019, and is estimated to reach \$7.5 billion by 2027, registering a CAGR of 7.2% from 2020 to 2027 [27]. However, the current COVID-19 pandemic is projected to have at least a moderately negative impact on the global food market.

People who are on a gluten-free diet due to their choice (trends followers, family members supporters etc.), and on average, consumers pay attention to product labelling. Additionally, both claims are often associated with a better-for-you choice.

5. Technological Aspects

Gluten has a technological function in conventional bakery products. As a high-quality protein with high functionality, it is responsible for the creation of a spatial network in bread dough. This gluten matrix is a major factor determining the rheological features of wheat dough, including but not limited to elasticity, extensibility, mixing tolerance, and gas holding capacity. Carbon dioxide generated during the fermentation process is retained in the matrix, producing the proper crumb structure and volume desired by consumers. Furthermore, the gluten's properties for binding significant amounts of water result in appropriate moisture of the bread crumb.

A series of studies have been conducted over the years to measure the basic characteristics of gluten and wheat doughs, using oscillation [28–32], stress relaxation [33], creep [31,34], creep-recovery [28,32], and uniaxial compression [28,35], among others. These studies have revealed a connection between the physical character of dough and gluten on one hand, and the protein composition and extent of glutenin polymer formation on the other [28]. Edwards et al. [31] similarly observed that a higher content of glutenin increased the strength of the dough network, whereas gliadin enhanced the viscous flow properties and weakened the mixing strength of the dough. These findings are supported by research by Janssen et al. [29] and Lee et al. [33]. In short dough, the lack of gluten can have an impact on the distribution of water. As a result, rheological properties of the non-fat phase, and hence the mixing properties, might be affected as well [30]. Other dough constituents, such as sucrose, also affect solvent quality and thereby possibly the properties and development of gluten. Processing conditions (mixing time, intensity of mixing) can also influence the rheological properties of dough [34].

Many researchers have studied the correlation between rheological properties and the quality attributes of the end-products [36–39]. According to Autio et al. [36], no single rheological parameter is sufficient to predict the baking quality of different bread wheat flours. Wang and Sun [38] observed a high correlation between the maximum recovery strains and the baking volumes of flours. They concluded that higher recovery strains favored larger loaf volumes. Furthermore, dough springiness or elasticity can have an important influence on bread volume. Bran reincorporation into the gluten network deteriorates dough properties such as mixability, viscosity, resistance to extension, and extensibility. Bran causes thinning and weakening of the gluten matrix. As a result, it decreases the specific volume, moisture, and water activity, resulting in harder bread [39].

6. Gluten Substitutes

Most often, gluten-free products use hydrocolloids to perform the function of the gluten network. These long-chain biopolymers with high water-binding ability are usually plant secretions (e.g., guar gum), substances produced by microorganisms (xanthan), or plant materials modified by chemical and physical methods (cellulose derivatives). However, all are classified as food additives under the provisions of the food law and have E numbers in accordance with the EU regulation no 1333/2008 [1]. The number of such stabilizers and thickeners can be applied in the production of high quality gluten-free

bread, including gelatin [40], hydroxypropyl methylcellulose (HPMC) [41–44], sodium carboxy methyl cellulose (CMC) [40,45], psyllium [41,43], β -D-glucan [45,46], pectin [45], carrageenan [40], and xanthan [41,42,45,47].

An adequate water content as well correct water distribution in the matrix is essential when producing different gluten-free breads. It was found that higher hydration level has a positive impact on the specific volume and height of the loaf as well as on crumb firmness. The interactions of HPMC and water have a strong effect on crumb grain structure [44]. In formulas with a high water content, studies confirmed an association of batter consistency and bread volume. A number of factors and conditions are involved in the process such as the type and amount of hydrocolloids added, the amount of water added, and the interactions between the hydrocolloid and batter ingredients. [40,41].

Hager et al. [42] found that hydrocolloids impact on gluten-free model systems may vary depending on the raw ingredients used. HPMC improved the volume of teff and maize breads while decreasing the size of rice breads. The volume of buckwheat bread did not change. The usage of xanthan had a negative impact on the loaf volume of all studied breads. The addition of HPMC had a positive effect on crumb hardness of each and every bread type. The crumb hardness of the teff and buckwheat breads was increased by the addition of xanthan gum. The opposite effect was observed in the case of maize breads, whereas xanthan gum had no impact on rice bread crumb hardness. Table 2 summarises the impact of thickeners on volume and crumb hardness depending on the raw material.

Table 2. Impact of thickeners on volume and crumb hardness depending on the raw material [42].

Raw Material	HPMC		Xanthan	
	Volume	Crumb Hardness	Volume	Crumb Hardness
Buckwheat	No impact	Positive impact	Negative impact	Negative impact
Teff	Positive impact	Positive impact	Negative impact	Negative impact
Maize	Positive impact	Positive impact	Negative impact	Positive impact
Rice	Negative impact	Positive impact	Negative impact	No impact

Crumb grain characteristics such as the surface area of cells and cell wall thickness were also influenced by the hydrocolloids. Lazaridou et al. [45] reported that the influence of specific hydrocolloids on bread quality depended on the type and the amount. The high rigidity of doughs bearing xanthan had a twofold impact on breads characteristics. A negative effect was observed on loaf volumes, and a positive one on the elasticity of the crumb. The usage of β -D-glucan had a beneficial outcome in terms of bread loaf volume at both addition levels. An improved porosity was observed using 1% of β -D-glucan. Agarose at concentrations of up to 1% also had a positive effect on loaf volume. The formulations bearing 1% of CMC or 2% of pectin resulted in breads with substantially improved breads characteristics such as volumes, crumb porosity and elasticity [45]. Table 3 summarises the impact of thickeners on volume, porosity and crumb elasticity depending on the dosage. McCarthy et al. [44] report that water has a greater effect on the quality of GF bread than HPMC.

Of the substances mentioned above, only psyllium and β -D-glucan can be considered as potential replacements for gluten in clean label formulations. The other substances have E numbers, which many consumers associate with artificial additives and chemicals.

Table 3. Impact of thickeners on volume, porosity and crumb elasticity depending on the dosage [45].

Hydrocolloid	Dosage %	Volume	Porosity	Crumb Elasticity
Pectin	1	No impact	Positive impact	Negative impact
Pectin	2	Positive impact	Positive impact	Positive impact
CMC	1	Positive impact	Positive impact	Negative impact
CMC	2	Negative impact	No impact	Positive impact
Agarose	1	Positive impact	Negative impact	Negative impact
Agarose	2	Negative impact	Negative impact	Positive impact
Xanthan gum	1	No impact	Positive impact	Negative impact
Xanthan gum	2	Negative impact	Negative impact	Positive impact
Beta glucan	1	Positive impact	Positive impact	Negative impact
Beta glucan	2	Positive impact	Positive impact	Positive impact

7. Use of Fiber

Several studies have shown that the type and origin of fiber can affect not only the specific volume, apparent viscosity, and consistency of gluten-free dough, but also the sensory perception, shelf life, and texture of baked goods. The fiber length, degree of polymerization, soluble/insoluble fiber ratio, level of enrichment and the interaction of fiber with other ingredients are the key parameters [48–51]. Various sources of fiber have been investigated, including by-products of milling and fruit processing, such as inulin [47,50–52], apple [48,53], maize [54], sugar beet [53,55], oat fiber [47,54], psyllium [48,55], tomato [48], wheat [54], barley [54], pectin [52], soya [52], and lupin [52]. However, these fibers are treated as enrichment ingredients and not as structure-forming agents. The incorporation of fiber also has a beneficial impact on the nutritional properties of gluten-free baked goods. To limit its negative effects, the optimization of hydration is again essential. The addition of insoluble fibers with high water capacity can lead to an excessive bread hardness if an adequate amount of water is not incorporated into the formulation [47,55,56].

As a consequence of high water-binding capacity, oat β -D-glucan affects the ratio of the viscous portion of the batter to the elastic portion. The incorporation of inulin does not cause significant changes in the structure of the batter. The use of inulin affects crumb hardness and the rate of staling. Although β -D-glucan is partly degraded during bread production, Hager et al. [47] recommended this fiber for increasing the nutritional value of gluten-free bread. According to Korus and Achremowicz [48], the use of psyllium (addition level 5–10%) can have a very positive influence on crumb hardness. Crumb hardness fell by 52.5–67.0% in comparison to the reference bread on day 0, and by 37.4–57.7% on the fourth day of storage. Similar findings were reported for apple fiber. Crumb hardness was lowered by 30.5–64.2% on day 0 and by 13.8–51.0% after 4 days [48]. These results are similar to those reported in a study by Cappa et al. [55]. A more effective antistaling effect of psyllium vs. sugar beet fiber was observed after three days of storage, presumably due to the higher water binding capacity of psyllium. Another study has shown that apple fiber in comparison to sugar beet fiber was more efficient in terms of the improvement of gluten-free bread specific volume, crumb softness, and chewiness. Gluten-free breads containing 4 g/100 g HPMC and 3, 5, 7 g/g sugar beet or apple fiber were rated as excellent by a sensory evaluation panel. They were characterized by an appealing crust and crumb color and a fine crumb texture. Proximate composition analysis results for gluten-free breads containing 3 and 7 g/100 g sugar beet or apple fiber show a nutritional profile similar to commercially available gluten-free breads fortified with fiber [53].

Morreale et al. [50] suggest that inulin-type fructans might be impacted by processing, depending on their degree of polymerization (DP). Low DP inulins are hydrolyzed to some extent during breadmaking, which affects both the final fiber content in the bread and its structuring potential. Therefore, special attention should be paid to the selection of the type of inulin. According to this research, it is also advisable to use yeast with low invertase activity to leaven inulin-containing gluten-free baked goods. Inulin overdose (10% content in the recipe) is necessary to obtain 3% fiber in the final baked goods [50].

Diowksz et al. [52] investigated the impact of fortifying gluten-free breads with fiber preparations of various origins. Fiber formulations (in paste form) were used alone or in combination. The rheological properties of the gluten-free batters were examined, as well as the volume and porosity of the bread crumb. It was found that lupin fiber alone or in combination with inulin had the most beneficial effect on the rheological properties of the batter. Lupin fiber also had the most beneficial effect on the volume and porosity of the bread. This research confirmed previous observations regarding the significant difference between the rheological properties of doughs fortified with only one type of hydrocolloid and those fortified with a blend of two or more. By using mixtures of polysaccharides, it is possible to obtain compounds with much higher viscosity than with a single hydrocolloid. The influence of the high absorption capacity of fibers on the rheological properties of dough was also highlighted.

8. Prospective Gluten Substitutes with Clean Label Status

8.1. Beta Glucan

β -glucans are the primary constituents of the cell walls of cereal grains. Oat and barley have been found to contain 70% β -(1 \rightarrow 4)-linked and 30% β -(1 \rightarrow 3)-linked β -D-glucopyranosyl residues organized in blocks of β -(1 \rightarrow 4)-linkage sequences (cellotriosyl and cellotetraosyl cellulose-like segments) separated by single β -(1 \rightarrow 3)-linkages [57]. Other types of β -glucan [(1 \rightarrow 3), (1 \rightarrow 6) β -glucan] have been found in fungi. However, due to their different structure, such β -glucan have totally different properties. Physical properties, such as water solubility, water binding capacity, wettability (how easily the powder sinks in water), dispersibility (the ability of the powder to distribute homogeneously in water when stirred), and viscosity, as well as gelation properties result from the molecular and structural features of cereal β -glucans [58]. Usage of the β -D-glucan rich oat and barley fractions at certain concentrations, may lead to loaf volume increase [59]. This can be explained by the increase in dough viscosity, which is itself due to the high water binding capacity of β -D-glucan. In wheat baked goods, (1 \rightarrow 3)(1 \rightarrow 4) β -D-glucans have a positive effect on crumb grain. They seem to stabilize air cells in the bread dough and prevent coalescence of the cells. This may result in a reduction in the mean cell size [60]. High molecular weight (1 \rightarrow 3)(1 \rightarrow 4) β -D-glucans have a large surface area per unit of weight. This enables them to improve the extensibility of the dough and to stabilize gas cells. An aspect of gas cell stabilization was analyzed by Gan et al. [61], who suggested that a large quantity of fluid was structured in the dough phase, thereby improving the mechanical strength of the liquid film. This dual film hypothesis was confirmed by Sroan et al. [62]. The possible existence of the coalescence and disproportionation of gas cells phenomenon at the end of proofing process, as well as in the early baking stages of breadmaking is limited by liquid lamellae [62].

From a physiological point of view, β -D-glucan forms a viscous gel in the stomach, which traps nutrients and slows the digestion of food by digestive enzymes. This results in slower gastric emptying and steady, more sustained absorption of sugars, reducing the post-prandial glycaemic response. In Europe, EFSA and the European Commission have granted two health claims of oat β -D-glucan (European Commission Regulation, Article 13.1) [63].

Pastuszka et al. explored the impact of replacing part of the hydrocolloids blend with β -D-glucan [64]. They concluded that 0.5–1.0% β -D-glucan had no significant effect on bread quality parameters (mass, volume, yield and total baking loss). Baked goods were highly sensory-rated by consumers (classified as first quality class). The use of 1.5% β -D-glucan did not have a significant effect on most of the qualitative features of the final product, except for reducing the volume. Additionally, these breads were classified the same way although they had a smaller volume. Increasing the β -D-glucan content (up to 2.5%) resulted in a significant deterioration of quality attributes resulting in sensory disqualification by consumers. Karp et al. [65] studied the application of β -D-glucan in gluten-free yeast leavened cake. Experimental samples were prepared with different

amounts of β -D-glucan. The reference structuring agent was HPMC. Both β -D-glucan and water had a significant impact on the gluten-free yeast-leavened cake. The oat β -D-glucan not only increased the specific volume and lightness, but also decreased the color and firmness. Bread characteristics that were lower such as baking yield, specific volume, and lightness were impacted by water. It can be concluded that the usage of oat β -D-glucan in gluten-free baked goods is feasible when the water content is well optimized.

8.2. *Psyllium*

Psyllium consists of approximately 80–90% soluble fiber and is an exceptional resource of both soluble and insoluble fractions. According to Fischer et al. [66], this compound is typically composed of 75% xylose, 23% arabinose and small quantities of other sugars. Containing about 35% non-reducing terminal residues, the polysaccharide is highly branched acidic arabinoxylan containing both (1–4) and β -(1–3) glycosidic linkages in the xylan backbone. Psyllium has technological limitations due to its strong water uptake and gelling properties, creating solutions with high viscosity. Each gram of psyllium binds approximately 10 g of water [67]. Cappa et al. [55] remark that the enrichment of gluten-free baked goods with psyllium must be carefully modulated, as it could lead to excessive bread hardness if inadequate amounts of water are added to the recipe. Korus and Achremowicz [48] have also investigated the effect of using psyllium on the properties of fiber-enriched gluten-free bread. They found that the addition of 5–10% psyllium is able to reduce crumb hardness by 52–67% and also effectively elevates bread yield, due to its high water binding capacity. In a study by Mariotti et al. [67], psyllium fiber was found to generally enhance the physical characteristics of doughs, due to the film-like structure it created during kneading. Fratelli et al. [68] report that the use of psyllium has a positive impact on the volume, appearance, crumb structure and crumb characteristics, and general acceptability of gluten-free breads. Its use in baked goods can also decrease the glycemic response.

Zandonadi et al. [69] evaluated the impact of using psyllium on the sensory properties of gluten-free baked goods. The results of the study indicate that gluten-free bread containing psyllium was similar to conventional wheat-based bread in all evaluated sensory parameters (color, odor, taste, texture, and general evaluation). The analyzed bread was accepted by more than 93% of consumers both with or without celiac disease.

8.3. *Transglutaminase*

Enzymes are widely applicable as processing aids in the food industry. With some exceptions, they do not have E numbers. As typical proteins, enzymes are destroyed by the high temperatures during baking, so they are not listed on the product label. One enzyme that can be used in clean label baked goods is transglutaminase. Transglutaminase catalyzes acyl transfer reactions between the γ -carboxamide group of L-glutamine and primary amines. Research has demonstrated that transglutaminase not only affects the protein structure, but also the rheological and viscoelastic properties of dough, enhancing gluten strength. As a consequence, gas retention, dough stability as well as the volume and bread structure is being improved, moreover, the bread crumb is strengthened [70,71].

Transglutaminase has an impact on dough water absorption, viscoelastic behavior, and thermal stability. In a study by Huang et al. [70], the water absorption of oat dough was found to decrease as the enzyme level increased. Protein cross-linking was observed, as well as the formation and stabilization of a network structure. The longer dough development time and increased stability indicate that the elasticity of the oat dough was strengthened by enzyme activity. Ogilvie et al. [71] reported similar results for wheat-based doughs. Transglutaminase increased dough resistance by about 60%, while decreasing extensibility by around 57%, so the dough was tougher but less pliable. It is interesting to note that with higher enzyme content, the loaf volume diminished rapidly, with a corresponding increase in its weight. This can be explained by the fact that when the dough consistency is too tight, dense air cells are not able to develop. As a consequence, a sufficient amount of

gas is not trapped in cells and its expansion during baking is not possible. This leads to a smaller bread volume, which in turn slows the rate of water evaporation during baking. As a result, the overall loaf weight increase is being observed.

Moore et al. [72] examined the correlation between transglutaminase and three protein sources (soya flour, skimmed milk powder, egg powder) in gluten-free breads. No significant effects were seen in breads containing soya flour. However, in case of breads with skimmed milk powder and egg powders, the usage of transglutaminase led to formation of a stable protein network. Shin et al. [73] investigated the effects of transglutaminase and three types of proteins (whey protein, sodium caseinate, soy protein isolate) on gluten-free rice breads prepared using non-waxy rice flour. Different effects of the simultaneous use of the enzyme and protein were noticed. In the case of crumb hardness, an improvement was observed, while in the case of springiness, no impact was detected. The protein and transglutaminase were involved in the formation of a network that retained carbon dioxide. As a consequence, the bread volume increased. The highest volume increase was observed for a combination of the enzyme with soy protein isolate and whey protein. There was no significant difference between the volumes of the prototypes with sodium caseinate and those of the samples with caseinate and transglutaminase.

Onyango et al. [74] investigated the impact of transglutaminase on the properties of gluten-free formulations consisting of pregelatinized cassava starch, sorghum, and egg white. Increasing the storage time led to crumb cohesiveness, chewiness, and resilience reduction, whereas increasing the enzyme content had a positive impact on firmness and chewiness. However, increasing the enzyme concentration beyond a specific point did not induce any further fundamental alterations in the rheological quality of the batters and breads. Renzetti et al. [75] investigated the impact of the mentioned above enzyme on various proteins such as albumin, globulin, and glutelin derived from buckwheat flour. The enzyme was not fraction specific; all protein types were involved in network formation. Furthermore, the enzyme was reactive towards both the acidic and basic subunits of the protein fractions. These fractions showed high levels of both glutamine and lysine residues. It may be inferred, therefore, that protein reactivity depended mostly on the accessibility of both ingredients.

Renzetti [76] showed that by using transglutaminase in gluten-free bread systems it is feasible to create a stable network. However, both the structure and the composition of the proteins seem to be key elements determining the influence of the enzyme. The availability and specificity of certain aminoacids, such as glutamine and lysine, in the protein matrix is essential, as these are substrates for the cross-linking reaction. Lysine may even be the limiting factor in such reactions. The different effects of transglutaminase on ingredients with similar glutamine and lysine contents can be explained by the differences in substrate accessibility. The amounts of enzymes added can also play an important role, as demonstrated by Sadowska and Diowski [77]. In their study, increasing the dose of transglutaminase resulted in an increase in the volume of buckwheat bread. The enzyme also improved the porosity of the crumb by increasing the number of small, thin-walled, and evenly spaced cells.

9. Conclusions

In recent years, there have been efforts by the baking industry to replace chemical compounds and additives with E numbers, in response to demand from consumers for more natural and sustainable products, with a “clean label”. However, producing gluten-free breads to clean label standards is much more challenging, due to the difficulty of obtaining a good quality product without using numerous functional additives products. The use of texturants of natural origin (classified as food ingredients without E numbers) is a promising avenue for manufacturing gluten-free bakery goods with clean label status. More research is needed to optimize the use of clean label ingredients in gluten-free recipes. The possible synergistic effects of combinations of natural texturants should also be explored.

Author Contributions: Conceptualization, M.K. and A.D.; investigation, M.K.; resources, M.K. and A.D.; writing—original draft preparation, M.K.; writing—review and editing, M.K. and A.D.; supervision, A.D. Both authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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