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Review Article

Technological and Health-Related Aspects of Gluten - a

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ABSTRACT

Gluten is a composite of storage proteins found in the endosperm of wheat, rye and barley, and their hybrids. This protein of the unique viscoelastic properties is characterized by the beneficial technological properties. Gluten contributes to the batter emulsification, provides cohesiveness to dough during processing, retains leavening gases, sets the crumb structure and imparts elasticity to the bread texture. Although cereals are used extensively in food production, their proteins cannot be tolerated in some individuals. Gluten and other wheat components are the triggers of a wide range of gluten-related and wheat-related disorders, like coeliac disease, wheat allergy and gluten sensitivity. In this article a "dual nature" of gluten is discussed, firstly, its technological properties then, its role as a factor contributing to several disorders.

KEYWORDS: Cereals; Wheat; Gluten proteins; Technological properties; Coeliac disease; Gluten-free diet

INTRODUCTION

Cereals, including wheat, barley and rye, are important source of well-balanced macro- and micronutrients therefore, their role as the essential component of the daily diet is emphasize in the nutritional recommendations and guidelines. Cereals supply a great amount of vegetable proteins. One of them is gluten, characterized by the beneficial technological properties. In the traditional breadmaking, cereals containing gluten are milled into flour and used to make different types of bread, rolls and cakes. Gluten provides a high quality of these products. From the other side, gluten is the major trigger of a range of gluten-related disorders. The need of avoidance of wheat- and gluten-containing products is a worldwide problem. Coeliac disease is one of gluten-related disease, but gluten can be a trigger of other allergic reactions/intolerances. In this short review a "dual nature" of gluten will be presented.

TECHNOLOGICAL ASPECT OF GLUTEN

The Egyptians gave a bread baking the art dimension. Consequently, the bread making techniques spread to all parts of Europe. Bread as well as other baked products became staple food for ages. Their ubiquitous consumption placed baked products in a position of a global importance in international nutrition. However, the successful bread baking performance could not exist without its essential component – gluten. Gluten is a heterogeneous mixture of storage proteins found in the endosperm of the mature grain of wheat and same other cereals within the grasses family, including rye and barley. It consist mainly of protein (75-85%) and lipids (5-10%); most of the remainder is starch and non-starch carbohydrates, being the residue occurring after washed out the starch granules and other soluble substances from the wheat flour [1]. Based on the solubility in alcohol–water solutions, gluten proteins have been generally divided into the soluble gliadins and the insoluble glutenins. Both fractions are characterized by high content of glutamine and proline [2].

Gliadins are a mixture of heterogeneous monomeric proteins, divided into α/β, γ and ω-gliadins. α/β and γ-gliadins are low molecular weight proteins (MW 28–35 kDa) with six and eight cysteine residues respectively, whereas ω-gliadins (MW 40–75 kDa) lack cysteine [1]. The glutenin fraction comprises aggregated proteins linked by interchain disulphide bonds; they have varying size ranging from about 500,000 to more than 10 million [3]. Due to their unique physicochemical properties, gliadins and glutenins are equally responsible for the viscoelastic properties of dough. In comparison with glutenins, gliadins are less elastic and less cohesive; they contribute mainly to the viscosity and extensibility of the dough; in contrast, hydrated glutenins are responsible for dough strength and elasticity. Gluten is formed when wheat flour and water are simply mixed together. Under conditions providing sufficient dough hydration and when the dough is optimally developed by the mixing process, the disruption of the initially spherical protein particles takes place, together with the stretching and alignment of proteins, which leads to the formation of a three-dimensional structure. By holding gases produced during dough proofing or fermentation, the gluten network allows bread to rise. Finally, during the baking, which is the last step of breadmaking, gluten changes its characteristics from elastic to semi rigid, contributing to the change from dough to crumb. The crumb structure is then formed. These functions of the gluten network are what give bread its chewy and elastic texture.

GLUTEN-FREE TECHNOLOGY

Recently, the rising prevalence of gluten-related disorders parallels with the increasing demands for gluten-free products, including bread. The replacement of gluten is yet a technological challenge, as it is an essential structure-building protein which is necessary for formulating high quality cereal-based goods, thus the production of such products is difficult.

Gluten-free baking technology is different from the traditional processing of gluten-containing cereal foods. Gluten-free dough itself varies considerably from wheat dough; it is more like a batter than a wheat bread dough [4]. The consistency of the gluten-free dough is greatly dependent on the amount of water or hydration, showing very low consistency during mixing when water adsorption is higher than 90% [5]. From that reason, the technology of gluten-free dough does not require kneading, like standard dough do, and it is blended in the mixer. Despite the intensive development of the gluten-free production, still many baked gluten-free breads and confectionery currently on sale are of inferior quality. The lack of gluten makes it very difficult to obtain the acceptable texture and volume of baked goods because of the absence of a proper protein network necessary to hold the carbon dioxide produced during proofing. Therefore, obtained products have a crumbling texture and a pale crust [6]. Furthermore, gluten-free products, mainly composited of different starches, age very fast and are characterized by a reduced quality compared to gluten-containing counterpart. Additionally, gluten-free products are often of a low nutritional value. They lack several important nutrients, especially proteins and mineral components, as well as non-nutritional but physiologically important components, like dietary fibre. For that reason, the efforts are made to improve the nutritional value of gluten-free products. Several dairy ingredients were used in the production of gluten-free goods resulting in nutritional benefits and improved volume, appearance, and sensory aspects of the loaves [5, 7, 8]. The application of calcium supplements as dough components affected gluten-free bread enriched in calcium and of improved overall quality [9, 10]. Highly nutritional grains,

like quinoa, teff, buckwheat and amaranth were also applied in the production of gluten-free bakery goods [11-13]. Rice, corn, soya, millet, buckwheat and potato starches, in combination with different fat sources (palm oil, cream powder, microencapsulated high fat powder and low fat dairy powders) were applied in the gluten-free biscuits formulation [14].

GLUTEN - A COMMON DENOMINATOR OF ALLERGY, INTOLERANCE AND SENSITIVITY

Although wheat, barley and rye are used extensively in food products, they cannot be tolerated in some individuals. Ingestion of gluten-containing food has been associated with gluten-related disorders, among which the best known are diseases mediated by the adaptive immune system: coeliac disease and wheat allergy.

Coeliac disease (CD) is a lifelong intestinal disorder that occurs in genetically predisposed individuals characterized by specific autoantibodies against tissue transglutaminase and endomysium. This disease is characterized by an immune reaction to the gliadin fraction of gluten. The clinical presentation of CD varies widely and depends on the patient's age, duration and extent of disease, and presence of extra-intestinal manifestations. In CD, a mucosal inflammation and villous atrophy is observed [15]. Its proximal location in the small intestine often results in malabsorption of calcium, iron, folic acid and fat-soluble vitamins. Screening studies have shown that the general prevalence of CD is about 1%, although differences have been observed across different European countries (from 0.3 up to 2.4 %) [16], and over the years, its occurrence has been increasing considerably.

Wheat allergy (WA) is an adverse reaction to wheat proteins, caused by an immunological mechanism. A factor causing allergic reactions to wheat are not only gluten proteins, but also other non-gluten wheat components. WA diagnosis is based on the determination of the level of specific IgE levels and skin tests. Allergic reactions can result from wheat consumption, but also, in some cases, by inhaling wheat flour. It is assumed that about 0.4 % of the world's population (mainly children) suffers from this type of allergy [17]. WA symptoms may varies depending on the method of exposure to allergen and the mechanism of immune response. The symptoms of wheat allergy develop within minutes to hours after gluten ingestion and include itching and swelling in the mouth, nose, eyes and throat, skin rash and wheezing, and life-threatening anaphylaxis [18]. The gastrointestinal manifestations of wheat allergy may be similar to those of CD but instead does not cause permanent intestine damage [19]. Much of the research on adverse allergic reactions to wheat has focused on respiratory allergy (baker's asthma), which is one of the most prevalent occupational allergies in many countries [17]. Although it is less common than CD, WA affects a high proportion of food-allergy sufferers in Northern Europe.

Besides CD and WA, there are cases of gluten reactions in which neither allergic nor autoimmune mechanisms are involved. Non coeliac gluten sensitivity (NCGS) is a condition in which symptoms are triggered by gluten ingestion, in the absence of CD-specific antibodies and of classical coeliac villous atrophy, with variable Human Leukocyte Antigen (HLA) status and variable presence of first generation anti-gliadin antibodies (AGA) [20]. The prevalence of NCGS is still unknown. However, NCGS occur very often in adults with irritable bowel syndrome (IBS) and IBS-like symptoms [18].

Currently, a strict and life-long adherence to a gluten-free diet (GFD) is considered to be the only medical nutrition therapy for patients suffering from CD. At the same time, GFD is the only proven treatment that results in improvements in symptomatology and small bowel histology [21]. Patients with WA also benefit from the GFD, although these individuals often do not need to restrict rye, barley, and oats from their diet. NCGS patients have varying degrees of symptomatic improvement on the GFD [19]. In reality, a complete avoidance of gluten intake is very difficult, due to hidden gluten sources and food contamination. United States Food and Drug Administration (August, 2014) has set the limit of < 20 ppm gluten for gluten-free foods.

CONCLUSIONS

Cereals containing gluten and their products are widely consumed in many parts of the world. Widespread use of wheat flour in food is attributed to the viscoelastic properties of its protein – gluten. However, it become evident that in some conditions the ingestion of gluten may cause negative health reactions in some individuals. This article explains the technological aspects of gluten utilization as well as provides the knowledge concerning the phenomena of gluten-related disorders.

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REFERENCES

1. Wieser H. Chemistry of gluten proteins. See comment in PubMed Commons below Food Microbiol. 2007; 24: 115-119.
2. Jansens KJA, Lagrain B, Rombouts I, Brijs K, Smet M, et al. Effect of temperature, time and wheat gluten moisture content on wheat gluten network formation during thermomolding. J. Cereal Sci., 2011; 54(3): 434–441.
3. Wieser H, Bushuk W, MacRitchie F. The polymeric glutenins. In: Wrigley, C., Bekes, F., Bushuk, W. (Eds.), Gliadin and Glutenin: the Unique Balance of Wheat Quality. St. Paul American Association of Cereal Chemistry, 2006, pp. 213–240.
4. Houben A, Höchstötter A, Becker T. Possibilities to increase the quality in gluten-free bread production: an overview. Eur. Food Res. Technol. 2012; 235: 195–208.
5. Marco C, Rosell CM. Breadmaking performance of protein enriched gluten free breads. Eur. Food Res. Technol., 2008; 227: 1205–1213.
6. Wronkowska M, Troszynska A, Soral-Smietana M, Wolejszo A. Effects of buckwheat flour (Fagopyrum esculentum Moench) on the quality of gluten-free bread Pol. J. Food Nutr. Sci., 2008; 58(2): 211-216.
7. Nunes M, Ryan L, Arendt EK. Effect of low lactose dairy powder addition on the properties of gluten-free batters and bread quality. Eur. Food Res. Technol., 2009, 229, 31–41.
8. Gallagher E, Kenny S, Arendt EK. Impact of dairy protein powders on biscuit quality. Eur. Food Res. Technol., 2005; 221: 237–243.
9. Krupa-Kozak U, Troszynska A, Baczek N, Soral-Smietana M. Effect of organic calcium supplements on the technological characteristic and sensory properties of gluten-free bread. Eur. Food Res. Technol., 2011, 232, 497–508.
10. Krupa-Kozak U, Altamirano-Fortoul R, Wronkowska M, Rosell CM. Breadmaking performance and technological characteristic of gluten-free bread with inulin supplemented with calcium salts. Eur. Food Res. Technol., 2012; 235: 545–554.
11. Brito IL, de Souza EL, Santos F, Suenia S. Nutritional and sensory characteristics of gluten-free quinoa (Chenopodium quinoa Willd)-based cookies development using an experimental mixture design. J. Food Sci. Technol.-Mysore, 2015; 52: 5866-5873.

12. Sanz-Penella JM, Wronkowska M, Soral-Smietana M, Haros M. Effect of whole amaranth flour on bread properties and nutritive value. LWT – Food Sci. Technol. 2013; 50: 67-685.

13. Alvarez-Jubete L, Arendt EK, Gallagher E. Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. See comment in PubMed Commons below Int J Food Sci Nutr. 2009; 60 Suppl 4: 240-257.

14. Arendt EK, O'Brien, CM, Schober T, Gormley TR, Gallagher E. Development of gluten-free cereal products. Farm and Food. 2002; 12: 21–27.

15. Gujral N, Freeman HJ, Thomson AB. Celiac disease: prevalence, diagnosis, pathogenesis and treatment. See comment in PubMed Commons below World J Gastroenterol. 2012; 18: 6036-6059.

16. Mustalahti K, Catassi C, Reunanen A, Fabiani E, Heier M, et al. The prevalence of celiac disease in Europe: results of a centralized, international mass screening project. See comment in PubMed Commons below Ann Med. 2010; 42: 587-595.

17. Sapone A, Bai JC, Ciacci C, Dolinsek J, Green PH, et al. Spectrum of gluten-related disorders: consensus on new nomenclature and classification. See comment in PubMed Commons below BMC Med. 2012; 10: 13.

18. Biesiekierski JR, Newnham ED, Irving PM, Barrett JS, Haines M, et al. Gluten causes gastrointestinal symptoms in subjects without celiac disease: a double-blind randomized placebo-controlled trial. Am. J. Gastroenterol. 2011; 106: 508–514

19. Pietzak M . Celiac disease, wheat allergy, and gluten sensitivity: when gluten free is not a fad. See comment in PubMed Commons below JPEN J Parenter Enteral Nutr. 2012; 36: 68S-75S.

20. Catassi C, Bai JC, Bonaz B, Bouma G, Calabrò A. Non-Celiac Gluten sensitivity: the new frontier of gluten related disorders. See comment in PubMed Commons below Nutrients. 2013; 5: 3839-3853.

21. Haines ML, Anderson RP, Gibson PR. Systematic review: The evidence base for long-term management of coeliac disease. See comment in PubMed Commons below Aliment Pharmacol Ther. 2008; 28: 1042-1066.