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Review

Physicochemical alterations of wheat gluten proteins upon dough formation and frozen storage – A review from gluten, glutenin and gliadin perspectives

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ABSTRACT

Background: Gluten proteins are considered as quality determinants in cereal-based food product by forming the backbone structure of dough. Freezing technique has largely expanded the dough shelf life and brought revolutionary development to the bakery industry. However, deterioration of gluten network in frozen dough is one of the major factors leading to the quality loss of bakery products. During the manufacturing process of frozen dough, hydration with optimum mixing is the first and critical step to manage the control dough quality, followed by the freezing and frozen storage to achieve the long time storage of dough, which determines the final dough quality.

Scope and approach: Series of physicochemical alterations in gluten proteins occur upon the dough formation and frozen storage. Understanding these fundamental changes is important for the research community to propose more rational implementation of specific improvement principals for frozen dough. In this review, the physicochemical alterations of wheat gluten proteins are investigated from the perspectives of gluten and its component glutenin and gliadin.

Key findings and conclusions: A more structure-ordered, homogeneous and elastic gluten network is formed at the optimum mixing stage as a consequence of glutenin and gliadin interactions. Comparative studies in different model systems demonstrate that further frozen storage exerts detrimental effects on gluten proteins in diverse ways from both gluten proteins-water interactions and structure-functionality perspectives.

1. Introduction

Bakery product is one of the most important and popular food consumed in the world. Wheat flour, water and leaveners (biological or chemical leavening agents) are the most significant ingredients in a bakery recipe. The basic step in breadmaking is combining water with wheat flour and then kneading the mixture to form a viscoelastic dough (Bushuk, 1985). Flour from wheat, rather than from other cereal grains, is used because only wheat gluten possesses the ability to form three-dimensional network during dough formation.

With a rapid development toward the value-addition sector in bakery industry, freezing technology is increasingly being employed for the preservation of dough. In the last decade, the production of frozen dough kept rising because of direct sales to the consumers and the growing number of in-store bakeries. The growing interest of the market toward frozen bakery goods has

Abbreviations: AA, amino acids; CD, central domain; CLSM, confocal laser scanning microscopy; DSC, differential scanning calorimetry; FTIR, Fourier transform infrared spectroscopy; GMP, glutenin macropolymer; GSH, glutathione; G′, elastic modulus; G″, viscous modulus; G*, complex modulus; HMS, high molecular weight glutenin subunits; LMS, low molecular weight glutenin subunits; Mw, molecular weight; N- and C-TD, amino- and carboxyl-terminal domain; R/E, maximum resistance to extension; RP-HPLC, reversed-phase high-performance liquid chromatography; SDS, sodium dodecyl sulfate; SDS-PAGE, sodium dodecyl sulfate polyacrylamide gel electrophoresis; SEC-MALLS, size exclusion chromatography with multiangle laser light scattering; SEM, scanning electron microscopy; SH, sulfydryl; SS, disulphide; tanδ, loss tangent; TEM, transmission electron microscopy; TD, terminal domain; TD-NMR, time-domain nuclear magnetic resonance; T_p, transition peak temperature; η_0, steady-shear viscosity; ΔH, melting enthalpy.

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been driven mainly by the economic advantage of a centralized manufacturing and distribution process as well as the standardization of product quality (Asghar, Anjum, & Allen, 2011). However, the notorious disruption of gluten network integrity caused by ice formation or recrystallization in frozen dough results in the loss of gas retention (Autio & Sinda, 1992), poor loaf volume and strong alteration in the textural properties of the baked products (Inoue & Bushuk, 1992). This is one of the most serious challenges for the frozen dough industry.

A typical process flow diagram of frozen dough is shown in Fig. 1. Upon the process, the end-use quality greatly depends on the dough formation and further the frozen storage conditions. Crucial changes of gluten network during these two stages were attractive to the researchers for establishing their relationships with frozen dough quality. This review summarizes the current knowledge on the physicochemical changes of gluten proteins upon dough formation and frozen storage from the perspectives of gluten and its component glutenin and gliadin. Suggestions for future research on the subsequent changes of gluten proteins during baking of frozen dough are provided to understand the integrated gluten transformations from farm to fork. However, the complex changes are not fully understood due to not only the diverse wheat cultivars and natural structure of gluten proteins, but with the wide range of reactions occurring during processing.

2. Classification, structure and functionality of gluten proteins

2.1. Gluten

For the common bakery products, wheat gluten is a main determinant for the end-use quality of wheat by conferring water absorption capacity, cohesivity, and viscoelasticity on dough. Both quantity and quality (composition) of gluten proteins are important for breadmaking, these are evident from the observation that breadmaking performance of wheat flour is linearly related with its protein content and that different linear relationships exist for different wheat varieties (Goesaert et al., 2005; Shewry, Popineau, Lafiandra, Belton, & Lellis, 2001). The molecular weight (Mw) of native gluten ranges widely from around 30,000 to more than 10 million.

Gluten can be further divided into two fractions according to the solubility in alcohol–water solutions: the soluble monomeric gliadins (≈50%–60%) and insoluble polymeric glutenins (≈40%–50%) (Payne, Holt, Jackson, Law, & Damania, 1984). They are interchangeably regarded as gluten proteins. The unique viscoelastic properties of gluten are mostly ascribed to the viscous gliadin and elastic glutenin respectively. These two types of protein differ a lot from both structure and functionality. They contribute to the unique properties of gluten and thereby the dough products (Wieser, 2007).

Gluten proteins contain high contents of glutamine, nonpolar amino acid (AA) proline and glycine and low contents of AA with ionizable side chains. They showed high polymerization behavior in liquid solutions, leading to the low solubility together with the lack of crystallinity. This is the main barrier in advancing the knowledge of determining their structures (Veraverbeke & Delcour, 2002). Nevertheless, models have been proposed for gluten polymers to simplify and interpret the structure-functionality relationships. A typical molecular model of gluten is shown in Fig. 2a. In this model, only two classes of protein are distinguished: linear proteins which represent the high molecular weight glutenin subunits (HMS) and globular proteins include low molecular weight glutenin subunits (LMS) and the monomeric gliadin. The linear proteins interact with each other via disulphide (SS) bonding. The chains interact with the globular proteins by SS bonding and non-covalent bonding forces such as Van de Waals interactions. The number of linear–linear protein interactions as well as the number of linear-globular protein interactions depend on the effective length of the linear proteins.

2.2. Gliadin

Gliadins are heterogeneous mixture of monomeric proteins

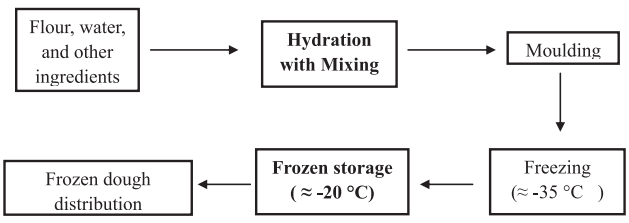

Fig. 1. Manufacturing process of frozen dough.

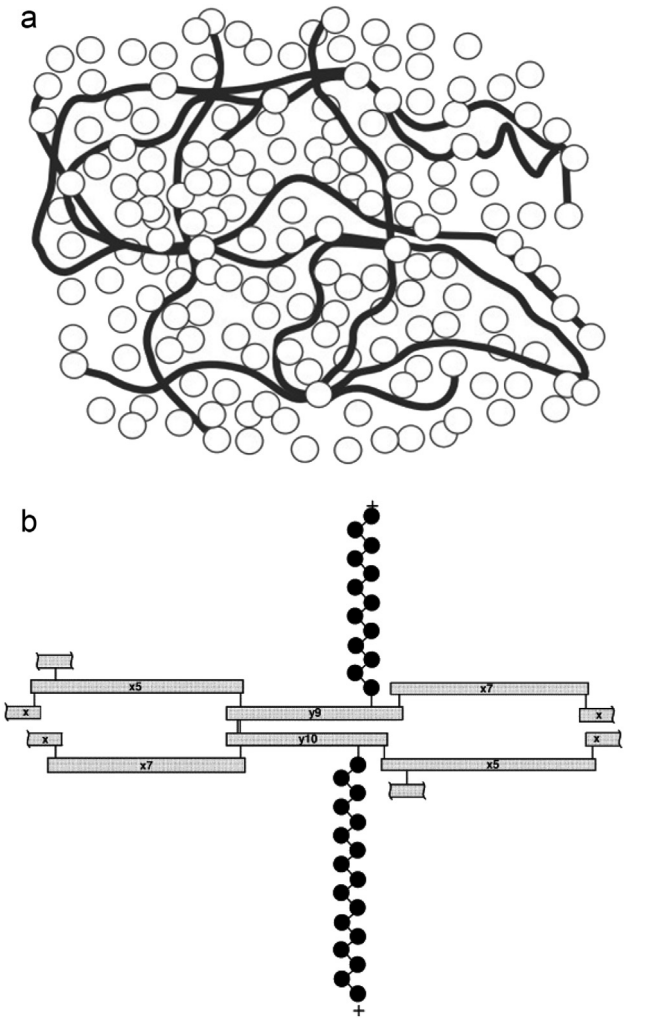

Fig. 2. (a). A model for the molecular structure of gluten. HMS are approximated by linear polymers, LMS and gliadin are approximated by spheres (Adopted from Belton, 1999); (b). A model double unit for the interchain disulphide structures of LMS (●) and HMS (□) of glutenin polymers (Based on Wieser, 2007).

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