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Hydrocolloids in wheat breadmaking: A concise review

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ABSTRACT

The present review analyzes the effect of the most common hydrocolloids on diverse aspects of wheat breadmaking. This encompasses exudate gums, gums from seaweeds, modified celluloses, pectins, galactomannans from leguminous seeds and exopolysaccharides from microbial fermentation. Hydrocolloids are employed to improve dough performance, bread characteristics and sensorial quality. They are also added to minimize non desired changes in crumb texture during storage (anstistaling effect). In bake off technologies (frozen dough, par-baked bread) they can help to preserve the structure from damage by freezing thus rendering acceptable products. Finally, nutritional improved mixtures of wheat and other flours can take advantage from hydrocolloids addition in order to compensate a diminished quality.

1. Introduction

Bread is one the most popular and consumed foods in the world. Bread characteristics depend on both flour quality and the breadmaking procedure. High-quality bread from refined WF (white bread) is characterized by a high volume, soft and elastic crumb with uniform appearance, and a relatively extended shelf life. Flour quality is a key factor for achieving an acceptable product and is mainly related to GP quality and quantity. Since deficiencies in flour quality must be compensated to obtain an acceptable product, the addition of flour improvers (oxidizing agents, emulsifiers and enzymes) is a common practice in breadmaking (Stauffer, 1990). In recent years, there has been increasing interest in hydrocolloids due to their natural origin, effects on dough rheology and bread quality. Hydrocolloids have also been satisfactorily used as antistaling agents. Moreover, new technologies such as BOT (baking off technologies) can use these improvers to compensate for the damage by freezing (Selomulyo & Zhou, 2007).

Nutritional trends towards a more healthy diet have promoted the consumption of WG breads and composite breads (mixtures formulated with WF and flours from other sources) that can include high contents of fiber and/or other beneficial components. Despite the increasing interest in these functional foods, the marked sensory differences with respect to standard products continue to be barriers to consumers' acceptance (Heiniö et al., 2016). Among the strategies to enhance acceptance, the use of hydrocolloids can help improve the technological and sensory quality of these breads. The present review summarizes some topics on traditional and new applications of these additives in breadmaking, with a focus on the contributions from recent years (see Table 1).

2. Hydrocolloids as dough and fresh bread improvers

The mechanisms involved in the effect of hydrocolloids on dough and bread characteristics have deserved considerable attention.

The addition of hydrocolloids to WF leads to changes in water absorption. The water absorbing capacity of WF is mainly associated with GP hydration and the development of the gluten network during kneading. Due to their hydrophilic nature, the addition of

Abbreviations: AG, arabic gum; AL, sodium alginate; BG, brea gum; BOT, baking off technologies; κ-CAR, Kappa carrageenan; ι-CAR, Iota carrageenan; λ-CAR, Lambda carrageenan; CH, chitosan; CLSM, confocal laser scanning microscopy; CMC, carboxymethyl cellulose; D, dextran; DSC, differential scanning calorimetry; FOS, fructo-oligosaccharides; GG, guar gum; GOS, gluco-oligosaccharides; GP, gluten proteins; HMP, high methoxyl pectin or high esterified pectin; HPC, hydroxypropyl cellulose; HPMC, hydroxypropylmethyl cellulose; IN, inulin; LBG, locust bean gum; MCC, microcrystalline cellulose; SEM, scanning electron microscopy; Tg, glass transition temperature; TG, tragacanth gum; TSG, tamarind seed gum; WEAX, water-extractable arabinoxylans; WF, wheat flour; WG, whole grain; WUAX, water-unextractable arabinoxylans; XG, xanthan gum.

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gums strongly affects this parameter. Several authors have reported enhanced farinographic water absorption when adding hydrocolloids (AL, k-CAR, XG, MCC, CMC, HPMC, GG, LBG, HMP, D) in a wide range of concentrations (0.1%–5% flour basis-f.b.) (Correa, Añón, Pérez, & Ferrero, 2010; Linlaud, Puppo, & Ferrero, 2009; Maleki & Milani, 2013; Rosell, Rojas, & Benedito, 2001; Tavakolipour & Kalbasi-Ashtari, 2006; Zannini, Waters, & Arendt, 2014). Other methods for evaluating water absorption, such as water imbibing capacity or sedimentation tests, have confirmed this trend (Linlaud et al., 2009). Moreover, linear relationships between hydrocolloid content and water absorption were reported for modified celluloses (Correa et al., 2010; Zannini et al., 2014) and also for other gums such as XG and D (Zannini et al., 2014). Interestingly, the type of hydrocolloid seems to be a more important factor than concentration, as demonstrated by Bárcenas, De la O-Keller, and Rosell (2009), who studied the effect of AG, HPMC and HMP on the hydration properties of gluten-hydrocolloid systems (0.002–0.013 g hydrocolloid/g gluten).

Hydrocolloid interaction with GP does affect the characteristics of the gluten network. León et al. (2000) studied the interactions between different isoforms of carrageenans and GP by IR spectroscopy and SDS-PAGE, and reported that λ-CAR (the most sulfated isoform) could interact better with GP due to its higher hydration capacity and its particular conformation. Furthermore, Ribotta, Ausar, Beltramo, and León (2005) evaluated the interactions between different hydrocolloids (ι-CAR, λ-CAR and κ-CAR, AL, LBG, GG, HMP, XG) and GP by viscosity measurements and electrophoresis. They reported that HMP and λ-CAR have a high ability to form complexes with GP through ionic interactions (through carboxylic and sulfated groups, respectively), which would explain the effect of these gums on dough strength. According to the authors, hydrogen bonding may also play a key role in polysaccharide-GP interactions, which would explain the effects of nonionic gums on dough.

FT-Raman spectroscopy revealed changes in the secondary conformation of GP when hydrocolloids were added to dough (Correa, Ferrer, Añón, & Ferrero, 2014; Linlaud, Ferrer, Puppo, & Ferrero, 2011). The analysis of the amide I band indicated that GG, XG, HPMC and CMC (1%–1.5% f.b.) decreased α-helix conformation, increasing more unfolded, disordered structures. Rosell and Foegeding (2007) studied protein solubility in HPMC-gluten systems and suggested that HPMC could have an interfering role in gluten network formation, reducing cross-linking. Thus, at 85 °C protein extractability decreased, indicating the formation of aggregates but the presence of HPMC promoted protein solubility. By CLSM, Correa et al. (2014) determined that HPMC addition could induce the formation of aggregates, thus leading to a more open gluten network, particularly in the presence of NaCl. On the other hand, the use of CMC led to a more cross-linked network.

Conformational changes in GP were also observed by FT-IR when fiber-rich ingredients containing cellulose and pectin (carob pulp, apple-cranberry, cacao, and oat) were added to dough at 6% (f.b.) (Nawrocka, Miś, & Szymańska-Chargot, 2016). These authors proposed that β-sheets and β-turns located outside the protein complex could form β-like structures between two protein molecules. These changes correlated positively with the increase in the resistance to extension. Nawrocka, Szymanska-Chargot, Mis, Kowalski, and Gruszecki (2016) studied gluten-fiber systems with chokeberry, cranberry, cacao, carrot, oat and flax fibers (3%–9% w/w gluten-fiber mixture basis) by FT-IR. All fibers decreased the α-helix proportion and increased the content of antiparallel β-sheet, suggesting that cellulose, the component present in all of them, could promote these changes. These authors proposed that other changes in the gluten structure related to disulfide bridge conformation and protein folding or aggregation were more dependent on the type of fiber and could be associated with pectin interaction with GP.

As the competition of gluten and hydrocolloids for water and the intermolecular interactions between hydrocolloids and GP affect the network structure, the rheological behavior of dough is also affected. Farinograph dough development time (DDT-the time elapsed from the first addition of water to the development of the maximum dough consistency) is related to gluten network formation and can be longer, depending on the type and concentration of gum (Correa et al., 2010; Maleki & Milani, 2013; Rosell et al., 2001; Zannini et al., 2014). The effect on farinograph dough stability (the time elapsed between the moment the top of the curve reaches 500 BU and the moment it falls below 500 BU), a parameter related to flour strength, seems to vary greatly depending on the type and concentration of hydrocolloids, flour characteristics and the presence of other components like NaCl. It has been reported that GG increases stability at 0.25%–1.5% f.b. (Linlaud et al., 2009), but some authors indicated a positive effect only at 0.1% f.b. (Maleki & Milani, 2013). Rosell et al. (2001) reported a high increase in this parameter when XG was added at 0.5% f.b., but a scarce effect was noted by other authors (Linlaud et al., 2009). In the case of modified celluloses, stability seems to depend strongly on the presence of salt (Correa et al., 2010). Stability decreases significantly in dough with HPMC (0.5–1.5% f.b.) and NaCl because salt can promote hydrophobic interactions with GP. On the other hand, the interaction with charged molecules like CMC (0.5%–1.5% f.b.), which reduces stability, seems to be favored in the absence of NaCl, probably due to a screening effect when salt is present. From a microstructural point of view, less stable and softer dough has a more disrupted gluten network, as observed by SEM. Tavakolipour and Kalbasi-Ashtari (2006) reported a decrease in extensograph extensibility and an increase in resistance (R_{50}) for CMC and HPMC added dough (0.1%–0.5% f.b., with salt). Bollaín and Collar (2004) found major effects on extensional parameters by the combined addition of hydrocolloids and emulsifiers (HMP/HPMC, DATEM/HMP and DATEM/HPMC) at maximum addition levels (0.372%, 2.088% and 0.844% f.b. for HPMC, HMP and DATEM, respectively). It can be concluded that hydrocolloid competition with gluten proteins for water is a key factor that affects gluten development. However, the effect on dough rheology will also depend on the particular interactions between hydrocolloids and gluten proteins. A positive interaction would lead to a reinforced dough, but a negative one can produce a disrupted network and a less stable and softer dough.

During baking, starch gelatinizes, protein coagulation takes place and the spongy structure obtained during leavening is fixed, forming the bread crumb. It has been stated that granule swelling can be reduced, leading to a stiffening effect, by the presence of hydrocolloids (particularly in high concentrated systems) that can interact with the molecules lixiviated from starch granules (Biliaderis, Arvanitoyannis, Izydroczyk, & Prokopowich, 1997; Krüger, Ferrero, & Zaritzky, 2003). Thus, due to these interactions, crumb structure and texture are influenced by the presence of gums. However, concerning the starch thermal behavior, at the levels usually used (up to 2% f.b.), hydrocolloids would not have a marked effect on calorimetric parameters (Correa & Ferrero, 2015a; Linlaud et al., 2011). At higher concentrations, hydrocolloids can affect the thermal behavior of dough. Santos, Rosell, and Collar (2008) studied the effects of flour replacement at medium-high levels (6%–34%) by soluble (IN), partially soluble (from sugar beet, pea cell wall), and insoluble (from pea hull) dietary fiber on wheat dough thermal profiles using differential scanning calorimetry (DSC). According to the higher initial and peak gelatinization temperatures, lower end temperature and gelatinization enthalpy (ΔH), these authors concluded that fibers would restrict starch swelling by restricting the availability of water for the remaining

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