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Effect of egg white solids on the rheological properties and bread making performance of gluten-free batter

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ABSTRACT

Developing baked gluten-free (GF) products is difficult since gluten is essential for many organoleptic properties like texture and taste. Egg white proteins (EW) show strong cohesive behavior with excellent foaming capacity and stability, which may improve both organoleptic quality and nutritional value of GF bread. This work aimed to study the impact of two EW powders prepared by different methods (e.g. P110 and M200) on bread volume, shape, texture and their potential use in retarding the staling process. The two EW samples were used to substitute 5–15% of GF flour in a control GF bread formulation. Compared with control, breads with EW had larger specific volumes and more homogeneous texture. The rheological properties of GF bread batter were evaluated through temperature and frequency sweep tests. In general, addition of EW increased the elasticity of GF batter and improved the texture properties of resultant bread during storage. M200 with more water-soluble protein aggregates produced a more significant improvement in bread quality than general standardization sample P110. To elaborate the stabilizing mechanism of EW on bread network, the surface properties of the two EW samples including surface tension, zeta-potential as well as their conformational changes during thermal treatments were studied and compared.

1. Introduction

The production of high quality baked gluten-free (GF) foods remains a technological challenge and the degree of challenge is closely associated with how functional gluten is in a particular food product. For bread, gluten plays a crucial role in the gas retention and structure formation (Hager & Arendt, 2013). And the lack of gluten results in a significantly reduced retention of carbon dioxide produced by yeast and hence a coarse and rigid texture and short shelf-life of products made with GF flours (Skendi, Mouselemidou, Papageorgiou, & Papastergiadis, 2018). In addition, GF flours and starches are not generally enriched or fortified, which may lead to nutritional deficiencies in protein and micronutrients of resulting GF breads (Capriles, dos Santos, & Arêas, 2016). A GF bread with good organoleptic properties and high nutritional value is still the most desired product by individuals with gluten-related disorders (Sandri, Santos, Fratelli, & Capriles, 2017).

Many studies have been focused on quality improvements of GF bread by the addition of hydrocolloids including both polysaccharides and proteins (Anton & Artfield, 2008; Bize, Smith, Aramouni, & Bean, 2017). It is suggested that they can mimic viscoelastic properties of gluten and increase the gas retention properties of the dough, and thus enhance the loaf volume and retard the hardness of the resultant bread (Morreale, Garzón, & Rosell, 2018). Polysaccharides such as xanthan gum, hydroxypropyl methylcellulose (HPMC) and guar gum have frequently been incorporated into GF formulations to help form a network structure and then improve the bread quality (Foschia, Horstmann, Arendt, & Zannini, 2016; Morreale et al., 2018). However, since the production background of these polysaccharides may vary (e.g. by biosynthesis pathway) and some production information do not appeal to consumers, there are some concerns regarding the economic production of polysaccharides with stable and standardized quality and the appropriate incorporated doses (Giavasis, 2014; Horstmann, Axel, & Arendt, 2018). And the product with addition of polysaccharide alone may still not resemble traditional bread in texture and sensory (Crockett, Ie, & Vodovotz, 2011). Alternatively, proteins are incorporated to GF bread, in combination of polysaccharides such as

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HPMC, to improve both the perceived quality and texture by enhancing Maillard browning and flavor, increasing elastic modulus and gas retaining capacity (Crockett et al., 2011; Phongthai, D'Amico, Schoenlechner, & Rawdkuen, 2016). For example, egg white solids at 15% improved the loaf volume of GF bread (Crockett et al., 2011). The nutritional value of GF breads can also be improved by protein enrichment. Egg white protein, as the most widely used surface active agent, can form strong cohesive viscoelastic films which are essential for gas retention in GF bread (Bize et al., 2017). An improvement of the overall quality and storage stability of GF breads has been observed by the addition of liquid whole egg at 20–30% (flour basis) while increased height and specific volume of GF muffin were achieved by adding egg white powder at 17.3% (flour basis) with a combination of HPMC or xanthan gum (Bize et al., 2017; Matos, Sanz, & Rosell, 2014). In these previous studies, it was obvious that, when egg white applied, especially at a low concentration, a combination of other hydrocolloids such as HPMC, pectin and guar gum was needed to achieve the improvement on GF bread quality (Ziobro, Juszczak, Witczak, & Korus, 2016; Bize et al., 2017). As stated by Ziobro et al. (2016), adding egg white in the absence of guar gum and pectin showed negative influence on bread staling. Meanwhile, a reduced dough stability was observed on HPMC-treated GF formulation supplemented with egg white at 5% and 10%, while the antagonistic interaction with HPMC network was overcome by 15% egg white (Crockett et al., 2011). There is still much room for improvement in developing GF bread formulation supplemented with egg white at a low concentration. In addition, the role of egg white in the dough network formation and stabilization, and the resultant improvement of GF dough/batter and baked bread remains somewhat unclear, which retards its further development as a regular ingredient in GF formulations.

Therefore, two spray-dried egg white solids with same chemical compositions but manufactured by different industrial processes were incorporated into GF formulations and the resultant batters were baked in this study. The first objective was to investigate the impact of egg white solids at different levels on the rheological properties of GF bread batters and the quality of resultant breads, and hence to enunciate the function of egg white in the structure of bread. The second objective was to develop a GF bread with better quality.

2. Materials and methods

2.1. Materials

Two spray-dried egg white solids M200 and P110 were provided by Henningsen Foods, Inc. (Omaha, NE). The physical and chemical attributes of these two samples are shown in Supplementary Table 1. Commercial all-purpose gluten-free flour (a mixture of garbanzo bean flour, potato starch, tapioca flour, whole grain sorghum flour and fava bean flour) were purchased from Bob's Red Mill Natural Foods, Inc. (Milwaukie, OR). Rice fiber came from J. Rettenmaier (Schoolcraft, MI), while the tapioca starch was obtained from Tate &Lyle Ingredients, Inc. (Decatur, IL). The rest of ingredients including Fleischmann's Active dry yeast, trehalose (100% pure), sugar (sucrose), salt and soybean oil were acquired in the local market. The extrinsic fluorescence probe ANS (8- anilinonaphthalene-1-sulfonic acid) was purchased from Sigma-Aldrich (St. Louis, MO) while other reagents were purchased from either Fisher Scientific Inc. (Pittsburgh, PA) or Bio-Rad Laboratories, Inc. (Hercules, CA).

2.2. Preparation of gluten-free batter and bread

The GF batters were prepared following the recipe on a 100 g GF flour basis with 0%–15% substitution of egg white solids. Other ingredients were constant in all the formula: 4% rice fiber, 3% tapioca starch, 10% sucrose, 1.6% salt, 5% trehalose, 12% vegetable oil, 3% dry yeast and 100% water. The formulations of GF batters incorporated with two egg white solids at different levels are stated in Table 1.

Table 1
The formulas of gluten-free batters with/without substitution of egg white solids.

Formulas	% flour basis	Control	M5	M10	M15	P5	P10	P15
Ingredients		(g)						
GF flour	100–85	200	190	180	170	190	180	170
Egg white M200	0–15	–	10	20	30	–	–	–
Egg white P110	0–15	–	–	–	–	10	20	30
Rice fiber	4	8	8	8	8	8	8	8
Tapioca starch	3	6	6	6	6	6	6	6
Sugar	10	20	20	20	20	20	20	20
Salt	1.6	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Trehalose	5	10	10	10	10	10	10	10
Soybean oil	12	24	24	24	24	24	24	24
Yeast	3	6	6	6	6	6	6	6
Water	100	200	200	200	200	200	200	200

Note: M5 represents using 5% of Egg white solids M200, P5 represents using 5% of Egg white solids P110. Same rules were applied to M10, M15, P10, and P15.

The dry yeast was prehydrated in water (38–43 °C) for 8 min. The other dry ingredients were blended to homogeneity. The yeast mixture was added, and the batter was mixed for 5 min using a Kitchen-Aid Professional Stand Mixer (KitchenAid, St. Joseph, MI) with a dough hook at speed 4 (scale = 1–10). For each bread loaf, 350 g batter was placed into non-stick baking pan (L = 21.6 cm × W = 11.4 cm × H = 7.35 cm) and proofed in a proofing chamber (Model 6030, CARON Products & Services, Inc., Marietta, OH) at 38 °C and 75% relative humidity for 45 min. The GF batter samples were then baked in an electric oven for 25 min at 176 °C. After baking, loaves were removed from pans and cooled for 5 h at room temperature (21 °C) before measurements. To study the effect on staling, bread loaves were sealed in polyethylene bags and stored in ambient conditions for up to 4 days. Three breads were made for each recipe.

2.3. Bread quality

2.3.1. Specific volume

Bread loaves were weighted 5 h postbaking and their volumes were determined following AACC method 10–14.01 by using a laser sensor with a BVM-L 370 vol analyzer (Texvol Instruments, Viken, Sweden). The specific volume for each loaf was calculated by dividing the sample volume (cm^3) by the sample weight (g). All measurements were done in triplicate for each recipe.

2.3.2. Moisture measurement

The bread moisture content was determined following AACC method 44–11.01 by using HB 43-S Halogen moisture analyzer (Mettler Toledo Inc., Greifensee, Switzerland). Weight loss during baking was assessed by weighing the pans before and after baking. All breads were analyzed in triplicate.

2.3.3. Texture analysis

The crumb texture was determined using a TA-XT2 texture analyzer (Stable Microsystems, Surrey, UK) with the "Texture Expert" software. A 25 mm diameter cylindrical probe was used in a 'Texture Profile Analysis' (TPA) double compression test to penetrate to 30% depth, with a test speed of 1 mm/s, and a 10 s delay between the first and second compressions. Hardness (g_f), springiness, cohesiveness, resilience and chewiness were calculated from the TPA plot based on the methods stated by Gómez, Ronda, Caballero, Blanco, and Rosell (2007). For each recipe, texture determinations were made in triplicate using bread slices with 25 mm thickness.