LWT - Food Science and Technology 96 (2018) 13–18

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Antistaling effects of hydrocolloids and modified starch on bread during cold storage

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ARTICLE INFO

Keywords:
Bread
Corn starch
Hydrocolloids
Modified starches
Antistaling
Crumb texture

ABSTRACT

Antistaling effects of some hydrocolloids (guar gum, xanthan, and sodium alginate; 0.3 g/100 g flour) and modified starches (acetylated, oxidized and hydroxypropylated corn starches; 10 g replacing flour) on bread during cold storage (4 °C for 10 d) were investigated. Loaf volume, moisture content, texture, and the degree of starch recrystallization of the bread crumb were examined. The minor addition of hydrocolloids increased the loaf volume of fresh bread and retarded textural changes of crumb induced by cold storage. The partial replacement (10%) of flour with modified starches induced antistaling effects similar to those obtained by hydrocolloid addition. In particular, acetylated or hydroxypropylated starches were more effective than oxidized starch. Crystallinity analysis of bread crumb using X-ray diffraction pattern revealed that the effects of hydrocolloids and modified starches on the starch recrystallization were not substantial. Amorphous rearrangements in starch were responsible for changes in crumb texture during storage, and the minor addition of hydrocolloids and the partial replacement of flour with modified starches retarded the rearrangement induced by the storage.

1. Introduction

Staling of bread is a complex physico-chemical phenomenon typically occurring during storage, which may occur in both crust and crumb fractions of bread (Bechtel, Meisner, & Bradley, 1953). Staling of crust primarily results from moisture loss or moisture migration from crumb (Lin & Lineback, 1990), whereas crumb staling is more complicated and less understood (Short & Roberts, 1971). The staling of bread generally accompanies with changes in textural properties such as decreased crust crispiness, and increased hardness and crumbliness of crumb (Fadda, Sanguinetti, Del Caro, Collar, & Piga, 2014; Gray & Bemiller, 2003). These phenomena are influenced by numerous factors including starch retrogradation, water migration, changes in the gluten network, and interactions among the ingredients (Anton & Artfield, 2008; Gray & Bemiller, 2003). Because staling decreases consumer acceptance of bread, substantial studies have been performed to develop techniques or processes to retard staling. One of the approaches is the use of additives including enzymes, hydrocolloids, and emulsifiers (Anton & Artfield, 2008; Guarda, Rosell, Benedito, & Galotto, 2004; Rosell, Rojas, & De Barber, 2001).

Among the additives currently used in the baking industry hydrocolloids, which have a high degree of water affinity, may stabilize the breads against staling during extended periods of storage (Lee, Baek, Cha, Park, & Lim, 2002). In addition, some hydrocolloids were reported to enhance dough development and water retention, thereby improving intermolecular viscosity and thus permitting the entrapment of gas in the dough (Das, Raychaudhuri, & Chakraborty, 2015; Ferrero, 2017). Further, it was reported that minor addition of hydrocolloids can increase moisture retention in bread and retard starch retrogradation, which improves the overall quality of bread (Collar, Andreu, Martınez, & Armero, 1999; Guarda et al., 2004). However, the effects of hydrocolloids differ to a large extent, depending on their origin and chemical structure (Rojas, Rosell, & Benedito de Barber, 1999). Schiraldi, Piazza, Brenna, and Vittadini (1996) reported that addition of guar gum (GG) considerably improved the quality of fresh bread. The addition of GG, xanthan gum (XT), and carboxymethyl cellulose (CMC) in rye and cassava breads greatly improved the bread quality and shelf-life (Mettler & Seibel, 1972; Shittu, Aminu, & Abulude, 2009). Hydroxylpropyl methylcellulose (HPMC) was also added to wheat bread to improve physical properties including specific volume, and crumb softness, and thus to enhance the overall sensory characteristics (Collar et al., 1999; Rosell, Rojas, & Barber, 2001). In addition, other hydrocolloids such as sodium alginate (SA) and k-carrageenan were reported to be effective in improving the stability of dough during proofing (Das

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https://doi.org/10.1016/j.lwt.2018.05.009
Received 26 January 2018; Received in revised form 17 April 2018; Accepted 3 May 2018
Available online 07 May 2018

et al., 2015; Rosell et al., 2001).

Modified starches could be used as alternatives to natural hydrocolloids. The use of modified starches to retard the staling of bread has been suggested since the 1990s (Inagaki & Seib, 1992), and chemically modified starches have been widely used in the baking industry to improve bread quality. Addition of modified starches may change the texture of bread crust and crumb, allowing the development of unique breads that differ from conventional bread (Miyazaki, Van Hung, Maeda, & Morita, 2006). Later, some authors reported that up to 20% substitution with modified starches for wheat flour could improve bread quality without deterioration. Among many chemically modified starches, hydroxypropylated (HP) starch was reported to be most effective in retarding bread staling due to the slow retrogradation of amylopectin (Miyazaki et al., 2006). Acetylated (AC) starch also can improve the storage stability of bread compared to native starch by interrupting the linearity of amylose and amylopectin segments, and sterically interfering with the intermolecular alignment (Harper & Clark, 1979). Therefore, AC starch might prevent undesirable changes in the texture and appearance caused by retrogradation during processing and storage (Miyazaki et al., 2006). The same authors found that oxidized (OX) starch can lower the degree of retrogradation compared to native starch because of the bulky carboxyl or carbonyl groups that are substituted on starch.

Numerous studies have explored the use of hydrocolloids and modified starches to preserve bread quality, but little attention has been paid to their effect on the staling of bread induced by cold storage. In the present study, the effects of the common hydrocolloids (GG, XT, and SA), and different modified starches (AC, OX, and HP corn starches) were investigated concerning their function as antistaling agents during cold storage.

2. Materials and methods

2.1. Materials

Wheat flour, sugar, and salt were products of CheilJedang Co., Ltd. (Seoul, South Korea). Shortening was obtained from Ottogi Co., Ltd. (Anyang, South Korea). Skim milk powder was purchased from Seoul Milk Co., Ltd. (Seoul, South Korea). Yeast was purchased from Lesaffre Yeast Co., Ltd. (Milwaukee, WI). Hydrocolloids including GG, XT, and SA were purchased from NutraSweet Kelco Co., Ltd. (San Diego, CA). Native corn (CN) and OX starches were gifts from Daesang Co., Ltd. (Seoul, South Korea), and AC starch was a gift from Samyang Genex Co., Ltd. (Seoul, South Korea). HP starch was prepared in the laboratory following the procedure of Kim, Jane, and Lamsal (2017). All the modified starches were of food-grade, and all the chemicals used in this study were of analytical grade.

2.2. Bread samples

Breads were baked using an automatic baking machine (HB 158C; Ohsung Co., Ltd, Changwon, South Korea). The sample formulations are shown in Table 1. For dough formation, a mixture of different ingredients in distilled water (140.0 g) was warmed for 20 min at 35 °C in the baking machine, and then kneaded for 13 min. The dough was allowed to rest for 50 min and then kneaded again for 12 min at the same temperature. The dough was then fermented for 20 min, degassed for 4 s, fermented again for 15 min, and degassed again for 4 s. The rest of the baking process including proofing (40 min at 35 °C), baking (50 min at 100 °C), and cooling (20 min–30 °C) was carried out by following the procedure given by the manufacturer of the baking machine. Finally, the loaves were cooled to room temperature prior to slicing (about 30 mm thickness) and the slices were stored at 4 °C for 10 d after being packed in polypropylene bags.

Table 1
Composition of breads added with different hydrocolloids or replaced for flour by different modified starches.

Ingredients (g)	Plain bread (PB)	Hydrocolloids (GG, SA, XT)	Native corn starch (CN)	Modified starches (AC, OX, HP)
Water	140	140	140	140
Hydrocolloids	–	0.6	–	–
Flour	200	200	180	180
Corn starch	–	–	20	–
Modified starches	–	–	–	20
Sugar	18	18	18	18
Salt	3	3	3	3
Milk powder	15	15	15	15
Yeast	5	5	5	5
Shortening	15	15	15	15

PB, GG, SA, XT, CN, AC, OX, and HP indicate plain bread, bread containing guar gum, bread containing sodium alginate, bread containing xanthan gum, bread containing native corn starch, bread containing acetylated corn starch, bread containing oxidized corn starch and bread containing hydroxypropylated corn starch, respectively.

2.3. Loaf volume of bread

The loaf volume of fresh breads was measured using the rapeseed displacement method (AACC, 2010). It was carried out after the loaves were cooled to room temperature for 2 h.

2.4. Moisture content of crumb

The crumb (~1.0 g each) were taken from the center of fresh and stored (0, 4, and 10 d) bread slices and then their moisture contents were determined using a standard AOAC procedure by drying at 105 °C for 3 h in a convection oven (AOAC, 2007).

2.5. Texture profile analysis

Texture profile analysis (TPA) of the fresh and stored breads was determined for the crumb in the center of bread slices using a texture analyzer (TA-XT2i; Stable Micro System, Haslemeres, UK) equipped with a cylindrical probe (25 mm diameter) and a 5 kg load cell. Briefly, the ~30 mm thick bread slices were compressed to 60% strain at a testing speed of 2 mm/s with a 3.0 s delay between the first and second compressions. Hardness, cohesiveness, and springiness were calculated from the TPA profiles.

2.6. X-ray diffraction analysis

The crystalline structure of fresh and stored breads was characterized with freeze-dried samples of the bread crumb using an XPERT MPD X-ray diffractometer (Philips, Almelo, Netherlands). Fresh and cold stored samples were freeze-dried and then ground to powder after passing through a 300 μm sieve. The XRD analyzer was operated at 40 kV and 40 mA with Cu-κα radiation.

2.7. Statistical analyses

All experiments were conducted in triplicate and the data were analyzed using one-way analysis of variance. Means were compared using Duncan's multiple range test with significance at $P < 0.01$. All statistical analyses were carried out using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).