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Starch affecting anti-staling agents and their function in freestanding and pan-baked bread

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ABSTRACT

Anti-staling agents with different mechanisms were added to a normal white wheat bread to investigate the relation between bread staling, amylopectin retrogradation and water-related properties (i.e. water content and distribution between crumb and crust). Bread was baked both as pan-baked and freestanding loaves. The anti-staling agents maltogenic α-amylase, distilled monoglyceride and lipase had a direct influence on starch retrogradation, whereas gluten and waxy wheat flour diluted the amylopectin content or changed the ratio between amylose and amylopectin. The degree of staling was measured as the firmness and springiness, together with two new methods, crumbliness and cutability. In addition, the degrees of amylopectin retrogradation and amylose–lipid complex formation were analyzed by differential scanning calorimetry, and the water content, water loss and water migration were measured. The addition of α-amylase improved most staling parameters, although the changes were not as large as expected. Furthermore, monoglyceride and lipase increased the formation of amylose–lipid complexes, but only lipase gave better results regarding the specific volume and firmness. Increased amylose–lipid complex formation was seen to increase water migration from crumb to crust. Adding 10% waxy wheat flour appeared to lead to a slight overall improvement i.e. lower water migration and better cutability. Adding gluten or 3% waxy wheat flour only improved the specific volume. The method of baking the loaves, i.e. freestanding or pan-baked, had a greater influence than the anti-staling agents, which shows that bread quality is not always improved by starch affecting anti-staling agents without process changes.

1. Introduction

Today, several anti-staling agents are used in the bread making industry. These anti-staling agents have different mechanisms, which provides the opportunity to influence the properties of the product. Anti-staling agents may have a direct or an indirect influence on starch retrogradation, one of the key factors contributing to staling. Examples of direct influences are degradation of the amylose and/or amylopectin molecules, the formation of inclusion complexes with amylose or the outer branches of the amylopectin molecule, and a delay in the swelling and rupture of the starch granules. These effects can be caused by enzymes and emulsifiers. Starch-diluting anti-staling agents, for example, gluten, have an indirect influence on starch retrogradation.

Amylases, which have a direct influence on starch retrogradation, are divided into α- and β-amylases. They both act on the α-(1,4) glycosidic bonds. α-Amylase acts randomly, giving low-molecular-weight dextrins and other oligosaccharides, while β-amylase cleaves every second bond producing maltose and β-limiting dextrin (Bowles, 1996; Goesaert, Slade, Levine, & Delcour, 2009). The hydrolysis hinders the formation of amylopectin double helices, thereby preventing the crosslinking of the amylopectin molecules, and weakening the three-dimensional network (Goesaert et al., 2009). It has been shown that the retrogradation of amylopectin is dependent on the exterior chain length; less retrogradation being seen for shorter chains (Lundqvist, Nilsson, Eliasson, & Gorton, 2002). Furthermore, the addition of α-amylases effectively reduces the firmness of the bread (Goesaert et al., 2009; Hug-Iten, Escher, & Conde-Petit, 2003; Martin & Hoseney, 1991), improves the crust color and flavor due to Maillard reactions (Goesaert et al., 2009), enlarges the gas cells, and retards amylopectin retrogradation.

Lipases also have a direct influence on starch retrogradation, by hydrolyzing the di- and triglycerides into mono- or diglycerides and lysolipids (Castello, Jollet, Potus, Baret, & Nicolas, 1998). The addition of lipases enhances the gluten strengthening effect in dough, affording increased stability and improved bread quality

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(Si, 1997). Furthermore, lipases affect the amylose–lipid complex, resulting in an increase in the energy required to melt the complex, i.e. increased complex formation (Andreu, Collar, & Martinez-Anaya, 1999; Siswoyo, Tanaka, & Morita, 1999). Amylose–lipid complexes may have an inhibiting effect on starch retrogradation when storage times are long (Davidou, Le Meste, Debever, & Bekaert, 1996), but not for short periods (<15 days) (Andreu et al., 1999). The addition of lipases to dough improves the bread volume, air-hole regularity, crumb structure, and texture, and retards staling. (Monfort, Blasco, Sanz, & Prieto, 1999; Si, 1997; Siswoyo et al., 1999).

Monoglycerides have a direct influence on starch retrogradation, and are commonly used to improve the softness of the crumb and the volume of the loaf (Forssell, Shamekh, Härkönen, & Poutanen, 1998; Gómez et al., 2004; Heflich, 1996). Their physical state when added to the dough is of importance for their anti-staling effect; the lamellar liquid-crystalline phase being the most effective for the formation of inclusion complexes with amylose and amylopectin (Krog & Nybo Jensen, 1970). A correlation has been found between the amylose complex formation index and the anti-firming effect (Krog & Nybo Jensen, 1970; Krog, Olesen, Toernaes, & Joensson, 1989). However, monoglycerides are process sensitive to the processing conditions, and too short proofing time may result in a decrease in dough stability, bread volume and in the softening effect (Gómez et al., 2004). Emulsifiers also have good film-forming properties, resulting in reduced starch granule swelling and rupture during the baking process, due to coating of the granules (Eliasson, 1985). When adding monoglycerides, brighter crumb color, less gumminess, improved slicing and a tighter and more uniform crumb structure can be expected (Heflich, 1996).

Other ways of influencing the staling of bread are to change the ratio of starch to protein (Erlander & Erlander, 1969; Kim & D'Appolonis, 1977), or change the composition of the starch (Bhattacharya, Erazo-Castrejón, Doehlert, & McMullen, 2002; Park & Baik, 2007), which can be regarded as indirect ways of influencing starch retrogradation. This can be achieved by adding more gluten protein or waxy flour/starches to the dough. With higher gluten protein content in the flour, the strength and water absorption of the dough increase, as well as the specific volume, leading to improved crumb texture with decreased firmness (Callejo, Gil, Rodríguez, & Ruiz, 1999; Codina, Bordei, & Paslaru, 2008; Cornell, 2003; Maleki, Hoseney, & Mattern, 1980). In starch gels, amylopectin retrogradation has been found to increase with increasing proportion of amylopectin in the gel (Gudmundsson & Eliasson, 1990; Russell, 1987). However, when adding waxy flours, the water absorption of dough increases and a decrease in both the firmness and the amylopectin retrogradation enthalpy during storage can be achieved, although small or no changes in volume have been found (Bhattacharya et al., 2002; Hayakawa, Tanaka, Nakamura, Endo, & Hoshino, 2004; Morita et al., 2002; Park & Baik, 2007; Qin, Ma, Wu, Kong, & Zhang, 2009). It is thus not clear how manipulation of the amylose/amylopectin ratio will affect staling. Furthermore, the origin and the chain length of the amylopectin must also be considered when adding waxy starches/flours to a dough, since these influence the extent of starch retrogradation (Fredriksson, Silverio, Andersson, Eliasson, & Åman, 1998).

The retrogradation of amylopectin is considered to be the major factor causing staling of bread. However, other factors have also been suggested to play important roles, such as water distribution and migration. Moreover, if the addition of waxy starches/flours reduces staling, the role of amylopectin retrogradation might not be as straightforward as often assumed, and the effects could also be dependent on the amount added.

The aim of the present study was to investigate the relation between staling of bread, the retrogradation of amylopectin, and water-related factors (i.e. the water content and the distribution of water between the crumb and the crust). Staling was measured in terms of firmness and springiness. Moreover, two new methods of assessing staling, crumbliness and cutability, were introduced for additional evaluation of staling. In order to investigate the retrogradation of amylopectin, several common anti-staling agents known to affect amylopectin retrogradation by different mechanisms were used. α-Amylase was used to hydrolyze the starch molecules, whereas lipase hydrolyzes the lipids. The emulsifier added (distilled monoglycerides) and products resulting from the action of lipase affect amylose and amylopectin by complex formation. Waxy wheat flour was added to change the ratio between amylose and amylopectin, and gluten was added to dilute the starch concentration in the dough.

The effects of the water content and its distribution between the crust and the crumb during storage on anti-staling parameters were also studied. Since it has previously been seen that the water content and the baking process have significant effects on staling (unpublished results) bread was baked both as freestanding loves and in pans.

2. Materials and methods

2.1. Materials

The different additives used in the study were α-amylase (Novamyl 10000 BG, granulated maltogene amylase from *Bacillus subtilis*, 10,000 manu/g, provided by Novozymes A/S, Bagsvaerd, Denmark), lipase (Lipopan Xtra BG, granulated lipase from *Aspergillus oryzae*, 7.2 KLU/g, also provided by Novozymes A/S), monoglyceride (Dimodan®HP 75/B Kosher, distilled monoglyceride made from palm-based oil, provided by Danisco, Copenhagen, Denmark), wheat gluten (Gluvital Cargill, provided by Lantmännen AB, Malmö, Sweden) and waxy wheat flour (Purafarin N 001 W, provided by Kampffmeyer Food Innovation GmbH, Hamburg, Germany). Other ingredients used were: wheat flour ("Bagerivetemjöl", Lantmännen AB, Malmö, Sweden), water (tap water), yeast ("Kronjäst original", Jästbolaget AB, Sollentuna, Sweden), salt, sugar and lard. The amounts of additives used in the recipes were either those recommended by the producers or based on the results of a previous study (see Table 1).

2.2. Experimental design

A multivariate, full-factor design was set up containing three experimental variables: anti-staling agent, baking method (pan-baked vs. freestanding loaves), and storage time. Four loaves, (two pan-baked and two freestanding), were baked with each additive and analyzed 0, 1, 3 and 7 days after baking. The Unscrambler software, version 9.0, was used for the experimental design and part of the evaluation. Principal component analysis (PCA) was used to evaluate the results.

Table 1
Description of additives and dosages used.

Anti-staling agent		Description	Dosage (flour weight basis)
Dimodan®	MG	Monoglyceride	0.5%[a]
Gluten	Glu	Gluten protein	3%[b]
Lipopan Xtra	Lip	Lipase	39 ppm[a]
Novamyl 10000 BG	α-am	α-Amylase	78 ppm[a]
Purafarin N 001 W	wwf	Waxy wheat flour	3% and 10%[b]

[a] Dosage recommended by the manufacturer.
[b] Dosage determined from a previous study (unpublished results).