Food Chemistry 120 (2010) 44–51

Contents lists available at ScienceDirect

Food Chemistry

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

A model approach to starch and protein functionality in a pound cake system

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ARTICLE INFO

Article history:
Received 21 April 2009
Received in revised form 10 August 2009
Accepted 21 September 2009

Keywords:
Pound cake
Cake quality
Modified starch
Protein
Batter viscosity
Crumb texture

ABSTRACT

Different modified wheat starches were used in a model pound cake recipe. The properties of the starches were linked to differences in batter viscosity, cake height and protein extractability during baking, collapse during cooling and final cake quality. The impact of incorporation of 30% cross-linked (CL) starches on batter properties during baking was much smaller than that of incorporation of the same level of hydroxypropylated (HP) starches. Incorporation of HP starches with various degrees of modification in the recipe caused batter viscosity during baking to start rising from 92 or 88 °C rather than at 96 °C and diminished oven rise significantly. Furthermore, the extractability of the protein in cakes containing HP starch was significantly higher. During cooling, control cake collapsed less than did CL starch-containing cake, which itself collapsed significantly less than did HP starch-containing cake. Presumably, most of the cake collapse takes place before the starch gel is formed during cooling. Protein and starch apparently function in determining cake quality, by providing the cell walls with structural material and high resistance to collapse. Starch does not prevent cake collapse, but still co-determines crumb structure, whereas a strong correlation was found between the gel-forming capacity of starch blends and intrinsic crumb firmness ($r = 0.99$). Furthermore, a strong negative correlation was found between springiness and percentage of extractable protein in final cakes ($r = -0.95$). We conclude that the combination of a protein network, formed during baking, with a starch gel, formed during cooling, makes up the crumb cell walls and determines cake quality.

1. Introduction

Cake batter needs to be sufficiently viscous to trap gas bubbles during mixing and retain them during heating (Wilderjans, Pareyt, Goesaert, Brijs, & Delcour, 2008). During heating, the formation of a structural framework of starch granules and protein, strong enough to support itself when the cake is removed from the oven, is crucial (Donovan, 1977). Starch gelatinisation and egg protein coagulation increase the viscosity of the batter tremendously. This imparts a solid character to the cake. The combined effect of the swollen starch granules, and the continuous egg protein gel phase surrounding them, provides the firm structure of the cell wall material (Guy & Pithawala, 1981).

According to Donovan (1977), starch granules serve two major simultaneous functions during angel cake baking: they swell to form the 'building bricks' of the final crumb and, during swelling, they bind excess water. Starch hence acts as a temperature-triggered water-sink in cake and is responsible for the transformation of an aqueous, fluid batter into a solid, porous cake structure. Sollars and Rubenthaler (1971) compared different starches in layer cake making. Baking performance varied with granule size and gelatinisation temperature as well as water absorption by the starch. According to Kim and Walker (1992), variations in high-ratio cake quality can be related to the point of baking at which the cake sets, which itself depends on the starch gelatinisation temperature. It is well known that cake volume is related to the gelatinisation temperature of its starch, which itself is affected by moisture and sugar levels (Derby, Miller, Miller, & Trimbo, 1975; Kim & Walker, 1992). Most authors further agree that the extent of water absorption by the starch granules co-determines final cake quality. Properly baked cake contains sufficiently swollen granules that make mutual contact. Nevertheless, it is essential, for the formation of a good cake structure, that most of the swollen starch granules still retain a recognisable granular shape (Howard, Hughes, & Strobel, 1968; Lorenz & Kulp, 1981). From the above, it is obvious that starch is important for good cake baking performance.

In the past, modified starches have proven successful for studying the role of starch in different food applications. In bread-mak-

Abbreviations: ANOVA, analysis of variance; CL, cross-linked; DSC, differential scanning calorimetry; HP, hydroxypropylated; RVA, rapid visco analyser; SDS, sodium dodecyl sulphate; SE-HPLC, size-exclusion high performance liquid chromatography.

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doi:10.1016/j.foodchem.2009.09.067

ing, modified starches exert some positive effects. Breads made in a recipe in which regular wheat flour is partly substituted with hydroxypropylated (HP) starch, are less firm and retain softness during storage longer than those with other modified starches or wheat flour alone. Cross-linked (CL) starches make the bread crumb more rigid because the cross-linking allows the starch to retain its granular structure in the gluten network (Miyazaki, Van Hung, Maeda, & Morita, 2006). Goesaert, Leman, and Delcour (2008) reported similar conclusions for initial firmness values of gluten-wheat starch model breads. Breads containing CL starches had higher, and breads with HP starches had lower, initial firmness than had control breads. However, the firming rate for HP starch model breads was higher and, for CL starch-containing bread models, comparable to that of native wheat starch model breads. Delcour, Vansteelandt, Hythier, and Abecassis (2000) showed that pasta model ingredient bills containing HP starches are detrimental for cooked pasta quality, while corresponding ingredient bills containing CL starches made pasta firmer.

To the best of our knowledge, only one paper describes the use of modified starches in cake making. Karaoglu, Kotancilar, and Celik (2001) investigated four different types of modified wheat and maize starches (pregelatinised, acid-thinned, cross-linked, and dextrinised) in egg foam cake making. They found that inclusion of modified starch in the recipe increases cake softness and extends its shelf-life, even if it lowers volume and leads to an unacceptable appearance.

The present study aimed to clarify the relative roles of protein aggregation and starch gelatinisation and gel formation in defining pound cake quality. Using HP and CL starches, the impact of wheat starch properties on batter and cake quality in a pound cake formula is studied. In the recipe, a gluten-wheat starch blend is used as flour model. Then, 30% of the total starch in the blend is replaced with either HP or CL starches. The starch characteristics are investigated with a rapid visco analyser (RVA) and related to batter and cake characteristics. To address our research objective, and in contrast to experimental approaches in other papers, changes in protein properties of cakes induced by the use of different starches are also taken into account. To that end, this study uses size-exclusion high performance liquid chromatography (SE-HPLC) to investigate the protein population in the resulting cakes.

2. Materials and methods

2.1. Materials

Wheat starch [14.7% moisture, 2.0% damaged starch] and dry vital wheat gluten [6.62% moisture, 78.0% protein ($N \times 5.7$), 10.6% starch, 5.0% damaged starch] were provided by Syral Belgium (Aalst, Belgium). Moisture contents were determined according to AACC method 44-19 (AACC, 1983). Protein contents were determined using an adaptation of the AOAC Official Method (AOAC, 1995) to an automated Dumas protein analysis system (EAS vario Max C/N, Elt, Gouda, The Netherlands), with 5.7 as the nitrogen to protein conversion factor. Starch levels in wheat gluten were determined by gas–liquid chromatography, as described by Courtin and Delcour (1998). Starch damage was determined according to the Megazyme International Limited (Bray, Ireland) procedure [AACC Method 76-31 (AACC, 1983)]. All contents were expressed on a dry matter basis.

Starch hydroxypropylation and cross-linking were performed as described by Goesaert et al. (2008). In short, wheat starch (1200 g) was incubated under alkaline conditions with propylene oxide (40.0 or 80.0 ml) to create two wheat starches with different degrees of hydroxypropylation, further referred to as HP 40 and HP 80. Wheat starch (1500 g) was also incubated under alkaline conditions with sodium trimetaphosphate solution [5.0% (w/v), 50.0 or 150.0 ml] to give two wheat starch samples with different degrees of cross-linking, encoded as CL 50 and CL 150.

Flour models were prepared by dry-blending the wheat starch (793.0 g) 24 h with gluten (138.0 g) in a ratio of 84–16, based on dry weight, with a Chopin rotating mixer (Model MR2L, Chopin, Villeneuve La Garenne, France). This flour model was used as control sample in further experiments. In the ingredient bills using modified starches, 30% of the dry matter of the starch fraction in the control blend was replaced by a similar level of the modified starches.

Commercial sugar (700 μm average crystal size) was from Lotus Bakeries (Lembeke, Belgium). The margarine (19.0% moisture) was from Puratos (Groot-Bijgaarden, Belgium). Sodium bicarbonate (BICAR®) was from Solvay Chemicals International (Brussels, Belgium) and sodium pyrophosphate from Acatris Food Belgium (Londerzeel, Belgium). Salt and eggs were commercial grade products.

Chemicals and reagents were purchased from Sigma–Aldrich (Steinheim, Germany) and were of at least analytical grade unless specified otherwise.

2.2. Cake batter preparation and baking procedure

Table 1 lists the cake batter formulation. The mixing and baking methods were those described by Wilderjans et al. (2008). Margarine and sugar were mixed for 3 min at speed level 6 in a KitchenAid Professional mixer (Model KPM5, Kitchen Aid, St. Joseph, MI, USA). Then, the fresh broken whole eggs were poured into the mixer as was the additional water necessary to bring the moisture content of the flour model to 14.0%. After 30 s, the starch–gluten mixture, salt and baking powder were added. After another 4 min of mixing, 250 g of batter were placed in baking forms (length 180 mm, width 76 mm, and internal height 50 mm). For each recipe, two batches of six cakes were baked.

The cakes were baked in a rotary oven (Model Hearth, National Manufacturing, Lincoln, NE, USA) at 175 °C for 45 min. Time-lapse photography was conducted by measuring the change in centre height during baking with a camera (Canon Powershot S50, Canon, Machelen, Belgium). Photographs were taken at 2 min intervals. A ruler, placed behind the baking form, allowed monitoring of centre height. Oven spring was defined as the difference between cake centre height at the start of baking and the maximum centre height reached during the process. The time at which the maximum height was reached was registered. Total collapse was calculated by subtracting the centre height after cooling for 2 h from the maximum height noted in the oven. After cooling for 2 h to room temperature, cake centre temperature was 30 °C and cake weights (g) and volumes (cm^3) were measured by rapeseed displacement.

Baking of six loaves on two different days led to volume differences not exceeding 5%.

2.3. Rapid viscosity analysis

A Rapid Visco Analyser (Model RVA-4D, Newport Scientific, Sydney, Australia) was used to study pasting and viscosity properties

Table 1
Batter formulation for standard cake baking.

Ingredient	g
Gluten-starch blend (14% moisture)	450
Sugar	450
Margarine	450
Fresh eggs	450
Sodium bicarbonate	5.14
Sodium pyrophosphate	3.86
Salt	4.5