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The role of ingredients on thermal and rheological properties of cake batters and the impact on microcake texture

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A B S T R A C T

Starch is the major ingredient in cakes which are composed from flour, eggs, fat and sugar. Starch gelatinization plays an important role – together with the protein network – in defining the structure and quality of the final product. Rheology, texture and batter thermal and pasting properties were used to determine the effect of ingredients on batter and microcake (cake without bubbles) properties. The rheology of the batter was controlled by the water content which governed the phase transitions of the batter constituents. Differential scanning calorimetry clearly attested that ingredients addition shifted the gelatinization endotherm to higher temperatures. This was in agreement with the Micro-ViscoAmyloGraph (MVAG) measurements, where the batter ingredients addition to flour increased the pasting temperature and the peak viscosity. When 20% of the flour was replaced by the pregelatinized wheat or maize starch, a decrease in the peak viscosity and setback was observed which could explain the texture improvement. The association of these different techniques helped to better understand the effects of the different ingredients of the batter on starch properties that are important for improving the quality of these high sugar and fat content cakes.

1. Introduction

The concept of quality for cakes includes various attributes such as volume, uniform crumb structure, softness and other parameters (Gélinas, Roy, & Guillet, 1999). To achieve these attributes, cake batter needs to be sufficiently viscous to trap gas bubbles during mixing and to retain them during heating (Wilderjans, Pareyt, Goesaert, Brijs, & Delcour, 2008). Although the cake making process is of utmost importance for cake quality, it is often based on empirical knowledge concerning the ingredients transformation (Wilderjans, Luyts, Brijs, & Delcour, 2013). Starch and protein in combination with the other ingredients such as sugar and fat are fundamental to the structure, rheology, and other physical properties of the baked products. During baking, the cake structure sets as a result of starch gelatinization and egg protein coagulation. This structural framework that should be strong enough to support itself when the cake is removed from the oven is crucial (Donovan, 1977).

In cakes, starch is responsible for the transformation of an aqueous, fluid batter into a solid, porous cake structure (Donovan, 1977). It has been shown that cake-baking performances and collapse of the structure varied with the gelatinization temperature as well as water absorption by the starch and sugar levels (Kim & Walker, 1992). As regards protein, Donelson and Wilson (1960) stated that gluten proteins serve as a binder in cakes, rather than as a structural element such as in bread, where it makes up the basic framework. Recently, Wilderjans et al. (2008) highlighted the effect of added gluten proteins in increasing batter viscosity, improving during baking the capacity of batter to retain expanded air nuclei, and leading to the desired product volumes. Egg proteins

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contribute in stabilizing the gas cells migrating from the fat to the aqueous phase during the first stage of baking. In the final stage of baking, starch gelatinization and egg protein coagulation increase the viscosity of the batter tremendously, imparting a solid structure to the cake (Guy & Pithawala, 1981). Fats contribute to the incorporation of air into the dough, enhance heat transfer during baking and give the finished products a moist mouth feel and a soft texture (Conforti, 2006). Sucrose affects starch gelatinization and protein denaturation by limiting water availability to starch granules and by changing the hydration properties of proteins (Donovan, 1977; Spies & Hoseney, 1982).

Modified starches (pregelatinized, acid-thinned, cross-linked, and dextrinised) have been considered as flour substitutes in egg foam cake making by Karaoglu, Kotancilar, and Celik (2001). They found that these substitutions increased cake softness and extended the shelf-life, with the disadvantage of lowering its volume. In more recent studies, the pregelatinized starches were used to obtain a less firm cake crumb capable of retaining softness during storage (Hesso, Loisel, Chevallier, & Le-Bail, 2014; Sozer, Bruins, Dietzel, Franke, & Kokin, 2011).

Baking process emphasizes the physical and chemical changes in the product components leading to a specified volume and a stabilized crumb structure. In this study, the role of the pregelatinized starch along with the other batter ingredients during cake making process were investigated by using model and real batter systems. Starch pasting properties (gelatinization and gelling properties) with and without addition of the pregelatinized starch were studied and related to the rheological and thermal properties of the batter. To address our research objective, a material science approach was applied by using the microcake (cakes without any bubbles) to study the impact of the ingredient on the texture of the cake matrix. Finally, the study aims to elucidate the complex interactions of all batter ingredients (flour, pregelatinized starch, sugar, fat and eggs) during heating and cooling processes.

2. Materials and methods

2.1. Materials

Wheat flour (protein: 11.6 g/100 g, starch: 83 g/100 g on dry basis) was supplied by Giraudineau (France). Whole liquid eggs (protein: 12.1 g/100 g, fat: 10.2 g/100 g) were purchased from Ovoteam (France). Sugar was purchased from Saint Louis (France). Fat consisting of rapeseed oil (70 g/100 g) and anhydrous milk fat (30 g/100 g) was supplied by Corman (Belgium). Sodium bicarbonate was supplied by Princeton (USA). Physically modified starches, pregelatinized wheat starch (PWS) and pregelatinized maize starch (PMS), were supplied by Roquette (France).

The reference cake batter (batter R) was taken from Hesso et al. (2014): 29.5 g/100 g wheat flour, 25 g/100 g sugar, 25 g/100 g eggs, 20 g/100 g of fat and 0.5 g/100 g sodium bicarbonate. Batter PWS and batter PMS contained the same proportion of ingredients with 20 g/100 g of flour replaced by PWS and PMS respectively.

2.2. Methods

2.2.1. Batter preparation

Batter ingredients were mixed together in two steps (speed 6 for 2 min and speed 8 for 3 min), using a "Kitchen-Aid" mixer (KSM90, Kitchenaid, St. Joseph, MI) with a wire whip as reported by Hesso et al. (2014). The flour and the pregelatinized starches were incorporated during the last step.

For microcake batter, no sodium bicarbonate was used. Indeed, using microcake subtracts the impact of the cellular structure on the texture and allows the assessment of the matrix alone making the final aerated crumb under controlled conditions.

2.2.2. Microcake baking

The miniaturized baking system "Peltier Oven" (Le-Bail, Boumali, Jury, Ben-Aissa, & Zuniga, 2009) was used to mimic the baking process with the following time–temperature profile: heating from 20 to 98 °C during 10 min followed by a plateau at 98 °C during 5 min and a cooling step to 30 °C during 30 min. About 25–30 g of batter were placed in plastic bags and sealed under vacuum until 10 mbar using vacuum packaging Multivac C400 (Hesso et al., 2014). Reference microcake (μcake R), pregelatinized wheat starch microcake (μcake PWS) and pregelatinized maize starch microcake (μcake PMS) were baked by this Peltier system. Three experiments were conducted for each microcake.

The samples of microcakes after baking were cut in two different shapes: disks (7 × 4 mm diameter) for compression tests and rectangular samples (35 × 12 × 4 mm) to assess viscoelastic properties.

2.2.3. Moisture content

The water content of each sample was measured by drying the sample at 130 °C for 20 min by an infrared balance (MB 45, OHAUS, Parsippany, NJ, USA).

2.2.4. Viscoelastic properties

2.2.4.1. Batter properties. Rheological measurements of the flour systems (flour, flour + PWS and flour + PMS) at 40 g/100 g water content (wet basis) and batters (batter R, batter PWS and batter PMS) at 24 g/100 g water content were carried out using the AR-1000N rheometer (TA Instruments, USA). A 40 mm plate–plate geometry (serrated surface to avoid slippage) with a gap of 2 mm at 25 °C was used. The sample was placed between the plates and a cover laid to prevent sample drying during the test. A frequency sweep test (0.1–10 Hz at 0.1% strain; in the linear regime) was realized on all samples (Jekle & Becker, 2011). All measurements were done at least in duplicate. Dynamic rheological properties of samples were recorded from the shear storage modulus G' and the shear loss modulus G''. The loss factor tan δ was calculated according to Eq. (1):

$$\tan\delta = G''/G' \quad (1)$$

2.2.4.2. Microcake properties. The Dynamic Mechanical Analyzer (DMA Q800 – TA- Waters instruments – 78 Guyancourt – France) was used at ambient temperature with the rectangular microcake samples, to apply a frequency sweep with a dual cantilever clamp (Hesso et al., 2014). The frequency ranged from 1 to 10 Hz at 1% strain and four replicates were performed. Storage modulus, loss modulus and tan δ ($\tan\delta = G''/G'$) were obtained for the three microcakes (reference, PWS and PMS).

2.2.5. Differential scanning calorimetry (DSC) measurements

700–800 mg of batter were placed into the stainless pans and 600–700 mg of water placed into the reference pan. Pans were heated from 20 to 120 °C at 1.2 °C/min by using the SETARAM micro-calorimeter Micro DSC VII (France). All measurements were performed at least in duplicate.

2.2.6. Texture of microcakes

The texture of the microcakes samples was investigated by a compression test using the Q800-DMA with a parallel plate system