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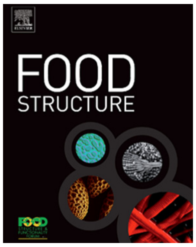

Formulation effect study on batter and cake microstructure: Correlation with rheology and texture

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ABSTRACT

Changes in the mechanical and micro-structural properties of cake batter as a function of formulation impact are described. Mechanical properties were investigated by batter rheology and cake texture. Confocal laser scanning microscope (CLSM), together with image analysis technique, was used to obtain the microstructure of batters and cakes. Results showed an increase in rheological moduli values with the addition of pregelatinized starch in the batter, while fat replacement by rapeseed oil decreased the moduli values of the batter. These changes in batter visco-elastic properties resulted in different cake structures. A significant increase in the surface area of the lipid domain has been observed on CLSM images for cakes using pregelatinized starches. This was explained by the fact that part or all of the pregelatinized starch was embedded in the lipid domain for these formulations. This fact may explain the expected softer texture of the cake using such starches. CLSM in combination with image processing has been proved as an applicable tool for examining and quantifying the fat and protein microstructure in batter and cake. Hence, it was possible to prove the dependency of the texture on the microstructure of the batter and the baked ''cake''.

1. Introduction

Cake batters composed of flour, eggs, fat and sugar, exhibit viscoelastic behavior, combining the properties of a fluid and a solid. Each ingredient is essential in the batter, exhibiting an important role in defining structural, rheological and textural properties of the cake. Mixing leads the cake batter to be a stable emulsion of fat and water, sufficiently viscous to trap gas bubbles and retain them during baking (Conforti, 2006; Wilderjans, Pareyt, Goesaert, Brijs, & Delcour, 2008). During baking, the combined effect of starch swelling and protein denaturation in presence of other ingredients transformed the liquid batter into a solid foam (dough–crumb transition). These events first tremendously increase the viscosity of the batter and finally provide the firm structure of the matrix

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(continuous phase) (Guy & Pithawala, 1981; Wilderjans, Luyts, Brijs, & Delcour, 2013; Wilderjans, Luyts, Goesaert, Brijs, & Delcour, 2010).

The cake making process entails structural modifications depending on the formulation and the process conditions, which are of enormous importance for cake quality and could be investigated by rheological and structural means. Wilderjans et al. (2008) used viscosity measurements and image analysis to correlate gluten concentrations to the changes in cake batter properties during baking and to the final cake quality. Schirmer, Jekle, Arendt, and Becker (2012) showed that replacing sucrose with polydextrose substitute in pound cake gave similar quality characteristics regarding batter structural changes, crumb grain characterization and cake texture. Upadhyay, Ghosal, Ghosal, and Mehra (2012) correlated the viscoelastic properties of batter with the microstructure. They found an inverse relation between bubble size and storage modulus in bread dough.

Light microscopy and scanning electron microscopy were used by Sanchez-Pardo, Ortiz-Moreno, Mora-Escobedo, Chanona-Perez, and Necoechea-Mondragon (2008) to compare the microstructure of crumbs as a quality criteria of pound cakes baked in a microwave and in a conventional oven.

The microstructure determines, among others things, appearance, shelf life, taste perception and rheology. Letang, Piau, and Verdier (1999) have already shown that microstructure control is essential to compare the evolution of different dough formulations. Understanding the microstructure in relation to macroscopic properties would enable the improvement of existing products and an effective design of new ones (Blonk, Don, Van Aalst, & Birmingham, 1993). Microscopic methods such as scanning electron microscopy (Sanchez-Pardo et al., 2008; Turabi, Sumnu, & Sahin, 2010), light microscopy (Sanchez-Pardo et al., 2008; Sowmya, Jeyarani, Jyotsna, & Indrani, 2009) and confocal laser scanning microscopy (CLSM) (Beck, Jekle, Selmair, Koehler, & Becker, 2011; Bousquieres, Deligny, Riaublanc, & Lucas, 2014; Jekle & Becker, 2011a, 2011b, Schirmer, Jekle, & Becker, 2011, Upadhyay et al., 2012) were often used with image processing for this purpose.

The advantage of CLSM is to allow a dynamic and nearly non-invasive observation of the microstructure of one specific focal plane of the sample, which can be combined to have a 3D insight of the structure. Components such as starch granules, lipids or proteins can be dyed and separately detected. The present study aimed to clarify the relative roles of batter formulation in defining pound cake quality. Therefore, the effect of the pregelatinized starch addition or the type of fat on the batter rheology and cake texture was investigated. To address our research objective, a specific dying method with CLSM spectral imaging, which has not been yet used on batter systems, was performed to investigate and explain the changes in batter rheology and cake texture properties induced by the formulation.

2. Materials and methods

2.1. Materials

Wheat flour (14.8% water content, 9.9% protein, 1.1% fat, 71.5% starch and 0.4% ash) was supplied by Giraudineau (France), whole liquid eggs (0.8% minerals, 12.1% protein, 10.2% fat and 0.8% carbohydrates) were purchased from Ovoteam (France). Fat is a ready-to-use blend consisted of rapeseed oil (70%) and anhydrous milk fat (AMF: 30%) was supplied by Corman (Belgium). Its solid fat content (Corman NMR method) depends on the temperature and is around 18% at 20 °C. Pure rapeseed oil (RO) was supplied by Primance (EMB, France). Baking powder (sodium bicarbonate) was supplied by Brenntag. Pregelatinized wheat starch (PWS) and pregelatinized maize starch (PMS) were supplied by Roquette (France).

Table 1 – Details of ingredients in cake formulations.

Ingredients	Batter R (wt.%)	Notes
Flour	29.5	
Sucrose	25	
Fat	20	Blend AMF/RO 70/30 provided by Corman
Whole liquid eggs	25	Water content: 77%
Sodium bicarbonate	0.5	
Batter PWS	Substitution of 20% of flour by pregelatinized wheat starch	
Batter PMS	Substitution of 20% of flour by pregelatinized maize starch	
Batter RO	100% flour; 100% rapeseed oil. No AMF	

The reference cake batter recipe (batter R) was taken from Hesso, Loisel, Chevallier, and Le-Bail (2014): 29.5% wheat flour, 25% sucrose, 25% whole liquid eggs, 20% fat and 0.5% sodium bicarbonate, all at wt.% (Table 1). Batter PWS and batter PMS contained the same proportion of ingredients with 20% of flour replaced by PWS and PMS, respectively. Batter RO contained the same proportion of ingredients as the batter R except replacing 100% of fat by 100% rapeseeds oil.

2.2. Methods

2.2.1. Batter preparation

Batter ingredients were mixed together in two steps using a Kitchen Aid mixer (KSM90, Kitchenaid, MI) at room temperature as explained by Hesso et al. (2014). The ingredients were mixed in two steps: firstly, fat, eggs and sugar were mixed at speed 6 during 2 min and then flour and baking powder were added.

2.2.2. Cake baking

Conventional baking was performed in a ventilated oven using a prototype based on a domestic oven as shown by Hesso et al. (2014). The batter was installed in a preheated oven at 180 °C for 15 min then cooled down to room temperature. Four formulations were baked: reference cake (cake R), pregelatinized wheat starch cake (cake PWS), pregelatinized maize starch cake (cake PMS) and rapeseeds oil cake (cake RO).

2.2.3. Texture of cakes

The double compression test (TPA: Texture Profile analysis, Bourne, 2002) was performed on cakes with a TA-XT+ texture analyzer (Stable Microsystems, Surrey, UK). The test was performed with a 25 mm diameter cylinder probe at 1 mm/s speed and 40% strain, on cake disks (25 mm diameter). All measurements were performed at least in triplicate. The hardness (first force peak) and the cohesion (A2/A1; A1 total area of the first compression step and A2 total area of the second compression step) were calculated from the TPA curves.