Journal of Food Engineering 170 (2016) 24–32

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Puff pastry with low saturated fat contents: The role of fat and dough physical interactions in the development of a layered structure

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ARTICLE INFO

Article history:
Received 16 March 2015
Received in revised form
20 June 2015
Accepted 10 September 2015
Available online 14 September 2015

Keywords:
Saturated fatty acids
Puff pastry
Dough development
Fat rheology

ABSTRACT

In puff pastry, fat and dough rheological behavior during sheeting control pastry dough development by formation of the layered structure which is essential for product quality. The aim of this work was to unravel the influence of fat and dough physical interactions during sheeting, as affected by variations in fat composition, to the rheological behavior, the microstructure and baking performance of pastry dough. Rheological data at small and large deformations were collected on bulk dough and pastry dough as function of sheeting steps and fat composition. The resistance of fat to work related deformation, i.e. fat consistency, and softening behavior during sheeting were also studied by means of a multi extrusion cell. The physical interaction of bulk dough and bulk fat during sheeting promoted progressive structuring of the pastry dough in a multi-layer system of solid layers alternating with soft gel layers. Structuring resulted in increasing elastic-like behavior and consistency of the pastry dough. Pastry dough elastic-like behavior and consistency increased with increasing fat consistency, until a maximum was reached. Such maximum corresponded to an ideal fat-layered structure, as indicated by microscopic analysis, and provided puff pastry with the best baking and textural quality. A further increase in fat consistency had detrimental effect on pastry dough structure and baking performance.

1. Introduction

During the past decades, international dietary recommendations have focused on the reduction of fat intake in relation to correlated diseases such as coronary heart disease. In response, the food industry has been prompted to develop and launch commercial products labeled as low-fat or fat-free (Hu et al., 2001). However, simply lowering the percentage of energy from fat intake is considered unlikely to reduce incidence of coronary heart diseases. In fact evidence from metabolic studies, epidemiologic investigations and clinical trials have indicated a link between the type of dietary fats, i.e. saturated fatty acids (SAFA), and incidence of coronary heart diseases (Hu and Willett, 2002). In view of these findings, most recent nutritional guidelines have advised to keep the daily intake of saturated fats below 10% energy (EFSA, 2010).

Puff pastry usually contains 30% or more fat (Baldwin et al., 1972), of which about 50% in the form of SAFA (Simovic et al., 2009; Yella Reddy and Jeyarani, 2001). Fatty acid composition as well as their position in the triglyceride molecule, the crystal structure, polymorphism, solid fat content (SFC), hardness and the processing conditions determine the physical properties of the fat (Garcia-Marcias et al., 2011; Marangoni and Narine, 2002; Campos et al., 2002). In order to obtain puff pastry with good baking quality, the key characteristics of the fat (i.e. margarine or shortening) include: plasticity, consistency and melting properties (Brekke, 1980; Skogerson et al., 2006; Keogh and Morrissey, 1990). Puff pastry dough is characterized by a layered structure of several alternating layers of fat and dough resulting from a repeated folding and sheeting process. The fat layered structure is essential for the puff and flaky texture of the baked product (Baldwin et al., 1972); it keeps the dough layers separate and traps the water vapor during baking, leading to the final expanded structure. To achieve an optimal layered structure, plasticity and consistency of the fat are required to retain a continuous, unbroken layer during sheeting (Yella Reddy and Jeyarani, 2001; Chrysam, 1985). It has been suggested that fat for pastry application should have the same consistency as the bulk dough across the temperature range which includes the processing temperatures (Stauffer, 1994; Johnson, 1999). As the fat deviates from this consistency, sheeting quality decreases (Stauffer, 1994).

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http://dx.doi.org/10.1016/j.jfoodeng.2015.09.009
0260-8774/

Margarine and shortenings can be generally described as particle gels, consisting of a network of weakly bonded solid particles associated with triacylglycerol fluid (Ghotra et al., 2002; Narine and Marangoni, 1999a,b). Such structural organization is directly responsible for the mechanical behavior (i.e. elasticity) of the fat (Narine and Marangoni, 1999a,b; Pernetti et al., 2007). The application of large deformations, i.e. sheeting, induces structural changes to the particle network of fat, resulting in decreased elasticity of the fat (Gonzalez-Gutierrez and Scanlon, 2013; Kloek et al., 2005). Therefore, the product consistency during sheeting changes from brittle to spreadable. Given the relation between the particle crystal network and elasticity, fats for puff pastry application are generally characterized in terms of SFC as a function of temperature (Doerry, 1996; Stauffer, 1996). Despite important, lipid composition cannot adequately predict the rheological properties of fats (Narine and Marangoni, 1999a,b), which addresses the need for understanding their behavior for specific processing applications.

During rolling and sheeting, wheat flour dough is subjected to a combination of uniaxial extension and shear at relatively high deformation rates (MacRitchie, 1986; Morgenstern et al., 1999) which determine the rheological properties of the dough at each step in the process. Puff pastry quality (e.g. volume) is strongly related to the rheological properties of the dough before baking. In fact, the mechanical response of the dough at large deformations is associated to the strain-hardening behavior of the gluten network (van Vliet, 2008) and it is suggested to control the formation of thin dough layers as required in puff pastry (Sliwinski et al., 2004).

With the increasing desire to reduce SAFA contents in bakery products, such as puff pastry, the fundamental understanding of the effect of variations in the characteristics of the fat on dough development and final product quality becomes important. To the best of our knowledge, there are no studies which address changes in the rheological behavior of pastry dough during sheeting in relation to variations in the rheological behavior of fat. Therefore, the aim of this work was to relate the rheological behavior of fat and pastry dough during processing to puff pastry quality, as affected by variations in fat composition. In order to do so, small and large deformation rheological tests were performed on fat and pastry dough at different steps during the sheeting procedure. Bulk dough, i.e. pastry dough without the layered fat, was also studied at similar sheeting steps in order to gain insight of the contribution of fat to the rheological behavior of the pastry dough. Light microscopy of selected pastry dough samples was performed in order to gain insights on the effects of fat variation on dough microstructure. Finally, baking tests were performed for each of the pastry doughs varying in fat composition.

2. Materials and methods

2.1. Materials

Commercial wheat flour for pastry application (Meneba Meel BV, Rotterdam, The Netherlands) was used in conjunction with table salt and tap water. The flour had a moisture, protein and ash content of 15.5%, 11.6% and 0.6%, respectively.

Palm stearin, palm oil and rapeseed oil were used for the preparation of six different fat blends varying in SAFA content (Table 1). All fats were purchased from Remia BV (Den Dolder, The Netherlands).

2.2. Pilot production of shortenings

Fats were first melted and mixed in a jacketed tank at 70 °C. Fat blends were left to cool to 55 °C and then transferred to a scraped surface heat exchanger (VK 60/400-F, Gerstenberg Schröder, Germany) at 100 rpm. The pump was set at 12.8 bar and the flow rate was 79.5 L/h. The temperature at the outlet was 20 °C. Once processed, fats were stored for 1 month at −20 °C.

2.3. Fat pre-working

Prior to their use, all fats were conditioned at 18 °C and then pre-worked in a Kemper spiral mixer (Kemper SP15, Shelton, USA). Pre-working was performed by mixing 2500 g of fat for 2 min at speed 2 of the mixer. The pre-worked fat was stored overnight at 18 °C.

2.4. Bulk dough preparation

Bulk doughs were prepared and used in combination with the different fat blends. The water amount to be added to the flour was calculated taking into account flour moisture content and the farinograph water absorption. To 100 g of flour 10 g of fat were added together with 1 g of salt. The ingredients were conditioned overnight at 18 °C. After addition of water (10 °C), the ingredients were mixed in a Kemper mixer (Kemper Spiral Mixer, Shelton, USA) for 1 min at low speed (speed I of the mixer). The speed was then changed to a higher rate (speed II of the mixer) until the temperature of the dough reached 18 °C as measured by thermocouples which were placed in the mixer. The dough was weighed (4500 g), rounded and cooled at 5 °C for 5 min. Afterwards, the bulk dough was sheeted with a reversible Rondo sheeter (Rondostar Eco, Rondo, Burgdorf, Switzerland) into a square shape of 600 × 600 mm and 8 mm thickness.

2.5. Pastry dough preparation

In order to prepare the pastry dough, the pre-worked bulk fat from the different fat blends (2000 g) was sheeted with a reversible Rondo sheeter (Rondostar Eco, Rondo, Burgdorf, Switzerland) into a square shape of 400 × 400 mm and 13 mm thickness. The fat was then conditioned overnight at 18 °C. The next day the bulk dough was prepared and the bulk fat was closed inside the bulk dough like an envelope, and the edges sealed together (see supplementary material for description of sheeting steps). The pastry dough was sheeted to 10 mm thickness (pre-sheeting step). Then the pastry dough was folded according to the French method (three folds), turned 90°, sheeted to 10 mm and folding by the Dutch method (four folds), which was followed by 30 min rest at 5 °C (first sheeting step). After resting, the dough was sheeted to 10 mm, folded by the French method, then sheeted again to 10 mm and folded by the Dutch method, which was followed by 30 min rest at 5 °C (second sheeting step). Finally the pastry dough was sheeted to 12 mm, folded in two and sheeted to 6 mm (final sheeting step). The puff pastry was then cut using a custom-made device resulting in squares of 100 mm length and with an inner hole of 50 × 50 mm length. The pastry dough was then rested for 60 min at 18 °C.

2.6. Puff pastry baking

Puff pastry samples were baked in a Rothoterm oven (Werner & Pfleiderer, Dinkelsbühl, Germany) in two steps: 21 min at 200 °C and 8 min at 160 °C. After baking, the puff pastries were cooled for 60 min at 28 °C and then stored overnight at 18 °C in sealed plastic bags prior to analyses. Baking was performed in duplicates for each of the six fat variations, producing 12 puff pastries for each independent duplicate.