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The impact of redox agents on further dough development, relaxation and elastic recoil during lamination and fermentation of multi-layered pastry dough

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ABSTRACT

The role of gluten proteins during lamination and fermentation of multi-layered wheat flour pastry dough was examined by including oxidizing or reducing agents in the recipe to respectively strengthen or weaken the gluten protein network. Pastry burst rig textural measurements showed that dough strength increases during lamination up to 16 fat layers. However, further lamination up to 64 and 128 fat layers decreases the dough strength, most likely due to destruction of layer integrity. Redox agents strongly affect dough strength. Furthermore, fermentation and spread tests showed that they strongly influence elastic recoil immediately after lamination and during relaxation. Moreover, elastic recoil consistently occurs to a greater extent in the final direction of sheeting. None of the observed changes in dough strength and relaxation behaviour could be linked to changes in the levels of protein extractable in sodium dodecyl sulfate containing medium (SDS-EP). This suggests that changes occur preferentially either within the SDS-extractable or within the non-SDS-EP fraction and that they do not render non-extractable protein fractions extractable or vice versa. Furthermore, elastic recoil is most likely caused by reformation of inter- and intramolecular hydrogen bonds and hydrophobic interactions.

1. Introduction

Laminated dough systems are used for producing different puff and fermented pastry products (Hay, 1993). Typically, predough (as it is called) is prepared with a straight-dough mixing procedure in which all ingredients are mixed together in a single step (Bent, 2007). It is then sheeted and a (single) fat layer (i.e., the 'roll-in fat') is enclosed within a bottom and top layer of the predough (Bennion et al., 1997) Repeated sheeting and folding of this layered paste produces a laminar system with alternating sheets of (pre) dough and fat (Bent, 2007; Cauvain and Young, 2009).

Gluten proteins strongly affect the structure and texture of various wheat-based baked goods, and of their intermediates. However, surprisingly, their role in multi-layered wheat flour dough-margarine systems has hardly been discussed. Gluten proteins make up 80–85% of the total wheat flour protein (Lagrain et al., 2008) and consist of monomeric gliadin and polymeric glutenin (Shewry et al., 1992). Gliadin proteins are a heterogeneous mixture of α-, γ- and ω-gliadins (Lagrain et al., 2008). The α- and γ-gliadins contain cysteine residues which are all involved in intramolecular disulfide (SS) bonds, 3 and 4 respectively. In contrast, ω-gliadins lack cysteine residues (Lagrain et al., 2008). Glutenin polymers consist of high molecular weight (HMW) and low molecular weight (LMW) glutenin subunits (GS) (Gianibelli et al., 2001) which are linked together by intermolecular SS bonds. In addition, glutenin also contains intramolecular SS bonds (Lagrain

Abbreviations: AA, ascorbic acid; CSH, cysteine; D1, diameter in the direction of the final sheeting direction; D2, diameter in the direction perpendicular to the final sheeting direction; EA&G, extractable albumin and globulin proteins; EGLI, extractable gliadin proteins; EGLU, extractable glutenin proteins; EP, extractable proteins; GM, gluten macropolymer; GS, glutenin subunits; HMW, high molecular weight; LMW, low molecular weight; SDS, sodium dodecyl sulfate; SH, sulfhydryl group; SS, disulfide.

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et al., 2007). GS are released under reducing conditions. Wheat flour dough properties are strongly related to the properties of very large glutenin aggregates (Don et al., 2003). (Part of) these glutenin polymers can be isolated as a gel layer which is not extractable in a sodium dodecyl sulfate (SDS) containing medium and which is referred to as glutenin macropolymer (GMP) (Don et al., 2003).

The gluten protein network confers upon dough its viscoelastic properties (Belton, 1999). Glutenin polymers are considered to be the determinants of dough elasticity and strength, whereas gliadins may act as plasticizers for the glutenin structure, thus weakening their interactions. In addition, they contribute to dough viscosity (Belton, 1999). Different types of bonds are crucial for forming a gluten network upon dough mixing. SS bonds are key in this respect. Other covalent bonds, such as isopeptide bonds have been suggested to also be important for the gluten network (Morel et al., 2002). Also, the high levels of glutamine in gluten proteins allow for formation of intermolecular as well as intramolecular hydrogen (H)-bonds (Gianibelli et al., 2001). Belton (1999) put forward a 'Train & Loop model'. In his view, glutenin elasticity is mediated by non-covalent interactions between and within individual glutenin chains. Furthermore, the importance of hydrophobic (Weegels et al., 1994) and ionic interactions (Fu et al., 1996) has been established.

Because the production of laminated dough involves repeated sheeting and folding steps, the gluten protein (development) is even more complex than that in wheat bread dough. Furthermore, literature on pastry dough rheology is scarce and has only focussed on measuring sheeted dough without roll-in fat, either with an Extensigraph (Hay, 1993) or with a probe (Dobraszczyk and Morgenstern, 2003) similar to the 'pastry burst rig' used in this study. However, to our knowledge, the rheology of a multi-layered dough containing roll-in fat has never been studied in detail.

An issue faced when sheeting dough is that when leaving the sheeting rolls it immediately becomes thicker than the distance between the rolls (i.e. the roll gap). This phenomenon has been referred to in literature as 'dough snapback', 'elastic recovery' or 'elastic recoil'. It has been studied mainly for bread dough, thereby focusing on predicting and controlling dough thickness after sheeting (Engmann et al., 2005; Ren et al., 2008). It is influenced by the sheeting mechanics (roll gap opening, degree of stepwise thickness reduction, number of sheeting steps, line speed, etc.) but also by the flour gluten content and quality (Engmann et al., 2005; Ren et al., 2008). Bousquieres et al. (2014) observed elastic recoil after sheeting in laminated dough. However, dough shrinkage was limited when higher amounts of roll-in fat were used. The layered structure of laminated dough thus adds another degree of complexity to recoil behaviour over that in bread dough. Furthermore, the laminating fat in itself contributes to product quality as well. Fat plasticity, consistency and melting properties are some of the key performance characteristics for roll-in fat (Pajin et al., 2011). Fat functionality during pastry production has been studied (Garcia-Macias et al., 2011; Pajin et al., 2011; Bousquieres et al., 2014) and reviewed (Wickramarachchi et al., 2015; Ooms et al., 2016) elsewhere.

In this study, we focus on gluten protein functionality during pastry dough making. Three redox agents are used to selectively alter gluten network formation during production of laminated dough. Ascorbic acid (AA), widely used as flour improver, increases dough strength and reduces its stickiness (Aamodt et al., 2003). Potassium iodate (KIO_3), a fast-acting oxidizing agent, impacts the dough thiol-SS system and can thus affect glutenin subunit polymerization (Joye et al., 2009) thereby increasing dough strength. L-cysteine (CSH), a reducing agent, weakens dough structure by reduction of intermolecular SS bonds (Joye et al., 2009).

2. Materials and methods

2.1. Materials

Commercial wheat flour (protein level: 12.2%, dry basis; moisture content: 13.7%) was provided by Vandemoortele (Izegem, Belgium). Its protein and moisture contents were determined with an adaptation of the AOAC Official Method 22 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 and according to AACC International Approved Method 44–15.02.23, respectively. A palm-oil based margarine (80% fat, free of emulsifiers) was used as in-dough and roll-in fat, and also provided by Vandemoortele. All reagents, solvents, and chemicals were of analytical grade and were from Sigma-Aldrich (Bornem, Belgium) unless indicated otherwise.

2.2. Standard pastry dough making

Supplementary Fig. 1 schematically represents the optimized in-house standard pastry making procedure used. Predough ingredients, on a 100.0 g wheat flour basis (14.0% moisture), were 6.0 g compressed yeast, 2.0 g salt, 10.0 g sucrose (all obtained from a local store), 50.0 ml tap water (cooled to 0–2 °C) and 5.0 g margarine. Predough mixing (500.0 g flour basis) was according to a straight bread dough method. A Vema Mixer with a mixing bowl volume of 7 L and a spiral-shaped beater (Machinery Verhoest, Izegem, Belgium) were used. Mixing time was 7 min at 23 °C. Roll-in fat (25.0% on dough weight, at 16 °C) was incorporated according to the French or envelope method ((Hay, 1993; Ooms et al., 2016). Laminated dough was sheeted with a Rondo (Burgdorf, Switzerland) STM 513 mechanical dough sheeter in seven reducing steps [roll gap distances 15, 13, 11, 9, 7, 6 and 5 mm (the latter twice), respectively]. The dough was turned 90° after the third reducing step. After the last sheeting, it was folded into four, thus yielding four fat layers. Depending on the experiment, folding and sheeting were repeated as described above 1, 2 or 3 times (with final folding in two rather than in four), yielding laminated dough with 16 (standard), 64 or 128 fat layers. Laminated dough was allowed to rest (20 min, 4 °C) after or in between lamination steps, depending on the experiment. Finally, dough was sheeted to its final thickness, again in seven steps. Eighteen dough cylinders were cut from the dough slice using a circular cutter (diameter 62,5 mm). Their diameters, heights and weights were measured. Next, they were placed in a fermentation closet at 32 °C and 95% relative humidity for 75 min. Deviations from this standard procedure in some experiments are addressed in the results section.

2.3. Addition of redox agents

AA and KIO_3 were added directly in the predough recipe [13.96 and 2.30 μmol/g protein respectively (*i.e.* 300 ppm and 60 ppm on flour basis)]. CSH was added likewise but as an aqueous solution saturated with N_2 to avoid oxidation [2.37 μmol/g protein (*i.e.* 35 ppm on flour base)].

2.4. Pastry burst rig texture analysis

Extensibility and strength of yeastless laminated dough at different moments during pastry dough making were analysed using a pastry burst rig (Stable Micro Systems, Godalming, Surrey, UK) adapted to an Instron 3342 (Norwood, MA, USA) equipped with a 5.0 kg load cell. A pastry dough piece was cut to size (10 × 10 cm) with a knife and fixed between two metal plates, exposing a circular section of the sample (diameter 6.5 cm). During analysis, a