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Intrinsic wheat lipid composition effects the interfacial and foaming properties of dough liquor

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ABSTRACT

Doughs were prepared from a single variety breadmaking flour (cv. Hereward), from three successive harvests (years; 2011, 2012 and 2013). A preparation of the aqueous phase from dough, known as dough liquor (DL), was prepared by ultracentrifugation and its physico-chemical properties were investigated. Surface tension and interfacial rheology, showed that the interface of DL was lipid-dominated and that 2013 DL had a different type of interface to 2011 and 2012 DL. This data was consistent with the improved foam stability observed for 2013 DL and with the types of lipids identified. All foams collapsed quickly, but the most stable foam was from 2013 DL with 89.2% loss in foam, followed by 2011 DL with 91.7% loss and 2012 had the least stable foam with a loss of 92.5% of the foam structure. Glycolipids (DGDG and MGDG) were enriched in 2013 DL, and were also present in DL foam, contributing towards improved stability. Neutral lipids, such as FFAs, were enriched in DL foams contributing towards instability and rapid foam collapse. Baking trials using 2012 and 2013 flour, showed increased loaf volumes and gas bubble diameter in 2013 bread compared to 2012 bread, highlighting the potential impact that surface active polar lipids, enriched in the aqueous phase of dough, could have on improving breadmaking quality.

1. Introduction

The breadmaking performance of wheat flour is determined by the composition and properties of the grain and the processes used for milling and baking (Cauvain, 2012). Of particular importance is the ability of the flour to form a viscoelastic dough which retains the gas produced during proving and baking to give a loaf with a light porous crumb structure (Chin & Campbell, 2005; Peighambardoust, Fallah, Hamer, & van der Goot, 2010). The physical properties of the dough will depend on various factors, with the amount and quality of the gluten proteins being the most important (D'Ovidio & Masci, 2004; Mills, Wellner, Salt, Robertson, & Jenkins, 2012; Shewry, Tatham, & Lazzeri, 1997). However, the physical properties of the dough will also be affected by other flour components, the dough formulation, including the addition of improvers and surfactants, and the dough mixing process (Cauvain, 2012).

The formation of an elastic gluten network requires shear forces during mixing to allow the proteins to interact and form an elastic network (Belton, 2005; Dobraszczyk & Morgenstern, 2003). The viscoelastic properties of the gluten-starch matrix allow the entrapment of gas cells formed during mixing, which grow during proving leading to the formation of a foam (Campbell & Mougeot, 1999) which is fixed during baking to give a light, porous crumb structure. If the dough is too “strong”, then it will resist the growth of the gas cells, conversely, if the dough is too “weak”, then the network cannot hold the gas cell structure as effectively (Chin & Campbell, 2005), and oven spring (the rapid, final increase in volume during baking) is also reduced (Dobraszczyk & Morgenstern, 2003). Hence, bread quality is determined by gluten strength and dough bubble stability, which have impacts on loaf volume and

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crumb structure, respectively.

Because the strength of the gluten network influences how gas cells develop, it is not surprising that this is by far the most important factor in controlling bread making quality. Gluten strength is mainly determined by the proportions of individual proteins and their interactions, with one specific protein group, the high molecular weight (HMW) subunits of glutenin, being particularly important (Cauvain, 2012; Chin & Campbell, 2005). However, gluten quality has been estimated to only account for approximately 70% of the variation in overall bread dough functionality (Gupta, Batey, & Macritchie, 1992; MacRitchie, 2016) and attention has focused on the identification of other functional components. In particular, it is likely that whereas gluten plays a key role in gas bubble development, other components are required to confer bubble stability.

Bubble stability determines the extent to which bubbles, created during mixing and proving, coalesce over time. Low levels of coalescence result in the fine texture typical of UK sliced bread, and poor bubble stability leads to a coarser texture and reduced loaf volume. It is clear that surface active components contribute to stabilising bubbles against coalescence, particularly proteins and lipids, but the mechanisms remain unclear (Primo-Martin, Hamer, & de Jongh, 2006; Salt et al., 2006; Wilde, 2012). There is therefore a need to elucidate the roles of different wheat components in determining bubble stability and mechanisms of action in order to develop clear targets for improving gas cell stability.

The gas phase in dough is critical for the texture and structure of bread: over 70% of the final loaf volume is made up of gas cells, the size, shape and number of which determines the final texture and structure. Gas cells or bubbles can be created and stabilised in the presence of any amphiphilic molecule, with the molecular structure and physico-chemical properties of the amphiphile (most commonly proteins, surfactants and lipids) determining the foam stability (Wilde, 2012). This stabilising layer is critical during proving of the dough in breadmaking (Campbell & Martin, 2012), as the gas cells come into contact and the risk of coalescence is markedly increased. At this point, the strength of the gluten network no longer controls the stability. Rather, it is the molecular properties of the stabilising layer that control the stability of the bubbles to coalescence, particularly at the end of proving and the start of baking (Hayman, Sipes, Hoseney, & Faubion, 1998; Shimiya & Nakamura, 1997).

Although previous work has focused on the protein and lipid components in dough, their relative contributions have not been defined, as the fragile nature of the dough means that it is very difficult to study the components present at the surface of gas bubbles without destroying the gas cell structure. Several proteins from wheat have been shown to possess surface activity including soluble fractions of gliadins, globulins and albumins (Keller, Orsel, & Hamer, 1997), non-specific lipid transfer proteins (Subirade, Salesse, Marion, & Pezolet, 1995), puroindolines (Biswas, Dubreil, & Marion, 2001; Kooijman, Orsel, Hamer, & Bekkers, 1998; Pauly, Pareyt, Fierens, & Delcour, 2014) and α-amylase/trypsin inhibitors identified in DL foams (Salt, Robertson, Jenkins, Mulholland, & Mills, 2005). However, the consensus is emerging that lipids are the main components controlling bubble stability (Gerits, Pareyt, & Delcour, 2014; Sroan & MacRitchie, 2009; Ukai & Urade, 2007).

Wheat flour contains a range of lipids (Pareyt, Finnie, Putseys, & Delcour, 2011), all of which are capable of adsorbing to the surface of the gas bubble, although some are bound up in different structures within the grain and the flour and are effectively not available. Differences in lipid molecular structures will determine the overall bubble stability and the lipid composition of the flour will therefore be critical for dough stability. Bekes et al (Bekes, Zawistowska, Zillman, & Bushuk, 1986). determined lipids in 26 spring wheat flours showing significant correlations between loaf volume and the ratios of neutral lipids to polar lipids and, in particular, of neutral lipids to glycolipids. It has been suggested that phospholipids and glycolipids may promote the formation of protein:lipid complexes during dough-making, through hydrogen bonds and hydrophobic interactions with gliadin and glutenin molecules (Belton, 2005; Dobraszczyk & Morgenstern, 2003). These interactions will in turn result in increased dough strength (as measured by mixing time) and gas retaining capacity and, therefore, in a higher loaf volume and better crumb structure. A role for glycolipids in bread-making was previously suggested by Chung et al (Chung, Pomeranz, & Finney, 1982). based on their structural similarity to bread softeners and surfactants which are commonly added to dough to improve bubble stability. MacRitchie and colleagues (MacRitchie & Gras, 1973; Sroan & MacRitchie, 2009) confirmed that the polar lipid content of dough has a major effect on dough stability and loaf volume and, together with other studies (Gerits, Pareyt, & Delcour, 2014; Salt et al., 2006), have shown that the surface properties of dough liquor are dominated by the lipid component. White wheat flour contains a range of polar lipids, including phospholipids (predominantly phosphatidyl choline), galactolipids (predominately monogalactosyldiglycerides (MGDG)) and digalactosyldiglycerides (DGDG)) and lyso-phospholipids (predominately lysophosphatidylcholine (LPC) (Gonzalez-Thuillier et al., 2015), the latter being integral lipids within the starch granules which are released on starch damage (which is affected by milling). Furthermore, lipolytic enzymes can be used to generate novel forms which may have better bubble stabilising properties than the endogenous flour lipids (Gerits, Pareyt, Decamps, & Delcour, 2014).

We report here studies of the role of lipids in gas bubble structure in white flour, using dough liquor and foaming to identify surface-active components. The cultivar Hereward was selected because it was the gold standard for UK bread making wheats for over 15 years, although its protein quality was not outstanding, and grain samples from three successive years (2011, 2012 and 2013) were compared to determine the extent of year to year variation in the amount, composition and properties of the lipids identified as functionally active.

2. Materials

Breadmaking wheat, c.v. Hereward was grown under standard agronomic conditions at Rothamsted Research (Harpenden, Hertfordshire UK) in 2011, 2012 and 2013 and milled at Campden BRI (Chipping Campden, Gloucestershire UK), using a Buhler–MLU-202 mill. This gave three break and three reduction fractions, which were combined to give white flour with yields of 79% (2011), 73% (2012) and 77% (2013).

All chemicals and reagents were supplied by Sigma-Aldrich (Poole, Dorset UK) unless otherwise stated.

3. Methods

3.1. Dough liquor extraction and preparation

Doughs were prepared as previously described by Salt et al. (Salt et al., 2005; Salt et al., 2006). Briefly, doughs were mixed in a Kenwood Chef mixer with a dough hook attachment, mixing for 4 min. Non-yeasted dough (500 g) was prepared using a basic recipe of 305 g flour (61%), 189 g (37.8%) water and 6 g salt (1.2%). The recipe was adjusted for the 2013 flour [318 g flour (63.6%), 175 g water (35%), and 6 g salt (1.2%)] based on the unusually low water absorption of 50.7% (which was determined by Farinograph (to the 600BU Line) using Cereals and Cereal Applications Testing (CCAT)