Journal of Cereal Science 42 (2005) 59–68

Journal of
CEREAL
SCIENCE

www.elsevier.com/locate/jnlabr/yjcrs

Effect of simple shear on the physical properties of glutenin macro polymer (GMP)

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Received 2 June 2004; revised 29 October 2004; accepted 22 December 2004

Abstract

Gluten plays a key role in determining the end-use quality of wheat flour. The important role of the highly aggregated fraction of gluten, glutenin macropolymer (GMP), in dough properties opens up new possibilities for revealing underlying mechanisms related to dough processing. Using a new shear cell and advanced methodology to study the GMP, we investigated the effect of simple shear on the physical properties of this fraction. Shear processing was compared with z-blade mixing, which involves both shear and elongational forces. Measurement of the amount of GMP and glutenin particle size distribution revealed large differences between simple shearing and z-blade mixing processes. In contrast to z-blade mixing, simple shearing at comparable levels of mechanical energy input, did not lead to a decrease in the wet weight of GMP or the size of glutenin particles. Confocal scanning laser microscopy of doughs revealed that shear processing produced a homogeneously distributed dough protein matrix, however, the GMP extracted from the sheared dough showed the presence of large clusters of particles. On the other hand, z-blade mixing led to disruption of these particles. Thus the type of deformation applied during dough processing is of crucial importance and in designing new equipment for dough processing the principles of different types of shear should be considered.

Keywords: Dough; Gluten; GMP; Glutenin particles; Simple shearing; Z-blade mixing

1. Introduction

Proteins are recognized as the most important components governing bread-making quality of wheat (Aussenac et al., 2001; Weegels et al., 1996a). Gluten, composed of gliadins and glutenins, is the major wheat protein (Pomeranz, 1988). A major glutenin fraction can be isolated from wheat flour as a gel known as glutenin macropolymer, GMP (Don et al., 2003a,b; Graveland et al., 1982), which is insoluble in 1.5% (w/v) SDS solution. The importance of this highly aggregated glutenin and its composition in assessing wheat quality and predicting dough properties has been discussed in many recent studies (Aussenac et al., 2001; Don et al., 2003a; Graveland et al., 1982; Moonen et al., 1986; Sapirstein and Suchy, 1999; Skerritt et al., 1999a,b; Tronsmo et al., 2002; Weegels et al., 1995, 1996a,b). The composition and quantity of GMP are influenced by processing since the amount of GMP is strongly related to the mixing state of the dough (Aussenac et al., 2001; Don et al., 2003a; Skerritt et al., 1999a; Weegels et al., 1996b, 1997a,b). Don et al. (2003a) compared the effect of mixing energy (using a z-blade mixer and a pin mixer) on the physical properties of GMP. They concluded that the reduction in GMP content and glutenin size observed

Abbreviations: CSLM, confocal scanning laser microscopy; db, dry matter basis; DMF, dimethylformamide; FITC, fluorescein isothiocyanate; GMP, glutenin macropolymer; GS, gluten–starch mixture; MC, moisture content; SC, shear cell; SDS, sodium dodecyl sulphate; SME, specific mechanical energy; SUP, supernatant; TTP, time to peak; ZD, zero developed.

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0733-5210/$ - see front matter
doi:10.1016/j.jcs.2004.12.007

depended on the mechanical energy input in both mixing systems.

Mixing energy, however, does not completely characterize the mixing process. The nature of the mixing action is also important, but is more difficult to specify (Bloksma and Bushuk, 1988). During mixing, dough is deformed by a combination of shear and uniaxial elongation at high rates (MacRitchie, 1986). In a Farinograph mixer a combination of rotational, shear and elongational components are involved, but in a Mixograph mixer the shear component is predominant (Jongen et al., 2003). It has also been reported, however, that the mixing action of a pin mixer is mainly elongational (Gras et al., 2000). Thus the complicated nature of mixing makes it difficult to understand dough processing on a mechanistic level. Moreover, a quantitative relationship between type of mixing deformation and resulting dough properties is lacking. It is therefore important to take into account the individual impact of different types of deformation involved in dough mixing.

The effects of well-defined shear and elongational deformations on dough properties have been studied (Campos et al., 1997; Lee et al., 2001; Schluentz et al., 2000). The different effects of shear and extension, and their combination, on dough properties was demonstrated by Lee et al. (2001). They concluded that shear or extensional deformations, alone, generated in an oscillatory test using a cone plate rheometer, did not produce dough quality, as judged by the amount of protein matrix, comparable to that produced by a Farinograph mixer. However, comparable energy inputs for the different shearing regimes were not used and it seems likely that the energy input in their oscillatory tests were well below that occurring in, for example, a Farinograph mixer. Consequently their results are difficult to interpret and no comparison with commercial processing is possible.

Mechanistic insight into the dough preparation process might be improved if comparable mechanical energy input and shear stress were applied when analysing the mixing process in terms of well-defined shear and extensional deformations. Van den Einde et al. (2003) and Peighambardoust et al. (2004) introduced a new method based on a pilot-scale shear cell, which applied high shearing stresses (up to 50 kPa) and SMEs (up to 400 kJ/kg) comparable to those used during industrial dough mixing and extrusion. Peighambardoust et al. (2004) used a well-defined shearing treatment obtained pasta-like products with acceptable properties, suggesting formation of a continuous gluten network. Furthermore, even at high SME the products did not show signs of over-processing. This prompted us to study the effect of simple shearing on the physical properties of gluten at a more structural level, especially with respect to its most functional part, the GMP fraction, and to compare it to the effect of z-blade mixing at comparable levels of energy input.

2. Experimental

2.1. Materials

Flours from Spring, a strong and hard Canadian wheat, and Soissons, a weak French wheat were kindly supplied by WCFS, Wageningen, The Netherlands. Both flours were from single wheat cultivars. Based on our previous study (Peighambardoust et al., 2004), a gluten–starch (GS) mixture with 11% gluten (db) was added to the experimental material. Commercial wheat gluten and starch were from Roquette Co. (France). Sodium dodecyl sulphate (SDS) >99% purity was from Sigma. All other chemicals and staining agents were at least of analytical grade.

2.2. Analytical methods

Moisture and ash content and the Farinograph characteristics of raw materials were determined using the AACC Approved Methods 44-15A, 08-01 and 54-21, respectively (AACC, 2000). The protein contents (N×5.7) of flour and freeze-dried GMP samples were determined by the Dumas method (Sebecic and Balenovic, 2001) using an NA2100 Nitrogen and Protein Analyzer (ThermoQuest-CE Instruments, Rodeno, Italy). Methionine was used as a standard. The chemical and physicochemical characteristics of the materials used in this study are presented in Table 1.

2.3. Preparation of zero-developed dough for shearing experiments

Zero-developed (ZD) dough was prepared in a walk-in-freezer (−18 °C) by the method of Campos et al. (1996) with modifications as described by Peighambardoust et al. (2004). NaCl (2%, w/w) was used in the preparation of all ZD doughs. Moisture contents of 53.0, 48.9 and 51.0% based on 14% moisture in flour were used for the preparation of GS, Soissons and Spring doughs, respectively. These values were selected to give a successful processing (no slippage) of material in the shearing device and also a good handling (no stickiness) of product

Table 1
Chemical and physicochemical characteristics of wheat flour samples and GS mixture

	Spring flour	Soissons flour	GS mixture
Moisture (%db)	13.5	13.6	10.4
Ash (%db)	0.57	0.48	0.41
Protein (%db)	16.1	11.3	8.5
Farinograph			
Optimal water absorption (%; 14% moisture)	57.9	53.2	53.0
Development time or TTP (min)	10.0	2.1	1.2
Stability time (min)	18.0	1.0	0.2
Time to breakdown (min)	33.0	2.5	1.2