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Viscoelastic properties of tablets from Osborne solubility fraction, pentosans, flour and bread using relaxation tests

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ABSTRACT

There is no previously published data covering the viscoelasticity of Osborne protein solubility fractions. Therefore, the objective of this study was to compare the viscoelastic properties of Osborne fractions, water soluble pentosans, flour and bread using relaxation tests. Sintered tablets from glutenins presented similar elasticity as gliadins but almost twice the viscosity. However, most of the wheat viscoelasticity performance in tablets was given by the sum of the non-gluten components (albumins, globulins, residue and especially water soluble pentosans). The residue was 86.1% w/w in flour and contained 4% protein while its estimated viscoelastic effect was higher compared to all the other flour components. Regarding the estimated viscosity in flour due to protein from specific fractions, it was higher in gliadins compared to glutenins. The residue although has low protein in flour (4.0%), the large amount of residue in flour had significant viscoelastic effect. The viscoelasticity of water soluble pentosans corrected by weight was similar to the Osborne protein fractions. The results indicate that the starch, pentosans, and non-gluten components may not be considered merely as inert filler and play a major role in determining the viscoelastic nature of flour and bread.

1. Introduction

Understanding the role of the various constituents of wheat flour in determining the functional properties of dough has been a major endeavor throughout the 19th century until now. Specifically, gluten proteins have been widely studied over a period in excess of 250 years, in order to determine their structures and properties and to provide a basis for manipulating and improving end use quality (Shewry et al., 2002).

Gluten is the main functional component of wheat flour that exhibits significant viscoelastic properties (Schofield and Scott Blair, 1937; Greenwood and Ewart, 1975; Lindsay and Skerrit, 1999; Masi et al., 1998). It is reasonable, therefore, to assume that this protein is the major determinant of viscoelasticity of the dough (Greenwood and Ewart, 1975). Based on that assumption, several theories had been proposed to describe gluten structure, viscoelasticity and its relation to function.

The presence of specific HMW-GS is significantly associated with several quality tests (Payne et al., 1987). However, few publications have addressed the influence of glutenin proteins on viscoelastic properties of wheat doughs (Lefebvre and Mahmoudi, 2007; Hernández-Estrada et al., 2014), in spite of their importance and influence on the machinability of the dough, gas holding capacity dynamics and quality of the baked bread (Bockstaele et al., 2011).

The first report of stress–strain curves of wheat dough and

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gluten washed from the same dough showed the similarity of their curves and suggested that the elasticity of wheat dough was due to gluten (Schofield and Scott Blair, 1937). Recently Hernández-Estrada et al. (2014), found that non-gluten components of dough showed significantly higher elastic modulus than wet gluten. Additional experiments showed that wet gluten from dough washed to remove most of the non-gluten components (albumins, globulins, starch and pentosans) presented lower elastic moduli than dough (Hernández-Estrada et al., 2015). This fact suggested that a major part of the viscoelasticity and functionality of the dough as a system is given by the non-gluten components. Other authors suggested that gluten was the major component responsible for the viscoelasticity of dough (Greenwood and Ewart, 1975; Lindsay and Skerrit, 1999; Masi et al., 1998). However, to date no effort has been made to examine the influence of pentosans, starch and other non-gluten components in the viscoelasticity of flour. To our knowledge there is no published data on the viscoelasticity of Osborne solubility fractions. In order to corroborate the hypothesis that, the non-gluten components of wheat significantly affected the viscoelastic properties, wheat flour was separated into Osborne solubility fractions. Sintered tablets made from protein fractions were evaluated using stress relaxation. The objective of this study was to compare the viscoelastic properties of tablets made from Osborne solubility fractions (glutenins, gliadins, albumins, globulins, and residue), pentosans, flour and bread using stress relaxation tests.

2. Materials and methods

2.1. Plant material

Wheat cultivars from three U.S. wheat classes were used in this study including four (Len, Butte, Era and Coteau) hard red spring (HRS), two (Adder, Fairfield) soft red winter (SRW), and two (Madsen and Louise) soft winter (SWW) wheat.

2.2. Flour and bread preparation

Wheat samples were tempered to 12% moisture before milling on a Quadrumat Jr. (C.W. Brabender, South Hackensack, NJ) laboratory mill. Straight grade flour was blended and rebolted through an 84 SS sieve to remove foreign material. The bread was prepared using a 2 h fermentation schedule to avoid over fermentation (AACCI, 1999). Bread loaves were sliced into approximately 10 mm slices and placed in a single layer on wire drying racks. The bread was dried overnight at approximately 25 °C and 35–40% relative humidity, ground to a fine powder in a food chopper, and freeze dried to reduce the moisture content about 1%.

2.3. Isolation of Osborne solubility fractions

Wheat flour was used for solvent solubility extraction according to the modified Osborne fractionation procedure (Fig. 1) modified by Chen and Bushuk (1970). Fractions were freeze dried and stored in tightly closed containers until needed for analysis. Water soluble pentosans were calculated by difference using the recovery of the fractions expressed in percentage of the original weight. Water soluble pentosans weight (%) = 100 − [glutenins (%)+ gliadins (%)+ albumins (%) +globulins (%) + residue (%)].

2.4. Sintered tablet preparation

Tablets of 0.42 mm height and 8.07 mm diameter (contact area of 51.52 mm^2) were sintered from Osbore protein fractions, flour and bread. For each tablet 0.3 g of the sample was weighed into a

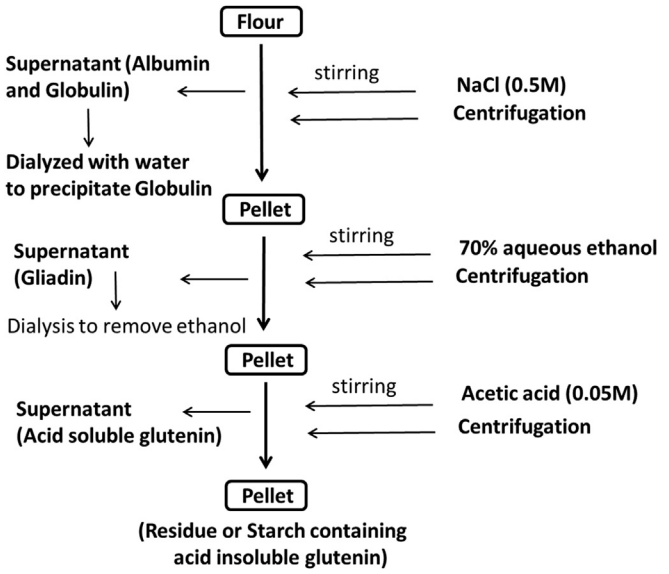

Fig. 1. Schematic of the Osborne protein fractionation carried out at 4 °C (Chen and Busuk, 1970). All centrifugations were at 5000× g for 30 min.

10 ml beaker sealed with parafilm and placed in a controlled temperature chamber at 20 °C for 2 h. The tablet-forming die of hardened steel had an inside diameter of 7.95 mm, and a length of 31.69 mm. Two hardenes steel dowels were used to apply the pressure necessary to form the tablets. The lower dowel (5.54 mm long) was inserted into a loose-fitting cylinder 31.69 mm high, and the die was placed on top of this cylinder with the dowel of 43.23 mm long positioned into the die. The sample was transferred into the die, the upper dowel placed into the lower die and the set positioned onto a table with hydraulic press (Trupper 501 of 50 tonnes capacity). The load on the die was gradually increased to reach 25 tonnes and mantained for 5 min before removing the tablet from the die. Reconstituted tablets were also prepared containing the percentage (w/w) of the fractions obtained.

2.5. Rheology

2.5.1. Selecting the viscoelastic conditions for the samples

Regarding the evaluation of linear regime, the experimental data was compared to the predicted data using the Hertz theory described elsewhere (Timosenko and Goodier, 1970; Mohsenin, 1986). The linear deformation (Z) due to a direct compression force (P) applied vertically expressed in terms of the Hertz theory equation is $Z = kP^{2/3}$, where the constant k from the equation transformed into log is the y-intercept when $x = 0$ of the force-deformation straight line ($logZ = logk + 2/3logP$). The data fitted well with the equation $Z = kP^{2/3}$($r^2 = 0.999$; $P < 0.0001$), meaning that under the conditions of this study the tablets from different wheat fractions met the linear elasticity response according to the theory of elasticity. The tablet possesses some elasticity; that is, if a force producing deformation is applied and it does not exceed the elastic limit, the deformation disappears with removal of the force (Figueroa et al., 2011).

2.5.2. Stress relaxation test

A TA.XT Plus texture analyzer with a 25,000 g load cell (Texture Technologies, Scarsdale, NY/Stable Micro Systems, Surrey, England) was used to measure the tablets response to compressive loadings using parallel plates. Before loading, the thickness of each tablet was determined with a caliper. In the stress relaxation test, a