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Characterization of bread dough: Rheological properties and microstructure

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ABSTRACT

The change in rheological and microstructural properties of wheat flour dough as a function of water and yeast content, and with addition of hydrocolloids is described. The rheological properties vary with the size of the bubbles and measurements were made on controlled shear/stress rheometer. Confocal laser scanning microscope (CLSM), accompanied with image analysis technique, was used to obtain microstructure of the dough. It was found that with an increase in water content the moduli values decreased and the mean bubble diameter increased. As concentration of yeast increased, the bubbles became smaller and the moduli values increased. Addition of hydrocolloids like sodium alginate and xanthan gum led to increased moduli values and generally caused the bubbles in the dough to shift towards narrower distributions. An inverse relation between bubble size and storage modulus is found.
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1. Introduction

Bread dough exhibits viscoelastic behavior, combining the properties of a purely viscous fluid and an elastic solid. Flour, water and yeast are essential ingredients in making dough. Each ingredient plays an important role in defining the structure and rheological properties of bread. The main components of the flour, such as the gluten and starch, clearly have a massive influence on the properties of the final product, but the presence of gas cells within the bread is also essential. The size and number of gas cells can vary greatly between bread types, and will change the sensory properties of the bread. For example, a standard tin loaf is characterized by numerous small gas cells, whereas baguette-type bread typically has fewer, larger gas cells (Wilde, 2003). Over fermented dough with its large cells, gives the baked item a moth eaten appearance and a coarse texture. Underfermented dough, in which the carbon dioxide was not properly distributed, results in a very dense loaf with thick cells, low volume, and a tough crust (Brown, 2008). Dough aeration not only affects the rheology (Chin et al., 2009) of the static dough through physical presence of gas bubbles following mixing, but also affects the development of its rheological properties within the mixer, as the gas bubbles affect the rate of work input that develops the dough and the turnover of air that supplies oxygen to facilitate this development (Chin et al., 2005). Ozkoc et al. (2009) suggested that the addition of gums may influence the stability of gas bubbles by forming a thick layer on their surface and reducing the opportunity for coalescence of individual gas cells. Thus, each bubble remains a separate, discrete identity, resulting in a ‘stable morphology’.

The quality of the baked product depends on the protein content, loaf volume, crumb grain quality and texture of bread. Bread crumb comprises a network of gas cells that originate from gas bubbles, initially introduced into the dough during mixing. The final gas volume of bread can be over 70% of loaf volume and the size and number density of the gas cells can vary, resulting in huge differences in the texture and sensory properties of the final product (Scanlon and Zghal, 2001). Crumb grain evaluation is based on several criteria like cell size, cell shape, cell wall thickness, etc. Several factors like air incorporation during dough mixing, mechanical handling of the dough and alteration of the gas–liquid interface by additives may affect the crumb grain of the product (Hayman et al., 1998).

The fundamental mechanical properties of wheat flour dough are very significant because they affect the dough handling behavior during processing and also influence the interactions among dough components. Dynamic testing methods developed for polymer rheology (Ferry, 1980) are also helpful in assessing viscoelastic properties of foods, including dough. The rheological response of any material is obtained physically by subjecting it to stress which is then related to the strain or strain rate that the material experiences. Dynamic oscillatory instruments simultaneously measure the elastic (G', shear storage modulus) as well as viscous (G'', shear loss modulus) properties of materials. The linear viscoelastic region is often the preferred deformation regime in rheological testing because in this small strain (<1%) regime, the applied stress does not affect the rheological characteristics of the test material and hence a dynamic oscillatory test is considered to be non-destructive. When conducted in the linear region, dynamic tests enable

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multiple rheological measurements on the same sample as the temperature, strain, or frequency is varied. In case of frequency sweep tests G', G'' follow power laws and in a typical experimental range, G' is greater than G'' indicating that the dough exhibits a viscoelastic behavior, with solid-like characteristics (Amemiya and Menjivar, 1992). An optimum storage modulus is necessary to form stable cells.

Several studies have been carried out to assess the effect of hydrocolloids (gums) on baked products (Barcenas and Rosell, 2005; Rosell et al., 2001). Hydrocolloids control water absorption and consequently dough rheology (Mandala et al., 2007). An improvement in wheat dough stability during proofing can also be achieved by the addition of hydrocolloids, namely sodium alginate, κ-carrageenan, xanthan gum and hydroxypropyl methyl-cellulose (Rosell et al., 2001).

It has been suggested that bubble numbers and sizes affect dough rheology (Bloksma, 1981). A variety of microscopic techniques are available for studying dough structure (Kalab et al., 1995). Different approaches for studying the microstructure of dough have been used, including transmission electron microscopy (TEM) and scanning electron microscopy (SEM). CSLM is another powerful technique for studying microstructure. It is based on the principle that the image of a light source is focused on a well-defined depth in the specimen and that information from this focal point is projected onto a pinhole in front of a detector. The depth of penetration of laser beam is essentially a function of its wavelength. It can be used in fluorescence mode and, therefore, can distinguish the spatial location of different components by detecting fluorescence from dyes specific to different chemical species.

Risen bread dough has a very high gas volume fraction (of the order of 0.68–0.8) and is therefore taken to be a foamy material (Campbell and Mougeot, 1999) and has been treated as foam in the literature (Mills et al., 2003; Hailemariam et al., 2007). Foam texture is significantly influenced by gas bubble size distribution (Herzhaft, 1999). In order to produce foam with desirable performance characteristics it is necessary to understand the relationship between foam structure and mechanical properties and then to understand the material and processing parameters required to

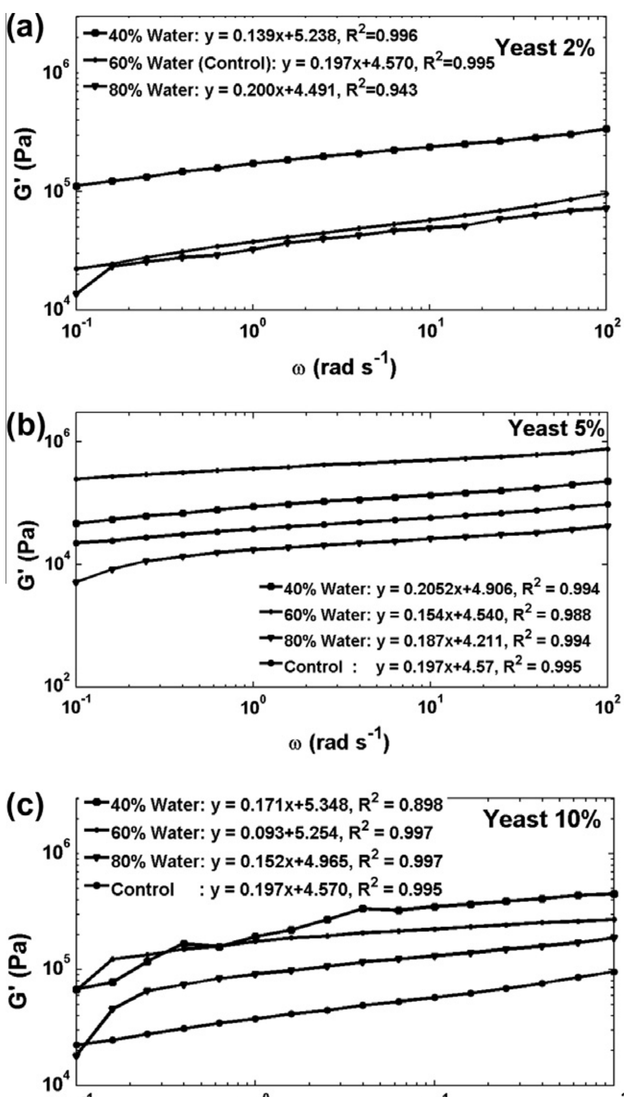

Fig. 1. Dynamic frequency sweep test of dough showing variation of G' with water content for a fixed yeast concentration (a) 2%; (b) 5%; (c) 10% yeast.

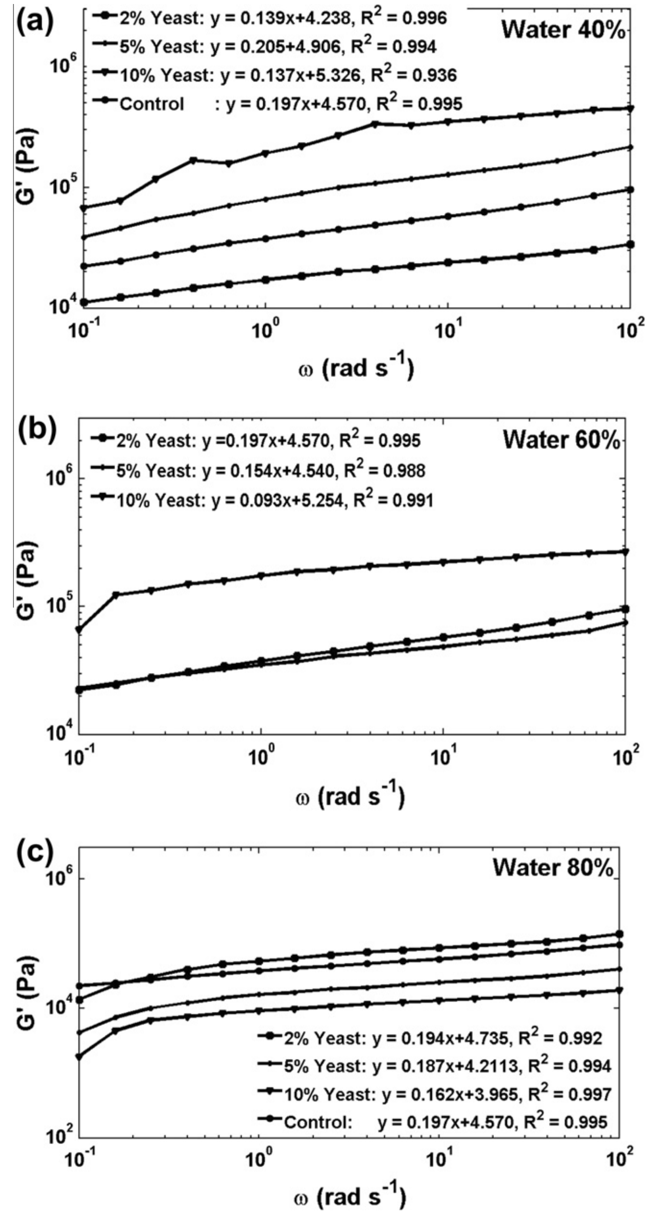

Fig. 2. Dynamic frequency sweep test of dough showing variation of G' with yeast concentration for a fixed water content (a) 40%; (b) 60%; (c) 80% water.

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