LWT - Food Science and Technology 44 (2011) 594–601

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Dough characteristics of Irish wheat varieties I. Rheological properties and prediction of baking volume

A. Ktenioudaki [a,b,*], F. Butler [a], E. Gallagher [b]

[a] UCD School of Agriculture, Food Science & Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland
[b] Teagasc, Ashtown Food Research Centre, Ashtown, Dublin 15, Ireland

ARTICLE INFO

Article history:
Received 18 May 2009
Received in revised form
5 November 2010
Accepted 9 November 2010

Keywords:
Dough rheology
Biaxial extension
Uniaxial extension
Baking

ABSTRACT

Eight wheat varieties suitable for cultivation in Ireland were examined for the rheological properties and baking quality. Large deformation extensional rheology was used employing the Extensograph, the Kieffer extensibility rig, the Alveograph and biaxial extension by uniaxial compression. Similar discrimination between the wheat samples was achieved with both uniaxial extension methods used. Stress during uniaxial extension was higher at all strains measured than biaxial extension and the difference between uniaxial and biaxial stress increased with increasing strain. Also, differences existed in the strain hardening index between uniaxial and biaxial extension which depended on the sample tested. Significant correlations were established between loaf volume and the rheological properties determined in both uniaxial and biaxial extension. It was found that high loaf volumes can be achieved when biaxial and uniaxial extensibility is high and biaxial extensional viscosity is low. The importance of considering the standard error for validating the value of the correlation for prediction purposes was also demonstrated. When the standard error of the correlation was considered, the value of the correlation for prediction purposes was limited in practice. Nevertheless, the rheological tests provided useful information, and the results were valuable for screening flours for baking quality.

1. Introduction

Breadmaking is a complex process that involves many physicochemical and structural transformations which lead to the production of an aerated baked product from basic ingredients such as flour, water, yeast and salt. Generally, the breadmaking process is divided into three main steps: mixing, fermentation (proving), and baking. During all these stages, deformations of different magnitudes take place and rheology is involved in every step of the process. During mixing, extreme deformations take place above the point of rupture as a result of forces exerted on the dough from the mixer, whereas during proving and baking the deformations are much smaller and are due to the difference in pressure between the gas cells and the atmosphere (Bushuk, 1985).

The importance of rheology in breadmaking and the impact of dough rheological properties on the quality of the baked product have led to the development of numerous rheological tests, employed both in research and in the cereal industry. Extensional flow measurements such as uniaxial and biaxial extension are considered more appropriate as extensional flow is present in many operations such as mixing, sheeting, moulding, and bubble expansion. According to Gras, Carpenter, and Anderssen (2000), the mixing action that occurs in a Mixograph can be interpreted as a series of extension tests. The extension to rupture occurring during an extension test corresponds to the elongate - rupture that occurs during mixing of the elongate-rupture-relax oscillations that form the bandwidth of the Mixograph test. Therefore the bandwidth recorded from the Mixograph can be used to better determine the evolving rheology of the dough during mixing. Ideally, every rheological test that aims at predicting the behaviour of the material should be taking place at relevant deformation conditions to what the material experiences during processing (Dobraszczyk, Smewing, Albertini, Maesmans, & Schofield, 2003).

According to van Vliet, Janssen, Bloksma, and Walstra (1992), the dough around a growing cell is tangentially extended in two directions parallel to the surface of the gas cell and compressed radially perpendicular to the surface of the gas cell due to the radially acting compression force caused by excess pressure inside the gas cells. Biaxial extension at large strains and low strain rates is considered to be the relevant deformation that takes place around a growing cell and it has been used to study the rheological

* Corresponding author. Teagasc, Ashtown Food Research Centre, Ashtown, Dublin 15, Ireland. Tel.: +353 8 51469941; fax: +353 1 8059550.
E-mail address: ktenioudaki@hotmail.com (A. Ktenioudaki).

0023-6438/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.lwt.2010.11.014

properties of dough (Janssen, van Vliet and Vereijken, 1996; Kokelaar, van Vliet, and Prins 1996; Rouille, Valle, Lefebvre, Sliwinski, and van Vliet., 2005; Sliwinski, Kolster, and van Vliet, 2004a). These tests make possible the calculation of a rheological property known as strain hardening, which van Vliet et al. (1992), have proposed it provides the dough films of expanding gas cells with greater stability and protects them against premature rupture. Therefore, the extent of strain hardening will determine the breadmaking potential. Many researchers have studied the strain hardening phenomenon and have demonstrated that it relates to the baking potential of flour (Dobraszczyk & Salmanowicz, 2008; Sliwinski, Kolster, and van Vliet, 2004b).

Numerous tests exist to measure the uniaxial extensional properties of dough. The test methods include the Simon extensometer, the Brabender Extensograph, and the Stable Micro Systems Kieffer dough and gluten extensibility rig. The Extensograph is an empirical test that has been used for years to perform uniaxial extension on dough and the measured properties have been correlated with baked volumes. However a few disadvantages exist such as: the force and the extension are not expressed in Newton and strain respectively, the amount of dough deformed increases with extension, and therefore the conversion of the Extensograph curves to stress and strain curves is restricted (Bloksma & Bushuk, 1988). An apparatus similar to the Extensograph was developed the Kieffer dough and gluten extensibility rig. With this apparatus only a small amount of dough is required (about 0.8 g), the force is measured in Newton and the speed of the test can be adjusted. This way more relevant strain rates can be applied and the results can be expressed in stress and strain data (Dunnewind, Sliwinski, Grolle, & van Vliet, 2004). Grausgruber, Schoggl, and Ruckenbauer (2002) compared the Kieffer extensibility rig with the Extensograph and found significant relationships between the parameters obtained from the two methods. Many researchers have used uniaxial extension tests to study the rheological properties of doughs (de Bruijne, de Looff, van Eulem, & Carter, 1990; Collar, Santos, & Rosell, 2007; Dobraszczyk & Salmanowicz, 2008; Sliwinski et al. 2004b; Suchy, Lukow, & Ingelin, 2000; Tronsmo et al., 2003) and good correlations with baking quality have been reported (Sliwinski et al., 2004b; Suchy et al., 2000; Tronsmo et al., 2003).

Sliwinski et al. (2004b) studied the large deformation and fracture properties of flour in uniaxial extension using the Kieffer rig. They found that high loaf volumes were achieved from those varieties that exhibited intermediate stress levels at large strains. They also found that the relationship between loaf volume and stress and strain fracture is rate dependant. Tronsmo et al. (2003) studied the rheological properties at small and large deformations of four wheat cultivars. Two varieties had the High Molecular Weight glutenin subunits (HMWgs) pair 5 + 10 and therefore resulted in good breadmaking quality and the other two had the HMWgs pair 2 + 12 that is known to result in poor performance during baking. They found that maximum resistance to extension (R_{max}) measured with the Kieffer rig and the biaxial strain hardening as measured with the Dobraszczyk/Roberts inflation rig could discriminate between these varieties.

Anderssen, Bekes, Gras, Nikolov, and Wood (2004) studied the rheological properties of eight wheat varieties using a uniaxial micro-extension test. They indicated the need to relate rheological properties such as strength and extensibility to the glutenin composition of the flours in order to achieve better understanding of their relation to baking performance. The eight flours were divided into three categories (weak, intermediate, strong) with distinct differences in the HMW glutenin subunit allelic composition. Distinct morphological differences in the extensograms were found leading to the conclusion that the alleles significantly affect the rheology of the flours. It was also shown that the measurement of maximum resistance to extension (R_{max}) clearly separates the flours depending on their HMW glutenin subunit allelic composition. They also calculated the extensibility at the point of R_{max} (E_{Rmax})as well as the extensibility at the point of rupture($E_{rupture}$) and found that parameters (E_{Rmax} and $E_{rupture} - E_{Rmax}$) other than the ones traditionally used were important in interpreting rheologically the extensograms and could significantly differentiate between the varieties.

The objective of this paper was to conduct a comprehensive study of the rheological properties of Irish wheat varieties and to identify the rheological properties that would successfully discriminate between varieties and predict their baking quality. Eight varieties suitable for growing in the Irish climate were chosen, as well as a Canadian and a German blend of varieties (for comparative purposes). Four large deformation extensional rheological tests were employed to provide empirical as well as fundamental measurements both in uniaxial and biaxial extension.

2. Materials & methods

2.1. Materials

Eight wheat varieties suitable for cultivation in Ireland were selected. The varieties were: Gulliver, Solstice, NSLWW89, Einstein, Consort, Equation, Trappe, and Raffles. These are considered to be breadmaking varieties, with the exception of Consort and Equation, which are considered to be suitable for biscuits and feed respectively, and were included in the study to achieve a wider variation in wheat properties. Four varieties were supplied from a UK breeding company (Einstein, Gulliver, Solstice, and NSLWW89), and the rest were provided by Irish suppliers (Goldcrop, SeedTech, and Germinal seeds) from various geographical locations. The seeds were from the 2007 harvest and approximately 50 kg of grains were received for each variety. A blend of Canadian varieties and also a blend of German varieties were included in the study, obtained from an Irish milling company (Odlum Ltd., Dublin). The varieties were cleaned using a sample cleaner (SLN3, A/s Rationel Kornservice, Denmark) and conditioned to 16% moisture content prior to milling. The samples were milled using a Bühler mill (Bühler, Switzerland) to a milling degree of 70% following the AACC Bühler method (AACC, 1988). Analysis for moisture content (ICC standard Method No. 110/1, 1976), α-amylase activity (ICC standard method No. 107, ICC, 1968), protein content using a Leco protein analyzer (Leco FP-428 Nitrogen Analyzer, Leco Corporation, St. Joseph, MI, U.S.A), and for starch damage using an amperometric method (SDmatic, Chopin, France) (ICC standard method No 172, ICC, 2007) took place. Duplicate measurements were carried out for the chemical analysis and the results were averaged. The mixing properties were investigated using the Brabender Farinograph (Brabender OHG, Duisberg, Germany) following the Farinograph British Standard method No. 4317-20:1999 (British standards, 1999) (one test per wheat type).

2.2. Dough preparation

Dough samples were prepared in a Farinograph mixing bowl using 300 g flour, 6 g salt (Pure Dried Vacuum salt, Ineos Enterprises, UK), and 3 g of emulsified bread fat (Irish Bakels Ltd., Dublin, Ireland). The amount of water added was as per the Farinograph water absorption value. The mixing times were based on the development time plus 1 min. A new batch of dough was mixed for each rheological test. All the experiments were replicated three times.