Assessment of breadmaking performance of wheat flour dough by means of frequency dependent ultrasound

2012 IOP Conf. Ser.: Mater. Sci. Eng. 42 012040

(http://iopscience.iop.org/1757-899X/42/1/012040)

Assessment of breadmaking performance of wheat flour dough by means of frequency dependent ultrasound

D Braunstein[1], JH Page[2], A Strybulevych[2], D Peressini[1] and MG Scanlon[3,4]

[1] Department of Food Science, University of Udine, via Sondrio 2/A-33100 Udine, Italy
[2] Department of Physics and Astronomy, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2
[3] Department of Food Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2

E-mail: scanlon@cc.umanitoba.ca

Abstract. Technological performance of wheat flour varies among different wheat varieties. Gluten plays a key role within the solid phase of dough in the formation and the retention of gas bubbles during breadmaking. Rheological tests are usually performed to predict breadmaking potential. The aim here was to investigate the ability of ultrasound to discriminate wheat doughs based on breadmaking qualities. The ultimate goal is the development of an on-line quality control system currently unavailable in the baked goods industry, rendering this work innovative. Samples were prepared from a strong wheat flour, with one control sample and one added with inulin and distilled monoglycerides, producing doughs of distinct breadmaking quality. Doughs were subjected to density determination, elongation tests, and ultrasound analysis. The ultrasound tests were performed in the frequency range of 300 kHz - 6 MHz. Ultrasonic phase velocity increased with increasing frequency to about 2 MHz, becoming constant and then decreasing from 3 MHz for the control sample. Distinct differences in attenuation coefficient between the fibre-enriched and control doughs were observed. Ultrasound can potentially add to a better understanding of dough quality and can discriminate between doughs of contrasting properties.

1. Introduction

Ultrasound is a useful technique for the non-destructive characterization of the physical properties and structure of materials. In recent years, there has been interest in using it to investigate the properties of wheat flour doughs [1-8]. These authors have shown that a number of useful technological parameters can be obtained from ultrasound measurements. For example, Bellido and Hatcher [6] showed that formulation changes in noodles that produced a change in ultrasonic properties were highly correlated with conventional measurements of mechanical properties, while Garcia-Alvarez et al [7] showed that dough consistency, an important criterion in the handling of breadmaking doughs, could be determined ultrasonically for a wide range of flour qualities.

Specific attributes of influential factors in breadmaking have also been the focus of ultrasonic studies of dough properties. As well as the highly influential effect of flour quality [9], ingredients

---

[4] To whom any correspondence should be addressed.

such as shortening have also been studied [10]. Bubbles, that are known to be critical influences on the properties of breadmaking doughs [11,12], have also been studied ultrasonically. Ultrasound is particularly sensitive to bubbles in dough because of large differences in the compressibility and density of the dough matrix compared to the gas in the bubbles [2,13].

Because of demonstrated health effects of dietary fibre, there has been considerable interest in enriching wheat flour doughs with dietary fibre [14,15]. However, issues with dough handling performance and the quality of the resulting loaf of bread have been reported [15,16]

The goal of this paper is evaluate whether an ultrasonic reflectance technique, that is able to interrogate the complex shear modulus at ultrasonic frequencies [17], can discriminate the properties of a fibre-enriched dough from a control dough using longitudinally polarized ultrasonic pulses.

2. Materials and Methods

2.1. Materials

Flour from common wheat with strong gluten properties (W= 325, P/L= 0.56) was used for this study. Farinograph water absorption and stability of flour were 52.4% (on 14% flour moisture basis) and 10.7 min, respectively. Distilled monoglycerides (MYVATEX MIGHTY SOFT LT) were kindly donated by Kerry Ingredients and Flavours (The Netherlands). Frutafit® TEX inulin (degree of polymerisation $\geq$ 22) was obtained from Sensus (The Netherlands).

2.2. Dough preparation

Control dough samples were mixed at 30°C to maximum development in a 50-g farinograph bowl, at optimum water absorption using flour (50 g on 14% m.b.) and tap water (26.2 mL). Dough was also prepared using flour (50 g on 14% m.b.), water (27 mL), inulin (4 g) and distilled monoglyceride (0.5 g). Ingredients were mixed until a consistency of 500 BU was reached. Mixing times were 4 and 14 min, and moisture contents 43.6 and 42.0% for control and fibre doughs, respectively.

2.3. Large deformation rheological properties

A texture analyser (TA.XT2) equipped with a 5 kgf load cell and Kieffer dough and gluten extensibility rig was used to perform a uniaxial extension test on the processed dough sample at 3.3 mms^{-1}. Extension was performed after a dough resting time of 75 min. Force-displacement curves were transformed into stress-strain data [18]. The fracture stress (σ_{max}), the Hencky strain (ε_H) at fracture stress, and the integrated area (A) under the stress-strain curve were taken as measures of resistance to extension, extensibility, and energy required to extension, respectively. An apparent strain hardening ($d \ln \sigma_{max} / d\varepsilon_H$) was computed in the strain interval of 20-95% fracture strain.

2.4. Density measurement

Dough density was measured to ascertain the amount of air incorporated into the dough using 25 mL gravimetric bottles (Kimble Glass Inc., Vineland NJ) using 5 g sub-samples of dough.

2.5. Ultrasonic experiments

A pulsed reflection technique [17], but employing longitudinally polarized ultrasonic pulses, measured the ultrasonic signal reflected from the dough. Dough samples were placed on a plexi-glass delay rod connected to a broadband transducer (0.3-6 MHz). A Fourier transform technique was used to extract phase velocity and attenuation coefficient data from the acquired signals as a function of frequency.

3. Results and Discussion

3.1. Repeatability of the reflectance technique

The ultrasonic phase velocity (UPV) and the attenuation coefficient (AC) for three replicates of the control dough (strong flour without additives) are shown in figures 1 and 2. The error bars are associated with the variability in the ultrasonic parameter between three sub-samples taken from a given replicate dough. It can be seen that variability depends on frequency, being more pronounced at the peak and at the higher frequencies.

The frequency dependent changes in both phase velocity and attenuation coefficient are very similar to those reported for strong breadmaking flours analysed by transmission experiments [8,13]. The peak in attenuation coefficient, that occurs at approximately 2 MHz, is indicative of a strong resonance arising from the bubbles entrained into the dough during mixing [13,19]. On the low frequency side of the peak, velocity and attenuation are lower, indicative of the long wavelength probing of an effective medium of matrix and bubbles that constitutes the dough [2,13]. Ultrasonic velocity at frequencies well above the resonance, where dough matrix properties are accessed [20], is somewhat higher than the velocity of sound in water (1500 m s^{-1}).

Thus, these results show that the reflectance technique is a repeatable means of measuring the ultrasonic properties of wheat flour doughs at frequencies (near resonance) where it is difficult to propagate ultrasound through samples in transmission experiments.

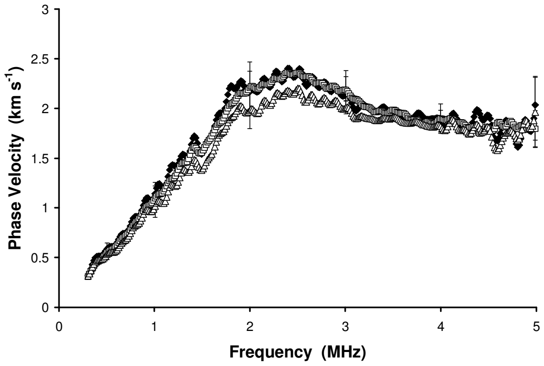

Figure 1. UPV vs frequency for control dough.

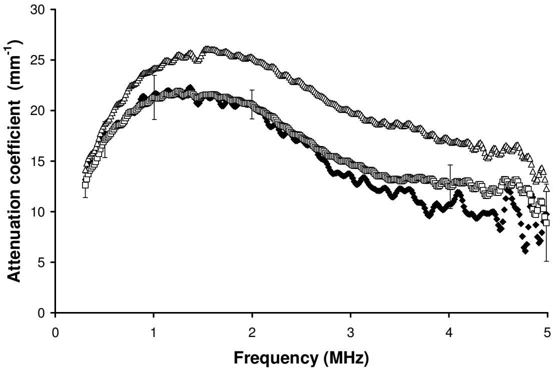

Figure 2. AC vs frequency for control dough.

3.2. The effect of fibre on dough properties

The addition of inulin resulted in a decrease in optimum moisture content of the dough probably due to a lubricating effect of sugars and oligosaccharides [15,16]. Time required for dough development, or to reach a dough consistency equivalent to 500 BU, greatly increased as a consequence of fibre addition [15]. This effect can be mainly related to inulin's intrinsic water absorption ability, leading to a competition with the gluten proteins for available water to form a gel [21]. Fibre-enriched doughs were of slightly lower density (1197±0.7 kg/m^3) than the control (1200±0.6 kg/m^3).

Large deformation rheological properties of dough are reported in table 1. Extensibility and strain hardening, predictors of breadmaking performance, were substantially reduced by fibre addition, resulting in gas cells that are less stable and inflate to a lower volume during proving [15,22]. Changes in rheological behaviour could be interpreted as the result of a decrease in water availability for gluten in the presence of inulin.

Table 1. Fracture parameters calculated from the stress-strain curves of doughs.

Samples	σ_{max} (kPa)	ε_H (-)	A (kPa)	d ln σ_{max} /dε_H(-)
Control	39.0±4.0	2.08±0.14	30.3±2.0	1.32±0.11
Fibre	33.9±3.4	1.20±0.07	27.5±2.8	1.05±0.12

The differences in large strain properties of the doughs are also evident in small strain ultrasonic measurements. In figure 3, substantial differences in AC occur at bubble resonance and at high frequencies. Since dough densities are not very different, and thus gas content is similar, the increase in AC in the fibre-enriched doughs is likely due to fibre's effect on the properties of the dough matrix.

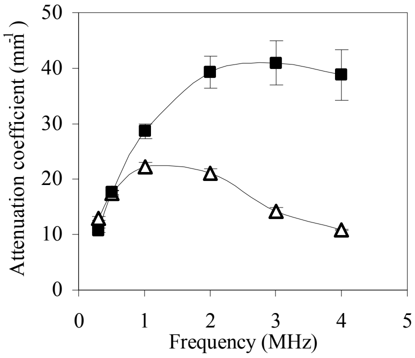

Figure 3. AC vs frequency for control (△) and fibre (■) doughs.

4. Conclusions

Ultrasonic reflectance measurements provide repeatable determinations of phase velocity and attenuation coefficient in complex industrial materials such as wheat flour doughs. Frequency-dependent evaluation of ultrasonic properties confirm that fibre has a pronounced effect on dough properties, effects that are manifest as large differences in the large strain material properties of the dough.

References

[1] Létang C, Piau M, Verdier C and Lefebvre L 2001*Ultrasonics* **39** 133
[2] Elmehdi H M, Page J H and Scanlon M G 2004 *Cereal Chem.* **81** 504
[3] Ross K A, Pyrak-Nolte L J and Campanella O H 2004 *Food Res. Int.* **37** 567
[4] Alava J M, Sahi S S, Garcia-Alvares J, Turo A, Chavez JA, Garcia M J and Salazar J 2007 *Ultrasonics* **46** 270
[5] Skaf A, Nassar G, Lefebre F and Nongaillard B 2009 *J. Food Eng.* **93** 365
[6] Bellido G G and Hatcher D W 2010 *Food Res. Int.* **43** 701
[7] Garcia-Alvarez J, Salazar J and Rosell C M 2011 *Ultrasonics* **51** 223
[8] Scanlon M G et al 2011 *Proc. 4th International Wheat Quality Conference* ed R. N Chibbar and J E Dexter (Jodhpur, India: AGROBIOS (International)) p 271
[9] Garcia-Alvarez J, Rodriguez J M, Yanez Y *et al 2005 IEEE Ultrasonics Symposium* **1-4** 1480
[10] Mehta K L, Scanlon M G, Sapirstein H D and Page J H 2009 *J. Food Sci.* **74** E455
[11] Campbell G M, Rielly C D, Fryer P J and Sadd PA 1998 *Cereal Foods World* **43** 163
[12] Babin P, Della Valle G, Chiron H et al 2006 *J. Cereal Sci* **43** 393
[13] Leroy V et al 2008 *Bubbles in Food 2: Novelty, Health and Luxury* ed G M Campbell et al (St Paul, MN :AACC Press) p 51
[14] Angioloni A and Collar C 2009 *J. Food Eng.* **91** 526
[15] Peressini D and Sensidoni A 2009 *J. Cereal Sci* **49** 226
[16] Wang J, Rosell CM and de Barber CB 2002 *Food Chem.* **79** 221
[17] Leroy V, Pitura K M, Scanlon M G and Page J H 2010 *J. Non-Newtonian Fluid Mech.* **165** 475
[18] Dunnewind B, Sliwinski E L, Grolle K and van Vliet T 2004 J. *Texture Stud.* **34** 537
[19] Scanlon MG, Page J H, Leroy V et al 2008 *Bubbles in Food 2: Novelty, Health and Luxury* ed G M Campbell et al (St Paul, MN: AACC Press) p 217
[20] Povey M J W 1997 *Ultrasonic Techniques for Fluids Characterization* (SanDiego, CA: Academic Press)
[21] de Gennaro S, Birch G G, Parke S A and Stancher B 2000 *Food Chem.* **68** 179
[22] van Vliet T, Janssen AM, Bloksma A H and Walstra P 1992 *J. Texture Stud.* **23** 439