The Effects of Mixing Time and Ingredients on Dough Properties as Assessed with Ultrasound

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ABSTRACT

Evaluation of interactions between process and ingredients is a key criterion in predicting dough performance and baked product quality. This study examined the effect of mixing time on the properties of dough formulated with various surface active agents. Dough density was determined independently by specific gravity measurements to evaluate air entrainment during mixing. Ultrasonic velocity and attenuation were measured in the doughs using low intensity ultrasound at 50 kHz. For all doughs mixed in air, ultrasonic velocity decreased and attenuation increased with mixing time as more bubbles were entrained. Shortening and distilled monoglycerides acted in a contrasting manner when added to the dough as assessed with ultrasound, with the former likely plasticizing the gluten polymers and the latter stiffening the dough, perhaps by better binding of water molecules within the dough matrix.

INTRODUCTION

Mixing is a critical stage in breadmaking as it controls gas cell nucleation and gluten development in the dough (Scanlon and Zghal 2001). Since the distribution of gas bubble sizes created in the dough during the mixing process has a direct effect on the gas cell structure of the baked loaf (Baker and Mize 1941), surface-active ingredients are often used in bakery products to improve loaf volume and to obtain a bread crumb with a fine and uniform cell structure, composed of thin gas cell walls (Brooker 1996). These surface-active ingredients will also affect the mechanical properties of the dough, and so the objective of this study was to use low-intensity ultrasound (a technique that has been successfully employed to probe the rheological properties of dough mixed under different headspace pressures (Elmehdi et al 2004)) to examine how mixing time affects the properties of dough formulated with various amounts of surface-active ingredients.

MATERIALS AND METHODS

Dough Preparation

Doughs were made from either hard red spring (CWRS) or soft white spring (SWS) wheat flours (both prepared by straight grade milling). Dough was prepared using a short-time mechanical dough development process using Flour (100 g), Salt (2.4 g) and Water (61 or 57 mL, so as to give optimum dough handling characteristics for the CWRS and SWS flours, respectively), and either Shortening (0, 2, 4 or 8 %) or Distilled Monoglycerides (0, 0.5, 1 or 2 %).

Doughs were mixed at atmospheric pressure or under vacuum (0.04 atm). Various mixing times were employed to obtain an overall picture of the mixing process from hydration of flour particles (undermixed) to optimum dough development (10 % past peak), to overmixing.

Dough Density

Density of dough samples was measured using Archimedes' principle (Elmehdi et al 2004).

Ultrasonic Measurements

A pulsed transmission technique was used to measure the ultrasonic velocity and attenuation of the dough by placing the dough sample directly in contact between two transducers. The central frequency of the transducers was 50 kHz (Panametrics).

For each treatment, dough sub-samples of various thicknesses (1 mm to 5 mm) were analysed. This process eliminates offset due to losses of acoustic signal at the transducer-sample interface so that velocity and attenuation can be accurately determined.

RESULTS AND DISCUSSION

Dough Density Changes

Regardless of flour type or surface-active ingredient, the effects of mixing on air entrainment were similar (Fig. 1). Mixing under vacuum does not permit entrainment of air bubbles into the dough (Campbell et al 1993), so dough density is high and remains essentially unaffected by mixing time. When mixed in air, longer mixing time entrains more bubbles so dough density decreases with mixing time. These air entrainment effects are evident regardless of the surface-active agent in the formulation.

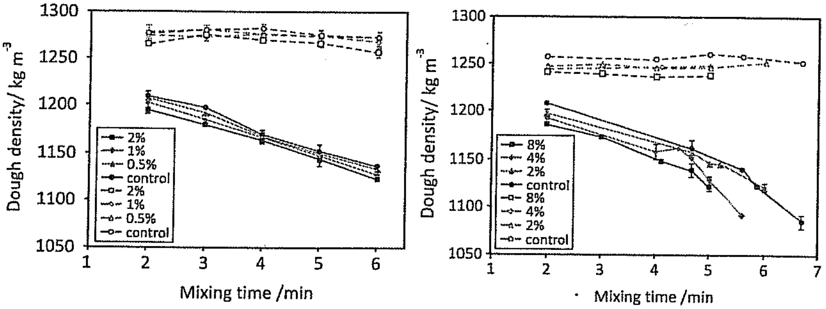

Fig. 1. Effect of mixing time (in air (solid lines) or in vacuum (dashed)) on dough density for doughs formulated with different amounts (%fwb) of shortening in CWRS flour (left) or distilled monoglycerides in SWS flour (right).

Ultrasonic Velocity Measurements

Ultrasonic velocity measurements provide insights into the compressibility of dough (Fig. 2). Because there are few bubbles present, the vacuum-mixed doughs have high velocities due to their incompressible nature, and the relative changes in velocity with increase in mixing time are slight since very few bubbles are entrained during mixing.

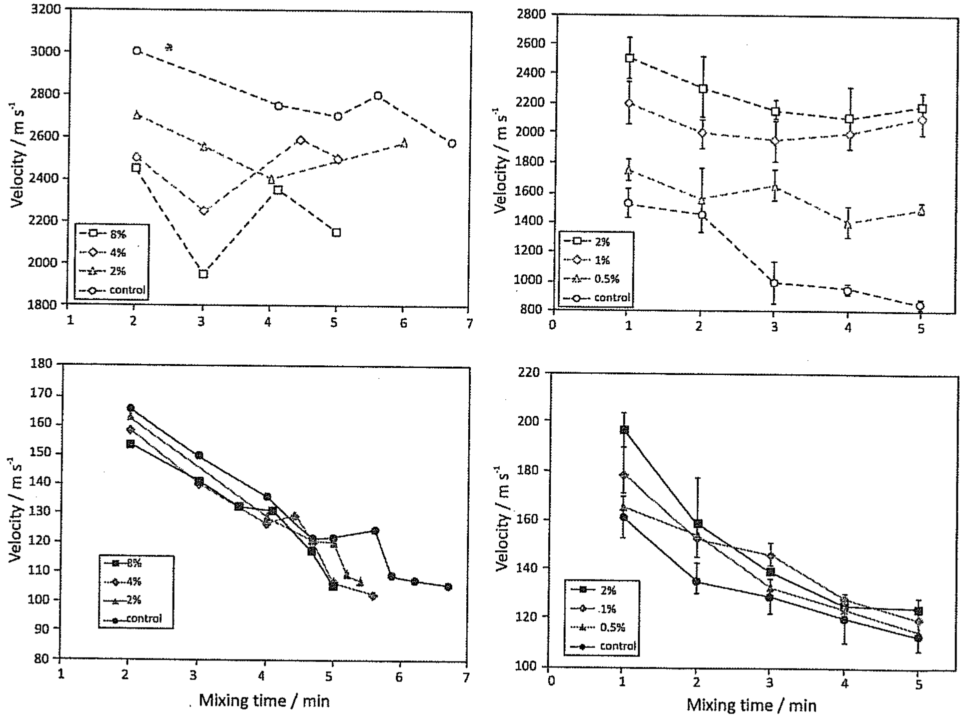

Fig. 2. Effect of mixing time (in vacuum [top] or in air [bottom]) on ultrasonic velocity for doughs formulated with different amounts (%fwb) of shortening in CWRS flour (left) or distilled monoglycerides in SWS flour (right).

For the doughs mixed in air, longer mixing time causes the dough to have lower ultrasonic velocity because greater numbers of bubbles make the dough more compressible. This is apparent in doughs formulated with both bakery ingredients. However, what is remarkable (since it contrasts with the density results) is that the effect of increasing concentration of ingredient on velocity is distinctly different for the doughs made with the distilled monoglycerides compared to those with shortening. This distinction is more noticeable in the vacuum-mixed doughs (where bubbles are absent), indicating that distilled monoglycerides exert their effect on the dough matrix itself, making it less compressible.

Ultrasonic Attenuation Changes

The difference in ultrasonic behaviour between the two types of ingredients is substantiated by the ultrasonic attenuation results (Fig. 3). Only the vacuum-mixed dough results are shown here to emphasize that the effect of the ingredient is manifest in the dough matrix. In the case of attenuation, greater amounts of shortening increase attenuation, while greater amounts of distilled monoglycerides decrease attenuation, inferring that distilled monoglycerides permit the dough matrix to better store the strain energy of acoustic pulses compared to the control dough and the doughs made with shortening. It is likely that the changes in dough matrix properties are brought about by the interaction of shortening with the hydrated proteins of the dough matrix (Fu et al 1997), while the lower compressibility of dough made with distilled monoglycerides is likely attributable to the unusual structuring of free water in the dough by these bakery surfactants (Krog 1981).

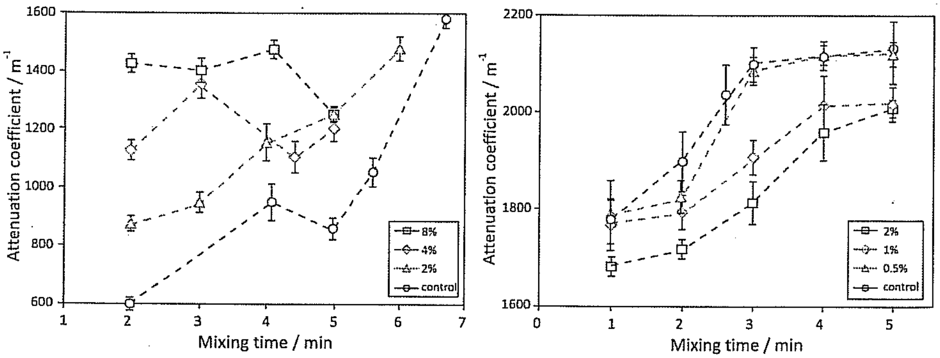

Fig. 3. Effect of mixing time in vacuum on ultrasonic attenuation for doughs formulated with different amounts (%fwb) of shortening in CWRS flour (left) or distilled monoglycerides in SWS flour (right).

To demonstrate that the effects of distilled monoglycerides were independent of flour type, doughs were prepared with a strong wheat flour (CWRS) to which distilled monoglycerides were added. Even though there are a limited number of mix times, it can be seen (Fig. 4) that the pattern of decreasing attenuation with increasing concentration of distilled monoglycerides is similar to that of the SWS flour.

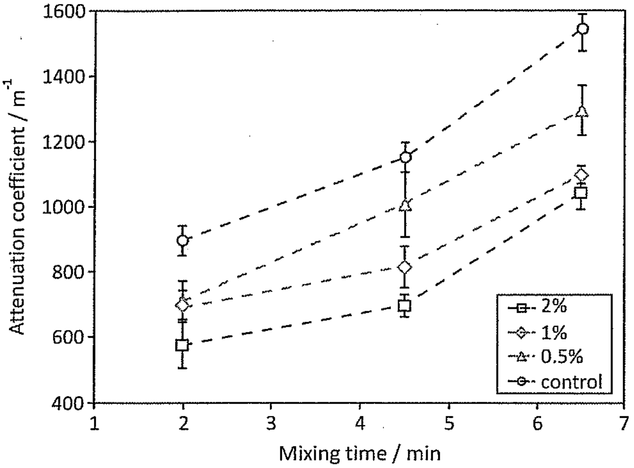

Fig. 4. Effect of mixing time and distilled monoglycerides on ultrasonic attenuation in vacuum-mixed doughs prepared with CWRS flour.

CONCLUSIONS

Low intensity ultrasonic velocity and attenuation measurements have been successfully used to examine the effect of mixing time on entrainment of bubbles into dough and on the properties of the surrounding dough matrix. Addition of shortening "weakened" the dough matrix as assessed by ultrasonic measurements, whereas distilled monoglycerides added to the doughs "strengthened" the dough matrix, an effect independent of flour type.

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LITERATURE CITED

Baker, J. C., and Mize, M. D. 1941. The origin of the gas cell in bread dough. Cereal Chemistry 18:19-33.

Brooker, B. E. 1996. The role of shortening in the stabilization of gas cells in bread dough. Journal of Cereal Science 24:187-198.

Campbell, G. M., Rielly, C. D., Fryer, P. J., and Sadd, P. A. 1993. Measurement and interpretation of dough densities. Cereal Chemistry 70:517-521.

Elmehdi, H. M., Page, J. H., and Scanlon, M. G. 2004. Ultrasonic investigation of the effect of mixing under reduced pressure on the mechanical properties of bread dough. Cereal Chemistry 81:504-510.

Fu, J., Mulvaney, S. J., and Cohen, C. 1997. Effect of added fat on the rheological properties of wheat flour doughs. Cereal Chemistry 74:304–311.

Krog, N. 1981. Theoretical aspects of surfactants in relation to their use in breadmaking. Cereal Chemistry 58:158-164.

Scanlon, M. G., and Zghal, M. C. 2001. Bread properties and crumb structure. Food Research International 34:841-864.