NOTE

Evaluating Dough Density Changes During Fermentation by Different Techniques

H. M. Elmehdi,[1,2,3] J. H. Page,[1] and M. G. Scanlon[2,4]

Cereal Chem. 84(3):250–252

Producing an aerated bread dough starts at the mixing stage where air bubble nuclei are incorporated into the dough. During fermentation, the production of CO_2, due to yeast's metabolic activities, causes the bubbles to increase in size thereby increasing the volume and reducing the density. Therefore, the way in which the density of the dough is reduced and the dough's ability to retain gas plays an important part in the production of good loaf volume. A number of studies have used different approaches to examine the effects of fermentation conditions on the rheology of dough. The internal pressure of fermenting dough has been measured by placing the dough in a glass cylinder (Matsumoto et al 1971). The expansion of the dough resulting from fermentation was studied by Miller at al (1954), who measured the expansion by displacement of a weak salt solution. In another study (Marek and Bushuk 1966), the buoyancy of fermenting dough was measured by placing it on a balance in a constant temperature bath of mineral oil. However, despite the importance of dough density changes as an indicator of gas holding capacity of the dough, a direct comparison of how the density changes as the dough ferments using a variety of measurement techniques has not been reported.

The objective of this note was to investigate the effect of measurement techniques on evaluation of dough density by measuring the decrease in density of fermenting dough under different geometrical constraints and comparing the results. To achieve this, the volume of the expanding dough was measured over time using three methods: 1) dough height increase within a graduated cylinder, 2) water displacement following free expansion of subsamples of the dough, and 3) radial expansion of dough constrained between two thick acrylic plates (measured using digital imaging).

MATERIALS AND METHODS

Dough samples used in these experiments were prepared from Canadian Western Red Spring (CWRS) wheat flour by mechanical dough development using the standard Canadian Short Process Method (Preston et al 1982) as described by Elmehdi et al (2003). One mixed dough was used for a given dough density measurement technique, and three replicates were examined for each technique. At the end of mixing, subsamples were immediately removed from the dough piece. In the free expansion method, typically 20 subsamples were removed from the mixed dough, while for the other methods, only one subsample was required to perform the measurement. After measuring the mass of the subsample, it was placed in the apparatus used to measure the volume. For the free expansion method, the subsamples were placed in the proofing cabinet and the volume of the expanding dough was measured by taking one subsample at ≈5-min intervals. For all three methods, the apparatus and the subsample were placed in a proofing cabinet that was set at normal proofing conditions (37°C and 83% relative humidity) (Preston et al 1982). The change in the volume of the fermenting dough with time was then measured using one of the three methods. Changes in mass of the dough were assumed to be small.

Graduated Cylinder Method

The change in volume of the dough was measured by following the rise in the height of the dough piece (≈70 g) that was placed in the graduated cylinder (width 2.5 cm). The dough was thus allowed to expand in one direction only (upwards). The walls of the cylinder were well lubricated with mineral oil to minimize frictional effects between the cylinder walls and the dough. The change in density as a function of fermentation time was calculated using $\rho(t) = m/Ah(t)$, where m is the mass, A is the cross-sectional area of the graduated cylinder, and $h(t)$ is the height of dough as a function of fermentation time. A potential drawback of this method lies in the fact that air pockets may exist underneath the dough when it is placed into the cylinder. These air pockets will interfere with attaining an accurate filling of only dough to the initial height, $h(0)$, and they will act as compressible sites into which the dough can expand during fermentation, thus introducing errors into the measurements.

Free Expansion Method

The small subsamples (≈3 g) that had been cut from the dough were allowed to ferment in the proofing cabinet. At approximately 5-min intervals, a subsample was taken from the proofing cabinet and gently immersed into a specific gravity bottle filled with water. The volume of the displaced water permitted measurements of dough volume. Drawbacks to this method were that the samples had to be small in order to fit into the specific gravity bottle and the samples had to be carefully handled because of their fragility. These factors limited the accuracy of the density measurements. After ≈30 min of fermentation, the subsamples had to be gently pushed down to submerge them and allow excess water to escape. A liquid displacement method was also employed by Campbell et al (2001), who measured the density of fermenting dough samples by weighing small dough samples in air and immersed in xylene (of known density).

Digital Imaging Method

A precisely weighed subsample (≈4 g) was placed between two acrylic plates 3 cm thick. The thickness of the sample was preset by using a set of 1-mm glass slides as spacers between the two acrylic plates. To restrict expansion of the dough to the radial direction only, the two plates were clamped together. The apparatus was then placed in the proofing cabinet and mounted directly below a digital camera (Fig. 1). Digital images of the dough were taken every 2 min. An example of typical digital images of the expanding dough is shown in Fig. 2. To evaluate the density of the dough

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[1] Department of Physics and Astronomy, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

[2] Department of Food Science, University of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2.

[3] Present address: Department of Physics, University of Sharjah, PO Box 27272, Sharjah, United Arab Emirates.

[4] Corresponding author. E-mail: scanlon@cc.umanitoba.ca

doi:10.1094/CCHEM-84-3-0250

as a function of fermentation time, the digital images were transferred to a computer and the area of the expanding dough was evaluated using a digital imaging analysis software program called Scion Image (Scion Corporation, Frederick, MD) downloaded from http://www.scioncorp.com. Because the distance between the acrylic plates was fixed throughout fermentation and the mass of the dough, m, was measured before the sample was placed between the plates, the density was found from $\rho(t) = m / LA(t)$, where L is the sample thickness and $A(t)$ is the area of the dough as a function of fermentation time.

RESULTS AND DISCUSSION

Figure 3 compares the dough densities as measured using the three methods. All three methods allow the overall relative dough density decrease to be monitored as a function of fermentation time. The density decrease over time is consistent with density measurements made on fermenting doughs in xylene (Campbell et al 2001), although absolute comparisons are hindered by differences in wheat flour strength and formulation.

The density measured using the graduated cylinder method is lower and this discrepancy is likely due to the presence of air pockets underneath the dough when it was placed into the cylinder. The expanding dough would then compress these air pockets, so density measured by this technique would be smaller. For the free expansion method, the lower rate of decrease in the density compared with the other techniques is attributed to edge effects. Small dough volumes release more gas per unit volume than a large piece does, so ρ falls more slowly. The imaging configuration has less exposed surface area where gas can escape so it exhibits the greatest change in density with time. Therefore, it appears that the geometrical constraints or boundary conditions under which the density of the fermenting dough is measured significantly affect the values of the dough density that are obtained and should be taken into account. For example, in rheological measurements using ultrasonic techniques (Elmehdi et al 2003, 2004), the digital imaging method was used to measure dough density because it corresponds directly to the constraints that are imposed by the experimental apparatus used to transmit an ultrasonic signal through the fermenting dough.

To conclude, it was evident that even though the pattern of overall decrease in dough density during fermentation was similar for all three methods, different techniques influenced the absolute measure of density as the dough expanded. Because boundary conditions ultimately affect measurements of dough density, the technique used to measure dough density should be appropriate and must be taken into account as they will influence the interpretation of the relationship between dough structure and dough rheology.

ACKNOWLEDGMENTS

We are grateful to the Natural Sciences and Engineering Research Council of Canada (NSERC) for Discovery research funds, and to the Canadian International Grains Institute for providing us with flour samples.

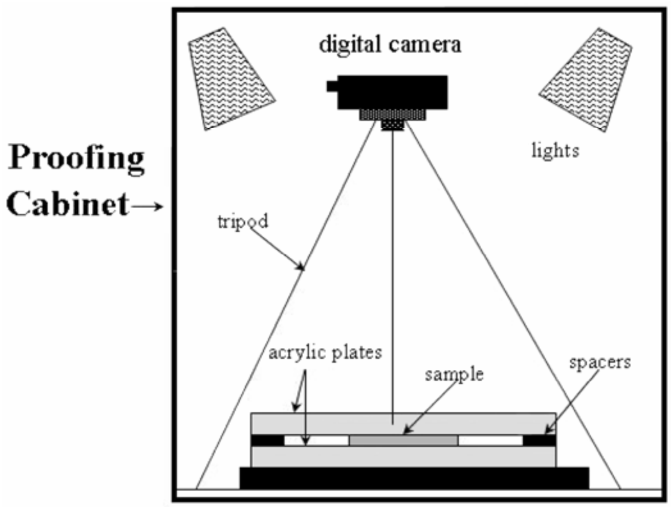

Fig. 1. Dough density measurements using a digital camera.

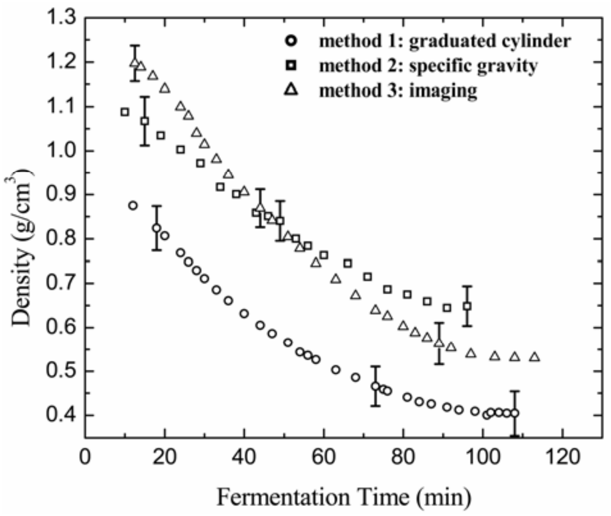

Fig. 3. Density of fermenting dough using graduated cylinder (○), free expansion (□), and digital imaging (△). Error bars represent standard deviation.

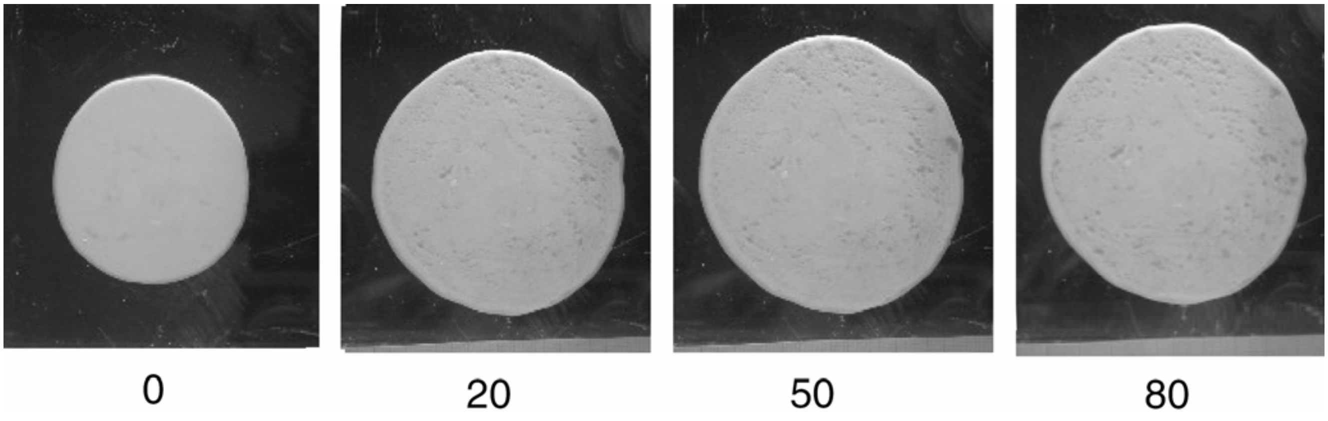

Fig. 2. Images of expanding dough at different fermentation times (min).

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[Received April 12, 2006. Accepted January 10, 2007.]