NOTE

Mixing Wheat Flour and Ice to Form Undeveloped Dough

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Dough, in the most basic form, is made by combining water, flour, and energy. The function of traditional instruments, such as the farinograph and the mixograph, is to uniformly distribute the total mass and add energy by rotating the mixing elements (Preston and Kilborn 1984, Hoseney 1985). Water causes the proteins to swell, and the addition of mechanical energy allows them to become organized into a continuous protein matrix (holding starch and other components) that gives dough a unique viscoelastic structure (Schofield and Scott Blair 1932). Mixing can be separated into three distinct elements: distribution of materials, hydration, and energy input to stretch and align protein molecules (Bloksma and Bushuk 1988). The phrase "development" may be associated with the energy input element of mixing. Undeveloped dough as the focus of this study, refers to a homogeneous, hydrated flour. Finished dough would allude to a wheat-flour system that was fully hydrated and developed with the adequate input of energy. The advantage of working with an undeveloped dough is that the influence of the flow field (shear vs. extensional), strain history, and energy input levels on the finished dough (and final product) can be carefully studied.

In preparing wheat dough for experimental analysis, the homogeneous distribution of components in the dough system is essential, particularly the uniform distribution of water to hydrate the protein and other flour particles. Traditionally, the hydration phenomenon (and subsequent dough development) is facilitated by the addition of energy input (Kilborn and Tipples 1972, 1975) through the mixing elements of the farinograph, the mixograph or similar equipment. Literature relating the effect of water content on the properties of the dough is very extensive. Although it is well established that dough rheological properties are extremely sensitive to the moisture content (Smith et al 1970, Navickis et al 1982, Abdelrahman and Spies 1985, Dreese et al 1988, Eliasson et al 1991, Berland and Launay 1995), data on the homogeneous distribution of water in the dough systems are not available. Published studies assume, implicitly, that water is uniformly distributed in the dough after the mixing process.

There have been some past efforts to produce dough without the addition of mechanical work. Olcott and Mecham (1947) produced dough by mixing powdered ice with flour and holding the mixture in a freezer at –9.4°C for one month before thawing it to room temperature. This study does not detail the method of preparing the powdered ice or the mixing procedure. A method of mixing ice particles and flour was also developed by Davies et al (1969). In their technique, powdered ice is prepared by grinding water, below the surface of liquid nitrogen, with a mortar and pestle. This material was added to flour, which was also suspended in boiling liquid nitrogen. The entire mixture was held, for ≈24 hr at –20°C while the nitrogen boiled off. Material was thawed to room temperature before testing. Particle sizes in this study were not evaluated. The focus of the Olcott and Mecham (1947) and the Davies et al (1969) studies was lipid binding in the dough matrix.

In this research, a new approach to achieve hydration was studied. Critical steps involve the distribution of uniform flour and ice particles, then warming the mixture to melt the ice and achieve hydration, thus forming an undeveloped dough. The main objective of this study was to determine whether a uniform distribution of water in the dough system was achieved. This was not considered in earlier work. This article describes the new methodology and compares the results obtained with the moisture distribution accomplished using the farinograph.

MATERIALS AND METHODS

A new method of blending flour and powdered ice in an environment below the freezing temperature was developed. Unlike previously reported work (Olcott and Mecham 1947, Davies et al 1969), size of the ice particles was carefully controlled in this study. The powdered ice was prepared in the presence of solid carbon dioxide (CO_2 or dry ice) which was required to absorb the heat generated in breaking the ice into smaller particles. Breaking or crushing the ice without using the CO_2 caused some of the ice particles to melt and others to clump together making the material difficult to handle.

The powdered ice was prepared inside a walk-in cooler. A Waring blender was used to achieve size reduction. Large pieces of CO_2 were first pulverized to generate a cold temperature condition in the blender. Ice chunks were then added and broken into smaller particles by the action of the rotating blades. Solid CO_2 and ice particles were sieved, and those with a particle size (150–250 μm) similar to flour were retained for further use. The powder mixture was then held inside a freezer at –8°C undisturbed, allowing sublimation of the solid CO_2 while keeping the ice intact.

The blending of flour and ice particles was also performed inside the walk-in freezer (–8°C). Materials were carefully weighed (to control the moisture content), placed into a centrifuge tube, and distributed uniformly using a vortex mixer for 2 min. The resulting flour and ice mixture was placed in a moisture-resistant container and held for a predetermined period of time at a set temperature (25°C). For convenience, a holding time of ≈24 hr was used. This holding period allowed the ice particles to melt and the water thus produced to diffuse into the system, resulting in the hydration of flour. This blending and thawing procedure was the critical step of this new approach making hydration, without the dough development associated with energy input, possible. A summary of the methodology is presented in Figure 1.

To determine whether water was uniformly distributed

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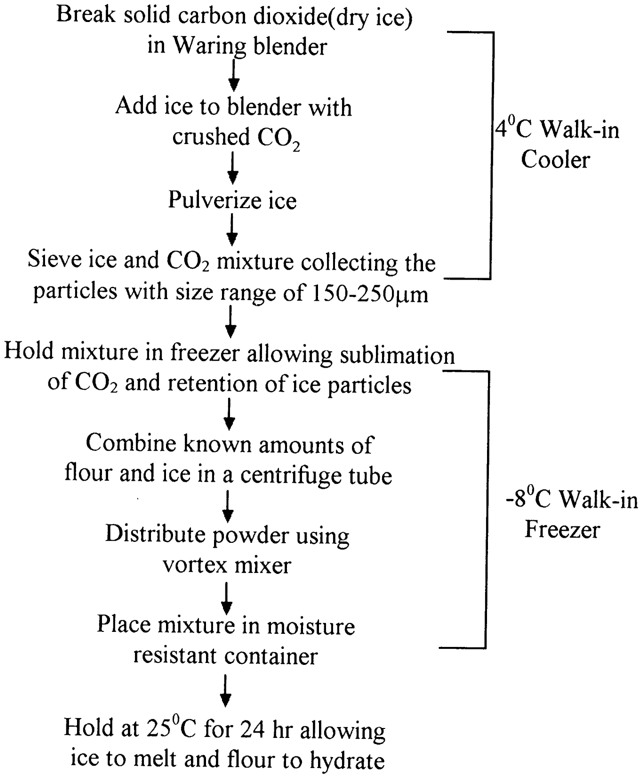

Fig. 1. Flow diagram of the powder method of making undeveloped dough.

throughout the system, six samples were prepared using the powder mixing procedure discussed above. Commercial soft white wheat flour was used in this experiment. A sample batch consisted of 6 g of flour and 3 g of ice particles, using a 2:1 flour-to-water ratio. Each batch of undeveloped dough was subdivided into four small lots, carefully weighed, and placed in the convection oven held at 135°C for 3 hr. The moisture content (percent dry basis) of each individual lot was calculated as:

$$\% \text{ MC} = ([\text{initial weight} - \text{final weight}]/\text{final weight}) \times 100\%$$

It is commonly accepted that mixing time of flour to achieve proper dough development strongly depends on the type and quality of the flour. In general, hard wheat flours require longer mixing times than soft wheat flours; hence, no standard mixing times can be prescribed. In this study, results were compared with dough samples made using the farinograph and the standard dough preparation procedure (AACC 1983). Dough samples were prepared in the farinograph mixer by combining 50 g of flour and a known amount of water (25 g), then mixed for a predetermined mixing time of 2, 4, and 8 min. Eight subsamples of each batch were taken, and moisture content was determined using the procedure described above.

RESULTS AND DISCUSSION

Data on the moisture content analysis of the dough prepared following the powder mixing method is presented in Table I. All moisture contents are expressed on a dry basis. From the six samples of undeveloped dough, four subsamples from each were taken. Results yield mean values of moisture content ranging from 70.26 to 70.89% and standard deviations ranging from 0.42 to 0.94%. Predetermined moisture content was calculated as 70.15% using a 2:1 flour-to-water ratio (and the 13.5% initial moisture content of the flour). Table II presents the results of the comparative experiment where dough was prepared using the farinograph method. Values were similar to those found for the

TABLE I
Percent Moisture Content of the Undeveloped Dough[a]

Sample Number	Flour-to-Water Ratio (g:g)	Mean (% mc, db)[b]	Standard Deviation (% mc, db)[b]
1	6:3	70.89	0.81
2	6:3	70.63	0.42
3	6:3	70.50	0.94
4	6:3	70.73	0.71
5	6:3	70.61	0.63
6	6:3	70.26	0.54

[a] Mean and standard deviation are based on sample size of 4.
[b] mc = moisture content; db = dry basis.

TABLE II
Percent Moisture Content of the Dough Made Using the Farinograph[a]

Mixing Time (min)	Flour-to-Water Ratio (g:g)	Mean (% mc, db)[b]	Standard Deviation (% mc, db)[b]
2	50:25	70.67	0.53
2	50:25	69.87	0.44
4	50:25	70.03	0.63
4	50:25	70.35	0.35
8	50:25	70.11	0.35
8	50:25	69.88	0.59

[a] Mean and standard deviation are based on sample size of 8.
[b] mc = moisture content; db = dry basis.

undeveloped dough (mean values ranging from 69.87 to 70.67%). Although standard deviations (0.35–0.63%) are slightly smaller than that of the undeveloped dough, the difference is statistically insignificant at the 5% level.

The initial concern in making the undeveloped dough (powder mixing) was that a new variable, nonuniform mixing, would be introduced into the process. The results in this experiment show that a homogeneous dough (similar to the level of the homogeneity achieved with the farinograph method) system can be made with the powder mixing method. This novel method of preparing dough will open unique opportunities in studying wheat products by decoupling the hydration and energy input steps involved in preparing finished dough. The current communication is written with the intention of letting this dough preparation technique be known to the scientific community with the hope of stimulating further research to elucidate the factors governing dough development.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC, 8th ed. The Association: St. Paul, MN.

ABDELRAHMAN, A., and SPIES, R. 1986. Dynamic rheological studies of dough systems. Pages 87-103 in: Fundamentals of Dough Rheology. H. Faridi and J. M. Faubion, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.

BERLAND, S., and LAUNAY, B. 1995. Rheological properties of wheat flour doughs in steady and dynamic shear: effect of water content and some additives. Cereal Chem. 72:48-52.

BLOKSMA, A. H., and BUSHUK, W. 1988. Rheology and chemistry of dough, Pages 131-217 in: Wheat Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

DAVIES, R. J., DANIELS, N. W. R., and GREENSHIELDS, R. N. 1969. An improved method of adjusting moisture in studies on lipid binding. J. Food Technol. 4:117-123.

DREESE, P. C., FAUBION, J. M., and HOSENEY, R. C. 1988. Dynamic

rheological properties of flour, gluten, and gluten-starch doughs. II. Effect of various processing and ingredient changes. Cereal Chem. 65:354-359.
ELIASSON, A.-C., SILVERIO, J., and TJERNELD, E. 1991. Surface properties of wheat flour-milling streams and rheological and thermal properties after hydration. J. Cereal Sci. 13: 27-39.
HOSENEY, R. C. 1985. The mixing phenomenon. Cereal Foods World. 30:453-457.
KILBORN, R. H., and TIPPLES, K. H. 1972. Factors affecting mechanical dough development I. Effect of mixing intensity and dough development. Cereal Chem. 49:34-47.
KILBORN, R. H., and TIPPLES, K. H. 1975. "Un-mixing"—The disorientation of developed bread doughs by slow speed mixing. Cereal Chem. 52:248-262.
NAVICKIS, L. L., ANDERSON, R. A., BAGLEY, E. B., and JASBERG, B. K. 1982. Viscoelastic properties of wheat flour doughs: variation of dynamic moduli with water and protein content. J. Texture Stud. 13:249-264.
OLCOTT, H. S., and MECHAM, D. E. 1947. Characterization of wheat gluten. I. Protein-lipid complex formation during doughing of flours. Lipoprotein nature of the glutenin fraction. Cereal Chem. 24:407-414.
PRESTON K. R., and KILBORN, R. H. 1984. Dough rheology and the farinograph, Pages 38-42 in: Farinograph Handbook. B. L. D'Appolonia and W. H. Kunerth, eds. Am. Assoc. Cereal Chem.: St. Paul, MN.
SCHOFIELD, R. K., and SCOTT BLAIR, G. W. 1932. The relationship between viscosity, elasticity and plastic strength of soft materials as illustrated by some mechanical properties of flour doughs. Proc. R. Soc. (London) A138:707-718.
SMITH, J. R., SMITH, T. L., and TSCHOEGL, N. W. 1970. Rheological properties of wheat flour doughs. Rheol. Acta 9:239-252.

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