The Effects of Flour Lipids on the Expansion Rate and Volume of Bread Baked in a Resistance Oven[1]

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ABSTRACT

When baked in an electrical resistance oven, doughs made with shortening attained a greater height than doughs made without shortening. The expansion rate of doughs made without shortening decreased at temperatures above 55° C. Fractionation and reconstitution experiments showed that the rheological changes observed in nonshortening doughs were caused by the free polar lipids and gluten proteins of flour.

It is well known that shortening increases the volume of bread, although doughs with or without shortening proof to equivalent heights. The shortening effect can be clearly seen as increased volume during the initial phase of baking, generally referred to as ovenspring. Pomeranz et al (1965) reported that volume increase is related to the amount of shortening added, up to about 3% flour weight.

The effect of shortening also was shown to vary depending upon the flour strength and whether the flour had been defatted (Pomeranz et al 1968). Defatting strong flours with petroleum ether improves the loaf volume when no shortening is used. Shortening added to defatted flour has no effect on loaf volume. Petroleum ether soluble lipids plus shortening are beneficial to loaf volume, whereas the petroleum ether soluble lipids alone are detrimental to loaf volume. However, poor quality flours react differently.

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MacRitchie (1980) clearly showed that adding total free lipids to defatted flour in the absence of shortening will first cause a decrease in loaf volume followed by an increase in volume at higher levels of addition. A similar response was found for polar lipids added to an almost completely defatted flour in the presence of 3% shortening (Hoseney et al 1969). Thus, at certain levels, flour lipids can be detrimental to loaf volume.

The purpose of this study was to learn more about the effects of various lipid and flour fractions when reconstituted and baked in an electrical resistance oven.

MATERIALS AND METHODS

Flour

Commercial bread flour obtained from Ross Mills, Wichita, KS, was used. It contained 12.4% protein (N × 5.7), 0.44% ash, and 0.8% free lipids on a 14% moisture basis. Moisture and protein were determined by AACC methods 44-15A and 46-10 (1983).

Dough Procedure

Doughs used for all baking experiments were prepared using a slight modification of the straight-dough procedure described by Finney (1984). Malted flour was used in lieu of adding malt syrup. Doughs were mixed to optimum in a National 100-g pin mixer

(National Mfg. Co., Lincoln, NE) and fermented at 30° C, 86% rh, for 180 min, and punched mechanically at intervals of 105 and 155 min. The dough was molded mechanically in the usual manner and panned. The top of the loaf (opposite the seam) was cut along its length to a depth of about one-third of its diameter. Doughs were then placed with the cut side up in the bottom of the electrical resistance oven and proofed 55 min. The top was cut to reduce rounding during proofing and baking and thus maximize dough contact with the electrodes. Because the other dimensions are fixed, loaf volume is a function of dough height. A commercial partially hydrogenated soybean oil (Crisco) was obtained from Procter and Gamble, Cincinnati, OH.

Resistance Baking

An electrical resistance heating device was first described by Baker (1939), and construction details of a simplified resistance oven were presented by Junge and Hoseney (1981). Prepared doughs were placed in the resistance oven, proofed for 55 min, and baked for 20 min. The constant 75 V potential applied to the electrodes heated the doughs at a sufficient rate to give ovenspring equivalent to that of doughs baked in a standard convection oven. Temperatures were measured by inserting a thermocouple directly into the dough 3 cm above the base through a small hole in the resistance oven.

Flour Fractionation

Flour was fractionated by mixing in a pin mixer with 62% (flour weight) water for 3 min. The dough was placed in a large beaker containing 100 ml of water and massaged for 4 to 5 min. This washing was repeated 10 times, and water slurries were decanted and collected. The combined water slurries were centrifuged for 20 min at 1,000 × *g* to separate starch and water-soluble fractions. All fractions were frozen and lyophilized. Starch and gluten fractions were ground to pass a 40-mesh sieve. The moisture content of lyophilized starch was adjusted by spreading the starch in a thin layer at 20° C, 95% rh, for a time sufficient to attain a moisture content of 12 to 13%. Flours were reconstituted on a moisture-free protein basis equivalent to the original flour.

Defatted Flour

Free lipids were removed from flour by exhaustive extraction (24 hr) of 500-g batches of flour with petroleum ether (35–60° C bp) in a large Soxhlet extractor. Heating rate was adjusted to obtain complete solvent exchange hourly. Residual solvent was removed from the flour by air-drying for 4 hr, stirring hourly.

Flour Lipids

Total free lipids (TFL) were recovered from the petroleum ether by evaporating the solvent to dryness under reduced pressure and with slight warming (< 45° C).

Silicic Acid Chromatography

Silicic acid (Bio-Sil A; Bio-Rad, Richmond, CA) was washed with excess distilled water and dried at 130° C for 4 hr. Lots of 150 g were washed with chloroform and chloroform/methanol mixtures using the solvent ratios described by Daftary and Pomeranz (1965). Columns (45 × 3 cm) of silicic acid were poured (Hirsch and Ahrens 1958), using chloroform as the solvating medium, and were allowed to settle overnight before use.

Lipid Fractionation

TFL obtained from the flour defatting process was solubilized in chloroform and fractionated into nonpolar and polar fractions using chloroform followed by methanol as eluting solvents. Each fraction was checked by thin-layer chromatography for completion of elution. Solvent containing the polar and nonpolar fractions was evaporated under reduced pressure and slight warming (< 45° C).

Lipid Reconstitution

Lipid fractions were reconstituted using the procedure described by Pomeranz et al (1965). Sufficient quantities of lipid fractions were used to attain levels of 0.8, 0.6, and 0.2% for TFL, nonpolar, and polar lipids, respectively.

TABLE I
Effect of Various Lipid Fractions Reconstituted with Defatted Flour on Set Temperature and Final Dough Height

Flour	Added Lipid[a] (%)	Shortening (%)	Set Temperature	Final Dough Ht	*n*	SD
Native	0	0	55	3.0	17	0.21
	0	3	80	4.8	19	0.14
Defatted	0	0	77	3.7	9	0.20
	0.8 TFL	0	55	2.8	5	0.36
	0.6 NP 0.2 PL	0	55	2.6	2	...[c]
	0.6 NP	0	74	3.0	2	...[c]
	0.2 PL	0	55	3.1	5	0.32

[a]TFL, total free lipids; NP, nonpolar lipids; PL, polar lipids.
[b]Set temperature, the temperature at the first change in slope. Standard deviation for determining set temperature, 2.6° C.
[c]Standard deviation not determined but assumed to be similar to the others.

RESULTS AND DISCUSSION

Height as a Function of Time

The height increase of doughs as a function of time, equivalent to

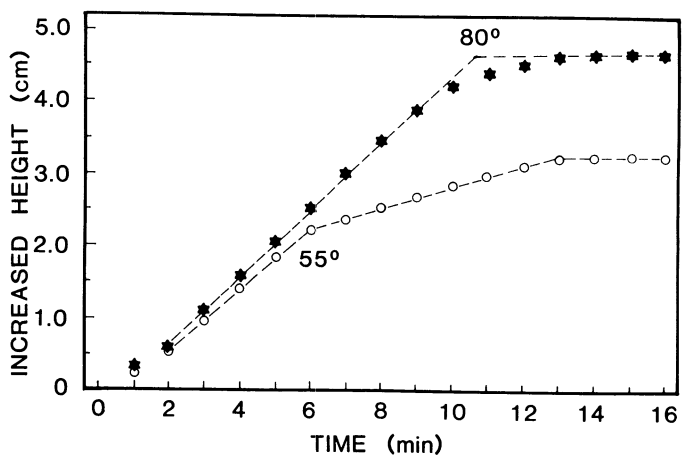

Fig. 1. Dough height as a function of bake time in the resistance oven: (★) shortening and (o) no shortening. The temperature indicated is the temperature at the change in slope.

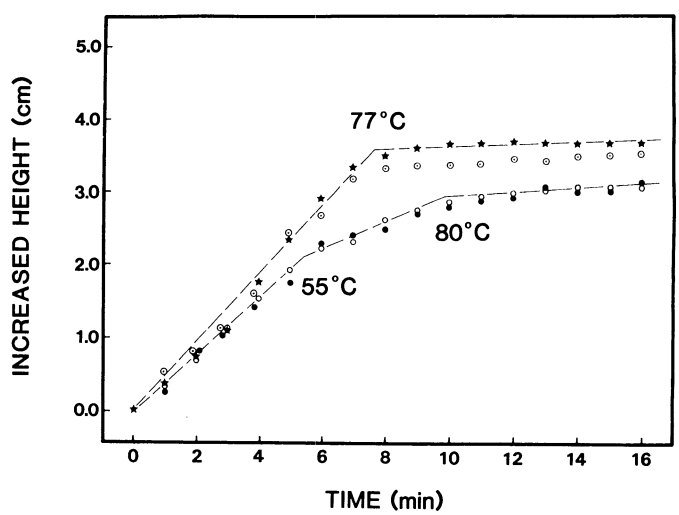

Fig. 2. Dough height as a function of bake time in the resistance oven: (★) defatted flour, no shortening; (o) native flour, no shortening. Effects of exchanging gluten between native and defatted reconstituted flour on loaf height (o) gluten from defatted flour, (•) gluten from native flour. The temperature indicated is the temperature at the change in slope.

ovenspring, is presented in Figure 1. Addition of 3% (flour weight) shortening resulted in greatly increased loaf heights over those made without shortening (Table I).

The expansion rate of doughs made without shortening decreased (from 0.44 to 0.15 cm/min) after they were baked for a time sufficient to reach an internal temperature of about 55° C (about 6 min). Doughs without shortening continued to expand at the lower rate until a total bake of 13 to 14 min had elapsed and the dough set. The data presented by Junge and Hoseney (1981) are essentially the same as reported above. However, they do not call attention to the change in slope at 55° C; instead they treat the change in slope as a single, not biphasic, event.

Effects of Gluten Exchange

Gluten separated from defatted flour was reconstituted with the remaining components from native flour, and the native flour gluten was combined with the remaining components from defatted flour. Doughs from reconstituted flours containing gluten from defatted flour expanded for a time and attained a volume similar to those of nonfractionated, defatted flours. Doughs prepared from reconstituted flours containing gluten from native flour were essentially equivalent to those from unfractionated flour (Fig. 2). These results indicate that gluten and associated native, free lipids were the components responsible for the change in expansion rate at 55° C for native flour, nonshortening doughs.

Effects of Free Lipid Fractions of Flour on Dough Properties

TFL (0.8%) was reconstituted with defatted flour. Doughs prepared from this reconstituted flour showed a reduced rate of expansion at lower temperatures than doughs from defatted flour. The set temperature for doughs from defatted flour with TFL added was the same as those from native flour without shortening (Table I).

TFL fractionated into polar and nonpolar components was added to defatted flour at 0.2 and 0.6%, respectively. The combination of polar and nonpolar lipids in defatted flour resulted in a set temperature of 55° C that was the same as for doughs from native flours baked without shortening and defatted flour with 0.8% TFL (Table I).

Polar and nonpolar lipids were also reconstituted individually with defatted flour at 0.6 and 0.2% levels, respectively, similar to those occurring naturally in wheat flour. Reconstituted doughs containing 0.6% nonpolar lipids set at a temperature of 74° C, which is slightly lower than that (77° C) for the defatted flour dough (Table I). Doughs prepared from defatted flour reconstituted with 0.2% free polar lipids set at 55° C (Table I). These results indicated that free polar lipids were responsible for the low set temperature (55° C) typical of native flour doughs made without shortening.

These experiments indicated that both the protein and lipid fractions were responsible for the dough expanding at a slower rate at temperatures above 55° C. Nonpolar lipids alone had a minor effect; however, adding a polar lipid fraction caused a reduction in the temperature at which the expansion rate decreased.

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