Defatted and Reconstituted Wheat Flours. VII. The Effects of 0–12% Shortening (Flour Basis) in Bread Making[1]

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ABSTRACT

From 10 g (dry basis) of a composite flour of hard red winter wheats, petroleum ether (PE) extracted 91 mg of free lipids—69 mg of nonpolar (NL) and 22 mg of polar (PL), and 2-propanol (2-PrOH) extracted 136 mg of total (free plus most of bound) lipids (69 mg of NL and 67 mg of PL). Extracted and reconstituted flours were baked with 0, 0.375, 0.75, 1.5, 3, 6, 9, and 12% commercial shortening. In general, mixing time increased and water absorption decreased as the shortening level increased. Loaf volume (LV) obtained using the control flour increased rapidly as the shortening increased up to 1.5% and changed little after 3%. Shortening increased the LV of PE-defatted flour and its NL-reconstituted flour but decreased the LV of 2-PrOH-defatted flour and its NL-reconstituted flour. Shortening slightly increased the LV of PE or 2-PrOH-defatted flours reconstituted with PL. For reconstituted flour containing total PL but no NL, only about 0.5% shortening was enough for optimum LV and crumb grain, provided only free PL had been removed originally. However, if total PL had been extracted and then added back to 2-PrOH-defatted flour, 3% shortening was required for good LV. Insofar as LV and crumb grain were concerned, free PL of wheat flour could be replaced by 9–12% shortening, irrespective of the presence of NL, whereas total PL could not be replaced by any level of shortening.

Shortening, or fat, is used in commercial baking to bring out the best in a bread-making wheat flour: to help in handling and processing throughout all the stages from dough to finished bread, to produce a loaf of good volume and crumb grain, to improve slicing, and to enhance freshness retention and overall consumer acceptance (Bell et al 1977, Pomeranz 1971, Ponte and Al-Madani 1977). Our previous study (Chung et al 1980) showed that in defatted flour shortening had a detrimental effect on loaf volume (LV) and crumb grain; the detrimental effect was linearly related to the amount of polar lipids (PL) removed from the flour. Consequently, flour PL are essential to beneficial effects of shortening. Thus far, we have studied only the effect of 0 or 3% shortening on bread-making characteristics of flours containing various amounts of PL in the absence of nonpolar lipids (NL).

The objectives of this study were: 1) to determine the effects of various levels of shortening on bread-making characteristics of flours containing different amounts and classes of native flour lipids, 2) to determine if shortening can replace a certain class of native flour lipids, and 3) to determine at what level shortening can replace a certain lipid class. Answers to those questions would help to determine the role of wheat flour lipid classes in bread making, and might help in the production of acceptable loaves of bread from flours that do not contain required amounts and/or classes of native flour lipids.

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[4] Reference to a company or product does not imply approval or recommendation of the product by the USDA to the exclusion of others that may also be suitable.

MATERIALS AND METHODS

Materials

Regional Baking Standard 75—an untreated, straight-grade flour—was milled in the laboratory with an Allis mill from a composite grist of many hard red winter wheat varieties harvested at many locations throughout the Great Plains in 1974. The flour contained 12.4% protein (N × 5.7) and 0.42% ash (14% mb). It had a good LV potential and medium mixing and oxidation requirements.

Organic solvents were analytical reagent grade, and solutions were prepared from analytical reagent-grade compounds. Silicic acid for chromatography of lipids was from Mallinckrodt, NY, and shortening was a commercial vegetable product (Crisco) that is partly hydrogenated and has a slip point of 41°C.

Analytical and Baking Procedures

Protein, ash, and moisture contents were determined by AACC methods. The 10-g baking procedure has been described elsewhere (Shogren et al 1969). In this study, nonfat dry milk solids were replaced by defatted soy flour (Ardex 550, Archer Daniels Midland Co., Decatur, IL). The following shortening levels (percent flour basis) were used: 0, 0.375, 0.75, 1.5, 3.0, 6.0, 9.0, and 12.0. The amounts of oxidants used in this study were 5 ppm of potassium bromate and 50 ppm of ascorbic acid. The amount of yeast per 10 g of flour ranged from 0.2 to 0.275 g, depending on the yeast's activity as measured by a gassing power test (Shogren et al 1977). Doughs were fermented for 150 min and proofed for the time required to reach a 3.6-cm dough height of the unextracted control dough at 30°C. Bakes were replicated four times. The loaves were cooled at 25°C, and LV was determined by the displacement of dwarf rapeseed. Loaves were cut and their crumb grains were evaluated as follows: S, satisfactory; Q, questionable; and U, unsatisfactory.

Extraction and Fractionation of Flour Lipids

Lipids were extracted from flour in two ways: 1) with petroleum ether (PE), bp 38–57°C, by a Soxhlet for 24 hr and 2) with 2-propanol (2-PrOH) in a water-bath shaker at 75° C for 2 hr (Chung et al 1977). Lipids were purified from the dried 2-PrOH extracts by redissolving the extracts in PE and centrifuging the mixture. To simplify the presentation, lipids extracted with PE are defined as free lipids and those with 2-PrOH as total lipids containing all free lipids plus most of the bound lipids.

Flour lipids were fractionated by silicic acid column chromatography into nonpolar and polar lipids with chloroform and methanol, respectively, as eluting solvents. Complete elution was ascertained by spot tests on thin-layer plates. Lipid extractions were replicated four times and fractionations four times. The average recovery from silicic acid column fractionation was 98.3% for free lipids and 93.1% for total lipids.

Reconstitution of Defatted Flour with Flour Lipids

The defatted flours were air dried at room temperature in a hood until the solvent odors were no longer detected and were then sifted through a 100-mesh sieve (149-μm openings). The defatted flours (75 g, db) were reconstituted with appropriate amounts of lipids in a Stein mill for 1 min. The moisture contents of the reconstituted or defatted flours were raised to about 14% by the placement of 100-ml beakers of water (with wicks) in the center of flours (4–5 mm layer) in closed containers.

TABLE I
Description of Flours

Flour	Treatment	Lipid Content (mg/10 g of flour, db)	
		Polar Lipids (PL)	Nonpolar Lipids (NL)
A	Unextracted	67 (free + bound)	69
B	PE[a]-defatted	45 (bound)	···
C	2-PrOH-defatted	···	···
D	PE-defatted, then NL-reconstituted	45 (bound)	69
E	2-PrOH-defatted, then NL-reconstituted	···	69
F	PE-defatted, then PL-reconstituted	67 (free + bound)	···
G	2-PrOH-defatted, then PL-reconstituted	67 (free + bound)	···

[a]PE = petroleum ether.

Statistical Analysis of Data

Analysis of variance (ANOVA) and tests for Fishers' least significant difference (LSD) were computed to study the significance of flour effects, shortening level, and their interaction and also the significant difference of mean values (Fryer 1966).

The flour effect refers to difference between treatments of flour samples. The control flour (A) was not extracted with solvent; flours B and C were extracted with PE for free lipid removal, and 2-PrOH for total lipid removal, respectively; flours D, E, F, and G were the defatted flours reconstituted with NL or PL only (Table I).

RESULTS AND DISCUSSION

From 10 g (dry basis) of flour, petroleum ether extracted 91 mg of free lipids (69 mg of NL and 22 mg of PL), and 2-PrOH extracted 136 mg of total (free plus most of bound) lipids (69 mg of NL and 67 mg of PL). Over 75% of the free lipids were NL and about 25% were PL, whereas about 50% of the total lipids were NL and 50% PL. Although both solvents extracted the same amounts of NL, 2-PrOH extracted three times as much PL as PE did.

Water Absorption

Water absorption was shown by ANOVA to be significantly affected by shortening level, flour, and the interaction between the two at the 0.01 level. The LSD test showed that differences in water absorption greater than 1.0% were significant at the 0.05 level and those greater than 1.3%, at the 0.01 level.

In general, water absorption of the unextracted flour (A) and the PE-treated flours (B,D,F) decreased as shortening increased, indicating that at the high levels used in some of these experiments, shortening interferes with water binding in dough formation, perhaps by mechanically coating the flour particles (Fig. 1). At shortening levels above 1.5%, water absorption was consistently highest for the flour reconstituted with PL (flour F) and lowest for the unextracted control flour. Free lipids, especially free PL, are bound to proteins during dough mixing (Chiu and Pomeranz 1966, Chung and Tsen 1975, Hoseney et al 1970, Mann and Morrison 1974, Olcott and Mecham 1947). The highest water absorption for the flour reconstituted with PL indicates that free PL might facilitate water binding by interacting with proteins and that this effect of PL is enhanced by the absence of NL. When shortening levels exceeded 6% for the PL-reconstituted flour, water absorption decreased, probably because the coating effect of shortening prevailed over the PL facilitation of water binding (Fig. 1).

For the flours treated with 2-PrOH (flours C, E, and G), water

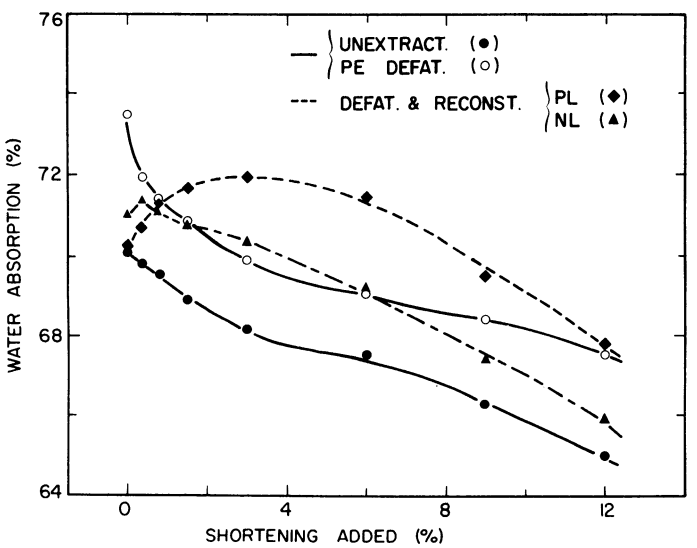

Fig. 1. The effect of shortening level on water absorption of unextracted control flour, flour defatted with petroleum ether (**PE**), and flour defatted with PE and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). The overall standard deviation of four replicates was 0.48%.

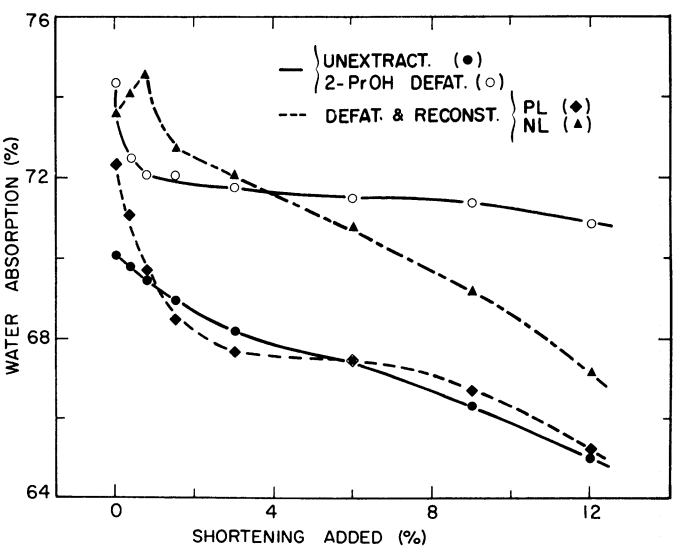

Fig. 2. The effect of shortening level on water absorption of unextracted control flour, flour defatted with 2-propanol (**2-PrOH**), and flour defatted with 2-PrOH and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). The overall standard deviation of four replicates was 0.53%.

absorption also decreased, in general, as the shortening level increased (Fig. 2). Water absorption of the 2-PrOH-defatted flour decreased significantly as shortening level was increased to 0.75%. Further increases in shortening had no significant effect on water absorption.

At all shortening levels, higher water absorption was required for 2-PrOH-defatted flour and its NL-reconstituted flour than for PE-defatted flour and its NL-reconstituted flour (Fig. 3). However, lower water absorption was required for flour defatted with 2-PrOH and then reconstituted with PL than for flour defatted with PE and then reconstituted with PL at shortening levels higher than 0.375%. The two flours reconstituted with PL, irrespective of the solvent used for extraction, contained no NL and all PL of the control flour. Yet, their water absorptions varied widely, especially at the 3% shortening level. Thus, the water absorptions associated with the 2-PrOH-treated flour may indicate a change in protein structure due to bound PL removal and/or an effect of 2-PrOH on proteins. The difference in water absorption between the treated flours varied with the shortening level; the difference in water absorption was significantly greater at low shortening levels for the flours reconstituted with NL or PL and increased with shortening level for the defatted flours.

Mixing Requirement

Mixing time of both types of treated flours generally increased as shortening increased (Figs. 4 and 5). Previously we found that in doughs containing 0 or 3% shortening, mixing time usually increases with an increase in water absorption. In this study, the increase in mixing time was not due to an increase in water absorption, however, because water absorption decreased as shortening increased (Figs. 1 and 2).

Mixing time as shown by ANOVA differed significantly by shortening level, by flour, and also by the interaction between them at the 0.01 level.

Fisher's LSD test showed that differences in mixing time longer than 0.21 min were significant at the 0.05 level and differences longer than 0.27 min at the 0.01 level. Little differentiation was found in mixing time among the flours at 0–3% shortening (Fig. 4); similar mixing times were required for all PE-treated flours at 1.5 and 3% shortening levels. At 6% or higher shortening levels, defatted flours required significantly longer mixing times than did the unextracted control flour, and the reconstituted flours required significantly longer mixing times than did either the unextracted or PE-defatted flours (except at the 12% shortening level).

Unlike the PE-treated flours (Fig. 4), flours containing different amounts of lipids by 2-PrOH extraction differed significantly, at all the shortening levels, in mixing time (Fig. 5), although mixing time was not significantly different for 2-PrOH defatted flour and its PL-reconstituted flour baked with 0–0.75% shortening.

At all shortening levels, the mixing requirement was longer for

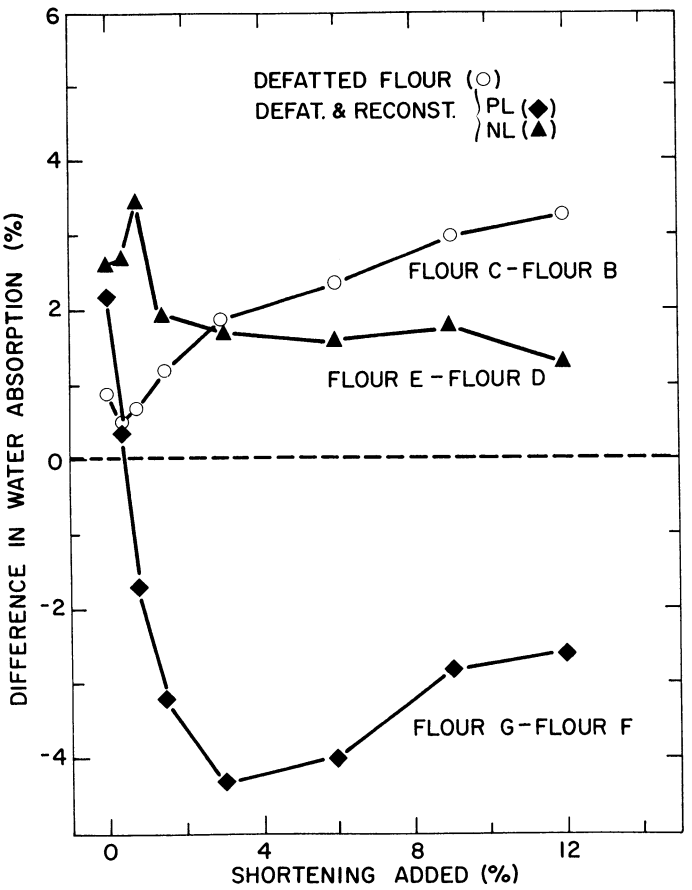

Fig. 3. The effect of shortening level on difference in water absorption of flour defatted with 2-propanol or its flour reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**) and of flour correspondingly treated with petroleum ether. Flours **C, E,** and **G** were defatted with 2-propanol, flours **B, D,** and **F** with petroleum ether.

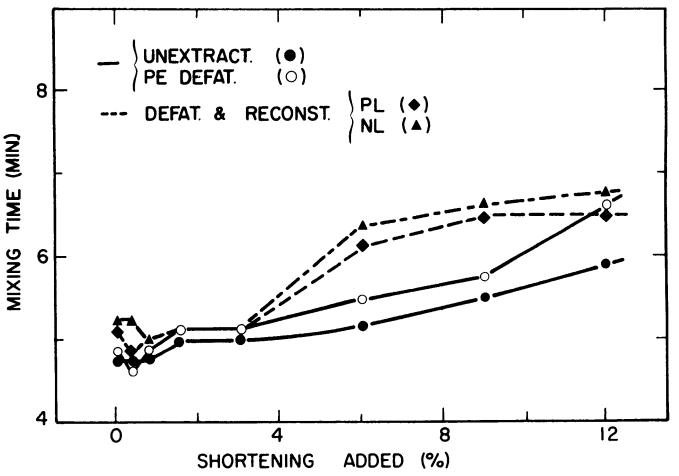

Fig. 4. The effect of shortening level on mixing time of unextracted control flour, flour defatted with petroleum ether (**PE**), and flour defatted with PE and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). At 0.75% shortening level, the mixing time was same for flours reconstituted with NL and PL; at 1.5 and 3.0%, the mixing time was same for defatted flours and flours reconstituted with NL and PL. The overall standard deviation of four replicates was 0.13 min (< 1/8 min).

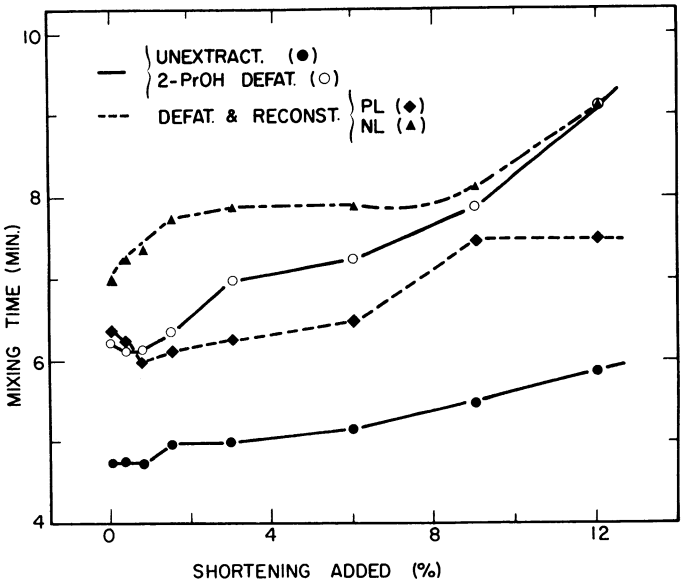

Fig. 5. The effect of shortening level on mixing time of unextracted control flour, flour defatted with 2-propanol (**2-PrOH**), and flour defatted with 2-PrOH and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). The overall standard deviation of four replicates was 0.10 min (< 1/8 min).

all the 2-PrOH-treated flours (Fig. 5) than for the corresponding PE-treated flours (Fig. 4). The differences in mixing times between the two types of treated flours were affected significantly by the shortening level. The extended mixing requirement for 2-PrOH-treated flours may have been caused by the 2-PrOH effects on proteins and/or a change in protein structure resulting from removal of bound PL.

LV and Crumb Grain

LV was shown by ANOVA to be affected significantly at the 0.01 level by shortening level, flour, and the interaction between them. The LSD test showed that differences in LV greater than 2.2 cc were significant at the 0.05 level and those greater than 3.0 cc, at the 0.01 level.

LV increased, in general, as shortening level increased for all PE-treated flours as well as for the unextracted control flour (Fig. 6). The control flour, which contained all the native flour lipids, benefited most from shortening in the lower range up to 3%. The LV of breads baked with flour defatted with PE and then reconstituted with PL (flour F) were the most uniform, probably because PL, especially in the absence of NL, were potent enough to raise LV to nearly maximum potential, even at 0% shortening. However, a small amount of shortening (0.375%) improved crumb grain of PL-reconstituted bread (Table II). LV differentiation among PE-treated flours containing different amounts and classes of lipids was best at 0% shortening. The LV differentiation among flours decreased as shortening level increased; almost no differentiation was found at shortening levels above 9%. At high shortening levels, excess shortening apparently masked the effects of differences in amounts and in classes of free lipids in flour. Thus, in terms of LV and crumb grain, 9–12% shortening would be required to replace native flour free lipids (NL plus PL) or free PL (Fig. 6 and Table II) in the composite flour.

For the flour defatted with 2-PrOH and then reconstituted with PL (flour G), the LV response to shortening was similar (Fig. 7) to that of PE-defatted and PL-reconstitued flour (flour F, Fig. 6). However, shortening had a detrimental effect on LV of 2-PrOH-defatted flour and its NL-reconstituted flour (E), unlike the improving effect of high shortening levels on the PE-defatted flour and its NL-reconstituted flour (D). LV of 2-PrOH-defatted flour decreased significantly with shortening up to 6% and then leveled off. At all shortening levels, LV was lowest for the flour containing only NL (flour E). At 6% shortening or higher, LV for 2-PrOH-defatted flour (flour C) and its NL-reconstituted flour (E) were not

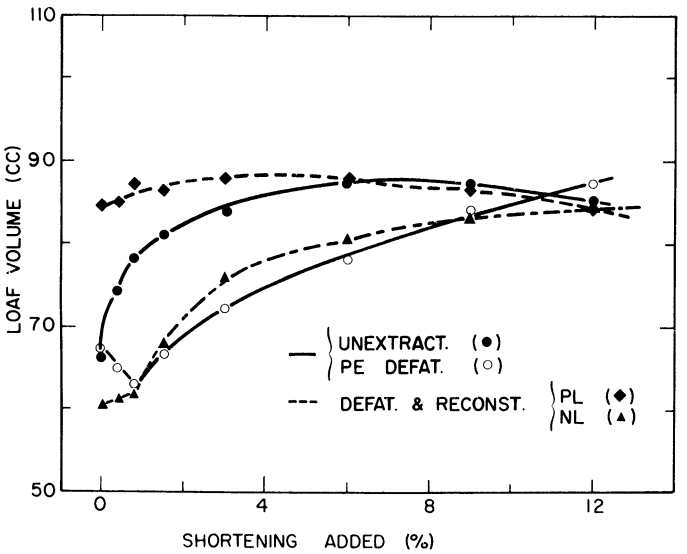

Fig. 6. The effect of shortening level on loaf volume of bread baked from unextracted control flour, flour defatted with petroleum ether (**PE**), and flour defatted with PE and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). The overall standard deviation of four replicates was 1.27 cc.

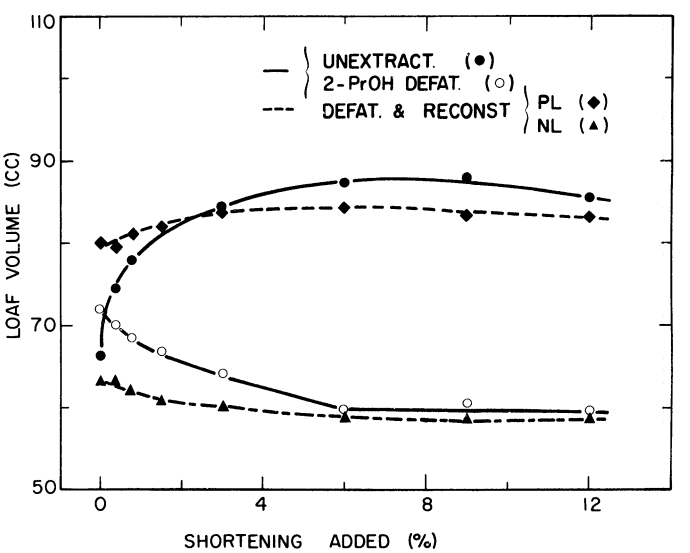

Fig. 7. The effect of shortening level on loaf volume of bread baked from unextracted control flour, flour defatted with 2-propanol (**2-PrOH**), and flour defatted with 2-PrOH and then reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**). The overall standard deviation of four replicates was 1.47 cc.

TABLE II
Crumb Grain[a] of Bread Baked with 10 g of Flour at Various Shortening Levels[b]

	Flour						
		Petroleum Ether Extraction			2-Propanol Extraction		
			Defatted and Reconstituted with			Defatted and Reconstituted with	
Shortening Level (%)	Unextracted Control (A)[c]	Defatted (B)	NL[c] (D)	PL[d] (F)	Defatted (C)	NL (E)	PL (G)
0	U	Q-U	U^2	Q-S	Q-S	Q-U	Q-S
0.375	Q-U	U	U^2	S	Q	Q-U	S
0.75	Q	U	U^2	S	Q	Q-U	S
1.5	Q-S	U	U	S	Q	Q-U	S
3.0	S	Q-U	Q	S	Q	Q-U	S
6.0	S	Q-S	S	S	Q-U	Q-U	S
9.0	S	S	S	S	Q-U	Q-U	S
12.0	S	S	S	S	U	U	S

[a] S = Satisfactory, Q = questionable, U = unsatisfactory. (Superscript numbers indicate poorer crumb grain).
[b] Average of four replicates.
[c] Flour designations A–G are given in Table I.
[d] NL = Nonpolar lipids, PL = polar lipids.

significantly different.

The important relation between shortening level and native flour PL as an improver of LV is illustrated graphically in Fig. 8. The differences in LV of breads baked with flours defatted with PE and 2-PrOH increased with an increase in shortening level. The difference in LV apparently resulted from bound lipids because PE-defatted flour contained bound lipids but no free lipids and 2-PrOH-defatted flour contained neither free lipids nor bound lipids. A similar relationship was obtained for flours defatted with PE and 2-PrOH and then reconstituted with NL only. The two NL-reconstituted flours, irrespective of the solvent used for extraction, contained the original level of NL. The NL-reconstituted flour of PE extraction contained bound PL but no free PL, whereas the NL-reconstituted flour of 2-PrOH extraction contained neither free PL nor bound PL. Therefore, the presence of bound PL in flour was essential to the beneficial effects of shortening. In the absence of shortening or at low shortening levels, up to 0.75%, a larger LV was obtained from flour defatted completely or its NL-reconstituted flour than from flour defatted partially or its NL-reconstituted flours (Fig. 8). For the PL-reconstituted flours, LV of all breads baked from 2-PrOH-treated flour were smaller than LV of breads baked from PE-treated flour at all shortening levels, although the differences in LV were more significant in the 0–0.75% shortening range than above 1.5%.

In conclusion, the minimum shortening level for optimum LV and crumb grain was about 3% for the unextracted control flour containing all native flour lipids. At that level, water absorption was reduced about two percentage points and mixing time was practically unaffected. For flours containing no free PL (flours B and D), irrespective of the presence of NL, shortening requirement for optimum LV and crumb grain increased to between 9 and 12%.

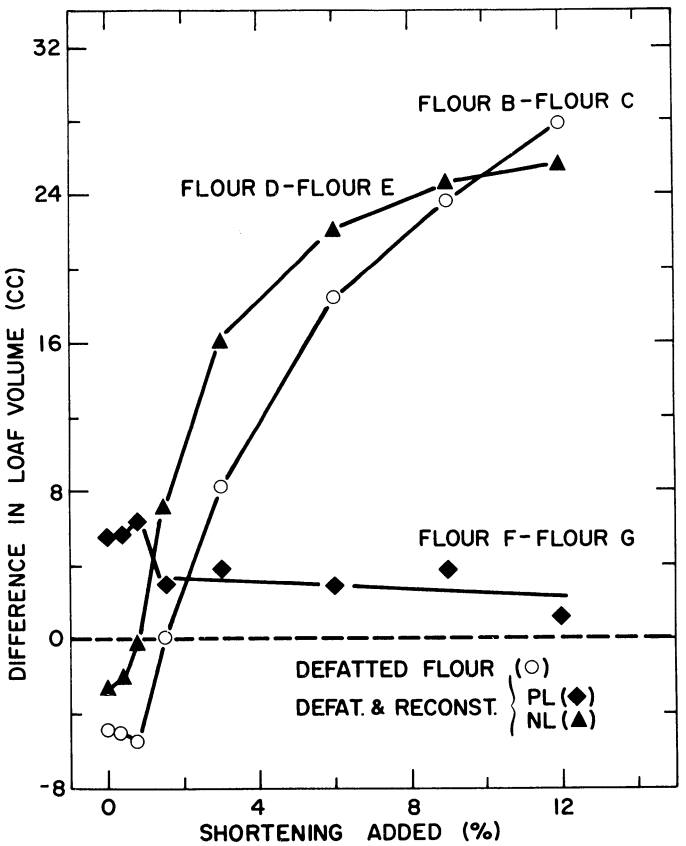

Fig. 8. The effect of shortening level on difference in loaf volume of flour defatted with petroleum ether or its flour reconstituted with polar lipids (**PL**) or nonpolar lipids (**NL**) and of flour correspondingly treated with 2-propanol. The dotted line denotes no difference in loaf volume. Flours **B, D,** and **F** were defatted with petroleum ether, flours **C, E,** and **G** with 2-propanol.

For flours containing PL but no NL (flour F), only 0.5% shortening was enough for optimum LV and crumb grain, provided only free PL had been removed and then added back. However, if both free and bound PL had been extracted and then added back to 2-PrOH-defatted flour (G), 3% shortening was required for good LV. No level of shortening restored LV and crumb grain if PL was completely absent in flour, irrespective of the presence of NL (flours C and E). Insofar as LV and crumb grain were concerned, free PL could be replaced by 9–12% shortening, whereas total PL could not be replaced by any level of shortening. High shortening levels required to restore optimum LV and crumb grain were usually accompanied by significant decreases in water absorption and/or substantial increases in mixing time—both undesirable in commercial baking. Thus, the ability of shortening to replace flour lipid components is great and yet limited. Only small amounts (eg, 0.5%) of shortening would be required to produce good quality bread if a new variety of wheat naturally contained only PL and little NL. The use of shortening adds a level-dependent dimension to bread-making characteristics: some levels may be desired to facilitate handling and processing as well as freshness retention; other levels may be needed to bring out the best in a bread-making flour; and still other levels may be optimum to produce the best bread from flours that contain various amounts of lipids and probably also from flours that vary in bread-making potential.

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