Defatted and Reconstituted Wheat Flours. VI. Response to Shortening Addition and Lipid Removal in Flours That Vary in Bread-Making Quality[1]

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ABSTRACT

Eleven wheat flours that vary in bread-making quality were defatted at 75° C with Skellysolve B or 2-propanol. Skellysolve B extracted 0.93–1.13% unfractionated lipids (0.66–0.79% nonpolar plus 0.24–0.38% polar) and 2-propanol extracted 1.32–1.55% unfractionated lipids (0.68–0.84% nonpolar plus 0.54–0.77% polar). All defatted flours contained only small amounts of residual nonpolar lipids; flours defatted by Skellysolve B contained more residual bound polar lipids than did flours defatted by 2-propanol. Lipid removal increased mixing time; the increase was greater for 2-propanol than for Skellysolve B extraction. Removal of lipids affected mixing time substantially more than did addition of 3% shortening. Small differences in amounts of free polar lipids in flours that vary in bread-making quality accentuated differences in "loaf volume (LV) potential" of flours through the interaction of the free polar lipids and shortening: the better the inherent quality of a flour, the greater the benefits derived from adding shortening. Removal of most of the bound polar lipids may result in improvement of LV in bread baked from propanol-defatted flour without shortening. The amount of improvement was related to the inherent quality of the flours, probably because of differences in their protein quality and protein-protein interactions. We concluded that good LV and crumb grain can be obtained from flours with good protein quality in which adequate protein aggregation is enhanced by free polar lipids that can interact with proteins and shortening. As a mechanism to bring out the maximum LV potential of flours, the multiple interaction of protein-lipid (free polar)-protein in the presence of shortening seems to be superior to the mere formation of protein-protein aggregates.

Shortening, or fat, increases loaf volume (LV) and improves dough handling properties, crumb grain, and retention of freshness. Although shortening has long been used in bread-making, the mechanism of its action is not well understood (Bell et al 1977, Bell and Fisher 1977). Previously, Chung et al (1980) studied the effects of shortening on the baking characteristics of a composite hard red winter wheat flour that had good loaf volume potential and medium mixing and oxidation requirements and that was differentially defatted by a combination of solvents and temperatures. They reported that native flour lipids, especially polar lipids, were essential to obtain the beneficial effects of shortening on LV and crumb grain. They concluded that in the absence of flour nonpolar lipids, LV was affected by the quantity of flour polar lipids, presence of shortening, and interaction of shortening and polar lipids.

Studies have demonstrated the significant contributions that both the quantity and the quality of wheat flour proteins make to the LV of breads (Finney and Barmore 1948, Whiteside 1958). The quantity of protein is influenced mainly by environmental factors, but the qualilty of protein is mainly a heritable characteristic. The objectives of this study were: a) to determine if the shortening effects depend on inherent differences, presumably in protein quality, among wheat flours; b) to verify the interaction of shortening and polar lipids in wheat flours that vary in bread-making quality; and c) to determine how the binding of lipids to other flour constituents affects the shortening-lipid interaction. The study was designed to explain, at least in part, what makes good quality bread-wheat flours good and poor ones poor, insofar as interaction with lipids is concerned.

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MATERIALS AND METHODS

Materials

The 11 flours used in this study are listed in Table I. Two samples were regional baking standards, composite grists of many hard red winter wheat varieties harvested throughout the Great Plains in 1973 and 1974. Nine samples were from six cultivars, some of which were grown in different years. All samples were experimentally milled (Allis) and yielded from 70.6 to 75.4% flour. The protein contents of flours ranged from 11.7 to 14.1% and the ash contents from 0.33 to 0.46%. Protein contents of the cultivars varied from year to year.

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

Analytical Procedures

Protein, ash, and moisture contents were determined by AACC Approved Methods 46-11, 08-01, and 44-15A, respectively. The 10-g baking procedure has been described elsewhere (Shogren et al 1969). The amount of oxidant used was 5 or 10 ppm potassium bromate (5 ppm potassium bromate for flours requiring mixing for longer than 4 min) and 50 ppm ascorbic acid. The amount of yeast, proof time, and methods for grading the crumb grain of bread were described previously (Chung et al 1977). Bakes were replicated three times.

Extraction and Fractionation of Flour Lipids

Lipids were extracted from 30 g (db) of flour and 240 ml of solvent (Skellysolve B or 2-propanol) in a water bath shaker (Lab-line Instruments, Cat. No. 3581) at 75° C for 2 hr (Chung et al 1977. Lipids were purified, and the defatted flours were sifted as described by Chung et al (1978).

Flour lipids were fractionated by silicic acid column chromatography into nonpolar and polar lipids with chloroform and methanol, respectively, as eluting solvents. Lipid extractions were replicated three times and fractionations two times. Total recovery of lipids from silicic acid column fractionation ranged from 87.6 to 99.3%; average recovery was 94.8%.

The lipids extracted with Skellysolve B were arbitrarily defined

as free lipids and those extracted with 2-propanol as total (free plus a large portion of bound) lipids. Although 2-propanol did not extract all of the bound lipids, 2-propanol extraction in a shaker at 75° C maximized the lipid extraction with minimized damage to the bread-making properties of reconstituted flours (Chung et al 1977).

RESULTS AND DISCUSSION

Flour Lipids

The free lipid content extracted with Skellysolve B at 75° C was 0.93–1.13% for the unfractionated lipids (the sum of nonpolar and polar lipids), 0.66–0.79% for the nonpolar lipids, and 0.24–0.38% for the polar lipids (Table II). Substantially more lipids were extracted by 2-propanol than by Skellysolve B at 75° C; the total lipid content ranged from 1.32 to 1.55% for the unfractionated lipids, from 0.68 to 0.84% for the nonpolar, and from 0.54 to 0.77% for the polar lipids. With 2-propanol, the extractability of the unfractionated lipids was increased 25.7–50.5% (average, 34.7%); extractability of nonpolar lipids 4.2–13.0% (average, 4.7%); and extractability of polar lipids 80.6–158.3% (average, 103.1%). Therefore, the defatted flours probably contained only very small amounts of residual nonpolar lipids, and the flours defatted by Skellysolve B contained more bound polar lipids than did the flours

TABLE I
Milling Yield and Protein and Ash Contents of Flours

Sample[a]	Crop Year	Milling Yield (%)	Protein[b] (N × 5.7) (%)	Ash[b] (%)
RBS (Composite)	1973	72.5	12.4	0.41
	1974	71.3	12.4	0.42
Cfk/Tm				
(KS501099)	1972	73.7	11.7	0.37
(KS501097)	1973	73.3	13.4	0.46
Ot Sel. (KS619042)	1972	70.6	11.9	0.38
	1973	74.5	14.1	0.42
	1975	74.7	13.4	0.41
WRC (Unknown)	1971	73.7	13.1	0.36
Con/2* Tr (KS644)	1974/1976	72.8	12.5	0.33
Qv/Tm/2/Mql/Oro (CI 12995)	1972	72.8	12.1	0.35
Shawnee (CI 14157)	1973	75.4	13.0	0.40

[a]RBS = Regional Baking Standard; Cfk/Tm = Chiefkan/Tenmarq; Ot Sel. = Ottawa Selection; WRC = White Red Chief; Con/2*Tr = Concho/2* Triumph; Qv/Tm/2/Mql/Oro = Quivira/Tenmarq/2/Marquillo/Oro; numbers are selection or CI numbers.
[b]Expressed on 14% moisture basis.

TABLE II
Flour Lipids Extracted with Skellysolve B or 2-Propanol at 75° C

	Lipids (%)[a]					
	Free (Skellysolve B)			Total (2-Propanol)		
Sample/Crop Year	Unfractionated	Nonpolar	Polar	Unfractionated	Nonpolar	Polar
RBS[b]						
1973	1.05	0.71	0.34	1.32	0.68	0.64
1974	1.06	0.72	0.34	1.34	0.70	0.64
KS501099/1972	1.06	0.73	0.33	1.48	0.80	0.68
KS501097/1973	0.93	0.69	0.24	1.40	0.78	0.62
KS619042						
1972	1.13	0.79	0.34	1.52	0.84	0.68
1973	1.05	0.77	0.28	1.37	0.76	0.61
1975	1.04	0.73	0.31	1.40	0.77	0.63
WRC[c]/1971	0.96	0.69	0.27	1.32	0.78	0.54
KS644						
1974 and 1976	1.09	0.73	0.36	1.39	0.74	0.65
CI 12995/1972	1.11	0.73	0.38	1.55	0.78	0.77
CI 14157/1973	1.03	0.66	0.37	1.39	0.69	0.70

[a]Values are averages of three extractions for total lipids (overall standard deviation, 0.020) and of two fractionations for nonpolar and polar lipids (overall standard deviation, 0.018), expressed as percent of sample weight on dry basis.
[b]RBS = Regional baking standards.
[c]WRC = White Red Chief.

TABLE III
Water Absorption of Unextracted Flours and Flours Defatted with Skellysolve B or 2-Propanol

	Water Absorption (%)[a] of Flour Defatted with					
	None		Skellysolve B		2-Propanol	
Sample/Crop Year	No Shortening	3% Shortening	No Shortening	3% Shortening	No Shortening	3% Shortening
RBS[b]						
1973	65.9	63.4	68.5	66.8	70.0	68.8
1974	69.8	68.3	73.5	70.6	73.3	72.8
KS501099/1972	66.5	64.0	69.5	66.5	72.2	71.0
KS501097/1973	65.8	64.4	69.1	67.6	70.2	68.8
KS619042						
1972	60.6	58.6	63.1	61.9	68.9	66.9
1973	63.5	62.2	66.7	65.5	67.5	66.5
1975	66.2	62.5	67.9	66.0	70.8	68.6
WRC[c]/1971	62.3	60.3	64.1	63.0	64.8	64.5
KS644/1974 and 1976	63.5	62.3	67.5	66.0	68.8	67.8
CI 12995/1972	63.0	62.5	67.5	66.0	69.3	67.3
CI 14157/1973	67.3	65.3	73.0	71.5	72.3	70.0

[a]Values are averages of three replicates (overall standard deviation, 0.352), expressed as percent of sample weight on 14% moisture basis.
[b]RBS = Regional baking standard.
[c]WRC = White Red Chief.

defatted by 2-propanol. Lipid contents of the same cultivar varied somewhat from year to year.

Water Absorption and Mixing Requirements

In the absence of shortening, removal of lipids increased water absorption from a level of 60.6–69.8% (average, 64.9%) for unextracted flours to 63.1–73.5% (average, 68.2%) for flours defatted with Skellysolve B and to 64.8–73.3% (average, 69.8%) for flours defatted with 2-propanol (Table III). In the presence of shortening, water absorption increased from a level of 58.6–68.3% (average, 63.1%) for unextracted flours to 61.9–71.5% (average, 66.5%) for flours defatted with Skellysolve B and to 64.5–72.8% (average, 68.5%) for flours defatted with 2-propanol. The addition of 3% shortening to the dough decreased water absorption, on the average, 1.9 percentage points for unextracted control flours, 1.7 percentage points for Skellysolve B-defatted flours, and 1.4 percentage points for the propanol-defatted flours.

Generally, lipid removal increased mixing time (MT), irrespective of shortening (Table IV). The increase in MT by lipid removal was related linearly to MT of the unextracted flour; the simple linear correlation coefficient was 0.845 for flours defatted by Skellysolve B and 0.948 for flours defatted by 2-propanol (Fig. 1). The average increase in MT by lipid removal at 75° C was larger for flours defatted by 2-propanol (83.1%) than for those defatted by Skellysolve B (24.2%). Adding shortening had little effect on MT for the untreated flours; MT decreased an average of 15 sec in flours defatted with Skellysolve B and 30 sec in flours defatted with 2-propanol; the decrease was consistent for the flours with longer MT. Therefore, the response of MT to the addition of shortening was much less than the response of MT to lipid removal.

LV and Crumb Grain

Adding shortening increased the LV of bread made with unextracted flours except for bread made with the very poor quality flour KS501097; shortening reduced the LV of bread made with all flours defatted with Skellysolve B except for the poor quality flours KS501097 and KS619042 from 1973. Shortening more consistently reduced the LV of breads baked with flours defatted with 2-propanol than it did the LV of breads with flours defatted by Skellysolve B (Table V). For unextracted flours, the LV ranged from 51.6 to 73.3 cc for breads baked without shortening and from 47.3 to 91.7 cc for breads baked with shortening because the LV response to shortening was not the same for all the flours.

Addition of 3% shortening improved the crumb grain of loaves baked with unextracted flours but not of loaves baked with defatted flours (Table VI). Therefore, although native flour lipids

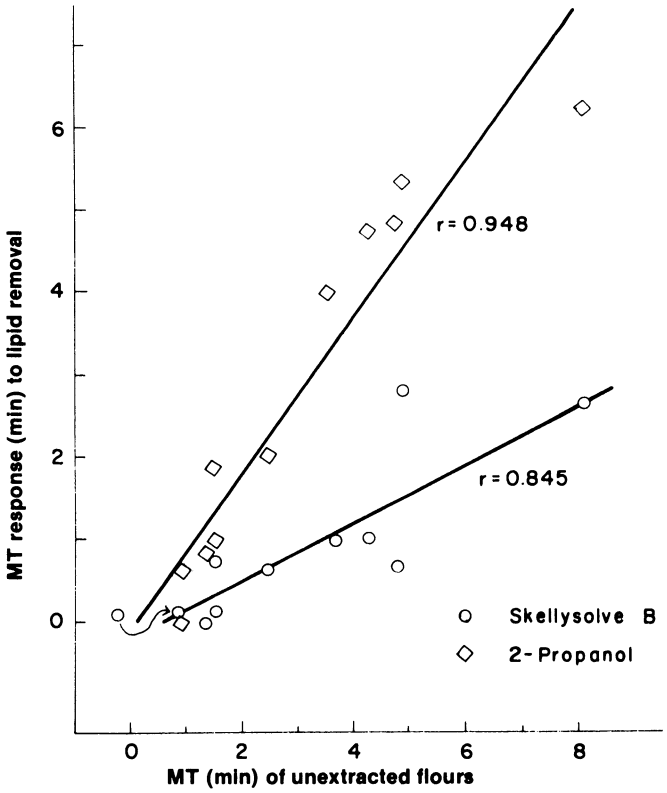

Fig. 1. Mixing time (MT) responses to lipid removal from flours defatted with 2-propanol (◇) and Skellysolve B (○) plotted against MT values of unextracted control flours that vary in bread-making quality. The MT response was calculated by subtracting the MT of defatted flour from the MT of the unextracted flour. No shortening was added. The arrowed circle indicates two coinciding points at 7/8 min.

TABLE IV
Mixing Time of Unextracted Flours and Flours Defatted with Skellysove B or 2-Propanol

	Mixing Time (min)[a] of Flour Defatted with					
	None		Skellysolve B		2-Propanol	
Sample/Crop Year	No Shortening	3% Shortening	No Shortening	3% Shortening	No Shortening	3% Shortening
RBS[b]						
1973	4 ¼	4 ⅝	5 ¼	5 ⅜	9.0	8 ⅞
1974	4 ¾	4 ⅞	5 ⅜	5 ⅛	9 ⅝	9 ½
KS501099/1972	1 ½	1 ⅜	2 ¼	1 ⅝	2 ½	2 ⅜
KS501097/1973	⅞	⅞	1.0	⅞	⅞	⅞
KS619042						
1972	1 ½	1 ⅝	1 ⅝	1 ⅝	3 ⅜	3 ⅝
1973	⅞	⅞	1.0	1.0	1 ½	1 ⅜
1975	1 ⅜	1 ⅜	1 ⅜	1 ⅜	2 ¼	2 ⅝
WRC[c]/1971	3 ⅝	3 ⅞	4 ⅝	5 ¼	7 ⅝	7 ⅜
KS644/1974 and 1976	2 ⅜	2 ⅜	3.0	2 ⅝	4 ⅜	½
CI 12995/1972	8 ⅛	8 ⅛	10 ¾	10.0	14 ⅜	11 ½
CI 14157/1973	4 ⅞	5 ⅜	7 ⅝	7 ¼	10 ¼	9.0

[a]Values are averages of three replicates (overall standard deviation, 0.123 [≈1/8] min), expressed in minutes.
[b]RBS = Regional baking standard.
[c]WRC = White Red Chief.

are essential for a beneficial effect of shortening on crumb grain (Whiteside 1958), the extent of the beneficial effects varies with flours.

We computed correlation coefficients between LV characteristics and the amounts of lipids (unfractionated, nonpolar, and polar), the ratio of nonpolar to polar lipids, the flour protein content, and the LV potential of flours (Table VII). We considered that LV potential was equivalent to the volume of a loaf of bread baked by an optimized bake procedure with an optimized formula containing 3% shortening. A combination of optimized formula and bake procedure can best differentiate, in a linear manner, flours that vary in bread-making quality (Finney 1978).

LVs of unextracted flours or defatted flours and LV response to lipid removal or to shortening were not significantly related to amounts of unfractionated (nonpolar plus polar) lipids, irrespective of extractant (Table VII). LVs of unextracted control flours were negatively related to the ratio of nonpolar to polar lipids of free lipids extracted with Skellysolve B because the amounts of free polar lipids in flours were positively related to the LV of control flours (ie, the more free polar lipids in the flour, the larger the LV). On the other hand, the nonpolar/polar ratios of total lipids extracted with 2-propanol were negatively related to the

TABLE V
Loaf Volume of Bread Baked from 10 g of Unextracted Flours or Flours Defatted with Skellysolve B or 2-Propanol

	Loaf Volume (cc)[a] of Bread Baked from Flour Defatted with					
	None		Skellysolve B		2-Propanol	
Sample/Crop Year	No Shortening	3% Shortening	No Shortening	3% Shortening	No Shortening	3% Shortening
RBS[b]						
1973	69.3	85.8	71.0	65.8	78.4	72.8
1974	67.0	83.0	71.0	67.5	77.5	68.7
KS501099/1972	67.7	72.6	68.5	63.2	74.3	62.1
KS501097/1973	51.6	47.3	46.3	53.2	53.0	42.1
KS619042						
1972	62.0	63.3	60.6	57.7	65.0	54.8
1973	58.7	62.3	56.7	61.7	64.3	58.3
1975	64.2	68.6	63.8	61.0	67.6	61.3
WRC[c]/1971	61.6	76.6	65.9	60.2	68.1	59.3
KS644/1974 and 1976	65.0	79.5	69.0	62.3	70.9	60.6
CI 12995/1972	64.4	80.0	68.5	63.2	72.2	64.9
CI 14157/1973	73.3	91.7	75.7	73.3	80.3	72.3

[a]Values are averages of three replicates (overall standard deviation, 1.47 cc).
[b]RBS = Regional Baking Standard.
[c]WRC = White Red Chief.

TABLE VI
Crumb Grain of Bread Baked from 10 g of Unextracted Flours or Flours Defatted with Skellysolve B or 2-Propanol

	Crumb Grain[a] of Bread Baked with Flour Defatted with					
	None		Skellysolve B		2-Propanol	
Sample/Crop Year	No Shortening	3% Shortening	No Shortening	3% Shortening	No Shortening	3% Shortening
RBS[b]						
1973	U	S	Q	U	Q-S	Q-S
1974	U	S	Q-U	U	Q-S	Q
KS501099/1972	Q-U	Q	Q-U	U	Q	Q-U
KS501097/1973	U^4	U^4	U^5	U^4	U^4	U^5
KS619042						
1972	U^3	U	U	U^3	Q	Q-U
1973	U^4	U^3	U^4	U^3	U	U^2
1975	U^3	Q-U	U	U^2	Q	Q-U
WRC[c]/1971	U^3	Q	Q	U	Q-S	U
KS644						
1974 and 1976	U	S	Q-S	Q-U	Q	Q-U
CI 12995/1972	U	S	Q-U	U	Q-S	Q
CI 14157/1973	Q-U	S	Q	Q	Q-S	Q

[a]S = Satisfactory, Q = Questionable, U = Unsatisfactory (the higher the superscript number, the poorer the crumb grain).
[b]RBS = Regional Baking Standard.
[c]WRC = White Red Chief.

LV of unextracted control flours because the amounts of total nonpolar (mostly free) lipids in flours were negatively related to the LV of control flours (ie, the more nonpolar lipids in the flour, the smaller the LV). For flours defatted with Skellysolve B, LV, LV response to free lipid removal, and LV response to shortening were all significantly related to amounts of free polar lipids removed from the flours. For flours defatted with 2-propanol, none of the LV characteristics were significantly related to amounts of total polar lipids removed; however, the LV of defatted flours (with or without shortening) and the LV response to defatting (in the absence of shortening) were negatively related to amounts of nonpolar lipids removed from flours. Therefore, the amount of free polar lipids, rather than the sum of free plus bound polar lipids, is related to LV characteristics.

LVs of unextracted control flours (baked with or without shortening) were, expectedly, not significantly related to protein content (Table VII). Protein content is the single most important factor accounting for differences in LV within a wheat variety but not among varieties that differ widely in protein quality (Finney and Barmore 1948). Flour protein content was not significantly related to most LV characteristics; it was, however, related to LV of flours defatted with 2-propanol when no shortening was added and to LV response to shortening for flours defatted with Skellysolve B.

As stated before, LV potentials may vary significantly for flours that vary widely in protein quality, a heritable varietal characteristic. LVs of flours defatted with either Skellysolve B or 2-propanol were related highly significantly to LV potential of the flours (Table VII). The effects of shortening on LV (y-axis, Fig. 2) increased linearly (r = 0.954) with an increase in LV of breads baked with unextracted control flours with 3% shortening (X-axis, ie, LV potential representing the inherent quality of the flour). The better the inherent quality of the unextracted flour, the greater the benefits derived from adding shortening. The x-axis in Figs. 2 and 3 will hereafter be referred to as LV potential of control flour.

When free lipids were removed by Skellysolve B extraction, LV response to shortening showed a significant negative correlation (r = −0.729) to the LV potential of the control flours. Only poor quality flours defatted by Skellysolve B benefited from shortening; LV of good quality flours were reduced by shortening. When total lipids were extracted, addition of shortening reduced the LV of flours exrracted with 2-propanol. This reduction showed no significant relation (r = 0.303) to the LV potential of the control flours (Table VII and Fig. 2).

The LV response to lipid removal with Skellysolve B or 2-propanol was correlated negatively with the LV potential of the control flours (Table VII, Fig. 3). In the presence of shortening, the adverse effects of removing either free or total lipids were greater for flours of good bread-making quality than for flours of poor quality (Fig. 3); the adverse effects of removing free lipids were greater than the effects of total lipid removal. In the absence of shortening, removing free lipids with Skellysolve B slightly decreased LV for poor quality flours and slightly increased LV for good quality flours (Table V); removing both free and bound lipids by extraction with 2-propanol improved LV for all flours, and the extent of improvement resulting from lipid removal correlated positively with LV potential (Fig. 3). Crumb grain and LV of loaves baked without shortening from defatted flours were better than those of loaves baked from unextracted control flours (Fig. 4);

TABLE VII
Simple Linear Correlation Coefficients between Lipids, Protein Content, or Loaf Volume Potential and Loaf Volume Characteristics[a]

	Lipids			Ratio	Protein	Loaf Volume
	Unfractionated	Nonpolar (N)	Polar (P)	N/P	Content	Potential
	Removal of Free Lipids by Skellysolve B Extraction					
LV of unextracted flours						
No shortening	0.447	−0.239	0.794***	−0.882***	−0.454	0.914***
3% shortening	0.334	−0.371	0.751***	−0.867***	−0.359	1
LV of defatted flours						
No shortening	0.434	−0.270	0.801***	−0.899***	−0.473	0.969***
3% shortening	0.267	−0.380	0.676**	−0.786***	−0.160	0.894***
LV response to lipid removal[b]						
No shortening	0.303	−0.263	0.620**	−0.709**	0.393	0.834***
3% shortening	−0.340	0.321	−0.719**	0.826***	−0.445	−0.960***
LV response to shortening[c]						
Unextracted flours	0.213	−0.428	0.637**	−0.761***	−0.249	0.954***
Defatted flours	−0.484	0.039	0.678**	0.727**	0.684**	−0.729**
	Removal of Total Lipids by 2-Propanol Extraction					
LV of unextracted flours						
No shortening	−0.055	−0.553*	0.396	−0.643**	−0.454	0.914***
3% shortening	−0.208	−0.667**	0.289	−0.592*	−0.359	1
LV of defatted flours						
No shortening	−0.140	−0.631**	0.349	−0.644**	−0.503	0.953***
3% shortening	−0.211	−0.691**	0.306	−0.639**	−0.292	0.940***
LV response to lipid removal [b]						
No shortening	0.264	−0.639**	0.191	−0.507	0.338	0.824***
3% shortening	0.150	0.457	−0.188	0.364	−0.374	−0.839***
LV response to shortening[c]						
Unextracted flours	−0.299	−0.678**	0.178	−0.489	−0.249	0.954***
Defatted flours	−0.337	−0.475	−0.045	−0.222	0.461	0.303

[a] Significant at 0.10(*), 0.05(**), and 0.01(***) levels. Loaf volume potential = LV of bread baked under optimized conditions from 10 g of unextracted flours with optimized formula containing 3% shortening.

[b] Loaf volume response to lipid removal was calculated by subtracting the LV of bread baked with defatted flour from the LV of bread baked with unextracted control flour.

[c] Loaf volume response to shortening was calculated by substracting the LV of bread baked without shortening from the LV of bread baked with 3% shortening.

improvement in bread-making quality by lipid removal was greater for 2-propanol than for Skellysolve B extraction and greater for good quality than for poor quality flours.

CONCLUSIONS

Flour quality may be affected by protein aggregation; for instance, protein dispersibility in an aqueous urea solution and the amounts and types of dilute acetic acid-soluble proteins are related to flour quality (Orth and Bushuk 1972, Pomeranz 1965). In earlier work, Finney and Yamazaki (1946) showed that LV correlated highly with the gel weight of a flour suspension centrifuged in a dilute lactic acid solution. Recently, Chung et al (1979) reported that decreases in protein extractability of defatted flours were related to quantities and types of lipids and their association with proteins. The authors postulated that lipid removal might induce protein aggregation, possibly by a glutenin-glutenin interaction.

In the present study, formation of protein aggregates by lipid removal probably extended the MT of defatted flours (Table IV). The increase in MT was greater for flours defatted with 2-propanol than for flours defatted with Skellysolve B, probably because removal of both free and bound lipids by 2-propanol induced more protein aggregation than did removal of only free lipids by Skellysolve B. The increase in MT was related linearly to the MT of the unextracted control flour because flours with longer MT probably contain more aggregated proteins than do flours with shorter MT.

The data suggest that loaf volumes were related linearly to free polar lipids but not to total polar lipids in flours because small differences in free polar lipids in flours that vary in bread-making quality accentuated differences in LV potential of flours through the interaction of free polar lipids and shortening. Native polar lipids in flour interact with shortening. When they are absent, shortening may provide a mechanical barrier that interferes with formation of protein-protein complexes. That interference may be responsible for the reduction in LV of loaves baked with 3% shortening in defatted flours. In the absence of shortening, however, formation of protein aggregates may be enhanced by

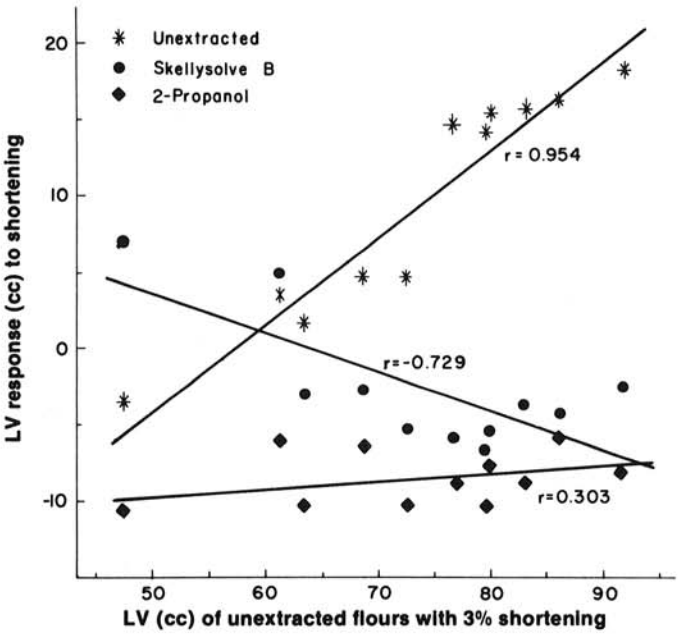

Fig. 2. Loaf volume (LV) responses to shortening in extracted flours or flours defatted with Skellysolve B or 2-propanol, plotted against LV values of breads baked with 3% shortening from untreated control flours that vary in bread-making quality. The LV response was calculated by subtracting the LV of bread baked without shortening from the LV with shortening.

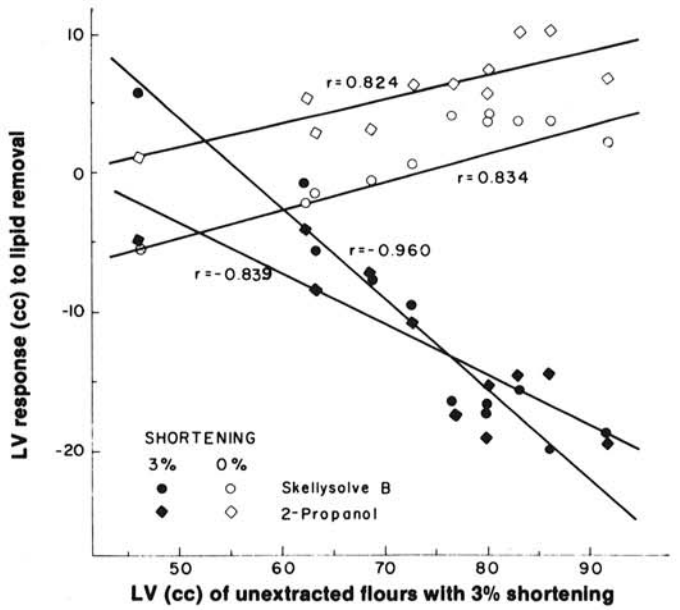

Fig. 3. Loaf volume (LV) responses to lipid removal of breads baked from extracted with Skellysolve B or 2-propanol plotted against LV values of breads baked with 3% shortening from unextracted control flours that vary in bread-making quality. The LV response was calculated by subtracting the LV value of defatted flour from the LV value of the untreated flour. The regression lines with correlation coefficients–0.960 and –0.839 represent relations for loaves baked with 3% shortening from flours defatted with Skellysolve B and 2-propanol, respectively.

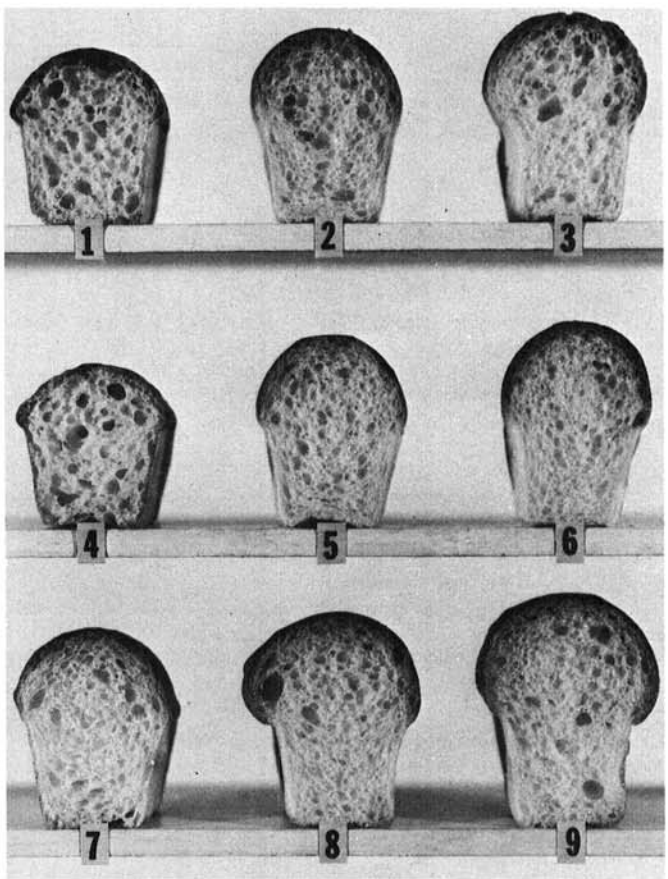

Fig. 4. Breads baked without shortening from 10 g of KS619042/1972 (breads 1, 4, and 7), CI 12995 (breads 2, 5, and 8), and CI 14157 (breads 3, 6, and 9) flours; top row breads (1–3), unextracted control flours; middle row breads (4–6), flours defatted with Skellysolve B; and bottom row breads (7–9), flours defatted with 2-propanol.

removal of lipids, expecially both free and bound lipids; this may improve LV and crumb grain of loaves baked from the defatted flours. The magnitude of the improving effects depended on the inherent quality of flours, probably due to the difference in their protein quality and their protein-protein interactions.

In conclusion, good LV and crumb grain can be obtained from good protein quality flours in which adequate protein aggregation is enhanced by free polar lipids that can interact with proteins and with shortening. With all the flours tested in this study, larger LV and better crumb grain were obtained with unextracted control flours with 3% shortening than with flours defatted with either solvent without shortening added. Consequently, to bring out the maximum LV potential of flours, the multiple interactions protein-lipid (free polar)-protein in the presence of shortening seem to be more effective than the mere formation of protein-protein aggregates in the absence of polar lipids.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1962. Approved Methods of the AACC. Method 08-01, approved April 1961; Method 44-15A, approved October 1975; Method 46-11, approved October 1976. The Association: St. Paul, MN.

BELL, B. M., DANIELS, D. G. H., and FISHER, N. 1977. Physical aspects of the improvement of dough by fat. Food Chem. 2:57.

BELL, B. M., and FISHER, N. 1977. The binding of model shortenings during mixing of mechanically developed bread doughs from fresh and stored flours. J. Am. Oil Chem. Soc. 54:479.

CHUNG, O. K., POMERANZ, Y., FINNEY, K. F., and SHOGREN, M. D. 1977. Defatted and reconstituted wheat flours. II. Effects of solvent type and extracting conditions on flours varying in breadmaking quality. Cereal Chem. 54:484.

CHUNG, O. K., POMERANZ, Y., FINNEY, K. F., and SHOGREN, M. D. 1978. Defatted and reconstituted wheat flours. III. Effects of flour moisture content and aqueous binary azeotropes on functional (breadmaking) properties. Cereal Chem. 55:31.

CHUNG, O. K., POMERANZ, Y., FINNEY, K. F., SHOGREN, M. D., and CARVILLE, D. 1980. Defatted and reconstituted wheat flours. V. Bread-making response to shortening of flour differentially defatted by varying solvent and temperature. Cereal Chem. 57:106

CHUNG, O. K., POMERANZ, Y., HWANG, E. C., and DIKEMAN, E. 1979. Defatted and reconstituted wheat flours. IV. Effects of flour lipids on protein extractability from flours that vary in breadmaking quality. Cereal Chem. 56:220.

FINNEY, K. F. 1978. Contribution of individual chemical constituents to the functional (breadmaking) properties of wheat. Page 267 in: HULTIN, H. O., and MILNER, M. (eds.) Post Harvest Biology and Biotechnology. Proc. IFT Symp. Food & Nutr. Press Inc.: Westport, CT.

FINNEY, K. F., and BARMORE, M. A. 1948. Loaf volume and protein content of hard red winter and spring wheats. Cereal Chem. 25:291.

FINNEY, K. F., and YAMAZAKI, W. T. 1946. Water retention capacity as an index of the loaf volume potentialities and protein quality of hard red winter wheats. Cereal Chem. 23:416.

ORTH, R. A., and BUSHUK, W. 1972. A comparative study of the proteins of wheats of diverse baking qualities. Cereal Chem. 49:268.

POMERANZ, Y. 1965. Dispersibility of wheat proteins in aqueous urea solution–A new parameter to evaluate breadmaking potentialities of wheat flours. J. Sci. Food Agric. 16:586.

SHOGREN, M. D., FINNEY, K. F., and HOSENEY, R. C. 1969. Functional (breadmaking) and biochemical properties of wheat flour components. I. Solubilizing gluten and flour proteins. Cereal Chem. 46:93.

WHITESIDE, A. G. O. 1958. The Plant Breeder and Wheat Quality, p. 25. Annu. Proc. Arbeitsgemeinschaft Getreideforsch: Detmold, Germany.

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