Surfactants as Replacements for Natural Lipids in Bread Baked from Defatted Wheat Flour[1]

O.K. CHUNG, Y. POMERANZ, K.F. FINNEY, and **M.D. SHOGREN,**
U.S. Grain Marketing Research Laboratory, Science and Education Administration,
U.S. Department of Agriculture, Manhattan, Kansas 66502

ABSTRACT

Petroleum ether (PE) extracted 1.00% total free lipids (0.70% nonpolar and 0.30% polar) and 2-propanol (PrOH) extracted 1.36% total free and bound lipids (0.73% nonpolar and 0.63% polar) from wheat flour; the lipid fractions were characterized by thin layer chromatography. PE- or PrOH-defatted flours were baked after reconstitution with total, nonpolar, or polar wheat flour lipids; or with equivalent amounts of nonionic sucrose monopalmitate (SMP), ethoxylated monoglycerides (EMG) – each with a hydrophile-lipophile balance (HLB) of 14.0 or anionic sodium stearoyl-2-lactylate (SSL) – with an HLB value of 9.0. Defatted flours supplemented with surfactants alone or in combination with wheat flour lipids were used in bread with no-shortening and with 3%-shortening. The importance of the polar flour lipids in breadmaking was verified. The lipids in wheat flour were essential for maximizing the beneficial effects of shortening on breadmaking quality. Nonionic SMP or EMG completely replaced both PE-extractable wheat flour free total lipids (or their nonpolar or polar fractions) and 3% shortening; nonionic surfactants with high HLB were better than the anionic SSL for replacing free flour lipids. No surfactant completely replaced unfractionated PrOH-extracted lipids (free + bound) and shortening or total polar flour lipids (free + bound). All surfactants, especially anionic SSL, added with PrOH-extracted polar lipids improved the overall breadmaking properties of the PrOH-defatted flour both in the absence and in the presence of shortening.

INTRODUCTION

Ever since the discovery that wheat flour lipids, especially glycolipids, improve breadmaking quality (1-3), there have been many attempts to produce wheat flour lipids in large amounts for use to enhance and improve breadmaking quality. The need for polar lipids has become especially acute since the realization that in the production of high protein bread the amounts of polar lipids present in wheat flour are not sufficient to alleviate the adverse effects of protein-rich additives, such as soy flour, and would have to be supplemented.

We therefore looked at the possibility of using materials related to, rather than identical with, wheat flour lipids. Such materials include surfactants with different hydrophile-lipophile balances (HLB). Lipid-related surfactants are useful because of their numerous functional properties; they are used as antistaling agents (4-6), as dough modifiers (7-9), as shortening-sparing agents (10-13), and as improvers for production of high-protein breads (10,14-17). Native flour lipids were shown to be partially displaced by surfactants at binding sites of dough constituents during dough formation; the degree of displacement and the types of displaced flour lipids depended on the amounts and types of the added surfactants (9,18-20).

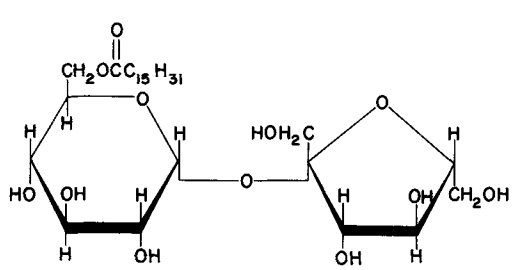
We determined the effects of three surfactants on the baking properties of defatted flours. The surfactants were used to replace total, nonpolar, and polar fractions of petroleum ether (PE)-extractable free lipids, and of 2-propanol (PrOH)-extractable free plus bound lipids. We also studied the effects of the surfactants when used with extracted lipid fractions in bread made from the defatted flours with or without 3% shortening. Studies of the multiple interactions of flour lipids, shortening, and surfactants may enable us to better understand the mechanism of the improving effects of surfactants in breadmaking; and a better understanding may enable us to utilize surfactants more effectively in producing high-protein breads.

MATERIALS AND METHODS

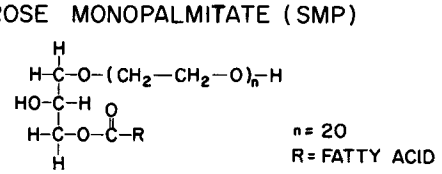
Materials

Regional Baking Standard (RBS-75) – an untreated, straight-grade flour – was experimentally milled (Allis) from a composite grist of many varieties of hard red winter wheat grown at locations throughout the Great Plains in 1974. The flour contained 12.4% protein (N x 5.7) and 0.42% ash (14% mb); it had good loaf-volume potential, with medium mixing and oxidation requirements.

Commercially manufactured surfactants were used. We obtained sucrose monopalmitate (SMP, F-160) from Dai-Ichi Kogyo Seiyaku Co., Ltd., Tokyo, Japan, and both ethoxylated monoglycerides (EMG) and sodium stearoyl-2-lactylate (SSL) from Patco Products, Kansas City, MO. Chemical structures of surfactants are shown in Figure 1. SMP and EMG are nonionic surfactants with HLB of 14.0, and SSL is an anionic surfactant with an HLB of about 9.0. Use of SMP in foods has not yet been cleared by the U.S. Food and Drug Administration.



SUCROSE MONOPALMITATE (SMP)



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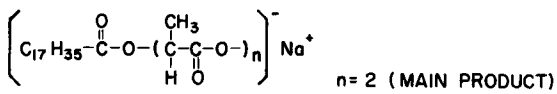

SODIUM STEAROYL – 2– LACTYLATE (SSL)

FIG. 1. Chemical structures of surfactants.

[1] Presented at the AOCS Meeting, New York, May 1977.

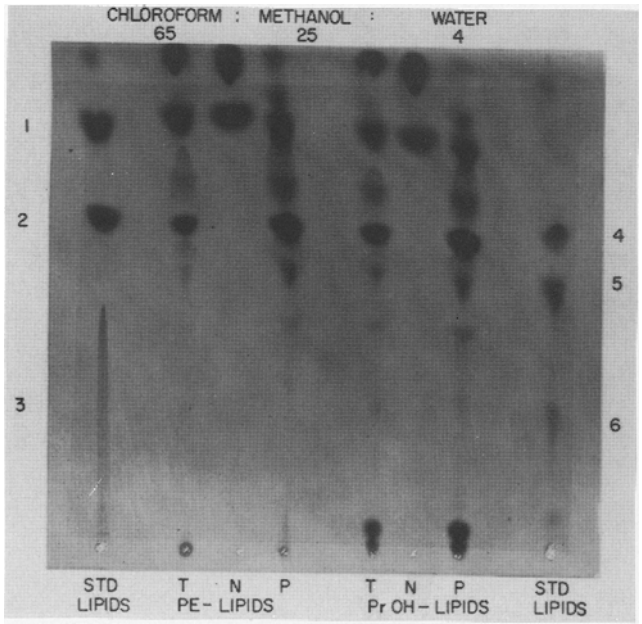

FIG. 2. Thin layer chromatogram of standard lipids and flour lipids developed with hexane-diethyl ether-95% ethanol-methanol (80:18:2:1, v/v/v), charred with 0.6% $K_2Cr_2O_7$ solution in 55% H_2SO_4, and photographed under UV light. From left to right, standard lipids, total (T), nonpolar (N), and polar (P) fractions of PE-lipids (free) and PrOH-lipids (free + bound), and standard lipids, respectively. Standard lipids were: 1) triolein, 2) 1,3 diolein, 3) 1,2 diolein, 4) monoolein, 5) β-sitosteryl palmitate, 6) β-sitosterol, and 7) oleic acid. Amount applied: 30 μg of each standard lipid and 150 μg of flour lipids.

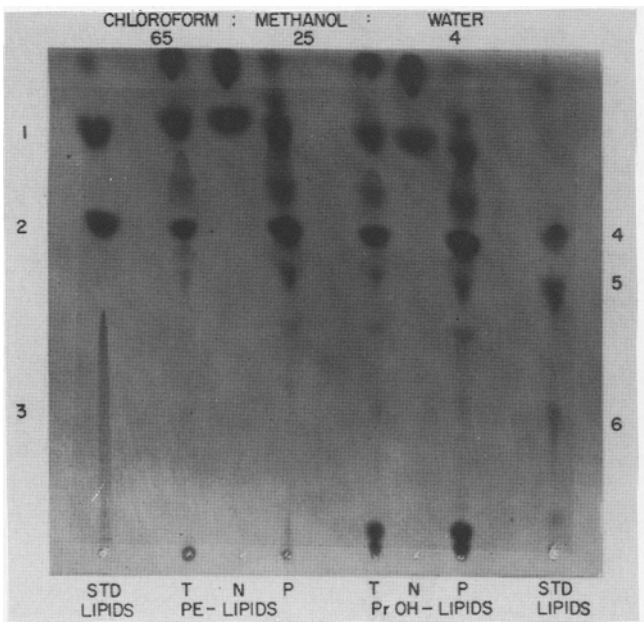

FIG. 3. Thin layer chromatogram of standard lipids and flour lipids developed with chloroform-methanol-water (65:25:4, v/v/v), charred with 0.6% $K_2Cr_2O_7$ solution in 55% H_2SO_4, and photographed under UV light. The legend of Figure 3 is the same as in Figure 2 except that the standard lipids were: 1) monogalactosyl diglyceride, 2) digalactosyl diglyceride, 3) phosphatidylserine, 4) phosphatidylethanolamine, 5) phosphatidylcholine, and 6) lysophosphatidylcholine.

Silicic acid for chromatography of lipids was from Mallinckrodt, New York, NY. Organic solvents were analytical reagent grade, and solutions were prepared from analytical reagent-grade compounds. Reference lipids were from Applied Science Laboratories, Inc., State College, PA.

TABLE I

Flour Lipids[a] Extracted with Petroleum Ether and 2-Propanol

Lipids	Lipids (% flour, db) extracted with	
	Petroleum ether	2-Propanol
Total	1.00	1.36
Nonpolar	0.70	0.73
Polar	0.30	0.63

[a]Averages of three replicates.

Analytical Procedures

Protein, ash, and moisture contents were determined by AACC Approved Methods (21).

Extraction and Fractionation of Flour Lipids

Lipids were extracted from 500 g RBS-75 flour with about 2.8 liters of PE in a Soxhlet for 48/hr with a condensation rate of 1 to 2 drops/sec, as described previously (22). Soxhlet extraction with 2-PrOH infinitely increased the mixing time and irreversibly impaired the functionality of reconstituted, with lipids, good breadmaking flours (23). However, extraction with 2-PrOH by a shaker, under certain conditions, yielded high amounts of extracted lipids and caused minimum damage to breadmaking properties (23). Therefore, RBS-75 flour was also defatted with eight volumes of 2-PrOH by the water-bath shaker method at 75 C (23). Lipids extracted with 2-PrOH were purified as previously described (22).

Flour lipids were fractionated by silicic acid column chromatography (24) into nonpolar and polar lipids with chloroform and methanol, respectively, as eluting solvents. Complete elution was determined by a spot test on a thin layer plate.

Thin Layer Chromatography (TLC)

Glass plates (20 x 20 cm) were coated with 250-μm layers of Silica Gel G, and the thin layers were activated for 3 hr at 130 C. The solvent systems for one-dimensional ascending development were: hexane-diethyl ether-95% ethanol-methanol (80:18:2:1, v/v/v, solvent system I) for standard nonpolar lipids and flour lipids; and chloroform-methanol-water (65:25:4, v/v/v, solvent system II) for standard polar lipids and flour lipids. Plates were sprayed with a 0.6% $K_2Cr_2O_7$ solution in 55% H_2SO_4 and heated for 25 min at 180 C (25). The plates were photographed under ultraviolet light. Lipids separated by TLC were tentatively identified by comparison of the R_f values with reported values for lipids (26-29). For the testing of those identifications, samples and pure standard compounds were chromatographed on the same plate, and their R_f values compared.

Blending Defatted Flours with Flour Lipids or Surfactants

The defatted flours (75 g, db) were blended with appropriate amounts of the extracted flour lipids and/or surfactants in a Stein Mill (Fred Stein Laboratories, Atchinson, KS) for 1 min.

Baking Procedures

The method employed optimum mixing time, water absorption, and oxidant (5 ppm potassium bromate + 50 ppm ascorbic acid), and a formula that included: flour 10 g (14% mb), sugar 0.6 g, salt 0.15 g, yeast 0.2 g, nonfat dry milk 0.4 g, and 60° Lintner malt extract 0.05 g. The required amount of yeast varied from 0.2 to 0.275 g, depending on activity of yeast batches, as measured by a gassing test (30). Shortening (0.3 g) was included as indicated.

TABLE II

Water Absorption (% Flour Weight, 14% mb)[a] of Petroleum Ether- or 2-Propanol-Defatted Flours without Shortening but Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level % Flour (db)		Water absorption (%) of flour supplemented with					
		Flour lipids			Surfactants		
		Total	Nonpolar	Polar	SMP	EMG	SSL
0	Untreated	69.8					
A. Petroleum ether-defatted flour							
0	Defatted:	73.5					
0.3				69.5	71.7	70.3	72.7
0.7			71.7		70.2	69.7	73.7
1.0		71.5			70.2	69.2	73.8
1.0	(0.3 polar + 0.7 surfactant)				72.7	72.7	73.7
1.0	(0.7 nonpolar + 0.3 surfactant)				72.2	72.2	71.2
B. 2-Propanol-defatted flour							
0	Defatted:	74.5					
0.63				73.3	73.8	73.8	75.3
0.73			73.2		73.2	73.2	75.2
1.36		71.6			71.2	71.2	76.2
1.36	(0.63 polar + 0.73 surfactant)				73.3	73.3	74.2
1.36	(0.73 nonpolar + 0.63 surfactant)				73.3	73.1	74.3

[a]Averages of three replicates. Water absorption of untreated flour dough with 3% shortening was 68.3%.
[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

TABLE III

Mixing Time (min)[a] of Dough from 10 g Petroleum Ether- or 2-Propanol-Defatted Flours without Shortening but Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level % Flour (db)		Mixing time (min) of dough supplemented with					
		Flour lipids			Surfactants		
		Total	Nonpolar	Polar	SMP	EMG	SSL
0	Untreated:	4-3/4					
A. Petroleum ether-defatted flour							
0	Defatted:	5-3/8					
0.3				5-7/8	5-1/2	5-3/8	6.0
0.7			5.0		6.0	5-7/8	6-1/2
1.0		5-5/8			6-1/4	6-1/4	7-3/4
1.0	(0.3 polar + 0.7 surfactant)				7-3/8	8-7/8	7-5/8
1.0	(0.7 nonpolar + 0.3 surfactant)				5-3/4	5-3/4	6-1/8
B. 2-Propanol-defatted flour							
0	Defatted:	9-5/8					
0.63				9-1/4	9-1/4	9-3/8	12-1/4
0.73			9-1/2		9.0	8-7/8	11-3/4
1.36		7-3/8			8-1/2	7-7/8	11-5/8
1.36	(0.63 polar + 0.73 surfactant)				8-1/2	8-5/8	11-1/2
1.36	(0.73 nonpolar + 0.63 surfactant)				10-3/4	9-7/8	12-3/8

[a]Averages of three replicates. Mixing time of untreated flour dough with 3% shortening was 4-7/8 min.
[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

Doughs were fermented 150 min and proofed to 3.6 cm dough height at 30 C. The procedure was described in detail elsewhere (31,32). The loaves were cooled to 25 C, and loaf volumes were determined by dwarf rapeseed displacement. Loaves were cut and their crumb grains were evaluated: VS, very satisfactory; S, satisfactory; Q, questionable; and U, unsatisfactory.

RESULTS AND DISCUSSION

Wheat Flour Lipids

PE extracted 1.0% total free lipids, which were comprised of 30% nonpolar and 70% polar lipids (Table I). Lipid extractability increased 36% with 2-PrOH, which extracted, presumably, total free lipids plus a major portion of bound lipids. The increase in lipids extracted with 2-PrOH was primarily due to an increase in polar lipids that were bound to other flour constituents, presumably, mainly flour proteins. There was a 110% increase in polar lipids and a 4.3% increase in nonpolar lipids with 2-PrOH over PE extraction. Lipids extracted by PE are denoted as PE-lipids and those by 2-PrOH as PrOH-lipids.

Total unfractionated PE-lipids and PrOH-lipids contained qualitatively the same nonpolar components (Fig. 2), but PE-lipids were slightly richer in some nonpolar components than PrOH-lipids (Table I and Fig. 2). Nonpolar lipids fractionated by column chromatography from PE- and PrOH-lipids contained similar types and amounts of components (Figs. 2 and 3).

TABLE IV

Loaf Volume (cc)[a] of Bread Baked from 10 g Petroleum Ether-Defatted Flours Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level		Loaf volume (cc) of bread supplemented with					
		Flour lipids			Surfactants		
% Flour (db)		Total	Nonpolar	Polar	SMP	EMG	SSL
A. No shortening added							
0	Untreated:	64.9					
0	Defatted:	71.0					
0.3				76.0	66.5	71.5	66.3
0.7			68.0		81.8	82.4	77.0
1.0		68.2			82.4	81.9	75.5
1.0	(0.3 polar + 0.7 surfactant)				86.5	90.0	87.0
1.0	(0.7 nonpolar + 0.3 surfactant)				65.6	72.2	62.0
B. 3% Shortening added							
0	Untreated:	81.0					
0	Defatted:	67.5					
0.3				84.9	73.5	73.5	66.5
0.7			70.5		78.2	82.1	77.3
1.0		80.1			84.2	81.2	78.3
1.0	(0.3 polar + 0.7 surfactant)				88.8	88.0	83.0
1.0	(0.7 nonpolar + 0.3 surfactant)				78.7	78.0	72.5

[a]Averages of three replicates.

[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

Nonpolar lipids were richest in triglycerides, were rich in free fatty acids and steryl esters, and contained small amounts of diglycerides, monoglycerides, and free sterols. The results generally agreed with previous results (22,33,34); but the diglyceride content was lower, probably because of different extraction conditions.

Polar components of the lipids separated by solvent system II produced different chromatograms for PE- and PrOH-lipids (Fig. 3); specific sprays (26-29) showed that both glycolipids and phospholipids were higher in total unfractionated PrOH-lipids (low in nonpolar components) than in total unfractonated PE-lipids (high in nonpolar components). Polar lipids fractionated by column chromatography from PrOH-lipids contained more glycolipids than those from PE-lipids, primarily because components with low R_f values, near the origin, were essentially present in only the PrOH-lipids. These components near the origin stained purple with α-naphthol (29) and presumably contained sucrose and raffinose (35). PrOH-polar lipids contained slightly more lysophosphatidylcholines than PE-polar lipids. The nonpolar fractions of the PE- and PrOH-lipids were separated by solvent system II into two major spots: one consisting of all nonpolar components at the solvent front and the other of free fatty acids with an R_f value of monogalactosyl diglyceride, as reported previously (9).

Water Absorptions and Mixing Requirements

Water absorption which was 69.8% in the untreated flour, increased to 73.5% in PE-defatted flour and to 74.5% in PrOH-defatted flour. Adding the extracted flour lipids and/or surfactants, in general, slightly decreased water absorption (Table II). Increasing the amount of nonionic SMP or EMG, generally, decreased water absorption; anionic SSL had an opposite effect. Water absorption was lower for the PE-defatted flour than for the PrOH-defatted flour and for the 3% shortening series than for the no shortening series (data not shown).

Removing free lipids alone by PE extraction slightly increased mixing time, from 4-3/4 min for the original flour to 5-3/8 min; but removing all free lipids and most bound lipids by 2-PrOH extraction substantially increased mixing time to 9-5/8 min (Table III). Adding 0.3% polar, 0.7% nonpolar, or 1% total free lipids to PE-defatted flour had no major effect on mixing time; adding 0.3%, 0.7%, or 1% surfactant consistently increased mixing time; mixing time was longest when 0.7% surfactant was added in combination with 0.3% polar lipids to replace PE-nonpolar lipids. When PrOH-defatted flour was supplemented with flour lipids, adding 1.36% total lipids, shortened mixing time from 9-5/8 to 7-3/8 min. When up to 1.36% surfactant was added to the PrOH-defatted flour, mixing time slightly decreased with increase in surfactant level, unlike the effect on the PE-defatted flour. Mixing time was longest when 0.63% surfactant was added in combination with 0.73% nonpolar lipids to replace PrOH-polar lipids. The mixing time increase was larger for anionic SSL than for the nonionic SMP or EMG; in agreement with data reported previously (9,19). Adding 3% shortening decreased mixing time by 1 to 2 min for PE-defatted or PrOH-defatted flours supplemented with surfactant in combination with polar lipids, and decreased mixing time by 1/4 to 1/2 min for flour supplemented with nonpolar lipids and surfactant alone or in combination (data not shown).

Loaf Volumes

Loaf volumes (LV) are the simplest and most reproducible quantitative parameters to which practically all other parameters in breadmaking are related. With defatted flours, LV responses to flour lipids depended on the presence of shortening. Removing free lipids, increased LV, which was 64.9 cc for the original flour, to 71.0 cc in the absence of shortening and substantially decreased LV from 81.0 to 67.5 cc with 3% shortening added (Table IV). When shortening was not included in the formula, adding 1.0% free total lipids or 0.7% free nonpolar lipids to the PE-defatted flour slightly decreased LV, but 0.3% free polar lipids increased LV to 76.0 cc, which was still smaller than the LV for untreated flour with 3% shortening, 81.0 cc. However, LV was comparable, or larger than, that for the

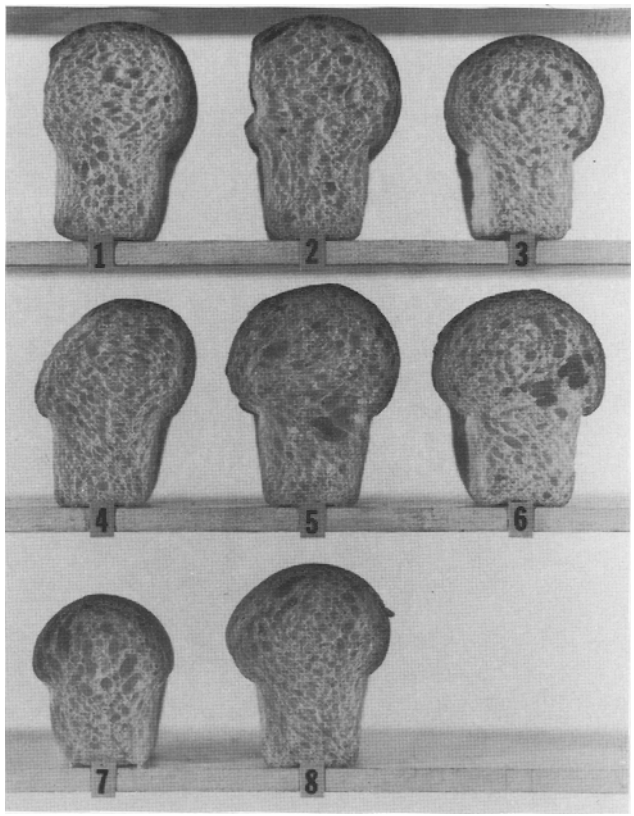

FIG 4. Microloaves of bread baked without shortening from 10 g PE-defatted flour. *Top row:* Supplemented with 1% sucrose monopalmitate (SMP) (1), 1% ethoxylated monoglycerides (EMG) (2), and 1% sodium stearoyl-2-lactylate (SSL) (3); *middle row:* Supplemented with 0.3% PE-polar lipids plus 0.7% SMP(4), EMG(5), and SSL(6); and *bottom row:* Baked from 10 g untreated control flour without (7) and with (8) 3% shortening.

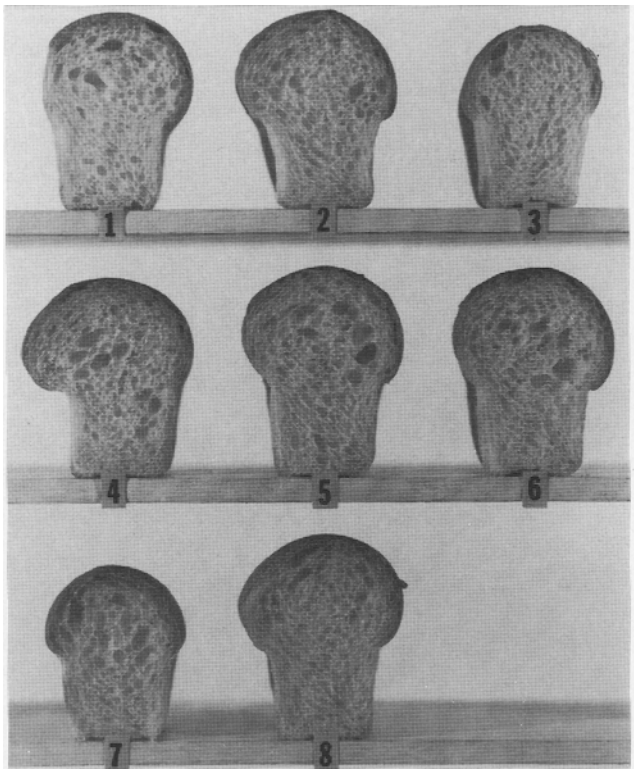

FIG. 5. Microloaves of bread baked without shortening from 10 g PrOH-defatted flour. *Top row:* Supplemented with 1.36% sucrose monopalmitate (SMP) (1), 1.36% ethoxylated monoglycerides (EMG)(2), and 1.36% sodium stearoyl-2-lactylate (SSL)(3); *middle row:* Supplemented with 0.63% PrOH-polar lipids plus 0.73% SMP(4), EMG(5), and SSL(6); and *bottom row:* Baked from 10 g untreated control flour without (7) and with (8) 3% shortening.

untreated flour with 3% shortening when 0.7% SMP or EMG was added to the PE-defatted flour. Therefore, surfactants, especially nonionic SMP or EMG with HLB of 14.0, effectively replaced some functions of wheat flour PE-extractable free lipids and can have a shortening-sparing effect. Surfactants, including anionic SSL with an HLB of 9.0, in combination with extracted free polar lipids of wheat flour improved bread quality above those of the untreated control (Fig. 4 and Table IV). All three surfactants had an improving effect when added with PE-polar lipids but not when used at 0.3% with 0.7% PE-nonpolar lipids.

For a positive shortening response, native flour lipids were required. Adding 3% shortening to the untreated flour increased LV by 16.1 cc (Table IV), from 64.9 to 81.0 cc; adding shortening to the PE-defatted flour decreased LV by 3.5 cc, from 71.0 to 67.5 cc. A positive shortening response was shown when free lipids were added to the PE-defatted flour; the response was larger with unfractionated free total lipids than with fractionated nonpolar or polar lipids. Shortening did not significantly improve LV of bread from PE-defatted flour supplemented with either surfactant alone or in combination with PE-polar lipids; apparently, because LV were already close to or even larger than the LV for the untreated control bread with shortening (81.0 cc).

Removing free plus bound lipids by PrOH extraction increased LV from 64.9 to 73.0 cc in the absence of shortening but substantially decreased LV from 81.0 to 62.5 cc when 3% shortening was added (Table V). When PrOH-defatted flour was baked without shortening but with 0.63% PrOH-polar lipids, LV was 82.5 cc – slightly greater than the LV for the untreated flour with 3% shortening. Adding 0.73% nonpolar or 1.36% total PrOH-lipids to PrOH-defatted flour decreased LV from 73.0 to 68.1 cc or to 63.2 cc, respectively. Increasing surfactant level slightly increased LV; however, only the bread with 1.36% SMP had LV, 74.1 cc, greater than that of bread baked from the PrOH-defatted control. LV was larger than that of the untreated bread with 3% shortening when 0.73% surfactant was added together with 0.63% PrOH-polar lipids, and the improving effect was greatest for SSL and smallest for SMP (Table V and Fig. 5). A combination of 0.63% surfactant and 0.73% PrOH-nonpolar lipids produced bread (no shortening) with a LV smaller than the LV of bread supplemented with either 0.73% nonpolar lipids alone or 0.63% surfactant alone. Therefore, surfactants alone did not replace completely total PrOH-extractable lipids (free + bound) and shortening or PrOH-polar lipids (free + bound) in breadmaking.

Unlike the PE-defatted flour, the PrOH-defatted flour showed a substantial positive LV response to shortening only when supplemented with unfractionated total PrOH-lipids (Table V); shortening had little or a negative effect on LV when 0, 0.63% polar or 0.73% nonpolar lipids were added. Shortening had little effect for the PrOH-defatted flour supplemented with 0.63% polar PrOH-lipids alone or in combination with 0.73% surfactants, presumably, because LV were already equal to or larger than the LV of bread baked from untreated flour with shortening (81.0 cc).

The deleterious effect of added nonpolar lipids in the defatted flours was counteracted more effectively by the co-addition of polar lipids rather than surfactants, especially in the PrOH-defatted flour baked with shortening.

TABLE V

Loaf Volume (cc)[a] of Bread Baked from 10 g 2-Propanol-Defatted Flours Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level		Loaf volume (cc) of bread supplemented with					
		Flour lipids			Surfactants		
% Flour (db)		Total	Nonpolar	Polar	SMP	EMG	SSL
A. No shortening added							
0	Untreated:	64.9					
0	Defatted:	73.0					
0.63				82.5	60.9	67.4	63.8
0.73			68.1		61.7	69.0	65.4
1.36		63.2			74.1	72.1	67.5
1.36	(0.63 polar + 0.73 surfactant)				81.0	83.1	85.4
1.36	(0.73 nonpolar + 0.63 surfactant)				60.8	63.3	61.8
B. 3% Shortening added							
0	Untreated:	81.0					
0	Defatted:	62.5					
0.63				79.0	54.3	54.5	58.0
0.73			60.5		58.5	60.5	60.0
1.36		74.9			76.5	69.5	72.0
1.36	(0.63 polar + 0.73 surfactant)				82.3	82.5	85.5
1.36	(0.73 nonpolar + 0.63 surfactant)				62.8	63.0	65.5

[a]Averages of three replicates.

[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

TABLE VI

Crumb Grain[a] of Bread Baked from 10 g Petroleum Ether-Defatted Flours Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level		Crumb grain of bread from flour supplemented with					
		Flour lipids			Surfactants		
% Flour (db)		Total	Nonpolar	Polar	SMP	EMG	SSL
A. No shortening added							
0	Untreated:	U					
0	Defatted:	Q					
0.3				Q	Q-U	Q-U	Q-U
0.7			U		VS	S	Q-S
1.0		U			VS	S	Q-S
1.0	(0.3 polar + 0.7 surfactant)				S	S	S
1.0	(0.7 nonpolar + 0.3 surfactant)				U	Q	U
B. 3% Shortening added							
0	Untreated:	S					
0	Defatted:	Q-U					
0.3				S	Q-S	Q	Q
0.7			Q		S	S	S
1.0		S			S	S	S
1.0	(0.3 polar + 0.7 surfactant)				VS	VS	S
1.0	(0.7 nonpolar + 0.3 surfactant)				Q-S	Q	Q

[a]VS = very satisfactory; S = satisfactory; Q = questionable; U = unsatisfactory.

[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

Crumb Grains

In the absence of shortening, crumb grain was improved from unsatisfactory for untreated control flour to questionable for the PE-defatted flour (minus free lipids) (Table VI) and to questionable-satisfactory for the PrOH-defatted flour (minus free lipids and most of the bound lipids) (Table VII). Adding nonpolar and unfractionated total lipids of both PE- and PrOH-extracts to the defatted flours somewhat impaired crumb grain of bread baked without shortening. All surfactants, even at the 0.7% level, improved grains of bread from PE-defatted flour; SMP improved grain the most and SSL the least; surfactants in combination with polar lipids, but not with nonpolar lipids, produced satisfactory grain (Table VI). For the breads from the PrOH-defatted flour, surfactants alone did not produce satisfactory grain. A combination of polar lipids and surfactant, however, produced satisfactory grain (Table VII).

Shortening was essential for satisfactory crumb in bread from the untreated flour; shortening also improved grains of breads baked from PE-defatted and PrOH-defatted flours that were reconstituted with the extracted flour lipids (total, nonpolar, or polar) but not of breads from PrOH-

TABLE VII

Crumb Grain[a] of Bread Baked from 10 g 2-Propanol-Defatted Flours Supplemented with the Extracted Flour Lipids and/or Surfactants[b]

Lipid and/or surfactant level		Crumb grain of bread from flour supplemented with					
		Flour lipids			Surfactants		
% Flour (db)		Total	Nonpolar	Polar	SMP	EMG	SSL
A. No shortening added							
0	Untreated:	U					
0	Defatted:	Q-S					
0.63				Q	Q-U	Q-U	Q
0.73			U		Q-U	Q-U	Q
1.36		U			Q-S	Q-S	Q-S
1.36	(0.63 polar + 0.73 surfactant)				S	S	S
1.36	(0.73 nonpolar + 0.63 surfactant)				U	U	Q-U
B. 3% Shortening added							
0	Untreated:	S					
0	Defatted:	Q-U					
0.63				Q	Q-U	U	Q-U
0.73			S		Q-U	U	Q-U
1.36		Q-S			S	Q-U	Q-S
1.36	(0.63 polar + 0.73 surfactant)				VS	Q-S	VS
1.36	(0.73 nonpolar + 0.63 surfactant)				U	Q-U	Q-U

[a]VS = very satisfactory; S = satisfactory; Q = questionable; U = unsatisfactory.
[b]SMP = sucrose monopalmitate; EMG = ethoxylated monoglycerides; SSL = sodium stearoyl-2-lactylate.

defatted flours that were supplemented with surfactants alone.

The mechanism of the improving effects of surfactants in breadmaking and of the extracted flour lipids, especially polar, when added to the defatted flour is evidently complex. The optimum balance between the HLB of the surfactant (13) and the number of charged groups as well as degree of their polarity (20) depends on the quantity and quality of flour lipids in the flour, the presence or absence of shortening, and, in the production of high-protein breads, the quantity and nature of the protein-rich additives (14,15,36).

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REFERENCES

1. Pomeranz, Y., G.L. Rubenthaler, and K.F. Finney, Food Technol. 19:1724 (1965).
2. Daftary, R.D., Y. Pomeranz, M.D. Shogren, and K.F. Finney, Ibid. 22:327 (1968).
3. Ponte, J.G. Jr., and V.A. DeStefanis, Cereal Chem. 46:324 (1969).
4. Newbold, N.W., Baker's Dig. 50(4):37 (1976).
5. Dubois, D.K., and D.J. Ash, Ibid. 45(1):32 (1971).
6. DeStefanis, V.A., J.G. Ponte Jr., F.H. Chung, and N.A. Ruzza, Cereal Chem. 43:13 (1977).
7. Knightly, W.H., Baker's Dig. 47(5):64 (1973).
8. Langhans, R.K., and W.G. Thalheimer, Cereal Chem. 48:283 (1971).
9. Chung, O.K., and C.C. Tsen, Ibid. 52:549 (1975).
10. Finney, K.F., and M.D. Shogren, Baker's Dig. 45(1):40 (1971).
11. Tsen, C.C., and W.J. Hoover, Ibid. 45(3):38 (1971).
12. Hoseney, R.C., K.F. Finney, and M.D. Shogren, Cereal Chem. 49:366 (1972).
13. Chung, O.K., Y. Pomeranz, D.R. Goforth, M.D. Shogren, and K.F. Finney, Ibid. 53:615 (1976).
14. Pomeranz, Y., M.D. Shogren, and K.F. Finney, Ibid. 46:503 (1969).
15. Pomeranz, Y., M.D. Shogren, and K.F. Finney, Ibid. 46:512 (1969).
16. Tsen, C.C., W.J. Hoover, and D. Phillips, Baker's Dig. 45(2):20 (1971).
17. Chung, O.K., and C.C. Tsen, Cereal Sci. Today 19:407 (1974).
18. Chung, O.K., and C.C. Tsen, Cereal Chem. 52:823 (1975).
19. Chung, O.K., and C.C. Tsen, Ibid. 52:832 (1975).
20. Chung, O.K., and C.C. Tsen, Ibid. 54:857 (1977).
21. American Association of Cereal Chemists, "Approved Methods of the AACC," Methods 08-01, 44-15A, and 46-11, Am. Assoc. Cereal Chem., St. Paul, MN.
22. Chung, O.K., Y. Pomeranz, K.F. Finney, J.D. Hubbard, and M.D. Shogren, Cereal Chem. 54:454 (1977).
23. Chung, O.K., Y. Pomeranz, K.F. Finney, and M.D. Shogren, Ibid. 54:484 (1977).
24. Pomeranz, Y., O.K. Chung, and R.J. Robinson, JAOCS 43:45 (1966).
25. Blank, M.L., J.A. Schmidt, and O.S. Privett, Ibid. 41:371 (1964).
26. Lepage, M., J. Chromatogr. 13:99 (1964).
27. Dittmer, J.C., and R.L. Lester, J. Lipid Res. 5:126 (1964).
28. Mangold, H.K., JAOCS 38:708 (1961).
29. Feldman, G.L., L.L. Feldman, and G. Rouser, Ibid. 42:742 (1965).
30. Shogren, M.D., K.F. Finney, and G.L. Rubenthaler, Cereal Chem. 54:665 (1977).
31. Shogren, M.D., K.F. Finney, and R.C. Hoseney, Ibid. 46:93 (1969).
32. Finney, K.F., and M.D. Shogren, Baker's Dig. 46(2):32 (1972).
33. Chung, O.K., and C.C. Tsen, Cereal Chem. 52:533 (1975).
34. MacMurray, T.A., and W.R. Morrison, J. Sci. Food Agric. 21:520 (1970).
35. Ling, L.Y., "A Study of Lipids of Chickpea," M.S. Thesis, Kansas State University, 1972.
36. Pomeranz, Y., M.D. Shogren, and K.F. Finney, J. Food Sci. 42:824 (1977).

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