Hard Red Spring and Durum Wheat Polar Lipids.
II. Effect on Quality of Bread and Pasta Products [1]

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ABSTRACT

Total wheat flour and semolina lipids were fractionated into five fractions by a batch technique using silicic acid. Nonpolar lipids added at the 0.5% level to either the untreated or the petroleum ether-defatted flour caused an increase in farinogram mixing time and mixing tolerance, and a slight decrease in water absorption. Digalactosyl diglyceride (DGDG) and phospholipids generally showed no pronounced effect on absorption, mixing time, or mixing tolerance of the dough from the untreated flour; however, a reduction in water absorption and mixing time was noted with the addition of DGDG to the defatted flour. Extraction of wheat flour with petroleum ether resulted in bread with reduced loaf volume and poorer crumb and crust characteristics. The baking quality was restored with the addition of any of the five lipid fractions at the 0.5% level, when shortening was present in the bread formula. Without shortening, the baking properties were restored and improved only by the fraction rich in DGDG. The effect of the nonpolar lipids and phospholipids on bread properties baked from the untreated flour containing shortening was small. However, DGDG at 0.4 to 0.6% consistently improved the loaf volume; this was more pronounced without shortening in the bread formula. Extraction of durum semolina with petroleum ether resulted in a higher pasta water absorption and in loss of yellow color in the spaghetti. Addition of 0.6% nonpolar lipids to the defatted semolina restored and slightly improved the spaghetti color. Nonpolar lipids and monogalactosyl diglyceride slightly increased water absorption of the untreated semolina and the firmness of spaghetti while DGDG and phospholipids decreased these factors. In general, neither nonpolar nor polar lipids affected the cooking quality of the spaghetti to any extent.

Recently, wheat flour lipids have been of interest to cereal chemists because of their potential role in breadmaking. Although many investigations have been made on this subject, the results obtained have not always been in agreement. Numerous papers concerning the effect of flour lipids on breadmaking have been reviewed by Mecham (1) and Pomeranz (2). Considerably fewer studies have been conducted on the effect of lipids on pasta-making.

In this study, an investigation was made to determine the effect of wheat polar lipids on pasta products and bread quality.

MATERIALS AND METHODS

Wheat Samples

One variety of hard red spring (HRS) wheat, Chris, grown in North Dakota at several locations in 1968, was combined and milled on a pilot Miag mill. The flour was bleached with Novadel and malted to the 550-Brabender Unit (B.U.) line on the amylograph.

A single durum wheat variety, Leeds, grown at Minot, N. Dak., during 1969 was used. The wheat sample was milled on a Buhler mill into semolina.

Petroleum Ether-Defatted Flour or Semolina

To obtain large amounts of petroleum ether (PE)-defatted flour or semolina, 800 g. of sample was mechanically stirred with 1,400 ml. of PE for 15 min. The mixture was filtered on a Buchner funnel, and the residue was reslurried with an additional 1,000 ml. of PE, stirred, and filtered. The defatted flour or semolina was spread to dry at room temperature. The residual lipid content in the defatted material was not determined.

Isolation of Lipids

Both HRS wheat flour and durum semolina were extracted for lipids according to the procedure of De Stefanis and Ponte (3). The semolina was reground on a Labconco mill (Laboratory Construction Co., Kansas City, Mo.) to finer particle size before extraction. In addition, the n-hexane solubles of methanol extracts were dried and redissolved in a small amount of chloroform. The lipid solution was centrifuged at 39,080 X g to remove any remaining insoluble matter.

Separation of Lipid Fractions

The separation of lipids into five fractions going from nonpolar to polar was performed according to the batch technique of De Stefanis and Ponte (3) with minor modification. Silicic acid (325-mesh, Research Specialties Co., Richmond, Calif.) was used instead of the silica gel of the original method. The ratio of silicic acid to lipids was 4.5:1. Eight separate extractions were made for each fraction. The solvent systems for fractions 2 and 3 (F-2 and F-3) were changed to benzene-acetone (90:10) and benzene-acetone (50:50), respectively. After the combined supernatants of each fraction were evaporated to dryness, the lipids were redissolved in $CHCl_3$ and centrifuged at 39,080 X g to remove fine particles of silicic acid and other insoluble material.

Quantitative Determination of Major Galactolipids in the Lipid Fractions

The quantitative analysis of monogalactosyl diglyceride (MGDG), digalactosyl diglyceride (DGDG), and digalactosyl monoglyceride (DGMG) in the lipid fractions was performed by thin-layer chromatography (TLC). The silica gel TLC plates of 0.3 mm. thickness were prepared by spreading the slurry of silica gel G and water followed by activation at 120°C. for 30 min.

For the determination of MGDG in F-2 and F-3, three spots of a given concentration of each lipid fraction were applied to the TLC plate. Four different amounts of the standard MGDG ranging from 5 to 20 γ were applied to the same plate. The plate was developed in the solvent system of $CHCl_3$-MeOH-H_2O (80:8:1 v./v./v.). The analysis of DGDG in F-2, F-3, and F-4 was conducted in a similar manner; however, a solvent system consisting of $CHCl_3$-MeOH-HoAc-H_2O (170:25:25:4 v./v./v./v.) was employed. The determination of DGMG in F-4 was performed using a purified lipid of DGMG as the standard and a mixture of $CHCl_3$-MeOH-H_2O (65:35:8 v./v./v.) as the developing system.

After chromatography, the plates were air-dried for 10 min. and sprayed with 3% cupric acetate solution in 8% phosphoric acid until uniformly transparent (4).

The plates were heated in an oven at 180°C. for 15 min. or until the spots were charred.

After visualization, the spots were scanned on a photovolt densitometer (filter No. 610), equipped with a Varicord recorder. Peak areas on the recording chart were measured by triangulation.

Reconstitution

All lipid fractions, obtained as described in the preceding section under separation of lipid fractions, were used for reconstitution with either flour or semolina. Both untreated and defatted flour and semolina to be reconstituted were wetted with PE at the ratio of 1:1 (w./v.). The appropriate fraction was dissolved in a small amount of diethyl ether and added to the flour at 0.1, 0.25, and 0.5%, except F-4, which was added to the flour at 0.2, 0.4, and 0.6% levels, based on the material to be reconstituted. Semolina was reconstituted with all lipid fractions at 0.2, 0.4, and 0.6% levels. After mixing under a stream of nitrogen, the reconstituted flour or semolina was spread to dry overnight at room temperature.

Farinogram Properties

Both untreated and defatted flour that had been reconstituted with individual lipid fractions at the 0.5% level were tested for dough properties using the farinograph. The constant-flour method (5), using the 540-B.U. line for the center of the curve, was used.

Baking Study

A straight-dough method using 25 g. of flour was employed, with the following formula: flour (control and reconstituted), 25 g.; sugar, 1.25 g.; salt, 0.5 g.; dried skim milk, 0.75 g.; yeast, 0.75 g.; bromate, 5 p.p.m. An alternative formula that included 0.5 g. shortening (melted Crisco) also was used. A constant absorption of 67.8% was used for all doughs. Mixing was performed in a National Mixer (National Mfg. Co., Lincoln, Neb.). Mixing time varied between 3.5 and 5.5 min., depending on the flour sample used. After mixing, the dough was removed from the mixer, rounded into a ball, and placed in the fermentation cabinet at 30°C. and 95 to 100% r.h. A 3-hr. fermentation and a 55-min. proof period were used. The loaves were baked for 20 min. at 225°C. After they were baked, they were cooled and scored for crumb color, grain, texture, and loaf volume.

Spaghetti Making

The procedure of micro-spaghetti processing by Walsh et al. (6) was used. Thirty grams of semolina was mixed with water in a micromixer, water-jacketed at 35°C. for 2.5 min. to form a stiff dough. The amount of water to be added was determined by the extrusion pressure required by the dough. After it was mixed, the dough was kneaded into a homogeneous mass by passing it through corrugated rolls for 3 min. The kneaded dough was extruded, using an extrusion pressure of 500 to 600 p.s.i. The wet spaghetti was allowed to "case-harden" under ambient conditions for 15 min., and then placed in an experimental dryer set at 38°C. and 95% r.h. (7). The automatic controls lowered the r.h. inside of the dryer during a 15-hr. period in a straight-line gradient from 95% at the beginning to 65% at the end of drying.

The color of the dried spaghetti was measured by the method of Walsh (8). The

cooked weight and cooking loss of the spaghetti were determined by AACC
Approved Methods (5). Cooked spaghetti firmness was measured as described by
Walsh (9).

RESULTS AND DISCUSSION

Isolation and Separation of Lipids

The total lipid content (hexane-solubles) of methanol extract of Chris flour and
Leeds semolina was 1.0 and 0.7%, respectively. Five fractions were obtained, using
the silicic acid batch technique. The yield for each of the five fractions for both the
HRS and durum wheat samples is shown in Table I. Analysis of the five fractions by
TLC is shown in Fig. 1. These results indicate that the separation of nonpolar lipids
from the polar fractions was highly effective and that fractions rich in neutral
lipids, MGDG, DGDG, and phospholipids were obtained. The total recovery of lipid
fractions was 3% lower in the present study than the reported by De Stefanis and
Ponte (3), who used silica gel as adsorbent. In addition, the change in the ratio of
benzene-acetone mixtures from the original procedure (3) for the elution of F-2
and F-3 increased the content of MGDG in F-2 and both yield and content of
DGDG in F-4.

Quantitative Analysis of the Major Galactolipids in Polar Lipid Fractions

Since the galactolipids, such as MGDG, DGDG, and DGMG, were of prime
interest in this study, a quantitative TLC procedure (4) was used to estimate the
percentage of these particular lipid components present in each fraction. The
analysis of galactolipid fractions in both varieties of wheat investigated is given in
Table I. The results showed that high concentrations of MGDG and DGDG were
found in F-2 and F-4, respectively, although the values in Leeds were lower than
those in Chris.

Effect of Nonpolar and Polar Lipid Fractions on Faringram Properties of Dough

The effect of adding the different lipid fractions on the farinogram properties of
dough is summarized in Table II.

TABLE I. FRACTIONS OF WHEAT LIPIDS

Fraction	Solvent System	Yield[a] Chris %	Leeds %	Principal Component	Percent of Major Component Chris	Leeds
1	Diethyl ether (100%)	60.9	69.7	Nonpolar lipids	---	---
2	Benzene:acetone (90:10 v./v.)	0.8	0.8	MGDG	81.4	72.0
				DGDG	11.8	13.3
				Others	6.8	14.7
3	Benzene:acetone (50:50 v./v.)	11.3	7.2	MGDG	5.1	4.6
				DGDG	46.2	54.5
				Others	48.7	40.9
4	Acetone:methanol (97:3 v./v.)	12.0	7.9	DGDG	71.3	68.7
				DGMG	15.5	13.5
				Others	13.2	17.8
5	Methanol:water (95:5 v./v.)	10.2	9.7	Phospholipids	---	---

[a]Based on total starting material; an average of 95.2% recovery was obtained from
triplicate samples of Chris flour; an average of 95.3% was obtained from
duplicate samples of Leeds semolina.

The results show that extraction of wheat flour with petroleum ether increased the farinogram absorption. On the contrary, Johnson (10) reported that extraction with ether did not affect the baking absorption or farinogram absorption.

PE-defatted HRS wheat flour had a slightly longer mixing time and shorter mixing tolerance than the untreated original flour. Tao and Pomeranz (11) reported that hard red winter (HRW) wheat flours extracted with PE gave shorter mixing times as compared to the untreated flours, whereas Mecham and Pence (12) reported that water-saturated butanol-defatted flours required longer mixing times.

F-1 (mainly nonpolar lipids) added at the 0.5% level to either the untreated or the PE-defatted flour caused an increase in farinogram mixing time and dough stability and a slight decrease in water absorption. The results on the effects of nonpolar lipids on the farinogram properties of untreated flour agreed with Tao and Pomeranz (11), who added 2% of nonpolar lipids to HRW flours of different protein quality.
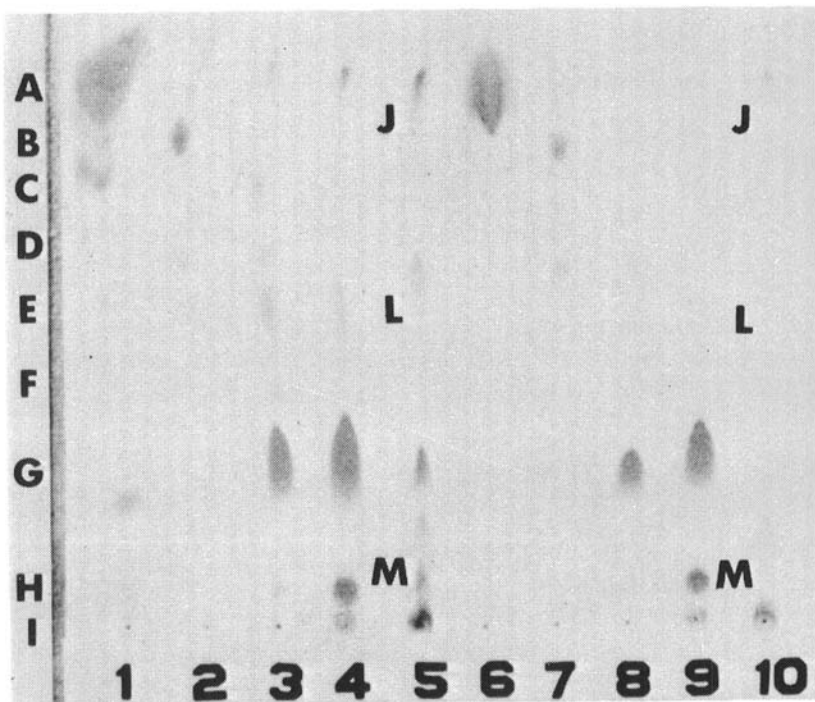

Fig. 1. Thin-layer chromatogram of lipid fractions. Absorbent, silica gel G. Solvent system, chloroform-methanol-acetic acid-water (170:25:25:4 v./v./v./v.). Spray reagent, 20% perchloric acid. Numbers 1–5 represent Chris fractions 1–5; numbers 6–10 represent Leeds fractions 1–5. Letters A–I apply for all fractions except in numbers 5 and 10, where J, L, and M specify otherwise. A, neutral lipids; B, monogalactosyl diglyceride; C, esterified monogalactosyl monoglyceride; D, steryl glucoside; E, cerebroside; F, monogalactosyl monoglyceride; G, digalactosyl diglyceride; H, digalactosyl monoglyceride; I, material at origin; J, N-acyl phosphatidyl ethanolamine; L, N-acyl lysophosphatidyl ethanolamine; M, phosphatidyl choline, phosphatidyl ethanolamine, and their lyso analogues.

F-3, which contained nearly 50% DGDG and 50% other glycolipids, had no effect on water absorption of the dough from either untreated or PE-defatted flour. However, the mixing time was increased slightly. This may be due to the effect of glycolipids other than DGDG present in this particular fraction.

F-4, which contained 71.3% DGDG and 15.5% DGMG, showed no pronounced effect on water absorption, mixing time, and stability of the dough made from the untreated flour; however, with the defatted flour, these lipid components decreased slightly the water absorption and reduced the mixing time.

F-5 (mainly phospholipids) generally showed no pronounced effects on the farinogram properties of the untreated or defatted flour.

The overall results with polar lipids in which DGDG and phospholipids were predominant were similar to those reported by other workers (11).

Effect of Solvent Treatment on Baking Quality

Since the reconstitution of flour with wheat lipids was performed in the presence of PE, preliminary investigations were concerned with the possible effects of the solvent on baking properties. The mixing time of the dough made from the PE-treated (wetted) flour was 15 to 30 sec. less than the dough made from the untreated flour, regardless of the presence or absence of shortening in the bread formula. However, bread produced from the treated flour showed no differences in crumb grain and loaf volume, when compared to the untreated flour. These results agree with those of Pomeranz et al. (13).

Effect of Shortening on Baking Quality

Preliminary investigations also were concerned with the effect of shortening on both untreated and PE-defatted flours (Table III). Adding 2% shortening to the untreated flour improved loaf volume, crumb grain, crumb color, and crust characteristics, while no improvement was noted when it was added to the defatted flour. Without shortening, bread baked from the defatted flour generally had a better grain than that from the untreated flour. The shortening response with the

TABLE II. EFFECT OF LIPID FRACTIONS ON
FARINOGRAM PROPERTIES OF DOUGHS[a]

Description	Absorption at 540 B. U. %	Mixing Time min.	Dough Stability min.
Untreated flour (Chris, 1968 Crop Year)			
Control	63.4	7.5	14.5
0.5% F-1 added	62.6	13.5	17
0.5% F-3 added	63.4	10	12
0.5% F-4 added	63.3	6.75	15
0.5% F-5 added	63.0	8.25	15
PE-defatted flour (Chris, 1968 Crop Year)			
Control	66.8	8.75	11.75
0.5% F-1 added	66.0	10.5	13.5
0.5% F-3 added	66.5	9.5	12
0.5% F-4 added	66.0	6.5	11
0.5% F-5 added	66.5	9.25	12.5

[a]Due to limited material of F_2 this fraction was not investigated.

TABLE III. EFFECT OF LIPID FRACTIONS ON
LOAF VOLUME AND CRUMB GRAIN OF BREAD[a]

| | Untreated Flour[b] | | | | PE-Defatted Flour[c] | | | |
| | With 2% shortening | | Without shortening | | With 2% shortening | | Without shortening | |
Addition of Lipid	Loaf volume c.c.	Crumb grain[d]	Loaf volume c.c.	Crumb grain[d]	Loaf volume c.c.	Crumb grain[d]	Loaf volume c.c.	Crumb grain[d]
Control	181	S	144	Q-S	167	S	160	S
0.10% F-1	177	S	148	Q-S	172	S	144	S-Q
0.25% F-1	177	S	144	Q-S	172	S	145	S-Q
0.50% F-1	171	S	142	Q-S	186	S	142	S-Q
Control	182	S	144	Q	156	S-Q	156	S-Q
0.10% F-2	177	S	142	Q-S	166	Q-S	146	Q-S
0.25% F-2	176	S	141	Q-S	175	S-Q	140	S-Q
Control	181	S	144	Q-S	167	S	160	S
0.10% F-3	172	S-Q	143	Q-S	174	S-Q	148	S-Q
0.25% F-3	171	S	171	S-Q	182	S	183	S
0.50% F-3	179		179	S	184	S	187	S
Control	181	S	144	Q-S	156	S-Q	148	S
0.20% F-4	175	S	148	Q-S	166	S-Q	150	S
0.40% F-4	181	S	161	S-Q	181	S-Q	166	S
0.60% F-4	189	S	176	S	178	S	189	S
Control	181	S	144	Q	156	S-Q	156	S-Q
0.10% F-5	182	S	144	Q-S	162	S-Q	152	S-Q
0.25% F-5	180	S	153	Q-S	174	S-Q	144	S-Q
0.50% F-5	181	S	160	S-Q	178	S	152	Q

[a]All measurements were averages of duplicate determinations.

[b]1968 crop year, Chris variety.

[c]Same flour as above, but it was extracted with PE.

[d]S, satisfactory; S-Q, satisfactory-questionable; Q-S, questionable-satisfactory; Q, questionable.

defatted flour was not as sensitive as with the untreated flour. These results agree with those of Pomeranz et al. (13) for HRS and HRW flours.

Effect of Nonpolar and Polar Lipid Fractions on Baking Quality

Table III shows the effect of wheat flour lipid fractions on loaf volume and crumb grain of bread from the untreated and the PE-defatted flours. Extraction of wheat flour with PE resulted in bread with reduced loaf volume and poorer crumb and crust characteristics. The baking quality was not improved with the use of 2% shortening with the PE-defatted flour; however, it was improved with the addition of any one of the five lipid fractions at the 0.5% level, when shortening was present in the bread formula. Thus in this study the lipid fractions extracted were functional and essential in breadmaking. The bound polar lipids, which were unextractable with PE, also may play an important role in functionality (14).

The addition of F-1 (mainly nonpolar lipids) in the presence and absence of shortening to the untreated flour had little effect on loaf volume or crumb grain. However, the nonpolar lipids (F-1) were detrimental to the grain and reduced the loaf volume of bread baked from the defatted flour without shortening (Fig. 2). With shortening, the baking characteristics were restored by addition of nonpolar
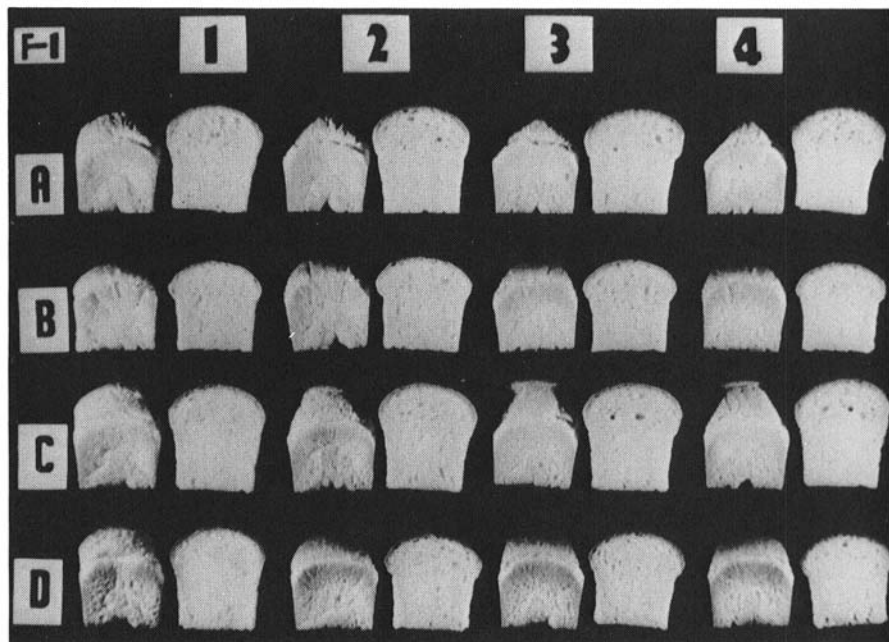
Fig. 2. Effect of F-1 on loaf volume, crust, and crumb of bread. 1, control; 2, 0.10% F-1 added; 3, 0.25% F-1 added; 4, 0.50% F-1 added; A and B, untreated flour with and without shortening, respectively; C and D, PE-defatted flour with and without shortening, respectively.

lipid fraction at the 0.5% level. Hoseney et al. (14) and Daftary et al. (15) reported that loaf volume and crumb grain of bread baked from PE-defatted HRW flour were not restored by addition of nonpolar lipid fraction at the 0.6% level.

F-2, which contained 81% MGDG added at the levels of 0.10 and 0.25%, caused a reduction in loaf volume of the bread baked from the untreated flour containing shortening and in the defatted flour without shortening. However, this fraction showed a slight improvement in the crumb grain of the bread made without shortening from either the untreated or defatted flour. Ponte et al. (16) found that MGDG added at the 0.25% level had very little effect on loaf volume of bread made from the untreated flour using the sponge and dough system. Daftary et al. (15) reported that addition of MGDG at the 0.20% level improved loaf volume and was detrimental to the crumb grain of bread from PE-defatted flour without shortening.

F-3, when added at the 0.25 and 0.50% levels to either the untreated or PE-defatted flour in the absence of shortening, increased loaf volume and improved crumb grain. With shortening, this fraction also improved loaf volume of bread made from the PE-defatted flour (Fig. 3).

F-4, when added at the 0.4 and 0.6% levels to both flours with or without shortening, improved crumb grain and increased loaf volume (Fig. 4). These results agree with data reported by other investigators (14,15).

When purified DGDG was prepared from F-4 and was added to the untreated flour, the increase in loaf volume was even more pronounced, and was most noticeable in the bread without shortening.
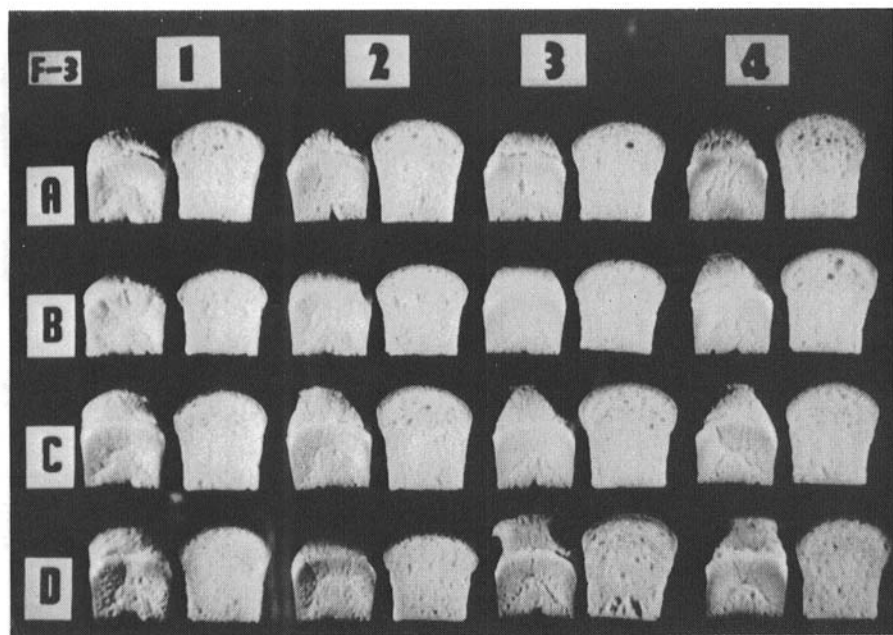
Fig. 3. Effect of F-3 on loaf volume, crust, and crumb of bread. 1, control; 2, 0.10% F-3 added; 3, 0.25% F-3 added; 4, 0.50% F-3 added; A and B, untreated flour with and without shortening, respectively; C and D, PE-defatted flour with and without shortening, respectively.

With shortening in the formula, F-5 increased loaf volume and improved crumb grain of bread baked from the defatted flour. F-5 caused a slight increase in loaf volume and improved the grain of bread made from the untreated flour without shortening.

Effect of Polar Lipids on the Quality of Spaghetti

Table IV summarizes the effect of lipid fractions on the quality of spaghetti. PE-defatted semolina required a higher amount of water to make a pasta desirable for extrusion into spaghetti. Extraction of semolina with PE removed certain pigments, resulting in a certain loss of yellow color in the spaghetti. The removal of free lipids from semolina did not affect the cooking quality of the spaghetti to any extent. Addition of nonpolar lipid fractions (F-1) and MGDG-rich fraction (F-2) at the 0.6 and 0.4% levels, respectively, to the defatted semolina restored and slightly improved the spaghetti color. Addition of nonpolar and polar lipid fractions at the 0.6% level to the untreated semolina in general improved the spaghetti color. This improvement in color was from pigments present in the lipid fractions.

Water absorption of the untreated or defatted semolina suitable for extrusion of the spaghetti was affected only to a limited extent by the addition of the lipid fractions. Nonpolar lipids and MGDG fractions slightly increased water absorption of the untreated semolina, while DGDG (F-4) and phospholipid (F-5) fractions decreased it.

As given in Table IV, cooking quality, such as cooked weight (about 35 g.).
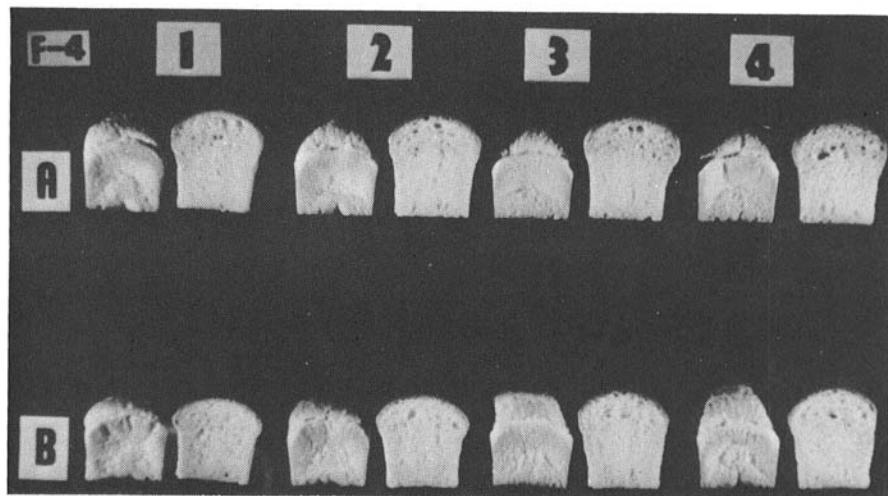
Fig. 4. Effect of F-4 on loaf volume, crust, and crumb of bread. 1, control; 2, 0.20% F-4 added; 3, 0.40% F-4 added; 4, 0.60% F-4 added; A and B, untreated flour with and without shortening, respectively.

cooking loss (6 to 7%),and firmness of all samples tested were within the acceptable range. Addition of any lipid fraction lowered the cooked weight of the finished product made from the untreated semolina, while this reduction in cooked weight was quite small in spaghetti made from the defatted semolina. Nonpolar lipids (F-1) did not lower the cooked weight as much as the DGDG (F-4) and phospholipids (F-5) for spaghetti made from the untreated semolina. F-3, which contained DGDG (54.5%) and other glycolipids, was similar to F-4 and F-5 in reducing the cooked weight. F-3, F-4, and F-5 also slightly decreased the cooked weight of spaghetti made from defatted semolina. It is speculated that phospholipids and glycolipids such as DGDG added to semolina before spaghetti processing have cementing properties that prevent easy swelling during cooking.

Removal of free lipids with PE from semolina did not affect the cooking loss. Addition of the lipid fractions to the untreated or defatted semolina before spaghetti processing appeared to have no effect on cooking loss. Dahle and Muenchow (17) extracted spaghetti strands with water-saturated n-butanol and found that removal of lipids resulted in higher amounts of amylose in the cooking water. These workers explained that this may be due to a loss of the amylose-complexing properties of the polar lipids.

Extraction of durum semolina with PE did not result in any change in firmness of the cooked spaghetti. Addition of nonpolar lipids (F-1) and MGDG-rich fraction (F-2) at the higher levels slightly increased the firmness of spaghetti made from the untreated semolina, while the glycolipids (F-3 and F-4) and phospholipids (F-5) decreased it. However, in general all of the lipid fractions decreased the firmness of spaghetti made from the PE-defatted semolina. Based on the evaluation method of Walsh (9), the spaghetti made with the addition of glycolipids (F-3 and F-4) or phospholipids (F-5) at the 0.4% level to the untreated semolina would be graded as optimum to slightly firm in firmness. The control spaghetti, as well as that made

TABLE IV. EFFECT OF LIPID FRACTIONS
ON THE QUALITY OF SPAGHETTI

Addition of Lipid Fraction	Water Absorption at 550 p.s.i. %	Color Score	Cooked Weight g.	Cooking Loss %	Firmness Score g. cm.
Control (untreated semolina[a])	32.7	9.5	35.0	6.0	6.49
0.20% F-1	32.7	9.5	35.0	6.0	5.79
0.40% F-1	33.3	9.5	34.0	5.0	6.79
0.60% F-1	33.3	10.0	33.8	7.0	6.73
0.20% F-2	33.3	9.5	34.1	6.0	6.23
0.40% F-2	33.3	10.0	33.6	6.0	6.97
0.20% F-3	32.7	9.5	33.2	6.0	6.29
0.40% F-3	32.3	9.5	33.2	6.0	5.97
0.60% F-3	33.0	10.0	33.3	5.0	6.25
0.20% F-4	31.7	9.5	33.3	6.0	6.65
0.40% F-4	31.3	9.5	33.9	6.0	5.43
0.60% F-4	32.3	9.5	33.0	7.0	5.59
0.20% F-5	32.0	9.5	33.4	7.0	5.81
0.40% F-5	32.0	9.5	33.1	6.0	5.41
0.60% F-5	31.7	10.0	33.6	6.0	6.57
Control (PE-defatted semolina[b])	35.0	9.0	34.5	6.0	6.47
0.20% F-1	34.7	9.5	34.9	6.0	6.41
0.40% F-1	34.7	9.5	35.1	6.0	6.13
0.60% F-1	34.4	10.0	34.3	6.0	6.19
0.40% F-2	34.0	10.0	34.4	7.0	5.45
0.20% F-3	34.7	9.0	33.6	6.0	6.17
0.40% F-3	34.4	9.0	34.1	7.0	5.45
0.60% F-3	34.4	9.0	33.9	7.0	5.75
0.20% F-4	34.4	9.0	35.0	6.0	5.99
0.40% F-4	35.0	9.0	33.6	6.0	6.13
0.60% F-4	34.7	9.0	33.7	6.0	5.73
0.20% F-5	35.0	9.0	33.1	6.0	6.11
0.40% F-5	35.3	9.0	34.7	6.0	6.21
0.60% F-5	35.0	9.0	34.0	6.0	5.81

[a]1969 crop year Leeds variety grown at Minot, N. Dak.
[b]Same semolina as above, but it was extracted with PE.

from the untreated semolina and the addition of nonpolar lipids or MGDG-rich fraction were considered to be more firm. However, none of the samples would be graded as "mushy" or "tough."

In general, neither nonpolar nor polar lipids affected the cooking quality of the spaghetti to any degree. The effect of the various lipid fractions on spaghetti quality was not as great as their effect on bread quality.

Acknowledgments

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