Noodles VIII. The Effect of Wheat Flour Lipids, Gluten, and Several Starches and Surfactants on the Quality of Oriental Dry Noodles[1]

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ABSTRACT

Cereal Chem. 66(4):276–282

Removal of free lipids from hard wheat and soft wheat flours increased the whiteness and strength of the dry noodles; it increased cutting stress but decreased surface firmness of cooked noodles. In fractionation and reconstitution studies, nonpolar lipids effectively restored surface firmness of cooked noodles, whereas nonpolar lipids and glycolipids reduced breaking stress of dry noodles. Gluten from the hard wheat flour gave stronger noodles in dry and cooked form than did the soft wheat gluten, but both glutens were equally detrimental to surface firmness at levels above 7% in the flour. Addition of 10% modified wheat starch or waxy maize starch to the hard wheat flour increased the cutting stress and surface firmness of cooked noodles. At 0.5% level, lecithin increased the strength of the noodles, whereas sodium stearoyl-2-lactylate and monoglycerides improved surface firmness of cooked noodles.

The role of flour components in breadmaking has been examined by fractionation and reconstitution methods for over 40 years (Finney 1943, Bushuk 1966, Shogren et al 1969, Chung et al 1977, MacRitchie 1985). The same experimental approach has been used to examine pasta (Dexter and Matsuo 1978, 1979), cookies (Yamazaki 1955, Sollars 1956, Doescher 1986), cakes (Sollars 1961), and saltine crackers (Rogers 1987). In the case of Oriental dry noodles, Oh et al (1985d) found that the gluten fraction was responsible for the difference in internal firmness between two hard wheat noodles.

The role of lipids in pasta has been extensively investigated (Matsuo et al 1986, Laignelet 1983). In noodles, free fatty acids and their esters have been reported to interact with starch (Niihara et al 1973, Mohri 1980). This paper concerns flour lipids and their role in the color and strength of dry noodles and the surface and internal firmness of cooked noodles. Exchange and reconstitution of gluten and nongluten fractions from two wheat flours were used to determine their role in noodle quality. Finally, the functional effects of several starches and surfactants were investigated in dry noodles made from hard red winter (HRW) wheat flour.

MATERIALS AND METHODS

Materials and Assay Methods

All chemicals were reagent grade. Silica gel was Bio-Sil A (100–200 mesh) from Bio-Rad Laboratories, Richmond, CA. Wheat, corn, and potato starches were from Sigma Chemical Co., St. Louis, MO. Modified wheat starch was Midsol 2 from Midwest Grain Products, Atchison, KS, and waxy corn starch from National Starch and Chemical Corp., Bridgewater, NJ. Surfactants included soybean lecithin (40% L-α-phosphatidylcholine, Sigma), distilled monoglycerides (type AM 431, Grinsted Products, Industrial Airport, KS), and sodium stearoyl-2-lactylate (SSL; Patco Products, Kansas City, MO).

Wheats were a commercial mixture of hard red winter wheats (CHRW) grown in the Great Plains in 1985 and western white (WW) wheat (soft white/club = 9/1) grown in the Northwest in 1985. The WW was obtained from the USDA, ARS, Western Wheat Quality Laboratory, Pullman, WA. Straight-grade (70–72% extraction) flours were prepared on a Buhler pilot mill at the Department of Grain Science and Industry, Kansas State University. Protein (N × 5.7), ash, and moisture were determined by AACC (1983) methods 46-11, 08-01, and 44-15A, respectively. Protein in the fractions from wheat flour was assayed by an AACC (1983) micro-Kjeldahl method 46-13.

Extraction and Fractionation of Flour Lipids

The methods used were those described by Chung et al (1977). Briefly, wheat flour (450 g) was extracted for 48 hr with petroleum ether using a Soxhlet apparatus, and the defatted flours were air-dried and sifted through a 60-mesh screen. A portion of the free lipids (~200 mg) was fractionated by column chromatography (10 × 200 mm) on silica gel (10 g). Nonpolar lipids, glycolipids, and phospholipids were eluted with 150 ml of chloroform, acetone, and methanol, respectively. The mean recovery of lipids was 97%.

Fractionation of Flours

Native flours from CHRW and WW wheats were fractionated into gluten, water solubles, and starch using a modification of the method described by Finney et al (1982). Flour (100 g, 14% mb) was mixed at its optimum absorption for 30 sec using a 100-g pin mixer (TMCO-National Mfg. Co., Lincoln, NE). The dough was placed in a 1-L beaker with 150 ml of chilled water for 15 min and then gently kneaded with one hand (rubber glove) using special care to keep the dough intact. After decanting the liquid phase, kneading and decanting were repeated with a series of different amounts of chilled water (2 × 100 ml, 4 × 75 ml, and 4–6 × 50 ml). The liquid phases from the various washing steps were combined, strained through a 32-mesh screen, and the small pieces of gluten on the screen were combined with the gluten ball. The filtrate was centrifuged at 2,000 × *g* for 20 min, the supernatant (water-solubles) was decanted, and the tailing starch was scraped off the top of the prime starch with a spatula. Each fraction was freeze-dried, and the dried fractions were ground in a mortar to pass a 60-mesh sieve. The freeze-dried water-soluble fraction was pulverized in a mortar without sieving. The recovery of dry solids in the fractionation scheme was 96–98%.

TABLE I
Composition[a] of Flours from a Commercial Hard Red Winter (CHRW) Wheat and a Western White (WW) Wheat

Flour	Protein (%)	Ash (%)	Free Lipids (%)	Lipid Composition (% of free lipids): Non-polar	Glyco-lipids	Phospho-lipids
CHRW	14.3	0.45	1.08	72.4	18.6	9.0
WW	10.1	0.49	0.94	66.1	24.0	10.0

[a] Data reported at 14% moisture.

[1] Contribution no. 88-533-J, from the Kansas Agricultural Experiment Station, Manhattan. Cooperative investigation between the U.S. Department of Agriculture, Agricultural Research Service, and the Kansas Agricultural Experiment Station. Presented in part at the AACC 71st Annual Meeting, Toronto, ON, Canada, October 1986.

Mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

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Reconstitution of Flours

Lipids were added back to the defatted flour by pipetting a petroleum-ether solution of a lipid corresponding to 100 and 150% of the original level onto 100 g (db) of flour. After evaporation of the solvent, the treated flour was mixed with a mortar and pestle.

Starch and water-soluble fractions were blended together to give a nongluten fraction. The four fractions used in interchange and reconstitution studies in noodles were the gluten and nongluten fractions from CHRW and from WW.

Fractionated flours were reconstituted by one of two methods.

Method A. Blended fractions were brought to 14% moisture by hydration of 5-mm layers of flour in a closed container at 95% relative humidity and 25° C (Chung et al 1981).

Method B. Fractions (100 g, db) were mixed in a 100-g pin mixer (TMCO-National Mfg.) for 1 min with 40–45 ml of distilled water, and the resulting dough was crumbled into small nodules and dried at room temperature for 48 hr. The air-dried nodules were ground in a cyclone sample mill (model MS, Udy Corp., Fort Collins, CO)

TABLE II
Noodles Made from Flours with Various Free Lipids[a]

Wheat Flour	Free Lipids (%)	Dry Noodle: Color	Dry Noodle: Breaking Stress (g/mm²)[b]	Cooked Noodle: Cooking Time (min)	Cooked Noodle: Cooking Loss (%)	Cooked Noodle: Cutting Stress (g/mm²)[b]	Cooked Noodle: Surface Firmness (g/mm)
CHRW[c]							
Control	1.08	66.1	3,397	14	10.7	35.8	37.8
Defatted	0	75.0	3,587	13	12.4	39.1	32.9
Reconstituted with							
100% Lipids	1.08	68.0	3,241	12	10.1	36.8	35.8
150% Lipids	1.62	64.4	1,929	12	···	30.4	36.1
WW[d] lipids	1.08	69.9	1,918	12	···	35.6	35.4
WW[d]							
Control	0.94	89.9	1,462	10	9.8	23.5	52.7
Defatted	0	92.4	1,957	9	10.9	29.8	42.2
Reconstituted with							
100% Lipids	0.94	88.1	1,577	8	9.5	22.6	54.5
150% Lipids	1.41	83.3	940	8	···	20.8	51.0
CHRW lipids	0.94	86.7	983	8	···	21.6	46.0
LSD ($P < 0.05\%$)	···	1.7	157	1	···	1.6	2.3

[a] Average of four replicates.
[b] Units can be converted from grams-force/mm to kilopascal (kPa) by multiplying by 9.8.
[c] Commercial hard red winter wheat.
[d] Western white wheat.

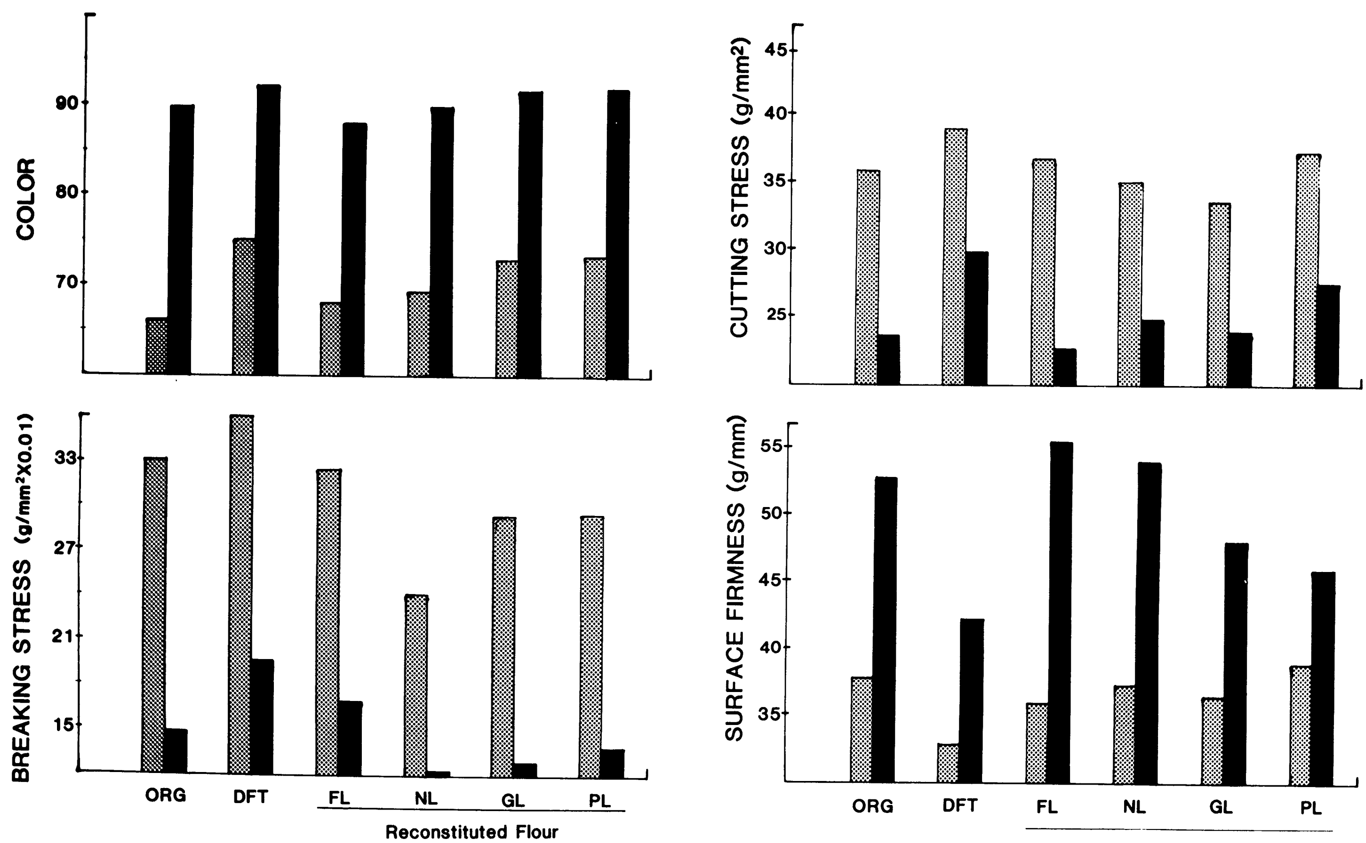

Fig. 1. Effects of lipid fractions on the properties of noodles made from commercial hard red winter (▨) and western white (■) wheat flours. The defatted flour (100 g, db) was reconstituted with the appropriate amount of free lipids or their individual fractions, rehydrated to 14% mb, and made into noodles. Least significant difference (LSD) at $P < 0.05\%$ was as follows: color, 1.6; breaking stress, 142 g/mm^2; cutting stress, 1.7 g/mm^2; and surface firmness, 2.2 g/mm. **ORG** = original flour, **DFT** = defatted flour, **FL** = reconstituted with free lipids, **NL** = reconstituted with nonpolar lipids, **GL** = reconstituted with glycolipids, **PL** = reconsitituted with phospholipids.

to pass through a 40-mesh wire screen (375-μm opening), and then sealed in a glass jar for 48 hr (Rogers 1987).

Noodles

Dry noodles were prepared using 100 or 200 g of flour (Oh et al 1983). Some noodles made from the CHRW flour contained 5–15% added starch or 0.1–0.5% added surfactant based on flour weight. The color of a dry noodle sample was assessed by a light reflectance meter (Oh et al 1985b), and breaking stress by the Instron universal testing machine (Oh et al 1985b). Noodles (10 g) were cooked in gently boiling water (500 ml) until the white core disappeared (optimum cooking). The cutting stress and surface firmness of cooked noodles were measured as previously described (Oh et al 1983, 1985a). Data on noodle characteristics were analyzed for each experiment using analysis of variance and the derived least significant difference (SAS 1985).

RESULTS AND DISCUSSION

Wheat Lipids and Noodle Properties

Protein was 4% higher in the flour from the hard wheat (CHRW) than in that from soft wheat (WW), whereas free lipids were almost equal (Table I). Interestingly, the free lipids from the WW wheat flour were lower in nonpolar but higher in glycolipids than the free lipids from the CHRW flour.

Defatted flours gave dry noodles with improved whiteness and

TABLE III
Yield[a] and Protein Content[b] of Fractions from Commercial Hard Red Winter (CHRW) and Western White (WW) Wheat Flours

	CHRW				WW			
			% of Total				% of Total	
Fractions	Yield (g)	Protein (%)	Dry Matter	Protein	Yield (g)	Protein (g)	Dry Matter	Protein
Gluten	10.8	80.6	12.9	85.3	7.4	81.3	9.0	81.5
Starch								
Tailings	22.5	1.4	26.8	3.1	19.1	2.0	23.1	5.1
Prime	46.0	0.2	55.0	0.9	51.0	0.2	61.9	1.2
Water-solubles	4.4	24.5	5.3	10.7	5.0	18.2	6.0	12.2

[a] Yield in grams from 100 g of flour (14% mb).
[b] CHRW and WW contained 14.3% and 10.1% protein, respectively. Percentage given on a 14% mb. Average of three replicates.

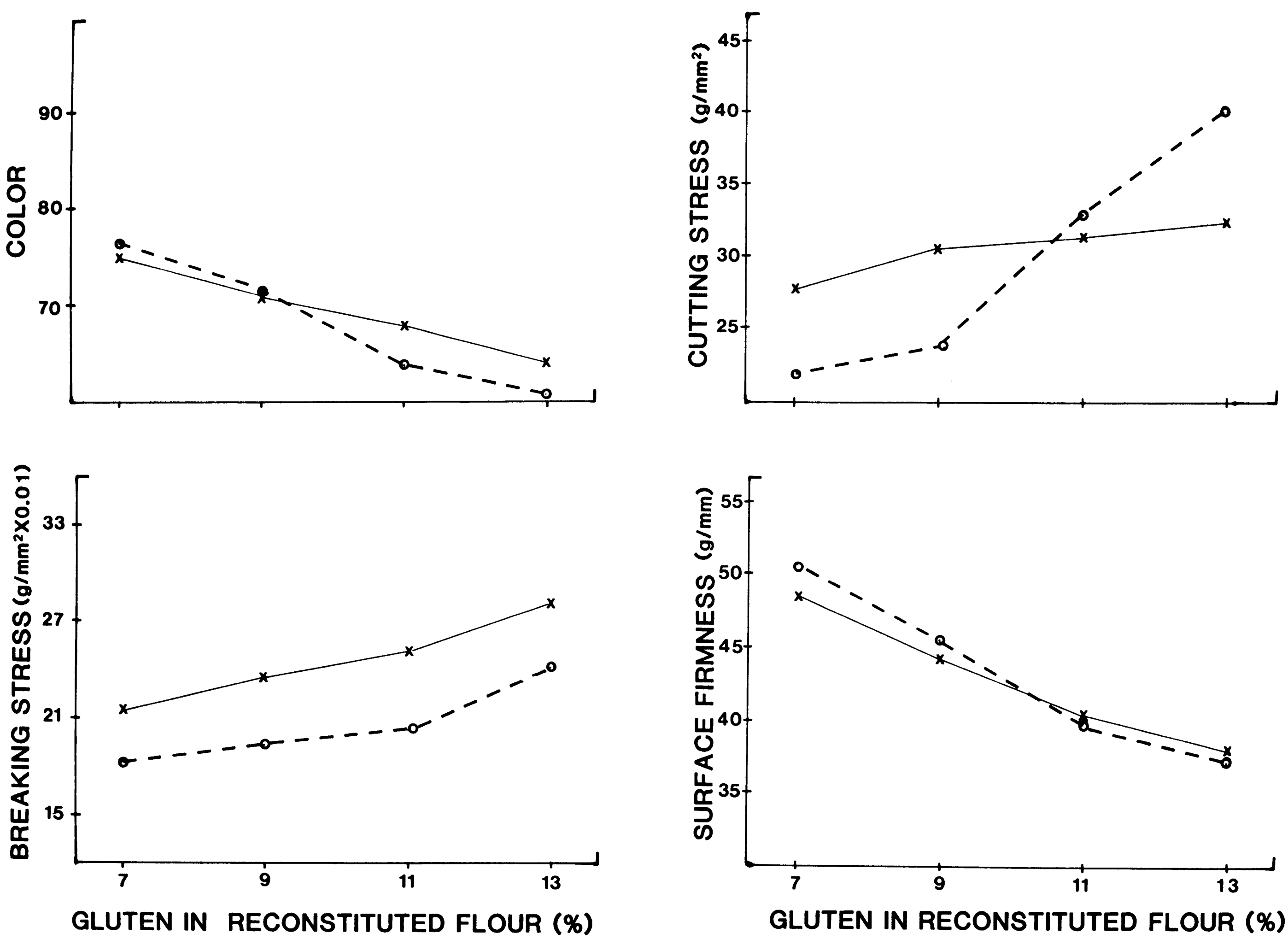

Fig. 2. Properties of noodles made from the nongluten fraction of commercial hard red winter wheat flour and the two gluten fractions added separately. The total mass in each reconstituted flour was the same. Western white gluten (O) or commercial hard red winter gluten (x). Least significant difference at $P < 0.05\%$ was as follows: color, 1.8; breaking stress, 156 g/mm^2; cutting stress 1.7 g/mm^2; and surface firmness, 2.5 g/mm.

breaking stress (Table II). Cooking time was reduced, but cutting stress of the cooked noodles increased, indicating an increase in chewiness. On the other hand, surface firmness decreased, and cooking losses increased approximately 1% when the flour was defatted. Recently, Matsuo et al (1986) reported that cooked spaghetti prepared from defatted semolina is stickier than control spaghetti and showed increased cooking loss.

Reconstituting the flours with free lipids generally restored their original properties, except that cooking time was significantly reduced. Increasing lipids 50% above the original levels gave noodles with a weakened structure, which is a typical shortening effect, but no change in surface firmness. Interchange of the free lipids between the WW and CHRW flours caused little difference in color, but breaking stress reduced significantly. The cutting stress of the cooked noodles showed no changes, but the surface firmness of the WW noodle was decreased significantly from 52.7 to 46.0 g/mm (Table II).

The nonpolar lipid (NL) fraction, which accounted for 66–72% of the free lipids in the flours, was largely responsible for the functionality of the free lipid. Using the defatted noodle for comparison in Figure 1, restoration of the NL fraction to the defatted flour, as compared to the glycolipid (GL) and the phospholipid (PL) fractions, usually decreased breaking stress of dry noodles more but generally increased surface firmness of cooked noodles more. The cutting stress of the cooked noodle seemed to be influenced more by the PL than either the GL fraction or the NL fraction.

Noodles from Reconstituted Flours

The yield and protein content of the fractions isolated from the CHRW and WW flours, as well as the distribution of dry matter and protein in the fractions, are given in Table III. The gluten and nongluten fractions (starch plus water solubles) used in the reconstitution-exchange experiments contained 80.6 and 14.7% protein, respectively, for CHRW compared with 81.3 and 18.5% for WW.

TABLE IV
Properties of Noodles Made from Parent and Reconstituted Flours[a]

	Dry Noodle		Cooked Noodle		
Flour	Color	Breaking Stress (g/mm^2)	Cooking Time (min)	Cutting Stress (g/mm^2)	Surface Firmness (g/mm)
CHRW[b]					
Parent	66.0	3,397	14	36.0	37.8
Reconstituted A	67.9	2,498	10	31.1	40.4
Reconstituted B	67.1	3,260	10	36.6	39.5
WW[c]					
Parent	89.0	1,462	10	23.5	52.7
Reconstituted A	88.2	1,220	8	23.6	56.7
Reconstituted B	89.4	1,477	8	22.6	54.8
LSD ($P < 0.05$)	1.6	142	1	1.7	2.2

[a] Flours were reconstituted using method A or B (Materials and Methods).
[b] Commercial hard red winter wheat.
[c] Western white wheat.

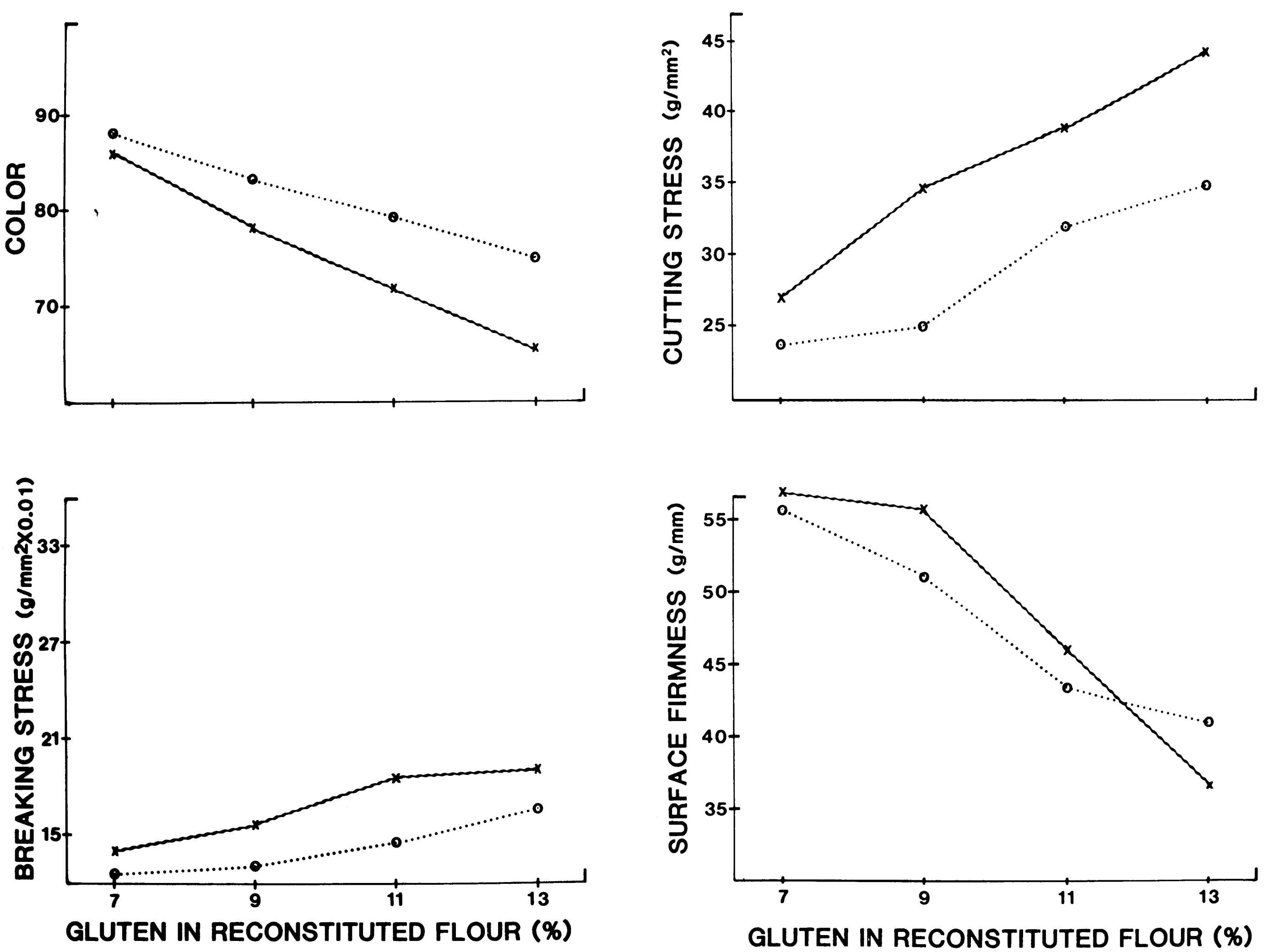

Fig. 3. Properties of noodles made from the nongluten fraction of western white wheat flour and the two gluten fractions added separately. The total mass in each reconstituted flour was the same. Western white gluten (O) or commercial hard red winter gluten (x). Least significant difference at $P < 0.05\%$ was as follows: color, 1.2; breaking stress, 132 g/mm^2; cutting stress 1.5 g/mm^2; and surface firmness, 2.1 g/mm.

When the flours were reconstituted by dry blending the fractions followed by humidifying (method A), the noodles made from those reconstituted flours showed reduced breaking stress, reduced cooking time, reduced cutting stress, and increased surface firmness (Table IV). Color was not affected. It is apparent that noodles from the flours reconstituted by method A, especially those from the CHRW wheat flour, had a weaker structure than those from the original flour.

Fractionation and reconstitution experiments on cookie flours (Doescher 1986) and on cracker flours (Rogers 1987) recently confirmed Yamazaki's (1955) early finding that an extra step is needed to reconstitute flours used in low-moisture formulations of baking foods. In the extra step, the combined fractions are moistened with 40–45 parts of distilled water and then dried at room temperature. During wetting and drying of the combined fractions, it is hypothesized that some components reassociate to give structural features nearly the same as in the original flour. Those structural features appear to be particularly important during processing and cooking of low-moisture doughs.

In our fractionation-reconstitution work on noodles, it appears that when the dry-blended flour fractions were used to bake noodles, most of the starch, gluten, and other hydrophilic molecules were exposed and competed for the limited water added to the formula. However, when noodles were made from the original flours, it may be that the surface molecules of flour particles were heavily hydrated, especially in the hard wheat flour. Polymers nearer the center of a flour particle could remain relatively dry. During sheeting of the noodle dough, the flour particles with heavily hydrated surfaces would give strong bonding and strong noodles. When an extra hydration and drying step was used during reconstitution (method B), the noodles from reconstituted flours approached those made from the original hard and soft wheat flours (Table IV).

We used method A in our reconstitution-exchange work before we tested method B. Even though the noodles reconstituted using method B were somewhat weaker than those from the original flours, consistent trends in noodle properties were observed for reconstituted flours and for reconstituted flours with exchanged fractions. Figures 2 and 3 show that noodle whiteness and surface firmness decreased with increasing gluten (above 7%) in the flours, whereas breaking stress and cutting stress increased, although the increase for gluten from CHRW was slight. Generally, compared with the soft wheat gluten, the hard wheat gluten gave higher breaking strength and cutting stress up to approximately 10.7% gluten, regardless of the source of the nongluten fraction. However, increasing levels of gluten from either the hard or soft wheat flour were equally detrimental to surface firmness. The nongluten fraction of WW flour gave whiter noodles and higher surface firmness, except at a higher gluten level, but lower breaking stress than the nongluten fraction from CHRW flour. However, no clear trends were found for cutting stress (compare Figs. 2 and 3).

Other workers previously reported that an increase in flour protein correlated with an increase in color, cooking time, and internal firmness in noodles (Oh et al 1985c, Miskelly 1984). After fractionation and interchange of fractions on two hard wheat flours, Oh et al (1985d) reported that protein quality influenced

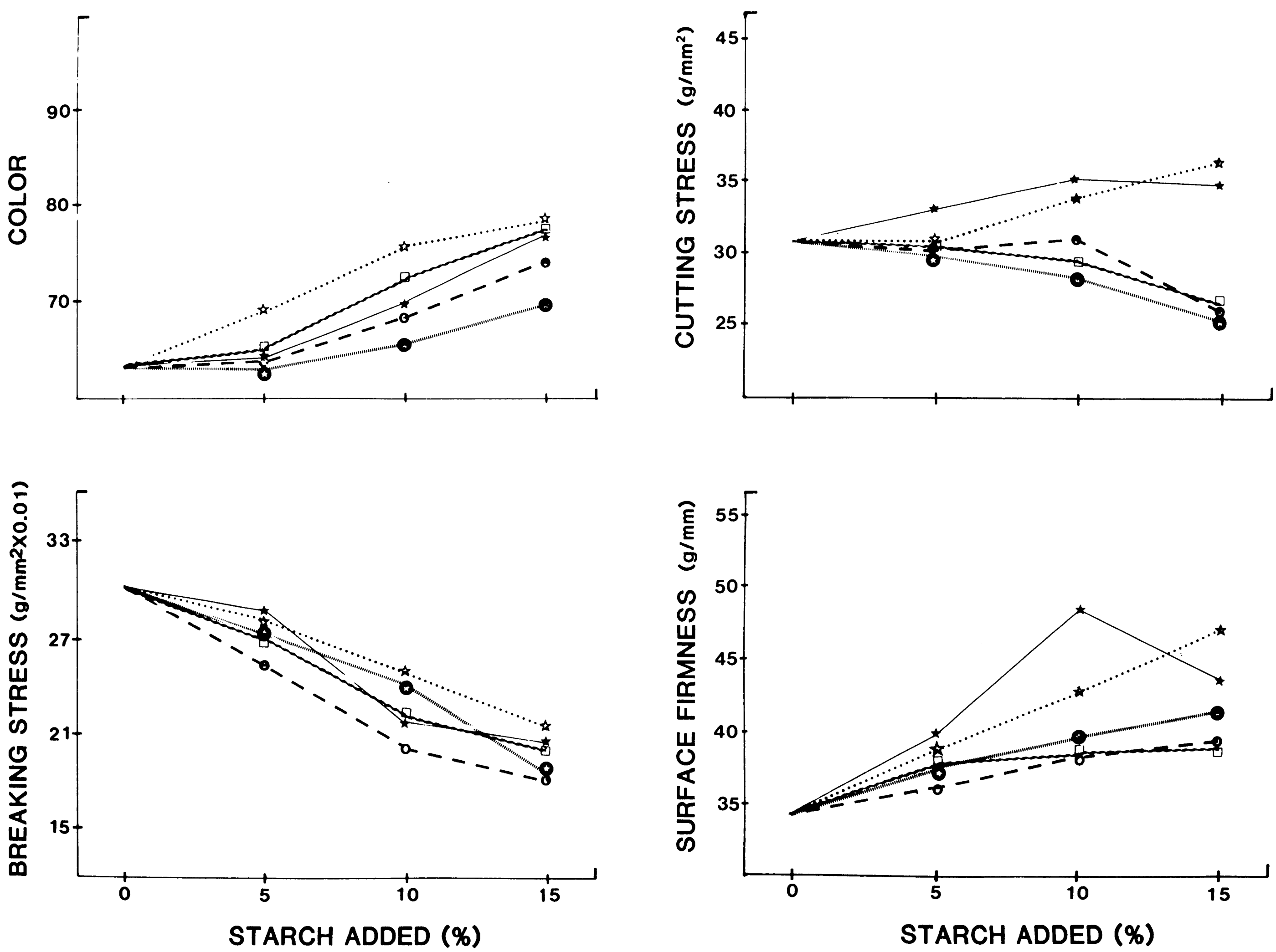

Fig. 4. Characteristics of dry noodles made from commercial hard red winter wheat flour to which was added 5, 10, and 15% of modified wheat starch (★), waxy corn (✪), potato (☆), corn (□), and wheat starch (○).

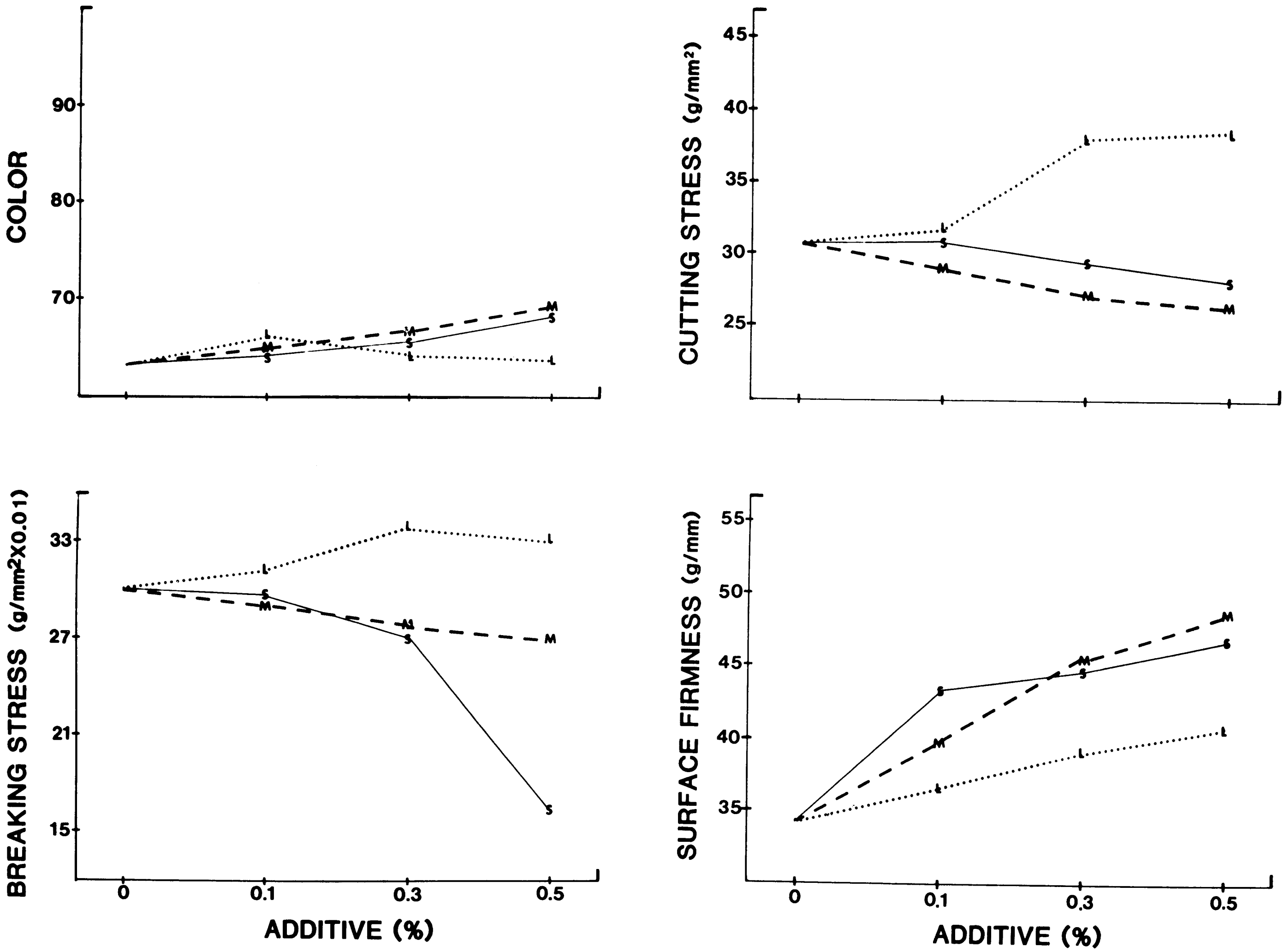

Fig. 5. Characteristics of dry noodles made from commercial hard red winter wheat flour to which was added sodium stearoyl-2-lactylate (**S**), monoglyceride (**M**), and lecithin (**L**). Least significant difference at $P < 0.05\%$ was as follows: color, 1.8; breaking stress, 156 g/mm^2; cutting stress, 1.9 g/mm^2; and surface firmness, 2.5 g/mm.

surface firmness. However, our results showed that gluten from soft and hard wheats was equally detrimental to surface firmness. Additional information is needed to determine how protein in soft and hard wheat affects the surface firmness of cooked noodles.

Addition of Starch to Hard Wheat Noodle Flour

At high levels, the starches improved the whiteness of noodles, but they weakened breaking stress (Fig. 4). At the 10–15% level, all starches increased surface firmress, especially waxy corn starch. Modified wheat starch improved surface firmness dramatically at 10% but was less effective at 15% for some unknown reason.

The various starches affected the cutting stress of the cooked noodles differently. Waxy corn starch and modified wheat starch increased cutting stress, while potato, corn, and wheat starches decreased cutting stress, especially at the 15% addition.

The modified wheat starch showed high swelling power in the amylograph and good stability against shear and heat (data not shown). It is hypothesized that the modified wheat starch improved the surface firmness of cooked noodles because it swelled to fill many of the voids between gluten fibrils, yet avoided disintegration because of its resistance to the shearing action of boiling water.

Effects of Surfactants on Noodles from Hard Wheat Flour Flour

Among the three surfactants, lecithin appeared unique; it increased the internal binding forces in the noodle as evidenced by increased breaking stress and cutting stress (Fig. 5). In contrast, monoglycerides and SSL seemed to weaken somewhat the noodle structure, since breaking stress and cutting stress decreased (Fig. 5). Monoglycerides and SSL improved surface firmness from 34 g/mm with no additive to 45 g/mm at the 0.5% level; lecithin was much less effective in improving surface firmress. We found that all three surfactants improved sheetability of the noodle dough.

CONCLUSIONS

Lipids added to noodles affect quality differently. Lecithin increases the cutting stress of cooked noodles made from a hard wheat flour but does not increase surface firmness; the opposite is true for monoglycerides and sodium stearoyl-2-lactylate. Some starches improve noodle texture while others are detrimental. It appears that reconstitution of noodle flours after wet fractionation should include a rewetting of the blended fractions followed by drying at 25° C.

ACKNOWLEDGMENTS

The authors thank the Kansas Wheat Commission for financial support; Paul Mattern, Gary Paulsen, and Gordon Rubenthaler for wheat samples; and Steve Curran for milling of wheats.

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[Received June 30, 1988. Revision received February 21, 1989. Accepted February 23, 1989.]