CEREAL CHEMISTRY

VOL. 40 JULY, 1963 NO. 4

PERFORMANCE OF FATS AND OILS IN PASTRY AND BISCUITS[1]

RUTH H. MATTHEWS AND ELSIE H. DAWSON[2]

ABSTRACT

The performance of corn oil, cottonseed oil, soybean oil, lard, and two hydrogenated vegetable fats, each at five different levels, was measured in pastry and in baking-powder biscuits. The fats and oils used were produced for the retail market.

Taste panel evaluations of tenderness and flakiness showed highly significant correlations with physical measurements. Under the conditions of this research, the oils were more efficient shortening agents in pastry, and the solid fats in baking-powder biscuits. Pastry was nearest optimum in quality characteristics at the 45% level of oil, and at the 51% level of solid fat. In baking-powder biscuits, a level of fat between 25 and 38% was optimum for all six fats.

For good-quality pastry, even distribution and high specific gravity of oil droplets or fat crystals are important. In baking-powder biscuits, however, plasticity and low specific gravity, as well as fine crystals of fats, are essential for good shortening ability. Good-quality pastry and baking-powder biscuits were made with any one of the fats and oils investigated.

Little research has been reported in the literature in recent years on the shortening performance of fats and oils marketed for household use. In 1938 Lowe, Nelson, and Buchanan (9) investigated shortening values of various lards and hydrogenated cottonseed oil by measuring the breaking strength of pastry and cookies. Hornstein and co-workers in 1943 (6) studied the effect of butter, various lards, hydrogenated vegetable oil, and margarine on the breaking strength of pastries and shortbread. In 1950 Hunter *et al.* (7) investigated the effect of hydrogenated shortening, margarine, and lard on batter structure, compressibility, and volume of cake. Hirahara and Simpson (4) reported recently on the microsopic appearance of gluten in pastry dough, establishing a relationship between gluten in unbaked dough and tenderness of baked pastry.

[1]Manuscript received June 1, 1962. Presented at the 47th AACC annual meeting, St. Louis, Mo., May 1962.

[2]Human Nutrition Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

Advances in food technology are apparent in the physical and chemical properties of shortenings. For nearly 50 years, vegetable oils and lards have been hydrogenated to some degree. Emulsifiers are being added to fats to help distribute the oil-soluble ingredients homogeneously throughout the baked product (11). Plasticization during processing has improved creamy smoothness, air content, and crystal structure of shortenings (12).

The present research was conducted on six kinds of liquid and solid fats produced for the retail market to determine their performance in pastry and in baking-powder biscuits. Performance at different levels of fat content was determined by tenderness as measured by breaking strength and shear force, and by flakiness, flavor, and tenderness as evaluated by a taste panel. The preparation methods for pastry and baking-powder biscuits were developed to yield flaky as well as tender products. Suitable mixing techniques were used for products made with liquid and solid fats.

It is well known that the shortening power of fats and oils varies with differences in temperature and mixing techniques. A constant room temperature of 74°F. and mixing techniques for small-quantity baking were chosen for this study because they are representative of conditions of consumer use. Tolerance tests involving the influence of various temperatures and baking procedures were not within the scope of this experiment.

The amount of water in the formula was the same for both fats and oils at each fat level, since moisture content is important in developing flakiness. Moisture content was further controlled by preparing samples in a laboratory with constant temperature and relative humidity, by baking in a well-regulated experimental baking oven, and by cooling for a constant length of time in the laboratory with controlled atmospheric conditions.

Materials and Methods

Six kinds of fats produced for the retail market were used in this research — corn, cottonseed, and soybean oils, a votated lard, and two vegetable fats hydrogenated to different end-points. Each lipid was analyzed for acid value and iodine number by the official method of the AOAC (1). Melting points of solid fats were determined with the Fisher-Johns melting-point apparatus. Specific gravity was determined on all samples. Viscosity of oils was taken using the Brookfield viscometer (Model LVF) with spindle 1 at 30 r.p.m. Consistency of solid fat was measured on the Precision penetrometer with the cone attachment and 250-g. weights for 5 sec.

All pastry and biscuit samples were prepared and physical measurements except melting-point determinations were taken in a laboratory with a controlled temperature of 74°F. and 60% r.h.

Statistical Design and Analysis. Separate randomized block designs (2) were used for the pastry and for the biscuits made with each of the six fats. Each of five levels of added fat was replicated four times. Analysis of variance and correlation coefficients were made. Differences between means were tested for significance by the method of Duncan and Bonner (3).

Preparation of Samples. Shortly before use, each fat or oil was purchased from a local market in the quantity required. One lot was obtained for each replication of each baked product. All other ingredients were purchased in large enough supply to complete all tests. Separate lots of all-purpose flour were used for the pastry and baking-powder biscuits. In pastry and biscuits the percentages of added fat, based on total weight of flour, and the volume ratios of flour to fat were as follows:

Pastry		*Baking-Powder Biscuits*	
Added Fat (% of wt. of flour)	*Vol. of flour / Vol. of fat*	*Added Fat (% of wt. of flour)*	*Fat (tbsp. per cup flour)*
25	8:1	6	½
33	6:1	13	1
41	5:1	25	2
45 (oils only)	4½:1	38	3
51	4:1	51	4
68 (solid fats only)	3:1		

The weight of water used in pastry made with 140 g. flour and in baking-powder biscuits made with 440 g. flour was constant for each level of added fat as follows:

Pastry		*Biscuits*	
Added Fat (% of wt. of flour)	*Wt. of Water*	*Added Fat (% of wt. of flour)*	*Wt. of Water*
	g.		*g.*
25	55	6	265
33	45	13	250
41	35	25	220
45	30	38	190
51	25	51	160
68	15		

Pastry and baking-powder biscuits were prepared in essentially the same manner. Electric household-type mixers were used for all mixing of dough. When solid fats were used, fat and dry ingredients were blended together and water was sprinkled into the mixture. For samples prepared with oil, a temporary emulsion of water and oil, made by shaking the mixture in a container, was sprinkled gradually into the dry ingredients.

Frames were used for rolling pastry dough to 3/32-in. and biscuit dough to 1/2-in. thickness. Pastry samples were cut into 1 3/8-in. by 2 1/4-in. rectangles and biscuit samples were cut into 2-in. rounds. Pastry was baked for 12 min. at 425°F. and biscuits for 15 min. at 450°F. in a rotary-hearth experimental baking oven.

Quality Evaluation of Samples. Palatability of the products was assessed by a taste panel of four staff members, trained to recognize slight differences in the quality factors. Pastry was scored 1.5 to 2 hr. after baking and the biscuits 8 to 10 min. after baking. Coded samples of pastry and biscuits were rated on 7 to 1 rating scales for tenderness and richness of flavor, and in addition, pastry was rated for flakiness.

Physical measurements were made on baked samples of pastry and baking-powder biscuits after they had cooled for 1 hr. in a laboratory with constant temperature and relative humidity. Breaking strength of pastry was measured on the Bailey shortometer. Shear force of top crusts of biscuits and shear force of whole biscuits were measured on the Warner-Bratzler shear machine and on the Kramer shear press, respectively. Moisture content of duplicate lots of baked pastry and of baked biscuits was determined on the Cenco moisture balance.

Results and Discussion

Fats and Oils. As expected, the oils were consistently more unsaturated than the solid fats, as shown by iodine values given in Table I.

TABLE I
PHYSICAL AND CHEMICAL MEASUREMENTS OF FATS AND OILS

Kind of Fat or Oil	Specific Gravity	Viscosity of Oil	Consistency of Fat	Acid Number	Iodine Number	Melting Point
		cp.	mm.			°C.
Liquid						
Corn oil	0.89	60.8	...	0.464	121	....
Cottonseed oil	.89	61.0	...	.406	112	....
Soybean oil	.92	64.6	...	.118	104	....
Solid						
Hydrogenated vegetable I	.83	...	21.8	.519	70	42–44
Hydrogenated vegetable II	.82	...	19.4	.212	88	40–44
Lard	0.86	...	17.8	0.616	62	41–46

Of the types of oils included in this research, soybean oil was highest in specific gravity and viscosity. Soybean oil is known to be higher than corn or cottonseed oils in linolenic acid (13). Of the types of solid fats used, lard was most firm and most saturated. The fats and oils in order of decreasing free fatty acid content were lard, hydrogenated vegetable fat I, corn oil, cottonseed oil, hydrogenated vegetable fat II, and soybean oil.

Pastry: Tenderness. With increasing amounts of added fats in pastry from 25 to 51%, optimum tenderness was achieved at lower levels with corn, cottonseed, or soybean oils than with any one of the solid fats investigated. This finding was usually shown both by shortometer readings (Fig. 1) and by panel tenderness scores (Table II). Baked pastry samples made with different fats and oils were comparable in moisture content at any one level of added fat.

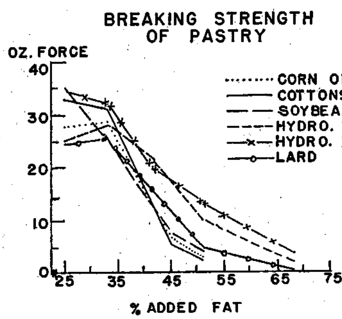

Fig. 1. Shortometer readings (breaking strength) of pastry made with six fats in five different levels.

Between the 25 and 51% levels of added fat there was a 26- to 31-oz. difference in breaking-strength readings and a 4.3- to 5.0-point difference in tenderness scores for oil pastries, in contrast with somewhat smaller differences in readings or scores for solid-fat pastries.

Shortometer readings of pastry made with 25 or 33% added fat or oil usually varied little between the two levels of added fat (Fig. 1). Soybean oil pastry was an exception, however, and was significantly more tender with the use of 33% added fat (25-oz. force) than with 25% added fat (35-oz. force).

Pastry samples made with the 41% level of corn, cottonseed, or soybean oil had nearly identical shortometer readings ranging from 13 to 14 oz.; those made with lard had readings of 16 oz.; and pastries made with hydrogenated vegetable fats I and II had readings of 22- and 20-oz. force, respectively. At the 45% level, only pastry made with

TABLE II

QUALITY CHARACTERISTICS OF PASTRY MADE WITH FATS AND OILS

KIND OF FAT OR OIL	ADDED FAT[a]	TENDERNESS SCORE[b]	FLAKINESS SCORE[b]	FLAVOR SCORE[b]
	%			
LIQUID				
Corn oil	25	1.2	1.5	1.2
	33	1.8	1.8	1.8
	41	3.5	3.4	3.4
	45	4.7	4.6	4.5
	51	5.5	5.1	5.3
Test difference[c]		0.4	0.8	0.6
Cottonseed oil	25	1.3	1.4	1.4
	33	1.8	2.2	2.0
	41	3.7	3.8	3.6
	45	4.9	4.6	4.9
	51	5.8	5.2	6.2
Test difference[c]		0.5	0.6	0.5
Soybean oil	25	1.1	1.1	1.1
	33	2.2	2.2	2.1
	41	4.9	4.2	4.6
	45	5.4	5.4	6.0
	51	6.1	6.6	6.9
Test difference[c]		0.8	0.4	0.5
SOLID				
Hydro. veg. fat I	25	1.8	1.8	1.6
	33	1.8	2.3	1.8
	41	3.3	3.2	3.4
	51	4.4	4.0	4.7
	68	5.7	5.2	6.0
Test difference[c]		0.4	0.7	0.5
Hydro. veg. fat II	25	1.2	1.3	1.2
	33	2.0	1.9	1.9
	41	3.6	3.8	3.9
	51	5.1	5.1	5.3
	68	6.6	6.8	7.0
Test difference[c]		0.7	0.7	0.7
Lard	25	1.6	2.1	1.6
	33	2.8	2.9	3.0
	41	4.1	4.0	3.9
	51	5.4	4.6	5.1
	68	6.6	5.6	6.6
Test difference[c]		0.5	0.7	0.5

[a] Based on total weight of flour.

[b] Mean of 16 scores (four scores × four replications). Rating scales were as follows: Tenderness: 7, crumbly; 6, slightly crumbly; 5, tender; 4, moderately tender; 3, slightly tough or firm; 2, moderately tough or firm; 1, very tough or firm. Flakiness: 7, compact, too fine; 6, indistinct layers; 5, many thin layers; 4, thin layers; 3, thick and thin layers; 2, thick layers; 1, few thick layers. Flavor (richness): 7, excessively rich; 6, slightly fatty; 5, natural, rich, well-blended; 4, moderately rich; 3, slightly rich; 2, slightly lean; 1, lean, flat.

[c] The difference between two means is significant if it equals or exceeds the test difference (3).

cottonseed oil was significantly more tender than corresponding pastry at the 41% level.

At the 41% level of added fat in pastry, fats and oils that were highest in shortening quality, as shown by shortometer readings, were usually highest in specific gravity. Among the oils, soybean oil was most viscous and highest in shortening quality at the 41% level. Of the solid fats at the 41% level, lard was most firm in consistency and highest in shortening quality.

Pastries containing 51% added fat (listed in order of decreasing tenderness as indicated by higher shortometer readings in oz. force) were: cottonseed oil, 2.5; corn oil, 2.6; soybean oil, 4.2; lard, 4.8; hydrogenated vegetable fat I, 10.2; and hydrogenated vegetable fat II, 13.4. Pastries made with oil at the 45% level with readings of 5- to 8-oz. force were similar in tenderness to solid-fat pastries at the 51% level with readings of 5- to 13-oz. force.

Solid-fat pastries made with 68% added fat had breaking-strength readings ranging from 0.5 to 4.0 oz. Only pastry made with hydrogenated vegetable fat II was significantly more tender with 68% added fat than with 51%.

For assessing shortening values, the most critical level of fat appeared to be 41%. At the lower level of 25 or 33%, little fat is present in the product and therefore the tenderizing property of the fat is of less importance in the tenderness of the pastry. Oil pastries at the 51% level and solid-fat pastries at the 68% level were considered too tender. It is known that pastries made with high amounts of fat or oil vary little in tenderness regardless of the type of fat used (8).

Tenderness scores for pastries made with oils were nearest the optimum score of 5 at the 45% level (Table II). Solid-fat pastries were nearest optimum tenderness at the 51% level, with scores ranging from 4 to 5. At the 68% level of added fat, pastry samples scored from approximately 6 to 7 for tenderness, indicating they were too crumbly.

From 79 to 96% of the variation in tenderness scores was associated with variation in breaking-strength readings as shown by correlation coefficients. The correlation coefficients between tenderness scores and breaking-strength readings showed a closer association for pastries made with hydrogenated fat II ($r = -0.98$) than for pastries made with hydrogenated vegetable fat I ($r = -0.90$).

Pastry: Flakiness. The number and the thickness of layers in pastry was evaluated as flakiness. Optimum scores were given to samples with many thin layers. Pastry samples with indistinct layers were rated too flaky, with scores above 5.0; those with thick layers were considered not flaky enough and scored lower than 5.0. Optimum flakiness in pastry was reached at different levels for the different fats and oils; from 41 to 45% added fat for soybean oil; from 45 to 51% for corn oil, cottonseed oil, and hydrogenated vegetable fat II; and between 51 and 68% for lard and hydrogenated vegetable fat I (Table II). The most- to least-flaky pastries in a customary proportion of flour to fat were at the 51% level: soybean oil, cottonseed oil, corn oil, hydrogenated vegetable fat II, lard, and hydrogenated vegetable fat I. Pastries that scored high for flakiness also scored high for tenderness (Fig. 2).

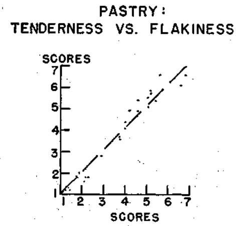

Fig. 2. Relation of tenderness and flakiness in pastry.

Flakiness scores and breaking-strength readings were correlated (r = −0.83 to −0.99, significant at 1% level). The lowest and the highest correlations were for hydrogenated fats I and II, respectively.

Pastry: Flavor. Scores for richness of flavor in pastry varied according to the level of added fat and according to the kind of fat (Table II). Soybean oil pastry was considered nearest optimum in richness of flavor (score of 5) at the 41% level; cottonseed oil pastry at the 45% level; and corn oil pastry at a level between the 45 and 51% levels. The three solid-fat pastries were nearest optimum in richness of flavor at the 51% level. Pastry made with 68% added solid fat was rated excessively rich and fatty. These findings differ from those of Wheeler (14), who stated that a minimum of 60% added fat is needed for desirable eating quality and richness in pastry. He also reported that many commercial pastries contain from 75 to 80% added fat.

Baking-Powder Biscuits: Tenderness. Shear readings of top crusts and of whole biscuits decreased and tenderness scores increased consistently as the fat level was raised from 6 to 51%, indicating increases in tenderness of baked biscuits (Fig. 3 and Table III). Moisture content of baked biscuits made with the different fats and oils was comparable at each of the levels of added fat investigated.

Whole biscuits made with the 25% level of any one of the solid fats were more tender (shear readings of 275 to 333 lb.) than whole biscuits made with an equal amount of any one of the oils (shear readings of 352 to 362 lb.). Top crusts of biscuits made with solid fats were also more tender at the 25% level than crusts of biscuits made with

TABLE III

QUALITY CHARACTERISTICS OF BAKING-POWDER BISCUITS MADE WITH FATS AND OILS

Kind of Fat or Oil	Added Fat[a]	Shear Value of Top Crust[b] (Warner-Bratzler)	Palatability Scores[c]		
			Tenderness		Flavor
			Crust	Crumb	
	%	lb. force			
LIQUID					
Corn oil	6	8.2	1.6	1.9	1.8
	13	6.3	2.8	3.3	3.1
	25	3.8	4.6	4.5	4.5
	38	1.8	5.4	5.8	5.8
	51	0.6	6.8	6.6	6.6
Test difference[d]		1.6	0.7	0.5	0.6
Cottonseed oil	6	7.8	1.8	2.1	1.8
	13	6.7	2.3	2.8	2.6
	25	3.8	4.6	4.6	4.8
	38	1.8	5.4	5.8	6.0
	51	0.4	6.9	6.9	6.9
Test difference[d]		1.2	0.6	0.8	0.5
Soybean oil	6	8.4	1.2	1.4	1.2
	13	7.1	2.2	2.7	2.4
	25	4.6	3.7	4.4	4.3
	38	1.5	5.7	5.5	6.1
	51	0.1	6.8	6.6	6.9
Test difference[d]		1.2	0.7	0.6	0.3
SOLID					
Hydro. veg. fat I	6	7.1	2.4	2.6	2.2
	13	5.1	3.1	3.2	2.9
	25	3.1	4.3	4.4	4.2
	38	2.3	5.6	5.4	5.4
	51	1.4	6.2	6.1	6.2
Test difference[d]		1.0	0.6	0.6	0.6
Hydro. veg. fat II	6	6.0	1.7	1.8	1.8
	13	4.4	2.8	2.8	2.6
	25	2.7	4.6	4.6	4.4
	38	1.9	5.5	5.3	5.7
	51	1.1	6.6	6.5	6.8
Test difference[d]		0.8	0.7	0.7	0.6
Lard	6	7.6	1.7	1.9	1.7
	13	5.8	2.4	2.8	2.6
	25	3.5	4.0	4.2	4.4
	38	2.7	5.1	5.4	5.5
	51	1.2	6.1	6.1	6.5
Test difference[d]		0.9	0.8	0.4	0.8

[a] Based on total weight of flour.
[b] Mean of 16 values (four readings × four replications).
[c] Mean of 16 scores (four scores × four replications). Rating scales were as follows: Tenderness of crust: 7, crumbly; 6, slightly crumbly; 5, tender; 4, moderately tender; 3, slightly hard; 2, moderately hard; 1, very hard. Tenderness of crumb: 7, crumbly; 6, slightly crumbly; 5, tender; 4, moderately tender; 3, slightly tough; 2, moderately tough; 1, very tough. Flavor (richness): 7, excessively rich; 6, slightly fatty; 5, natural, rich, well-blended; 4, moderately rich; 3, slightly rich; 2, slightly lean; 1, lean, flat.
[d] The difference between two means is significant if it equals or exceeds the test difference (3).

oils. At the higher levels of 38 and 51% added fat, biscuits made with oils had more-tender crusts than those made with solid fats.

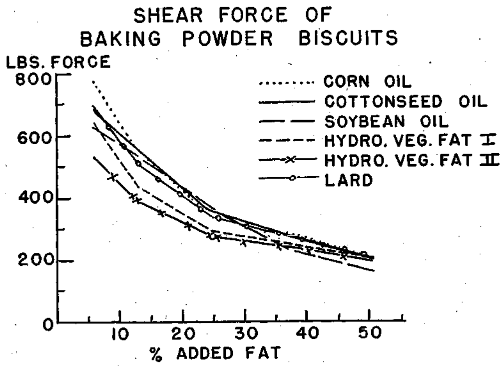

Fig. 3. Kramer shear readings of whole baking-powder biscuits made with six fats in five different levels.

The most- to least-effective shortenings in biscuits made with two levels of fat as shown by shear readings of whole biscuits were as follows:

Added Fat, 25% Level	*Added Fat, 38% Level*
Hydrogenated vegetable fat II	Soybean oil
Hydrogenated vegetable fat I	Hydrogenated vegetable fat II
Lard	Hydrogenated vegetable fat I
Cottonseed oil	Cottonseed oil
Corn oil	Lard
Soybean oil	Corn oil

At the 25% level of added fat in biscuits, the fats and oils that ranked highest in shortening ability, as measured by shear of whole biscuits, were lowest in specific gravity. Of the solid fats, the more unsaturated, the better their shortening power in biscuits. In either the solid or the liquid fats, free fatty acid content did not appear to influence their shortening power in biscuits at the 25% level of added fat.

Baking-powder biscuits, made with 33% added fat, were analyzed by Matthews *et al.* (10) and found to contain approximately two to three times more fat in the baked product than frozen biscuits, or biscuits made from commercial mixes.

Palatability scores for crust and crumb tenderness showed a consistent, but not always significant, increase in tenderness with increases in percent added fat in the formula. Optimum scores for both palatability factors occurred between the 25 and 38% levels of added fat. Tenderness scores and shear readings of top crusts were closely associated, as shown by correlation coefficients of −0.91 to −0.98. Crumb-tenderness scores and shear readings of whole biscuits were also significantly correlated ($r = -0.87$ to -0.98).

Crust and crumb of biscuits made with 25% added corn or cottonseed oils were scored about equal in tenderness to biscuits made with the same level of hydrogenated vegetable fats I and II. Biscuits made with soybean oil or lard were slightly less tender than biscuits made with the four previously mentioned fats and oils. The flaky crusts and layered crumb of corn- or cottonseed-oil biscuits may explain the high scores for tenderness which do not agree closely with shear force readings of biscuits.

Baking-Powder Biscuits: Flavor. Optimum richness in flavor was attained with 25% added fat for cottonseed-oil biscuits (score 4.8) Biscuits made with other fats at this level were scored as follows: corn oil, 4.5; hydrogenated vegetable fat II, lard, and soybean oil, 4.4; and hydrogenated vegetable fat I, 4.2. At the 38% level, flavor of pastries made with all fats scored above 5.0, the optimum score. From these results, it appears that levels of added fat between 25 and 38% are needed for optimum richness in biscuits made with any of these fats and oils.

Relationships of Properties of Fats and Oils. As judged by the taste panel, tenderness scores for each baked product were influenced by the texture characteristic of flakiness. Flakier pastries and flakier layered biscuits in this experiment were rated more tender by the panel.

Performance of fats and oils in baked products was influenced by specific gravity and by the size of fat crystals or oil droplets. Oil and water droplets were distributed evenly throughout the dry ingredients by means of a water-in-oil emulsion. High specific gravity was important for shortening pastry and low specific gravity for shortening biscuits.

Hydrogenated fats are better shortening agents in biscuits than lards. The small *beta prime* crystals present in hydrogenated fats cover a larger surface area than the large *beta* crystals known to be present in most lards (5). The mono- and diglyceride emulsifiers in hydrogenated fats help distribute the fat-soluble ingredients homogeneously throughout baked products (11) and help retain moisture – two factors that contribute to tenderness in many baked products.

Within the scope of this study, it appears that 41% added fat in pastry and 25% added fat in biscuits were best for studying performance of different fats and oils. With high concentrations of fat in dough there is little discernible difference in shortening properties between fats and oils. Relative performance among fats and oils studied varied with the level of the fats used in the formula for pastry and biscuits mixed by standard methods. Good-quality pastry and baking-powder biscuits were made with either oil or solid fat when the proper amount of fat and proper mixing techniques were used. The use of other procedures would probably have given different results than those reported here.

A fat or oil that was particularly good for shortening pastry was not necessarily as good for shortening biscuits. Therefore, quality evaluations of fats need to be made in the baked products in which the fat is to be utilized.

Acknowledgments

The authors wish to express their thanks to JoElissa Larsen and Sandra Wood for their assistance in preparation of samples and in carrying out the physical measurements; to Jacob N. Eisen for his statistical analysis of the data; and to James P. Sweeney, Margaret Hoke, and Margaret Martin for analysis of the fat and oil samples.

Literature Cited

1. Association of Official Agricultural Chemists. Official methods of analysis (9th ed.). The Association: Washington, D.C. (1960).
2. Cochran, W. G., and Cox, Gertrude M. Experimental designs. Wiley: New York (1950).
3. Duncan, D. B., and Bonner, R. C. Simultaneous confidence intervals derived from multiple F and range tests. Va. Agr. Expt. Sta., Tech. Rpt. 10a (1954).
4. Hirahara, Sachiye, and Simpson, Jean I. Microscopic appearance of gluten in pastry dough and its relation to the tenderness of baked pastry. J. Home Econ. **53:** 681–686 (1961).
5. Hoerr, C. W. Morphology of fats, oils, and shortenings. J. Am. Oil Chemists' Soc. **37:** 539–546 (1960).
6. Hornstein, Lydia R., King, Florence B., and Benedict, Frances. Comparative shortening value of some commercial fats. Food Research **8:** 1–12 (1943).
7. Hunter, Mildred B., Briant, Alice M., and Personius, Catherine J. Cake quality and batter structure. N.Y. Agr. Expt. Sta., Bull. 860 (1950).
8. Lowe, Belle. Experimental cookery. Wiley: New York (1955).
9. Lowe, Belle, Nelson, P. Mabel, and Buchanan, J. H. The physical and chemical characteristics of lard and other fats in relation to their culinary value. I. Shortening value in pastry and cookies. Iowa Sta. Coll. Agr. Expt. Sta., Research Bull. 242 (1938).
10. Matthews, Ruth H., Murphy, Elizabeth W., Marsh, Anne C., and Dawson, Elsie H. Baked products — consumer quality, composition, yield, and preparation time of various market forms. U.S. Dept. Agr., Home Econ. Research Rpt. 22 (in press).
11. Pratt, C. D., and Hays, W. W. Food emulsifiers bring new highs in uniformity. Food Eng. **24:** 109–112 (1952).
12. Rini, S. J. Refining, bleaching, stabilization, deodorization, and plasticization of fats, oils, and shortening. J. Am. Oil Chemists' Soc. **37:** 512–520 (1960).
13. United States Department of Agriculture. Fatty acids in food fats. Home Econ. Research Rpt. 7 (1959).
14. Wheeler, F. G. Let's make quality pies. Bakers' Weekly **192:** 34–36 (1961).