PERFORMANCE OF FATS IN WHITE CAKE[1]

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ABSTRACT

A variety of physical measurements was used to assess performance of fats and eating quality of white cake. Specific gravity and viscosity of batters varied according to the kind of fat. Hydrogenated fats contributed to low specific gravity and high viscosity of batter, whereas the reverse was true with the use of margarines. Butter contributed to intermediate viscosity readings and low specific gravity readings. Shear-force readings of cake made with the three higher levels of fat (50, 75, or 100%, based on weight of flour) did not vary greatly among the fats. Panel evaluations of tenderness, velvetiness, and evenness of grain varied among the fats. Cakes made with butter rated highest for tenderness and velvetiness, and those made with hydrogenated vegetable fat rated highest for evenness of grain. Viscosity of batters and shear-force measurements of cakes were good methods for assessing the performance of fats in cakes, as illustrated by high correlations with panel scores for tenderness, velvetiness, and evenness of grain of cakes. Volume index of cake was also a good measure of the performance of fat and the eating quality of cakes; compressibility was found to be a rather poor measure of performance.

New types of fats available for household use have come on the market and into use in recent years. No research on their performance in batters and cakes has been reported in the literature, however. Research on five fats in white cake was conducted to ascertain differences among household fats in tenderizing and softening ability of cake crumb as well as in other functional quality characteristics of batters and baked cakes. A white cake formula was selected to avoid adding significant amount of fat from ingredients other than the fat being investigated. For this reason, nonfat dry milk was used in place of fresh whole milk in the formula. Amount of egg white was increased concomitantly with amount of fat to provide needed emulsification.

Results of research on performance of fats and oils in pastry and biscuits were reported previously by the authors (1). In the research reported here, emphasis was placed on the effects of kind and level of fat on eating quality of cake and on the effectiveness of physical measurements in assessing eating quality.

Materials and Methods

Preparation of Samples. Cakes were prepared and physical measurements were taken in a laboratory with a controlled temperature of 74°F. and relative humidity of 60%.

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Five fats produced for the retail market were used in white cake: butter; two hydrogenated fats with mono- and diglycerides added (one fat made of all vegetable oil and the other, a mixture of vegetable oil and animal fat); and two kinds of margarine, corn oil type and regular type, which was made from a mixture of soybean and cottonseed oils. For representative sampling, separate lots of fat were obtained for each day's experiments. Other ingredients — cake flour, sugar, instantized nonfat dry milk, salt, and baking powder — were purchased in quantities large enough to complete all tests. Fresh eggs from one source were obtained weekly; a composite sample of egg whites was made each day of preparation. Nonfat dry milk was blended with the other dry ingredients and water was added as the liquid.

Before final formulas for cakes could be established, triplicate samples of each fat, procured on different days, were analyzed for fat, sodium chloride, and water content. Weights of fat, sodium chloride, and water were adjusted accordingly. Each fat sample was analyzed for acid value, iodine number, and moisture content by official methods of the AOAC (2). Fat content was determined by Soxhlet extraction and sodium chloride content by the Schonberg procedure. Melting point range was determined with the Fisher-Johns melting apparatus and consistency measurements with the Precision penetrometer by methods described previously (1).

Levels of Fat Investigated. Each fat was used in five levels, 12.5, 25, 50, 75, and 100%, based on the weight of flour. The levels of 25, 50, and 75% are similar to those customarily used in white cakes by many homemakers. To provide needed emulsification of fat in the batter, egg whites were increased 15% (based on weight of flour) for each increment of fat in the formula. Amounts of ingredients calculated as a percentage of the total weight of ingredients are shown in Table I.

TABLE I

FORMULAS FOR WHITE CAKES MADE WITH FIVE LEVELS OF FAT

LEVEL OF FAT[a]	INGREDIENTS[b]							
	Fat	Flour	Sugar	Salt	Baking Powder	Nonfat Dry Milk	Water	Egg Whites
%	%	%	%	%	%	%	%	%
12.5	3.8	30.3	30.3	0.8	2.3	2.3	25.7	4.5
25.0	7.1	28.3	28.3	0.7	2.2	2.2	22.7	8.5
50.0	12.9	25.8	25.8	0.6	2.0	2.0	19.3	11.6
75.0	17.7	23.6	23.6	0.6	1.9	1.9	16.5	14.2
100.0	21.8	21.8	21.8	0.5	1.7	1.8	14.2	16.4

[a] Based on weight of flour.
[b] Based on total weight of ingredients.

Measurements of Quality. Apparent viscosity of the batters at 74°F. (23.5°C.) was determined with the Brookfield viscometer (Model RVF) with spindle 6 at 20 r.p.m. On the baked cakes, measurements included compressibility as described previously by Matthews *et al.* (3); shear force on the Warner-Bratzler shear machine, with a slice of cake 3 cm. wide by 5 cm. long; and area of a center-cut slice (volume index), by the compensating polar planimeter (4).

A five-member taste panel evaluated the eating quality of each of the baked cakes for tenderness, velvetiness, and evenness of grain, as follows: tenderness – 7, crumbly, to 1, tough and rubbery; velvetiness – 5, velvety, to 1, harsh; evenness of grain – 7, too fine and even, to 1, coarse.

Statistical Design and Analysis. A factorial design using three replications was selected for preparation of cakes to compare kinds and amounts of fat. Five of the 75 cakes were prepared daily. Analyses of variance, Duncan's multiple range tests (5), and coefficients of correlation were computed.

Results and Discussion

Analyses of Fats. Results of chemical analysis and physical measurements on the fats are given in Table II.

TABLE II
CHEMICAL AND PHYSICAL MEASUREMENTS OF FATS

Kind of Fat	Acid Value		Iodine Value		Melting Point	Consistency Reading	
	Mean	Range	Mean	Range	Range	Mean	Range
					°C.	mm.	mm.
Butter	0.89	0.47–1.82	24	19–29	19.0–38.0	26.0	22.1–29.0
Hydrogenated vegetable and animal fat	0.28	0.17–0.56	51	46–55	35.0–45.0	20.9	17.9–22.2
Hydrogenated vegetable fat	0.25	0.18–0.62	74	64–83	29.0–44.0	19.7	18.9–20.3
Corn oil margarine	0.49	0.43–0.55	67	60–72	19.0–38.0	20.8	20.4–21.3
Regular margarine	0.48	0.44–0.56	62	53–67	19.0–37.0	19.5	18.2–21.9

Butter was the most saturated of the fats, as indicated by iodine values of 19 to 29, but consistency readings showed it to be the softest of the fats at room temperature. The hydrogenated fats and margarines were quite similar in consistency, 20 to 21 mm., and varied between 46 and 83 for iodine value. It appears, therefore, that iodine value has little or no connection with consistency readings for these fats.

The acid value was highest in butter and lowest in the hydrogenated fats. The melting point ranges for butter and the two types of margarines were nearly identical; those for the hydrogenated fats were somewhat different.

Quality of Batters and Cakes. Batters became lighter with added levels of each fat, as shown by low specific gravity determinations, because the fat ingredient aids in incorporating air into the batter. Under the conditions of this research, batters made with butter at the 12.5, 25, and 50% levels had significantly lower specific gravity than those made with corresponding levels of hydrogenated vegetable fat; at the 75 and 100% levels, however, specific gravity readings were quite similar. Batters made with either type of margarine were significantly higher in specific gravity than batters made with any other fat.

Viscosity of batters increased significantly with each increment after the 25% level of fat in the formula when data for all fats were combined (Fig. 1). However, data on the individual fats showed that

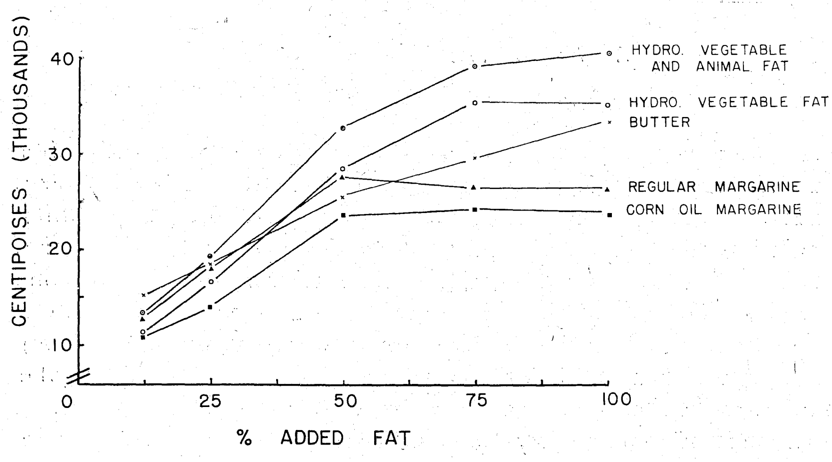

Fig. 1. Viscosity of cake batters made with five fats, each in five amounts.

differences were significant only for butter and hydrogenated vegetable and animal fat. Observations indicated that the emulsions made with margarines at the 75 and 100% levels were separated into clumped fat, the protein-starch suspension, and the aqueous fraction. Batters made with the 50% level of margarine were slightly or moderately curdled. At the 12.5% level, batters made with butter were significantly thicker than batters made with any of the other fats. At higher fat levels, batters made with hydrogenated vegetable and animal fat were thickest, followed in viscosity by batters made with hydrogenated vegetable fat, butter, and the two margarines. Because cake batters are non-Newtonian in nature, different combinations of speeds and spindles with the Brookfield viscometer would have given different viscosity readings (6).

Cakes became increasingly compressible up to the 50% level of fat; butter cakes were softest at the 75% level (Fig. 2). At the 25 or 50%

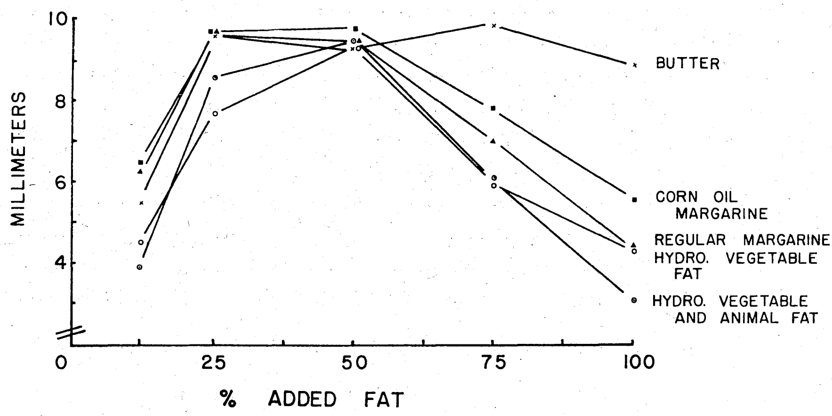

Fig. 2. Compressibility of cakes made with five fats, each in five amounts.

level, cakes made with butter or the margarines were significantly softer than cakes made with hydrogenated fats. With all kinds of fat used, cakes made with the 50% level of fat were about equal in compressibility, ranging from 9.3 to 9.8 mm. At the 75 and 100% levels, butter cakes were significantly more compressible than cakes made with any one of the remaining fats. When all levels were combined in the statistical analysis, cakes made with butter were most compressible (8.6 mm.), followed by those made with corn oil margarine (7.9 mm.), regular margarine (7.4 mm.), and the two hydrogenated fats (6.2 and 6.3 mm.). Assessment of cake quality by compressibility measurement was reported previously (3).

As shown in Fig. 3, cake usually increased significantly in volume index with each increment of most fats to the maximum at the 50% level and decreased significantly with succeeding increments. However, cakes made with corn oil margarine did not change significantly in volume index between the 25 and 50% levels. Kuhrt and Welch (7), in research using molecularly distilled monoglycerides, reported that the desirable shortening level in cake was 50% of the weight of the flour. They reported the volume of cake to be seriously diminished when the shortening level was reduced to 25% of the weight of the flour. In research reported here, cakes made with hydrogenated fats were highest or among the highest in volume index at nearly all fat levels. This was to be expected, because these fats contained added emulsifiers. Cakes made with 75 or 100% levels of either type of margarine were significantly lower in volume index than cakes made with the same levels of any other kind of fat.

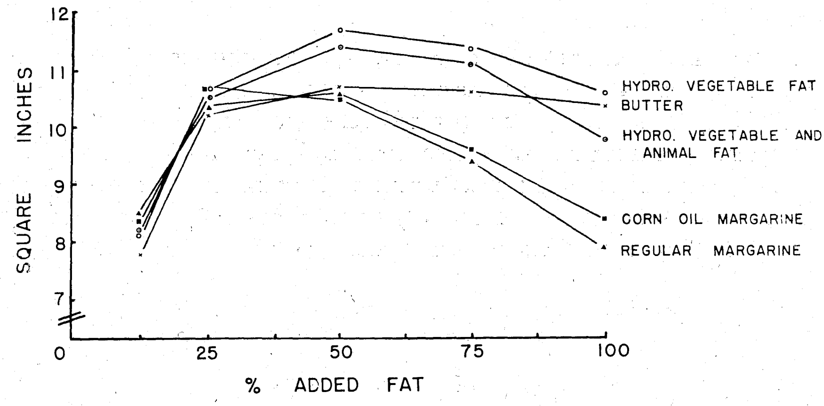

Fig. 3. Volume index of cakes made with five fats, each in five amounts.

Shear force of cake decreased significantly, indicating increases in tenderness, with increases in amount of fat in the formula from 12.5 to 100% (Fig. 4). At the 12.5% level of fat, the least to most tender cakes were those made with regular margarine, hydrogenated vegetable fat,

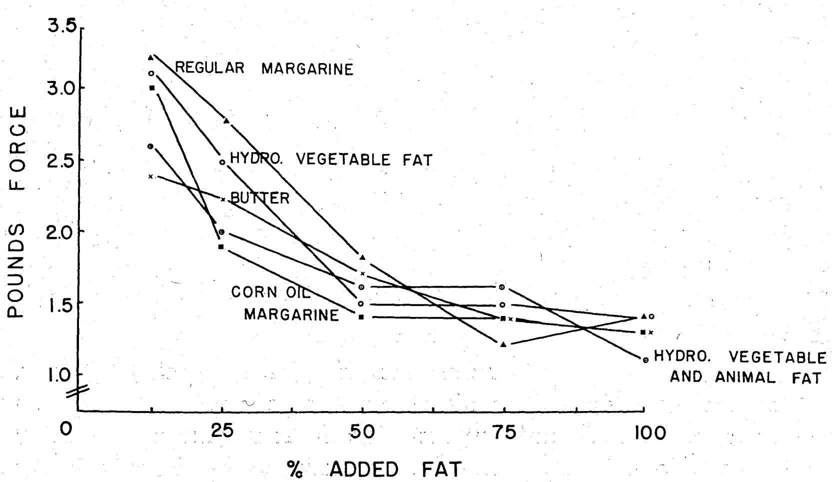

Fig. 4. Shear force of cakes made with five fats, each in five amounts.

corn oil margarine, hydrogenated vegetable and animal fat, and butter. At the 50% level, the least to most tender cakes were those made with regular margarine, butter, hydrogenated vegetable and animal fat, hydrogenated vegetable fat, and corn oil margarine. The first two were each significantly less tender than the remaining cakes. Cakes made with the 75 or 100% level of fat were similar in tenderness, regardless of the kind of fat used.

Eating quality characteristics of cake — velvetiness, tenderness, and evenness of grain — were significantly influenced by kind and amount of fat in the formula. The panel rated cakes made with butter among the highest in tenderness and velvetiness, and those made with hydrogenated vegetable fat, highest in evenness of grain. In most cases, the panel scored cakes made with the 50% level of fat nearest optimum in tenderness (Fig. 5) and those with higher levels, too crumbly. Cakes

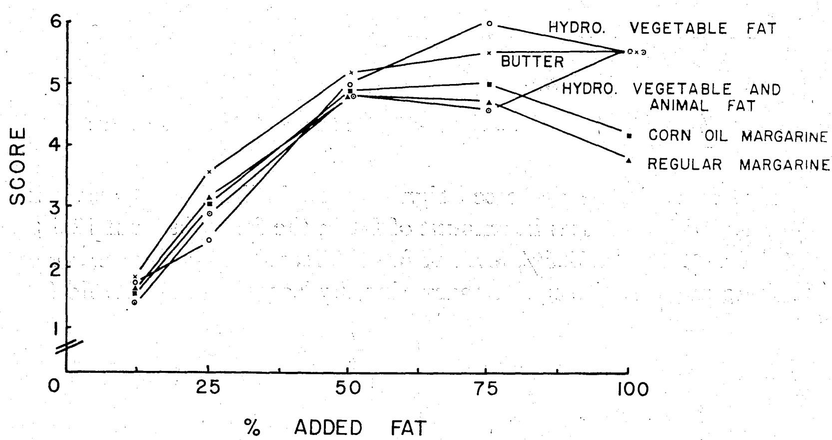

Fig. 5. Scores for tenderness of cakes made with five fats, each in five amounts.

rated nearest the optimum score for evenness of grain were made with the 50% level of fat (score 5.5). The most velvety cakes were made with the 50 or 75% levels (scores 4.6 and 4.5). Flavor scores of cakes made with the different kinds and amounts of fat were not significantly different from each other. Eating quality, in general, was considered best for cakes made with the 50% level of fat.

Relation of Physical Measurements and Panel Scores. Generally, batters with high viscosity readings made cakes that scored high in tenderness, velvetiness, and evenness of grain after baking; correlation coefficients were 0.81, 0.78, and 0.85, respectively, for all cakes in this study (Table III). A significant correlation between viscosity readings

TABLE III
CORRELATION OF PHYSICAL MEASUREMENTS OF BATTERS AND CAKES WITH PANEL SCORES FOR CAKES

PHYSICAL MEASUREMENTS	PANEL SCORES FOR CAKES		
	Tenderness	Velvetiness	Grain
Batters			
Viscosity	0.81**	0.78**	0.85**
Cakes			
Shear force	−0.81**	−0.81**	−0.83**
Volume	0.59**	0.64**	0.50**
Compressibility	0.23*	0.28*	0.06

of batters and shear-force readings of cakes confirmed the fact that thicker batters made more tender cakes. The relationship between viscosity of batter and volume index of cakes was also significant (r = 0.55), but explained only 30% of the variation between these two characteristics. The relationships between viscosity of batter and qualities of cake may have been different had other speeds or spindles, or both, been used with the Brookfield viscometer.

Shear-force measurements on the baked cakes were also good indicators of eating quality, as shown by the high correlations with panel scores for tenderness, velvetiness, and evenness of grain (Table III). Volume index was related to scores for tenderness, velvetiness, and evenness of grain, but the relations were not as close as shear-force readings and the panel scores.

The low correlation coefficients (0.23 and 0.28) between compressibility and tenderness or velvetiness scores indicated that this physical measurement was a rather poor assessment of these qualities of baked cake. Griswold (8) reported that compressibility is not a measure of tenderness, but a measure of firmness or softness. From the research reported here and the principle involved in this measurement, it appears that compressibility assesses elasticity rather than tenderness of cake. Compressibility readings were significantly related to the volume index of baked cakes (r = 0.59), but the correlation of compressibility with shear-force values of cake was not significant.

Acknowledgments

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Literature Cited

1. MATTHEWS, RUTH H., and DAWSON, ELSIE H. Performance of fats and oils in pastry and biscuits. Cereal Chem. **40:** 291–302 (1963).
2. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official methods of analysis (9th ed.). The Association: Washington, D.C. (1960).

3. 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. 39 pp. (1963).
4. HALLIDAY, EVELYN G., and NOBLE, ISABEL T. Food chemistry and cookery. Univ. of Chicago Press: Chicago, Ill. (1943).
5. DUNCAN, D. B. Multiple range and multiple F tests. Biometrics **11:** 1–15 (1955).
6. BROOKFIELD ENGINEERING LABORATORIES, INC. Solutions to sticky problems. Stoughton, Mass. n.d.
7. KUHRT, N. H., and WELCH, E. A. Molecularly distilled monoglycerides. II. Cake baking experiments. J. Am. Oil Chemists' Soc. **27:** 344–346 (1950).
8. GRISWOLD, RUTH M. The experimental study of foods. Houghton-Mifflin Co.: Boston, Mass. (1962).