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Elaidinized Lipid in Relation to its Effect on Batter Structure

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To the Graduate Council:

I am submitting herewith a thesis written by Rebecca Jane Snodgrass entitled "Elaidinized Lipid in Relation to its Effect on Batter Structure." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Ada Marie Campbell, Major Professor

We have read this thesis and recommend its acceptance:

Gracyce E. Goertz, Mary Jo Hitchcock

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 3, 1971

To the Graduate Council:

I am submitting herewith a thesis written by Rebecca Jane Snodgrass entitled "Elaidinized Lipid in Relation to Its Effect on Batter Structure." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science.

Ada Marie Campbell
Major Professor

We have read this thesis and recommend its acceptance:

Grayce E. Goertz

Mary Jo Hitchcock

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

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ELAIDINIZED LIPID IN RELATION TO ITS EFFECT ON BATTER STRUCTURE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Rebecca Jane Snodgrass

August 1971

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ABSTRACT

Batter aeration as affected by substitution of elaidinized lipid and related to other properties was investigated. Elaidinized lipid was substituted for hydrogenated safflower oil shortening at four levels, 0, 40, 60, and 80 percent,in the preparation of lipid samples. Lipid samples were characterized by gas-liquid and thin-layer chromatography and by melting point determination. Specific gravity and viscosity of the batters, volume index of the cakes, and lightness index of the crumb were determined. Batter structure was studied microscopically.

An increase in trans isomer concentration from 8.8 percent to 40.6 percent was accompanied by an increase in melting point from 41.0 to 47.1°C with increasing level of substitution. Batters from the unsubstituted shortening were most highly aerated, as indicated by specific gravity, and had the greatest dispersity of air and lipid, as indicated by microscopic sections. The decreased extent of emulsification was associated with decreased batter viscosity, as well as the decreased aeration. Volume index of cakes in part reflected differences in aeration. Decreased lightness index of cake crumb with increasing level of substitution resulted from the decreased light-reflecting surface and relatively poor aeration. Batter structure was not affected beneficially by substitution of elaidinized lipid for hydrogenated shortening under the conditions of this study.

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I. INTRODUCTION

The use of vegetable shortenings has increased in the United States during recent years. The majority of these shortenings are either hydrogenated vegetable oils or mixtures of hydrogenated and unhydrogenated oils. During the process of hydrogenation, oils are converted to plastic shortenings. A vegetable oil may be changed to a solid fat also by the process of elaidinization, in which the formation of trans isomers of unsaturated fatty acids is the chief chemical effect (Cochran et al., 1961).

Positional and geometric isomers are formed during hydrogenation (Eckey, 1954; Allen and Kiess, 1955; Swern, 1964). Hydrogenated shortenings available to Americans contain an average of 30 percent trans fatty acids (Mabrouk and Brown, 1956).

The functional properties of elaidinized lipids have not been studied until recently. Ostrander (1968) and Klouda (1969) studied shortening power of lipids as affected by substitution of elaidinized lipid. Willis (1971) investigated elaidinized lipid in relation to its effect on batter aeration, but actual batter structure was not observed. She indicated that an apparent effect of elaidinized lipid on aeration may have been influenced by a non-homogeneous distribution of the elaidinized lipid.

Relationships between the microscopic structure of batters and doughs and the quality of the resulting baked products were of interest in early studies (Carlin, 1944; Jooste and Mackey, 1952). Usually the quality of the baked product was assessed on the basis of volume and

sensory qualities. Pohl *et al.* (1968) reported a method of freeze-drying cake batter for microscopic study of batter structure. They considered the procedure to represent an improvement over study of batter smears.

In the present investigation batter aeration was studied in cake batters in which elaidinized lipid was substituted at four levels for a hydrogenated shortening. The shortenings were made homogeneous by melting and mixing. The structure of batter and cake was observed microscopically by the method recommended by Pohl *et al.* (1968).

II. REVIEW OF LITERATURE

Structure of Cake and Cake Batters

Handleman *et al.* (1961) reported that the cells of a cake originate as bubbles of incorporated air. The size distribution, inflation, movement, film permeability, and stability of the bubbles thus determine the strength, texture, volume, shape, and grain of cakes. Early research by Dunn and White (1939) indicated that the air cells either were trapped in the fat or collected at the oil-water interface. Results of Carlin (1944) and Kearney (1969) suggested that cake batters were suspensions of air bubbles in fat which in turn was distributed in a medium of flour and liquid.

Pohl *et al.* (1968), studying freeze-dried cake batters microscopically, reported that air bubbles were not incorporated primarily in the fat particles but were distributed throughout the aqueous phase. Similar results were obtained with several types of shortenings. Aeration was shown to be dependent on fat content. These workers postulated that air incorporated during mixing is trapped at the dough cleavage planes occurring at the aqueous-fat interfaces. The use of freeze-dried batters was considered to result in less distortion of structure than does the use of batter smears.

Microscopic studies of cake batters conducted by Jooste and Mackey (1952) revealed that cake batters were two-phase systems, the dispersed phase being fat and the continuous phase consisting of all other ingredients of the mixture. They further reported that a network of protein gave structure to the cake crumb and the fat appeared as a coating on the protein framework.

Carlin (1944), using a heating stage on a microscope, studied batter structure changes during baking. He found that the fat melted and released the air cells held in suspension during the first five minutes of baking. The air cells thus were transferred from the fat to the aqueous phase. The fat then collected in small lakes throughout the baking batter. Upon continued baking, the air spaces and fat globules appeared to flow with the aqueous medium along the path of a convection current. Little further coalescence between separate fat areas was observed; conversely, air spaces coalesced readily, as larger cells often absorbed the smaller ones. Rapid movement, distortions, and explosion of air spaces occurred as the baking process neared completion.

Relation of Fat to Batter and Cake Structure

Fat was designated by Kearney (1969) as a necessary ingredient in cakes because of the role it plays in the development of the physical structure of the baked product. The inherent characteristics of the fat itself, the methods employed in incorporating it, and the amount of fat in the formula are closely related to volume, texture, and tenderness of baked cakes.

The effect of fat on batter and cake structure is related primarily to the incorporation and distribution of air. Incorporated air, whether introduced into the plastic shortening during creaming, added with the sifted flour to which it clings, or introduced by stirring, provides the nuclei for the gas cells. Steam and carbon dioxide formed during baking diffuse into the cell nuclei; therefore, the air

distribution in a batter determines the grain of the baked cake (Charley, 1970).

In addition to creaming effects, fat affects batter viscosity which tends to be related positively to cake volume and sensory qualities (Lowe, 1955; Matthews and Dawson, 1966). The relationship between batter viscosity and cake quality can be affected by other factors such as emulsifiers, however. Carlin (1944) observed that batter from fat plus monoglyceride was less viscous than batter from the same fat without the monoglyceride; yet the fat with the emulsifier produced the better cake. Willis (1971) studied elaidinized lipid in relation to its effect on batter aeration and found a positive relationship between batter viscosity and volume index at the 0, 40, and 60 percent levels of substitution of elaidinized lipid for shortening. Substitution of elaidinized lipid had a deleterious effect on cake grain, however.

Specific gravity is inversely related to batter aeration. Jooste and Mackey (1952) determined specific gravity of batters made with butter and hydrogenated vegetable oil, with and without added emulsifiers. They found specific gravity of batter to be affected by the type of lipid and related to cake volume either negatively or positively, depending on the presence of emulsifier. In the absence of emulsifier, relatively high cake volume was obtained from batters having a relatively low specific gravity. With added emulsifier, higher volume was associated with higher specific gravity. Since volume was not correlated with air incorporation in the presence of emulsifier, these researchers postulated that greater gas retention was responsible for

increased volume. Relatively great elasticity of air bubbles during the later stages of baking might have been responsible for the increased gas retention. Ellinger and Shappeck (1963), using liquid shortenings in cakes, found an inverse relationship between specific gravity and cake volume. They reported that specific gravity also affected grain, texture, tenderness, fragility, and peaking.

Air distribution in cake crumb, which is affected by fat, influences the apparent color. Ellinger and Shappeck (1963) reported that cakes with relatively fine structures reflected more light and thus appeared lighter in color than those with larger air spaces.

Charley (1970) indicated that shortening performs another important function in cakes. Melting of fat crystals during baking contributes to fluidity and mobility of cake batter. The increased mobility permits expansion rather than explosion of cell walls under the pressure of expanding gases.

Elaidinization

During the process of hydrogenation, liquid oils can be converted to plastic shortenings with the formation of many positional and geometric isomers (Eckey, 1954; Allen and Kiess, 1955; Swern, 1964). A vegetable oil may be changed to a solid fat also by the process of elaidinization in which the formation of trans isomers of unsaturated fatty acids is the chief chemical effect (Cochran *et al*., 1961). Several catalysts have been used to produce elaidinized lipids (Eckey, 1954; Allen and Kiess, 1955). Bertram (1949) found selenium to be a useful catalyst for elaidinization.

Elaidinization results in lipids that have better keeping quality and higher melting points than ordinary or hydrogenated oils and fats. The enhanced keeping quality was explained by Bertram (1949) as resulting from the higher proportion of solid glycerides in elaidinized lipids at the same melting point; therefore, their percentage of liquid unsaturated oil is lower.

III. PROCEDURE

Preparation of Shortenings

Hydrogenated shortening[1] containing no added emulsifier and elaidinized vegetable oil[2] were used in the preparation of four shortenings. Elaidinized lipid was substituted for hydrogenated safflower oil shortening at four levels: 0, 40, 60, and 80 percent. Willis (1971), who substituted elaidinized lipid for lard, suggested that her results may have been influenced by non-uniform distribution of the elaidinized lipid. In the present study, each shortening, including the unsubstituted hydrogenated shortening, was heated to approximately 50°C in a 60°C waterbath. Melted shortenings were mixed under nitrogen in a cold room (approximately 0°C) with a Hobart Mixer, Model N-50, at speed one, until they solidified (10-25 min). Individual portions for each of eight replications were stored in glass jars at -20°C.

Analysis of Shortenings

Fatty acid methyl esters were prepared from each shortening by the method reported by Ostrander (1968). These methylated samples were used in gas-liquid chromatographic analysis (Klouda, 1969) of the fatty acids and thin-layer chromatographic analysis (Ostrander, 1968) of the proportion of trans isomers in the safflower shortening and elaidinized lipid. The values obtained were used for calculating fatty

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[1]Hain safflower shortening, Hain Pure Food Company, Los Angeles.

[2]Confectioner's hard coating butter, Durkee Famous Food Company, Chicago.

acid and trans isomer concentrations in the substituted lipids. Melting points of the shortenings were determined by the AOCS official capillary tube method (AOCS, 1963).

Preparation of Cakes

The lean formula developed by Kissell (1959) was used because it essentially eliminates any sources of lipid other than the experimental samples (Table 1).

Table 1. Lean formula cake

Ingredient	Quantity	Percent by Weight of Flour
Flour, cake	150 g	100.0
Sugar	195 g	130.0
Shortening	41.8 g	27.9
Baking powder (SAS-phosphate)	7.1 g	4.7
Water, distilled	163.5 ml	109.0

Flour and baking powder were pre-weighed and sifted together into double paper bags and stored at room temperature in a tightly covered container until the morning of use. Sugar was pre-weighed also into double paper bags and stored at room temperature in a tightly covered container until the morning of use. The pre-weighed shortenings

were removed from freezer storage on the day preceding each replication. All ingredients and equipment were at room temperature during mixing.

Kissell's procedures were followed with these exceptions: (1) a Hobart N-50 mixer with paddle attachement was used; (2) the mixing method was modified; (3) 300 g of batter per cake were weighed into teflon-lined aluminum loaf pans 7 3/8 x 3 5/8 x 2 1/4 in.; and (4) cakes were baked in a Despatch rotary oven. The baking temperature used by Kissell (375°F) was not modified. Kissell's mixing procedure was modified in that the sugar was creamed with the shortening rather than added as a solution. The procedure used was the following: Cream lipid 1 min at speed _2_. Cream lipid and sugar 1 min at speed _2_. Scrape down. Add one-half flour-baking powder mixture and one-half distilled water and mix 2.5 min at speed _2_. Scrape down. Add remaining flour-baking powder mixture and distilled water and mix 0.5 min at speed _2_. Scrape down. Mix 0.5 min at speed _1_.

Physical Measurements on Cake Batters

Specific gravity of batters was measured as described by Hunt *et al*. (1955). The wide-mouth glass pycnometer (25 ml) had a ground glass standard taper stopper (24/12) with a 1.6 mm central opening. All batters and distilled water were maintained in a 25°C waterbath until weights were taken.

Viscosity of the batters at room temperature was determined with the Brookfield viscometer (Model LVF) with spindle 4 and speed 12 as described by Willis (1971). After stabilization, three readings were taken 30 sec apart and averaged.

Physical Measurements on Cakes

Volume index was determined as the area of a center-cut slice measured with a compensating polar planimeter as reported by Matthews and Dawson (1966).

Crumb color was measured with the Color-Eye (Model D-1). Readings for two samples per cake were taken on surfaces 7/8 and 1 3/4 in. from the end of the loaf and averaged. Lightness index ($L = Y^{1/2}$) was computed for each treatment in each replication on the Olivetti Programma 101 desk top computer.

Microscopic Evaluation of Batters and Cakes

Cake and cake batter were prepared for microscopic study by the method described by Pohl et al. (1968). The method involves freeze-drying, followed by fixation and staining of the lipid with osmium tetroxide, embedding in paraffin, and sectioning. Two 1 mm samples for each treatment were taken during each of the following phases of cake preparation: (1) from interior of mass of freshly prepared batter; (2) from center interior of cake after: (a) 5 min of elapsed baking time, (b) 10 min of elapsed baking time, and (c) completion of baking; and (3) from crust at center top exterior of baked cake. A stainless steel spatula approximately 3 mm wide was inserted to a depth of about 1/2 in. for removal of all samples except crust.

The sample holder used for freeze-drying differed from that used by Pohl et al. (1968). Frozen samples were placed in coded compartments of baskets improvised from wire mesh, stacked, and wired together to fit into a 500 ml freeze-drying flask.

After freeze-drying, staining, and embedding, samples were sectioned on a rotary microtome to a thickness of 15 μ. One slide per freeze-dried sample was prepared with four sections selected randomly from the microtome ribbon. Xylene was used for clearing and balsam for mounting.

A panel of four judges evaluated slides from: freshly prepared batter, batter after 5 and 10 min of elapsed baking time, crumb, and crust. Coded slides for the four levels of substitution in each replication were ranked on three attributes: increasing degree of dispersion of air and of lipid and increasing total amount of air (Appendix, page 34). The use of four microscopes permitted direct comparison of the slides representing the four levels of substitution for each type of sample. Batter samples were evaluated in one series of observations and each of the other sample types in another series. Numerical values were assigned to each rank following panelists' evaluation (1-4 in increasing order). Representative photomicrographs were taken with Panatomic FX 135 film, an exposure time of 1/10 sec and a total magnification of 450X.

Statistical Analysis

Duncan's New Multiple Range Test (Steel and Torrie, 1960) was applied to the data for batter viscosity and specific gravity, cake volume and lightness indices, and judges' rankings of microscopic sections. Standard error was calculated for each treatment mean for each of the above measurements.

IV. RESULTS AND DISCUSSION

Properties of Lipids

Composition of Lipids. The composition of the four lipid samples is shown in Table 2. Mono- and dienoic acids, in nearly equal concentration, comprised 67 percent of the total fatty acids of the hydrogenated safflower oil shortening. Trans isomer concentrations ranged from 8.8 to 40.6 percent of the total fatty acids. The four lipids differed as to their relative proportions of oleic (18:1 cis), elaidic (18:1 trans), and linoleic (18:2) acids.

Melting Points. Melting points of the four shortenings, also shown in Table 2, increased from 41.0°C for the unsubstituted shortening to 47.1°C for the 80 percent level of substitution.

Physical Measurements on Cake Batters

Specific Gravity. Specific gravity (Table 3) was lowest for the unsubstituted batter and highest for the batter from lipid of the 80 percent level of substitution. Batters from lipids of the 40 and 60 percent levels differed from the other batters in specific gravity but not from one another ($P < 0.01$).

Viscosity. Viscosity of cake batters (Table 4) decreased ($P < 0.01$) as the level of substitution of elaidinized lipid increased.

Physical Measurements on Cakes

Volume Index. Volume index values for cakes from the four

Table 2. Composition and melting points of shortenings

Substitution Level of Elaidinized Lipid, %	Fatty Acids, Percent of Total							Melting Points
					C 18:1			
	C 12:0	C 14:0	C 16:0	C 18:0	Cis	Trans	C 18:2	°C
0	- -	2.0	22.4	8.2	25.4	8.8	33.2	41.0
40[a]	0.9	2.0	24.0	9.5	19.0	24.7	19.9	43.1
60[a]	1.3	2.0	24.8	10.2	15.8	32.6	13.3	44.7
80[a]	1.8	2.0	25.6	10.8	12.6	40.6	6.6	47.1

[a]Values calculated from those for the safflower shortening and elaidinized lipid.

Table 3. Specific gravity of batters

Replication	Substitution Level of Elaidinized Lipid, %			
	0	40	60	80
1	0.916	0.969	1.042	1.164
2	0.910	0.993	1.022	1.170
3	0.965	0.975	1.050	1.206
4	0.915	0.964	1.065	1.231
5	0.908	1.010	1.098	1.217
6	0.908	0.995	1.041	1.140
7	0.940	0.997	1.097	1.231
8	0.926	0.980	1.145	1.200
Mean	0.924	0.985[a]	1.070[a]	1.195
Standard Error	0.008	0.006	0.015	0.012

[a]Means not having the same superscript differ at the level $P < 0.01$.

Table 4. Viscosity of batters[a]

Replication	Substitution Level of Elaidinized Lipid, %			
	0	40	60	80
1	31,666	26,500	19,583	8,667
2	30,417	25,333	19,167	11,167
3	29,416	24,000	18,000	8,833
4	33,333	24,250	17,750	8,583
5	30,416	22,250	12,250	8,000
6	31,083	22,166	18,083	10,083
7	29,416	22,166	14,916	8,416
8	32,166	24,583	12,250	10,666
Mean[b]	30,989	23,906	16,499	9,301
Standard Error	424	502	924	364

[a]Centipoises at 25°C.

[b]All means differ at the level $P < 0.01$.

shortenings are shown in Table 5. Cakes containing elaidinized lipid at the 80 percent level of substitution were smallest in volume ($P < 0.01$). Volumes of cakes from the other three shortenings did not differ from one another.

Crumb Color. Lightness index values are shown in Table 6. The cakes from lipid of the 80 percent level of substitution were the least light in color, as indicated by their lowest mean lightness index ($P < 0.01$). Although the means for the cakes from the other three shortenings tended to show decreasing lightness with increasing substitution, differences were not consistent among the replications.

Microscopic Evaluation of Batters and Cakes

Microscopic examination indicated that level of substitution of elaidinized lipid affected dispersion of air and lipid and amount of air (Table 7). According to the judges' microscopic evaluation of samples taken before, during, and after baking, the cakes from lipid of the 80 percent level of substitution had the poorest dispersion of air, the lowest amount of air, and the poorest dispersion of lipid ($P < 0.01$). Cakes from the other three shortenings were not significantly different in any of these attributes, although their means suggest decreased amount and dispersity of air with substitution. The photomicrographs in Figures 1 and 2 also suggest this trend.

Judges' evaluation of slides did not include direct comparison of samples taken at different stages. Photomicrographs, however, do show changes during baking. Photomicrographs for the zero level of substitution in one replication are shown in Figure 3. In the batter the air

Table 5. Volume index of cakes[a]

Replication	Substitution Level of Elaidinized Lipid, % 0	40	60	80
1	33.0	32.0	31.6	31.1
2	25.2	33.2	32.4	30.4
3	32.4	30.6	31.6	29.6
4	34.6	32.9	31.6	30.4
5	34.2	33.5	34.0	29.4
6	34.7	32.8	32.2	30.2
7	34.4	34.1	32.0	29.3
8	33.4	32.4	31.2	29.6
Mean	32.7[b]	32.6[b]	32.0[b]	30.0
Standard Error	0.98	0.33	0.27	0.19

[a]Each value is average in sq cm for two readings from each of two samples of each cake.

[b]Means not having the same superscript differ at the level $P < 0.01$.

Table 6. Lightness index of cake crumb

Replication	Substitution Level of Elaidinized Lipid, %			
	0	40	60	80
1	9.283	9.268	9.296	8.748
2	9.287	9.235	9.105	8.697
3	8.883	9.244	9.091	8.669
4	9.422	9.388	9.176	8.721
5	9.012	8.934	8.898	8.374
6	8.899	8.852	8.757	8.473
7	9.168	8.681	8.760	8.743
8	8.855	9.003	8.767	8.650
Means	9.101[a]	9.076[a]	8.981[a]	8.634
Standard Error	0.06	0.07	0.07	0.04

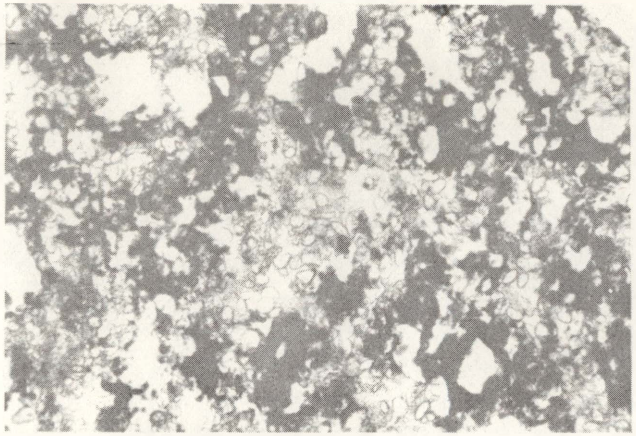
[a]Means not having the same superscript differ at the level $P < 0.01$.

Table 7. Rank scores[a] of microscope slides

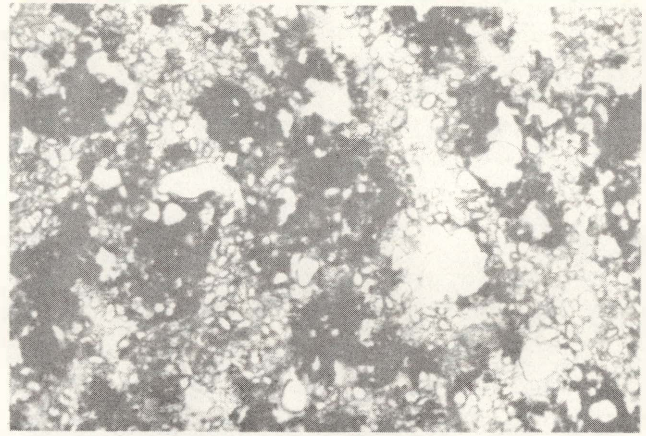
Elaidinized Lipid, %	Air Dispersity				Amount of Air				Lipid Dispersity			
	0	40	60	80	0	40	60	80	0	40	60	80
Sample												
Batter	2.90	2.40	2.40	2.28	2.90	2.15	2.46	2.46	2.81	2.78	2.68	1.62
5 min	2.88	3.12	2.25	1.75	3.53	2.54	2.25	1.68	2.25	3.34	2.18	2.21
10 min	3.00	2.81	2.25	1.84	3.04	2.71	2.25	2.00	2.81	3.12	2.50	1.56
Crumb	2.81	2.38	2.46	2.34	2.44	2.28	2.71	2.56	2.56	2.62	2.56	2.25
Crust	2.28	2.84	3.12	1.75	2.18	3.65	2.50	1.65	2.10	2.50	2.78	2.62
Mean	2.77[b]	2.70[b]	2.50[b]	1.99	2.81[c]	2.66[c]	2.43[c]	2.07	2.50[d]	2.87[d]	2.54[d]	2.05
Standard Error	0.13	0.14	0.16	0.13	0.24	0.26	0.09	0.19	0.14	0.16	0.10	0.20

[a]Average of four judges' scores for each sample in all replications; ranked in increasing order from 1 to 4.

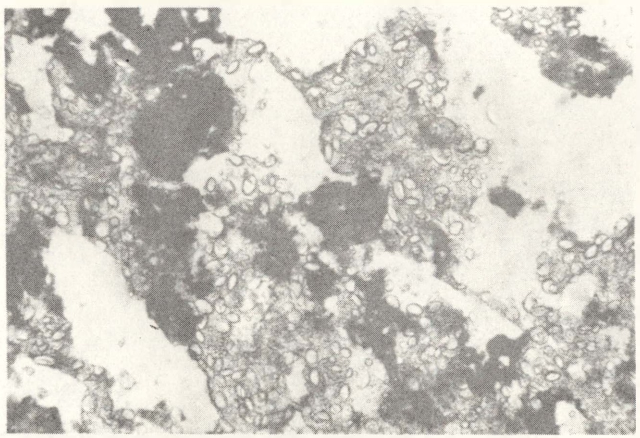
[b,c,d]Means not having the same superscript differ at the level $P < 0.01$.



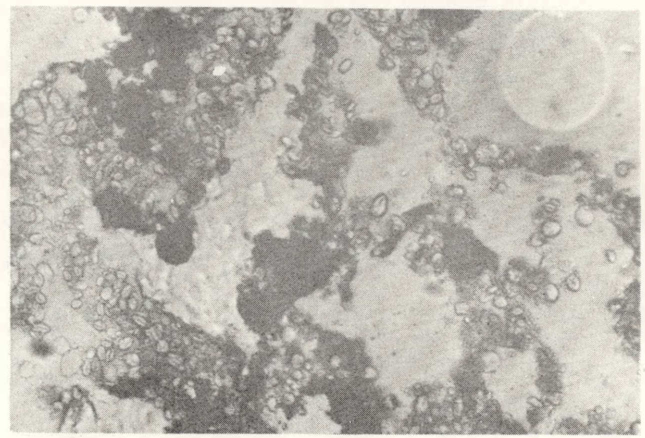
a. 0% Elaidinized Lipid



b. 40% Elaidinized Lipid

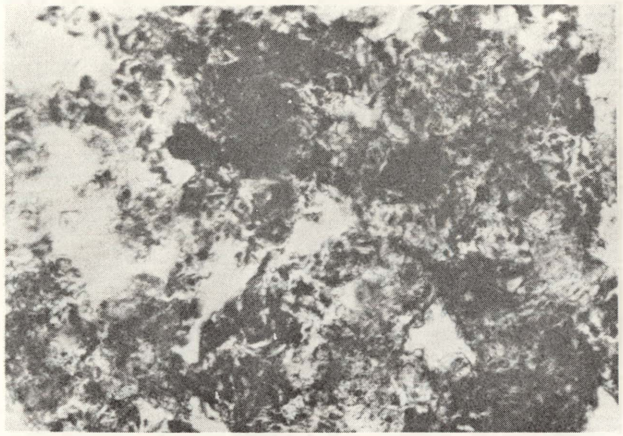


c. 60% Elaidinized Lipid

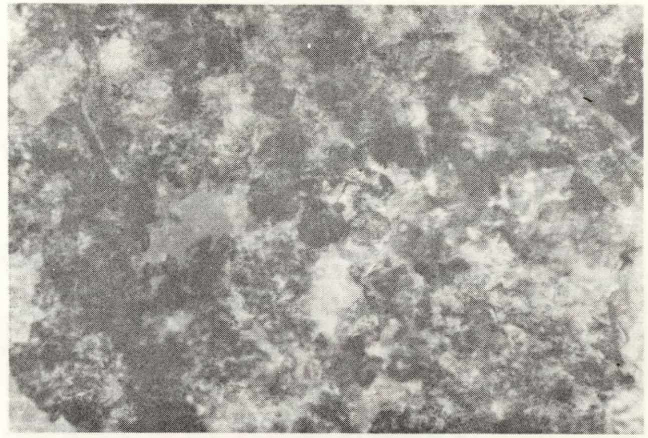


d. 80% Elaidinized Lipid

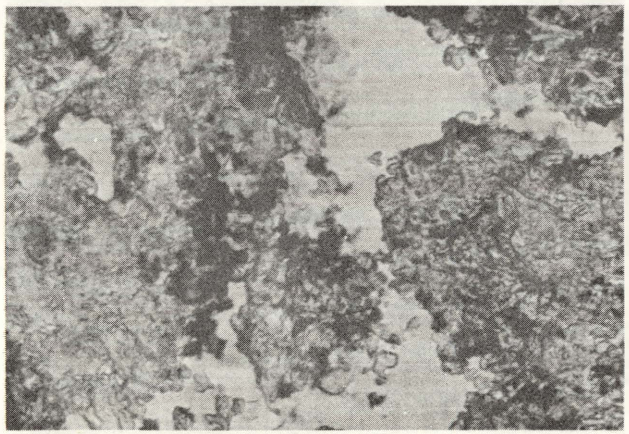
Figure 1. Photomicrographs of cake batter from four shortenings.



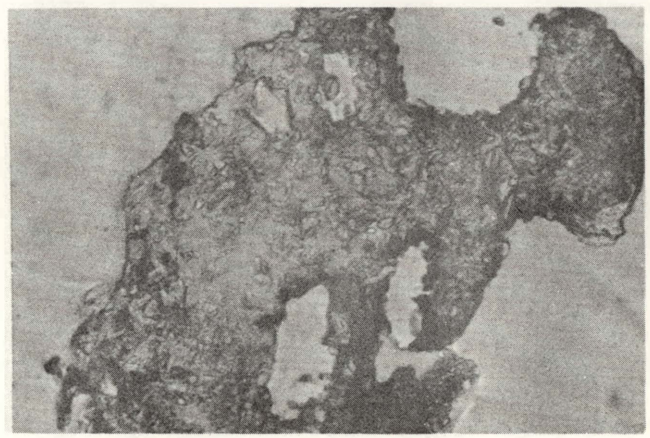
a. 0% Elaidinized Lipid



b. 40% Elaidinized Lipid

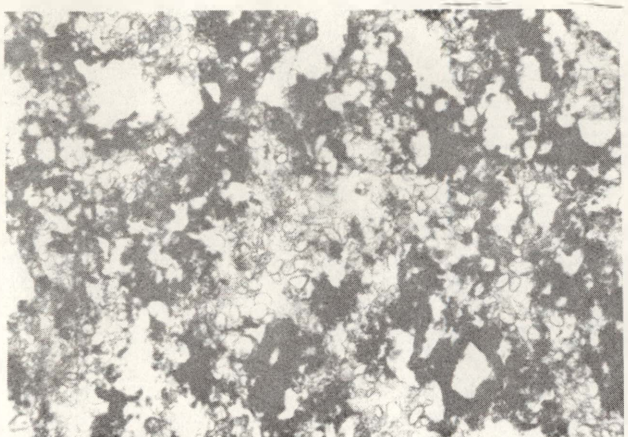


c. 60% Elaidinized Lipid

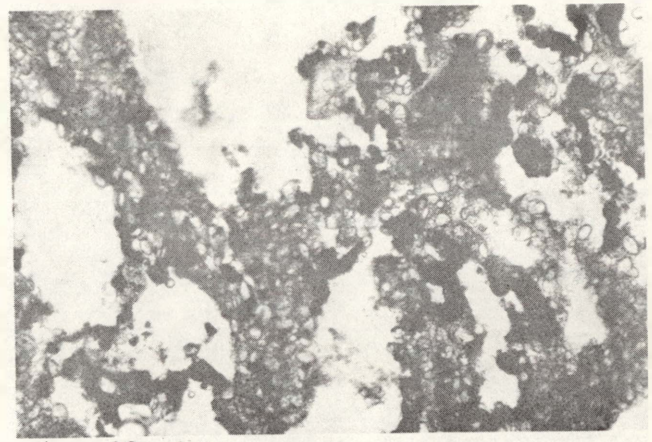


d. 80% Elaidinized Lipid

Figure 2. Photomicrographs of cake crumb from four shortenings.

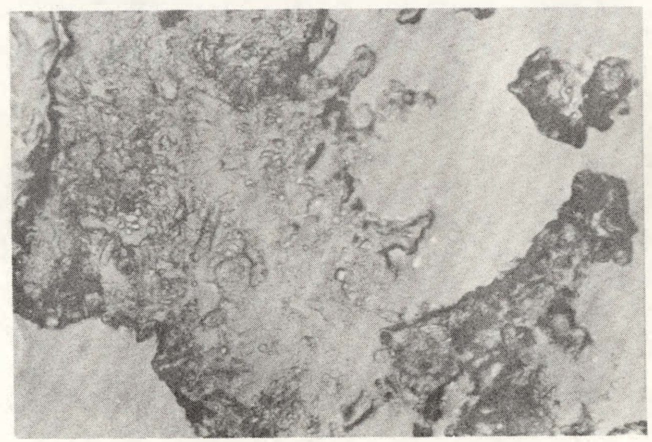


a. Batter



b. 10 min

c. Crumb



d. Crust

Figure 3. Photomicrographs of cakes from unsubstituted shortening at different stages of preparation.

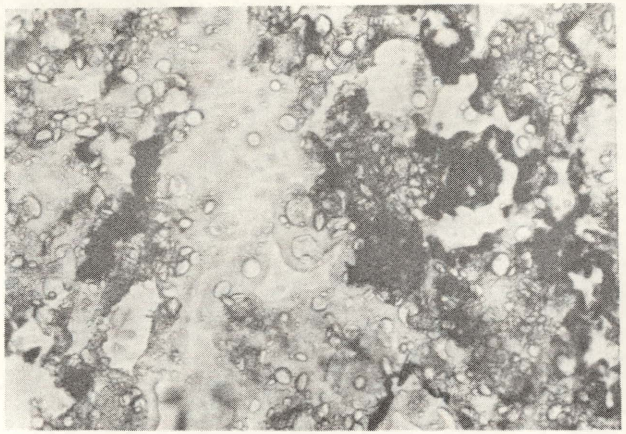
and the lipid were relatively well dispersed. During baking the air spaces enlarged and the lipid apparently melted and decreased in dispersity. Lipid in the crust sample was almost entirely at the outer edges.

At the 80 percent level of substitution (Figure 4), similar changes occurred but both air and lipid were less well dispersed than in the unsubstituted sample. The large air spaces seen in the photomicrographs in Figure 4, as compared with those in Figure 3, indicate the differences in grain, which can be seen also in the photographs of cross-sectional slices of the cakes (Figure 5). Decreased crust browning with substitution of elaidinized lipid also can be seen in the photographs.

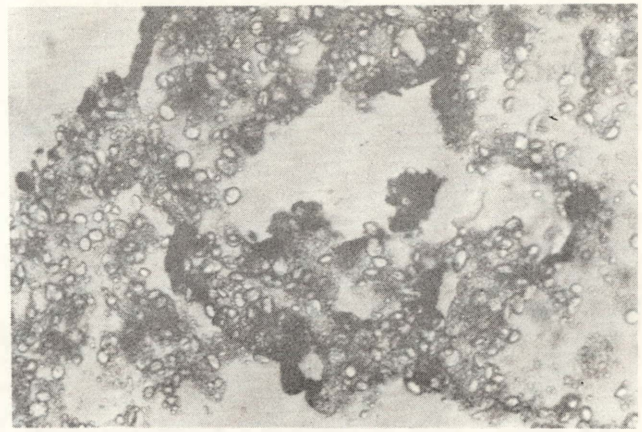
Relationships Among Measurements

Several possible relationships may be seen in the response to substitution of elaidinized lipid for hydrogenated safflower shortening in cake batter. Batter viscosity decreased with level of substitution. The decrease in viscosity probably was related to the reduced dispersity of the lipid with increasing substitution, as evidenced by the photomicrographs. It is known that emulsion viscosity is positively related to extent of emulsification (Becher, 1965).

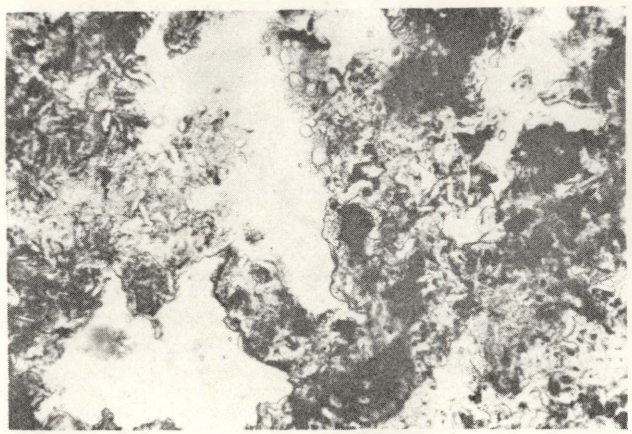
The decreased extent of emulsification with increasing substitution probably is related to the melting point increase. Consistency measurements are not available, but it was observed that shortenings became firmer with substitution of elaidinized lipid. A relatively firm shortening would offer more resistance to subdivision than would one that is soft.



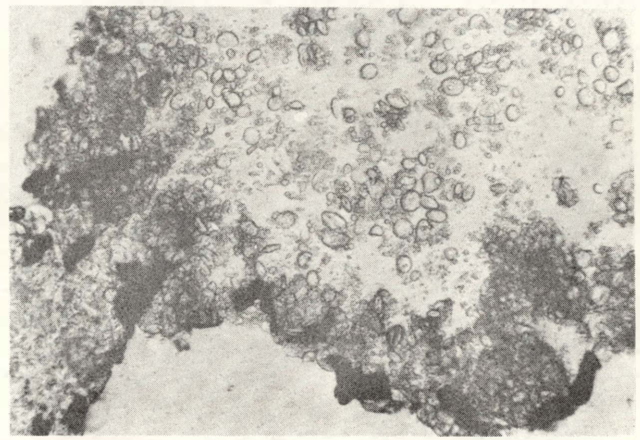
a. Batter



b. 10 min



c. Crumb

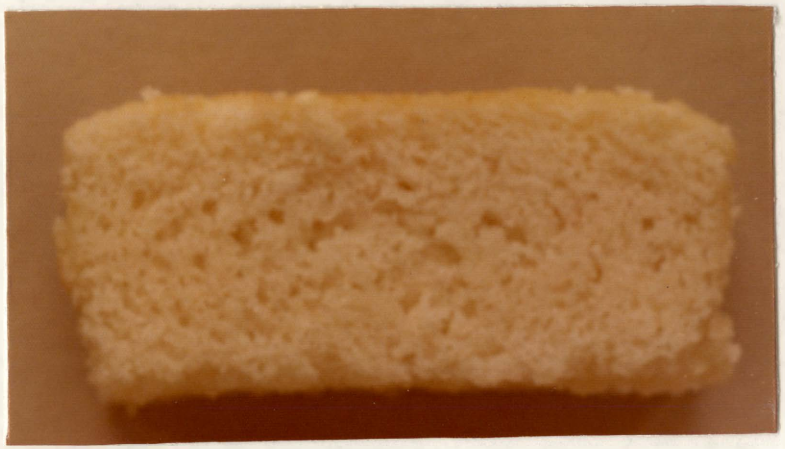


d. Crust

Figure 4. Photomicrographs of cakes from 80 percent substituted shortening at different stages of preparation.

a. 0% Elaidinized Lipid

b. 40% Elaidinized Lipid



c. 60% Elaidinized Lipid

d. 80% Elaidinized Lipid

Figure 5. Photographs of cross-sectional slices of cake.

Batter aeration with substitution of elaidinized lipid was reduced, as indicated by increased specific gravity of batters as well as by the photomicrographs. An inverse relationship between specific gravity and cake volume, which has been reported by others (Ellinger and Shappeck, 1963) was not clear-cut in the present study except with the products at the 80 percent level in relation to the others. The cake batter with lipid of the 80 percent substitution level did have the highest specific gravity and produce cake with the lowest volume index. Poor retention of air in a batter of low viscosity also may have contributed to the significantly lower volume index in the cakes of highly substituted lipid.

A relationship between dispersity and crumb color is indicated by the photomicrographs and the lightness indices. Data are clear-cut only at the 80 percent level of substitution, at which the lightness index was lowest and the air dispersity was judged to be least. Although differences were not significant among other levels of substitution the data do suggest trends, which are supported also by the cake photographs (Figure 5). As the level of substitution increased, the air spaces in the crumb became fewer and larger. The decreased lightness associated with increasingly coarse grain is the result of decreased light-reflecting surface.

A relationship between batter aeration and lipid is indicated by the greatest dispersity of both air and lipid in the batters with unsubstituted lipid and the least dispersity of both in the batters of highly substituted lipid. Their close association in the batter structure is apparent in the photomicrographs (Figure 1, page 21).

Willis (1971) obtained the greatest cake volume, along with no evidence of increased aeration, at the highest level of substitution of elaidinized lipid. Her suggestion that the apparent discrepancy may have been related to the non-homogeneous nature of her substituted shortenings is supported by the relatively low volume associated with poor aeration at the highest level of substitution in the present study, in which the lipid mixtures were homogeneous. Elaidinized lipid substituted for hydrogenated shortening in cakes did not have any beneficial effects on batter aeration or structure under the conditions of the present study.

V. SUMMARY

Batter aeration as affected by substitution of elaidinized lipid and related to other properties was investigated. Elaidinized lipid was substituted for hydrogenated safflower oil shortening at four levels, 0, 40, 60, and 80 percent, in the preparation of lipid samples. Lipid samples were characterized by gas-liquid and thin-layer chromatography and by melting point determination. Specific gravity and viscosity of the batters, volume index of the cakes, and lightness index of the crumb were determined. Batter structure was studied microscopically.

An increase in trans isomer concentration from 8.8 percent to 40.6 percent was accompanied by an increase in melting point from 41.0 to 47.1°C with increasing level of substitution. Batters from the unsubstituted shortening were most highly aerated, as indicated by specific gravity, and had the greatest dispersity of air and lipid, as indicated by microscopic sections. The decreased extent of emulsification was associated with decreased batter viscosity, as well as the decreased aeration. Volume index of cakes in part reflected differences in aeration. Decreased lightness index of cake crumb with increasing level of substitution resulted from the decreased light-reflecting surface and relatively poor aeration. Batter structure was not affected beneficially by substitution of elaidinized lipid for hydrogenated shortening under the conditions of this study.

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APPENDIX

SCORE CARD FOR MICROSCOPE SLIDES

Name ______________________________ Code Number __________

Instructions: Rank A, B, C, D[a], with respect to:

Increased degree of dispersion air: ____________________

Increasing total amount of air: ____________________

Increasing degree of dispersion of fat: ____________________

Comments:

[a]After judging, numerical values assigning ranks to treatments were substituted for letters and used for data analysis.

VITA

The author, Rebecca Jane Snodgrass, was born in Bristol, Virginia, on October 25, 1948. She received the Bachelor of Science degree in Home Economics Education from East Tennessee State University in June, 1970. Miss Snodgrass was initiated into Kappa Omicron Phi and Kappa Delta Pi at East Tennessee State University. She was a member of the American Home Economics Association and a student member of the Institute of Food Technologists. In June 1970, she accepted a teaching assistantship at The University of Tennessee and began working toward the Master of Science degree in Food Science.