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Elaidinized Lipid in Relation to Its Effect on Emulsification

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To the Graduate Council:

I am submitting herewith a thesis written by Amelia Gail Brown entitled "Elaidinized Lipid in Relation to Its Effect on Emulsification." 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:

Grayce E. Goertz, John T. Smith

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Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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166

August 22, 1971

To the Graduate Council:

I am submitting herewith a thesis written by Amelia Gail Brown entitled "Elaidinized Lipid in Relation to Its Effect on Emulsification." 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

John T. Smith

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

ELAIDINIZED LIPID IN RELATION TO ITS EFFECT ON EMULSIFICATION

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

Amelia Gail Brown

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ABSTRACT

Emulsification as affected by substitution of elaidinized lipid was investigated. Cream puffs were prepared with lipids of 0, 40, 60 and 80 percent levels of substitution of elaidinized lipid for corn oil. Viscosity of the lipids at 61°C was measured. Oil separation data were obtained from frozen, thawed and centrifuged batter. Penetrability of batters was measured. Volume by rapeseed displacement was determined for the baked products. Samples of batter, interior and crust were prepared for microscopic study by freeze-drying, staining of lipid with osmium tetroxide vapors, infiltration with paraffin and sectioning. Judges evaluated the sections on a descriptive score sheet. Batter sections for the four levels of substitution also were ranked in order of increasing dispersity of lipid.

Viscosity of the lipids increased with level of substitution of elaidinized lipid. The batters with elaidinized lipid at the zero and 40 percent levels showed more oil separation than those at the 60 and 80 percent substitution levels, although photomicrographic examination of batters revealed that dispersity of lipid decreased with substitution. Highly substituted lipid probably left the batter with difficulty because of relatively high viscosity. Differences in seepage from the baked products were observed visually; the less finely dispersed, highly substituted lipid was lost more readily than was the unsubstituted lipid. Batters with elaidinized lipid had relatively low penetrability; they also had relatively low volumes, probably because of greater resistance to expansion of the firmer batters. Judges did not detect any differences

attributable to the four treatments for the interior and crust samples.

Substitution of elaidinized lipid for oil in cream puffs appeared not to be of practical benefit. The reduced tendency for lipid to separate from batter containing elaidinized lipid and subjected to a low storage temperature suggests a possible application in the making of mayonnaise.

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CHAPTER I

INTRODUCTION

The consumption trend in the United States today is away from butter and lard and toward margarine and vegetable shortenings. Much of this increase may be attributed to the process of hydrogenation.

During the commercial process of hydrogenation, elaidinization may occur (Jones _et al._, 1965). Hydrogen can add at a double bond to form a radical with an unsaturated center on either of the two carbons. A second hydrogen can add resulting in saturation. If, instead of this addition, another hydrogen is removed, a double bond may be reformed in either the cis or trans configuration (Allen and Kiess, 1955). Elaidinization refers to the process resulting in fatty acids with the trans configuration at double bonds.

Nearly 3,000,000,000 lb of margarines and shortenings are consumed annually in the United States. The trans fatty acid content of these products averages 30 percent. Thus Americans are consuming nearly 1,000,000,000 lb of trans fatty acids, most resulting from the hydrogenation process (Mabrouk and Brown, 1956).

A search of the literature revealed little information on the functional properties of elaidinized lipids. Ostrander (1968), working with laboratory-elaidinized lipid, and Klouda (1969), using commercially elaidinized lipid, studied shortening power in pastry; elaidinized lipid was substituted for varying proportions of non-elaidinized lipid. Willis (1971) investigated the effect of elaidinized lipid on aeration

of cake batter. No additional studies on functional properties of lipids as affected by elaidinization were found.

Emulsification is an important functional property of lipids. Cream puff batter contains a large proportion of emulsified lipid (Charley, 1970; Lowe, 1955). Emulsions may be oil-in-water or water-in-oil types. Pohl et al. (1968) stated that by microscopic study of freeze-dried batter, it was possible to demonstrate conclusively the oil-in-water structure of cake batter. They considered freeze-drying to result in relatively little distortion of cake batter. The technique thus was applied to a study of the effect of elaidinized lipid on emulsification in cream puff batter.

CHAPTER II

REVIEW OF LITERATURE

Elaidinization

One of the oldest reactions in lipid chemistry is the elaidinization reaction. Upon hydrogenation of monounsaturated fatty acids, many geometric and positional isomers are formed (Allen and Kiess, 1956; Feuge and Cousins, 1960; Jones et al., 1965; Mabrouk and Brown, 1956). Temperature is recognized generally to be more effective than catalyst concentration as a tool for changing the properties of a hydrogenated oil (Feuge and Cousins, 1960). As temperature of hydrogenation increased up to 200°C, the proportion of trans isomers increased (Sims and Hilfman, 1953; Subrahmanyam and Quackenbush, 1964).

The catalyst used either for hydrogenation or for elaidinization and the conditions of its use affect the amount of trans isomers formed. Catalysts studied have included selenium, nitrous vapors, sulfur dioxide, palladium, nickel and mercaptans (Allen, 1968; Blekkingh et al., 1957; Kircher, 1964). Palladium catalysts used in hydrogenation were found to produce more trans isomers than nickel catalysts (Allen, 1968). Litchfield et al. (1965) stated that selenium and oxides of nitrogen are the most widely used agents in elaidinization. Kircher (1964) reported that elaidinization of methyl oleate with mercaptans was a function of mercaptan structure, solvent, temperature, the presence or absence of sunlight and of oxygen and the mercaptan concentration.

The equilibrium composition of elaidinized lipid can be 70-80 percent trans and 30-20 percent cis double bonds (Kircher, 1964; Allen

and Kiess, 1955). Trans fatty acids have a higher melting point than corresponding cis acids (Litchfield et al., 1965). Thus elaidinization can be used to harden fats without loss of unsaturation (Cochran et al., 1961). Sims and Hilfman (1953) found that the content of trans isomers was an important factor in determining melting point and consistency of glycerides. The effect on consistency probably is related to the finding of Bertram (1949) that elaidinized oils contain more solid glycerides and a lower percentage of liquid unsaturated oil than most hydrogenated oils of an equal melting point. Other properties also are affected by elaidinization. Trans octadecenoic acids were shown to be less soluble than the cis acids (Mabrouk and Brown, 1956). Lipids with the elaido configuration were shown to be relatively resistant to oxidation and to yield lipids with better keeping qualities than hydrogenated lipids (Bertram, 1949).

Definition of Emulsions

An emulsion is a heterogeneous system, consisting of droplets of one liquid intimately dispersed in another, the continuous phase. The two liquids are immiscible. Droplet diameters of the dispersed phase, in general, exceed 0.1 μ. Such systems possess a minimal stability, which may be accentuated by emulsifying agents, finely-divided solids or mechanical devices (Becher, 1965).

Emulsions are commonly classified as oil-in-water or water-in-oil dispersions. Most food emulsions are of the oil-in-water type. Other types of dispersion are in coexistence with an emulsion in a batter (Kearney, 1969). These include a colloidal dispersion, a solution and

a foam. Grewe (1937) considered cake batter to consist of a water-in-oil emulsion in which air bubbles are trapped in the fat. Most authors have considered batters to be oil-in-water emulsions with air dispersed in the lipid (Carlin, 1944; Hunt and Green, 1955; Kearney, 1969). Pohl et al. (1968) more recently concluded that cake batter is an oil-in-water emulsion in which air bubbles are dispersed along with other constituents in the aqueous medium. Regardless of the view taken as to the type of emulsion, batters are complex mixtures.

Properties of Emulsions

Particle size is an important emulsion property. Average diameters range from 0.25 μ to 5 μ (Becher, 1965). Variability exists between emulsions and within a single emulsion. Average particle size and size distribution change with aging of the emulsion. The smaller particles may be subject to Brownian motion. This has a negative effect on the stability of the small emulsion droplets because of frequent collisions of particles and resultant coalescence. The net effect is a shift toward larger particles during aging.

In addition to average particle diameter as a means of describing an emulsion, the mean interfacial area may be employed as an index of dispersity (Becher, 1965). Change in the mean interfacial area with time can be used as an indication of degree of stability.

Light scattering and turbidity can be measures of optical properties of emulsions. Viscosity measurements give considerable information about the structure of emulsions and clues to their stability (Becher, 1965).

Electrical conductivity provides a method for distinguishing between oil-in-water and water-in-oil emulsions. If the aqueous phase is continuous, high conductivity is shown. On the other hand, emulsions with oil as the continuous phase exhibit little or no conductivity (Becher, 1965).

Stability of Emulsions

The stability of an emulsion is its ability to resist breaking or the coalescence of particles of dispersed phase (Grewe, 1937; Bikerman, 1958). A good emulsion should not separate into layers; it should not discolor on aging, and it should not change in consistency (Bennett, 1947).

The stability of an emulsion is a function of the size of the dispersed droplets. The presence of a large number of small particles is characteristic of a relatively permanent emulsion (Berkman, 1935; Schulman and Cockbain, 1940). Emulsions containing large droplets separate rapidly. Schulman and Cockbain (1940) reported evidence that oil droplets of about 4 μ diameter are sufficiently small to permit only slow separation.

Microscopic methods have been used for measurement of average particle size and size distribution. King and Mukherjee (1939) studied the stability of emulsions in relation to particle size; they counted the droplets in each of several size groups in a square of known diameter projected on a screen. With soap-stabilized emulsions they noted that the finer dispersions were often the more stable.

Microprojection techniques of Berkman (1935) also showed that the percentage of large droplets was extremely small in stable emulsion

systems. Their increasing appearance indicated a transition to an unstable form. The higher the initial proportion of small droplets, the slower was the shift toward larger droplets.

Fischer and Harkins (1932) also found that the mean size of the oil droplets in the emulsion increased with age. The small droplets disappeared by coalescence with larger ones, and the resultant growth was of the larger drops.

Increased concentration of an emulsifier enhances emulsion stability. Berkman (1935) stated that emulsions containing a small amount of emulsifier are short-lived. With an increase in the concentration of the emulsifier, a higher proportion of small droplets is obtained. Droplets of an emulsion are surrounded by an interfacial film which not only impedes their coalescence but also keeps them uniformly dispersed (Bennett, 1947). The strength and compactness of this interfacial film are important factors favoring emulsion stability.

Phase-volume ratios of emulsions may affect emulsion stability. If the proportion of dispersed phase is increased above 70 percent, the droplets are packed so closely together that they lose their shape (Bennett, 1947). The interfacial film may break and the droplets coalesce.

Temperature changes affect stability of emulsions. Heat may produce profound chemical or physical changes which may break an emulsion. Heating of emulsions usually increases globule size (Bennett, 1947). Becher (1965) stated that raising the temperature yields an increased rate of flocculation. The interfacial viscosity decreases

with higher temperatures, thus contributing to increased coalescence through increased film rupture.

Many emulsions may be broken by freezing. Freezing an emulsion forms ice crystals which rupture the protective film and the emulsion may break when it is thawed (Dean, 1948). Rochow and Mason (1936) obtained information by microscopic methods on breaking emulsions by freezing. The process of freezing an oil-in-water emulsion started with crystallization of water and collection and entrapment of oil droplets between ice crystals. True contact was established between adjacent interfacial films in the absence of the orienting influence of water. With increased time, there was a decrease in film area. Actual coalescence of the droplets occurred as soon as thawing permitted them to change their shape.

Hanson and Fletcher (1961) reported that the kind of oil in an emulsion affects low temperature stability. They investigated factors influencing oil and water separation after storage at temperatures ranging from +20 to -50°F. Salad dressings made from various vegetable oils were centrifuged after storage and the percent of separated oil was calculated. The main cause of oil separation after freezing and thawing was solidification of the emulsified oil in crystalline form. No separation occurred if the oil did not solidify at freezing temperatures. With slight solidification, minimal separation was shown. As the temperature was lowered, separation increased to a maximum, and then generally decreased. The temperature that favored maximum separation varied with the oil. Extensive solidification of oil in the crystalline form apparently destroys the relationship between dispersed

oil droplets and the protective emulsifying film, leaving oil droplets free to coalesce during thawing.

Separation of oil was used also in evaluating the stability of emulsions made with processed eggs and allowed to stand 30-120 min at room temperature. Both the albumen and yolk emulsifying properties seemed to contribute to those of the whole egg (Zabik, 1969).

Measuring the rate of separation of the dispersed phase under a constant centrifugal force provides a rapid, quantitative method for determining emulsion stability. Using 3000 rpm in a No. 1, Type SB International clinical centrifuge, Merrill (1943) plotted volume of oil separation against the time of centrifuging. Until 60 to 75 percent of the dispersed phase was separated, the rate of separation nearly was constant. After that, the rate decreased markedly. Increasing the centrifuge speed increased the rate of phase separation.

Schulman and Cockbain (1940) studied the emulsifying properties of various substances added to emulsions containing gelatin, "nujol" and water. Oleic and elaidic acids aided emulsification.

Lipid Behavior in Batters and Cakes

Progressive changes in lipid behavior in the preparation and baking of cakes have been observed microscopically. Carlin (1944) published one of the early studies. Lipid was observed in dark, irregular clumps or "lakes" in the batter rather than as the continuous phase. The continuous field was made up of the aqueous phase with its dissolved sugar, salt and baking powder and its suspended flour and egg solids. Air spaces were suspended only in lipid lakes. Dispersion of lipid was much finer with lard than with hydrogenated vegetable shortenings.

Carlin's study was unique in that the microscope was equipped with a heating stage. Batters cooked on this stage were compared with partially cooked batters taken from cakes during the regular process of baking. During baking, lipid and air moved with the aqueous medium along the convection current path. Lipid spaces remained separate whereas air spaces coalesced in the aqueous medium.

Jooste and Mackey (1952) reported that the lipid in cake batter appeared in clumps together with occluded air bubbles. Vegetable oil batters had more gas bubbles than butter batters. During the last stages of baking the melted lipid lakes ran into the openings left by escaping gas bubbles. In cake the lipid appeared as a coating for the protein and partially covered starch granules. Starch granules appeared embedded in the lipid.

Hunt and Green (1955) also observed that lipid was dispersed in the aqueous phase in irregular clumps and small gas bubbles appeared only in the lipid areas. Lipid in the baked cake was irregularly distributed.

The smear method of slide preparation was used in the three preceding studies. In an attempt to eliminate compression and distortion of structure, Pohl et al. (1968) adapted a freeze-drying technique that had been applied previously to biological specimens. The procedure involves freeze-drying cake batter, then staining, paraffin embedding and sectioning. By this method, Pohl et al. (1968) demonstrated the oil-in-water structure of cake batter. The lipid particles were irregularly "globular" shaped droplets of various sizes dispersed throughout the aqueous starch-protein matrix. Air bubbles were

dispersed in the batter at the water-lipid interface rather than within the lipid. The presence of lipid appeared to be necessary for the retention of air during mixing. When lipid was added to a lipid-free formula and when level of lipid was increased further, aeration and batter viscosity were increased. Lipid distribution in baked cake was not reported.

No report was found of a study of lipid distribution in cream puffs, either unbaked or baked.

CHAPTER III

PROCEDURE

Preparation of Lipids

Elaidinized vegetable lipid from a commercial source[1] was substituted for corn oil at four levels: 0, 40, 60 and 80 percent. The mixtures were prepared before experimental work was begun and individual portions of the lipids for all replications were stored under nitrogen in glass jars at -20°C.

Viscosity of Lipids

Viscosity of the lipids at 61°C was determined with the Brookfield viscometer (Model LVF) with spindle 1 at 30 rpm. The samples, in tall-form beakers, were held in a water bath for temperature equilibration and viscosity measurement.

Preparation of Cream Puffs

The cream puff formula, used in the eight replications, (Table 1) was adapted from Lowe (1955) with these exceptions: Corn oil was the control lipid, and dried egg whites[2] were used. Flour was preweighed into paper bags for all treatments for each replication and stored at room temperature in a tightly covered container. Egg whites were preweighed into double sandwich bags for each replication and stored in the refrigerator until the morning of use. The preweighed lipids

[1]Confectioner's hard coating butter, Durkee Famous Food.

[2]White-N-Lite, Nifda Inc.

were removed from freezer storage on the day preceding use. All ingredients and equipment were at room temperature prior to mixing.

Table 1. Cream Puff Formula

Ingredient	Amount
Flour, Soft-Wheat, All-Purpose	112 g
Lipid	112 g
Egg White (Reconstituted)	192 g
Water, Distilled	240 ml

The dried egg whites were reconstituted with a Hobart N-50 mixer with paddle beater (Funk et al., 1970) for each replication. One-hundred-twenty grams of dried egg whites were mixed with 300 ml distilled water for 30 sec on speed 1. The remaining 540 ml water were added, and mixing was continued at the same speed for 30 sec. The eggs were strained for assurance of complete reconstitution, and individual portions were weighed.

The method of Funk et al. (1970) was used for cream puff preparation. Lipids and water were heated to 99°C in a stainless steel mixing bowl covered with foil. Flour was mixed with the lipid and water for 15 sec at speed 2. The sides of the bowl were scraped and mixing was continued for 45 sec. The flour-lipid-water mixture was allowed to cool to 51°C. The eggs were added in two equal portions and the mixture

was beaten after each addition at speed 1 for 2.5 min and finally at speed 3 for 5 min. Thirty gram portions were baked on lecithin-coated baking sheets in a rotary hearth oven preheated to 440°F. During the first 20 min of baking, the top oven heater was on low, the bottom oven heater turned off, and the damper closed. For the remaining 25 min of baking, the top oven heater was turned off and the damper opened. The cream puffs were allowed to cool at room temperature.

Measurements on Cream Puff Batter

The amount of oil separating from a 5 g sample of frozen, thawed batter was determined by a modification of the method of Hanson and Fletcher (1961). Samples, in 15 ml centrifuge tubes, were thawed after 5 days of storage at -20°C, warmed to 25°C and centrifuged 30 min at 2500 rpm in an International Model U centrifuge. A weighed "tube" of paper toweling was used for removing separated oil and was reweighed. Weight of separated lipid was obtained by difference.

A Universal Precision penetrometer with a 13.3 g aluminum cone was used for penetrability measurement of batter samples contained in crystallizing dishes 3.5 cm deep and 5.8 cm in diameter. The penetration of the cone into the batter during 30 sec was measured at a batter temperature of 25°C.

Measurements on Baked Cream Puffs

Volume was determined in duplicate by seed displacement. Volume of rapeseed required to fill a can 5.5 x 4 in. (diameter) was determined with and without the cream puff. The volume of each cream puff was measured by difference.

Cream puff weights were obtained after baking and cooling. Two cream puffs from each lot were dried at 65 ± 1°C for 24 hr and reweighed.

Photomicrographs

Microscopic study of batter, interior portion and crust was performed essentially according to the method described by Pohl et al. (1968). The technique consisted of rapid freezing of approximately 1 mm samples on dry ice, freeze-drying in baskets improvised from wire screen, followed by fixation and staining of the lipid with vapors of osmium tetroxide, paraffin embedding and sectioning on a rotary microtome to a thickness of 15 μ. Xylene was used for clearing and balsam for mounting in the preparation of slides.

After a training session, four judges evaluated batter, interior and crust sections for each treatment and replication. Descriptive terms for distribution, size, predominant shape and number of fat lakes and distribution of space not occupied by fat were checked on the score card (Appendix, page 37). It proved impossible to quantitate the qualitative descriptions; therefore, three judges also ranked the coded batter sections representing four levels of substitution in order of increasing dispersity of lipid. Four microscopes were used in order to facilitate comparison among the substitution levels. Mean ranks were submitted to data analysis. The judges' ratings were used also as an aid to selection of typical sections for photographing. Photomicrographs were taken at a total magnification of 450X with Panatomic FX135 film and an exposure time of 1/10 sec.

Photomicrographs of all treatments of batter for one replication were enlarged to 8 x 10 in. Total area occupied by the section on the

enlargement was measured with a compensating polar planimeter. A grid having 144 dots per square inch was placed over the negative. Dots were counted over the space not occupied by lipid and division by 144 gave area of this space. The area occupied by lipid was found by difference and its percent of total area was calculated.

Statistical Analysis

Duncan's New Multiple Range Test was used for comparing treatment means for lipid dispersity, oil separation and penetrability of batters and volume of cream puffs (Steel and Torrie, 1960). Standard error of each treatment mean was calculated for the measurements listed above.

CHAPTER IV

RESULTS AND DISCUSSION

Viscosity of Lipids

Viscosity of the four lipid samples is given in Table 2. A direct relationship between viscosity and level of substitution of elaidinized lipid is seen.

Table 2. Viscosity of Lipids

Substitution Level of Elaidinized Lipid, %	Viscosity in cp at 61°C
0	17.6
40	19.3
60	21.3
80	22.6

Physical Measurements on Cream Puff Batters

Oil separation. Oil separation values of cream puff batters are shown in Table 3. The batter with elaidinized lipid at the 40 percent level of substitution showed the highest level of oil separation. The oil separation values for the 60 and 80 percent levels were lower

Table 3. Oil Separation from Cream Puff Batters[1]

Replication	Substitution Level of Elaidinized Lipid, % 0	40	60	80
1	0.75	2.49	0.17	0.14
2	2.06	2.58	0.22	0.14
3	1.41	0.20	0.10	0.07
4	1.85	2.61	0.21	0.16
5	1.71	1.49	0.13	0.09
6	1.13	2.46	0.17	0.10
7	0.93	1.38	0.18	0.17
8	1.49	2.49	0.17	0.14
Mean[2]	1.42[a]	1.96[a]	0.17[b]	0.13[b]
Standard Error	0.16	0.31	0.01	0.01

[1]Each value is an average of three measurements, expressed as percent of batter weight.

[2]Means not having the same superscript are significantly different ($P < 0.01$).

($P < 0.01$) than those for the zero and 40 percent levels of substitution of elaidinized lipid.

Penetrability. Penetrability values are given in Table 4. The penetrability of batters from the unsubstituted lipid was greater ($P < 0.01$) than that of batter from the other lipids. The batters from the lipids of 40, 60 and 80 percent substitution did not differ consistently as to penetrability.

Volume of Baked Cream Puffs

As seen in Table 5, mean volume of cream puffs at the unsubstituted level was higher ($P < 0.05$) than that of cream puffs at the other levels. Volume did not differ consistently at the other levels of substitution.

Photomicrographs

Representative photomicrographs of cream puff batter made with lipid of the different levels of substitution are shown in Figure 1. At the zero percent level of substitution, lipid droplets were small and uniformly distributed. With increasing level of elaidinized lipid, the distribution of lipid particles became less dispersed; agglomerates and ribbons were observed. Data for judges' evaluation of lipid dispersity in the batter (Table 6) reflect the differences seen in Figure 1. Judges considered lipid to be most finely dispersed at the zero percent level of substitution and least finely dispersed at the 80 percent level ($P < 0.05$). Ranking means for the 40 and 60 percent levels did not differ significantly.

Table 4. Penetrability of Cream Puff Batters[1]

Replication	Substitution Level of Elaidinized Lipid, % 0	40	60	80
1	15.2	9.6	9.6	9.5
2	14.4	9.3	8.8	8.6
3	14.6	9.1	10.4	9.2
4	14.7	9.4	8.4	9.4
5	14.0	9.2	8.6	9.6
6	14.2	9.2	8.3	7.4
7	13.6	9.6	7.4	9.3
8	14.0	9.5	7.8	9.6
Mean[2]	14.4	9.3[a]	8.7[a]	9.1[a]
Standard Error	0.18	0.07	0.34	0.26

[1]Each value is an average of two readings in mm.

[2]Means not having the same superscript are significantly different ($P < 0.01$).

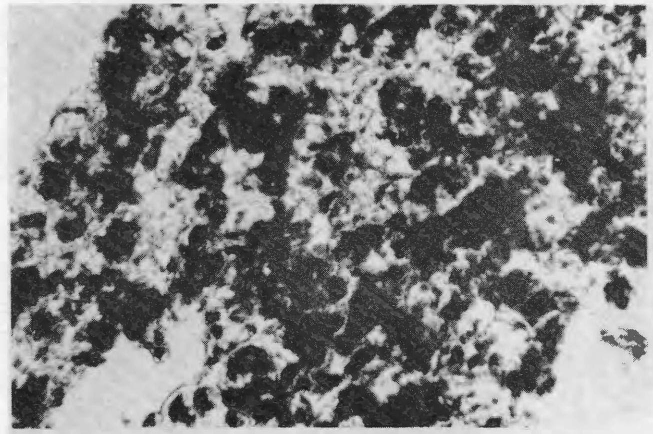
Table 5. Volume of Cream Puffs[1]

Replication	Substitution Level of Elaidinized Lipid, % 0	40	60	80
1	51.8	48.8	49.2	45.5
2	43.0	19.2	14.2	20.5
3	36.8	36.8	18.0	21.8
4	56.8	46.8	48.0	54.2
5	56.8	58.0	60.5	56.8
6	59.2	39.2	39.2	40.5
7	43.0	35.5	24.2	25.5
8	53.0	44.2	30.5	28.0
Mean[2]	50.0	41.0[a]	35.5[a]	36.6[a]
Standard Error	2.87	4.05	5.82	5.15

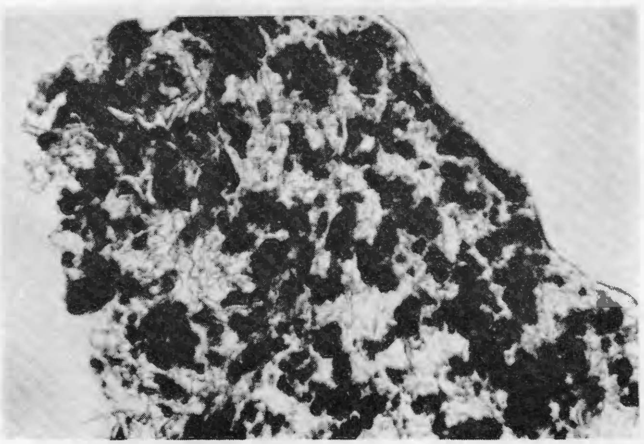
[1]Each value is an average for two measurements, in cc, for each of two cream puffs.

[2]Means not having the same superscript are significantly different ($P < 0.05$).

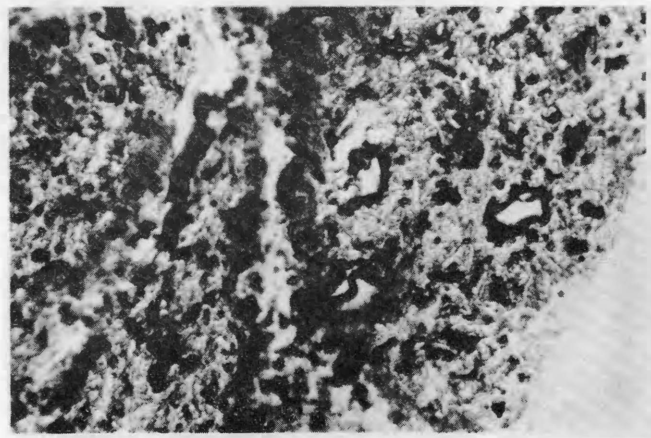
a. Zero Percent



b. 40 Percent



c. 60 Percent



d. 80 Percent

Figure 1. Cream Puff Batter with Lipids of Four Levels of Substitution.

Table 6. Rankings of Lipid Dispersity in Cream Puff Batter Sections[1]

Judge	Substitution Level of Elaidinized Lipid, %			
	0	40	60	80
1	3.3	2.6	2.2	1.8
2	3.3	2.5	2.4	1.8
3	3.5	2.7	2.2	1.6
Mean[2]	3.4	2.6[a]	2.3[a]	1.7
Standard Error	0.07	0.06	0.07	0.07

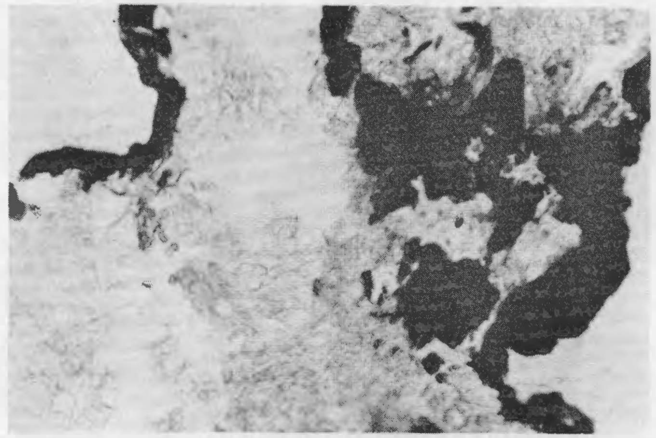
[1]Rankings from 1 to 4 on basis of dispersity of lipid (1 = least dispersed). Each value is the average of rankings for 16 slides (two per replication).

[2]Means not having the same superscript are significantly different ($P < 0.05$).

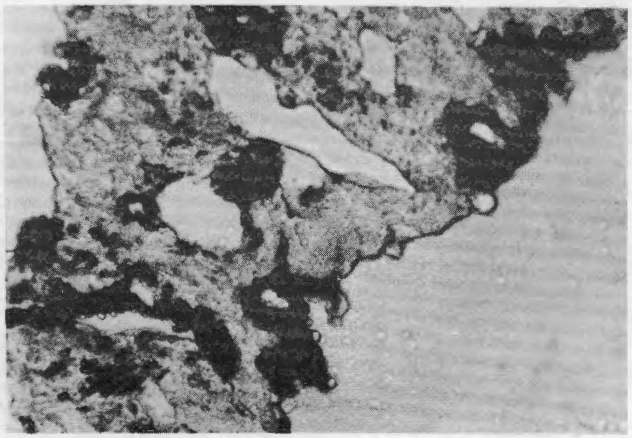
When representative photomicrographs of batter sections were enlarged and lipid areas were calculated, lipid appeared to occupy 81 percent of the total area in the unsubstituted batter section and 80, 74 and 69 percent in batter sections from the 40, 60 and 80 percent substituted lipids respectively. These apparent differences in amount of lipid are seen in the photomicrographs (Figure 1, p. 22). The batters were alike as to proportions of lipid, and the samples photographed had not had an opportunity to lose lipid; therefore, differences in amount of lipid could be real only if the batters differed in water loss during the mixing process. Total moisture loss during baking and oven-drying was essentially equal, averaging 18.6, 18.5, 18.5 and 18.6 g per cream puff for batters with lipid of increasing level of substitution, indicating the unlikelihood of differences in evaporative loss during mixing. The apparent difference in cross-sectional area occupied by the lipid most likely represents differences in extent of agglomeration. The largest agglomerates are most likely to extend all the way through the section so that less of the lipid present is visible than in the case of the more finely dispersed lipid.

Photomicrographs of interior portions and crust of baked cream puffs are shown in Figures 2 and 3, respectively. These photomicrographs show the lipid distributed as elongated ribbons or agglomerates around edges and air cells. During baking, the lipid apparently moved to the edges of the crust and of the thin partitions within the cream puff. Findings of agglomerates and ribbons support the statement of Becher (1965) that heating an emulsion produces increased flocculation. Photomicrographs and judges' observations showed no difference between levels of substitution for interior and crust.

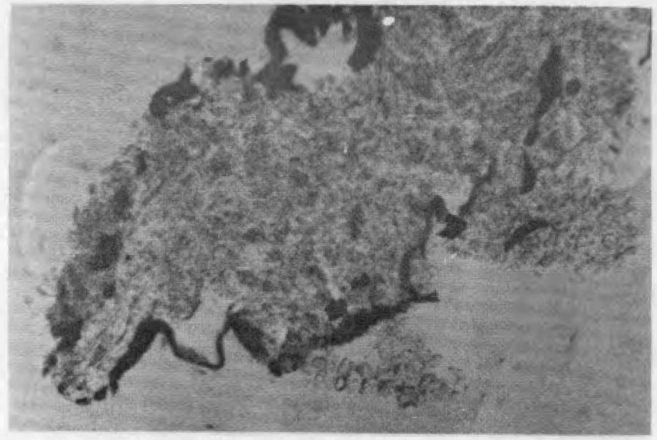
a. Zero Percent



b. 40 Percent

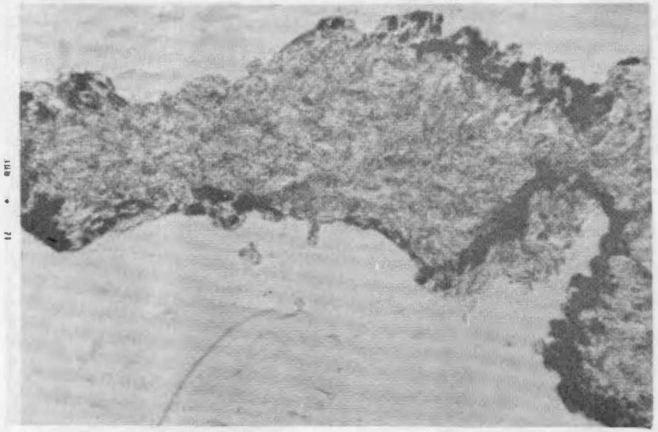


c. 60 Percent

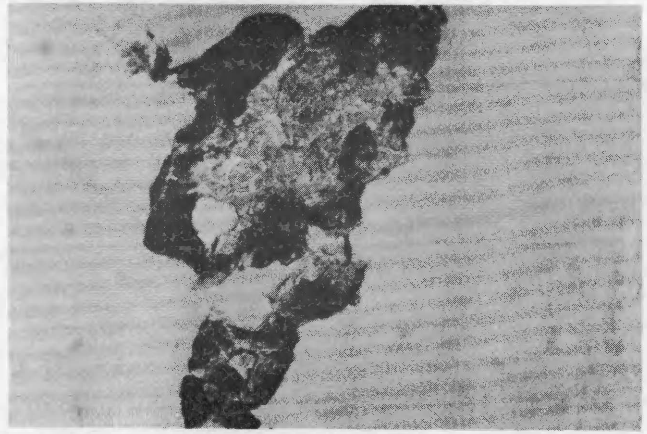


d. 80 Percent

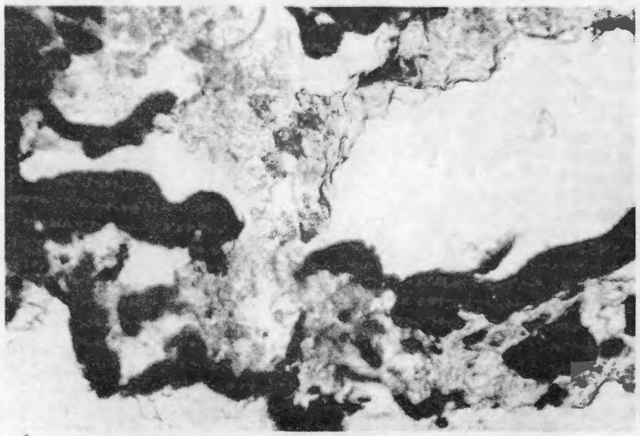
Figure 2. Cream Puff Interior with Lipids of Four Levels of Substitution.



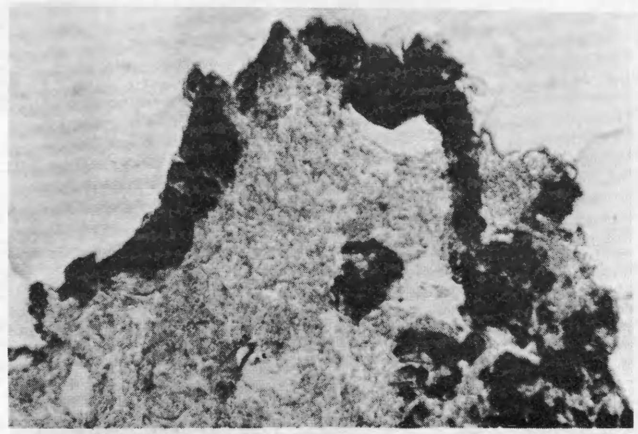
a. Zero Percent



b. 40 Percent



c. 60 Percent



d. 80 Percent

Figure 3. Cream Puff Crust with Lipids of Four Levels of Substitution.

Discussion

Lowe (1955) reported that increased batter stiffness with emulsification contributes to emulsion stability. In this study the substitution of elaidinized lipid for oil did result in increased batter stiffness and decreased loss of oil from frozen, thawed and centrifuged mixtures. As indicated previously, however, batter photomicrographs showed a decreased extent of emulsification with substitution of elaidinized lipid. In addition, it was observed that when the baked cream puffs were allowed to stand on paper towels, those with lipid of the zero and 40 percent levels of substitution left little or no lipid on the paper toweling, whereas the 60 percent level left some and the 80 percent level left the most lipid on the paper toweling. Lowe's statement pertains to emulsions containing a single fat, whereas in this study the batters contained mixtures of two different fats.

The apparent stabilizing effect of substitution evidenced by only slight lipid separation at the 60 and 80 percent levels could be related to viscosity in a different way. According to Platt and Fleming (1923), a viscous shortening spreads less easily through a flour mixture, but runs out of the mixture less readily than does a shortening of low viscosity. The samples representing the two highest levels of substitution thus could have been relatively resistant to the particular stresses involved in freezing, thawing and centrifuging because of the greater viscosity of their lipids and of their batters.

Penetrability of the batters possibly was related to volume of baked products. Lower volume with substituted than with unsubstituted

lipids could be the result of greater resistance to expansion with greater batter stiffness.

The effect of elaidinized lipid on emulsification in cream puff batter can be summarized as follows: Substitution of elaidinized lipid for corn oil resulted in a decreased extent of emulsification, as indicated by photomicrographs of batter; increased stability, as indicated by oil separation after freezing, thawing and centrifuging; and decreased stability, as indicated by observed oil seepage from the baked cream puffs.

The apparent discrepancy with respect to stability could be explained by a difference in the stresses involved. Stability of a frozen emulsion is endangered by the damaging effect of ice crystals on the emulsifying films. The relatively high viscosities of the batters containing highly substituted lipid could have made the formation of large ice crystals difficult. In baking, the primary de-emulsifying forces are loss of dispersion medium through evaporation and thermal activity, resulting in migration and coalescence of lipid globules. Weight loss during baking averaged 14.1, 13.6, 13.9 and 14.2 g per cream puff for samples of increasing level of substitution; differences in emulsion stability during baking cannot be explained on the basis of dispersion medium loss. If ease of migration of oil in the batter were a factor, the greater viscosity at the higher levels of substitution should have offered more rather than less protection from coalescence. Probably the products with lipid at the highest levels of substitution lost the most lipid ultimately simply because of their less fine dispersion initially. Less coalescence was required for the formation of masses large enough to escape from the interior of the batter.

In considering the total effect of elaidinized lipid on emulsification in cream puffs, this author concludes that elaidinized lipid did not aid emulsification in cream puff batter. Since cream puffs are subjected to stresses during baking, it seems logical to accept visual evidence of seepage as one criterion of emulsion stability. The apparent beneficial effect on freeze-thaw stability is not of practical importance with respect to cream puffs. The results suggest, however, the possibility of a real advantage of using elaidinized lipid in mayonnaise. Study of emulsification in mayonnaise containing elaidinized lipid might be worthwhile.

CHAPTER V

SUMMARY

Emulsification as affected by substitution of elaidinized lipid was investigated. Cream puffs were prepared with lipids of 0, 40, 60 and 80 percent levels of substitution of elaidinized lipid for corn oil. Viscosity of the lipids at 61°C was measured. Oil separation data were obtained from frozen, thawed and centrifuged batter. Penetrability of batters was measured. Volume by rapeseed displacement was determined for the baked products. Samples of batter, interior and crust were prepared for microscopic study by freeze-drying, staining of lipid with osmium tetroxide vapors, infiltration with paraffin and sectioning. Judges evaluated the sections on a descriptive score sheet. Batter sections for the four levels of substitution also were ranked in order of increasing dispersity of lipid.

Viscosity of the lipids increased with level of substitution of elaidinized lipid. The batters with elaidinized lipid at the zero and 40 percent levels showed more oil separation than those at the 60 and 80 percent substitution levels, although photomicrographic examination of batters revealed that dispersity of lipid decreased with substitution. Highly substituted lipid probably left the batter with difficulty because of relatively high viscosity. Differences in seepage from the baked products were observed visually; the less finely dispersed, highly substituted lipid was lost more readily than was the unsubstituted lipid. Batters with elaidinized lipid had relatively low penetrability; they also had relatively low volumes, probably because of greater resistance

to expansion of the firmer batters. Judges did not detect any differences attributable to the four treatments for the interior and crust samples.

Substitution of elaidinized lipid for oil in cream puffs appeared not to be of practical benefit. The reduced tendency for lipid to separate from batter containing elaidinized lipid and subjected to a low storage temperature suggests a possible application in the making of mayonnaise.

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APPENDIX

CHECK SHEET FOR MICROSCOPE SLIDES

Name ______________________________ Replication Number ________

Instructions: Place check mark after the appropriate description for each sample.[1]

Characteristic	A			B			C			D		
	B	I	C	B	I	C	B	I	C	B	I	C
Distribution of fat lakes												
Uniform												
Around air cells												
Around edges												
Size of fat lakes												
Small												
Medium												
Large												
Predominant shape of fat lakes												
Discrete particles												
Irreg. agglomerates												
Elongated ribbons												
Number of fat lakes												
0 - 20												
21 - 50												
Above 50												
Space that is not fat												
Continuous												
Discontinuous												

Comments -

[1]A, B, C and D represent codes assigned randomly to levels of substitution; B, I and C represent types of sample: batter, interior and crust.

VITA

Amelia Gail Brown was born in Oak Ridge, Tennessee, on November 3, 1947. She received a Bachelor of Science degree in Home Economics Education from East Tennessee State University. She was initiated into Kappa Omicron Phi, Phi Kappa Phi and Kappa Delta Pi at East Tennessee State University and Omicron Nu at The University of Tennessee. Miss Brown was a member of the American Home Economics Association and a student member of the Institute of Food Technologists. In 1969 she accepted a research assistantship and began study toward a Master of Science degree in Food Science at The University of Tennessee, Knoxville.