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A COMPARISON OF TYPES OF HYDROGENATED SHORTENINGS: MEASURED BY SPECIFIC GRAVITY, VISCOSITY, AND QUALITY OF POUND CAKE

By

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A PROBLEM

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INTRODUCTION

Hydrogenated shortenings on the current market differ in the source of fat, type and amount of emulsifier added, and/or type of antioxidant added, and method of hydrogenation. These variations might be expected to produce differences in physical and chemical characteristics of the shortenings and to cause quality variation in baked products in which the shortenings have been incorporated.

Each advertiser claims, "This product is the best." Many recipes use only the designation "shortening." Interest, therefore, was stimulated to determine if hydrogenated shortenings as used in baked products are truly interchangeable.

Sabtier's work (1896) on hydrogenation of unsaturated products laid the foundation for the shortening industry as we know it today. The hydrogenation process added hydrogen ions to the double bonds of unsaturated compounds (8). The hydrogenation of fats and oils yielded a white fat with a high melting point and with a greater resistance to rancidity (27).

"Shortening," an American invention, was originally developed as a substitute for lard; compounded of hydrogenated vegetable oils and animal fats, shortening had 1) superior physical properties, 2) good creaming and mixing ability, 3) high stability, and 4) product uniformity (2).

Shortening may be either the 1) compound, blended form, or 2) the all hydrogenated form depending on the processing treatments. The compound form is composed of 88-90% liquid oil, or liquid oil

plus a slightly hydrogenated oil; the consistency is controlled by adding 10-12% highly hydrogenated oil. The all hydrogenated form is composed of one oil or a blend of two or more oils; each oil is partially hydrogenated to a different melting point; the consistency is adjusted by the addition of small amounts of completely hydrogenated oil (17, 27). The all hydrogenated form is more stable than blended shortening. A completely hydrogenated fat is too hard for usefulness in food products.

Four major types of shortenings are produced through variation in the source of oil and/or fat: 1) a single vegetable oil, 2) a blend of several vegetable oils, 3) a blend of vegetable oils and animal fats, and 4) a blend of animal fats and vegetable oils.

Adding emulsifiers to shortening yields a high ratio shortening, promotes dispersion of the fat, and promotes the incorporation of air in baked products. Some of the commonly used emulsifiers include lecithin, glycerol monostearate, and sorbitan monostearate; the amount varies between 6 and 8% (4).

In addition to the emulsifiers, antioxidants are incorporated in shortenings to prevent rancidity; butylated hydroxytoulene (BHT), butylated hydroxyanisole (BHA), propyl gallate (PG), and nordihydroguaiaretic acid (NDGA) are used alone or in several combinations. The labels of cooking fats must list the antioxidant and emulsifier used in the product (7, 29).

The quality of baked products made from shortening might be affected by 1) the source of oils and fats, 2) the method of hydrogenation, and 3) the amount and type of emulsifiers and antioxidants used.

In reviewing the literature, shortening, referred to any type of fat or oil used in the baked product. A more restricted definition of "shortening" as used in this study is given at the beginning of the experimental procedure.

REVIEW OF LITERATURE

The quality of a cake batter has been attributed to the creaming ability of the fat used. Little is known about the effect of composition or physical properties of a shortening on its creaming ability (27).

Lowe (21) defined creaming ability "as the forming of a foam by incorporating air bubbles in fat by stirring." She also stated that creaming with sugar incorporated air. Martin reported Proctor and Gamble studies indicated that volume and quality of the baked product depended on the creaming volume and quality of the shortening (24). Maximum creamed volume appeared with a larger proportion of fat to sugar and slower mixer speeds (22). At 25°C. more air could be incorporated into a shortening than at lower temperatures (13). Creaming fat and sugar together caused a 1°-7° C. rise in mixture temperature. This temperature rise was thought to be due to friction and the heat of adsorption. Although emulsifiers decreased creaming ability, they stabilized the finely dispersed shortening and air resulting in a more stable batter (19).

Cakes from which the air had been evacuated did not rise (9): one-half the volume increase in pound cakes occurred because of the thermal expansion of incorporated air; the remaining rise was due to evaporated moisture collecting and expanding in the air spaces. Support for this work came in another study (15) on leavening agents; largest volumes occurred in products using air/water vapor/carbon dioxide leavening; slightly smaller volumes developed in products using air/water vapor leavening. Conditioning temperatures and shortening

temperatures at the time of creaming influenced the amount of air incorporated. Optimum conditioning temperature was given as between 19°-25°C.; creaming temperature for hydrogenated shortening was given as 26°C. (24).

A high creaming volume did not always produce a high dough or loaf volume (9). Lowe reported that cake volume tended to be small when creaming volume was large, but this relationship of creamed volume to cake volume did not hold true for pound cake (22). The addition of emulsifiers increased cake volume which indicated a larger amount of gas was retained at the time of protein coagulation (19).

A simple correlation existed between creaming volume and cake scores as reported by Lowe and Nelson (22). The conditions which gave higher volumes also gave higher scores. Higher scores had a slight tendency to accompany higher relative humidity (22), although cake volumes were lower (9). Lowe and Nelson reported a study by Buel in which highly significant correlation occurred between the temperature of the creamed mixture, the temperature of the batter, and the cake volume; the greatest volume appeared at 25°C. (22). Creaming volume was related to viscosity of batter and score values; more viscous batters and higher score values occurred with larger creaming volumes (21, 22, 24). Similar results were reported on pound cake; high initial batter viscosity produced cakes of good volume and crumb texture (22). In a conflicting report (19), shortenings to which monoglycerides had been added produced less viscous batters but better cakes. A microscopic analysis of batters showed that thin batters contained few, large-sized, gas bubbles; thick batters had numerous, small, evenly distributed, gas bubbles which appeared close together or in grape-like clusters. Less gas escaped from viscous batters (6). Scores for compactness

and tenderness were lower for cakes made from fats without emulsifiers (19). In all of the studies reported, several different kinds of fats were used: lard, butter, and/or hydrogenated shortenings.

Food and Drug laws require ingredients listed on a label to be given in a decreasing order of quantity of ingredient (29). A label which gives the information, "vegetable oil and animal fat" contains a higher quantity of vegetable oil than animal fat; a label which states "animal fat and vegetable oil" contains a higher quantity of animal fat than vegetable oil.

EXPERIMENTAL PROCEDURE

This study compared four types of hydrogenated shortening; 1) cottonseed oil, 2) a blend of several vegetable oils, 3) a blend of vegetable oils and animal fats, and 4) a blend of animal fats and vegetable oils. Information relating to composition was taken from the respective label. As used in this study the term "shortening" will be restricted to these products.

A standard pound cake (Appendix A) was selected as the baked product in which to compare these shortenings since the quality of pound cake depends on the creaming ability of the shortening (17). The four shortenings were purchased in one pound cans, with the exception of the hydrogenated cottonseed oil, from several local stores and represented two or three commercial processing lots.

Thirty-two cakes, eight replications of each shortening, were baked. The dry ingredients and shortenings for cakes baked in one week were weighed at one time. During the first five weeks of the study, ingredients were held at room temperature; during the last two weeks, all ingredients except eggs were stored in a controlled temperature box; under both storage conditions the temperature was approximately 25°C. Eggs were weighed and brought to temperature for each cake; the vanilla was measured as needed.

Two Hamilton Beach household mixers were used to combine the cake ingredients. The conventional method of combining ingredients was used in order to determine the creaming ability of the shortening. The shortening was placed in the 3 quart mixer bowl and creamed for 15 minutes at speed three; the bowl was scraped at 2 1/2 minute

intervals to insure complete creaming of the shortening. Specific gravity for the creamed shortening was taken at the end of the 15 minute creaming period before sugar was added. Four specific gravity determinations were made except where the increase in volume was not large enough to give a fourth determination. The same 1/4 size measuring cup was used for all specific gravity measurements. The sugar was divided into three portions; one 1/4 cup and two 1/2 cups: each portion was added gradually to the creamed shortening at the beginning of a 5 minute creaming period. The bowl was scraped at 2 1/2 minute intervals. Sugar and shortening were creamed a total of 15 minutes at number three speed. Four specific gravity measurements and a temperature reading were then taken and recorded. Vanilla was added. Unbeaten eggs were added gradually in three portions as the sugar; each addition was mixed for 2 minutes at speed three for a total mixing time of 6 minutes. The bowl was scraped 30 seconds after the addition of the eggs. The mixer was slowed to speed one (very slow) and the flour and salt, sifted together twice, were added at 30 second intervals. The flour-salt mixture was divided into four portions: one, approximately 1/4 cup and three, approximately 1/2 cup. The last addition of flour was blended for 1 minute: total mixing time for addition of flour was 3 minutes. The bowl was scraped 15 seconds after each flour addition. Blending time on the mixer for each cake was 39 minutes. Four specific gravity measurements and temperature readings were taken of the cake batter. Three, 5 ounce, glass custard cups with straight sides were filled to 1/4 inch from the top with cake batter and covered with Saran. These samples were used for viscosity tests on the Micrometer Penetrometer. Four hundred grams of batter were weighed into new, ungreased, unlined, aluminum loaf pans, 8 3/8" x 4 3/8" x 2 5/8". The cakes were baked in two

small wall ovens at a temperature of $350^{\circ}F.$ for 30 minutes; the temperature was then reduced to $325^{\circ}F.$ for the final 25 minutes of baking. The cakes were baked a total of 55 minutes. While the cakes baked, viscosity tests were made on the cake batters.

Viscosity of the cake batters was measured both by the MacMichael Viscosimeter and by the Micrometer Penetrometer. A number 26 wire was used to support the spindle and to measure the torque on the MacMichael Viscosimeter; the smallest size cup attachment was filled 3/4 full of batter. Readings were taken at 5 and 10 seconds in empirical MacMichael units. The plunger assembly with the grease cone attachment of the Micrometer Penetrometer weighed 150 grams, the plunger was released for 5 seconds to penetrate the test sample. Depth of penetration was measured by 1/10th millimeters. (Data have been converted to millimeters).

The cakes were allowed to cool approximately 20 minutes in the pans; then they were removed to wire cooling racks. The cake, when cool, was wrapped in Saran to measure volume.

Cake volume was measured in a standard volumemeter (3). The difference in the quantity of rape seed contained by the volumemeter box without the cake present and with the cake in the box represented the volume of the cake; this measurement was in cubic centimeters.

The cakes were cut for testing as follows: the first cut dividing the cake into two portions was made 5 1/4 inches from one end of the cake. Starting at the cut surface, three 1/2 inch slices were cut from the smaller portion and were used for taste panel. Again starting at the cut surface, seven 1/2 inch slices were cut from the larger portion: the first slice containing the first cut into the cake was used for the sand retention test; the next slice, for the compressibility test; and the remaining slices, for the taste panel. Width of all slices was standardized by cutting the cake in a miter box. Samples for the sand retention and compressibility were obtained by cutting 4 discs from as near the center portion of the slice of cake as possible; a bore of one inch diameter was used to cut the discs. Sand retention was measured as suggested by Swartz (28). Compressibility was measured by the Micrometer Penetrometer using the disc attachment. A 100 gram weight was added to increase the total weight of the assembly to 172.8 grams; the sample was compressed for 10 seconds. The cakes were scored the same day as baked by a seven member taste panel consisting of class members. Each judge scored slices of cake taken from the same relative position in each cake. The cakes were scored for four characteristics: texture, tenderness, flavor, and general conclusions. A seven point score card (Appendix B) was used. The judges were asked to indicate acceptability of the cakes using the term, "Yes," or "No." The judges were also asked to rank the cakes as 1st or 2nd; or 1st, 2nd, or 3rd; or 1st, 2nd, 3rd, or 4th depending on the number of cakes baked and scored each day.

A photographic record (5) was made of one series of cakes which was typical of all the cakes baked. One photograph compared the volumes and the typical surfaces of the whole cakes. A second photograph compared textures of the cut surfaces. The cake slice, used later for the compressibility test, was lightly inked with printer's ink slightly diluted with a few drops of salad oil. The ink was applied with a four inch roller. Photographs were taken using a close-up lens on a "Brownie" Kodak.

Differences in the characteristics of the plain shortenings were measured by the specific gravity, by the Micrometer Penetrometer, and by measuring the volume of a given weight of shortening after it had been melted. The specific gravity of the plain shortening was taken

using a 1/4 cup size measuring cup. All specific gravity values were obtained by the formula:

$$\text{Specific Gravity} = \frac{\text{Wt.}^{*} \text{ of a given measure of shortening at a definite temperature}}{\text{Wt. of the same measure of water at the same temperature}}$$

The Micrometer Penetrometer was used to measure viscosity of the plain shortenings: the grease cone attachment was used; a 100 gram and a 50 gram weight were added to give a total weight of 300 grams to penetrate the shortenings. Newly opened cans of shortening (3-3 pound cans for each) were used; the cone was allowed to penetrate the shortening for 1 minute. Seventy grams of undisturbed shortening were placed in a 100 milliliter graduate; the graduate was placed in a 90°-95°C. water bath for 2 hours. An immersion thermometer was placed in the graduate to indicate the temperature of the shortening. As the shortening melted, air bubbles rose to the top. At the end of the 2 hour heating period, the temperature of the shortening was between 88°-90°C.; by this time all visible air bubbles had been released from the sample. No attempt was made to measure the amount of air given off since some air was incorporated in putting the sample into the graduate. The thermometer was carefully removed from the melted shortening and the liquid level was read and recorded in milliliters. This test was substituted for the slip point test which proved impractical for this study.

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*This weight may be that of 1) plain shortening, 2) creamed shortening, 3) creamed shortening and sugar, or 4) batter.

RESULTS AND DISCUSSION

Except for the analysis of variance on the shortenings all statistical analyses are obtained by Kramer's Method of Analysis (20). An illustration of this technique is found in Appendix C--Tables 1 and 2.

The creaming ability of shortenings might be evaluated by using various types of objective tests on the shortening, on the batters made from the shortenings, and on the baked cakes made from the shortenings. Palatability scores might be used to evaluate shortening performance in the cakes.

For ease of discussion, the hydrogenated blended vegetable oils will be designated, BVO; the hydrogenated vegetable oils and animal fats, VOAF; the hydrogenated single vegetable oil, SVO; and the hydrogenated animal fats and vegetable oils, AFVO.

The shortenings appeared and reacted differently throughout the study. Undoubtedly some variation in behavior was due to humidity and to room temperature. No attempt was made to record daily humidity variations; room temperature was fairly constant during the study except for one warm day.

Shortening Characteristics

Specific Gravity

Specific gravities of the four shortenings determined on the shortening as purchased, creamed 15 minutes, and creamed with sugar 15 minutes were analyzed for significance. The results, given in Table 1,

indicated that the specific gravity was not affected as much by commercial processing treatment as by the amount of air incorporated by creaming the plain shortening for 15 minutes.

Table 1.--Analysis of Variance

Source of Variation	Degree Freedom	Sum of Squares	Mean Square	F Value
Total	11	.147898	.013445	22.2968
Shortening	3	.002561	.000854	1.4162
Specific gravity	2	.141717	.070859	117.5107**
Error	6	.003620	.000603	

**Highly significant at the 1% level.

Highly significant differences occurred because of the shortening's ability to incorporate air. No significant difference appeared between the shortenings in their ability to incorporate air. When evaluated by standard error of estimate, highly significant differences appeared between the shortening as purchased and after the 15 minute creaming period. Since the specific gravity readings were taken using a 1/4 cup measure of material, the specific gravity for shortening creamed with sugar contained an unknown weight of sugar. This masked the significance of the creamed shortening-sugar mixture. The actual averages of the specific gravities for the four shortenings as determined at four stages of combining ingredients have been presented in Appendix C, Table 3.

Melt Volume

The shortening was melted to determine the amount of air incorporated during commercial processing. After 2 hours in a hot water bath, duplicate 70 gm. samples of the plastic shortenings melted to yield average volumes: 79.5 ml. for BVO; 80.5 ml., VOAF; 80 ml., SVO; and 80 ml., AFVO. Since it was not possible to place samples of the plastic shortening into graduate cylinders without incorporating some air, no attempt was made to measure the amount of air released from the shortening during the melting period.

Viscosity - Micrometer Penetrometer

The results of the Micrometer Penetrometer tests on the plain shortening showed some differences; the viscosity of the plain shortening, AFVO, differed significantly from the viscosities of the other three shortenings at the 5% level. The Penetrometer readings are shown in Table 2.

Table 2.--A Comparison of the Micrometer Penetrometer Test on Plain Shortening (taken on three pound cans of shortening at 25^{o}C.), Volume of 70 gm. of Shortening Heated to Release Incorporated Air, and Specific Gravity of Plain Shortening

	Shortening			
	BVO	VOAF	SVO	AFVO
Specific Gravity	.526	.534	.512	.531
Micrometer Penetrometer (mm.)	2.2	2.277	2.177	1.99*
Liquid Volume (ml. at 88^{o}-90^{o}C.)	79.5	80.5	80.0	80.0

*Significant at the 5% level.

Specific Gravity, Melt Volume, Viscosity

The data for specific gravity, melt volume, and viscosity are presented in Table 2. An inverse relationship existed between the specific gravity and viscosity of the VOAF shortening; no relationship occurred in the other shortenings.

When the shortenings were creamed alone, AFVO shortening was usually soft and looked like soft whipped cream, almost runny. The VOAF shortening, when creamed, had more volume than the others and appeared light and fluffy. These changes continued upon the addition of the sugar, the AFVO gained body and lightness and became somewhat more viscous. The softness of AFVO may have been due to the result of slight warming due to friction with the mixer blades although the empirical temperature of the shortening did not change until the sugar had been added. Upon occasion the AFVO appeared waxy and was difficult to handle. Since the creamed shortenings were used in the cake batters, viscosity measurements on the cream shortenings were not made because of the danger of expressing air from the product.

Batter Characteristics

Specific Gravity

A low specific gravity indicates incorporation of a large amount of air. As air is the major leavening in pound cake, a low specific gravity in the batter for pound cake is more essential than in batters for other cakes with shortening. The specific gravities values at four stages of blending the cake ingredients have been given in Appendix C, Table 3. A relationship appeared between the specific gravity of shortening-sugar mixture and the specific gravity of their respective batters in AFVO and VOAF. Shortening VOAF had the lowest specific

gravity in both the shortening-sugar mixture and in batter, while shortening AFVO had the highest specific gravity in both the shortening-sugar mixture and in the batter. These differences were significant at both stages by the Kramer Method of Analysis. It would appear that the initial specific gravity of the shortening is not important to the ability of that shortening to incorporate air during the two creaming periods.

Viscosity

The average of readings from the MacMichael Viscosimeter and the Micrometer Penetrometer are summarized in Table 3. The MacMichael readings are empirical MacMichael units taken at 5 and 10 seconds. As the batter becomes more viscous, more force is exerted on the spindle which results in higher readings. If the batter is soft or runny, less force is exerted, thus the readings are lower.

Table 3.--A Comparison of Specific Gravity of Batter and Viscosity of Batter as Measured by MacMichael Viscosimeter and Micrometer Penetrometer with Volume of Baked Pound Cake

Shortening	Specific Gravity (batter)	MacMichael (units)		Micrometer Penetrometer (mm.)	Cake Volume (cc.)
		5 sec.	10 sec.		
BVO	.746	139.635	197.063**	34.417	1087.5
VOAF	.678*	183.125	263.438**	33.458	1187.5
SVO	.748	150.625	214.375	33.629	1128.1
AFVO	.791*	161.927	222.448	33.904	1059.4

*Significant at 5% level.

**Significant at 1% level.

Viscosity differences among the batters made from the four shortenings were apparent. By MacMichael readings VOAF was the most viscous followed by AFVO, SVO, and BVO; the difference between VOAF and AFVO was significant at the 1% level. BVO was the least viscous: this difference from SVO was also significant at the 1% level. The viscosity differences at 10 second readings for VOAF and BVO were highly significant. There was an expected positive relationship between the 5 and 10 second viscosimeter readings of all four shortenings; if the 5 second reading was low, the 10 second reading was also low. Collins (6) reported wide variations in viscosity readings even when the ingredients and mixing techniques were standardized. Reasons for the variation were stated as due to humidity and room temperature. The Penetrometer values for viscosity of this study have been in agreement with Collins' findings. In this study wide variations in MacMichael Viscosimeter readings were observed at both the 5 and 10 second readings. The batters became more viscous as the study progressed, probably due to the refinement of technique.

Viscosity of the four batters as measured by the Penetrometer showed slight variation between the four shortenings; the more viscous batter allowed less penetration by the cone which gave lower readings; the more liquid batters had greater penetration and higher readings. VOAF appeared the most viscous followed by SVO, AFVO, and BVO; measurements were not significantly different. The differences between the batters were slight according to these data, but subjective observations of the batters led to the opinion that actual viscosities were greater than those registered by the Micrometer Penetrometer. The necessary delay before testing, although the samples were covered, may have somewhat influenced the readings. Viscosity measurements by the MacMichael Viscosimeter and the Micrometer Penetrometer tended to agree for batters, made from shortenings, BVO and VOAF, which were the least viscous and the most viscous, respectively.

Cake Characteristics

The cakes were evaluated using subjective and objective measurements. A seven member taste panel, consisting of untrained class members, scored the cakes using a seven point score card (Appendix B). Objective tests included measurement of volume, tenderness, and texture. Photographs were also taken for permanent records.

Appearance

Some subjective observations were made on the appearance of the cakes; the color was fairly uniform among BVO, SVO, and AFVO; VOAF produced a cake that had a more yellow color due to the presence of carotene as a coloring agent in the shortening. Frequently, throughout the study, white spots appeared on the surface of the cake; more spots appeared on some days than on others. Jooste and Mackey (19) reported "white dots" on the surface of the cakes made from hydrogenated shortenings; these "dots" were suggested as gas bubbles which had raised the surface of the cakes. The cakes were crusty due to the long period of baking. The crust was usually uniform in color and was fairly smooth. Humped tops appeared in BVO and SVO cakes consistently even though the batter was pushed to the sides of the pan before baking.

Volumes

The volumes of the cakes differed as measured by the volumemeter; the larger numbers denoted larger volumes. The average volume of

VOAF cakes was 1187.5 cc.; SVO cakes, 1128.1 cc.; BVO cakes, 1087.5 cc.; and AFVO cakes, 1049.4 cc. VOAF cakes had significantly larger volumes and AFVO cakes had significantly smaller volumes than all other cakes at the 5% level. Subjective observations made of the cake batters showed that the batter volume of VOAF was consistently greater than for any of the other cakes; this batter also produced the largest cake volume.

The relative size and shape of the cakes were photographed near the end of the study (Illustration 1).

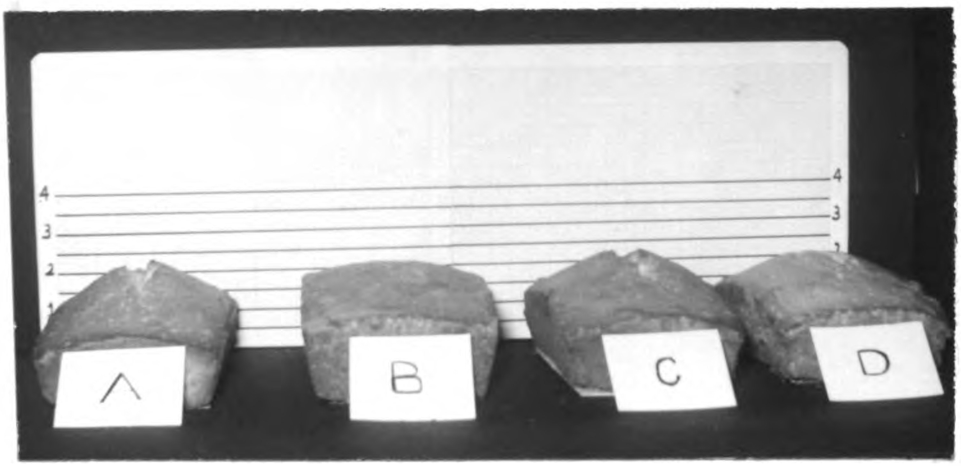


Illustration 1.--The relative size and shape of pound cakes made from four hydrogenated shortenings. A is blended vegetable oils shortening; B, vegetable oils and animal fat shortening; C, single vegetable oil shortening; D, animal fat and vegetable oil shortening.

Cake A (BVO) and cake C (SVO) were similar in appearance; the deep crack on top was typical. The height of the cakes masks the apparent volume as cake B (VOAF) had the largest volume. Some shrinkage occurred in all the cakes during the cooling process with the greatest shrinkage apparent in cake B (VOAF). The flat top of cake B (VOAF) was typical; the crack on top, if one developed, was always smaller than in the other three cakes. Cake D (AFVO) was always smaller in volume and had a fairly flat top although not as flat as B (VOAF).

Most of the literature relates high viscosity of cake batter to larger volumes of baked cakes. Cake volume data have been included in Table 3, page 15. In comparing cake volume to viscosity, VOAF produced the largest cake volume and had the most viscous batter by both MacMichael and Micrometer Penetrometer tests. This relationship occurred only with this one shortening.

When specific gravity of the batter was related to cake volume, Table 3, page 15, VOAF had the lowest specific gravity, the highest viscosity by both tests, and the largest cake volume. AFVO with the highest specific gravity, produced the cake of lowest volume; however, the two viscosity measurements were not related. Emulsifiers added to the shortening may have affected the viscosities and volumes. (Jooste and Mackey, 19).

Texture

Cake texture was measured both by sand retention and taste panel. Data have been recorded in Table 4. Lower numbers indicate less sand retention, therefore, finer texture (28). Since the differences in amounts of sand retained appeared only at the thousandths gram level these small differences were not statistically significant. Panel scores for texture were not statistically significant. However, VOAF cakes had both greatest sand retention (coarse texture) and lowest panel scores. No relationship appeared among texture, volume and specific gravity

Table 4.--A Comparison of Specific Gravity of Pound Cake Batter and Volume (cc.) of Baked Pound Cake; and of Texture Score Values, (7 high, excellent; 1 low, very poor) and Sand Retention (gms.)

Short-ening	Specific Gravity	Volume (cc.)	Texture Scores (score values)	Sand Retention (gms.)
BVO	.746	1987.5	4.736	.403
VOAF	.678	1187.5*	4.339	.429
SVO	.748	1128.1	4.535	.386
AFVO	.791	1059.4*	4.557	.381

*Significant at 5% level.

with the exception of VOAF; an inverse relationship occurred between specific gravity and volume; however, this shortening produced the poorest texture, Table 4 above. Central portions of the four cakes baked the same day were photographed. (Appendix D, Illustration 1) Slices of cake were inked. Cell walls formed the "solid" black surface of the slice and air cells appeared light.

Tenderness

Tenderness of the cakes was measured both by compressing samples of cake on the Micrometer Penetrometer and by the panel. The more tender cakes were compressed to a greater degree which gave higher readings on the Penetrometer. Average compressibility values (in mm.) were as follows: BVO, 1.436; VOAF, 1.367; SVO, 1.305; and AFVO, 0.919. Score values by the panel indicated cake VOAF was the most tender while cake AFVO was the least tender; the differences by each method of testing were not significant.

Palatability Test Scores

The average score values for palatability characteristics are shown in Table 5. For each of the palatability characteristics scored by the panel less than 0.5 of a score value occurred between the averages for the cakes made from the four shortenings. This would indicate that all cakes were equally acceptable to the panel. Acceptability was indicated by a YES or NO judgment. The number given with Y or N indicates the per cent acceptable cakes in the series.

Table 5.--A Comparison of Subjective Score Values for Palatability Characteristics of Pound Cakes Prepared from Four Hydrogenated Shortenings. (8 replicates, 7 judges, 7 point scale - 7 high)

	Shortening			
	BVO	VOAF	SVO	AFVO
Texture	4.736	4.339	4.535	4.557
Tenderness	4.991	5.25	5.003	4.243
Flavor	5.053	5.178	5.196	4.425
General Conclusions	4.923	5.089	5.018	4.357
Acceptability	Y-90.5% N- 9.5%	Y-98.1% N- 1.9%	Y-98.2% N- 1.8%	Y-88.6% N-11.3%

Flavor scores varied slightly but differences in score values were not statistically significant. Scores for general conclusions were not significant; scores of all the cakes generally increased during the study. A comment frequently made on the score sheets was that the cakes were dry; animal fat-vegetable oil shortening cakes received this comment more than any of the other cakes. Each judge was requested to give a YES value for each acceptable cake; percent acceptability was calculated by dividing the number of YES responses by the total number of responses given for that series. Each judge was requested to rank the cakes scored each day in order of preference. Depending on the number of samples presented at one scoring session, the cakes could be ranked 1st or 2nd; 1st, 2nd, or 3rd; or 1st, 2nd, 3rd, or 4th. Four samples were presented to the panel only once; two samples, at four sessions; three samples, at all other judging periods. Not all panelists were present at each scoring period so the total number of judgments for each cake varied. The analysis of preference for first choice did not show a significant difference among cakes baked from blended vegetable oil shortening, vegetable oil-animal fat shortening, and single vegetable oil shortening; however, cakes from animal fat-vegetable oil shortening were ranked significantly lower (5% level). These data have been recorded in Appendix C, Table 4.

SUMMARY AND CONCLUSIONS

Four hydrogenated shortenings were studied for variations in physical characteristics and for their performance in batters and in pound cakes baked from the batters. Evaluations were made on both batters and cakes the day the cakes were prepared; evaluations of the shortenings as purchased were made at the end of the cake baking period. If these latter tests had been run concurrently with the baking of the cakes, the data collected would have represented the shortenings actually baked into cakes.

Physical characteristics of the plain shortenings were evaluated by specific gravity of the shortenings as purchased, melt volume, and viscosity measurement. The viscosity measurement of animal fat-vegetable oil shortening differed significantly at the 5% level from those of all other shortenings. This was the only significant difference obtained in a comparison of the four shortenings by three measurements. A highly significant difference was obtained when the specific gravity of shortenings, creamed for 15 minutes at speed three on a household electric mixer, was compared to specific gravity of the shortenings as purchased. In order to retain the air incorporated, no viscosity measurements were made on the shortenings creamed for 15 minutes. Greater differences in specific gravity of plain shortenings might have been observed had a more refined method for determining specific gravity of shortening as purchased been possible. A more accurate specific gravity might have been obtained by comparing the measurement of shortening in the retail unit as purchased with an equivalent measure of water.

The evaluation of specific gravity of shortening and sugar creamed together for 15 minutes showed that the specific gravity of vegetable oil-animal fat shortening was significantly lower and the specific gravity of animal fat-vegetable oil shortening was significantly higher than the specific gravities of blended vegetable oil shortening or single vegetable oil shortening.

Cake batters were evaluated by specific gravity and viscosity as measured by two objective tests; the specific gravity of batters using vegetable oil-animal fat shortening was significantly lower while the specific gravity of batter using animal fat-vegetable oil shortening was significantly higher than the specific gravity of batters using single vegetable oil shortening or blended vegetable oil shortening. Vegetable oil-animal fat shortening had the lowest specific gravity in both the shortening-sugar mixture and in cake batter: animal fat-vegetable oil shortening had the highest specific gravity in both of these measurements. In the evaluation of viscosities of batters, the two methods of evaluation were not in consistent agreement; however, each method measured batters using blended vegetable oil shortening as the least viscous and vegetable oil-animal fat as the most viscous. The viscosity of the batters increased as the study progressed; this was probably due to improved technique by the operator. Viscosity readings may have been influenced by variations in humidity or by the length of the holding time of the batters.

The color of cakes prepared from vegetable oil-animal fat shortening was always a deeper yellow compared to the other cakes because of carotene added to the shortening.

Volumes of cakes made from vegetable oil-animal fat were larger and those from animal fat-vegetable oil shortenings were smaller than blended vegetable oil shortening and single vegetable oil shortening;

these differences were significant. The increase in volume in all cakes during the course of the study might be attributed to improved technique. Only one shortening, vegetable oil-animal fat, yielded consistent results by four methods of evaluation; it had the lowest specific gravity, greatest viscosity (two methods of measurement), and largest cake volume.

Texture of the cakes as measured by sand retention and taste panel did not differ significantly. Tenderness of the cakes as evaluated by the compressibility test and taste panel did not vary significantly; cakes made from animal fat-vegetable oil were the least tender and bordered on significance; results by the two methods of evaluation were not consistent. Some variation may be attributed to lack of uniformity in the test sample for compressibility; some samples were taken from the drier, outer portions of the cake. Score values for flavor showed no significant differences.

With few exceptions, all cakes were judged acceptable by the panel; the non-acceptance of a small percent of the cakes may have been due to poor technique at the beginning of the project rather than to the shortenings. Unfamiliarity of the judges with this particular type of cake may have influenced acceptability ratings.

If the time-temperature relation for baking the cakes could have been standardized, less variation in the acceptability of the cakes would be expected. It was not within the scope of this study to determine an optimum baking procedure.

Viscosity measurements for the cake batter may have been both more consistent and more valid if an additional 150 gm. weight had been added to the cone; this would have given a greater force for penetrating the batters. A longer time span for plunger release may have given readings that were more consistent with the appearance of the batters. A further study might investigate the relation of these two factors, time of application of force to the weight applied. The line spread test might have been used as a test for viscosity; this test may have shown more conclusive differences than the tests used.

More consistent cake compressibility readings might have resulted had additional batter been placed in the pans to give a slightly larger cake. Cutting only two 1 inch discs from the center of the cake slice would have avoided the drier outer areas and perhaps given more valid results.

The score sheet should have contained a judgment on moistness of the cakes; wetability could have been used as an objective test to check moisture content of the cakes. Storing the baked cakes for a 24 or 48 hour period would have more evenly distributed the moisture present in the cakes. Flavor differences might have been more obvious after a storage period.

There was some evidence that the panel was confused by the request to give the three judgments, "general conclusions," "acceptability," and "preference rank." This confusion might have been eliminated by combining the first two judgments into a general acceptability rating and given a point score value; this would have yielded a degree of acceptability for each cake.

Variations of the four shortenings evaluated by the methods described in this study were for all practical purposes not significant. However, the one shortening, vegetable oil-animal fat, was consistently at the higher range of acceptability while the animal fat-vegetable oil shortening was consistently at the lower range of acceptability.

REFERENCES

1. Bailey, Alton E. Cottonseed Oil. New York: Interscience Publishers, Inc. (1945), pp. 394-396.

2. Bailey, Alton E. Industrial Oil and Fat Products. New York: Interscience Publishers, Inc. (1945), pp. 203-231.

3. Binnington, D. S., and Geddes, W. F. "An Improved Wide-Range Volume-Mass Apparatus for Small Loaves," Cereal Chem. (1938) 15:235-246.

4. Carlin, George T. "A Microscopic Study of the Behavior of Fats in Cake Batters," Cereal Chem. (1944) 21:189-199.

5. Cathcart, William H. "A Practical Method of Obtaining Permanent Records of Baking Studies," Cereal Chem. (1938) 15:775-787.

6. Collins, Opal Dewey. "The Viscosity of Cake Batter as Related to Batter Structure." Unpublished M. S. thesis, Purdue University (1940).

7. Conroy, W. W. "Reports on Antioxidants in Oils, Fats and Waxes." Association of Official Agricultural Chemists - Journal (1959) 42:358-363.

8. Dean, Harry K. Utilization of Fats. New York: Chemical Publishing Co., Inc. (1938), pp. 40-59, 91-144.

9. Dunn, J. A., and White, J. R. "The Leavening Action of Air Included in Cake Batter," Cereal Chem. (1939) 16:93-99.

10. Dunn, J. A., and White, J. R. "Factor Control in Cake Baking," Cereal Chem. (1937) 14:783-801.

11. Feuge, R. O., and Bailey, Alton E. "Measurement of the Consistency of Plastic Vegetable Fats. A Standard Micropenetration Technique." Oil and Soap (1944) 21:78-84.

12. Freyer, Egbert. "A Micropenetrometer--It's Application to the Testing of Fats," Ind. Eng. Chem., Anal. Ed. (1930) 2:423-424.

13. Grewe, Emily. "The Emulsion-Foam Produced by Agitating Butter, Sugar, and Egg: A Method for Testing the Stability of the Emulsion and the Effect of Conditioning Temperature of the Fat," Cereal Chem. (1937) 14:802-818.

14. Holton, P., and Scott Blair, G. W. "The Relationship Between Conditions Governing Rupture and Flow in Flour Doughs," J. Phys. Chem. (1936) 40:811-819.

15. Hood, Maude Pye, and Lowe, Belle. "Air, Water Vapor, and Carbon Dioxide as Leavening Gases in Cakes Made with Different Types of Fats," Cereal Chem. (1948) 25:244-254.

16. Hunter, Mildred G., Briant, Alice M., and Personius, Catherine J. "Cake Quality and Batter Structure. Effects of Formula, Temperature of Ingredients, and Method of Mixing." New York: Cornell University Agr. Exp. Sta. Bull. 860 (1950).

17. Jacobs, Morris B. The Chemistry and Technology of Food and Food Products. Second ed., Vol. VII. New York: Interscience Publishers, Inc. (1951), pp. 1149-1150, 1154-1157.

18. Jamieson, George S. Vegetable Fats and Oils. Second ed. New York: Reinhold Publishing Corp (1943), pp. 215-381.

19. Jooste, Martha E., and Mackey, Andrea Overman. "Cake Structure and Palatability as Affected by Emulsifying Agents and Baking Temperatures," Food Research (1952) 17:185-196.

20. Kramer, Amihud. "A Rapid Method for Determining Significance From Rank Sums," Food Tech. (1960) 14:576-581.

21. Lowe, Belle. Experimental Cookery. Fourth ed. New York: John Wiley and Sons, Inc. (1955), pp. 438-480.

22. Lowe, Belle, and Nelson, P. Mabel. "The Physical and Chemical Characteristics of Lards and Other Fats in Relation to Their Culinary Value. II Use in Plain Cake." Iowa State Agr. Exp. Sta. Res. Bull. 255 (1939).

23. Maclay, W. D., and Matchett, J. R. "Fats and Oils and Their Future," Chemurgic Digest (1960) 19:9-12.

24. Martin, Elizabeth L. "The Creaming Qualities of Lards and Other Fats and New Ways of Mixing Them in Plain Cakes." Unpublished M. S. thesis, Iowa State College (1933).

25. Rich, A. D. "Methods Employed in Expressing the Consistency of Plasticized Shortenings," Oil and Soap (1942) 19:54-57

26. Sanders, J. H. "Processing of Food Fats--A Review," Food Tech. (1959) 13:41-45.

27. Schwitzer, M. K. Margarine and Other Food Fats. London: Leonard Hill Books, Ltd. (1956), pp. 1-49, 91-147, 193-228, 277-300.

28. Swartz, VeNona. "Two Further Simple Objective Tests for Judging Cake Quality," Cereal Chem. (1938) 15:247-250.

29. U. S. Dept. Health, Education, and Welfare. Food and Drug Administration Pub. no. 2. 1958 Revision. Sec. 201, Par. 402.

30. Vail, Gladys E. "Cooking with Fats High in Polyunsaturated Fatty Acids," J. of Am. Diet. Assn. (1959) 35:119-121.

APPENDICES

APPENDIX A

STANDARD POUND CAKE

Ingredient	Measure	Weight
Shortening	2 cups	453.6 grams
Sugar	2 1/4 cups	453.6 grams
Flour, cake	4 1/2 cups	453.6 grams
Eggs	2 cups (9 or 10)	453.6 grams
Vanilla	1 1/2 teaspoon	6
Salt	1 1/2 teaspoon	3 grams

One half of these amounts was prepared; 400 grams were baked in each cake; the remainder was used for batter tests.

Two Hamilton Beach household mixers were used to combine the cake ingredients. The conventional method of combining ingredients was used in order to determine the creaming ability of the shortening. The shortening was placed in the 3 quart mixer bowl and creamed for 15 minutes at speed three; the bowl was scraped at 2 1/2 minute intervals to insure complete creaming of the shortening. The sugar was divided into three portions; one 1/4 cup and two 1/2 cups: each portion was added gradually to the creamed shortening at the beginning of a 5 minute creaming period. The bowl was scraped at 2 1/2 minute intervals. Sugar and shortening were creamed a total of 15 minutes at number three speed. Vanilla was added. Unbeaten eggs were added gradually in three portions as the sugar. Each addition was mixed for 2 minutes at speed three for a total mixing time of 6 minutes. The bowl was scraped 30 seconds after the addition of the eggs. The mixer was slowed to speed one (very slow) and the flour and salt, sifted together twice, were added at 30 second intervals. The flour-salt mixture was divided into four portions: one, approximately 1/4 cup and three, approximately 1/2 cup. The last addition of flour was blended for 1 minute: total mixing time for addition of flour was 3 minutes. The bowl was scraped 15 seconds after each flour addition. The total blending time for each cake was 39 minutes. Four specific gravity measurements were taken and recorded at the end of the 15 minute creaming period of the plain shortening, at the end of the 15 minute creaming period of shortening and sugar, and after the cake batters were completed. Temperatures were taken and recorded before mixing began, at the end of the 15 minute creaming period of the plain shortening, at the end of the 15 minute creaming period of the shortening and sugar, and after the batters were completed. Four hundred grams of batter were weighed into new, ungreased, unlined, aluminum loaf pans, 8 3/8" x 4 3/8" x 2 5/8". The cakes were baked in two small wall ovens at a temperature of 350°F. for 30 minutes; the temperature was then reduced to 325°F. for the final 25 minutes of baking. The cakes were baked a total of 55 minutes.

APPENDIX B

SCORE CARD

Name: ____________________

Date: ____________________ Identification No. ______________

Use one score sheet for each product. Be sure that the score sheet and sample coincide and that you have filled in all data.

FACTOR	7	6	5	4	3	2	1
TEXTURE	EXTREMELY FINE small cells thin walls	very fine	fine	medium grain	slightly coarse	coarse	very coarse
TENDERNESS	extremely tender	very tender	tender	slightly tough	tough	very tough	rubbery
FLAVOR	bland well blended ingredients	very good	good	medium	fair	poor	off flavor very poor poorly blended
GENERAL CONCLUSIONS	excellent	very good	good	medium	fair	poor	very poor
ACCEPTABILITY yes or no							
PREFERENCES	On one sheet rank cakes in order. 1			2	3		

APPENDIX C

Table 1.--Kramer's Method of Analysis of Small Studies

The raw score readings are ranked 1, 2, 3, or 4 for each replication with 1 as the most desirable; in this case the most viscous or the largest number of MacMichael units. The ranks were then totaled and interpreted using the table. Significant numbers for 4 variables and 8 replications are below 13 and above 27. An illustration of this method follows.

RAW SCORES

Batter Viscosity - MacMichael readings at 10 seconds

Replication	BVO	VOAF	SVO	AFVO
1	127.667	161.667	146.667	170
2	238	253.334	250	193.334
3	207.5	283	218.334	260
4	150	325	162.5	165
5	195	245	242.5	226.25
6	236.25	310	218.75	257.5
7	183.334	263.75	231.25	265
8	238.75	263.75	245	242.5

RANKING

Replication	BVO	VOAF	SVO	AFVO
1	4	2	3	1
2	3	1	2	4
3	4	1	3	2
4	4	1	3	2
5	4	1	2	3
6	3	1	4	2
7	4	2	3	1
8	4	1	2	3
	30*	10*	22	18

*Significant at the 5% level.

Table 2.--Rank Sums

Kramer's Method of Analysis: significant numbers for 4 variables and 8 replications are below 13 and above 27.

	BVO	VOAF	SVO	AFVO
Plain shortening-				
Penetrometer*	9	10	8	3
Shortening-Sugar-Specific gravity	22.5	12	14.5	31
Batter-				
MacMichael 5 seconds	27	12.5	21	19.5
10 seconds	30	10	22	18
Penetrometer	22.5	19	18	20.5
Specific gravity	24	9	21	28
Cake-				
Volume	21.5	12.0	19.0	27.5
Compressibility	18	16	18	26
Sand Retention	23	23	17.5	16.5
Palatability Scores				
Texture	14.5	26.5	19.0	20
Tenderness	18	15.5	19	27.5
Flavor	18.5	17.5	17	27
General Acceptance	18	17.5	17	27.5
Preference	21	14	17	28

*Significant numbers for 4 variables, 3 replications lie below 4 and above 11.

Table 3.--A Comparison of the Specific Gravities of Four Hydrogenated Shortenings: as Purchased; Creamed 15 Minutes; Creamed With Sugar 15 Minutes; and as Incorporated in Pound Cake Batters

	Shortening			
	BVO	VOAF	SVO	AFVO
As purchased (25°C.)	.526	.534	.512	.531
Creamed 15 min. (25°C.)	.298	.278	.260	.264
Creamed with sugar 15 min. (30°C.)	.494	.442*	.447	.528*
Batter (25°C.)	.746	.678*	.748	.791*

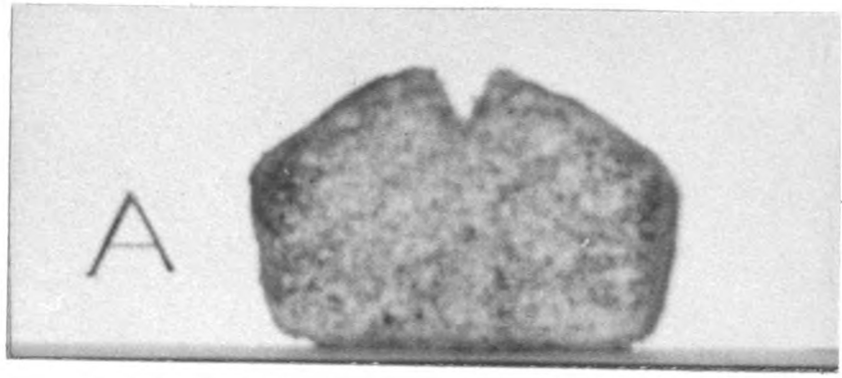
*Significant at 5% level.

Table 4.--Taste Panel Cake Preferences

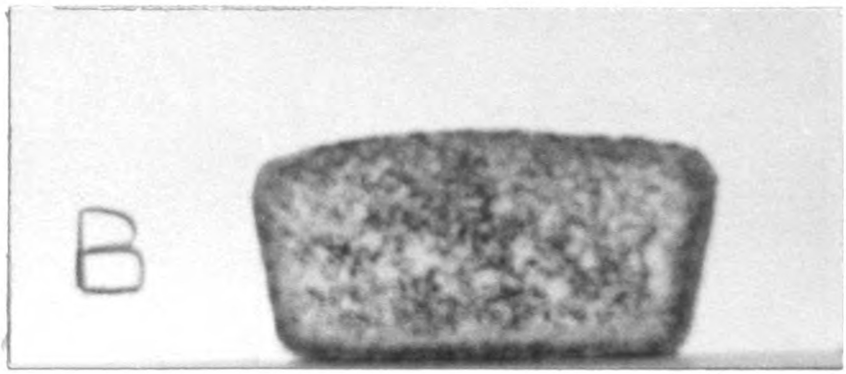
Variable Rep.	Choice	BVO	VOAF	SVO	AFVO
1	1	2	7	4	0
	2	4	0	2	7
2	1	4	3	4	1
	2	1	4	3	4
3	1	0	2	5	0
	2	6	5	2	0
	3	0	0	0	6
4	1	3	6	3	1
	2	4	0	2	1
	3	0	0	2	5
5	1	0	5	2	0
	2	2	2	5	0
	3	3	0	0	7
	4	2	-	-	-
6	1	2	5	1	1
	2	2	1	3	1
	3	1	1	2	1
	4	-	0	1	4
7	1	0	5	2	1
	2	2	1	2	1
	3	5	1	1	3
8	1	3	1	2	2
	2	1	2	3	4
	3	2	3	1	1
Total		49	54	52	51
Distribution	1	14 18.2%	34 44.1%	23 29.9%	6 7.8%
	2	22 28.6	15 19.5	22 28.5	18 23.4
	3	11 24.5	5 11.1	6 13.3	4 51.1
	4	2 28.6	0 0.0	1 14.3	4 57.1

The percentages of choices were taken from the total number of times that choice could have been made by the judges. There were 77 opportunities each for 1st and 2nd choices, 45 opportunities for 3rd choice and 7 opportunities for 4th choice. These variations are due to the variation in number of cakes made per day and in the number of judges present for the panel.

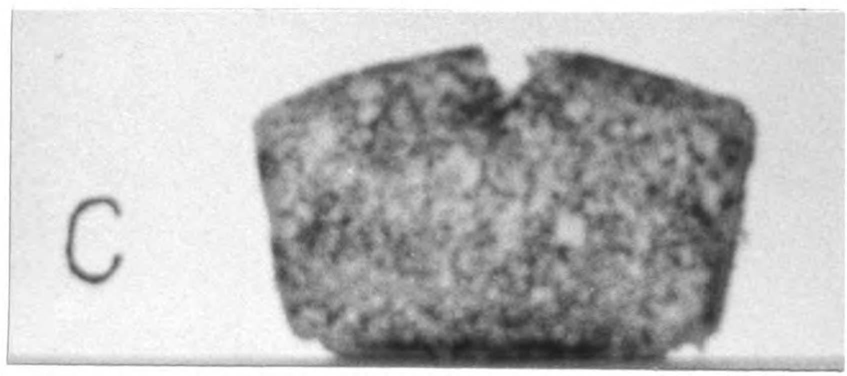
Cake made from blended vegetable oil shortening (BVO)



Cake made from vegetable oil-animal fat shortening (VOAF)



Cake made from single vegetable oil shortening (SVO)



Cake made from animal fat-vegetable oil shortening (AFVO)

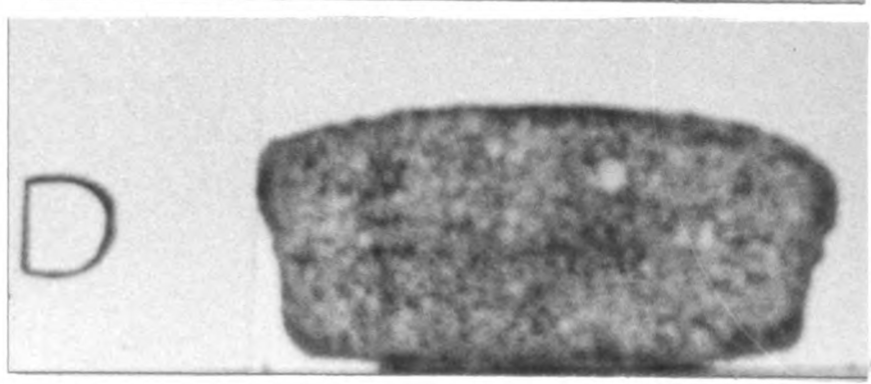


Illustration 2

Texture appeared similar in all cakes. Panel scores indicated Cake B had a slightly coarser texture. Magnification of these is not known nor standardized.