ers Manufacturing Company, Clarksdale, Miss., with 100. Tied for second place with grades of 99.8 were H.L. Hutton, Woodson-Tenent Laboratories, Clarksdale, Miss.; J.K. Sikes, Plains Cooperative Oil Mill, Lubbock, Tex.; J. M. Ridlehuber, Western Cottonoil Company, Abilene, Tex. Recalculation, with no tolerance, gave second place to Mr. Hutton.

The determination of oil resulted in a three-way tie for first place. With grades of 99.8 certificates were given to E.R. Hahn, Hahn Laboratories, Columbia, S.C.; Mr. Law; and M.P. Etheredge, Mississippi State University, State College.

The determination of nitrogen also resulted in a tie for first place, with perfect scores, to Mr. Hahn and Mr. Owen.

Tied for first place on the determination of crude fiber, with grades of 99.4, were Mr. Kesler and W.D. Simpson, Woodson-Tenent Laboratories, Wilson, Ark.

The Smalley Cup, given each year for combined proficiency on the determination of moisture, oil, and nitrogen, was won by Mr. Owen with a grade of 99.84. Mr. Hahn was second with 99.80.

IN VIEW of the exceptionally high quality of analytical work done in the Smalley program the committee believes that recognition should be given to those chemists who did not win certificates but still did outstanding work:

Meal

Combined moisture, oil, and nitrogen: Messrs. Hutton, Simpson, D.B. McIsaac, Mays, M.A. Clark, Bradham, and White

Moisture: B.D. Brock, Duane Tilson, E.C. Flack, and Robert Hein

Oil: Messrs. Simpson, Bradham, White, Clark, and Owen

Nitrogen: Messrs. Hutton, P. McG. Shuey, Mays, McIsaac, and Clark

Crude Fiber: W.J. Johnson

Vegetable Oil

Messrs. Mays, P.L. Philips, R.C. Pope, A.H. Preston, L.I. Clack, L.F. Diebel, and Stewart

Drying Oils

G.C. Reid and E.J. Jacobson

Edible Fat

Messrs. J.L. Hale, R.A. Marmor, N.J. Simon, R.M. Uschan, L.D. Belcher, Newcomb, T.C. Bond, J.J. Ganucheau, Adams, P.J. Maurer, A.H. Steffen, and J.G. Laird

Tallow and Grease

Messrs. J.R. Fortin, J.S. Boulden, J.E. Maroney, J.S. Cooley, and Preston

Other classifications are Mr. Pope, peanut; Mr. Owen, soybean; and G.G. Dickinson, cottonseed.

L.V. ANDERSON
T.J. BALDWIN
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K.H. FINK
J.R. HARRISON
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W.J. MILLER, chairman

Fluid Shortening Medium

ALAN S. GEISLER, Atlas Powder Company, Wilmington, Delaware

Because of an apparent interest in a liquid shortening with good baking properties, a program for the development of such a product was instituted. Past efforts to accomplish this by dissolving or suspending emulsifiers in vegetable oils had not had notable success. In this instance it was decided to use a different approach, that of making an emulsion in water, in trying to impart desirable baking properties to vegetable oils. It was also desired that a fluid product be produced from animal or hydrogenated vegetable fats, using the same approach.

Shortening emulsions were prepared by using sorbitan monostearate, polyoxyethylene-20-sorbitan monostearate, and mono- and diglycerides as dual-purpose emulsifiers to provide a stable emulsion and impart good baking properties. Emulsions were prepared and tested and found capable of utilizing all common shortening base-stocks in baking. In most cases also excellent results in cream icings were obtained.

The most serious problem which occurred was the tendency of emulsions made with animal fats to become plastic. A study of the causative factors was made, and the conclusion was reached that a stable fluid product could be obtained through careful selection of ingredients. Important factors which affected emulsion viscosity were monoglyceride level and hardness; the ratio of sorbitan monostearate to polyoxyethylene sorbitan monostearate, and their level; and the shortening base-stock used.

The stability of the emulsions was studied and the conclusions were reached that aging did not affect baking quality significantly although optimum effectiveness was reached apparently several days after preparation; the emulsions were not particularly subject to oxidative rancidity; bacteria and mold counts increased only slightly during storage periods as long as two months at room temperature.

An unexpected result was the markedly-improved performance when the shortening was pre-emulsified as shown by the baking data and icing quality factors which were reported.

CONSIDERABLE effort has been expended in studying the function of fats in baking and in improving shortenings through compounding and processing developments. The importance of plasticity and the value of emulsifiers have been demonstrated fairly conclusively, particularly by Carlin (1), and well summarized by Bailey (2). They have also shown that the finer the dispersion of the fat in the aqueous phase that can be obtained, up to a point, the greater the volume and the better the texture of the cake. It has also been demonstrated that the ability to trap air in the creaming of a batter is essential to the production of a cake with good volume. Plastic short-

White Layer Cake

	Plastic shortening	Emulsion
Mix 2 min., Speed No. 1	*g.*	*g.*
Cake flour	181.6	181.6
Sugar	236.1	236.1
Nonfat dry milk solids	18.2	18.2
Salt	4.5	4.5
Baking powder (double acting)	9.9	9.9
Cream of tartar	2.5	2.5
Plastic shortening	85.0	......
Emulsion	......	178.0
Water	106.0	13.0
Add slowly, mix 3 min., Speed No. 1		
Water	27.0	27.0
Add slowly, mix 2 min., Speed No. 1		
Whole eggs	13.6	13.6
Egg whites	122.5	122.5

Scale—350 g. of batter into two 8-in. pans.
Bake at 350°F. for 27 min.

Chocolate Layer Cake

	Plastic shortening	Emulsion
Mix 3 min., Speed No. 1	g.	g.
Cake flour	181.6	181.6
Sugar	236.1	236.1
Baking soda	3.4	3.4
Breakfast cocoa	36.3	36.3
Nonfat dry milk	31.7	31.7
Salt	5.7	5.7
Baking powder (double-acting)	9.1	9.1
Plastic shortening	75.0	.....
Emulsion	.....	157.0
Water	132.0	50.0
Mix 2 min., Speed No. 2		
Water	45.0	45.0
Mix 2 min., Speed No. 2		
Water	50.0	50.0
Whole eggs	100.0	100.0

Scale—350 g. of batter into two 8-in. pans.
Bake at 350°F. for 27 min.

Standard Method

Icing Volume Determination

Formula

Powdered 10X sugar (sifted)	681.0 g.
Shortening	150.3 g.
Distilled water	165.3 cc.
	996.6

Procedure. Place sugar, shortening, and one-half the water in a 3-quart Hobart bowl, using a paddle type of beater. Mix ingredients at Speed No. 1 until a thick paste is formed. Change Hobart to Speed No. 2 and, after 2 min., add remaining water slowly over a period of 3 min. Scrape down bowl. Continue creaming for a total of 24 min., taking a weight sample at 10, 15, 20, and 24 min. in a calibrated density cup.

Calculation. Volume of cup/weight of sample × 100 = volume of icing in cc. per 100 g.

enings, semi-solid at temperatures at which the batter is creamed and emulsified to provide greater dispersion throughout the aqueous phase, produce the best quality of cakes. Vegetable oils however, liquid at room temperature but not dispersed easily and therefore not able to trap significant quantities of air, produce cakes of singularly poor volume and texture in most instances. The vegetable oils do have the notable advantage of being fluid at room temperature and therefore easier to handle.

It has been held desirable for many years to develop a shortening with the baking characteristics attributed to plastic fats but with the fluidity of vegetable oils. The primary reasons advanced for this desirability have been the ease of handling such a product and the lower cost of using a vegetable oil rather than its hydrogenated counterpart. This latter reason was not always valid in view of the large quantities of lard and tallow which, on occasion, were available at lower cost for use in the baking industry, as can be witnessed in the recent past. In any event, the ease of handling and savings in labor and packaging cost possible from the use of a fluid or pumpable shortening would appear to make this a definite asset. What was desired then was a shortening which could be stored in a tank, unheated, needing no agitation, and which could be metered and pumped in exact proportions to the desired mixer.

The approach taken by most researchers in combining fluidity with baking properties has been to enhance the baking qualities of vegetable oils. Examples of such work can be seen in the patents of Linteris (3), Cross and Griffin (4), Mitchell (5), Brock (6), and Schulmann (7). Various products were added to the oils by certain specified methods so as to modify their composition and to provide better baking characteristics. These additives included saturated triglycerides, monoglycerides, modified monoglycerides, and esters and ethers of sorbitan and mannitan.

These shortenings, while certainly showing improved baking qualities as compared to unemulsified oils, still had some serious defects. They usually required stirring and heating prior to use. They were still not so effective as the best plastic, emulsified shortenings available, and they could not be used for cream icings.

The approach taken here in attempting to develop a product with as many favorable characteristics as possible, including fluidity, was by means of an oil-in-water emulsion whereby emulsifiers with known baking properties are added to plastic fats, and the mixture was then made fluid by adding to water and homogenizing. By this means also it was hoped that vegetable oils could be put in a stable form which would have improved baking properties as compared to vegetable oil shortenings developed to date.

It was felt that sorbitan monostearate (SMS), polyoxyethylene-20-sorbitan monostearate (PSMS), and mono- and diglycerides, all of which could be used to good effect as cake and cream icing emulsifiers, might serve the additional purpose of providing a stable emulsion of the fat in water.

Experimental Methods

The emulsions described in the following experiments were prepared by weighing together the shortening base-stock and emulsifier; melting by heating to 55°C.; and adding to an equal, or slightly more than equal amount of water at 55°C. with agitation. The crude emulsion was homogenized at 2,000–2,500 p.s.i. to achieve its final dispersion, then cooled. The emulsions were not tempered prior to use, or cooled in any way other than sitting at room temperature.

The formulas and procedures for the white and chocolate cakes used in the baking test were as follows (formulas are adjusted so that the fat content is equal in all cases).

TABLE I

Comparison of Effectiveness of Several Emulsions in White Cakes and Cream Icings. Plastic Shortening Base-Stock Used

Shortening	% Emulsifier (on fat)			Cake Performance			Icing Performance	
	SMS	PSMS	Plastic mono[a]	Batter sp. gr.	Texture	Volume	Volume	Texture
1. Control—Plastic shortening	.....	.....	6.0	1.04	Mod. tough	1765	131	Mod. light and fluffy
2. Emulsion	.....	.....	6.0	1.02	Sl. tough	1855	96	Soupy and separated
3. Emulsion	0.1	0.9	6.0	0.88	Tender	2330	122	Sl. wet and sl. fluffy
4. Emulsion	0.5	0.5	6.0	0.93	Sl. tender	2130	132	Mod. light and fluffy
5. Emulsion	0.9	0.1	6.0	0.90	Mod. tender	2260	121	Sl. wet and sl. fluffy
6. Emulsion	1.5	3.5	6.0	0.75	Tender	2335	170	V. light and fluffy
7. Emulsion	1.8	4.2	6.0	0.74	Tender	2400	176	V. light and fluffy
8. Emulsion	2.1	4.9	6.0	0.73	Tender	2450	172	V. light and fluffy

[a] 42% *alpha* monoglyceride, prepared by the glycerolysis of lard.

TABLE II

Comparison of Performance and Physical Characteristics of Emulsions Prepared from Varying Base-Stocks

Emulsion No.	Composition (% based on total fat)					Viscosity (96 hours)	Cake and Icing Performance				
							White Cake			Cream Icing	
	Hydrog. veg. oil	Soybean oil	SMS	PSMS	Plastic mono [a]		Batter sp. gr.	Texture	Volume	Volume	Texture
1	87.0	......	1.1	2.4	9.5	Very thick	0.74	Sl. tender	1975	173.0	V. Light and fluffy
2	78.3	8.7	1.1	2.4	9.5	Thick	0.72	Sl. tender	1975	......	......
3	65.3	21.7	1.1	2.4	9.5	Mod. thick	0.73	Sl. tender	1985	......	......
4	43.5	43.5	1.1	2.4	9.5	Sl. thick	0.72	Mod. tender	2025	185.8	Light and sl. stringy
5	......	87.0	1.1	2.4	9.5	Mod. thin	0.76	Mod. tender	2060	190.0	Soupy and stringy

[a] 42% *alpha* monoglyceride, prepared by the glycerolysis of lard.

Experimental Results

Evaluation of Effectiveness. The first series of emulsions compared the effectiveness of several formulations of SMS and PSMS in animal fats, using a constant mono- and diglyceride content of 6.0%, based on the fat in order to determine the feasibility of the pre-emulsion concept. The results (Table I) showed that stable emulsions could be prepared successfully and that increasing quantities of emulsifier produced improved cakes. The emulsion prepared by using mono- and diglycerides as the sole emulsifiers was unstable and produced poor cakes but of better quality than that of the plastic shortening containing the same mono- and diglycerides. In standard cream icings, higher emulsifier levels produced greater volume and improved quality. It was interesting to note however that the cream icing prepared from the unstable emulsion was much poorer than the plastic shortening control.

A series of emulsions was prepared, in which the shortening base-stocks were altered to measure the relative effectiveness of hydrogenated and nonhydrogenated vegetable oils and to examine the feasibility of the latter as a base stock in emulsion formulations. SMS/PSMS (30/70) was used at a level of 3.5% with 9.5% lard mono- and diglycerides, based on fat. Base stocks ranged from winterized vegetable oil to hydrogenated vegetable oil and included combinations of both. It was found (Table II) that the vegetable oil emulsions surprisingly produced better-volume cakes than the hydrogenated vegetable oil. In icings also, greater volume resulted from increasing proportions of vegetable oil, but formula modifications may be desirable to improve the texture.

Determination of Factors Affecting Fluidity. In all the test series to this point, little attention had been paid to the fluidity, or lack of it, in the emulsions and to the factors affecting this property. It had been noted that thinner emulsions were obtained with vegetable oils than with plastic fats, as might be expected. Until more knowledge could be gained concerning these factors, it would not be possible to develop formulations which could be expected to remain fluid at all times under normal conditions.

Regarding the tendency of emulsions to become plastic, it was found that this generally occurred within 12–24 hrs. after preparation, or not at all.

The first factors examined were physical: temperature of emulsions when homogenized; slow or rapid cooling; and practice of adding water to the fat in mixing or *vice versa*. None of these were deemed to be significant in emulsion thickening although it was decided that more consistent emulsions were obtained when the fat was added to the water.

The next step was to examine the effect of various ingredients, singly or in combination. Considerations were SMS/PSMS ratio and level; monoglyceride type and level; and the base-stock used. The quantity of water used was limited by the applications for which the emulsion was intended.

In one test to determine the relative effectiveness of different SMS/PSMS ratios and their effect on emulsion viscosity, it was found that decreasing the proportion of SMS to PSMS improved the fluidity markedly. It was decided that in order to have consistently fluid emulsions, the ratio of SMS to PSMS should not exceed 1.5.

A factorial experiment was then set up to determine the effect of varying levels of SMS/PSMS (30/70) in combination with varying levels of mono- and diglycerides (Table III). It was determined that lower total emulsifier levels produced the least viscous emulsions but that higher levels worked best in cakes and icings, thus necessitating a compromise. Indications were that the optimum combination could be obtained by using higher levels of SMS and PSMS but intermediate levels of monoglycerides since both emulsifier types apparently exerted a similar effect on viscosity. The sorbitan emulsifier seemed to be more effective per unit weight, from the standpoint

TABLE III

Factorial Experiment, Comparing the Effect of Varying SMS/PSMS and Monoglyceride Levels on Emulsion Viscosity and Cake, Icing Quality

SMS/PSMS ratio of 30/70 used in all emulsions; lard mono- and diglycerides used.

Emulsion No.	Emulsifiers				Viscosity	Performance Data		
	% SMS/PSMS	% Plastic mono [a]	Code SMS/PSMS	Code mono		Batter sp. gr.	Cake volume	Icing volume
1	2.5	1.46	−.7	−.7	Thin	0.95	1840	127.0
2	2.5	8.06	−.7	+.7	Mod. thick	0.77	1940	167.5
3	4.5	1.46	+.7	−.7	Mod. thick	0.87	1850	160.6
4	4.5	8.06	+.7	+.7	Very thick	0.82	1955	179.6
5	5.0	4.75	+1.0	0	Sl. thin	0.89	1860	173.3
6	2.0	4.75	−1.0	0	Sl. thick	0.92	1900	168.3
7	3.5	9.50	0	+1.0	Thick	0.80	2000	175.0
8	3.5	0	0	−1.0	Sl. thick	0.93	1850	144.5
9	3.5	4.75	0	0	Mod. thick	0.88	1925	178.0
10	3.5	4.75	0	0	Mod. thick	0.88	1950	180.4
Control—Emulsified plastic-shortening	......	......	......	......	......	0.95	1740	134.0

[a] 42% *alpha* monoglyceride, prepared by the glycerolysis of lard.

TABLE IV

Baking Quality and Physical Characteristics of Emulsions Prepared, Using Several Different Monoglycerides. All Emulsions Prepared from Soybean Oil Base-Stock

Mono Type [a]	% Emulsifiers				Viscosity	Cake Performance					
						White Cake			Chocolate Cake		
	SMS	PSMS	Mono	Mono I.V.		Batter sp. gr.	Texture	Volume	Batter sp. gr.	Texture	Volume
1. Lard, mono	1.1	2.4	9.5	60	Fluid, thin	0.72	Mod. tender	2075	0.94	Sl. tender	2000
2. Tallow, mono	1.1	2.4	9.5	40	Fluid, mod. thick	0.71	Mod. tender	2040	0.89	Sl. tender	2000
3. Lard/hyd. lard, mono	1.1	2.4	9.5	30	Plastic, mod. firm	0.73	Mod. tender	2075	0.78	Mod. tender	2100
4. Hyd. lard, mono	1.1	2.4	9.5	3	Plastic, mod. firm	0.77	Mod. tender	2040	0.78	Sl. tender	2070
5. Lard, mono	2.1	1.4	9.5	60	Fluid, mod. thin	0.70	Mod. tender	2025	0.90	Sl. tender	2090
6. Tallow, mono	2.1	1.4	9.5	40	Plastic, mod. firm	0.69	Sl. tender	1985	0.79	Mod. tender	2140
7. Lard/hyd. lard, mono	2.1	1.4	9.5	30	Plastic, mod. firm	0.74	Mod. tender	2050	0.75	Mod. tender	2140
8. Hyd. lard, mono	2.1	1.4	9.5	3	Plastic, very firm	0.78	Mod. tender	2050	0.74	Mod. tender	2220

[a] 42% *alpha* monoglyceride, prepared by the glycerolysis of the indicated base-stock.

of cake and icing performance, than were the monoglycerides, which in this case were only 40% *alpha* monoglyceride.

Finally a series of emulsions was prepared, using soybean oil as a base stock, in which the monoglyceride type was varied at two different SMS/PSMS ratios. While emulsions containing the larger quantity of SMS were somewhat more viscous than those with the greater proportion of PSMS, it was found that the monoglyceride type exerted an enormous effect on emulsion thickness (Table IV). Even vegetable oil, using optimum SMS/PSMS ratios, could be made nonfluid by a relatively small percentage of hard mono. Baking tests revealed very little difference in white cakes, using any of the FSE's prepared in this test, but in chocolate cakes the harder mono preparations did work somewhat more effectively.

Stability Studies. In order to complete development it was considered desirable to study such factors as the effect of age on baking quality; the propensity of the FSE to develop oxidative rancidity with different base-stocks; and the susceptibility of the emulsions to bacterial and mold contamination.

A relatively short-term study of the effect of age was made, comparing fresh, 5-day-old and 10-day-old samples of FSE. Two ratios of SMS/PSMS were used: 30/70 and 60/40. No significant differences were noted except that 5-day-old emulsions were slightly more effective than the others.

Resistance to oxidative rancidity of FSE, using different shortening base-stocks, was determined. The fats tested were hydrogenated vegetable oil, hydrogenated vegetable oil/lard, lard, and soybean oil. Peroxide values were obtained (8) over a storage period of one month at room temperature. None of the samples became rancid, but the soybean oil showed the greatest increase in peroxide value.

The final measurement of stability taken was the susceptability to bacterial and mold contamination. Plate counts of bacterial and mold content were made by using nutrient and malt agar, respectively. This experiment showed that 2-month-old emulsions contained an average of 26 mold spores and approximately 500 bacteria per gram; these were quite low. Freshly-prepared emulsion showed no count but probably contained 0–1 mold spore and 0–5 bacteria per gram. It was felt that the use of a low level of preservative in the emulsion would provide all the bacterial control that was necessary.

Summary

Development work has reached the stage where successful fluid shortening emulsions can be prepared by using such varied base-stocks as lard, vegetable oil, or hydrogenated vegetable oil. Baking tests, using any of the base-stocks mentioned, yield favorable results, improved over plastic shortenings containing the same emulsifiers. Many of the formulations work very well in cream icings and fillings.

Based on the results found in the foregoing test series and confirmed by later tests, it is evident that the most important factors in emulsion viscosity are the monoglyceride type, total emulsifier levels, SMS/PSMS ratios, and the base-stock used.

As regards stability, the bacteriological determination did show a small increase in count after 60 days of storage, but this increase does not appear nearly large enough to be a matter of concern. Also, in commercial practice, it is not expected that batches will stand unused for such a length of time.

Further development of this concept should enable the shortening industry to make a significant contribution toward more efficient, lower-cost operation for its customers.

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