Use of Oil in Baked Products—Part II: Sweet Goods and Cakes

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ABSTRACT

The discussion on the current trend in the United States to switch from the conventionally accepted lard or partially hydrogenated vegetable shortening to oil as the shortening medium in baked goods is continued. Problems encountered when oil is used to replace the plastic shortenings in sweet doughs and cakes are described. Test work has shown that surfactants are useful tools in counteracting the resultant negative aspects associated with the use of oil. A review of various surfactant systems with oil and their effects on finished sweet dough and cake quality are discussed.

INTRODUCTION

As was mentioned in Part I of "Use of Oil in Baked Goods, Background and Bread" (1), success with replacing plastic shortening with vegetable oil plus a conditioner-softener in bread encouraged evaluation of other areas in the baking industry where such a concept would be applicable. Sweet goods and cakes were two areas selected for study as large quantities of shortening are utilized in their preparation.

USE OF OIL IN SWEET GOODS

Although sweet goods are defined as yeast-leavened baked products, they represent a different segment of this classification than do white pan bread and rolls. The American Institute of Baking reports that sweet goods account for ca. 17% of the total cash sales in the bakery market. They are sold in the form of coffee rings, specialty breads and individual items prepared specifically for vending machines, institutions and cafeterias.

Unlike bread, sweet goods contain high percentages of sugar, shortening, eggs, and various other enriching ingredients. The percentage of these ingredients varies from formulation to formulation, depending on the bakery's facilities, capabilities, budget and, of course, on customer preference. As a result, lean, medium and rich sweet dough formulations exist containing a range of 10-30% shortening based on flour weight (fl. wt.).

Shelf life of these sweet good products is a critical aspect especially for the individual items, as they possess large surface areas which tend to dry out, and in addition, stale rapidly. As a result, it is generally accepted practice to incorporate high levels of mono- and diglycerides into the formulations to improve shelf life, as well as grain, texture and eating qualities.

As in bread, lard and partially hydrogenated vegetable shortening were at one time accepted as the standard shortenings for sweet goods. Vegetable oil was unacceptable for use as it promoted poor handling properties and an open, irregular grain. Table I briefly summarizes the data generated when soya oil is substituted in a sweet dough formulation for 15% plastic shortening (fl. wt.). As can be seen, the data confirm this previous statement concerning the negative effect of oil on dough quality.

Because of today's inflationary prices and the increased competition in the area of sweet goods, the industry is slowly moving toward a leaner formulation that contains less than 10% fat (fl. wt.). These same factors are creating the impetus toward the replacement of plastic fat with vegetable oil. Such changes must be made without negatively affecting the product's other qualities.

In conjunction with laboratory evaluations, it was learned that bakers in the industry were running trials in

[1]Presented at the American Oil Chemists' Society, San Francisco, CA, April 29-May 2, 1979.

TABLE I

Evaluation of Shortening in Sweet Dough

Type shortening	Handling properties	% Change in sp. vol. over control vol (cc)/wt. (g)	Grain	Softness index 2 Days	Softness index 6 Days
Plastic veg.	Good	---	Regular, SL. course	1.00	1.00
Soya oil	Poor, v. sticky	.90	Open, irreg.	.96	.93

TABLE II

Effect of Oil in Sweet Doughs

Shortening test	Emulsifier	% Emulsifier (fl. wt.)	Handling properties	% Change in sp. vol. over control vol. (cc)/wt. (g)	Structure	Average softness index over 6 days
Plastic, veg.	---	---	Good	---	Good	1.00
Plastic, veg.	Mono	2.0	Good	2.08	Good	.69
Plastic, veg.	Mono/poly 60	1.5	SL. sticky	2.08	SL. collapsed	.75
Oil, soya	Mono	2.0	V. sticky	5.86	SL. collapsed	.58
Oil, soya	Mono/poly 60	1.5	Good	5.29	Good	.59

which oil plus a mono- and diglyceride-polysorbate 60 blend was being used to replace the plastic fat in sweet dough formulations. It was reported that they were substituting 8% vegetable oil (based on fl. wt.) for the 12-15% plastic fat (based on the fl. wt.) contained in their formulas. This information was utilized in the test designs reported here.

The data in Table II are based on a control sweet dough formulation containing 15% partially hydrogenated vegetable shortening (fl. wt.). Eight percent (fl. wt.) vegetable oil was used to replace the plastic fat – a 45% decrease in total fat weight. A high mono- and diglyceride (62% total mono) and a mono- and diglyceride-polysorbate 60 blend in a 3:1 ratio were then evaluated in each of the two fat systems.

The results showed that when the plastic shortening was used, the mono- and diglycerides provided better handling properties and structure than did the mono- and diglyceride-polysorbate 60 blend. When soya oil was used, however, the mono- and diglyceride-polysorbate 60 blend provided equivalent specific volume and softness and superior handling properties to the use of mono- and diglycerides. It also should be noted that the use of soya oil plus the conditioner-softener provided results superior to the partially hydrogenated vegetable shortening plus the mono- and diglycerides.

Figure 1 describes the softness of the products at two and six days. As can be seen, use of 1.5% (fl. wt.) of the monoglyceride-polysorbate 60 blend with 8.0% soya oil (fl. wt.) provides softness in the finished product at two and six days equivalent to 15.0% plastic shortening and 2.0% mono- and diglycerides (fl. wt.). The data represent the grams of force necessary to compress the product four millimeters. The lower the value, the better the softness.

Studies (Table III) on the Brabender extensograph were performed to evaluate doughs containing the above fat systems and to determine the reasons for these performance differences. These measurements indicated that the oil produced a softer dough than did the plastic shortening; that is, doughs with oil had a lower resistance to extension to extensibility ratio that did doughs containing plastic fat. When the mono- and diglyceride was incorporated into the dough containing oil, an even softer dough was obtained as described by an even lower resistance to extension to extensibility ratio. When the mono- and diglyceride-polysorbate 60 blend was added into the dough containing oil, an increase in dough strength resulted. This was indicated by a higher resistance to extension to extensibility ratio, meaning resistance and reduced extensibility – both of which are important factors for a well conditioned dough. Thus, it can be seen that significant performance improvements and ingredient reductions can be realized in replacing the lard or plastic shortening with vegetable oil plus a conditioner-softener in sweet goods.

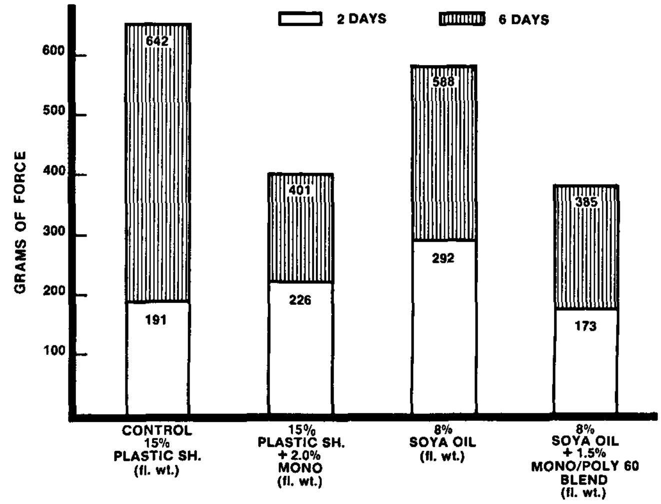

FIG. 1. Softness at 2 and 6 days in sweet doughs (as determined by Instrom).

USE OF OIL IN CAKES

The next area of study concerned vegetable oil as a shortening medium in cakes. Cakes are chemically leavened bakery products. Although produced in considerably less quantity than the yeast-leavened products discussed previously, cakes represent an important area for study due to their unique nature and their varied fat content which ranges from 0-50% based on flour weight. Bailey describes a cake as being "distinctive among baked products for its combination of extreme sweetness with a highly developed cellular structure. To dissolve the large proportion of sugar used in its composition, cake batters must contain high percentages of liquids. Hence, cake doughs are thinner and more fluid than other classes of baked goods. In order for the relatively watery cake batter to rise and assume the desired form in the baking operation, its structural requirements are extremely critical. The shortening used in the cakes plays a predominant role in determining the structure. Consequently, the quality requirements for cake making fats are much more exacting than for fats which are to be used for other baking purposes" (2). Although plastic fats are functional, liquid oils have been found to be generally inapplicable to cake baking. Pyler explains: "From a colloidal viewpoint, cake batters are emulsions consisting of an internal phase comprised of the fat, and an external phase made up of the remaining ingredients .... If a cake batter made up with a plastic fat to which a small amount of oil soluble dye has been added is examined under a microscope, it will disclose the fat to be dispersed throughout its mass in the form of small irregularly shaped praticles .... The fact that the fat appears in the batter in the form of irregularly shaped particles rather than as spherical droplets, as is usually true of the oily phases of an ordinary emulsion, is attributable to the plastic instead of liquid character of the shortening. If these fat particles are closely examined, it will be seen that they enclose numerous minute air bubbles which have been incorporated during the mixing process" (3). Hence, aeration is dependent on the ability of the plastic fat to retain air. Liquid oils do not have this property. Carlin, in his microscopic studies, showed dispersion of plastic fat into globules throughout the batter and the ability of the fat to incorporate air were directly related to volume and grain in the finished product (4). Hence, liquid oils without the ability to incorporate air

TABLE III

Extensograph Studies on Sweet Doughs

	Extensibility tests	
	% Emulsifier (fl. wt.)	Resistance BU/Extensibility mm @ 135 min.
Control, 15% plastic shotening	---	2.87
8% Soya oil	---	2.47
8% Soya oil + mono- and diglycerides	2.0	2.19
8% Soya oil + mono/poly 60 blend (50% active)	4.0	2.69

TABLE IV

Effect of Oil in:

% and type shortening (fl. wt.)	115% White cake				130% Devil's food cake			
	Batter		Cake		Batter		Cake	
	Visc. (mcps)	SP. GR.	Volume (cc)	Grain	Visc. (mcps)	SP. GR.	Volume (cc)	Grain
Plastic fat	26	1.02	743	Open, even	38	.92	950	Coarse, irreg.
Soya oil (1/3 Fat red.)	6	1.20	690	Open, coarse	4.8	1.20	925	Medium cell wall SL. uneven

TABLE V

Effect of Oil and Emulsifier Hydrate in 130% Yellow Cakes

% and type fat (fl. wt.)	% Comm. hydrate	SP. GR.	Volume increase over control (cc)	Grain, texture		Softness index 1 day
41% Plastic	2.0	.86	113	Open, even	SL. firm, good	.80
27% Liquid	4.0	.80	133	Open, even	Very tender	.69

produced low volume and poor grain.

Because of this need for plasticity, lard and butter were at one time the preferred fats for cakes. However, lard lacked creaming ability and was characterized by a lack of uniformity which caused variation in the quality of the finished product. As the demand for plastic shortenings increased before the 20th century, compound shortenings were produced by blending vegetable and marine oils with a percentage of high melting tallow stock. In the early 1900s, with the advent of the hydrogenation process for edible oils, it became possible to transform a liquid oil into a plastic fat and to control consistency without the addition of a hard fat fraction. Optimum fat crystal polymorphic type was crucial to the success or the ability of the shortening to incorporate air in the cake batter. Baldwin et al. performed studies on the creaming ability of shortenings stable in the α, β and β' crystalline forms. They found that it was essential for the fat to be in the β' crystal form to promote optimum creaming (5).

In the 1930s, the advent of the superglycerinated shortenings, followed quickly by other emulsified shortenings, made certain changes in cake formulations possible. These included the use of higher sugar and liquid levels and a decrease in dependency on the fat's plasticity for aerating and lubricating functions.

Within the last 30 years, additional advances have occurred in the area of cake technology. The development of the continuous cake mixing unit further minimized the dependence of aeration on the fat quality. The need for ingredients in bulk to reduce cost and improve manufacturing efficiency promoted the fluid shortening era for cakes. These products contained a suspension of hard stock and emulsifiers in triglycerides, such as soybean oil. As with the partially hydrogenated shortenings, success of these fluid shortenings depended on the development of the proper fat polymorph. Specialty emulsifier hydrates or dispersions of various emulsifiers in water were also marketed that further enhanced the finished cake quality.

Bakers, encouraged by the results of the vegetable oil plus conditioner-softener concept in bread, directly and indirectly required similar emulsifier systems that facilitated the replacement of plastic shortening with vegetable oil in cakes.

To accomplish this objective, laboratory studies involved comparative baking with vegetable oil and plastic shortening in cakes. Three formulations, a 115% white, a 130% devil's food, and a 130% yellow were used in these studies. As in the bread and sweet goods evaluations, a one-third reduction in total fat was used in making the replacement of vegetable oil for plastic shortening in initial test work. Batters containing the vegetable oil (Table IV) were less viscous. Finished cakes containing oil were greasy, had low volume and open grain when compared to cakes containing the partially hydrogenated plastic fat. This example clearly emphasizes the dependency of the batter on the plastic nature of the fat for aeration.

Test work then involved evaluating cakes containing vegetable oil in combination with commercial hydrated emulsifier systems. Table V describes test work where the liquid oil was again used at two-thirds the level of the plastic fat. The results showed that the emulsifier overcomes the negatives associated with the use of liquid rather than plastic fat. Although batters had increased fluidity when compared to batters containing plastic fat, cakes had excellent volume, grain, and crust appearance. Unfortunately, however, cakes also exhibited signs of extreme tenderness. The commercial hydrate used in this test contained a blend of mono- and diglycerides and polysorbate 60, and was about 50% active.

Studies next were directed to the oil level. Cakes were prepared with decreasing amounts of oil replacing the plastic shortening and a commercial cake emulsifier hydrate. Subjective and objective testing showed even greater than one-third reductions in total fat content could be realized when switching from plastic to liquid fat. Our results indicated that a 33% decrease and a 60% decrease in

TABLE VI

Performance of Emulsifier Blend in Cakes

% and type shortening	Type hydrate	% Hydrate (fl. wt.)	SP. GR.	Viscosity (mcps)	Volume increase over control (cc)	Grain, texture
115% White cake						
21% Plastic	Commercial hydrate	3	.94	32.2	85	Good, even
14% Oil, soya	Mono/poly 60/SSL	5	.89	20.0	60	Good, even
130% Devil's food cake						
41% Plastic	Commercial emulsifier	3	.91	48	35	Even, regular, good eating qualities
17% Oil, soya	Mono/poly 60/SSL	4	.88	11	70	Even, regular, good eating qualities

total fat (both based on fl. wt.) in the 115% white, and 130% yellow and devil's food cakes, respectively, provided best texture characteristics without negatively affecting any of the cake's other attributes.

Continued studies with various emulsifier combinations, stabilizers and hard fat flakes revealed that a blend containing mono- and diglycerides, polysorbate 60 and sodium stearoyl-2-lactylate was most functional (Table VI) in promoting the desired specific gravity, volume, grain and overall appearance as well as texture and shelf life in the finished cakes. This emulsifier blend facilitated the production of cakes made with liquid vegetable oil that were as high a quality as cakes made with plastic shortening plus a commercial emulsifier hydrate. In addition, this blend was equally functional in all three cake systems. Shown in Table VI are two examples of the performance of this hydrate in 115% white cakes and 130% devil's food cakes against a comparator containing plastic shortening and a commercial cake hydrate.

Even more recently, individual companies have been seeking recommendations for making their own fluid shortenings. These companies have plant facilities capable of melting and blending emulsifiers into liquid oil, and they feel that cost savings of producing their own fluid shortening would be significant if feasible. PGMS-Type 2180 is recommended for this purpose. This is a product that was introduced by Lensack and MacDonald in 1967 and is only now gaining acceptance (6). This is a propylene glycol monostearate compound containing 85-90% propylene glycol monoesters which is made by a propoxylation process (7). PGMS-Type 2180 is completely soluble in vegetable oil, and clear liquid shortenings containing 8-15% of this product can be very easily prepared. There is no concern with controlling the polymorphic form of the fat. Stability tests show that the liquid shortening remains as a stable, clear dispersion up to levels of 12% at 60-90 F for an indefinite time period. Cycling studies between 30 F and 110 F reveal that this liquid dispersion does congeal at low temperatures, but upon reaching 68-72 F returns to its original clear liquid form. Thus, there are no handling, storage or separation problems. Finally, once this clear liquid shortening is made, there is no further need for continued agitation. In addition to its ease of preparation, this clear liquid shortening is extremely functional in cakes. It promotes excellent batter aeration and appearance, and cake volume, grain, and texture. Figure 2 shows the effect of increasing levels of PGMS-Type 2180 in vegetable oil on white cake volume. As can be seen optimum performance levels here tend to be in the range of 10-12% based on the oil weight.

Table VII portrays laboratory data derived from our evaluations of PGMS-Type 2180 liquid shortenings in a 130% yellow cake formulation having 41% fat based on flour weight.

The clear liquid shortening blends containing 8-14% PGMS-Type 2180 were used as direct replacements for a commercial fluid cake shortening. In addition, a control cake was made with only soya oil. The results indicate that all the clear liquid shortenings were very effective in improving the cake quality over the control cake; in addition, these test blends were, at the least, as functional as the commercially made fluid shortening. All plant trials to date have confirmed these laboratory investigations.

Several factors, including inflationary ingredient prices, increased product competition, the new labeling laws, and the increased consumer interest in nutrition encouraged the baking industry to evaluate alternate ingredients for their formulations. As shortening represents one of the most expensive ingredients used in bakery formulations, particularly in bread, sweet goods and cakes, there is much enthusiasm for a concept that would not only insure supply but also reduce quantity and, hence, cost. Successful use of oil in baked goods has been a technological advancement in the bakery industry. With the proper emulsifier system, oil

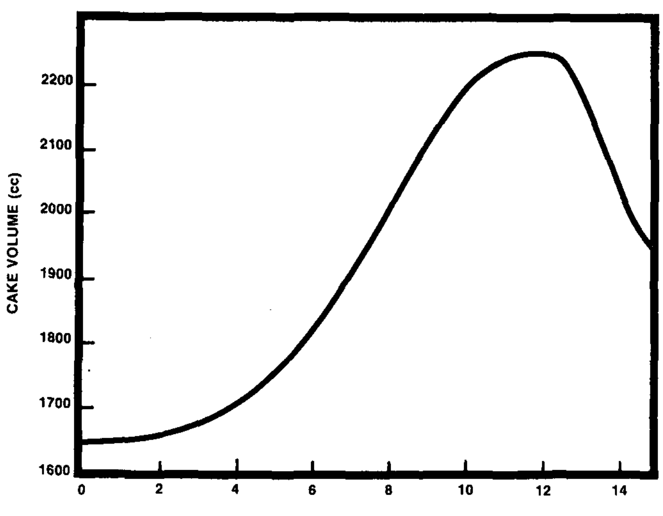

FIG. 2. Effect of PGMS-Type 2180 emulsifier in oil on cake volume.

TABLE VII

Evaluation of Liquid Shortening in Cakes

Type fat	% PGMS-Type 2180 short, wt.	Batter gravity	Volume increase over control (cc)	Texture, grain
Soya oil	8.0	.91	214	Reg. firm
Soya oil	10.0	.82	269	Reg. firm
Soya oil	12.0	.78	254	SL. tender, SL. open
Soya oil	14.0	.74	271	SL. tender
Soya oil	---	1.03	---	Greasy, grainy, tender
Fluid shortening, commercial	---	.93	141	SL. tender, SL. open

can be an effective alternative to plastic fats in bread, sweet goods and cakes.

REFERENCES

1. Hartnett, D.I., and W.G. Thalheimer, JAOCS 56:944 (1979).
2. Mattil, K., F. Norris, and A. Stirton in "Bailey's Industrial Oil and Fat Products," Edited by D. Swern, 3rd Edition, Interscience Publishers, New York, 1964.
3. Pyler, E.J., "Baking Science and Technology," Siebol Publishing Company, Chicago, IL (1973).
4. Carlin, G.T., Cereal Chem. 21:189 (1944).
5. Baldwin, R.R., R.P. Baldry, and R.G. Johansen, JAOCS 49:473 (1972).
6. MacDonald, I.A., G.P. Lensack, Cereal Sci. Today 12:10 (1967).
7. Brander, J.D., and G.J. Stockburger, U.S. Patent No. 3,499,917, 1970.

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