Technical

Cake Shortenings

D.I. HARTNETT, ICI Americas Inc., Food Laboratory, Wimington, DE 19897

ABSTRACT AND SUMMARY

Triglycerides have been traditionally used in cakes to provide tenderness and grain. Specialty cake shortenings are used today to improve batter aeration, cake volume, grain, and to extend shelf life. The role of emulsifiers in providing improved shortening characteristics will be discussed. The features that will contribute to a quality cake shortening – manufacturing procedures, characteristics, and specifications – will be reviewed. Methods of use and handling will be related to cake quality.

INTRODUCTION

Cakes made 100 years ago had low volume, coarse grain, and dry crumb. In comparison, cakes made today have good volume, regular grain, and a moist and tender crumb. Although many factors have contributed to these improvements, the shortening has played a major role.

One hundred years ago lard and butter were the preferred fats for cakes. Both imparted an excellent flavor and were of a soft consistency at room temperature which allowed for easy incorporation into a batter. Vegetable oils were too fluid, and tallow was too firm for use. Problems with the lard, however, centered in two areas (1): (a) its lack of uniformity which in turn caused variations in finished products; and (b) its poor creaming properties, that is, its inability to incorporate air.

Even with its shortcomings the demand for lard gradually exceeded the supply (2); this stimulated the production of compound shortenings made by blending vegetable and marine oils with a percentage of a high melting tallow stock called oleostearine. In the early 1900s, the development of the hydrogenation process for edible oils was a major advancement in shortening technology. This process permitted the transformation of a liquid oil into a plastic shortening without dependence on the addition of the hard animal fat fraction. In addition, it was possible to stop the hydrogenation process at intermediate stages allowing for considerable variation in consistency. Technology since has stimulated the production of shortenings that make many contributions to a cake batter, such as the following:

1. Aeration of the batter
2. Lubrication for ingredients
3. Structure to the finished product
4. Improved overall eating qualities, i.e., moistness, tenderness
5. Extended shelf life
6. Nutritional benefits

IMPROVED SHORTENING SYSTEMS FOR CAKES

In the 1930s, the development of the superglycerinated or high ratio® shortenings brought about another change in the baking industry. These shortenings contained a proportion of mono- and diglycerides, which are surface active agents. The mono- and diglycerides contributed to a finer dispersion of fat particles causing a greater number of smaller sized fat globules.

As a result of this occurrence, the mono- and diglycerides aided in strengthening the cake batter thus allowing the incorporation of additional liquids. This factor in turn permitted the dissolution of a greater percentage of sugar. Adjustments in formulation were now made possible. An example of such formulation changes is shown in Table I. When lard or a compound shortening was used, the typical formula balance was: (a) total weight of sugar = the total weight of the flour; (b) total weight of the fat = the weight of the eggs; (c) the combined weight of the liquid ingredients = the weight of the flour or sugar. These proportions were important as too much sugar affected the starch gelatinization and too much water weakened the structure. The strengthing effect that the mono- and diglycerides imparted allowed for the addition of a greater percentage of sugar and liquid ingredients based on flour weight (3).

These superglycerinated shortenings also had excellent creaming properties, that is, the ability to incorporate air. Since air bubbles entrapped in the fat serve as the focal point for gas expansion, the larger number of smaller sized fat globules created by the superglycerinated shortenings enhanced volume, grain evenness, and tenderness. As seen by the graph in Figure 1, volume is much improved by these shortenings (4). (The monoglyceride iodine value used is 60.) The level of the mono- and diglycerides that can be added to a cake shortening is limited by their effects. Cakes that are over-emulsified are characterized by being too tender, too crumbly, and have a collapsed center.

A slight variation of these superglycerinated shortenings is the general purpose blend recommended for improved performance in cakes and icings. These shortenings contain 4-5% total mono- and diglycerides with 0.25-0.30% Polysorbate 60. They have the advantage of allowing the baker to stock only one shortening for all his cake and icing products. As shown by data in Table II, both cakes and icings are improved with the general purpose shortening over the superglycerinated shortening. The disadvantage of using one shortening for both products is typified in Figure 2. In cakes as the alpha monoglyceride level increases up to 3-4%, the volume increases; however, an alpha monoglyceride content higher than 2.5% (based on shortening weight) is detrimental to the icing volume (4). (Monoglyceride iodine value used is 60.)

TABLE I

Yellow Layer Cake

Ingredient	Old type formula	High sugar ratio formula % of flour weight
Flour	100	100
Sugar	100	140
Shortening	50	55
Eggs	50	65
Milk	50	110
Baking Powder	2	6
Salt	2	3

[1]Presented in the Specialty Fat Symposium, AOCS Meeting, Chicago, October 1976.

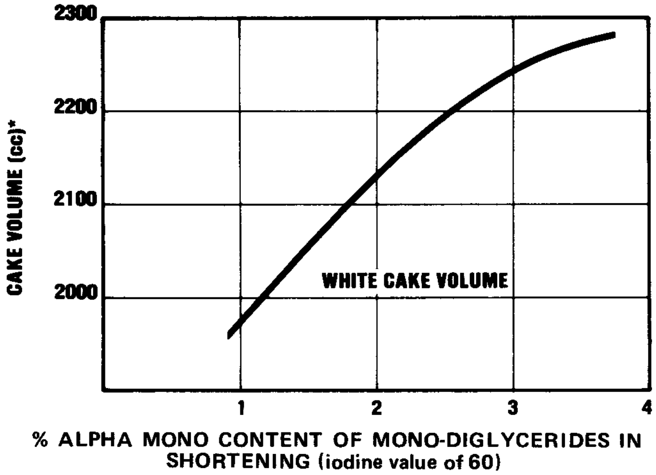

FIG. 1. The effect of emulsifier level in bakers' shortening on cake volumes. *As measured by volume with low density rapeseeds.

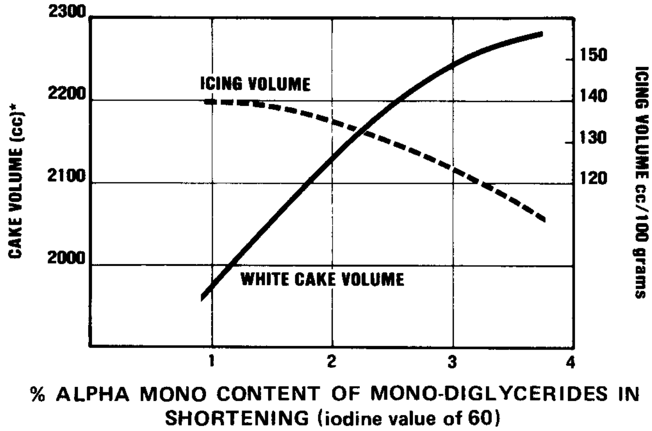

FIG. 2. The effect of emulsifier level in bakers' shortening on icing and cake volumes. * As measured by volume with low density rapeseeds.

The last 20 years have seen an increase in the usage of fluid or liquid shortenings for use in cakes. It is possible to pump, meter, and bulk store these shortenings as they are pourable at 65F to 90F. In addition, they provide excellent performance with respect to batter aeration, cake grain, texture, shelf life, and eating qualities. These fluid shortenings are dependent upon the emulsifiers they contain to provide the functionality necessary in cakes.

There are three classifications of such shortenings used (5): (a) fluid suspensions; (b) fluid emulsions; and (c) clear liquids. The first type is a suspension of hard stock and emulsifiers in triglycerides, such as soybean and cottonseed oil. Under certain conditions, however, these have a tendency to separate; this is their principal limitation. The second type of liquid shortening is classified as a fluid emulsion; it is an oil in water emulsion which was designed to eliminate all separation problems. The emulsion is stable due to the emulsifiers which in turn contribute to its performance in cakes. The limitation with this product involves the inherent cost of shipping water. The third classification of this shortening type is the clear liquid. The emulsifiers that are used are completely soluble, thus the shortening can solidify at low temperatures and return to a homogeneous liquid at room temperature.

In addition to the above-mentioned shortenings, there are also specialty cake shortenings designed to provide the optimum functionality for a specific cake system. These shortenings contain a blend of emulsifiers; they are developed through performance testing using the subject cake formulation. The disadvantage with specialty shortenings is the increased inventory. An optimum shortening for one cake may not be optimum or even satisfactory in another. For example, a shortening containing 0.6% sorbitan monostearate, 0.35% Polysorbate 60, and 0.65% mono- and diglycerides may provide excellent volume, grain, and eating qualities in a 140% white cake, but may not be at all functional in a devil's food cake or a pound cake.

Another approach a baker can take to produce the optimum performance from his shortening is to use a hydrated emulsifier system in addition to his regular shortening. A hydrate is a dispersion of surfactants in water; it can be added directly to a batter. Using a hydrate is a versatile way of achieving improved performance. The baker can stock one shortening and vary the amount or kind of hydrate to be added to each cake formula to yield the desired results. Table III shows some functionality data eith a high ratio® shortening vs. a typical hydrate containing 13% Polysorbate 60, 13% sorbitan monostearate, and 13% mono- and diglycerides.

One last area that should be mentioned as it is a total area in itself is that of shortenings for use in cake mixes. It is necessary for these mixes to have a great mixing tolerance to include much handling variability and still provide good volume, moistness, tenderness, and flavor. Shortenings play an important role in providing these characteristics; the most important factor being the emulsifier system. Generally 100 to 150% more emulsifiers are incorporated in a cake mix shortening over a baker's shortening. There are three factors to consider for selecting a cake mix shortening: (a) type of cake, (b) cost factors, and (c) manufacturer's preference. These shortenings must contribute sufficient creaming/aerating properties with minimum mixing and must remain functional over long periods of storage.

FACTORS AFFECTING SHORTENING QUALITY

Now that the types of shortenings available for cakes have been discussed, the factors that determine the shortening's functionality in cakes should be considered. Moncrieff has shown that the size, shape, and polymorphic form of the solid triglyceride play an important role in the shortening's performance, that is, in its creaming ability (6). There are four possible crystal structures that can be

TABLE II
Typical Functionality Data

	Typical high ratio®		General purpose 5% mono- and diglyceride 0.25% polysorbate 60	
Cake type	Vol. (cc)	Crumb and grain	Vol. (cc)	Crumb and grain
140% White cake	1944	Sl. coarse	1972	Close/fine
Devils food cake	1075	Sl. open and coarse	1025	Close/fine
28% Fat icing		Specific gravity		Body/texture
High ratio® shortening		0.73		Soft/smooth
Improved general purpose		0.52		Good/firm, smooth

TABLE III

Cake	High ratio® shortening			Hydrate 2-4% on flour[a] [typical use levels]		
	Batter gravity	Vol.	Crumb and grain	Batter gravity	Vol.	Crumb and grain
115% White cake	0.96	1878	Sl. open Sl. irreg.	.86	2085	Sl. irreg. good
130% White cake	1.04	1580	Compact Sl. irreg.	.93	1865	Sl. closed good
100% Yellow cake	1.02	1680	Sl. irreg.	.90	1980	Sl. irreg.

formed in shortening (7). These are the alpha, beta prime, intermediate, and beta. The alpha crystal has the lowest melting point, the lowest density, and is the least stable, while the beta crystal has the highest melting point, the highest density, and provides the best stability. Test work performed by Hoerr et al. using shortenings stable in the alpha, beta, and beta prime forms has shown that for optimum creaming ability in cakes (8) the shortening must be stable in the beta prime form. Glycerides with this crystal are characterized as having a small needle type shape. Further research has shown that these needles should be close together for maximum results. These shortenings are characterized by being smooth and creamy and exhibit excellent creaming capabilities. Shortenings stable in the beta form are waxy or grainy and lack creaming ability as the crystal structure deteriorates under stress. The goal then in producing a shortening that will be functional in cakes is to achieve the proper crystal structure (beta prime form) and crystal orientation.

There are five factors that play an important role in the development of the shortening quality. These can be categorized in the following order (7) : (a) composition, which consists of triglyceride combination and emulsifier content; (b) processing conditions; (c) tempering conditions; (d) storage conditions; and (e) usage temperatures.

As mentioned previously, plastic shortenings can be produced by blending a vegetable oil with a fully hydrogenated glyceride. The percentage and type of fully hydrogenated glyceride will affect the shortening's plasticity. The combination of glycerides is also important in respect to the shortening's plasticity. Using glycerides having varied melting points produces a shortening that will be workable in cake mixing over a wide range of temperatures. The solid fat index is a good indicator of this range. Taking into consideration the importance of the beta prime crystal, one of the best methods to assure that the shortening's composition will influence this crystal structure is to use a hydrogenated fat that is stable in the beta prime form (9). As shown in Table IV, this would include hydrogenated tallow, cottonseed oil, and palm oil. Fully hydrogenated soybean oil, peanut oil, and lard are stable in the beta form and therefore will not promote the development of the beta prime crystal structure.

The second variable listed under composition that can affect the crystal habit is the emulsifier content. The addition of mono- and diglycerideds to a plastic shortening promotes aeration, thus reducing the aeration responsibility of the crystalline fat. In fact, the emulsifiers can perform (10) the same functions that a properly developed shortening can perform, i.e., they aerate, act as lubricants, emulsify fat in the batter, build structure, improve eating qualities, and extend shelf life. The first emulsifiers used in shortenings for cakes were the mono- and diglycerides. The incorporation of other emulsifiers in the shortening followed. Table V shows the emulsifiers that have FDA approval for use in cakes. Polysorbate 60 will increase volume and tenderness and improve the grain and the crust color. Sorbitan monostearate will improve volume and grain when used in combination with a monoglyceride and Polysorbate 60. Others such as (a) acetylated monoglycerides, (b) propylene glycol monoesters, and (c) acid modified monoglycerides improve volume, grain, and shelf life.

TABLE IV

Crystal Structure of Various Fully Hydrogenated Fats in Their Most Stable State[a]

Alpha	Beta-prime	Beta
Acetoglycerides	Cottonseed	Soybean
	Palm	Safflower
	Rapeseed	Peanut
	Tallow	Corn
		Palm kernel
		Lard

[a]Source Wiedermann (1968).

TABLE V

Emulsifiers Approved for Use in Cakes

1. Mono- and diglycerides
2. Acid modified monoglycerides
3. Acid modified fatty acids
4. Propylene glycol and sorbitan partial esters
5. Polyoxyethylene sorbitan fatty acid esters
6. Polyglycerol esters

When considering the shortening's composition, it is necessary to include both the triglyceride combination and the emulsifier content. The emulsifier content in the shortening will have an effect on the rate of crystal transformation by either accelerating or retarding it. By understanding this it is possible to alter the processing conditions to obtain the desired beta prime crystalline form.

The processing conditions were the second factor mentioned in affecting the quality of the shortening. In this stage, commonly called the plasticizing stage, the melted shortening components go through a chilling unit and a crystallizing unit. The manner and speed at which the process is completed and the temperature of the plasticized product as it is packed have an effect on the formation of the crystals.

The finished shortening is then tempered or held at 80-85F for 2-4 days. During the tempering period, the crystal structure develops. Shortenings held at low temperatures after being filled will harden and have poor plasticity. Also, a freshly filled shortening will have poor creaming ability during the first few days.

Shortenings that have a composition conducive to promote the beta prime crystal structure and that have been properly processed and tempered can be altered adversely by improper and nonuniform storage conditions. Storage for long periods of time under variable temperature con-

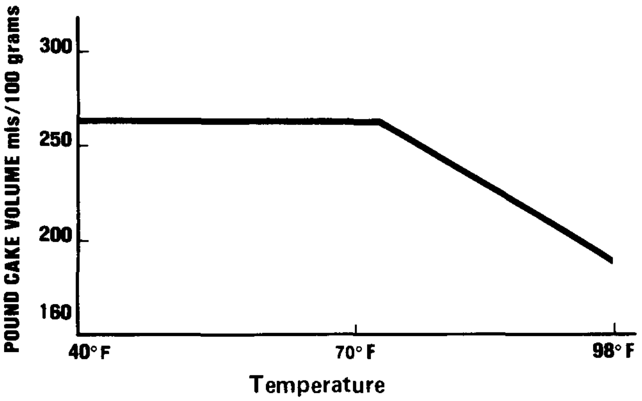

FIG. 3. Average effect of storage on general purpose shortenings.

ditions also has a negative effect on the shortening's crystal form and thereby affects its creaming properties, as seen by this graph shown in Figure 3. Wheeler concluded that creaming properties are reduced if the shortening is stored at too high a temperature for long periods of time and if exposed to extreme temperatures (11). As the temperature reaches the melting point of the lower fat fractions, they will melt and as the fat cools, these fractions will solidify into a more stable fat crystal that is less functional. If the exposure is for long periods or at extreme temperatures, such as 95F or more, by the time the shortening is used a great percentage of the fat fractions will be other than the beta prime crystals, and therefore the shortening will have poor creaming ability.

Finally, for optimum creaming performance, the shortening should be used between 70-80F. Again if the temperature is too high, the lower melting triglycerides will be in liquid form and creaming performance will be reduced.

In summary, technology has made possible the development of plastic shortenings that have a necessary consistency at a range of temperatures to allow for easy incorporation in cake batters. In addition, these shortenings when properly prepared will provide aeration of the batter, act as lubricants for ingredients, provide structure to the finished product, improve overall eating qualities, such as moistness and tenderness, and extend shelf life. The manufacturing and handling conditions of a shortening play a major role in determining its performance. A shortening that has crystallized in the beta prime form will be most functional in cakes as this crystal type promotes excellent creaming. There are five factors which must be controlled to assure the development of the proper crystal structure and optimum performance. These are the composition, processing conditions, tempering conditions, storage conditions, and usage temperatures. Emulsifiers contribute to the creaming ability of the shortening thus reducing the dependence of optimum creamy performance on the beta prime crystal form. Superglycerinated shortenings, improved multi-purpose shortenings, specialty cake shortenings, fluid shortenings, and hydrated emulsifier systems can all be used in cakes today to produce a product with markedly superior qualities. Only a brief analysis is required to conclude that there has been major progress in cake shortenings over the last 100 years.

REFERENCES

1. 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.
2. Hall, A., "Shortenings General," (A Seminar on Fats and Oils in Food Presented at The Center for Professional Advancement), March 1973, East Brunswick, NJ.
3. "Baking for Allied Personnel," American Institute of Baking, Chicago, IL, 1966.
4. "Handbook of Food Additives," Edited by T.E. Furia, 2nd Edition, CRC Press, Cleveland, OH, 1972.
5. MacDonald, I., and G. Lensack, Cereal Sci. Today 12:10 (1967).
6. Moncrieff, J., Baker's Dig. 44(5):60 (1970).
7. Baldwin, R.R., R.P. Baldry, and R.G. Johansen, JAOCS 49:473 (1972).
8. Hoerr, C.W., J. Moncrieff, and F.R. Paulicka, Baker's Dig. 40(2):38 (1966).
9. Weiss, T., "Food Oils and Their Uses," AVI Publishing Company, Westport, CT, 1972.
10. Howard, N.B., Baker's Dig. 46(5):28 (1972).
11. Wheeler, F., Ibid. 31(3):41 (1957).

[Recieved May 6, 1977]