Fat Systems for Bakery Products[1]

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ABSTRACT

Fat systems for cake, Danish pastries and bread are described in terms of physical and chemical characteristics as well as performance. Results indicate that additives, such as surfactants and dough conditioners in well formulated fat systems, can increase tolerance, improve uniformity and extend storage life of baked products. The polar and nonpolar lipids naturally present in flour are shown to affect finished bread quality, with the polar lipids showing an improving effect. The apparently divergent trends in the development and use of specialized shortenings for specific baked products vs. the development and use of multipurpose bulk systems for a variety of baked products are reviewed.

INTRODUCTION

In a good working relationship, the fats and oils industry has provided the baking industry with fat systems for a multitude of products. In our own use of the term "fat systems," we are including not only the basic fats and oils, but also the emulsifiers, surfactants and dough conditioners now commonly used to improve quality and uniformity as well as to permit greater tolerance in the production of baked goods.

It would be pertinent to review some of these fat systems from the baker's point of view. That is, how stable is the system? How is it used? How uniform? How functional? How tolerant? And how practical? Also something of the physical and chemical properties of the fat system, in relation to performance in specific products and the degree to which meaningful specifications can be written, should be considered.

Although it would be beyond the scope of this paper to cover all aspects of the subject, we will touch on fat systems for cake, sweet goods and bread. In the latter case we will comment on the lipids naturally present in flour and the role they play in bread quality.

First we might quickly review the reasons for using fat systems in bakery products (1): (a) They impart "shortness," richness and tenderness, thereby improving the eating qualities of the product; (b) They provide for aeration and resulting leavening of the product; (c) They contribute to the flavor, particularly special fats such as butter or lard; (d) They promote a desirable grain and texture; (e) They provide for the development of flakiness in products (Danish and puffed pastry products); (f) They modify the gluten, particularly in the development of yeast-raised doughs; and (g) They act as emulsifiers for the holding of liquids.

Table I gives a very general picture of the amount of shortenings used in bakery products. As can be seen, fat is a very major portion of a number of bakery products.

FAT SYSTEMS FOR CAKE

There are several milestones in the development of modern fat systems for cake items. About 100 years ago, butter and lard were the most commonly used shortenings. Cake products were quite variable, and cakes had a coarse, open grain.

Next came compound shortenings of vegetable oils and hardened oil stocks. These were markedly superior in functionality to lard because of their enhanced "creaming" characteristics. According to Richard (2), creaming characteristics are traceable to the composition of the solid portions of the shortenings. The nature of specific triglycerides pertinent to creaming properties has been identified, and these in turn related to the crystalline characteristics of the fat. The "Beta Prime" crystalline form of fats gives superior creaming characteristics because of its tendency to orient in small, tightly knit uniform crystals. Whereas lard generally made a very poor cake, the rearrangement or modification process made it possible to formulate lard shortenings for cake baking. Bailey (3) explains the results of this modification. It may be an over-simplification, but the concept of the fat crystals serving as blades in a mixer is a useful one. The characteristic large crystals in unmodified lard produce a coarse air distribution in a batter. Smaller crystals in modified lard result in better distribution of the air, similar to that in batters in which hydrogenated vegetable shortening is used. The fats and oils industry has learned very well how to control fat crystallization for optimum creaming and optimum cake quality. The control has been based on proper selection of fats, temperature control and mechanical working.

The next important development in the evolution of fat systems for cake was the advent of emulsifiers. Monoglycerides came on the scene in the 1930's. These were followed by lactated esters of monoglycerides, propene glycol esters of fatty acids, polysorbate and sorbitan esters, diacetyl tartaric acid esters of monoglycerides and others. All of these emulsifiers greatly reduced the dependence on solid fats of their crystalline forms for aerating properties of the fat systems. As a matter of fact, emulsifier systems have now been developed that do all of the aeration. All this has resulted in several approaches to the development of bulk fluid shortening systems which are attractive from the standpoint of automating cake baking operations.

There are, of course, now several commercial bulk fluid shortening products that can be used in cake operations and cake production. These fluid shortenings are usually based on hard fat flakes or emulsifier surfactant combinations, or both, either dissolved, dispersed or suspended in vegetable oils. Although performance of these systems is usually excellent in specific cake items, the existing products do not really serve as the hoped for all-purpose or universal shortening system; that is, a system that would be pumpable at room temperature, stable in storage over a range of temperatures, produce a wide variety of bakery products and be economical in usage and price. One option the baker has in the development of a more flexible, if not all-purpose bulk shortening, is to use a vegetable oil, i.e., soybean oil, and meter in the appropriate emulsifiers, surfactants or related additives, each designed for a specific product. A variety of cake products have, in fact, been made in this very fashion. Continental Baking recently developed and introduced to school systems a high protein cake with several specific nutritive attributes (4). One of the requirements for the cake was that it be made with an unmodified vegetable oil. The objective was reached by the addition of a surfactant system to soybean oil.

There are, however, some very serious problems to overcome before a truly all-purpose fat system can be used for the preparation of icings and cream fillings included in most cake products. In addition to aeration, shortenings also provide structure to the finished products. With cakes, other ingredients such as starch, protein and emulsifiers

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TABLE I

Fat Content of Various Baked Goods

Item	Per cent
Bread	2-5
Cake	5-25
Sweet goods	20-30
Puff Pastry	30-40
Pie crust	20-35

TABLE II

Distribution of Lipids in Flour and Flour Components

Material	Per cent distribution		
	Part of gluten	Protein	Lipid
Flour	--	13.9	2.1
Gluten	—	78.7	9.5
Aggregates	17	49.2	6.9
Gliadin	42	73.6	9.1
Glutenin	41	80.0	6.7

take over the function of structure when crystalline fat is removed. But in fillings and icings, the major structural ingredient is plastic shortening. Emulsifiers are of course used in icings and fillings to assist in aeration; however oil-based fluid shortenings have not been satisfactory, particularly for the preparation of cream fillings that would maintain desired texture and structure in a finished product over a period of time. Perhaps some day we will find the emulsifier, surfactant or related additive that in conjunction with liquid oil will provide the necessary structure.

Figure 1 compares the SFI curves of a regular hydrogenated cake shortening with soybean oil containing a combination of surfactants. It will be obvious that over the temperature range of 50-92 F, there is a wide variance in the SFI's of the two shortening systems. However, at the temperature at which leavening power is generated (100-110 F plus), the soybean surfactant combination is similar to the shortening system. At this critical stage the final volume and texture of the cake will be determined by the ability of the shortening system to retain the incorporated air and the gases produced by leavening agents.

In Figure 2, comparing cakes made with the two systems, it can be seen that the cake made with soybean oil plus a surfactant is quite comparable to that obtained with a conventional shortening. Cakes produced by the soybean oil surfactant system have excellent crumb softness and moisture-retaining properties which enhance the eating qualities of the cake.

Perhaps we should end discussion of cake with just one or two additional comments. Cake may be defined as a protein foam, stabilized with gelatinized starch, containing fat, emulsifier, salts and flavor, and aerated principally by gases evolved by chemical reaction. Now it is a well known fact that fat is an antifoam; egg albumin, for example, will not produce a foam in the presence of even small amounts of fat or oil. The aeration of a cake batter is therefore an apparent anomaly whereby fats are added to a protein foam which will be expected to result in a cake of good volume. By considering cake as a protein foam, it may be possible to comprehend more fully the function of the individual
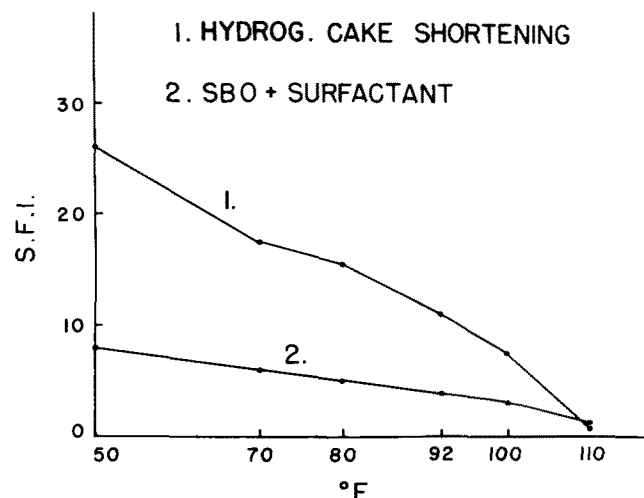
ingredients and the reason why certain preparation procedures are followed in the batter stage. The antifoam character of fats can be reduced with the use of surface active agents by changing the nature of the fat's surface. When a surface active agent comes in contact with fat, two things occur—the fat surface takes on a melting point approaching that of the adsorbed surfactant, and the surface of the fat is no longer lipid in character but more hydrophylic. The fat has in essence been encapsulated and is less capable of spreading into the protein to exert its antifoam influence. Of course the stability of the batter emulsion is improved (5).

On the one hand, the intent is to keep the fat away from the protein foam that is essential for cake baking. On the other hand, there is growing evidence that lipids interact with the protein to alter the film-forming properties. A more nearly semipermeable membrane is formed, and this too is essential for cake baking for optimum volume and for the prevention of collapse of the cake upon cooling.

Now, how do we write the specifications for fat systems for cakes? Until a great deal more is known of the function of fat in cake, we can't be very definitive. For the present, perhaps the most meaningful specification is "must perform in the product for which it is intended." Beyond this, of course, is the need for a continued emphasis on the stability of the fat systems, as well as the usual requirements for uniformity and freedom from off colors and off flavors. There is also the need for additives that can be used in bulk systems to lend greater flexibility to the system. Since fat is a factor in the shelf life of cake products, there is certainly need to continue the search for fat systems that would further prolong shelf life.

FAT SYSTEMS FOR DANISH PASTRIES

Danish pastry was originally introduced in this country at the turn of the century. At that time it was produced with a hard, imported Danish butter, and the product was more nearly puff pastry than the Danish we know today. The character of the product gradually changed—first by the substitution of domestic butters, and then with other margarines and more sophisticated fat systems. The present demand is still for Danish which has good flakiness but also tenderness and softness.

To the uninitiated, the steps in the production of Danish are almost unbelievable. The process involves making a sweet, yeast-raised dough, and after proper adjustments for consistency, rolling the dough out to a thickness of ca. 1 in. The dough slab is then spread with a roll-in fat over the top two-thirds of the dough's surface. The uncovered third portion of the dough should be folded over the middle third. The final third should be folded in to form five layers—three of dough and two of roll-in fat. The dough is again rolled out to a thickness of 1 in., folded as above, thus resulting in 15 layers of dough and roll-in fat. The dough is then placed in a retarder (35-38 F.) for 15-20 min, and the whole process may be repeated for a second and third time.

1. HYDROG. CAKE SHORTENING

2. SBO + SURFACTANT

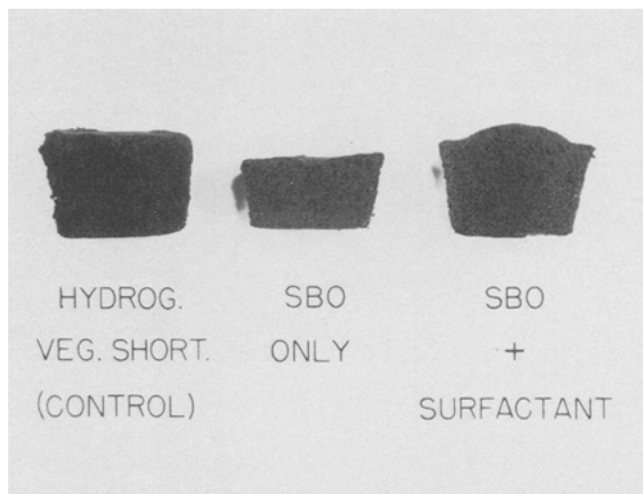FIG. 1. SFI curves of cake shortenings.

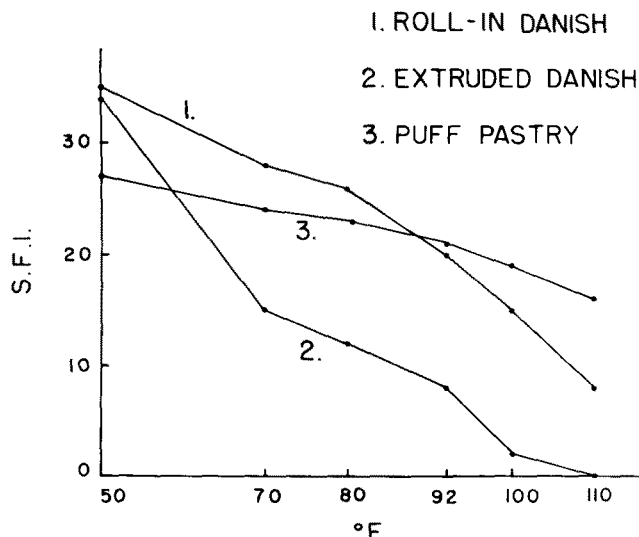FIG. 2. Cakes baked with various shortening systems.

FIG. 3. SFI curves of danish and puff pastry shortenings.

Since there is obviously a great deal of work involved in the production of Danish, a considerable effort has been made to mechanize the entire process (6). Great process has been achieved to this end through the development of dough pumps and shortening pumps which permit a fully mechanized system for Danish production. Unfortunately machinery doesn't adapt to slight variations in dough consistency, softness and other characteristics as readily as the skilled Danish baker.

However most of the potential troubles can be avoided through the use of the correct shortening. Some of the changes indicated in the nature of the shortening for hand operations versus mechanized operations are shown in Figure 3. With improvements in dough handling as well as fat handling equipment, Danish production of 5000-10,000 lb/hr has been accomplished with good quality and uniformity.

It should also be mentioned that in some instances suppliers have produced sheets of shortening which can be placed on dough slabs to speed up the hand operations. In an attempt to simulate the flaky character of Danish by a simplified or "Blitz" procedure, some suppliers have provided fat systems in crystal or flake form which can be mixed directly in the dough. The flakes retain their identity during mixing and handling and do produce a good product, although usually quite distinguishable from conventional Danish. Further efforts to improve on this approach are certainly justified.

FAT SYSTEMS FOR BREAD

Prior to the introduction of continuous process bread ca. 15 years ago, very little attention was paid to specific fat requirements for bread. Many Europen breads still contain little or no fat and are basically systems of flour, water, yeast and salt. In this country, consumer acceptance has dictated a number of additives including sugar, milk, vitamins, minerals and a fat system that may now contain emulsifiers and dough conditioners. Such fat systems were included in American bread for better texture, volume, machining properties and keeping quality. A great variety of fats are used, including lard, vegetable oils, butter and margarine.

Unique in fat systems for continuous mix bread has been an apparent requirement for a hard fat fraction usually added in the form of hydrogenated fat flakes. Such hard fats usually result in an improvement in both grain and specific volume. When continuous mix systems were installed in bakeries, provision was made for the blending of fats, oils, flakes and other additives. The so-called fat

blending tank provided the flexibility the baker needed to adjust his fat system to accommodate variations in other ingredients, primarily flour. Figure 4 shows bread baked with a lard hard fat flake system containing increasing amounts of flakes (7). With the zero per cent flakes, the bread was essentially a cripple. In this particular series, optimum bread was produced in the 12-20% flake range. It should be noted, however, that with the addition of emulsifiers and dough conditioners, the optimum level may change markedly and in some instances may be reduced to zero.

Figure 5 shows the SFI curve of these fat systems, all of which produced satisfactory continuous mix bread. Curve no. 1 shows a typical lard-flake system with appreciable solids left at 110 F (proof box temperature). Solids at 110 F were thought to be essential to performance. Curves 2 and 3 are soybean oil surfactant systems. The surfactants involved are most commonly known as dough conditioners or dough strengtheners, and they do have the ability to improve product quality and uniformity by increasing proofed dough strength.

But rather than discuss all of the fat systems which might be employed in the manufacture of bread, it would be appropriate to review a bit of the work in which we have attempted to determine the fate of fat in a loaf of bread and its apparent function.
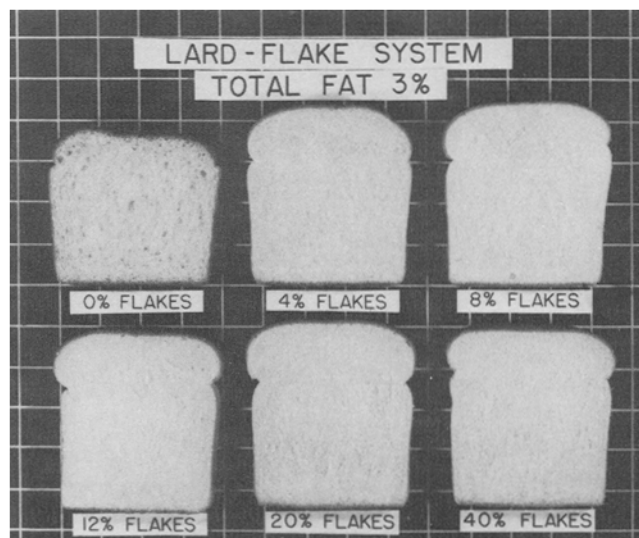

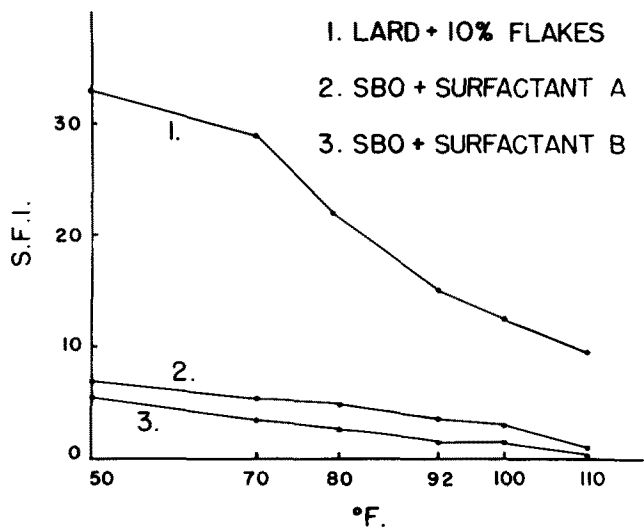FIG. 4. Bread baked with increasing levels of hard fat flakes.

FIG. 5. SFI curves of bread shortenings.

FIG. 7. Thin layer chromatography separation of flour lipids. A. Hydrocarbons and sterol esters; B. triglycerides; C. free fatty acids; D. 1,3-diglycerides; E. 1,2-diglycerides; F. monoglycerides; G. complex lipids.

The difficulty of extracting all of the fat from a finished baked loaf of bread has led to the concept of free and bound fats in baked products. A number of methods have been devised for deriving the amount of fat bound to protein and the amount of fat bound to starch. The methods are somewhat empirical and much in need of further development. Nevertheless some of the preliminary results are of interest in explaining the function of fat in bread. For example, in continuous mix bread baked with 3% of a model fat system containing equal amounts of mono-, di- and triglycerides, the following results were obtained: On a dry basis, the bread contained 5% fat. Of this, 20% was readily extractable with petroleum ether and was considered free fat; 24% of the total fat was apparently bound to the starch fractions, and 56% was bound to the protein fractions (7). Since this very preliminary work some 5 or 6 years ago, J.G. Ponte, Jr., in our Laboratories has attempted to obtain additional information, both on the nature of the protein fractions to which flour lipids were bound and the more specific nature of the lipid materials involved (8). The early objective of this work was to compare distribution of lipids among flour, gluten and certain gluten fractions. Some results are shown in Table II. The aggregates comprise ca. 17% of the gluten; glutenin and gliadin make up the remainder of the gluten in about equal proportions. The gluten and gliadin have lipid contents of slightly more than 9%, while the aggregates and glutenin contained ca. 7% lipids. The value for gliadin is higher than
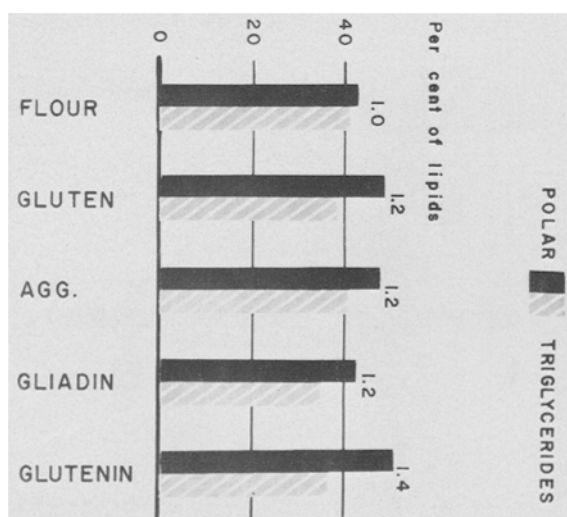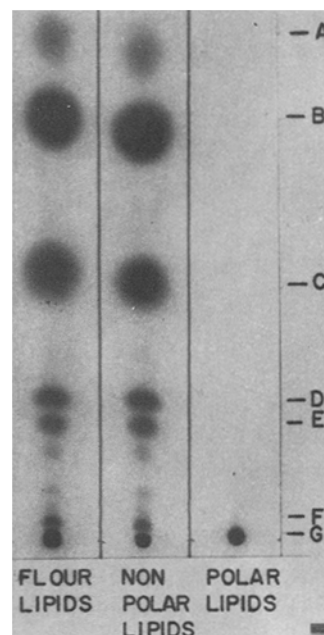
that reported by other workers (9,10).

Additional fractionation procedures have been employed, as well as additonal procedures for characterizing the lipid fraction as either polar or nonpolar. Figure 6 compares the amount of polar material and triglycerides in the various lipids (11). Although there appear to be no dramatic differences among these lipids, the glutenin lipids were relatively richer in polar material than the others. The numbers above the bars indicate the ratio of polar material to triglyceride for the various lipids. The glutenin lipids had a slightly higher value than the others.

Turning our attention to the effects of adding certain extracted flour lipids to dough on bread quality, we would first like to consider some baking effects of gross wheat lipid fractions. These fractions are indicated in Figure 7 (12). The lipids discussed here were extracted from a

FIG. 6. Comparison of the amounts of polar material and triglycerides in various flour and flour component lipids.
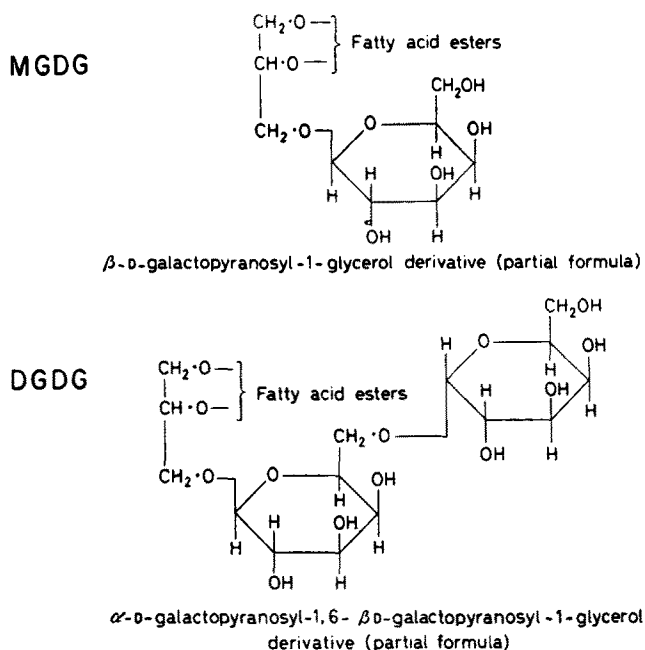
FIG. 8. Galactolipid structures. MGDG = monogalactosyl diglyceride; DGDG = digalactosyl diglyceride.

commercial bread flour. The first lane in the thin layer chromatography plate shows a typical distribution of flour lipids. These comprise classes of hydrocarbons and sterol esters, triglycerides, free fatty acids, diglycerides, monoglycerides and complex lipids. Using a batch adsorption technique, it was possible to divide these lipids into two gross fractions shown in the second and third lanes. The nonpolar fraction shown in the second lane is comprised of material ranging in polarity from hydrocarbons to monoglycerides, and a small amount of complex lipids. The polar fraction at the right lane is composed of complex lipids that do not migrate from the origin in this system. These complex lipids are predominantly phospholipids and glycolipids. Thus we have three materials—the starting flour lipids, a relatively nonpolar fraction and a relatively polar fraction. What happens when these materials are added to bread dough?

Table III shows the effect of these fractions on bread making (12). The bread discussed here were 1 lb loaves made by a sponge dough process; these data are the results of duplicate determinations. Two series were made, one with 3% lard and one without added lard. The trends in both series were about the same: the addition of 1% total flour lipids had relatively little effect. In both series the nonpolar fraction markedly decreased loaf volume, while the polar lipids increased bread volume as compared to the control.

We won't discuss the volume-decreasing effect of the nonpolar fraction; work on this fraction has been done in our Laboratories, and a report will be made shortly (13). Clearly the polar lipids had a bread-improving effect; this confirms the 1957 findings of Cookson et al. (14), on English bread and several reports of Pomeranz and coworkers (e.g., 15,16).

What compound or compounds in the polar fraction cause this improving effect? In approaching this problem, we had a strong hunch that of the polar lipids in flour the galactolipids should be singled out for study. The galactolipids were originally found in wheat flour but have since been discovered to be quite wide spread in nature. Over the years it has been speculated that the galactolipids might function as bread improvers by analogy of their structure to that of commercial mono- and diglycerides (17). No actual work was done on the possible functionality of the galactolipids until quite recently most likely because the compounds have not been available in quantity for study.

Figure 8 shows the structure of two galactolipids present in wheat flour lipids (18). These are partial formulas, showing the glycerol derivatives. The fatty acids would of course be esterified to the glycerol at the positions indicated. In both the mono- and digalactose compound, the galactose is attached to the alpha position of the glycerol by a beta linkage. The two sugars in the digalactosyl diglyceride are shown to be joined by an alpha linkage. Data on fractionation procedures by which sufficient quantities of monogalactosyl diglyceride and digalactosyl diglyceride were produced for test baking will be published at a later date. We can state at this time, however,

TABLE III

Effect of Polar and Nonpolar Fractions on Bread Loaf Volume

Type lipids added	Loaf volume, cc	
	With 3% lard	Without lard
Control	2626	2528
1% Total flour lipids	2557	2561
1% Nonpolar lipids	2364	2261
1% Polar lipids	2704	2667

that the baking properties of the two galactolipids were quite different. The monogalactosyl diglyceride at the level tested caused essentially no change in bread properties. The digalactosyl diglyceride, on the other hand, definitely brought about an increase in loaf volume (19). It would then appear that flour baking quality might, in part, be determined by the nature of the lipids naturally present.

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