New Foods Through The Use Of Emulsifiers

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Story in Brief

Emulsifier research in the O.S.U. Foods Laboratory during the past 12 years has indirectly resulted in new types of butter, low-calorie spreads, milk powders and shortenings. A method was developed to classify and measure emulsifiers on the basis of their water solubility. Tables of data also were accumulated which can be used to predict the amount and solubility of emulsifiers needed for foods of various compositions.

Materials and Methods

An emulsifier is a compound which holds fat and water together, much like a staple holds together two pieces of paper. The use of these compounds results in a "stable emulsion", i.e., in milk drinks they keep the liquid homogenious and prevent the formation of cream layer. During the past twelve years the use of these compounds in various foods has been studied by the Foods Laboratory at Oklahoma State University. A great many new products have resulted from the use of emulsifiers and some of these are the direct result of O.S.U. research.

Only a small quantity of emulsifier is usually added to a food (0.1 percent—0.5 percent), but this small quantity will cause remarkable changes. It is responsible for the increased loaf volume of modern-day bread, and causes the bread to appear moist and retain that appearance longer. Emulsifiers have the same effect on cakes, i.e., they produce larger cakes which are more moist. The cakes also have a finer texture (1,2). Emulsifiers added to a powdered milk product will cause that powder to be more easily dispersed in water (3). This has resulted in a whole line of new products including "instant" milk, "instant breakfasts" and various powdered diet foods. Research at O.S.U. and other universities has shown that the addition of certain emulsifiers to butter will make the product more spreadable at refrigerator temperatures. Still other emulsifiers make it possible to produce low-calorie spreads containing only half the fat of the normal product (4.) An emulsifier added to a cooking oil will prevent that oil from spattering when it's heated in the skillet. Emulsifiers added to milk or cream make that product readily whipable and have resulted in many new whipped creams and whipped topping products which are usually marketed in aerosol cans.

The unique characteristic of an emulsifier is the fact that it is soluble both in water and fat. This makes it possible for a portion of the molecule to dissolve in water while the other part of the same molecule is dissolved in fat. It's logical that to hold different amounts of fat and water together, different kinds of emulsifiers are needed, that is, emulsifiers with different water and fat solubilities. For example, in a food containing 80 percent fat and 20 percent water (a system similar to butter) an emulsifier is needed which is largely fat soluble, with only a small portion of the molecule being soluble in water. On the other hand, if the system to be stabilized contains approximately equal amounts of fat and water the emulsifier needs to be about 50 percent soluble in each substance (Figure 1).

Thus, different foods need emulsifiers with different solubilities and for optimum emulsifier performance one should know the amount of fat and water in the food which is to be emulsified. This ratio of water to fat in the product must then be matched with the water-fat solubility of the emulsifier molecule.

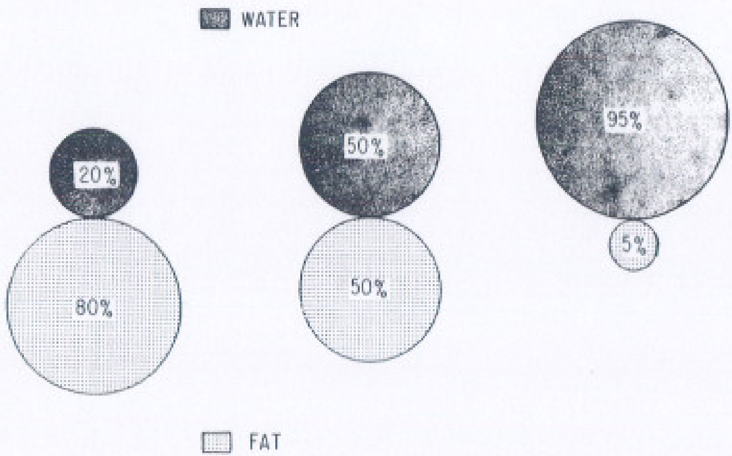

Figure 1. Graphical representation of emulsions containing 20, 50 and 95 percent water where circular areas represent the relative volumes of fat and water in each system.

Recent research at the O.S.U. Foods Laboratory has resulted in a technique which will measure the relative water-fat solubility of an emulsifier. This technique involves the use of a gas chromatograph and coating an inert support material (bleached firebrick for example) with the emulsifier to be tested, this coated support is packed into the column of a gas chromatograph then a test substance is injected—alcohols have been used. The speed with which the test substance passes through the emulsifier-coated support material is measured and this speed is proportional to the water-fat solubility ratio of the emulsifier coating (6).

The molecular configuration of an emulsifier will control its water-fat solubility ratio and this solubility ratio determines the effectiveness of the compound in a particular food. It's important to recognize that it is the water-fat solubility which controls an emulsifier's action but that more than one type of chemical formulation can result in the same solubility ratio. In work at Oklahoma State University (5, 6) a number of different emulsifiers with widely different molecular configurations were tested. The selection of these emulsifiers was so arranged that solubility ratios varied over a wide range. The results confirmed the fact that water-fat solubility ratio is the most important single factor governing an emulsifier's performance. This information tells one that if an emulsifier is needed that is 50 percent water soluble any molecular configuration with this solubility will do the job—i.e., a polysorbate, a diglyceride, a lactate or some other configuration.

Some authors claim that mixtures of two or more emulsifiers are more effective than a single one. However, the research to back up this statement often has been done without measuring the relative solubility of the emulsifier mixtures. A recent series of experiments at Oklahoma State University have shown that when two emulsifiers are combined the mixture acts as though it had a water solubility intermediate between the two components. For example, if an emulsifier which is 20 percent fat soluble is combined with an equal amount of an emulsifier that is 80 percent fat soluble, the solubility of the resulting mixture will be the average of the two components, or 50 percent (1, 2, 5, 6). What often happens, when two emulsifiers are combined is that the water-fat ratio of the product to be stabilized is more compatible with the solubility of the emulsifier mixture than with either of the individual components.

If only a limited number of emulsifiers are available to the manufacturer, mixing two of them is often the answer to an otherwise difficult emulsification problem. However, in today's market where a great many emulsifiers are available it usually is possible to find a single emulsifier with the proper solubility for any given food. When a single emulsifier can be found, it can be every bit as effective as would a combination of two or more.

Deciding Which Emulsifier to Use and How Much?

One should know the amount of water and fat in the product to be stabilized. These are simple measurements in the laboratory and any standard technique for moisture and fat will be adequate. In many cases though, the amount of fat and water can be calculated from the recipe of the product. An example of a cake recipe used in the O.S.U. laboratory is listed below (Table 1). In this recipe there are 48 grams of fat (as shortening) and 96 grams of water (in the skim milk). This is all that needs to be considered in this case since recent work at Oklahoma State University has indicated that the effect of ingredients other than fat and water on the emulsification of a cake is negligible. The addition of milk solids-not-fat for example, has an effect which is so small that for all practical purposes it can be disregarded. The same is true ofr flour and perhaps for other ingredients as well. In the recipe of Table 1, the amount of fat and water totals 144 grams and the fat percentage equals 48 ÷ 144 or 33 percent. The water:fat ratio then is 67:33.

With this information one consults a set of tables similar to those published from the O.S.U. laboratory in 1968 (6). To avoid confusion though, it is sometimes easier to use graphs derived from these tables. The data form a three-dimensional surface when three variables are considered and can be graphed that way (Figure 2). However, the same data can be shown as a family of curves (Figure 3) and this type of graph is often easier to use. Entering either Figure 2 or 3 at a point representing about 30 percent fat (or 70 percent water) one sees that the maximum emulsion stability results when an emulsifier is used which is 65 percent soluble in water. However, there is very little difference between this emulsifier and those which were 45 and 55 percent soluble in water. Since Figures 2 and 3 use data from systems containing only 1 percent emulsifier (as percent of the shortening), one must go back to the data

Table 1. Cake Recipe

Ingredient	Weight (grams)
Shortening	48
Sugar	120
Flour	96
Egg	32
Skim milk	105[1]
Baking powder	4
Salt	2
Flavoring & Color	1

[1] Contains 9 percent milk solids and 91 percent water (96 grams).

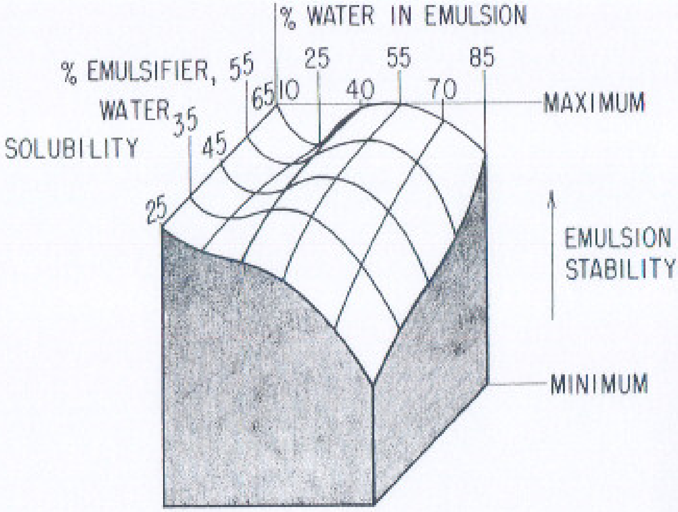

Figure 2. Three-dimensional graph showing the relative stability of fat-water emulsions containing percent emulsifier—calculated as a percentage of the fat.

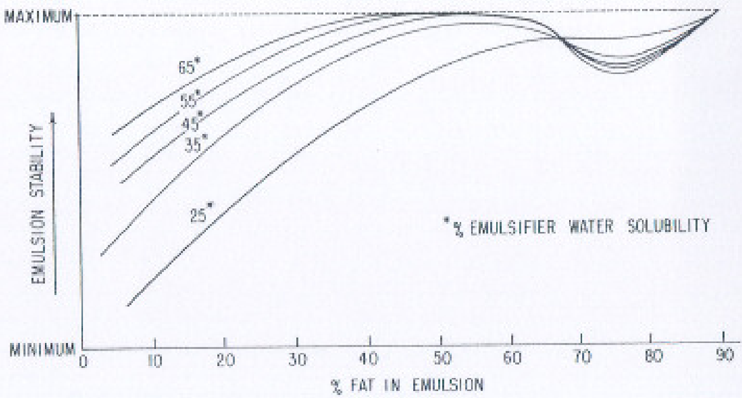

Figure 3. Two-dimensional graph showing the relative stability of fat-water emulsions containing 1 percent emulsifier—calculated as a percentage of the fat.

to complete the picture and determine how different amounts of emulsifier affect emulsion stability. From this graph (Figure 4) it also is apparent that when more than 1 percent emulsifier is used, the performance of emulsifiers with lower water solubilities (i.e., 45 and 55 percent) is almost equal to the performance of emulsifiers with water solubilities of 65 percent. This later was confirmed with actual cake baking trials.

Shortenings for Baked Goods

Many anhydrous fats can be used as shortenings in baked goods. However, these fats must be properly emulsified to be effective. An emulsifier with a water solubility of 50 percent will be satisfactory for a general-purpose shortening added to the fat at the rate of 1-2 percent (0.05-0.02 percent of the total product). However, it usually is preferable to "tailor-make" the shortening—that is, add emulsifiers of the proper water solubility to fit each individual product.

Anhydrous milk fat can be excellent shortening in properly emulsified. However, if butter is used as the source of this fat, one needs to remember that this product was designed as a table spread. It contains water and salt which the baker must take into account when calculating his recipe. In addition, the emulsifier in this product (lecithin) has a water solubility of approximately 80 percent, whch is too high for most

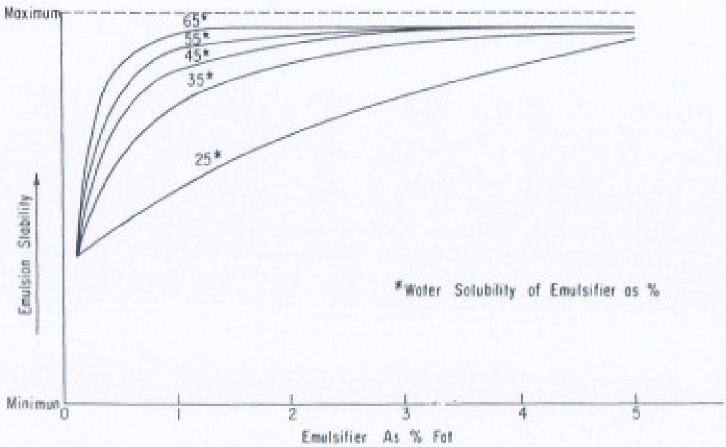

Figure 4. Two-dimensional graph showing the relative stability of emulsions containing 30 percent fat and 70 percent water with emulsifier levels of 1, 3 and 5 percent of the fat (0.3, 0.9 and 1.5 percent of the total emulsion).

baked goods. An emulsifier with a low water solubility needs to be added so the average water solubility is 45-65 percent. It usually is easier just to start with the anhydrous milk fat and add a single emulsifier of the proper solubility.

Cost of Emulsifiers

Emulsifiers currently can be bought for about 50 cents per pound. If added to a shortening at the rate of 1 percent, the emulsifier would add only ½ cent per pound to the ingredient cost of the shortening. If this shortening were added to a cake recipe calling for 12 percent shortening (as does the recipe in Table 1) the emulsifier in the shortening would represent only 0.5 percent of the total cake recipe and an additional ingredient cost of only 0.05 cents. This seems like a small price to pay for the vast improvements in texture which the emulsifier will cause, and a small price to pay for the improved flavor which results when milk fat is used in the cake (1, 2).

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