SYMPOSIUM: FATS AND OILS IN THE FOOD INDUSTRY

presented at the AOCS Meeting in Atlantic City, New Jersey

T.J. WEISS, Program Chairman

Food Emulsifiers—Science and Art[1]

NAT H. NASH and **LAWRENCE M. BRICKMAN**, PVO International, Inc.,
416 Division Street, Boonton, New Jersey 07005

ABSTRACT

General classifications of food emulsifiers are presented, and their functions are discussed. Examples of many food products are given, and recommended emulsifier usage levels are presented. Some of the food applications cited include: cakes, icings, toppings, bread, sweet goods, frozen desserts, coffee whiteners, peanut butter, margarine and confectionery coatings.

The marketing trend of food products has changed substantially over the last several years. Food companies are catering to the accepted principle of "less work for mother." This has led to the growth of "convenience" and "instant" foods, resulting in a greater selection and variety for the consumer. Because many of these products are being processed in plants many hundreds of miles from final consumption, the requirements for processing, distribution and storage have resulted in the need for increased stability and longer shelf life. This has led to the use of specialized food ingredients and additives including emulsifiers. In order to counter increased labor and ingredient costs, food processors have increased their research and development effort, which has resulted in the use of improved equipment and additives.

The production and utilization of food emulsifiers has grown to the point where these materials probably have the largest volume, in pounds, of all the food additives. It is estimated that ca. 180-200 million lb. of emulsifiers will be used by the food industry in 1971.

The term emulsifier is often used interchangeably with surface active agent or surfactant. It is not necessary to discuss at length the theory of surfactant or emulsifier chemistry. Most emulsifiers are esters or modified esters formed by the combination of polyalcohols with edible fatty acids or fats. The old thinking is that the food emulsifier functions by affecting solubility and miscibility behavior at the surface between two immiscible fluids. Later in this paper it will be pointed out that these concepts have become more sophisticated and that the food emulsifier serves many additional functions.

Emulsifiers are usually made by either alcoholysis or direct esterification. In direct esterification, fatty acids and polyalcohols are reacted together under controlled conditions to form esters. In alcoholysis, fats are reacted with polyalcohols to make analagous products. For example, the process is called glycerolysis when a shortening is reacted with glycerine to form mono- and diglycerides.

There are a limited number of natural emulsifiers which are used in foods. Lecithin is a good example. Often the natural emulsifier may be modified, e.g., hydroxylated lecithin, to change its properties. This paper will be devoted mostly to applications of synthetic emulsifiers. Listed below are the emulsifiers most often used in foods.

Types of Food Emulsifiers

1) Mono- and diglycerides
   a) Glycerol esters
   b) Distilled glycerol esters
2) Propylene glycol esters
3) Sorbitan esters
4) Polyoxyethylene sorbitan esters

[1]One of seven papers presented in the Symposium "Fats and Oils in the Food Industry," Atlantic City, October 1971.

INDEX

457-461 FOOD EMULSIFIERS—SCIENCE AND ART, by N.H. Nash and L.M. Brickman

462-467 FATS AND PROCESSES USED IN MANUFACTURING CHOCOLATE AND CONFECTIONERY COATINGS, by G.M. Johnston

468-472 ANTIOXIDANTS FOR FOOD FATS AND OILS, by E.R. Sherwin

473-477 FAT SYSTEMS FOR BAKERY PRODUCTS, by R.R. Baldwin, R.P. Baldry and R.G. Johansen

478-480 MARGARINE AND MARGARINE OILS: FINISHED PRODUCT QUALITY, by L.H. Wiedermann

5) Polyglycerol esters
6) Ethoxylated esters
   a) Ethoxylated monoglycerides
   b) Ethoxylated fatty acids
7) Lactated esters
   a) Lactylate esters
   b) Lactic acid derivatives
8) Lecithin and lecithin derivatives
9) Micsellaneous esters

Mono- and diglycerides are the most commonly used of the food emulsifiers. These consist of glycerol esters of various edible fatty acids and fat blends. Three types are usually manufactured: 40-45% alpha mono content, 50-56% alpha mono content and the distilled monoglycerides with 90% alpha mono content. Mono- and diglycerides are used in a great number of food products with strong emphasis in bakery products such as bread, cake, cake mixes and also frozen desserts. There are three physical forms of the mono- and diglycerides: "hard, soft and liquid."

Distilled monoglycerides are usually blended with mono- and diglycerides or fats in order to improve their dispersing properties. The mono- and diglycerides are on the GRAS list. The levels of use are limited to application requirements and to Standards of Identity where they apply.

The propylene glycol esters are usually offered as propylene glycol monostearate (PGMS) and propylene glycol monopalmitate (PGMP). They are most often used in cakes, cake mixes, whipped toppings and bread. The mixed propylene glycol esters are made by alcoholysis. Selected fats are reacted with propylene glycol; these are mostly used in cakes. The propylene glycol esters are approved for use in foods by the Food Additive Regulations at "levels required to produce their intended effect."

Sorbitan esters are made by reacting sorbitol with fatty acids. At present, sorbitan monostearate is the only one of this group that has been approved for food use at limited levels. It is most often used in combination with the polysorbates in cakes, cake mixes, whipped toppings, cake icings, fillings, confectionery coatings and coffee whiteners.

The polyoxyethylene sorbitan esters are reaction products of 20 moles of ethylene oxide with sorbitan esters. Whereas sorbitan monostearate is the only sorbitan ester approved for food use, the polyoxyethylene derivatives of sorbitan monostearate (Polysorbate 60), sorbitan tristearate (Polysorbate 65) and sorbitan monooleate (Polysorbate 80) are approved for food use at limited levels. Polysorbate 60 is most often used in cakes, prepared dry mixes, whipped toppings, icings, bread and yeast-raised products and coffee whiteners. Polysorbate 65 is used in frozen desserts, whipped toppings, coffee whiteners, cakes and cake mixes. Polysorbate 80 is most often used in frozen desserts, nonstandardized baked goods, prepared mixes, icings, fillings, toppings and very often as a solubilizing agent for flavors.

The polyglycerol esters are reaction products of polymerized glycerine and edible fatty acids or fats. Polyglycerol esters of fatty acids, up to and including the decaglycerol esters, may be safely used in foods at levels required to produce the intended effect. These represent a unique and diversified class of food emulsifiers. They are being used in whipped toppings, coffee whiteners, cakes, cake mixes, confectionery coatings and powdered desserts.

The ethoxylated esters are a group of emulsifiers, the use of which has grown in the last several years. Ethoxylated mono- and diglycerides are reaction products of 20 moles of ethylene oxide with mono- and diglycerides. They are used as dough conditioners in yeast-raised baked products in an amount not to exceed 0.5% by weight of the flour used. The ethoxylated fatty acids, such as polyoxyethylene (20) monostearate, are very versatile and interesting materials, but unfortunately have not been approved for food use.

There are several forms of lactated esters used in foods. Calcium and sodium stearyl lactylate have been approved for use as a dough conditioner in yeast-raised baked products. They are also used in whipped toppings, starch puddings, coffee whiteners and cake icings. Glycerol lacto palmitate (GLP) and glycerol lacto stearate (GLS) are reaction products of glycerine, lactic acid and fatty acids. They are most often used in cakes, cake mixes and whipped toppings.

Lecithin is most often used in chocolate and confectionery coatings, whipped toppings, coffee whiteners and bakery products. Hydroxylated lecithin is often used in cakes, cake mixes, bread and yeast-raised doughs.

There are a number of miscellaneous esters in use, such as: acetylated tartrated monoglycerides, acetylated monoglycerides, succinylated monoglycerides and sodium stearyl fumarate.

Emulsifiers perform one or more functions in a specific system. In many cases it is necessary to combine two or more emulsifiers to accomplish the desired effect. Often an emulsifier may perform one function at one level and a completely opposite function at another level. For example, Polysorbate 80 at 0.03-0.1% will act as an aerating agent, but at 0.005% will act as a defoamer. Emulsifiers perform in the manners as outlined in Table I.

In many cases it becomes necessary to combine the functions of two or more emulsifiers in order to obtain the desired effect in the food. As stated before, there is a definite optimum level of use for most emulsifiers. Low levels may not accomplish the functions desired, and high levels may destroy the system completely. This is further complicated by the fact that it becomes necessary to obtain the optimum blends of specific emulsifiers.

Based on these observations it is our feeling that the hydrophylic-lipophilic balance (HLB) system used for the selection of emulsifiers has limited value. This system is useful in the selection of emulsifiers for water-oil emulsions such as margarine or salad dressings, but has limited value in the more sophisticated foods that are currently being developed. For these reasons the selection of an emulsifier becomes an "art." In other words, the scientific method is applied to previous experience. In new applications it is suggested that analagous or similar food emulsifier systems be used as the starting point. For example, the emulsifier system used in frozen desserts such as ice cream and ice milk has been modified into a suitable system for whipped toppings.

Listed below are some of the influencing factors in the selection of a food emulsifier system.

Influencing Factors in Selection of Food Emulsifier System

1) Functional requirements of food product
2) Method of processing
   a) Homogenizing equipment used, if any
   b) Pasteurizing or sterilizing equipment
   c) Whipping and aeration equipment
3) Finished product form, e.g., liquid, powder, etc.
4) Consumer preparation technique
5) Storage requirements
6) Flavor
7) Formulation–effect of other ingredients
8) Cost
9) Legal aspects

It is important to clearly spell out the properties of the new food product being developed. The processing technique will also govern the final selection. The type of homogenizing and heating equipment available must also be taken into consideration.

TABLE I

Functional Properties of Food Emulsifiers

Functions	Examples
Stabilize oil in water emulsion	Salad dressings
Stabilize water in oil emulsion	Margarine
Whipping	Whipped topping, frozen desserts
Solubilizer	Pickles and pickle products
Dispersant	Flavors and vitamins
Conditioner	Bread
Plasticizer	Cake icings
Defoamer	Yeast and sugar manufacture
Humectant	Fudge icings
Starch complexing	Dried potatoes
Crystallization inhibitor	Starch jellies
Antistaling	Yeast-raised baked goods
Texture control	Cakes, bread
Antisticking	Candy and chewing gum
Freeze-thaw stability	Coffee whiteners, whipped toppings
Gloss additives	Confectionery coatings
Cloud	Beverages
Hydrating	Powdered milk drinks
Crystal modification	Confectionery coatings
Encapsulation	Flavor nuggets
Control fat separation	Peanut butter
Antispattering	Margarine and frying shortening
Wetting	Coffee whiteners and instant foods
Aerating	Cakes, toppings and icings
Gelation	Flavor emulsions
Agglomeration	Frozen desserts, whipped cream

The emulsifier system for a whipped topping made in a Hobart bowl in the bakery will be different from that of a topping whipped in an Oakes mixer. The emulsifier system that will work in a liquid coffee whitener must be altered when making a spray-dried product. Some of the other factors are: consumer preparation technique, storage requirements, flavor, effect of other ingredients in the formula, and cost and legal aspects. Therefore the evaluation of the food product must be done in a laboratory or in semipilot plant equipment similar to that being used in the plant.

The more important emulsifier applications and recommended usage levels are listed in Table II.

CAKE MIXES

One of the largest uses of emulsifiers is in the various shortenings that are offered to the baker, cake mix manufacturer and consumer. The baker has been convinced that the use of the "Hi Ratio" or emulsified cake shortening for all cakes and icings is outdated. He obtains better performance and improved products by using "specialty shortenings" for his various cakes and icings. This has resulted in a varied line of shortenings requiring different emulsifier systems. We have listed in Table II emulsifier systems for consumer and cake mix shortenings. Most of the specialty shortenings contain "tailored" emulsifier blends.

BREAD, ROLLS AND BUNS

The bread "emulsifier" market has developed into a wide array of products and product forms. In a practical sense these products can be divided into two basic functions: those which act as softeners and antistaling agents, and those which act as dough conditioners to permit dough tolerance in the bakery. Some emulsifiers will do an excellent job in one respect and just a fair job in the other. This has led to the marketing of combination emulsifier-dough conditioner products. Refer to Table II, Column 3 for recommended emulsifier usage in breads, rolls and buns.

There has never been a total agreement among the experts as to the mechanism on the action of mono- and diglycerides in bread, although this has been the subject for many papers in the baking field. Mono- and diglycerides are added to impart softness to bread. The function of the dough conditioner is less controversial in that there is less question about its starch complexing reaction. The more prominent dough conditioners are calcium or stearyl lactylate, EMG and Polysorbate 60.

It must be emphasized that the Federal Standards of Identity for Bakery Products set definite limits for emulsifier use. The mono- and diglycerides, ATMG and propylene glycol monoester usage in bread is based on the percentage of shortening, whereas the usage of the other material is based on flour weight. In the last few years combination products containing 40% EMG with 60% mono- and diglycerides and 40% Polysorbate 60 with 60% mono- and diglycerides have been offered to the baking trade as emulsifier-dough conditioner systems. The distilled monoglycerides in various combinations with some of the other listed emulsifiers are also used widely in bread, rolls and buns. Hydrated plastic forms of emulsifier blends are used because they are easily dispersible in the doughs. The acceptance of the continuous dough system has slightly altered the combinations and levels of the emulsifiers used, based on performance and handling requirements.

BAKER'S CAKES

As previously stated, the baker may use specialized shortenings for his individual cakes, or he may add the emulsifiers directly to the batter. Hydrated forms of the various emulsifier combinations are offered to the baker because they are easily dispersible in the wet system. Combinations of mono- and diglycerides, sorbitan monostearate and Polysorbate 60 seem to give the best results in most formulations. PGMS by itself and in combination with other emulsifiers is also used at levels referred to in Table II.

Polysorbate 60 and triglycerol monostearate act as aerating agents and result in cakes with smoother texture, greater volume and extended shelf life. PGMS is an excellent aerating agent, but does not affect the cell structure to the same extent. Mono- and diglycerides and sorbitan monostearate affect the grain of the cakes and to a lesser degree improve aeration. Cakes containing lower levels of shortening and eggs require higher levels of emulsifier in order to extend the shortening properties.

The emulsifiers recommended are on a shortening basis.

TABLE II

Usage of Emulsifiers in Specific Food Applications

Emulsifier type[a]	Consumer shortening[b]	Cake mix[b]	Bread, rolls and buns[c]	Cakes (baker's)[b]	Sweet goods[c]	Icings and fillings[b]	Frozen desserts	Vegetable type whipped topping	Frozen whipped topping	Coffee whitener, liquid	Coffee whitener, powdered	Peanut butter	Margarine	Confectionery coatings
Mono-diglycerides	1.5-4%	8-12%	0.4-0.5%	2-8%	10-20%	4-6%	0.1-0.3%	0.1-0.2%	---	0.25-0.1%	2-5%	1-4%	0.5%	0.25-0.4%
Monoglycerides (distilled)	---	---	0.1-0.3%	---	7-15	3-5	0.1-0.25	---	---	0.25-1.0	2-5	0.25-2	---	1-3
Monoglycerides (hydrated)	---	---	0.25-0.75	---	---	---	---	---	---	---	---	---	---	---
Polysorbate 60[e]	0.5-2	1-3	0.15-0.35	0.5-2	0.5-1	1-2	0.05-0.1	---	---	0.1-0.3	1-2	---	---	---
Polysorbate 65	---	---	---	---	---	---	---	0.1-0.3	0.4-0.6	---	---	---	---	---
Polysorbate 80	---	---	---	---	---	---	---	---	---	0.25-0.5	1-3	---	---	0.1-0.4
SMS	---	2-4	---	2-4	---	---	---	---	---	---	---	---	---	---
PGME	---	4-12	---	2-12	---	2-6	---	0.1-0.2	0.15-0.30	---	---	---	---	0.2-3.0
GLE	---	4-8	---	2-8	---	---	---	---	---	---	---	---	---	---
ATMG	---	---	0.4-0.5	---	---	---	---	---	---	---	---	---	---	---
EMG	---	---	0.25-0.5	---	0.25-0.5	---	---	---	---	---	1-3	---	---	0.5-1.0
Ca-*st*-2-L	---	---	0.25-0.5	---	0.25-0.5	---	---	---	---	---	---	---	---	---
Na-*st*-2-L	---	---	0.25-0.5	---	0.25-0.5	---	---	---	---	---	---	---	---	---
Succ. Mono	---	---	0.25-0.5	---	---	---	---	---	---	---	---	---	---	---
3-1-S	---	---	---	2-4	---	2-4	---	0.1-0.2	---	0.1-0.3	1-3	---	---	---
6-2-S	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3-1-O	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lecithin and derivatives	---	---	0.1-0.3	---	---	---	---	0.1-0.2	0.2-0.3	0.2-0.5	2-5	---	---	---
Hydrated blends[f]	---	---	---	0.25-1	0.5-1	---	---	---	---	---	---	---	---	0.5-1.0
GMS-Polysorbate 80 80/20	---	---	---	---	---	---	---	---	---	---	---	---	---	---
GMS-Polysorbate 65 60/40	---	---	---	---	---	---	---	---	---	---	---	---	0.5	0.25-0.4
SMS-Polysorbate 60 60/40	---	---	---	2-4	---	---	0.1-0.25	---	---	---	---	---	---	---
SMS-Polysorbate 60 70/30	---	---	---	2-4	---	---	0.1-0.25	---	---	---	---	---	---	---
SSF	---	---	0.25-0.5	---	0.25-0.5	---	---	---	---	---	---	---	---	0.2-0.5
							---	---	---	---	---	---	---	---

[a]Abbreviations: SMS: sorbitan mono stearate; PGME: propylene glycol monoesters; Ca-*st*-2-L: calcium stearyl-2 lactylate; Succ. Mono: succinylated monoglycerides; 6-2-S: hexaglycerol di stearate; ATMG: acetylated tartrated esters of mono- and diglycerides; GLE: glycerol lacto esters; EMG: ethoxylated monoglycerides; Na-*st*-2-L: sodium stearyl 2-lactylate; 2-1-S: triglycerol mono stearate; 3-1-O: triglycerol mono oleate; GMS: Polysorbate 80 80/20: blend 80% glycerol monostearate 20% polysorbate 80; and SSF: sodium stearyl fumarate.

[b]On a shortening basis.

[c]Flour basis.

[d]Refer to Federal Bread Standards.

[e]Polysorbate 60 is to be used in conjunction with other emulsifiers.

[f]Wet basis.

The hydrated blends are suggested on a wet basis.

SWEET GOODS

The emulsifier systems discussed for bread and rolls perform in a similar manner in the yeast-raised sweet doughs. Recommendations for sweet doughs may be found in Table II, Column 5. The first two emulsifier levels are based on their use in specialty sweet goods shortenings. They may also be added directly to the dough. The other recommendations are based on their direct addition to the dough and the levels suggested are on a flour basis.

ICINGS AND FILLINGS

Polysorbate 60 and triglycerol monoesters do an excellent job in aerated icings and fillings. Combinations of the emulsifiers listed in Table II are used successfully in consumer packaged icings.

FROZEN DESSERTS

The types and levels of emulsifiers used in frozen desserts are listed in the Federal Standards of Identity for Ice Cream and Ice Milk. The regulations in most states follow the Federal Standards. There are no Federal Standards for Mellorine, but several states list their own. In most cases the emulsifier systems are similar to those in the frozen dessert standards. The type and level of emulsifier depends on the marketed form of the frozen dessert, i.e., bulk, soft serve and novelties. Polysorbate 80 is an exceptional "drying agent" and is used in obtaining a "dry" product coming out of the freezer. Glycerol monostearate provides overrun and some dryness. For this reason, combination beaded products as shown in Table II, Column 7 are used.

VEGETABLE FAT WHIPPED TOPPINGS

The emulsifier system in whipped vegetable toppings is a good example of a sophisticated, sensitive system. The emulsifier composition depends on the type of fat used, the form in which the topping is marketed, the whipping equipment and the storage conditions. You will note that specific recommendations have been made for liquid topping mixes as shown in Table II. These are sold to institutional users in containers of up to 5 gal for varied applications. For toppings which are whipped, frozen and sold to the consumer in a frozen state, the suggested emulsifier levels are substantially different. The type and level of fat used in these formulations will also vary.

The emulsifier recommendations for a powdered topping are different than for the frozen, because the drying procedure will alter whipping and storage properties. One interesting aspect of emulsifier usage levels in whipped toppings is that high levels of mono- and diglycerides will cause gelling of the liquid mix at temperatures above 50 F.

Polysorbate 60 is the whipping and aerating agent in whipped toppings. Sorbitan monostearate, hexaglycerol distearate and GMS control the whipping and induce fat agglomeration and impart a dry appearance to the topping. Toppings that are marketed in aerosol cans, whipped in a bakery bowl or whipped in an Oakes type mixer will require different fat-emulsifier systems.

COFFEE WHITENERS

In a similar manner, liquid coffee whiteners and powdered coffee whiteners require different emulsifier systems. (Refer to Table II for recommendations.) Another variable in emulsifier selection for liquid whiteners is the form in which marketed—whether refrigerated, sterile or frozen.

The homo pressure in a two stage homogenizer used in manufacturing the coffee whiteners will also influence the level of emulsifier required. Frozen whiteners will require higher emulsifier levels than the refrigerated liquid whiteners. Combinations of Polysorbate 60 with sorbitan monostearate or hexaglycerol distearate impart good whitening properties and freeze-thaw stability. The level of use of Polysorbate 60 and sorbitan monostearate is limited by the Food Additive Regulations.

For powdered coffee whiteners it is necessary to examine the spray drying technique in order to determine the type and level of emulsifiers required. A powdered whitener used in vending machines will require a different fat-emulsifier system from that used for packaged consumer products.

PEANUT BUTTER

In peanut butter mono- and diglycerides of stearic and palmitic acids and the distilled monoglycerides are used at the levels suggested in Table II. They are often used in combination with vegetable stearine blends to inhibit oil separation and to improve palatability.

MARGARINE

Mono- and diglycerides and lecithin are used at levels up to 0.5% in margarine as stated in the Federal Standards (see Table II).

CONFECTIONERY COATINGS

In confectionery coatings the emulsifiers are often used by themselves or blended as shown in the table to control fat crystallization, to impart gloss, improve gloss retention and to improve eating qualities. They also aid in lowering the viscosity of the coating, thereby lowering fat requirements and improving the enrobing procedure.

The legal considerations must be examined before selecting an emulsifier system for any food. It is necessary to take into consideration the existence of federal or state standards and to determine which emulsifiers are permitted as optional ingredients. The Federal Food Additive Regulations also list the emulsifiers that are permitted and their limits. A thorough patent search should be made, since this could be a limiting factor in the selection of a system.

We have tried to list some of the more important aspects of food emulsifier function, usage and selection. It is possible to devote a full paper to many of the subjects discussed in this paper. The tremendous growth in the usage of emulsifiers in foods indicates that these additives contribute to the constant improvement and development of many edible products.

REFERENCES

1. "Code of Federal Regulations, Food Additives," Part 121, Chapter 1, Title 21, U.S. Dept. of Health, Education and Welfare.
2. Nash, N.H., and G.S. Knight, Food Eng. 1967:67, 142, 143.
3. Nash, N.H., and G. Cheselka, Bakers Dig. 40:58 (1966).
4. Technical Bulletins, Drew-Division of PVO, Inc.
5. Knightly, W.H., Food Technol. 23:37, 43, 46 (1969).
6. MacDonald, I.A., JAOCS 45:584A, 486A, 616A, 620A (1968).
7. Nash, N.H., and V.K. Babayan, "Polyglycerol Esters—Chemistry, Status and Use in Bakery and Other Food Products," American Association of Cereal Chemists, Minneapolis, Minn., April, 1963.

[Received November 18, 1971]