Functions of Emulsifiers in Food Systems

N. KROG, Grindsted Products, 38 Edwin Rahrs Vej, DK-8220 Brabrand, Denmark

ABSTRACT AND SUMMARY

The function of food grade emulsifiers in various food products (emulsions, starch based food, yeast raised bakery products, etc.) are reviewed. The stability of emulsions against coalescence of dispersed droplets is among other factors dependent on mono- or multimolecular interracial films with viscoelastic properties formed by adsorbed emulsifier molecules. Agglomeration of fat globules in whippable emulsion is needed to obtain desired foam stability and texture and can be controlled by lipophilic emulsifiers. Complex formation with starch components (amylose) is influenced both by the chemical structure of an emulsifier and by its physical behaviour in water. Interaction with proteins takes place primarily with anionic emulsifiers or very hydrophilic, nonionic types, which thereby improves the rheological properties of wheat gluten. Emulsifiers are also used as crystal modifying agents in fats where polymorphic changes during storage creates texture problems.

INTRODUCTION

Many of our foods are complicated multiphase systems consisting of water, carbohydrates, proteins, fats, and oils, which are processed under highly automated conditions, distributed, and often stored for a considerable length of time before consumption takes place. Therefore special ingredients like surface active agents, also called emulsifiers or stabilizers, are needed to ensure uniform quality and shelf life stability.

Food grade emulsifiers are esters of edible fatty acids originating from animal or vegetable source, and polyvalent alcohols like glycerol, propylene glycol, sorbitol, and sucrose. Furthermore, these products can be modified by making derivatives with ethylene oxide or by esterification with organic acids like acetic acid, diacetyl tartaric acid, succinic acid, citric acid, or lactic acid, which makes it possible to tailor-make surface active materials with specific properties.

Molecular structure and chemical composition of some of the most commonly used emulsifiers have been published recently (1) and will, therefore, not be dealt with here.

Emulsifiers are amphiphilic substances which according to their chemical structure possess both hydrophilic and lipophilic properties. Generally speaking the function of such materials in food systems can be one or more of the following: (a) to promote emulsion stability, control agglomeration of fat globules, and stabilize aerated systems; (b) to improve texture and shelf life of starch containing products by complex formation with starch components; (c) to modify rheological properties of wheat doughs by interactions with gluten proteins; (d) to improve consistency and texture of fat-based products by controlling polymorphism and crystal structure of fats.

In the following text these functions are discussed and related to the chemical-physical properties of the specific type of emulsifiers used in each case.

EMULSIONS

Interfacial Tension

Due to the hydrophilic-lipophilic properties of emulsifier molecules they always orientate themselves at air-water or oil-water interfaces. This interfacial adsorption takes place independent of how the emulsifier is added to the system, and is energetically a more favorable situation than complete solution of the emulsifier in either the oil or the water phase. As a consequence of the adsorption of emulsifiers at the interface the interfacial tension is reduced. Figure 1 shows interfacial tension between water and soybean oil measured by a Du Nouy Tensiometer at 50 °C.

Figure 2 shows interfacial tension between water and soybean oil containing 0.3% milk proteins (1 part skimmed milk + 10 parts distilled water). Addition of low polar emulsifiers like propylene glycol monostearate (PGMS) does not reduce the interfacial tension significantly even at concentrations of 5% of the oil phase. Lactylated monoglycerides (GLP) and distilled monoglycerides from sunflower oil (GMO) are slightly more active than PGMS. Anionic emulsifiers like sodium stearoyl-2-lactylate (SSL) or especially diacetyl tartaric acid ester of monoglycerides (DATEM) are very active in reducing interfacial tension when the water phase contains proteins. Strongly polar, nonionic emulsifiers like Polysorbate 60 behave in a similar way.

FIG. 1. Interfacial tension between soybean oil (SBO) and water at 50 °C. Measured by the Du Nouy ring technique. Following emulsifiers are tested: Distilled propylene glycol monostearate (PGMS), Acetylated monoglycerides, acetylation degree: 0.7 (ACMG), Lactylated monoglycerides (GLP), Distilled monoglycerides from sunflower oil (GMO), Sodium stearoyl-2-lactylate (SSL), Diacetyl tartaric acid ester of monoglycerides (DATEM), and Polysorbate 60 (PS).
Interfacial Film Formation in Pure Oil/Water (O/W) Emulsions

An emulsion is thermodynamically an unstable system, which with storage will separate into two liquid phases. The dispersed oil droplets in an o/w emulsion may first flocculate into clusters of oil droplets, which then concentrate at the top of the emulsion like a creaming off process in milk. The individual oil droplets will then after approaching each other coalesce into bigger droplets, which eventually will form an oily layer on top of the water phase. The flocculation process in itself is not a sign of decreased emulsion stability, and the clusters of oil droplets can be redispersed by simple mechanical treatment. In several food emulsions, like whippable creams or ice cream mixes, a certain degree of flocculation is desired in order to obtain optimum foam stability and stiffness in the aerated product.

The crucial point in emulsion stability is to avoid coalescence of the dispersed droplets. The formation of a mechanically strong film by adsorbed emulsifying agents on the surface of the oil droplets is therefore an important factor against coalescence.

Figure 3 illustrates schematically the situation at an o/w interface with a monomolecular layer of emulsifiers having low, medium, and high hydrophilic properties. It should be emphasized that the conditions described here apply only to pure o/w emulsions, and not to emulsions containing proteins.

The lipophilic emulsifiers (monoglycerides, propylene glycol esters etc.) will at low concentration levels be partitioned between the oil phase and the interface (Fig. 3a). Very hydrophilic emulsifiers, like ethoxylated monoglycerides and polysorbates, will tend to form micelles in the water phase, and the degree to which they absorb at the interface will allow only for the formation of expanded monolayers (Fig. 3c).

The optimum stability of pure o/w emulsions is obtained by emulsifiers or blends hereof with medium hydrophilic-lipophilic properties (HLB 8-12, see Fig. 3b), because they form condensed monolayers at the interface. Hydrophobic interaction between the closely packed fatty acid hydrocarbon chains in condensed monolayers is an important factor for obtaining surface films with viscoelastic properties which provide maximum stability against coalescence (2). If the concentration of the emulsifiers is high enough to form multilayered surface films, several other factors become important. The ability of many emulsifiers, even with low hydrophilic properties (monoglycerides), to form lyotropic, mesomorphic phases in aqueous bulk solutions (3) must be considered. Formation of liquid crystalline surface films built up by association of the emulsifier, oil, and water has been reported for many nonfood emulsions (4). Similar conditions may exist in food systems, but the