Chapter 14
Forecasting the Future of Food Emulsifiers

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In many areas, the first cut at forecasting future trends involves observing the past, and then extrapolating the data points into the future. For example, the consumption of food ingredients can be correlated with population and personal income growth. Forecasts of consumer tastes are much more difficult. Scientific and technical innovation generally follows an S-curve. Radical (discontinuous) innovation requires a jump to a new S-curve. Humans are generally disinclined to undertake radical experiments with their food consumption (with the possible exception of fad diets for weight loss). Current controversies surrounding genetically modified plants, cloned animals, and irradiation are prominent examples. Nevertheless, radical innovations in nutrition and technology do occur and stimulate changes in food consumption. Recent examples include the glycemic index and adverse health studies for trans fatty acids.

Food emulsifiers exert several technical effects (see Table 1.1), and can be useful tools to address these new trends. This chapter will discuss some trends that may impact on demands for new and modified emulsifier compositions and applications.

14.1 Globalization of the Food Industry

The food industry has historically been multi-domestic. Local tastes, national food regulations, and the cost of shipping have contributed to localization pressure. However, some strong counter-trends have begun to exert pressures toward globalization. Global communication, industry consolidation, income growth in developing countries, and international travel are a few of these forces. Alcoholic beverages, gourmet foods, and canned meats have been shipped internationally for decades. More recently, confectionery products have been shipping globally.

Shipment of food emulsions and dispersions can be problematic for their chemical, microbiological, and physical stability. For example, vibration may cause separation of an emulsion. The separated aqueous phase may serve as a medium for microbial growth. Many of the developing countries do not yet have widespread refrigeration for small stores and consumers. Food surfactants may help to solve some of these stability problems. Guidance might be obtained from the cosmetic and pharmaceutical industries, since they have developed emulsion/dispersion products which are shelf stable for several years.

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Table 14.1 Functionality of Surfactants in Foods

FUNCTION	SURFACTANT(S)	FOOD(S)
Emulsification	Polysorbate 60	O/W Emulsions - Salad Dressings, Mayonnaise
	Monoacylglycerols	W/O Emulsions – Margarine
Controlled Demulsification	Polysorbate 80	Ice Cream
Solubilization	Polysorbate 80, Polyglycerol Esters	Flavor Oils, Pickle brine
Aeration/Whipping	Propylene Glycol & Polyglycerol Esters	Cakes, Whipped Toppings
Viscosity Control	Lecithin, Polyglycerol Polyricinoleate	Chocolate
Dough Strengthening	DATE<, Succinylated Monoacylglycerols	Bread
Anti-staling	Sodium & Calcium Stearoyl Lactylate	Bakery Products
Crystal Inhibition	Oxystearin, Polyglycerol Esters	Salad Oils
Anti-stick Agents	Lecithin	Frying shortenings
Gloss Retention/Bloom Inhibition	Sorbitan Monostearate, Polyglycerol Esters	Compound Confectionery Coatings
Freeze-thaw Stabilization	Sodium Stearoyl Lactylate	Frozen Coffee Whiteners
Clouding Agents	Sucrose Acetate Isobutyrate	Beverages
Anti-spattering Agents	Monoacylglycerols, Lecithin	Margarines & Spreads

As global population continues to expand, food consumption will likewise increase. Arable land will be pressed toward higher yields. Further pressure from development of biofuels, such as ethanol and biodiesel, may be significant. A search for novel and less expensive sources of proteins, fats, and carbohydrates may pose interesting challenges for food product developers. Food surfactants will provide useful tools to optimize the functionality of these novel ingredients.

14.2 Nutritionally Driven Changes in Foods

Nutritional studies concerning diet and health, as well as their counterweight, diet and disease, are continually appearing in the literature, often with conflicting interpretations. Predicting trends in this area can be complex and confusing. There are a few areas where there is broad scientific consensus.

14.2.1 Total, Saturated, and Trans Fat Consumption

Obesity has become a serious problem, if not an epidemic, in developed countries. This is likely the result of increasing personal wealth and increasing availability of high calorie foods, which lead to increased consumption. More sedentary lifestyles have aggravated the upset in caloric balance (calories consumed > > calories burned). Dietary fat yields approximately 9 cal/g, compared to 4 cal/g for carbohydrates and proteins. Fat is therefore an efficient means for animals and plants to store energy. Development of reduced fat and fat-free products changes the relative phase volumes of lipid and water. This may change the type (W/O - > O/W) and/or stability of the emulsion. Non-lipid fat mimetics are added to restore textural attributes of fat, but may destabilize the system. Flack (1992) suggested that structured surfactants could assume the role of the missing fat. This has been accomplished for some applications and is described in greater detail in Chap. 12. As our knowledge of phase behavior continues to increase, additional applications will be targeted.

The contributing role of saturated fat to coronary artery disease has been studied for more than 50 years. Research demonstrated that diets high in saturated fats significantly increased serum cholesterol (Keys et al., 1965; Hegsted et al., 1965). Removal of highly saturated fats, such as lard, tallow, coconut, palm, and palm kernel oils proceeded at a rapid pace during the 1970s and 80s. Food surfactants were used extensively to provide functionality of the saturated fats. Mensink and Katan (1990) suggested that trans fatty acids also raised cholesterol levels. The issue was hotly debated until Judd (2002) demonstrated that diets high in trans fatty acids simultaneously raised LDL, and lowered HDL cholesterol levels. The Food and Drug Administration responded with regulations to disclose content of trans fatty acids in packaged foods (Federal Register, 2004). Unfortunately, trans fats have been used as substitutes for replacement of saturates. In frying oils, hydrogenation is used to improve oxidative stability, but generates trans isomers. Technologies have now been developed to create trans-free lipids for a number of applications (Kodali and List, 2006; Gunstone, 2006). The future will likely see active research on the use of surfactants to improve the functional and organoleptic properties of trans-free foods.

14.2.2 Low Sugar and Carbohydrate Products

Type II diabetes has been described as an epidemic in some developed countries. People who have this condition must carefully control their weight and carbohydrate intake. Development of the glycemic index (Warshaw et al., 2004) has identified carbohydrates to avoid and some which can be used in moderation. Substances with a high glycemic index values, such as sucrose, cause significant spikes in blood sugar. Starch is broken down into glucose units and needs to be limited. Fibers, such as bran, have low glycemic indices and their consumption should be increased. Reformulation of products to lower sugar and starch can lead to loss of functionality, particularly where carbohydrate/surfactant interactions are important (for example, see Chaps. 4 and 9).

Ingredient suppliers will continue to work with consumer food companies to overcome the challenges of developing desirable products for the growing population of diabetic and pre-diabetic patients. Answers may be found in discovery of surfactant interactions with novel carbohydrates. Stable heterogeneous formulations may also display interesting organoleptic properties.

14.2.3 Delivery of Nutrition to Special Populations

Progress is continuing in pediatric care of infants born prematurely. Delivery of nutrients to these patients will continue to be a challenging problem. The role of food surfactants in infant nutrition was discussed in Chap. 8.

As life expectancy increases, a population of the elderly with special dietary needs is also increasing (Morley and Thomas, 2007; Singh, 2000). Proper nutrition is essential to prevent degenerative conditions, such as osteoporosis. Sensory receptors associated with taste and olfaction decline with age. In many cases, elderly individuals lose interest in eating, since it is no longer an enjoyable experience. Formulations which enhance flavor release may help address this problem.

Physical activity is a factor that contributes to maintenance of good health. However, proper nutrition is necessary for endurance and muscle development (Driskell, 2007; Kern, 2005). Enhanced nutrition is also necessary to promote repair of damaged muscles and joints. As competitive sports become more demanding, delivery of nutrients to specific areas of the body may be seen as an advantage. Development of performance foods may be modeled after the pharmaceutical industry's use of surfactants to target drugs. Surfactants may prove to be useful tools to achieve these formulations.

14.3 Advances in Science and Technology

Although consumers are reluctant to embrace radical change, progress in science and technologies will undoubtedly influence the design of surfactant systems for food processing. Several areas are of particular interest.

14.3.1 Surfactant Structure and Phase Behavior

As described in Chap. 1, molecular structure determines the behavior of surfactants in food systems. Israelachvili (1992) correlated polymorphic structure to a critical packing parameter. The phase behavior of surfactants is described in detail in Chap. 6. The major difficulty in defining structure/functionality relationships is the occurrence of complex surfactant mixtures. This is particularly true for polyglycerol esters, sucrose esters, and polysorbates.

Dramatic progress in chromatography and mass spectroscopy (Byrdwell, 2005; Han and Gross, 2005; Larsen et al., 2005; Mossoha, 2006; Nunez et al., 2005; Yamaguchi,

2005) have allowed the analysis of very complex lipid mixtures. Supercomputers have enabled sophisticated molecular modeling. An energy minimization approach could be used to describe bilayer structures for mixed surfactants. A great deal has been learned about lipid crystal networks (for example, see Marangoni, 2004). Advances in the design of surfactants to form vesicles show promise for drug delivery and targeting (Ucheabu, 2000). Food scientists could search for structure/function relationships in model and real food products.

14.3.2 Advances in Measurement of Emulsions, Dispersions, and Foams

Recent developments in instrumentation have allowed scientists to measure bulk, surface and interfacial properties in many systems which contribute functionality in foods. Techniques for measurement of interfacial properties (McClements 2004a), emulsion rheology (Chakrabarti, 2006; McClements, 2004b), and microscopy (Groves, 2006) have been described in some detail. Of particular interest has been the effort to measure interfacial viscosity and elasticity, and to determine their effects on emulsion stability (Ivanov et al., 2005; Yarranton et al., 2007; Zerin and Narsinham, 2005). Since surfactants and surface-active proteins comprise the interfacial layer, surfactant systems may be designed to optimize interfacial properties. Techniques to measure interfacial rheology in intact emulsions throughout shelf life, would be very useful. Electron spin resonance (esr) line splitting, with an appropriate surface probe, might be a way to accomplish this.

14.3.3 Modulation of Flavor and Nutritional Molecules

Most flavor molecules are amphiphilic, having both polar and non-polar functional groups. Interactions of flavor systems with other food ingredients are well known (McClements, 2004c; Preininger, 2006). Food surfactants can be a two-edged sword with respect to flavor. As noted in Chap. 2, preparation at high temperatures generates by-products, which have disagreeable odors and flavors. Conversely, by modifying the partition coefficients between lipid, aqueous, and air phases, flavor release profiles can be modified. Enhancement of dairy flavor, through use of a surfactant coated fat, has been reported (Takada et al., 2004). The difficulty in developing this technology is a multi-dimensional labrynthian complexity. As previously discussed, commercial food surfactants are mixtures of molecular structures. Flavors are also mixtures, and each component has a unique threshold and partition coefficient. Flavor release is expressed as a time-intensity plot. Sophisticated computer modeling should contribute to more practical use of surfactants for flavor modulation. Progress is most likely with simple surfactants and flavors. However, serendipity has been known to jump-start the systematic approach.

Mesomorphic phases contain lipophilic and hydrophilic pockets, which can protect sensitive ingredients from external environments. For this reason, they have been utilized to deliver pharmaceutical molecules to targeted organs and control their release (for example, see Hiller and Lloyd, 2002; Ghosh, 2005). Food surfactants have been used to improve bioavailability of some vitamins and minerals (Geraert et al., 2005; Lee et al., 2006). As the development of functional and performance foods and drinks continues, efficient delivery of nutrients should become more refined.

14.4 Design, Synthesis, and Commercial Preparation

Due to the extraordinary cost and time required to establish safety for government approval, new synthetic food surfactants are unlikely to be developed. However, scientists and engineers will need to solve a number of synthetic and processing challenges. High temperature processes raise energy costs and produce undesirable side reactions. To solve this problem, innovative methods, such as enzymatic reactors or phase-transfer catalysis, must be developed to optimize reactive contact between polar and lipid starting materials. Laboratory synthesis and purification will be necessary to understand the function of pure surfactant molecules in complex applications, such as bioavailability and flavor modulation. High energy costs have led to the development of biodiesel fuels, derived from fats and oils. Saturated fatty acids and their derivatives are unsuitable for winter fuel use. These by-products offer an opportunity for new starting materials for manufacture of surfactants (Ahmad et al., 2007). Scientists will be challenged to convert these starting materials into food-grade ingredients.

Natural surfactants, such as phospholipids and proteins, will continue to be important in food formulations. Production of biofuels is likely to distort costs for these ingredients. Increased production of soybeans for biodiesel will increase the available supply of lecithin. As corn is diverted from food to ethanol, dairy and grain proteins will become more expensive. Researchers will need to adjust formulations to minimize cost, while continuing to deliver acceptable sensory attributes. Interactive effects, discussed in Chaps. 4, 5, and 6, may be leveraged to extend the functionality of costly ingredients.

14.5 Applications at the Frontiers

Product developers will be navigating an environment of changing consumer needs and preferences, government regulations, cost pressures, and limited R&D budgets. Partnerships with government and academic researchers will probably provide a useful range of analytical, ingredient and processing technologies.

Each category will face its own set of challenges and opportunities. The dairy industry must deliver nutritional and functional benefits, while minimizing saturated fats and sugar. Yogurts, for example, have recently claimed benefits promoting regularity and immune response. Indulgence foods, such as chocolate and ice cream, may also do this, but must retain their indulgent image. Specialty nutrition for infants, the elderly, and athletes will continue to evolve, and possibly invade mass marketing channels. Baking, as a substitute for frying, presents an opportunity to reduce fat absorption. However, the baked products must deliver the flavor and texture of the fried version. Many of these formulation issues involve surface or interfacial phenomena. Surfactants will undoubtedly be candidates to deliver solutions.

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