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Shear-induced fat particle structure variation and the stability of food emulsions: II. Effects of surfactants, protein, and fat substitutes

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Abstract

The shear-induced fat particle structure variation and stability of food emulsions were investigated by the back-light scattering technique. The effects of surfactants (including water-soluble and oil-soluble surfactants), protein, and fat substitutes on the fat particle packing structure and stability of food emulsions were studied. It was found that protein plays a very important role on the food emulsion stability under shear stress by the formation of an adsorption layer on the surface of fat particles and microlayering of protein submicelles around fat particles. The addition of a fat substitute into low-fat food emulsions decreases the fat particle packing structure due to the irregular shape and large size of the fat substitute particles.

Keywords: Shear stress; Fat particles; Aggregation; Stability; Food emulsions

1. Introduction

Surfactants are widely used in the food industry to facilitate the formation, stabilization, and controlled-fat destabilization of food emulsions. In addition to these small amphophilic molecules, food oil-in-water emulsions also contain proteins which act as both emulsifiers and stabilizers (Dickinson, 1989; Xu, Nikolov, Wasan, Gonsalves, & Borwankar, 1998). The distribution of these two classes of molecules between the droplet surface and the bulk phases is an important factor affecting the stability and rheology of the systems. The composition and structure of the stabilizing layer is determined by the competitive adsorption between proteins and surfactants at the oil/water interface and by the nature of surfactant–protein interactions (Dickinson, 1992). The competitive displacement of proteins from the interface by different types of proteins or small-molecule surfactants, including oil-soluble surfactants and water-soluble surfactants, has been observed (Chen & Dickinson, 1993, 1995a, 1995b, 1995c; Chen, Dickinson, & Iveson, 1993; Courthandon, Dickinson, & Dalgleish, 1991; Dalgleish, Srinivasan, & Singh, 1995; Dickinson & Gelin, 1992; Dickinson, Owusu, & Williams, 1993; Dickinson & Tanai, 1992; Elgersma, Zsom, Lyklema, & Norde, 1992; Lassen & Malmsten, 1996a, 1996b; Shirahama, Lyklema, & Norde, 1990; Srinivasan, Singh, & Munro, 1996) and predicted by analytic theory (Gurkov, Horozov, Ivanov, & Borwankar, 1994) and computer simulation (Dickinson, 1992; Dickinson & Euston, 1991, 1992; Dickinson & Galazka, 1991). It was found that oil-soluble surfactants in the dispersed phase substantially reduce the protein surface concentration in the presence of water-soluble surfactants (Dickinson & Tanai, 1992).

Many researchers have studied the effects of protein/protein and protein/surfactant competitive adsorption at the adsorbed layer of fat globules on the fat surface properties such as surface shear viscosity, interfacial tension and surface adsorbed layer composition (Chen & Dickinson, 1995a, 1995b, 1995c; Courthandon et al., 1991). It was found that fat surface properties could be changed by the variation of the composition of proteins and surfactants; as a consequence, the stability of food emulsions varied dramatically.

Dickinson, Golding, and Povey (1997) investigated the influence of protein content on the stability of concentrated oil-in-water emulsions (35 and 45 vol% oil) containing sodium caseinate as the sole emulsifying agent. Time-dependent creaming profiles were determined using

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the ultrasound velocity scanning technique. The results indicated that creaming kinetics had a complex dependence on the caseinate content. The emulsion was destabilized by bridging flocculation (accompanied by some coalescence) at a low protein content (1 wt%), corresponding to less than half that required for saturation monolayer coverage. The non-flocculated emulsion had good stability at a higher protein content (2 wt%) where individual droplets were fully protected against protein bridging or coalescence by the thick adsorbed protein layer. The observed creaming stability was reduced again with an increase in the protein content. They explained this phenomenon as the depletion flocculation by the unadsorbed casein submicelles.

Koczo, Wasan, Wasan, Borwankar, and Gonsalves (1996) suggested a new stability mechanism for food emulsions resulting from the layering of sodium caseinate submicelles in thin liquid films. They found that films thinned stepwise by stratification. The heights of the film step-transitions were in the same range as the effective size of the casein submicelles (about 20 nm). This showed that microlayering of submicelles took place in the stratifying film and a layer left the film via step-transitions. The number of steps increased with the increasing caseinate concentration. This new mechanism of microlayering in emulsion films could play an important role in the stability of food emulsions.

Xu et al. (1998) investigated shear-induced fat particle structure variation and stability of food emulsions using the back-light scattering technique. The influences of shear history, shear rate and temperature on the fat particle structure and stability of food emulsions were studied. It was found that increasing the shear time initially improved the fat particle structure; afterwards, the fat particle structure became less ordered with a further increase of the shear time. The effect of the shear rate on the fat particle structure as a function of shear time is complex. A well-developed fat particle structure depends on an optimal shear rate. The effect of temperature on the fat particle structure and stability of food emulsions is also complicated. At a low temperature, the fat-particle-ordering structure inside food emulsions nearly linearly increases with the shear time at high temperatures; the developed fat particle structure initially improves, but eventually declines. An optimal temperature exists for this system as well.

In Part I of the two-part series, the shear-induced fat particle structure variation and stability of food emulsions using the non-destructive back-light scattering technique were described. In Part II, the effects of surfactants (polysorbate 60, polysorbate 65 and sorbitan monostearate), protein (sodium caseinate), and fat substitutes on the fat particle structure and stability of food emulsions are discussed.

2. Experiment

The emulsion preparation was the same as that in Part I. The main ingredients inside the food emulsion samples are listed in Table 1.

As described in Part I, the non-destructive back-light scattering technique was employed to obtain information on the fat particle structure and stability of food emulsions.

3. Results and discussion

3.1. Fat particle size distribution inside food emulsions

The fat particle size distribution inside food emulsion samples was measured using a Horiba LA-900 particle-size-distribution analyzer (Horiba Instruments Incorporated, Irvine, CA).

The analyzed results are shown in Fig. 1. The fat particle size distribution inside the 296AF sample is the same as that of the 296AE sample, because both the 296AE and the 296AF samples were made from the dilution of a 7.5 wt% fat emulsion with deionized distilled water or starch solution to 5.13 wt% fat emulsions, respectively.

The fat particle size distribution inside the food emulsion samples is nearly the same except for the 296CE sample. The mean particle size of the 296CE sample was much larger than that of other samples. According to Table 1, the dominant surfactant existing in this sample is sorbitan monostearate. The sorbitan monostearate surfactant is an oil-soluble surfactant with

Table 1
The main components of the food emulsions

Samp.	Fat (wt%)	Caseinate (wt%)	Polysorbate 60 (wt%)	Sorb. mono. (wt%)	Polysorbate 65 (wt%)	Fat substitute (wt%)
296AE	5.13	0.45	0.089	0.029	0.061	0.00
296BE	5.13	0.00	0.310	0.029	0.061	0.00
296CE	5.13	0.00	0.089	0.120	0.061	0.00
296DE	5.13	0.00	0.089	0.029	0.210	0.00
196AE	5.13	0.23	0.089	0.029	0.061	0.00
296AF	5.13	0.45	0.089	0.029	0.061	1.35