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ScienceDirect
Food Hydrocolloids 22 (2008) 888–898
FOOD HYDROCOLLOIDS
www.elsevier.com/locate/foodhyd

Effect of lecithin and monoglycerides on the heat stability of a model infant formula emulsion

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Received 16 November 2006; accepted 24 April 2007

Abstract

The effect of two common emulsifiers, lecithin and monoglycerides, on the heat stability of a model infant formula emulsion was investigated. During homogenization the droplet diameter of the emulsion was more effectively reduced by monoglycerides than lecithin. The maximum in the heat coagulation time (HCT)-pH profile at 140 °C of the emulsion with no added emulsifier coincided with the unadjusted pH (~6.8). Addition of lecithin (0–5 g l^{-1}) progressively increased the maximum heat stability of the emulsion from 18 to 25 min and at 3–5 g l^{-1} slightly shifted the maximum in the HCT-pH profile to more acidic pH values. The addition of monoglycerides on the other hand decreased the heat stability; the emulsion containing 5 g l^{-1} had a maximum heat stability of 12 min. Particle size distribution and average particle diameter (D[4,3]) measurements following heating confirmed that lecithin conferred stability to heat-induced aggregation while monoglyceride destabilized the emulsions. The zeta potential of oil droplets/particles in the emulsions became increasingly less negative with increasing monoglycerides concentration which is indicative of protein displacement; this may explain the low heat stability of the monoglyceride containing emulsions. The addition of lecithin on the other hand had no effect on zeta potential possibly because negatively charged lecithin replaced interfacial protein or interacted with interfacial protein. Progressively, less hydrophobic sites were available for binding of a hydrophobic probe as the concentration of either surfactant increased; interaction of surfactant with exposed hydrophobic regions of aqueous phase and/or interfacial protein is a possible explanation and this type of interaction may explain the high heat stability of lecithin containing emulsions.

Keywords: Infant formula; Heat stability; Lecithin; Monoglycerides; Emulsion stability

1. Introduction

Ready-to-feed infant formulae are produced by combining a fat phase, typically a mixture of vegetable oils, with an aqueous phase, consisting of milk proteins, carbohydrate, minerals, vitamins and other nutrients and homogenising these two phases to form an oil-in-water (o/w) emulsion that contains sufficiently small droplets to ensure stability against creaming. The emulsion is sterilised by thermal processing such as ultra high temperature (UHT) processing (e.g. 135–150 °C for 3–5 s) or retort sterilization (e.g. 120 °C for 5–10 min) or a combination of these processes.

Lecithin and monoglycerides are common emulsifying ingredients used in the manufacture of heat-sterilized recombined milk-based beverages such as ready-to-use infant formulae. In regular first age infant formulae, governed by EU and Codex regulations, these are the only emulsifiers permitted (Codex Alimentarius Commission, 1981; Commission of the European Communities, 1991). The primary purpose of including these food additives is to aid in the emulsification process. Being low molecular weight surfactants they migrate rapidly to the surface of the small fat droplets that are formed during homogenisation and together with the milk proteins form a membrane surrounding the droplets, thus preventing coalescence and flocculation.

Surfactants influence the properties of emulsions in several ways. Dickinson, Mauffret, Rolfe, and Woskett

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0268-005X/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodhyd.2007.04.017

(1989) described some mechanisms by which low molecular weight surfactants, in general, influence the stability of dairy emulsions. Surfactants (i) reduce the dynamic surface tension, thus leading to the formation of small fat droplets during homogenisation; (ii) displace protein, that may otherwise be available for bridging flocculation, from the fat globule surface; (iii) interact with interfacial protein, leading to a thicker and stronger adsorbed layer; (iv) increase the viscosity of the aqueous phase through the formation of self bodying mesophase structures. Specific studies have been conducted on the effects of monoglycerides and lecithin on dairy emulsions. Mono- and diglycerides reduced the surface tension at the o/w interface in the presence of sodium caseinate (Doxastaxis & Sherman, 1984). In general, the average fat globule size of whey protein stabilized emulsions decreased as the proportion of lecithin (Dickinson & Iveson, 1993) or monoglycerides (Euston, Finnigan, & Hirst, 2001) to protein in the emulsion was increased. Several studies have demonstrated that displacement of interfacial protein by phospholipids (Courthaudon, Dickinson, & Christie, 1991; Dickinson & Tanai, 1992; Dickinson & Iveson, 1993; Fang & Dalgleish, 1996a, b) and monoglycerides (Barfod, Krog, Larsen, & Bucheim, 1991; Davies, Dickinson, & Bee, 2000, 2001; Gelin, Poyen, Courthaudon, Le-Meste, & Lorient, 1994; Heertje, Nederlof, Hendricks, & Lucassen-Reynder, 1990; Krog & Larsson, 1992; Pelen, Watts, Campbell, & Lips, 1997) occurs in dairy emulsions. As well as competing with proteins for space at the interface, emulsifiers can also interact with proteins adsorbed at the interface and with non-adsorbed proteins in the aqueous phase. Several studies have demonstrated that phospholipids interact with dairy proteins (Barratt & Rayner, 1972; Barratt, Austin, & Whitehurst, 1974; Brown, Sampugna, Pfeffer, & Carroll, 1982; Brown, Carroll, Pfeffer, & Sampugna, 1983; Fang & Dalgleish, 1995; Istarova et al., 2005; Sarker, Wilde, & Clark, 1995).

Lecithin improves the heat stability of milk (Hardy, Sweetsur, West, & Muir, 1985; McCrae & Muir, 1992; Singh, Sharma, & Tolkey, 1992), whey protein stabilised emulsions (Jiménez-Flores, Ye, & Singh, 2005) and other dairy-based products such as an artificial coffee creamer (van der Meeren, El-Bakry, Neirynck, & Noppe, 2005). The improvement in heat stability is achieved through a combination of interfacial protein displacement (Courthaudon et al., 1991; Dickinson, Owusu, & Williams, 1993) and the formation of protein/surfactant complexes (Jiménez-Flores et al., 2005; McCrae & Muir, 1992; Singh et al., 1992). Euston et al. (2001) noted that during the initial stages of heating of an o/w emulsion (1%, w/w, whey protein; 20%, w/w, soya oil) at 100 °C, low concentrations (<0.2%, w/w) of phosphatidylcholine (PC), accelerated the rate of heat-induced aggregation of emulsion droplets. However, higher concentrations of PC (0.5 or 1%, w/w) conferred resistance to heat induced aggregation of emulsions droplets. This study of Euston et al. (2001) is one of very few studies on the effects of monoglycerides on the heat stability of emulsions. They found that the rate of heat-induced aggregation of fat globules was faster in the emulsion containing 1% (w/w) glycerolmonostearate (GMS) compared to the control emulsion with no added low molecular weight surfactant.

It is clear that many of the studies on the effects of lecithin and monoglycerides on emulsions have focussed on model systems that feature one protein source, a pure hydrocarbon oil (e.g. *n*-tetradecane) and relatively pure surfactants such as the phospholipid, PC, and the monoglycerides, glycerolmonooleate (GMO), GMS or glycerolmonopalmitate (GMP). This study is concerned with the influence of lecithin and monoglycerides on the heat stability of a more complex food system—a model infant formula emulsion containing mixtures of dairy proteins, lactose, a food grade oil and commercial grade emulsifiers. It follows on from earlier research that focussed on the heat stability of model milk protein systems and model infant formula emulsions stabilized by milk proteins in the absence of emulsifiers (McSweeney, Mulvihill, & O'Callaghan, 2004).

2. Materials and methods

2.1. Materials

High heat skim milk (SMP), electrodialysed whey (EDW) and lactose powders were obtained from Carbery Food Ingredients, (Ballineen, Co. Cork, Ireland), Valio Ltd. (Helsinki, Finland) and Glanbia plc. (Ballyragget, Co. Kilkenny, Ireland), respectively. Soya oil was obtained from Cargill plc. (Lincoln, UK). The lecithin used was Emulpur IP, a de-oiled lecithin powder (Degussa Texturant Systems Ltd. (Berkshire, UK). The monoglycerides mixture, Myverol 18–04 K, was obtained from Quest International (Naarden, The Netherlands).

2.2. Compositional analysis

The composition of the SMP, EDW and lactose was previously reported (McSweeney et al., 2004). The phospholipid composition of the lecithin (Table 1) was determined by HPLC according to the method of Arnoldsson and Kaufmann (1994). The fatty acid composition of the monoglycerides (Table 1) was determined by gas-liquid chromatography (Morrison & Smith, 1964).

2.3. Preparation of the model infant formula

A model infant formula emulsion (15 g protein l^{-1}, 60:40 whey protein: casein; 72 g carbohydrate l^{-1}, 35 g oil l^{-1}, 1.9 g ash l^{-1}) was prepared as follows: the aqueous phase of the model infant formula was prepared by slowly reconstituting a blend of SMP, EDW and lactose in deionised water at ~70 °C. The oil-phase was soybean oil alone or soybean oil plus lecithin or, soybean oil plus monoglycerides. Lecithin, when used, was added to the