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Food Hydrocolloids 19 (2005) 521–526

FOOD HYDROCOLLOIDS

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Factors affecting the perception of creaminess of oil-in-water emulsions

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Abstract

Rheological properties and particle size distributions of butter fat-in-water emulsions stabilized by sodium caseinate (2–4 wt%) have been investigated in relation to the texture descriptors 'taste', 'thickness' and 'creaminess'. The effects of oil droplet size (0.5 and 2 μm), oil volume fraction (5–20 vol%), and the addition of low-methoxy pectin or xanthan on texture perception have been evaluated at various concentrations of the hydrocolloids (0.03–1 wt%). Particular sets of conditions were chosen so that the samples had the same apparent viscosities at high shear-rate (50 s^{-1}).

Sensory panel results show that the perception of all three descriptors was significantly influenced by the rheology and the fat content, with higher ratings of all three descriptors scored for samples with higher viscosity and higher volume fraction. Discrimination between 5 and 20 vol% oil samples was stronger in the more viscous samples. Creaminess perception appeared to be more enhanced by a higher viscosity than by a higher volume fraction of oil. Some correlations between the different texture descriptors and the shear-thinning rheology of the samples were detected. Changing the oil droplet size from 0.5 to 2 μm had no significant influence on the perceived perception of taste, thickness and creaminess.

Keywords: Oil-in-water emulsions; Creaminess; Droplet-size distribution; Butter fat content; Pectin; Xanthan; Shear-thinning

1. Introduction

Creaminess is related to a pleasant sensation on eating. It is associated with indicators of richness and high quality of food products, especially those containing fat. In the reduction of the fat content of food products, it is considered a challenge to mimic the rheological effects of the fat through the use of fat-replacing systems (Jones, 1996). With the wide range of hydrocolloids, fat mimetics and texture modifiers currently available, this approach is in principle a relatively easy route. However, the matter of rheological matching cannot be viewed in isolation, as it needs to be related to the perceived sensory characteristics of a product, in particular its creaminess.

Many of the sensory attributes of food emulsions—such as creaminess, smoothness and sliminess—are often difficult to characterize, but are probably related in some way to their rheological properties. Food emulsions generally exhibit non-Newtonian viscoelastic behaviour and measurement of viscoelastic properties has for a long time been a major area of research (Atkin & Sherman, 1980). Oral viscosity plays an important role in texture perception of fluids and semi-solid foods. Perceived 'thickness' has been one of the most extensively investigated textural attributes in fluids and beverages. A number of attempts have been made to develop correlations between sensory thickness and rheological properties and to determine the shear-rates acting in the mouth in order to relate thickness to the non-Newtonian shear-thinning behaviour of foods (Cutler, Morris, & Taylor, 1983; de Wijk, van Gemert, Marjolein, Terpstra, & Wilkinson, 2003; Kokini, Poole, Mason, Miller, & Stier, 1984).

In a study where a thickening agent was used to increase the viscosity of dairy samples of varying fat contents (Mela, 1988), only the sample with the highest fat content was perceived equivalent to heavy cream (38% in fat content). As dairy creams are oil-in-water emulsions, any influence that the fat content has on texture perception should be related to the physical properties of the fat globules. Some researchers have shown (Daget, Joerg, & Bourne, 1987;

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0268-005X/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodhyd.2004.10.017

Wood, 1974) that 'creaminess' is sensed only if a certain viscosity threshold is met. Despite extensive research in this area (Drewnowski, 1987; Jowitt, 1974; Kokini & Cussler 1983; Kokini et al., 1984; Richardson-Harman et al., 2000; Malone, Appelqvist, & Norton, 2003), the most appropriate choice of terminology and sensory attributes to describe the textural contributions of fat in food products is still to be fully resolved.

In a review of this subject, Kokini (1987) attempted to relate liquid and semi-solid texture to the rheological and frictional properties. Creaminess was supposed to depend largely on smoothness and thickness (Kokini et al., 1984). In turn, thickness and smoothness were separately considered to be related to the viscous and frictional properties experienced in the mouth, allowing the identification of measurable physical properties to predict perceived texture and mouthfeel.

Many of the food systems exhibiting 'creamy' characteristics are oil-in-water emulsions, and so these particular systems have received most attention. Mela, Langley, and Martin (1994) reported the results of a sensory panel where the perception of fat in model oil-in-water emulsions with different fat contents increased with increasing viscosity at a shear-rate of 48 s^{-1}. In addition to the basic rheological characteristics of oil-in-water food emulsions, the importance of the size and number of fat droplets has also received some attention (Richardson, Booth, & Stanley, 1993). The results of Mela et al. (1994) showed no apparent pattern in terms of oil droplet size as affected by fat content in emulsions containing 0–48% fat. Richardson and Booth (1993) investigated further the effect of viscosity, globule-size distribution and average inter-globule distance on the perceived creamy texture of milks and creams. It was suggested that a wide variation in globule size might contribute to a lack of smoothness in dairy emulsions. By varying the amount and dispersion of fat independently of the viscosity of the emulsion, Richardson and Booth (1993) concluded that there was support for the more general hypothesis that emulsified fat contributes something to creaminess in addition to its effect on viscosity. Another more complicated factor that can potentially influence the rheological behaviour of emulsions and their sensory perception in the mouth is the state of aggregation of the droplets (Depree & Savage, 2001; Tornberg, Carlier, Willers, & Muhrbeck, 2005; van Vliet, 1988).

Despite extensive research, however, it is still not fully understood what exactly causes the perception of creaminess. This present study investigates the influence of fat content, rheology and microstructure (particle size) on the perception of taste, thickness and creaminess in model butter fat-in-water emulsions. In contrast to many previous studies, particular attention is given here to the careful control of the particle size distribution and the shear-rate-dependent rheology of the emulsion samples. For the experiments reported in this paper, the system conditions are adjusted to avoid aggregation of the droplets: the concentration of protein (sodium caseinate) is above that giving bridging flocculation, but below that giving depletion flocculation (Dickinson & Golding, 1997), whilst the concentration of xanthan is above that giving extensive serum separation by depletion (Cao, Dickinson & Wedlock, 1990; Dickinson, 2003). The overall aim of the project is to investigate the main physico-chemical factors affecting the perception of creaminess of these model oil-in-water emulsions, and also to explore the general relationship between rheological and perceived sensory characteristics of dairy emulsions.

2. Materials and methods

2.1. Materials

Commercial sodium caseinate (5 wt% moisture, 0.04 wt% calcium) was a gift from DMV International (Veghel, Netherlands). This was a spray-dried, food-grade product with a minimum of 91% dry protein, a maximum moisture content of 5.0%, and less than 4.0% fat and ash. Butter fat was provided by the Hannah Research Institute (Ayr, UK). Two commercial biopolymers, low-methoxyl pectin (DE 31) and xanthan gum (food grade), were purchased from CP Kelco (UK).

2.2. Emulsion preparation and droplet size measurement

Sodium caseinate was dissolved in drinking water at room temperature. The aqueous phase (4 wt% protein, pH 6.8) and the butter fat were heated in a water bath at 50 °C for 40 min. Butter fat-in-water emulsions (30 vol%, 2.8 wt% sodium caseinate) were prepared at 50 °C using a laboratory-scale jet homogenizer (Burgaud, Dickinson, & Nelson, 1990) working at the operational pressure of 350 bar. Emulsions were diluted with drinking water in order to reduce the fat level to 5 or 20 vol% in the final emulsion. The hydrocolloid (pectin or xanthan) was carefully dissolved in distilled water to a solution of known concentration. Resulting solutions were then mixed with the emulsions by gentle stirring in order to adjust the viscosity.

Emulsion droplet-size distributions were measured using a Malvern Mastersizer MS2000 laser light-scattering analyser with absorption parameter value of 0.001 and refractive index ratio of 1.46. The average droplet size was characterized by the mean diameter d_{43}, defined by

$$d_{43} = \Sigma_i n_i d_i^4 / \Sigma_i n_i d_i^3,$$

where n_i is the number of droplets of diameter d_i. The d_{43} value was used to monitor changes in the droplet-size distribution of freshly made emulsions on storage. Creaming stability was assessed visually by determining the time-dependent thickness of cream and serum layers in emulsions stored at 6 °C.