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The effect of sonication and high pressure homogenisation on the properties of pure cream

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ABSTRACT

The homogenisation of milk and cream has been widely studied but the effect of sonication on the structural and functional properties of cream is not well known. In this study, raw milk, ultrafiltration retentate and cream samples were sonicated at 20 kHz and the rennet and acid gelation properties of these sonicated samples investigated. High pressure homogenisation at 80 bar was also performed for comparison. Sonication of raw milk and retentate samples led to a decrease in the fat globule size. Conversely, the fat globules in cream samples sonicated at <10 °C flocculated to form grapelike structures whereas the cream samples sonicated at 50 °C did not form such aggregates. High pressure homogenisation at 50 °C led to similar flocculated structures, but these were not observed at low temperatures. This suggests a potential benefit of sonication technology in allowing low temperatures to be utilised for cream homogenisation, reducing energy demand. However, a gel made using cheese-milk with sonicated cream resulted in separation of a fat layer rather than the incorporation of the fat globules into the gel matrix. Rennet gelation properties of both the sonicated or homogenised samples were significantly superior to a native control sample where the resultant gels had shorter coagulation times and decreased syneresis.

Industrial Relevance: Homogenisation of dairy cream is normally carried out at temperatures of around 50 °C, to ensure that the fat is in the liquid state. In this work, we show that we can achieve comparable changes to the fat globules within the cream using ultrasound at much lower temperatures (<10 °C). The ability to form flocculated fat particles at lower temperatures could lead to reduced costs through reduced energy demand.

1. Introduction

Milk fat is present in milk as droplets of diameter in the range of 1–10 μm. These globules are covered with a natural milk fat globule membrane (MFGM) composed mainly of phospholipids and enzymes. The sensorial and rheological properties of many dairy products depend greatly on the size distribution of the fat globules and on the composition of the membrane (Cho, Lucey, & Singh, 1999; Lopez & Dufour, 2001). Reduction of the fat globule size and the consequent disruption of the fat globule membrane through ultrasonication alone or in combination with conventional homogenisation may lead to a range of new dairy products with different physico-chemical and functional properties. Although, such fat globule size reduction is not desirable for Cheddar cheese manufacture, it has many benefits in the manufacture of soft cheeses and dairy gels where the resulting high moisture content, creamier, smoother and softer textures are desirable. Further, the smaller fat globules are more sensitive to the influence of the lipolytic enzymes in making specialised products, such as blue cheese.

The milk fat globule membrane (MFGM) does not interact with the protein network in native dairy gels and so the fat globules act mainly as an inert filler or structure breaker (Michalski et al., 2004). However, when such dairy systems are subjected to shear, the fat globules are disrupted and their average diameter decreases significantly (Bermudez-Aguirre & Barbosa Canovas, 2010). Milk homogenization also disrupts the fat globule membrane, which is replaced by membrane fragments complexed with casein (Tunick, van Hekken, Cooke, Smith, & Malin, 2000). These homogenized fat globules are then able to form

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cross links with the casein network, and this effect is enhanced by their large surface area (Metzger & Mistry, 1995). Michalski, Michel, and Geneste (2002a) found that homogenized milk contained three types of fat particles: (i) regular milk fat globules with a fraction of the surface covered by casein micelles, (ii) tiny native milk fat globules around 100 nm in diameter that are not affected by homogenization due to their size and (iii) small, newly formed lipid-protein complexes with new membrane composed mainly of casein. Dalgleish, Tosh, and West (1996) concluded that casein micelle fragments, rather than intact micelles, are adsorbed on the globules during micro fluidization of milk. They attributed the disruption of the casein micelles to the forces encountered during the shearing process, which are experienced by micelles adsorbing at the fat/serum interface. Hayes, Fox, and Kelly (2005) also found that fat globules in high pressure (HP) homogenised milk are surrounded by a layer of casein micelle fragments rather than intact casein micelles. In contrast, Tosh and Dalgleish (1998) stated that disrupted fat globules are mainly bound by intact casein micelles.

Several studies have found that such changes during homogenisation (Michalski et al., 2002a, 2004; Michalski, Carlou, Michel, & Garnier, 2002b; Sandra & Dalgleish, 2007; Shaker, Abu-Jdayl, Jumah, & Ibrahim, 2002; Titapiccolo, Alexander, & Corredig, 2010; Yi-ran, Lee, & Anema, 2011; Zamora, Ferragut, Jaramillo, Guamis, & Trujillo, 2006) and micro fluidization (Ciron, Gee, Kelly, & Auty, 2012; Lemay, Paquin, & Lacroix, 1994; Path, Gellman, Schimdt, & Herforth-Kennedy, 1989; Tunick et al., 2000; van Hekken, Tunick, Marlin, & Holsinger, 2007) influence milk gelation kinetics and the resulting milk gel properties. The reduction of fat globule size implies a dispersion of fat into an increased number of smaller globules. The newly built surfaces are modified by the presence of adhering casein particles and become part of the para-casein network, hindering shrinkage of the network and thus lowering the syneresis and fat loss (Lemay et al., 1994). Green, Marshall, and Glover (1983) observed that curds from conventionally homogenized milk had a less coarse protein network, which retained moisture more effectively than curds from non homogenized milks. However, the formation of complexes between casein and MFGM decreases the amount of casein available to form stronger casein-casein bonds (Lemay et al., 1994). In turn, this affects cheese body and texture by a reduction of curd firming (Emmons, Kalab, & Larmond, 1980; Green et al., 1983). The weaker texture is also due to the new milk fat globules participating directly in the network instead of remaining trapped within the casein matrix.

Similar fat globule – protein complexes have also been observed when milk is subjected to ultrasonication (Michalski et al., 2002a). During exposure to an acoustic field, microbubbles are generated within the dairy fluid. The collapse of these microbubbles induces localised shear forces that are readily capable of disrupting fat globules. Bermudez-Aguirre, Mawson, and Barbosa-Canovas (2008) found that the sheared fat globules had a roughened granular surface due to the interaction between the disrupted MFGM and nearby casein micelles. Such changes induced noticeable improvements in the quality of Hispanic Cheese (handmade cheese consumed in Latin America) when the cheese milk was sonicated at 63 °C for 30 min (Bermudez-Aguirre & Barbosa Canovas, 2010). The cheese had a whiter colour, higher cheese yield and better textural and micro-structural properties with only a minor degree of syneresis. Increased water holding capacities for Emmental cheese and high lipolytic enzyme activity for blue cheeses has also been achieved through a reduction in fat globule size using sonication of the feed milk (Michalski et al., 2004).

While there is much work on the use of both homogenisation and sonication of cheese milk prior to gel formation, there is no work available on the sonication of the raw cream alone; prior to addition to cheese milk. Cream is commonly used to increase the fat concentration of milk for the production of soft, cream or high fat hard cheeses. It is a common practice to homogenize this cream before addition, to improve texture (Madadlou, Mousavi, Asl, Emam-Djome, & Zargaran, 2007; Sanchez, Beauregard, Chassagne, Bimbenet, & Hardy, 1996). In this study, we have looked at the effect of sonication on cream as a comparison to the effect observed during homogenisation. Separate sonication of cream prior to addition to the cheese milk could avoid the casein-MFGM interactions that reduce the capacity for these proteins to participate in gel formation. The present study uses cream systems containing ~40% fat which were subjected to sonication (50 W for 1 min) or homogenisation (80 bar) prior to addition to standardised cheese milk. The acid and rennet gelation properties were then investigated using these cheese milk systems.

2. Materials and methods

2.1. Materials

Raw milk, ultrafiltrate (UF) retentate, skim milk (SM), skim milk concentrate (SMC) and cream were obtained from a local Victorian dairy manufacturer. The composition of these samples, as supplied by the manufacturer, is given in Table 1.

Cheese-milk is defined as the milk standardised for the manufacture of Cheddar cheese, obtained by blending skim milk with skim milk concentrate and cream to obtain the desired protein and fat content of 3.8% *w/w* and 4.6% *w/w*, respectively. Three types of cheese-milk were investigated in this study:

1. A blend of SM, SMC and cream with no treatment (native);
2. A blend of SM, SMC and sonicated cream.
3. A blend of SM, SMC and homogenised cream.

The milk was blended by hand stirring for 1 min and each mixture was pasteurized at 85 °C for 30 min.

2.2. Sonication and homogenisation conditions

Batch solutions of milk and cream were sonicated in a glass vessel equipped with a cooling jacket using a 20 kHz, 450 W Ultrasonic horn (19 mm diameter, Branson Sonifier 450, Danbury, CT). To maintain a constant energy density, samples of 40 ml were sonicated at an amplitude of 60% and samples of 60 ml were sonicated at an amplitude of 40%. The power draw, as determined from a single-phase energy cost meter (Arlec, Victoria, Australia), was measured as 101 and 189 W under these conditions, giving an input energy density of 152 ± 3 J/ml for one minute sonication in both cases. The settings equated to delivered power levels of 31 ± 2 W and 50 ± 2 W as determined by calorimetry (Contamine, Wilhelm, Berlan & Delmas, 1995). During sonication, water was continuously circulated through the cooling jacket to maintain the desired sample temperature.

The homogeniser used was a GEA Panda PLUS 1000 (GEA Nitro Savi, Parma, Italy) equipped with a cell disruption valve. Single stage and single pass homogenisation was performed on 500 ml of solution at an operating pressure of 80 bar. In this case, the power drawn was 570 W. The flow rate of the solution was set at 3.73 ml/s to provide an identical input energy density of 153 ± 3 J/ml.

2.3. Particle size distribution

The particle size distribution of the fat globules in samples was measured using a Mastersizer 2000 (Malvern Instruments, Malvern, UK) using a refractive index for milk fat of 1.460 (Ji et al., 2011). The milk sample was diluted (1:1) in ethylenediamine tetraacetic acid (EDTA; 50 mM, pH 7). The milk samples were then added into the circulating

Table 1
Composition of milk, retentate, concentrate and cream.

Composition	Raw milk	UF retentate	SMC	Skim milk	Cream
Protein	3.6 ± 0.2	7.1 ± 0.4	13.8 ± 0.1	3.68 ± 0.11	2.1 ± 0.2
Fat	4.2 ± 0.2	8.2 ± 0.6	0.22 ± 0.03	0.08 ± 0.01	42.0 ± 1.0

Data are mean ± standard deviation of mean (n = 3). SMC = Skim Milk Concentrate.

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