Rheological properties of microfluidized oil-in-water emulsions stabilized by dairy components

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Introduction

Recombined dairy emulsions are end products in themselves (culinary creams, coffee creamers), or can be used as ingredients, contributing to the structure of more complex products (ice-cream, cheese, whipped cream). The industry of recombined milk products has not stop to grow and the range of recombined emulsions continues to expand. Recently, recombining has expanded its horizons to "added value and specialty products" like dairy based ready-to-drink beverages, sports supplements, cultured milks and fortified milks (recombined dairy emulsions could be considered as suitable delivery vehicles for a range of nutritional and functional ingredients). Subsequently, different textures are required for the diverse range of products. Interaction of emulsion droplets can lead to the creation of structures in foods and hence to the perception of textures as they are consumed (Dalgleish, 2006). The composition of the interfacial layer, determined by the nature of the emulsifier, remarkably influences the properties of emulsions (stability, rheology). The aim of this work was to investigate the effect of different commercial dairy components (whey protein concentrate (WPC), skimmed milk (SM) and two kinds of buttermilk (BM1 and BM2) having different phospholipids contents) on the final structure of microfluidized-emulsions. Oil-in-water emulsions were characterized by particle size, microstructure, dynamic rheological measurements and stability.

Composition analysis of the dairy powders

Composition (%)	WPC	SM	BM1	BM2
Proteins[1]	75.93 ± 0.29	37.02 ± 0.17	31.99 ± 0.23	28.14 ± 0.24
Fats[2]	5.12 ± 0.14	0.71 ± 0.18	7.44 ± 0.21	12.99 ± 0.10
Phospholipids[3]	2.05 ± 0.03	0.23 ± 0.01	2.28 ± 0.02	7.53 ± 0.34
Dry matter	96.60 ± 0.18	95.44 ± 0.17	95.74 ± 0.04	96.15 ± 0.04

(1)Kjeldahl, (2) Rose-Gottlieb, (3) Total phosphorus dosage of the extracted lipid

Formulation and elaboration of recombined creams

Emulsion composition was fixed at 30% (w/w) fat, 2% (w/w) protein. Non-fat dry matter of the emulsion was set at 5.91% (w/w) with lactose. The pH of the dispersions was adjusted to 6.6.
Anhydrous milk fat was completely melted at 75°C and incorporated in the dairy dispersions using an Ultra-Turrax T45 at 10 000 rpm.
Emulsions were then homogenized at 50°C by a Microfluidizer M 110T at 400 bar.

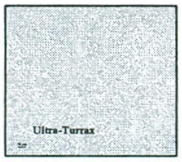
Effect of microfluidization on dairy emulsions

Droplet size measurement by laser light scattering

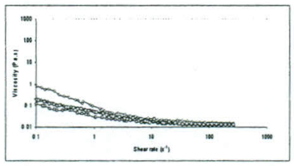
Structure of produced emulsions was visualized by an optical microscope

Dynamic viscosity analysis was used to compare the different cream samples

	Ultra-Turrax	
	Droplet diameter (d4,3) (µm)	Specific surface area (m2/g)
SM	7.36 ± 0.25	1.44 ± 0.05
WPC	5.17 ± 0.10	1.75 ± 0.06
BM1	5.17 ± 0.09	1.62 ± 0.08
BM2	3.58 ± 0.11	2.33 ± 0.05



A representative microscopy image of an emulsion obtained by the Ultra-Turrax

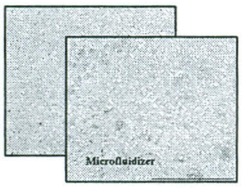


Viscosity plotted vs. shear rate profiles SM(◊), BM1(Δ), BM2(O), WPC (□)

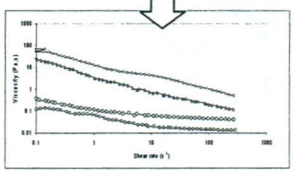
Emulsions obtained by the Ultra-Turrax showed non aggregated large droplets. At low shear rates, emulsions had a little shear thinning profile. All emulsions exhibited quite low viscosity.

	Microfluidizer	
	Cluster diameter ($d_{4,3}$) (µm)	Droplet diameter ($d_{4,3}$) (µm)
SM	30.06 ± 0.22	0.96 ± 0.01
WPC	1.02 ± 0.03	0.75 ± 0.03
BM1	18.67 ± 1.29	0.86 ± 0.01
BM2	3.57 ± 0.25	0.75 ± 0.04

Cluster diameters were obtained directly by dispersing emulsions in the sample cell of the particle size analyzer. Droplet diameter were obtained with samples that were diluted (1/1) in a 1% SDS solution before measurements.



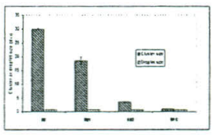
Representatives microscopy images of emulsions obtained by the Microfluidizer

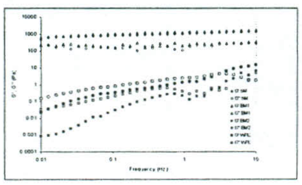


Viscosity plotted vs. shear rate profiles SM(◊), BM1(Δ), BM2(O), WPC (□)

Microfluidized emulsions showed very small droplets which formed clusters. Microfluidization increased the apparent viscosity and produced a change in the rheological behaviour of the emulsions. However, SM and BM1 samples showed a more shear thinning profile over the entire shear rate applied indicative of extensive interaction between particles.

Oscillation frequency sweep tests over a frequency range from 0.1 to 10Hz at a stress of 1Pa were performed for microfluidized emulsions

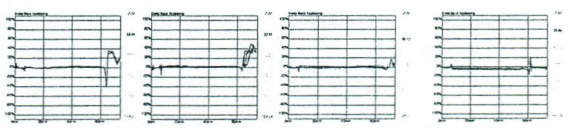




At low frequencies, the loss modulus (G'') is higher than the storage modulus (G') for WPC and BM2 (higher phospholipid content than BM1) indicating a more viscous than elastic response of the system. These emulsions show a weak structure having a more liquid character.

For extensive flocculated emulsions (SM and BM1) both moduli increased considerably. The storage modulus is higher than the loss modulus indicating the presence of a gel-like structure.

Creaming was monitored with an optical scanning instrument (Turbiscan MA 2000)



All microfluidized emulsions were stable, since the droplet size considerably diminished.

Conclusions

By changing the kind of the interfacial material (buttermilk, skim milk, whey protein), the particle-particle interactions can be modified leading from viscous liquid to unflowable creams.
Further investigation on the qualitative composition of the interface should be led in order to gain understanding on the interaction between particles.

Reference: Dalgleish DG. 2006. Food emulsions - their structures and structure-forming properties. Food hydrocolloids 20 (4): 415-422