International Dairy Journal 43 (2015) 33–41

Contents lists available at ScienceDirect

International Dairy Journal

journal homepage: www.elsevier.com/locate/idairyj

Fat destabilization and melt-down of ice creams with increased protein content

E. Daw, R.W. Hartel*

Department of Food Science, University of Wisconsin, Madison, WI 53706, USA

ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form
26 November 2014
Accepted 1 December 2014
Available online 17 December 2014

Keywords:
Ice cream
Fat destabilization
Melt-down
Protein

ABSTRACT

Effects of individual protein sources or blends on microstructure and melt-down rates of ice cream were investigated. Ice creams were formulated with non-fat dry milk (NFDM), milk protein concentrate, whey protein isolate (WPI), or procream to total protein concentrations of 4–10%. Ice creams were also made with protein blends containing 4% protein from NFDM with additional WPI or procream to total protein concentrations of 6–10%. Mean ice crystal and air cell sizes and overrun were not significantly impacted by protein source, blend, or concentration. Partially-coalesced fat decreased with increasing protein content, except in ice creams made with only NFDM. Melt rate tended to increase with protein content, with the exception of ice creams made with procream, which gave rapid melt rates at all protein concentrations. Protein type, blend and concentration were hypothesized to affect the properties of the emulsion interface, leading to differences in partial coalescence and melt-down rates.

1. Introduction

Ice cream is a complex matrix made up of fat globules, ice crystals, air cells, protein-hydrocolloid structures, and a serum phase containing unfrozen water with dissolved sugars, proteins and salts. The fat globules may be found as either individually distinct globules created during homogenization or as clusters of globules formed during freezing. A higher level of these partially-coalesced globule clusters indicates a greater degree of fat destabilization during freezing. The presence of these clusters has a significant effect on physical attributes of ice cream, particularly on melt-down (Goff & Hartel, 2013).

Increased protein content in ice cream boosts nutritional value, but it can also have a profound impact on structural elements, particularly the formation of partially coalesced fat during freezing (Segall & Goff, 1999). Proteins, usually present at about 4% in ice cream, initially stabilize the lipid emulsion after homogenization by forming a dense adsorbed layer on the fat globule interface, which prevents the droplets from coalescing by steric repulsion (Dickinson, 2003). However, each milk protein has differing adsorption properties and functions at the interface including how they unfold at the interface, how much they reduce the interfacial tension, how densely packed they can become, and their typical surface coverage. Each of these factors will have an impact on emulsion stability and the propensity for an emulsion to undergo partial coalescence during shear (Dickinson, 2003; Goff, Kinsella, & Jordan, 1989; Zhang & Goff, 2005).

The interfacial properties of the fat globules after aging of mix are typically dictated more by the emulsifiers than by the proteins (Goff & Hartel, 2013). About 0.1–0.3% emulsifiers are typically added to ice cream mix to help destabilize the emulsion. These small molecular weight surfactants, typically mono- and diglycerides and polysorbate 80, lower the surface tension more drastically than proteins and at much lower concentrations. As such, they decrease the overall interfacial energy, which makes it thermodynamically favorable for them to displace the proteins from the adsorbed layer on the fat globules (Nylander, Arnebrant, Bos, & Wilde, 2008). This makes the interface less stable and allows formation of partially-coalesced clusters during freezing.

Other compounds, such as phospholipids, which are naturally occurring in milk or in commonly added ingredients, such as egg yolk, also have an impact on the lipid–water interface. Zwitterionic phospholipids, like phosphatidylcholine, tend to coexist with milk proteins at interfaces. For example, in combination with sodium caseinate, lecithin does not predominate at the interface, it merely reduces the strength of the protein–protein interactions. This allows for increased surface mobility and thinning of the caseinate in the adsorbed layer (Dickinson, 2003). Some phospholipids merely

* Corresponding author. Tel.: +1 608 263 1965.
E-mail address: rwhartel@wisc.edu (R.W. Hartel).

http://dx.doi.org/10.1016/j.idairyj.2014.12.001
0958-6946/

reduce the amount of proteins at the interface to a very small degree, whereas others, like phosphatidic acid, may promote protein adsorption (Bergenståhl, 2008).

In order for partial coalescence to occur in ice cream the adsorbed protein layer after homogenization has to be modified; there is a certain level of protein desorption that has to occur to reduce the surface tension of the emulsion interface enough to allow partial coalescence to occur when the ice cream mix is sheared. At a certain protein load, partial coalescence is completely prevented and so increased protein adsorption makes little difference once a threshold is reached. Displacement of proteins by emulsifiers tends to increase with emulsifier concentration (Bolliger, Goff, & Tharp, 2000). Although fat destabilization is considered to be important in controlling ice cream properties, especially melt rate, the specific factors that influence both fat destabilization and melt rate are not clearly understood. Nevertheless, it is of interest to be able to optimize the protein content of an ice cream while still maintaining a high degree of partial coalescence.

In this study, the effects of increasing protein content on partial coalescence in ice cream were studied. Different milk sources were used to vary the protein composition in the mix, including nonfat dried milk (NFDM), milk protein concentrate, whey protein isolate and procream, a co-product of whey protein manufacture that contains high levels of both whey proteins and phospholipids (Bund & Hartel, 2013).

2. Materials and methods

2.1. Materials

Nonfat dry milk (NFDM) was obtained from Dairy America (Fresno, CA, USA). Milk protein concentrate 85 (MPC) and anhydrous milk fat (AMF) were obtained from Grassland Dairy (Greenwood, WI, USA). Whey protein isolate (WPI) and procream were obtained from Trega Foods (Appleton, WI, USA). Sucrose was obtained from United Sugars (Edina, MN, USA). The gum stabilizer, Germantown Premium Ice Cream Stabilizer, and mono- and diglyceride (MDG) were obtained from Dupont (New Century, KS, USA). Polysorbate 80 (PS80) was obtained from Mainstreet Ingredients (La Crosse, WI, USA). TruCal Milk Mineral Complex was obtained from Glanbia Nutritionals (Fitchburg, WI, USA). Lactose was obtained from Foremost Farms (Baraboo, WI, USA).

The different dairy sources contained different levels of lactose, ash, casein and whey proteins. NFDM contained 52.0% lactose, 7.1% ash, 28.9% casein, and 7.2% whey proteins. MPC contained 3.5% lactose, 7.0% ash, 67.2% casein, and 16.8% whey protein. WPI contained mostly whey protein (88.0%) with low levels of lactose (2.6%) and ash (2.2%). Procream contained 57.0% whey protein, 2.0% lactose, 4.0% ash, and the remainder as fat.

2.2. Experimental design

The study had two phases. The first phase investigated the impact of individual protein sources where one single protein source was used for the entirety of the protein content. Ice creams were formulated with NFDM, MPC, WPI, and procream to contain 4, 6, 8 and 10% protein content. All formulas were adjusted to match the composition of the control formula shown in Table 1 and to maintain a common freezing point temperature.

Table 1 shows the composition of the ice cream mixes made with different protein levels. Since the protein concentration was unique to each protein ingredient, in order to attain higher protein contents the protein ingredient was increased until the target protein content was reached. The protein powders also carry an amount of milk fat and ash that was adjusted to match the control formula (12% milk fat). To offset the increase in total solids, sucrose content was reduced and water content increased until the target freezing point temperature (−2.80 °C) was reached and total solids was comparable with the control formula (40.02–42.92%). Density was 1.15 ± 0.05 g mL^{-1} and total solids (calculated) ranged from 40.02% to 42.92%.

The second phase investigated the impact of protein blends on partial coalescence. Here, two specific protein blends were studied (NFDM and procream; NFDM and WPI) with the intent of comparing the co-product, procream with whey proteins. The blends were based on the control formula, which contained 4% protein from NFDM. Procream or WPI were added until the total protein content reached 6, 8 and 10%. These formulas were also adjusted to match the composition of the control formula and maintain a common freezing point temperature. Table 2 provides details of the formulations.

2.3. Ice cream mix production

The ice cream mix making process was broken into two separate heating segments due to excessive denaturation during pasteurization, particularly with the high protein content. In the first phase, 50% of the total water in the given formula was combined with all other ingredients excluding the protein ingredient. This mixture was heated in a Stephan (Stephan Machinery, Inc., Mundelein, IL, USA) mixer with steam to 83 °C to fully activate the gum stabilizers.

Table 1
Formula breakdown (%) for ice cream mixes containing different protein levels from either nonfat dried milk, milk protein concentrate, whey protein isolate or procream.[a]

Ingredient	4% Protein				6% Protein				8% Protein				10% Protein			
	NFDM	MPC	WPI	PRO	NFDM	MPC	WPI	PRO	NFDM	MPC	WPI	PRO	NFDM	MPC	WPI	PRO
Water	59.28	59.7	59.55	59.55	58.66	58.75	58.55	58.53	58.44	57.80	57.56	57.47	57.62	56.83	56.56	56.49
AMF	11.92	11.93	11.98	9.79	11.87	11.89	11.98	8.69	11.84	11.86	11.96	7.58	11.77	11.82	11.95	6.48
Sucrose	16.70	16.70	16.69	16.65	11.47	15.60	15.54	15.5	7.25	14.50	14.40	14.40	0.86	13.4	13.25	13.20
DM	0	0.78	1.08	0.84	0	0.56	1.02	0.67	0	0.35	0.95	0.48	0	0.13	0.89	0.31
Lactose	0	5.78	5.8	5.8	0	5.71	5.74	5.74	0	5.64	5.69	5.68	0	5.57	5.64	5.63
NFDM	11.75	0	0	0	17.65	0	0	0	22.12	0	0	0	29.40	0	0	0
MPC	0	4.76	0	0	0	7.14	0	0	0	9.50	0	0	0	11.90	0	0
WPI	0	0	4.55	0	0	0	6.82	0	0	0	9.09	0	0	0	11.36	0
PRO	0	0	0	7.02	0	0	0	10.52	0	0	0	14.04	0	0	0	17.54
MDG	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.23	0.12	0.12	0.12	0.12	0.12
PS80	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Stabilizer	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

[a] Abbreviations are: NFDM, nonfat dried milk; MPC, milk protein concentrate; WPI, whey protein isolate; PRO, procream; AMF, anhydrous milk fat; DM, dairy minerals; MDG, mono- and diglycerides; PS80, polysorbate 80.