High pressure processing for better ice cream

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ABSTRACT: Milk proteins play a crucial role in many food products, including ice cream. In this aerated frozen emulsion, milk proteins are crucial in the emulsification of the fat, the stabilization of air bubbles and the structuring of the continuous phase throughout which air bubbles and ice crystals are dispersed. When ice cream mixes are subjected to treatment by high pressure processing (HPP) prior to freezing, the casein micelles in milk are disrupted. As a result, the viscosity of the ice cream mix is increased strongly and ice cream free of stabilizer can be produced, without compromising on the stability and mouth feel of the product. Structuring of milk proteins in ice cream by HPP or other means thus offers opportunities for the replacement of fat and stabilizers in ice cream without compromising on hedonic quality parameters.

INTRODUCTION

Due to their abundance, ease of isolation and crucial role in human nutrition, milk proteins are the best characterized and most widely used food proteins. Milk proteins distinguish themselves from most other food proteins in that they naturally exist in an aqueous environment and are thus readily soluble. This solubility is combined with a high nutritional value, bland flavour profile and wide array of desirable functional properties, such as emulsification, foaming, gelation and heat stability. Two classes of milk proteins exist, i.e., the caseins and the whey proteins, which represent ~75 percent and 25 percent of protein in bovine milk, respectively. The whey proteins are a diverse class of globular, heat-labile proteins, of which α-lactalbumin, β-lactoglobulin, serum albumin and the immunoglobulins are the most abundant, whereas the caseins are a class of 4 rather unique phosphoproteins that exist in milk in the form of sterically-stabilized association colloids called casein micelles. These casein micelles are highly hydrated, containing ~75 percent water, and consist of ~10000 casein molecules, as well as small quantities of calcium phosphate. Casein micelles typically have a diameter of ~200 nm (Figure 1).

The unique properties of caseins and whey proteins, their interactions during processing (e.g., heat treatment), and their interaction with salts, are responsible for the desirable properties of a wide array of popular dairy and non-dairy food products, including cheese, yoghurt, caramels and milk shakes.

ICE CREAM STRUCTURE

Another widely-popular product in which milk proteins play a crucial role is ice cream. To produce ice cream, a mix is first prepared which contains fat, milk solids non-fat (MSNF), sweeteners, emulsifiers and stabilizer. Initial processing of this mix typically involves formulation, homogenization and pasteurization, following which it is aged for at least four hours at 4°C or lower; this step induces sufficient crystallization of the fat and restructuring of the emulsion droplet surface to facilitate sufficient partial coalescence of the fat droplets during freezing. The aged mix is then simultaneously aerated and frozen, typically using a continuous scraped-surface ice cream freezer. A schematic outline of the resulting ice cream structure is shown in Figure 2: ice cream has a continuous serum phase, with prominent ice crystals and air bubbles, stabilized by a network of partially-coalesced fat globules, in the matrix (1). In ice cream, the milk proteins contribute three crucial functional properties to development and maintenance of the desirable structure of ice cream (1):

1. Emulsification. In ice cream, milk proteins contribute strongly to emulsification of the fat and to partial coalescence of the fat globules and fat structure formation during ice cream manufacture. It is critical that the emulsion droplets are stable during mix preparation, but yet susceptible to partial coalescence during the freezing stage in manufacture. This can happen because the fat droplets are primarily covered by milk protein immediately after emulsification, but are gradually displaced by low molecular mass emulsifiers (e.g., monoglycerides) during ripening of the ice cream mix.

2. Aeration. Milk proteins play a crucial role in the stabilization of air bubbles during the initial stages of ice cream manufacture. During the manufacture of ice cream, air is incorporated in ice cream to approximately 50 percent of the volume phase of the final product. To stabilize this expanding air-liquid interface, it needs to be rapidly covered by surface active compounds. In ice cream, milk proteins dominate the air-water interface.

3. Structuring. In addition to emulsification and aeration, milk proteins play a crucial role in structuring the serum phase of ice cream. The hydration of milk proteins is important for the rheological properties of the serum phase of the ice cream. Together with the stabilizers, the
milk proteins are the primary determinants of the serum phase viscosity, and hence control the growth and stability of ice crystals.

**IMPROVING PROTEIN FUNCTIONALITY**

Despite the high functionality of milk proteins, consumer trends towards nutritious and healthy clean-label food products have put additional demands on milk proteins to deliver functional properties such as gelation, viscosity building, emulsification and foaming. Improvement of the textural properties of food products is a continuously increasing trend, which has long focussed on the creation of low-fat products. More recent trends also drive innovations towards low-salt and low-calorie food products. In addition, particularly for the elderly, there is currently a great demand for high-protein products. All these trends create increasing challenges for the food industry, to meet nutritional demands without compromising flavour, texture and stability of the products. While polysaccharide-based stabilizers have traditionally been applied widely as a convenient solution for texture improvement, such applications have also come under increasing pressure, due to consumer demands for additive-free, clean-label, food products. With these demands for tasty and nutritious clean-label food products, protein functionality has now, more than ever, become paramount for the food industry in achieving its goals. Innovative processing technologies, such as treatment with high pressure processing (HPP), ultrasound and pulsed electric fields, and biochemical modifications, such as enzymatic cross-linking and deamidation or glycation, are of interest as novel strategies for improving food texture. Some particularly promising results in this respect have been reported for HPP for structuring proteins in ice cream application. HPP involves the batch-wise or semi-continuous treatment of products at pressures ranging from ~100-600 MPa (1000-6000 bar). Commonly, samples are placed in a vessel which is subsequently closed, and pressure is built up using water, or another fluid, as a pressure-transmitting medium. Once the desired pressure is reached, the sample is maintained at this pressure for a certain time, after which pressure is released (2). Industrially, vessels with volumes of several hundred litres are available.
HIGH PRESSURE PROCESSING OF ICE CREAM

Treatment of milk and dairy products by HPP induces a number of effects. For instance, spoilage and pathogenic micro-organisms, as well as enzymes, can be inactivated, although the extent thereof appears insufficient to extend the shelf-life of milk to an extent which compensates for the additional processing costs [3]. However, from the point of view of product functionality, the effects of HPP on milk proteins are much more important. Like heat treatment, HPP treatment can result in the denaturation of whey proteins, which results in the formation of whey protein aggregates and the association of denatured whey proteins with the casein micelles [4, 5].

In milk and comparable systems, denaturation of whey proteins occurs at pressures >100 MPa. The most unique effects of HPP, however, are observed on the casein micelles. After HP treatment, casein micelle diameter, which is ~200 nm in normal milk, may be increased to >300 nm or decreased to <100 nm, depending on the conditions of treatment, i.e., pressure, time and temperature, as well as environmental conditions, such as pH and casein concentration [6-8]. In addition to changes in size, casein micelles in HPP-treated milk are also characterized by a higher water-binding capacity.

In addition, HPP-treated milk has been reported to yield stronger gels during manufacture of cheese and yoghurt [2,3].

A recent study by the authors, published in the International Dairy Journal [9], showed that, when ice cream mixes are treated with HPP, strong effects on the rheological properties of the milk and ice cream prepared from these mixes are observed. For instance, viscosity of the ice cream mixes can be increased >25-fold by treatment at pressures exceeding 400 MPa. These effects of HPP on ice cream mix can also be largely related to changes in the milk proteins in ice cream mix. Although the size of the emulsion droplets in ice cream is not affected by HPP, the casein micelles are strongly affected [9]. Evaluation of the microstructure of ice cream mix subjected to HPP shows that the casein micelles have been disrupted (Figure 3), increases in viscosity were further increased with increasing fat content, carbohydrate content and MSNF content, as well as with decreasing emulsion droplet size. Whey protein denaturation was found to contribute to viscosity only when denatured whey proteins did not interact with the casein micelle fragments [9]. The micellar fragments found in HPP-treated ice cream mix were also visible by electron microscopy in ice cream prepared from the HPP-treated mixes (Figure 4).

Along with the increased viscosity of the mixes, ice cream prepared from HPP-treated mixes had improved textural products, even in the absence of stabilizers. Along with improved texture, ice cream from HPP-treated mixes was also found to show greatly reduced susceptibility to meltdown. In addition, sensory assessment indicated that ice cream prepared from HPP-treated mix had a strongly improved mouth feel, thus offering opportunities for the preparation of reduced-fat or stabilizer-free ice cream.

CONCLUSIONS

Overall, it may be concluded that restructuring casein micelles in ice cream mix with HPP is an interesting technology for improving textural properties of ice cream and related products. It is worthwhile considering whether similar effects can be achieved using structured milk protein ingredients treated by HPP or other technologies, so as to circumvent the requirement of processing of the entire ice cream mix.

REFERENCES AND NOTES