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Effect of ultrasound-enhanced fat separation on whey powder phospholipid composition and stability

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ABSTRACT

Fat from freshly pasteurized liquid whey was partially separated by gravity for 5, 10, and 30 min, with and without simultaneous application of ultrasound. Ultrasound treatments were carried out at 400 and 1,000 kHz at different specific energy inputs (23–390 kJ/kg). The fat-enriched top layers (L1) and the fat-depleted bottom layers (L2) were separately removed and freeze-dried. Nonsonicated and sonicated L2 powders were stored for 14 d at ambient temperature to assess their oxidative stability. Creaming was enhanced at both frequencies and fat separation increased with higher ultrasonic energy, extended sonication, or both. The oxidative volatile compound content decreased in defatted whey powders below published odor detection threshold values for all cases. Sonication had a minor influence on the partitioning of phospholipids with fat separation. The current study suggested that ultrasonication at high frequency enhanced fat separation from freshly pasteurized whey while improving whey powder oxidative stability.

Key words: ultrasound, whey, fat separation, stability, phospholipids

INTRODUCTION

Whey is a liquid by-product of cheese production, and its solids contain up to 13% protein. High protein content in whey makes it suitable for the development of functional and nutritional ingredient formulations used in a variety of products such drinks, infant formulae, sport supplements, and pharmaceuticals, among other whey-based ingredients. Whey powders may contain fat ranging from 2.5 to 8%, which could adversely influence their functionality and flavor quality (Morr and Ha, 1993). Residual lipid affects whey powder functional properties such as gelation, solubility, emulsification, or foaming capacities. Autoxidative reactions of lipid can cause development of aged and stale off-flavors in whey powder during storage. In this instance, polar lipid species such as phospholipid fractions are more susceptible to lipid oxidation rather than neutral glyceride fraction (Morr and Ha, 1991).

Even though commercial centrifuges can remove a significant proportion of fat from liquid whey, they do not completely remove phospholipid fractions. Other commercial separation techniques such as membrane filtration require high pressures and cannot fully remove the entire whey lipids. Furthermore, membrane processes such as ultrafiltration often show limitations on fat separation process due to fouling of the membrane caused by the whey phospholipids (Morr and Ha, 1993). High-frequency ultrasound (400 to 2,000 kHz) has been recently studied as a technique for enhancing gravity separation of lipids from milk (Juliano et al., 2011, 2013a; Leong et al., 2014a,b) and oil-bearing materials (Juliano et al., 2013b, Leong et al., 2013). Unlike centrifugation, ultrasonic separation reactors do not require moving parts when adjusted to continuous processing lines.

Recent publications considered the application of high-frequency ultrasound to raw and recombined milk emulsions via single or multiple transducer configurations and showed the dependence of ultrasound-assisted gravity separation on frequency at similar energy densities (Juliano et al., 2011, 2013a). Further studies showed that gravity separation of cream from raw milk was better enhanced with 1,000 and 2,000 kHz transducers at increasing sonication time and sound energy input at 25°C (Leong et al., 2014a,b). Milk fat globule aggregation at high frequencies is enhanced above threshold

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values for specific energy and acoustic pressure of 100 to 200 kJ/kg and 50 to 200 kPa, respectively (Leong et al., 2014a,b).

The effect of ultrasonication on lipid oxidation in dairy products such as milk and whey has been investigated in a few studies (Riener et al., 2009; Chouliara et al., 2010; Marchesini et al., 2012; Juliano et al., 2014; Torkamani et al., 2014). Given that high rates of hydroxyl radical formation have been detected between 400 and 800 kHz, this is of concern for ultrasound separation applications in the high frequency range (Mason et al., 2011). Torkamani et al. (2014) reported that even though subsequent pasteurization promoted whey fat oxidation, ultrasound treatment of fresh whey (20, 400, 1,000, and 2,000 kHz at 8.0–390 kJ/kg) at 37°C did not further affect the concentration of volatile compounds related to lipid oxidation (Torkamani et al., 2014). The authors did not detect changes in phospholipid or free fatty acid composition after ultrasound.

Little or no information is available in the published scientific literature on the ability of high-frequency ultrasound to assist gravity separation of fat from whey. It is also important to understand the effect on the composition and storage stability of the lipid fraction remaining in whey ingredients after ultrasound-assisted fat separation. Therefore, the aim of this study was to investigate the effect of ultrasound on gravity separation of fat from whey at selected high frequencies (400 and 1,000 kHz) and ultrasound processing times (5–30 min). The effect on lipid composition and stability on reduced-fat whey powders was studied by monitoring lipid oxidation volatile compounds during storage. The partitioning of phospholipid fractions by ultrasound-assisted gravity separation was also evaluated.

MATERIALS AND METHODS

Sample Preparation and Handling

Fresh Cheddar cheese whey (fat content 0.41% wt/vol; TS 5.26% wt/vol) was obtained from the Food Processing Centre at the Commonwealth Scientific and Industrial Research Organisation (CSIRO, Werribee, Victoria, Australia). Whey was immediately pasteurized at 73.9°C for 15 s in a plate heat exchanger. Pasteurized whey was cooled and stored at 5°C in 2-L high-density polyethylene bottles with polystyrene caps in the dark and processed the same day.

Ultrasound Reactor Setup

A rectangular ultrasound reactor constructed from stainless steel was used (Figure 1). The plates were connected with screws instead of being welded to prevent erosion of welding material into whey during ultrasound treatment. The reactor was kept leak proof by inserting food-grade foam on plate intersections through the connecting points (Figure 1). The reactor was built in the smallest dimensions possible (250 × 180 × 80 mm) to maximize the effect of ultrasound waves and also fit the transducers.

The treatments were carried out by inserting submersible stainless-steel plate transducers (with an active area of 100 × 100 mm) operating at 400 and 1,000 kHz (Sonosys Ultraschallsysteme GmbH, Neuenburg, Germany; Figure 2). The walls of the reactor facing the transducer acted as reflectors promoting standing pressure waves. The induced power was fine-tuned from the power generator unit.

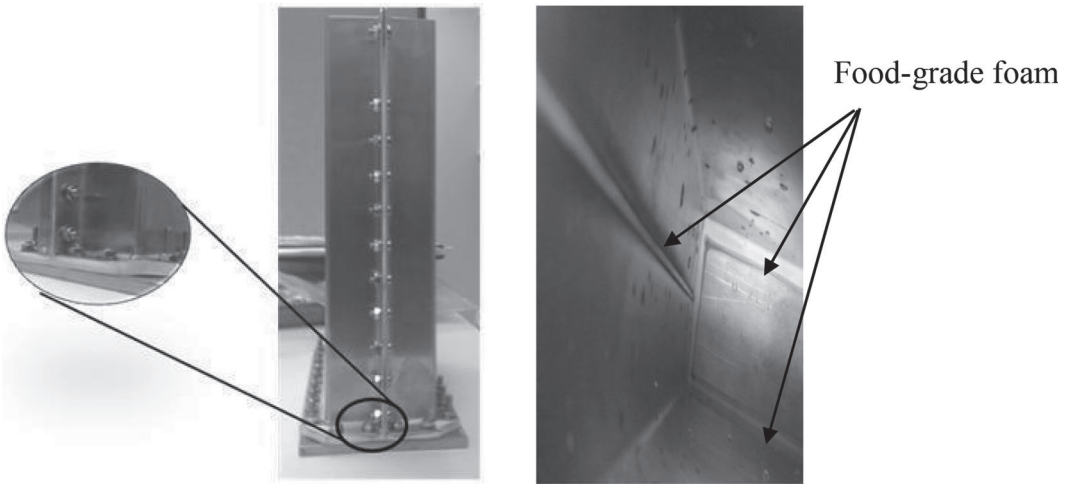

Figure 1. Structural design of the acoustic reactor chamber.