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Effect of processing on the composition and microstructure of buttermilk and its milk fat globule membranes

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Abstract

The effect of cream pasteurization on the composition and microstructure of buttermilk after pasteurization, evaporation and spray-drying was studied. The composition of milk fat globule membrane (MFGM) isolated from buttermilk samples was also characterized. Pasteurization of cream resulted in higher lipid recovery in the buttermilk. Spray-drying of buttermilk had a significant effect on phospholipid content and composition. After spray-drying, the phospholipid content decreased by 38.2% and 40.6%, respectively in buttermilk from raw or pasteurized cream when compared with initial buttermilks. Pasteurization of cream resulted in the highest increase in whey protein recovery in MFGM isolates compared with all other processing steps applied on buttermilk. A reduction in phospholipid content was also observed in MFGM isolates following spray-drying. Transmission electron microscopy of the microstructure of buttermilks revealed extremely heterogeneous microstructures but failed to reveal any effect of the treatments.

Keywords: Buttermilk; Milk fat globule membrane; Heat treatments; Phospholipids; Cream

1. Introduction

Buttermilk is the liquid phase released during churning of cream in the process of butter making. This liquid phase contains most of the water-soluble components of cream. After disruption of fat globules, milk proteins, lactose, minerals and some lipids are recovered in buttermilk as well as milk fat globule membrane (MFGM) fragments. MFGM is composed mainly of proteins, phospholipids and minerals (Walstra, Wouters, & Geurts, 2006). The MFGM fragments are of particular importance considering the various health-related properties described for its components (Spitsberg, 2005). For example, it was reported recently that MFGM fractions obtained from buttermilk and whey buttermilk have an anti-viral effect on rotaviruses strains (Ochonicky, Donovan, Kuhlenschmidt, Jiménez-Flores, & Kuhlenschmidt, 2005). Also, phospholipids have been reported as having potential physiological effects on brain health (Kidd, 2000), cholesterol binding in vivo (Noh & Koo, 2004), stress management (Rutenberg, 2002) and inhibition of tumour growth (Schmelz, Sullards, Dillehay, & Merrill, 2000).

Industrial treatments are known to have a major impact on the MFGM (van Boekel & Walstra, 1995). Heat is arguably the single most important factor affecting the MFGM. Adsorption of copper from milk plasma, aggregation of MFGM proteins, loss of MFGM proteins and phospholipids, and adsorption of caseins and whey proteins on the surface of the MFGM have been reported (Evers, 2004). Interactions between whey proteins and the MFGM also have been reported and are believed to be partly caused by sulphydryl–disulphide interactions (Dalgleish & Banks, 1991; Kim & Jiménez-Flores, 1995; Lee & Sherbon, 2002; Ye, Singh, Taylor, & Anema, 2002). Houlihan, Goddard, Kitchen, and Masters (1992) found both β-lactoglobulin (β-LG) and α-lactalbumin (α-LA) bound to MFGM after heating whole milk at 80 °C. Ye, Singh, James, and Anema (2004) proposed that interactions between β-LG and MFGM proteins were temperature dependent. Thermal denaturation of both β-LG and MFGM proteins results in disulphide linkage of MFGM

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aggregates and β-LG complexes. In another study, Lee & Sherbon (2002) reported that MFGM in milk heated for 3 min at 80 °C contain approximately 0.03 g of β-LG and 0.008 g of α-LA per 100 g of fat globules. These amounts increased with increased heating time. Lee and Sherbon (2002) also reported a loss of about 20% of lipids when MFGM are heated. However, the authors did not report the composition of the lipids lost during the heating process. It is believed that the migration of lipids from MFGM to the serum only occurs in presence of serum components (Houlihan et al., 1992).

To date, all the data collected on the effects of heat treatments on MFGM have been obtained after heat treatment of whole raw milk, which implies that the milk fat globules were structurally intact during heating. However, in the case of buttermilk, MFGM are not globular but rather sheet-like (Corredig & Dalgleish, 1997). MFGM components in both the inner and outer layers of the membrane are exposed to buttermilk serum. The interactions or repulsions between components might be drastically different from that of whole milk fat globules. At the industrial scale, buttermilk is often subjected to severe conditions (long holding time before evaporation and spray-drying, higher pasteurization temperatures for sanitary reasons), which are likely to induce changes in buttermilk microstructure.

Buttermilk can be a concentrated source of MFGM components. A number of studies aimed at concentrating or isolating MFGM from buttermilk have been reported (Corredig, Roesch, & Dalgleish, 2003; Jiménez-Flores & Morin, 2005; Morin, Jiménez-Flores, & Pouliot, 2004; Sachdeva & Buchheim, 1997; Surel & Famelart, 1995). Major variations in fractionation yields have been observed with buttermilks that had been obtained from different sources or had undergone different industrial treatments (Astaire, Ward, German, & Jiménez-Flores, 2003; Morin et al., 2004). Morin et al. (2004) used microfiltration (MF) membranes to separate phospholipids from MFGM and showed that the passage of phospholipids through the MF membranes was greatly affected by filtration temperature. In the same study, using the same filtration procedure, the authors found that phospholipid transmission was reduced by 50% when fresh pasteurized buttermilk was used as opposed to reconstituted powdered buttermilk (Morin et al., 2004). The major difference between the products was the processing history, indicating that processing steps may have a major impact on buttermilk phospholipids and MFGM. Little is known about the composition and microstructure of buttermilk and MFGM, which might explain the limited success of MFGM fractionation by MF.

Understanding the changes that occur in buttermilk composition and microstructure as a function of processing history could help to improve MF fractionation and enhance our understanding of the properties of buttermilk as a functional ingredient. The present study was aimed at investigating the effects of cream pasteurization and of the buttermilk processing steps, namely pasteurization, evaporation and spray-drying, on buttermilk composition and microstructure as well as on the composition of MFGM isolated from buttermilk.

2. Materials and methods

2.1. Processing conditions

Fresh raw cream (110 L; 43–44% fat) separated from raw milk at 35 °C was obtained from a local dairy (Natrel, Québec City, Canada) and divided into two batches on reception. One batch was pasteurized at 85 °C for 20 s using a tubular pasteurizer (Actini, Model Mini-Actijoule, Evian-Les-Bains, France). The pasteurized cream and raw cream were then stored at 10 °C overnight for maturation. Both cream samples were subsequently churned in a rotary churn (Fromagex, Rimouski, Canada) at 26 rpm and 13 °C. The raw and pasteurized creams broke down within an average ($n = 2$) of 23.3 ± 0.3 and 27 ± 0.8 min, respectively. The buttermilk was recovered in milk cans after separating the butter fines using a stainless steel filter. Residual lipids from both buttermilks types were removed by centrifugation using a milk separator (DeLaval model No. 619, Lund, Sweden) running at 6000 rpm and 18 °C. Sodium azide (0.02% (w/v)) (Fisher Scientific, Nepean, ON, Canada) was added as a preservative and samples were withdrawn for analysis. Both buttermilk types were pasteurized at 72 °C for 20 s using the tubular pasteurizer and samples were collected. Before evaporation, 30 ppm of anti-foaming agent (Dow Corning, Varennes, QC, Canada) was added. Each pasteurized buttermilks was then evaporated using a falling-flow evaporator (Mojonnier, LTS1 Laboratory Model Lo-Temp Evaporator, Chicago, IL, USA) at 60 °C until 20% solids was reached as measured using a handheld refractometer. A sample of concentrated buttermilk was collected for analysis. Lastly, the concentrated buttermilk was spray-dried using a pilot plant spray-dryer (Niro A/S, Hudson, WI, USA). Inlet and outlet air temperature were set at 195 and 85 °C, respectively. Samples of the powders were collected for analysis. The entire process has been repeated twice.

2.2. Isolation of MFGM

A sample of buttermilk (350 mL) obtained after each processing step was used for MFGM isolation with a slightly modified version of the procedure of Corredig and Dalgleish (1997). Briefly, sodium citrate (2% w/v) was added to buttermilks from raw and pasteurized creams. Buttermilk was stored at 4 °C overnight for maximum micelle dissociation. They were then centrifuged at $50{,}000 \times g$ at 4 °C for 2 h. The pellets were collected on Whatman #1 filter paper and rinsed with 25 mL of deionized water. The pellets were re-suspended in 100 mL of deionized water using a bench-top homogenizer (Polytron PT 3100, Brinkman, Westbury,