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Small scale production of cream cheese: A comparison of batch centrifugation and cloth bag methods

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ABSTRACT

Cream cheese production is well established at large scale but an effective small scale process could facilitate higher throughput and lower the cost of experimental studies. Whey was separated using centrifugation or the cloth bag method and the effect of heating prior to separation examined. Heat treatment and centrifugation resulted in cream cheese with a microstructure, composition and rheological properties comparable with that of a commercial scale cream cheese. Heating was necessary to achieve effective separation, the desired product microstructure and an adequate firmness and viscosity, with the heat induced denaturation of some whey proteins contributing to these properties. Whilst both whey separation methods resulted in a similar microstructure, centrifugation led to less fat loss and an optimal product. These data provide new insights into the development of cream cheese microstructure and provide a route to further understand and optimise this process.

1. Introduction

Cream cheese production has increased steadily in the last few decades, with more than 4.4×10^5 tonnes of cheese produced in the United States in 2015/16 (USDA, 2017) and 8.8×10^4 tonnes produced in Australia in 2015/16 (Dairy Australia, 2017). Cream cheese is defined by the Food and Agriculture Organisation (FAO) as a soft, spreadable, unripened and rindless product (FAO, 2016). An increase in the popularity of this cheese can be attributed to use in the food service sector, including in dips and spreads and as an ingredient in the baking industry, where the product structure contributes to functional properties including the rheological and textural properties. Whilst there are some existing studies on cream cheese at pilot and commercial scale in the literature (Sanchez, Beauregard, Chassagne, Bimbenet, & Hardy, 1994, 1996; Brighenti, 2009; Wendin, Langton, Caous, & Hall, 2000), there is no documented process that can model commercial processes at a laboratory scale. Such an advance would enable a detailed characterisation of the stages involved in cream cheese production and allow higher throughput studies to test the role of ingredients and process parameters on product properties.

In general, cream cheese typically belongs to two product categories defined by their fat content: double fat cream cheese made with milk standardised to at least 9–11% (w/w) fat and single fat cream cheese made with milk standardised to 4.5–5% (w/w) fat (Guinee, Pudja, & Farkye, 1993). Compositional requirements differ between countries and the food and drug administration in the US regulates that cream cheese should have a minimum milk fat content of 33% (w/w), with a moisture content no greater than 55% (w/w) (FDA, 2016). The FAO Codex standard also specifies a minimum dry matter of 22% (w/w) and minimum fat content of 5.5% (w/w) (FAO, 2016). In Australia, production is not regulated in this way but the most common product is similar to a US double fat cream cheese product.

The production of double fat cream cheese starts with the homogenisation and pasteurisation of standardised milk, followed by acidification with lactic acid bacteria (Phadungath, 2005). Fermentation leads to coagulation, where the milk protein aggregates to form a continuous protein network, commonly referred as an acidified milk gel. This gel is then subjected to heat treatment, which reduces the activity of the starter culture (Phadungath, 2005). The mesophillic starter cultures employed are typically inactivated by heating above 60 °C. Inactivation occurs after ~2 min at 60 °C for *Lactococcus lactis* subsp. *lactis* (Kang, Jeon, Shin, Kwon, & So, 2015). *L. lactis* subsp. *cremoris* is similarly expected to be

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inactivated at this temperature (Kim, Ren, & Dunn, 1999), although susceptibility may vary between strains.

Heating is typically achieved at commercial scale by breaking, stirring and pumping the gel to a tubular or a plate heat exchanger prior to feeding the curd into a centrifugal separator. The shear involved during this transfer depends on many factors including: the type of pump, pipe length and pipe diameter, temperature of the feed, separator feed flow rate, type and size of separator and factory layout (Mezger, 2014; Schmitt, Sturm, Grupa, & Hensel, 2016; Steffe & Daubert, 2006). Despite these differences, the net effect of this unit operation is an increase in the temperature of the curd and breakdown of the curd into smaller sized particles.

The heat treatment applied to inactivate the starter culture also affects whey separation during centrifugation. The simplified Stokes equation (Heymann, 2011; McCarthy, 2011) can provide a good indication of the effect of heat on whey separation, as temperature decreases the viscosity and fluid density of the sample (Bakshi & Smith, 1984), increasing the rate of the separation of particles in an ideal system where the radial separating velocity (v; m s^{-1}) is given by:

$$v = \frac{d^2\left(\rho_s - \rho_f\right)\left(\frac{\pi\omega}{30}\right)^2 r}{18\mu}$$

d is the diameter (m), ρ_s and ρ_f are the density of particle and fluid respectively (kg m^{-3}), r is the radius of rotation (m), μ is the viscosity of the continuous phase (Pa s) and ω is the speed of rotation.

In cream cheese, the particles will be in close proximity, so will be affected by more complex interactions between neighbouring particles, known as hindered settling. Nevertheless, this simplified expression gives a useful indication of the effect of process parameters on separation. Heat treatment can also denature whey proteins, altering interactions with casein proteins (Nguyen & Anema, 2017) but the extent of whey protein denaturation as a function of heat treatment in cream cheese production is unclear.

The continuous centrifugal separation employed at industrial scale ensures sufficient whey is removed to achieve a standard cream cheese moisture content of ~50–54% (w/w) (Brighenti, 2009; Phadungath, 2005). Such centrifugal separation allows for a faster continuous process, compared with traditional batch processing using cloth bags, allowing the hot sample to be pumped to a hopper where gums and salt are added, followed by shearing in a kettle and hot filling into packaging (Phadungath, 2005). Industrial separators have a throughput of 500 kg $^{h-1}$ to 4500 kg $^{h-1}$ (GEA, 2016), making these unsuitable for laboratory investigation. In this study, batch separation using a laboratory scale centrifuge was investigated as a model of small scale separation. Comparisons were also made with a process where whey was separated using the traditional cloth bag method and the properties of the resultant cream cheese compared.

Rheological and textural assessment are typically used to measure the properties of cream cheese (Brighenti, 2009; Brighenti, Govindasamy-Lucey, Nelson, & Lucey, 2008; Sanchez et al., 1994, 1996). While these tools have been coupled with structural analysis at the micron level to assess the effects of processing in other dairy products (Auty, Twomey, Guinee, & Mulvihill, 2001; Everett, Ding, Olson, & Sundaram, 1995; Nguyen, Ong, Kentish, & Gras, 2015; Ong, Dagastine, Kentish, & Gras, 2012), this approach has not previously been adopted for cream cheese. A few studies have examined the final cream cheese product using confocal laser scanning microscopy (CLSM), scanning electron microscopy (SEM) or transmission electron microscopy (TEM) (Kalab & Modler, 1985; Monteiro, Tavares, Kindstedt, & Gigante, 2009; Wendin et al., 2000) but the fat, which is a major component in cream cheese, is not typically retained within the microstructure when assessed using conventional SEM and TEM. The current study employs complementary CLSM and cryo SEM techniques to preserve the fat, protein and other components to investigate how the microstructure develops from milk to a continuous gel structure, a concentrated curd and the final cream cheese product after cooking, stirring and gum addition.

This study aimed to develop a small scale production process that can facilitate higher throughput and lower cost experimental studies. Four types of cream cheese were made using different whey separation processes: a batch centrifugation process and cloth bag method with the addition or absence of a heat treatment step prior to whey separation. These experiments sought to better understand whey separation and the role of temperature in this unit operation. The ingredients and the processing parameters used were selected to resemble commercial production, potentially allowing manufacturers to evaluate the effect of different ingredients and processing parameters that have a critical impact on the final product properties of cream cheese. A second aim of the study was to characterise the changes that occur to the microstructure during the production of cream cheese.

2. Materials and methods

Preliminary experiments including microstructure analysis, rheology and an evaluation of centrifugation (Sections 2.1–2.4) were performed to obtain an indication of the optimum temperature and centrifugation force for a laboratory scale separation of whey for batch cream cheese production. These parameters were then used for the cheese making trials described in Section 2.5.

2.1. Preparation of acid gels

Milk was collected from a commercial plant (Melbourne, Australia). The milk was standardised, homogenised and pasteurised in the factory. Fat was standardised by blending raw milk with cream to obtain a final concentration of 12.3% (w/w) fat and 3.4% (w/w) protein. The composition of the milk was measured using a Milko Scan FT120 (FOSS, Mulgrave, Australia). The milk was then homogenised at 14 MPa 55 °C and pasteurised at 72 °C for 15 s. The processed milk was stored at 4 °C and used within 1 week.

The acid gel was prepared by fermentation with 0.3% (w/w) frozen mesophillic starter culture (Chr. Hansen, Bayswater, Australia). Prior to the addition of the culture, the milk was heated to 31 °C in a water bath. The cultured milk was then added to 250 mL plastic containers for the analysis of microstructure by CLSM and rheological assessment (Sections 2.2 and 2.3) or added to 1.8 mL centrifuge tubes for centrifugation tests (Section 2.4); all samples were incubated at 31 °C in an incubator to assist fermentation (Thermoline, Wetherill Park, Australia). The fermentation was stopped when the pH of the sample reached pH 4.5 by cooling the sample in the fridge to 4 °C. The exception was for centrifugation samples, where after fermentation the samples were directly vortexed at 20 °C or 70 °C for 10 min prior to centrifugation.

2.2. Characterisation of milk and acid gel using CLSM

The microstructure of the standardised milk and acid gel was analysed using a Leica SP8 CLSM (Leica Microsystems, Heidelberg, Germany) following a published method used for milk and rennet gels, where the milk sample was diluted in simulated milk ultrafiltrate solution (SMUF) (Ong, Dagastine, Kentish, & Gras, 2010). Six milk and acid gel images were collected at different magnifications for each sample and a representative image is presented.