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The composition and functional properties of whey protein concentrates produced from buttermilk are comparable with those of whey protein concentrates produced from skimmed milk

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ABSTRACT

The demand for whey protein is increasing in the food industry. Traditionally, whey protein concentrates (WPC) and isolates are produced from cheese whey. At present, microfiltration (MF) enables the utilization of whey from skim milk (SM) through milk protein fractionation. This study demonstrates that buttermilk (BM) can be a potential source for the production of a WPC with a comparable composition and functional properties to a WPC obtained by MF of SM. Through the production of WPC powder and a casein- and phospholipid (PL)-rich fraction by the MF of BM, sweet BM may be used in a more optimal and economical way. Sweet cream BM from industrial churning was skimmed before MF with 0.2-μm ceramic membranes at 55 to 58°C. The fractionations of BM and SM were performed under the same conditions using the same process, and the whey protein fractions from BM and SM were concentrated by ultrafiltration and diafiltration. The ultrafiltration and diafiltration was performed at 50°C using pasteurized tap water and a membrane with a 20-kDa cut-off to retain as little lactose as possible in the final WPC powders. The ultrafiltrates were subsequently spray dried, and their functional properties and chemical compositions were compared. The amounts of whey protein and PL in the WPC powder from BM (BMWPC) were comparable to the amounts found in the WPC from SM (SMWPC); however, the composition of the PL classes differed. The BMWPC contained less total protein, casein, and lactose compared with SMWPC, as well as higher contents of fat and citric acid. No difference in protein solubility was observed at pH values of 4.6 and 7.0, and the overrun was the same for BMWPC and SMWPC; however, the BMWPC made less stable foam than SMWPC.

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INTRODUCTION

Over the past several years, the interest in high-protein ingredients such as whey protein concentrate (**WPC**) or isolate (**WPI**) has increased. Both WPC and WPI are usually produced from cheese whey. However, WPC can also be derived from the fractionation of skim milk (**SM**) by microfiltration. Skim milk WPC contains less minerals and has no caseinomacropeptides compared with traditional WPC from cheese whey. The functional properties of WPC from SM fractionation have recently been compared with those of cheese whey WPC by Coppola et al. (2014) and Evans et al. (2010). The WPC from SM fractionation have unique functionalities, such as excellent solubility, gelling after heat treatment, and foaming properties (Bacher and Køningsfeldt, 2000; Heino et al., 2007).

Buttermilk (**BM**), the by-product from the churning of butter, has a CN and whey protein ratio similar to that of SM (Corredig and Dalgleish, 1997), and spray-dried BM has a comparable nutritional value to that of SM powder (Morin et al., 2004). Govindasamy-Lucey et al. (2006) studied the use of BM in pizza cheese, and the solubility, foaming, and emulsifying properties of BM powders have been described in Sodini et al. (2006). However, a high fat content in BM may lead to sticky powder as well as increased risk of off-flavors from oxidation products. The fractionation of BM into a CN- and milk fat globule membrane (**MFGM**)-rich fraction and a whey protein fraction may increase the value of this by-product. Most of the BM produced today is used as animal feed (liquid) or for the production of BM powder, but it can also be exploited in a more optimal way to produce WPC, as the global demand for whey protein is increasing (Lafougère, 2014). Buttermilk is higher in MFGM protein and phospholipids (**PL**) than SM, which might alter the functional properties of its WPC.

Buttermilk is a rich source of MFGM components, such as proteins and PL (Rombaut et al., 2005), because parts of the MFGM are released from the fat globule into the serum phase during butter churning. Membrane technology is frequently used in the dairy industry to concentrate milk constituents, and by using microfiltration (**MF**), CN and MFGM can be separated from whey proteins. Several studies have focused on the separation and isolation of MFGM proteins or PL from BM by MF (Sachdeva and Buchheim, 1997; Corredig et al. 2003; Morin et al., 2006, 2007a, 2007b) for the further purification of the PL (Astaire et al., 2003). Few studies, if any, have focused on the utilization of the whey protein fraction obtained from BM.

The high ratio of CN to total protein in BM (Corredig et al., 2003) gives a high CN recovery during MF. The retentate from the MF of sweet BM could be used for further extraction of the PL. Achieving high-purity PL from the MF of BM is difficult, as CN micelles and MFGM fragments have similar size distributions (Rombaut et al., 2006; Singh, 2006). However, a MF retentate from BM, which is rich in CN and MFGM components, can be used as a starting material for further separation and purification of PL or as a supplement in other dairy processes. However, several studies have reported the transmission of PL and MFGM proteins through the MF membranes (Astaire et al., 2003; Morin et al. 2007a), thus affecting the composition and functional properties of the products used from these permeates. Whey proteins and PL are applied in the food industry as ingredients for baking, as well as in pharmaceuticals and in cosmetics (Vanderghem et al., 2010) due to protein solubility, foaming, and emulsifying properties.

The major whey proteins, which are most important for the functional properties in most food applications, are β-LG and α-LA. Heat treatment does influence the functional properties of the whey proteins (Abd El-Salam et al., 2009) or the sizes of their aggregates (Schokker et al., 2000; De La Fuente et al., 2002). At approximately 67.5 to 78°C, the β-LG starts to unfold, and at higher temperatures of 78 to 82.5°C aggregation occurs (Sava et al., 2005). Denatured β-LG may aggregate with other β-LG molecules, CN (Donato and Guyomarc'h, 2009), α-LA (Dalgleish et al., 1997), or MFGM proteins (Ye et al., 2004). α-Lactalbumin has no free thiol group and contributes less to the aggregation caused by denaturation (Calvo et al., 1993).

The objective of the current study was to compare the final WPC powders obtained by MF fractionation and further UF and diafilitration (**DF**) concentration of BM and SM MF permeates. The BM used was of industrial origin with varying cream pasteurization histories, whereas the SM used was obtained from controlled pasteurization (73°C/15 s).

MATERIALS AND METHODS

Experimental Design

The study was carried out at a pilot-scale dairy processing plant at the Norwegian University of Life Sciences (**NMBU**), Department of Chemistry, Biotechnology and Food Science (Ås, Norway). The fractionation, concentration, and spray drying were carried out for each of 4 batches of BM and SM. To yield enough MF permeate to produce 1 batch of approximately 3 kg of WPC powder, the skimmed BM or SM of each powder production was MF on 2 consecutive days. The MF permeate from the first day was kept at 4°C and pooled with the MF permeate from the second day before further concentration by UF/DF and the final spray drying. The 2 pooled MF permeates originated from the same raw material batch (BM or SM) and were, therefore, treated as a single MF replicate block during further analysis. The UF and powder production were repeated 4 times (4 replicate blocks).

BM and Cream Treatment

Four batches of fresh sweet BM were collected from TINE Sandnessjøen (Sandnessjøen, Norway). The cream used for churning originated from different dairy plants in northern Norway. As the cream was obtained from different dairy plants, the cream had undergone different pasteurization routines prior transportation to TINE (Sandnessjøen, Norway). The cream was pasteurized upon arrival at TINE. Therefore, the heat treatment of the cream might have been repeated 2 to 3 times using the following conditions: 74.2°C/20 s (approximately 40% of the cream) or 86°C/5 s (approximately 60%) based on different routines at the supplying dairies. Each batch of BM was pasteurized once (76°C for 20 s) before transportation to the NMBU pilot plant. Including transportation, the BM was stored cold (4°C) for up to 5 d before MF. Upon arrival at the NMBU pilot-scale dairy processing plant, the BM was skimmed by a cream separator to 0.3% fat at 55°C (SA 1–01–175, Westfalia Separator AG, Oelde, Germany) to minimize the differences in the residual fat in the 4 batches investigated. The TS content of the BM after skimming was 7.50 ± 0.56 g/100 g, on average, and the pH was 6.84 ± 0.19. After skimming, the MF feed was kept at approx. 50°C for a maximum of 4 h before fractionation.

MF of BM and SM

The MF of skimmed BM was carried out using pilot plant equipment (APV UF/MF pilot MCC RV