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A Microfiltration Process to Maximize Removal of Serum Proteins from Skim Milk Before Cheese Making*

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ABSTRACT

Microfiltration (MF) is a membrane process that can separate casein micelles from milk serum proteins (SP), mainly β-lactoglobulin and α-lactalbumin. Our objective was to develop a multistage MF process to remove a high percentage of SP from skim milk while producing a low concentration factor retentate from microfiltration (RMF) with concentrations of soluble minerals, nonprotein nitrogen (NPN), and lactose similar to the original skim milk. The RMF could be blended with cream to standardize milk for traditional Cheddar cheese making. Permeate from ultrafiltration (PUF) obtained from the ultrafiltration (UF) of permeate from MF (PMF) of skim milk was successfully used as a diafiltrant to remove SP from skim milk before cheese making, while maintaining the concentration of lactose, NPN, and nonmicellar calcium. About 95% of the SP originally in skim milk was removed by combining one 3× MF stage and two 3× PUF diafiltration stages. The final 3× RMF can be diluted with PUF to the desired concentration of casein for traditional cheese making. The PMF from the skim milk was concentrated in a UF system to yield an SP concentrate with protein content similar to a whey protein concentrate, but without residuals from cheese making (i.e., rennet, culture, color, and lactic acid) that can produce undesirable functional and sensory characteristics in whey products. Additional processing steps to this 3-stage MF process for SP removal are discussed to produce an MF skim retentate for a continuous cottage cheese manufacturing process.
(**Key words:** microfiltration, serum protein recovery, diafiltration, native casein)

Abbreviation key: DF = diafiltration, **MF** = microfiltration, microfiltered, **NCN** = noncasein nitrogen, **PMF** = permeate from microfiltration, **PUF** = permeate from ultrafiltration, **RMF** = retentate from microfiltration, **RUF** = retentate from ultrafiltration, **SP** = milk serum proteins, **SPC** = serum protein concentrate, **WPC** = whey protein concentrate, **WPI** = whey protein isolate.

INTRODUCTION

Ultrafiltration is used widely in the dairy industry, particularly in the processing of sweet whey. Dairy liquids with high protein content can be produced using UF because water, lactose, NPN, and soluble minerals pass through the UF membrane but casein or milk serum proteins (**SP**; mostly α-lactalbumin and β-lactoglobulin) do not pass through a UF membrane. Recently, UF has been used commercially on the farm to reduce transportation costs (Howie, 1999). The history of milk UF for Cheddar and Mozzarella cheese making was reviewed by Horton (1997). The goal of UF when first used before cheese making was to reduce heterogeneity of cheese composition when whey was drained from curd, retain more whey proteins in the cheese to increase cheese yield, and decrease pollution from whey protein disposal (Maubois and Mocquot, 1975). Unfortunately, when a high level of whey protein retention was achieved, the flavor and textural properties of hard cheeses (e.g., Cheddar and Mozzarella) were not acceptable for most commercial applications (Covacevich and Kosikowski, 1978). In contrast with Cheddar and Mozzarella cheeses, some soft cheeses (i.e., feta, and Pavé d'Affinois) have been produced successfully using UF (Horton, 1997). Today, the greatest use of UF in the United States dairy industry has been for the production of whey protein concentrate (**WPC**).

Microfiltration (**MF**) has not been widely used in the dairy industry. In recent years, interest in the use of MF of milk to remove bacteria, somatic cells, fat, and separate casein from SP has increased because of improved ceramic membranes and uniform transmembrane pressure technology that reduces membrane fouling (Saboya and Maubois, 2000). Bacteria and fat removal from cheese whey and cheese brine are other uses of MF technology (Saboya and Maubois, 2000).

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Successful use of low concentration factor MF before Cheddar cheese making has been reported in several research studies (St-Gelais et al., 1995; Neocleous et al., 2002a,b). Mozzarella cheese has been produced using high concentration factor MF (Brandsma and Rizvi, 2001). Garem et al. (2000) produced a whey protein-depleted skim milk powder with MF for use in countries that have a short milk supply. The low SP powder was a better alternative to skim milk powder for Mozzarella cheese making because β-lactoglobulin was not present to complex with κ-CN during thermal processing.

There are many reasons why it might be desirable to remove SP from milk before cheese manufacture. First, most of the SP are not retained in the cheese so removal before cheese making would produce the same cheese composition. Second, the permeate from MF (**PMF**) from a 0.1-μm membrane is virtually sterile and the proteins are in their native form. Third, the SP liquid produced using MF contains little or no fat and the SP products would not develop the defects associated with fat deterioration during storage. Some whey products contain between 1 and 7% fat (Huffman and Harper, 1999). The fat content of whey products has a negative effect on flavor (Morr and Ha, 1991) and foaming (Pearce et al., 1992). The off-flavors caused by fat oxidation limit the use of whey products. Lastly, SP may have functional advantages over the same proteins isolated from whey because they would not contain lactic acid, cheese color, and starter culture from the cheese making process (Britten and Pouliot, 1996). Depending on the value of the benefits that SP products have over whey protein products, recovering the SP before cheese manufacture to produce serum protein concentrate (**SPC**) may be an alternative to WPC or whey protein isolate (**WPI**) from whey.

Bacher and Kønigsfeldt (2000) produced an "ideal whey" using water diafiltration (**DF**) during MF, which had improved functional properties (i.e., solubility, foaming, and gelation) compared with WPC and WPI. If removal of serum proteins from milk can produce higher value milk serum protein products, then a process that maximizes the recovery of the SP from milk before cheese making will be needed. The objective of our research was to develop a multistage MF process to achieve a high recovery of serum proteins from skim milk while producing a low concentration factor skim retentate from microfiltration (**RMF**) with a concentration of soluble minerals, NPN, and lactose similar to skim milk used to standardize milk for use in traditional Cheddar cheese making.

MATERIALS AND METHODS

Milk Processing

Milk processing including the subsequent filtration and DF required 2 d of 1 wk due to the capacity of our equipment. The milk processing and filtration/DF were replicated 3 times. A different batch of milk was used for each replicate.

Pasteurization and separation. Whole raw bovine milk was received on the first day of processing from the Cornell University teaching and research dairy farm. The raw milk was pasteurized at 72°C for 15 s and quickly cooled to 4°C, using regeneration and cooling sections of a plate heat exchanger system. Next the cooled milk was heated to 50°C with a plate heat exchanger then separated into skim and cream using a centrifugal cream separator (model 619, DeLaval, Kansas City, MO). The skim portion was quickly cooled to 4°C using a plate heat exchanger and stored overnight at 4°C.

Process to remove SP. The total MF process (Figure 1) had 3 stages: 1) 3× MF of the skim milk, 2) DF using permeate from UF (**PUF**) as the diafiltrant, and 3) a second DF using PUF as the diafiltrant. On the second day of processing, approximately 300 kg of pasteurized skim milk (processed the day before) was warmed to 50°C using a plate heat exchanger with 60°C water as the heating medium and placed in a stainless vat connected to the MF unit. An MF unit capable of maintaining uniform transmembrane pressure (Tetra Alcross M7 Pilot Plant Type, Tetra Pak, Denmark) equipped with 0.1-μm nominal pore diameter ceramic Membralox membranes (total area of 1.7 m^2) was used to remove serum proteins from skim milk. Retentate and permeate MF bleed flow rates were 45 and 90 L/h, respectively. The MF system consisted of a feed pump, a retentate recirculation pump, and a permeate recirculation pump. The retentate and permeate inlet pressures (corrected for elevation differences) were approximately 422 and 384 kPa, respectively, and the retentate and permeate outlet pressures (corrected for elevation differences) were approximately 235 and 218 kPa, respectively. The difference between the inlet and outlet transmembrane pressures was maintained between 23 and 28 kPa. Conditions on the MF unit were set so that the weight of the RMF would be one-third the skim milk weight. The RMF from stage 1 was collected in stainless steel milk cans. One part RMF was diluted with 2 parts cold (≤4°C) PUF (Figure 1) using a process similar to that described by Kulozik and Kersten (2002). When the (stage 1) MF feed vat was almost emptied of skim milk, the RMF/PUF mixture was warmed with a plate heat exchanger to 50°C and placed into the feed vat. This batch was run through the MF at a 3× concentration factor and was the first PUF DF step (stage 2). This process (PUF DF) was completed a second time (stage 3) in the same manner as stage 2 (Figure 1).

UF to concentrate SP. The PMF (50°C) was weighed to the nearest gram and placed in the UF feed