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Effect of processing methods and protein content of the concentrate on the properties of milk protein concentrate with 80% protein

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ABSTRACT

In recent years, a large increase in the production of milk protein concentrates (MPC) has occurred. However, compared with other types of milk powders, few studies exist on the effect of key processing parameters on powder properties. In particular, it is important to understand if key processing parameters contribute to the poor solubility observed during storage of high-protein MPC powders. Ultrafiltration (UF) and diafiltration (DF) are processing steps needed to reduce the lactose content of concentrates in the preparation of MPC with a protein content of 80% (MPC80). Evaporation is sometimes used to increase the TS content of concentrates before spray drying, and some indications exist that inclusion of this processing step may affect protein properties. In this study, MPC80 powders were manufactured by 2 types of concentration methods: membrane filtration with and without the inclusion of an evaporation step. Different concentration methods could affect the mineral content of MPC powders, as soluble salts can permeate the UF membrane, whereas no mineral loss occurs during evaporation, although a shift in calcium equilibrium toward insoluble forms may occur at high protein concentration levels. It is more desirable from an energy efficiency perspective to use higher total solids in concentrates before drying, but concerns exist about whether a higher protein content would negatively affect powder functionality. Thus, MPC80 powders were also manufactured from concentrates that had 3 different final protein concentrations (19, 21, and 23%; made from 1 UF retentate using batch recirculation evaporation, a similar concentration method). After manufacture, powders were stored for 6 mo at 30°C to help understand changes in MPC80 properties that might occur during shelf-life. Solubility and foaming properties were determined at various time points during high-temperature powder storage. Inclusion of an evaporation step, as a concentration method, resulted in MPC80 that had higher ash, total calcium, and bound calcium (of rehydrated powder) contents compared to concentration with only membrane filtration. Concentration method did not significantly affect the bulk (tapped) density, solubility, or foaming properties of the MPC powders. Powder produced from concentrate with 23% protein content exhibited a higher bulk density and powder particle size than powder produced from concentrate that had 19% protein. The solubility of MPC80 powder was not influenced by the protein content of the concentrate. The solubility of all powders significantly decreased during storage at 30°C. Higher protein concentrations in concentrates resulted in rehydrated powders that had higher viscosities (even when tested at a constant protein concentration). The protein content of the concentrate did not significantly affect foaming properties. Significant changes in the mineral content are used commercially to improve MPC80 solubility. However, although the concentration method did produce a small change in the total calcium content of experimental MPC80 samples, this modification was not sufficiently large enough (<7%) to influence powder solubility.
Key words: milk protein concentrate, solubility, protein functionality, foaming

INTRODUCTION

Milk protein concentrates (**MPC**) have become popular dairy ingredients due to their nutritional quality and functionality (Agarwal et al., 2015). The rehydration of high-protein milk powders can be challenging (Singh, 2007; Baldwin, 2010; Richard et al., 2013; Crowley et al., 2015; Vos et al., 2016). Another issue is the deterioration in the solubility of high-protein (≥70%) powders, such as MPC, during storage, especially when storage is at temperatures >20°C (Anema et al., 2006; Havea, 2006; Mimouni et al., 2010a; Haque et al., 2011). Incomplete rehydration can impair important functional properties and limit the usage of high-protein powder

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in industrial and consumer applications. Rehydration properties of milk powders are influenced by the conditions used (solvent temperature, stirring rate), but also by the powder processing methods (Walstra et al., 2006). Several explanations have been proposed to explain the poor rehydration or solubility of MPC. Poor rehydration behavior has been associated with the low concentrations of lactose in high-protein MPC. Lactose molecules have been considered as a spacer material in powder particles, which keeps the proteins separated from each other and hinders protein interactions (Anema et al., 2006). Lactose is also thought to be a contributor to improved water penetration into the inside of a powder particle through a pore-like structural mechanism (Baldwin, 2010; Richard et al., 2013). However, the low lactose content of high-protein MPC cannot explain the significant deterioration in solubility observed during high-temperature powder storage. Another suggestion is increased cross-linking of casein micelles on the surface of the powder particles during storage, although the exact type of cross-linking is still unclear (Anema et al., 2006; Havea, 2006; Gaiani et al., 2007; Mimouni et al., 2010a; Haque et al., 2011). Lipids and proteins are thought to migrate from the core of the powder particle to the surface of the particle during storage, which might increase the hydrophobic interactions on the surface (Gaiani et al., 2009, 2010; Fyfe et al., 2011). It is thought that a crust is formed by the fusion of casein micelles on the surface of the powder particles, which becomes more insoluble or at least slower to disperse (Fyfe et al., 2011).

In recent years, several studies have examined the effect of various processes on MPC functionality, including sonication, ultrasound, and hydrodynamic cavitation (Augustin et al., 2012; Sun et al., 2014; Li et al., 2018), addition of calcium chelating agents (McCarthy et al., 2017), and spray drying conditions (DeCastro and Harper, 2003; Augustin et al., 2012: Fang et al., 2012; Park et al., 2016). The production process for MPC with 80% protein content (**MPC80**) involves UF and diafiltration (**DF**) to reduce the lactose content before spray drying of the concentrates. Evaporation is sometimes used to further increase the TS content of concentrates before drying (Mistry and Hassan, 1991; Singh, 2007). Spray drying requires more energy to remove water than processes such as evaporation or membrane filtration (Walstra et al., 2006). Thus, to reduce energy costs, powder manufacturers would prefer to use concentrates with high TS content. Concentrates with higher protein content would increase their viscosity (Patel et al., 2009) and could alter some functional properties such as solubility. The effect of varying the protein content of concentrates on the solubility and functionality of MPC80 powders is not well described. Augustin et al. (2012) altered the protein content of concentrates by using different concentration processes and noticed differences in the solubility of MPC. However, because of differences in production methods as well as final protein contents in these MPC powder samples, it was not clear if the solubility issues were caused by differences in protein content of the concentrate.

During the production of MPC80, the extensive UF and DF required depletes soluble minerals and lactose as these components permeate the UF membrane (Singh, 2007). It has been suggested that extensive DF could disrupt casein micelles, possibly due to loss of some colloidal calcium phosphate (**CCP**; Singh, 2007; Ferrer et al., 2011). It has also been suggested that the addition of an evaporation step after extensive UF/DF helps reassociate micelles due to increased ionic strength (Singh, 2007). If sufficient loss of stabilizing CCP from the casein micelles occurs, casein dissociation could occur from the micellar structure (Mimouni et al., 2010a).

One objective of our study was to compare different concentration methods on MPC properties for powders that were adjusted to have similar lactose-to-protein ratios. Another objective of our work was to produce MPC80 from concentrates that had different protein concentrations and then investigate various characteristics including solubility and functionality during powder storage at 30°C for 6 mo.

MATERIALS AND METHODS

Experimental Setup

Raw milk (~910 kg) was warmed to 32°C, skimmed, and pasteurized (73°C for 19 s) in the University of Wisconsin-Madison Babcock Hall dairy plant. The pasteurized skim milk was processed into 5 unique batches of MPC80 in the Center for Dairy Research pilot plant. Each processing condition was performed in duplicate, and ~5 kg of each powder containing ~80% protein were collected. During processing, the TS of the liquids were measured with a refractometer (Master-20M, Atago USA Inc., Bellevue, WA). Immediately after production, the MPC powders were stored at 30°C for 6 mo in airtight 50-mL tubes in an incubator and analyzed every 30 d for compositional and functional properties.

Manufacture of MPC with Different Protein Concentrations in the Concentrate

Pasteurized skim milk was concentrated to 20% TS (16 ± 1% protein) using an UF/DF system consisting of 6 elements, each 10.92 cm in diameter and 96.52