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Physico-chemical properties of skim milk powders prepared with the addition of mineral chelators

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ABSTRACT

The objective of this study was to determine the effect of mineral chelator addition during skim milk powder (SMP) manufacture on the solubility, turbidity, soluble protein, and heat stability (HS). Three chelators (sodium citrate dihydrate, sodium polyphosphate, and disodium EDTA) at 3 different concentrations (5, 15, and 25 mM) were added to skim milk concentrate (30% total solids), and the pH was adjusted to 6.65 before spray drying to produce SMP. Spray-dried SMP samples were tested for solubility index (SI). Additionally, samples were reconstituted to contain 9% total solids, adjusted to pH 7.0, and tested for turbidity, protein content from supernatants of ultracentrifuged samples, and HS. Lower SI values were observed for samples treated with 5 mM disodium EDTA and sodium polyphosphate than control samples or samples with 5 mM sodium citrate dihydrate. Furthermore, lower SI values were observed with an increased level of chelating agents regardless of chelator type. A decreased turbidity value was found with increasing levels of mineral chelating salt treatment. Low turbidity with increasing levels of added chelators may be associated with the dissociation of caseins from micelles. Furthermore, higher protein content was observed in supernatants of ultracentrifuged samples treated with increased level of chelators as compared with the control sample. Higher HS was observed in samples treated with 5 mM compared with samples treated with 25 mM mineral chelator. The results suggest improved solubility and HS upon addition of mineral chelators to SMP during its manufacture.

Key words: skim milk powder, chelators, solubility, turbidity, heat stability

INTRODUCTION

The functionality of skim milk powder (**SMP**) can be modified by tailoring milk composition and processing techniques. Proteins are responsible for playing a significant role in functional properties. Milk consists of 2 major proteins: casein and whey. Casein proteins form a stable complex with inorganic calcium phosphate and exist in the form of micelles (Schmidt, 1982) and can tolerate severe processing conditions.

Several factors are known to dissociate casein micelles such as pressure (Altuner et al., 2006), alkalization (Vaia et al., 2006), salt such as NaCl or KCl (Sikand et al., 2013), acidification (Famelart et al., 1999), and mineral chelating salts (Griffin et al., 1988; Ward et al., 1997; Udabage et al., 2000; de Kort et al., 2012). The applications of these factors to the protein solutions possibly may cause several changes in the casein micelle structure by disrupting ionic, hydrogen, and hydrophobic interactions (Morild, 1981). As a result, functional properties can be manipulated.

Chelators form a soluble complex with metal and alkaline earth ions. Addition of chelators to milk has been known to affect the structure of casein micelles by influencing distribution of calcium and phosphate in the colloidal and soluble phase (Udabage et al., 2000). Furthermore, simultaneous release of caseins from casein micelles (Lin et al., 1972), and reduced light-scattering capabilities (Munyua and Larsson-Raznikiewicz, 1980; Pitkowski et al., 2008) have been reported. These structural changes affect many functional properties such as solubility (Schuck et al., 2002), turbidity, and heat stability (**HS**; Mohammad and Fox, 1983; de Kort et al., 2012).

Schuck et al. (2002) reported that mineral salts play a significant role in the water transfer during spray drying of native micellar casein. Furthermore, these authors emphasized that the quality of native phosphocaseinate suspension depends on mode/time of incorporation of mineral salt. For example, the addition of mineral salt before spray drying results in de-structuring of casein micelles. Therefore, the mode of incorporation of min-

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eral salt addition (i.e., before, during, or after spray drying of milk powder) imparts different characteristics to the powder.

Mineral salt addition to milk products has been reported to improve the HS. Mineral salts such as citrate, EDTA, and oxalate have been reported to reduce Ca^{+2} in the milk, decrease the colloidal calcium phosphate, and enhance the HS of milk (Mohammad and Fox, 1983; Augustin and Clarke, 1990). de Kort et al. (2012) reported a range of effects on HS could be observed depending upon the type and concentration of mineral chelator. For example, disodium uridine monophosphate, a weak chelator, gave marked increase in HS compared with stronger chelators such as trisodium citrate and disodium hydrogen phosphate, which gave lower HS. The differences in heat stabilities were attributed to calcium ion activity and state of the micellar structure. Additionally, these authors stated that a high concentration of chelators may chelate calcium to such an extent that casein micelle integrity is disrupted. Thus, a high concentration of chelators caused casein micelle disruption, which can affect negatively the HS of milk (de Kort et al., 2012).

No single comprehensive study includes the effect of adding a range of chelators followed by pH adjustment before spray drying on solubility, turbidity, soluble protein, and HS. Because the present authors believe that the processing treatments may affect stability of milk, the current project aims to compare and understand the effect of the addition of chelator before spray drying of skim milk concentrate and its effects on the other functional properties. Three chelators [sodium citrate dihydrate (**SCD**), sodium polyphosphate (**SPP**), and disodium EDTA (**DSE**)] were selected. The objective of this study was to determine the effects of adding mineral chelators on the functional properties such as solubility, turbidity, soluble protein, and HS of SMP samples. This study would help to manipulate chelator concentration for end user applications in SMP-based products.

MATERIALS AND METHODS

Manufacturing of SMP Samples

The SMP powder samples were manufactured at Dairy Products Technology Center (San Luis Obispo, CA). All chemicals used were reagent grade. Commercial low heat SMP from the same lot was reconstituted to 30% TS concentrates. The required amount of SMP was blended with prewarmed (43°C) deionized water using a high shear mixer. Mixing continued for 30 min where after the concentrate was cooled to 4°C and allowed to fully hydrate for 48 h before use. On the day of spray drying, 9 to 11 kg (20 to 25 lb) batches of concentrate were warmed to 21°C and the required amount (e.g., 0.19, 0.33, and 0.15% to make 5 m*M*) of DSE, SPP, or SCD was added using the Silverson mixer at 50% power followed by pH adjustment to 6.65. Spray drying was conducted using a Niro FilterLab Spray Dryer (Hudson, WI). Inlet temperature was 208.7°C. Outlet air temperature was 82°C. One control and 3 powders with 3 chelating salts (DSE, SPP, and SCD) and 3 levels of concentration (5, 15, and 25 m*M*) were produced. Figure 1 shows the schematic diagram used in this study for manufacturing of skim milk powder. The chelated samples were named according to type and chelator concentration; for example, when SCD was used at the 5, 15, or 25 m*M* level, powder and reconstituted samples were referred to as SCD5, SCD15, and SCD25, respectively. Similar naming conventions were used for DSE (DSE5, DSE15, and DSE25) and SPP (SPP5, SPP15, and SPP25) samples.

Solubility Index

Solubility index (**SI**) was measured by the ADPI (1990) method. In this method, 10 g of SMP powder was mixed in a mixer with 100 mL of water. Three drops of antifoam B solution (Sigma, St. Louis, MO) were added and mixed at speed #1 (model 51BL31, Waring commercial blender, Torrington, CT) for 90 s. The mixed sample was kept in a beaker for 5 min. Fifty milliliters of the reconstituted milk sample was poured and centrifuged (163 × *g*, 5 min, 24°C) in a conical centrifuge tube. The top supernatant was decanted, and tube was filled with water and centrifuged again. This process was repeated 3 or 4 times to read the sedimentation level clearly. Analyses were performed in duplicate.

Preparation of Reconstituted Milk from SMP Samples

Ten types of SMP powder samples from 2 different trials were reconstituted in random order to contain 9% TS content. These samples were stirred for 4 h at room temperature (21°C). After 4 h of stirring at 900 rpm with a laboratory stirrer (R010 Power, IKA Works, Wilmington, NC), pH of samples was recorded and was in the range of 6.9 to 7.0. Therefore, pH of all the samples was adjusted to 7.0 with 0.1 *N* NaOH or 0.1 *N* HCl and samples were kept in a refrigerator overnight and brought to room temperature (21 ± 2°C) the next day. The pH of all the samples was measured again.