J. Dairy Sci. 96:5522–5531
http://dx.doi.org/10.3168/jds.2013-6617

Comparison of functional properties of 34% and 80% whey protein and milk serum protein concentrates

P. J. Luck,* B. Vardhanabhuti,† Y. H. Yong,‡ T. Laundon,* D. M. Barbano,§ and E. A. Foegeding*[1]
*Department of Food, Bioprocessing, and Nutrition Sciences, Southeast Dairy Research Food Center, North Carolina State University, Raleigh 27695
†Food Science Program, Division of Food System and Bioengineering, University of Missouri, Columbia 65211
‡Kraft Foods, Glenview, IL 60025
§Northeast Dairy Foods Research Center, Department of Food Science, Cornell University, Ithaca, NY 14853

ABSTRACT

This study compared the functional properties of serum protein concentrate (SPC) with whey protein concentrate (WPC) made from the same milk and with commercial WPC. The experimental SPC and WPC were produced at 34% or 80% protein from the same lot of milk. Protein contents of WPC and SPC were comparable; however, fat content was much lower in SPC compared with WPC and commercial WPC. The effect of drying methods (freeze vs. spray drying) was studied for 34% WPC and SPC. Few differences due to drying method were found in turbidity and gelation; however, drying method made a large difference in foam formation for WPC but not SPC. Between pH 3 and 7, SPC was found to have lower turbidity than WPC; however, protein solubility was similar between SPC and WPC. Foaming and gelation properties of SPC were better than those of WPC. Differences in functional properties may be explained by differences in composition and extent of denaturation or aggregation.
Key words: whey protein concentrate, serum protein concentrate, functional properties, microfiltration

INTRODUCTION

Whey, the liquid remaining after the coagulation of micellar caseins in cheese production or rennet casein production, is an important ingredient in the food industry. Whey proteins are produced as a co-product from the cheese and rennet casein industries. Sweet whey is obtained from the manufacture of cheese or rennet casein, whereas acid whey is from the production of acid casein (Mulvihill and Ennis, 2003), cottage cheese, and strained yogurts. Because whey proteins represent only 10% of the total solids of whey, several processes (e.g., UF-diafiltration, ion exchange, and ultracentrifugation) have been developed to recover whey proteins in a more concentrated form. Different whey products are categorized based on their protein concentration, with whey protein concentrate (**WPC**) having 30 to 85% protein and whey protein isolate (**WPI**) containing >90% protein (Foegeding et al., 2011).

Commercial WPC are produced by UF-diafiltration. In UF, a pressurized solution flows over a porous membrane allowing the separation of protein and fat from lactose, minerals, and water under mild temperature and pH conditions (Mulvihill and Ennis, 2003). Because of problems associated with UF, such as membrane fouling, diafiltration (retentate dilution with water and repeated UF) is used to further remove lactose and minerals and thus, increasing the protein concentration (de la Fuente et al., 2002; Yee et al., 2007). The retentate is concentrated by evaporation and spray dried into powder.

Like all other membrane separation processes, microfiltration (**MF**) is a pressure-driven separation technique using membranes with pore-size diameters of 10 to 0.1 μm (Saboya and Maubois, 2000). The major breakthrough for MF in the dairy industry came after the development of new ceramic membranes with multichannel geometry and a highly permeable support as well as the concept of uniform and low transmembrane pressure (Sandblom, 1974; Gillot and Garcera, 1986; Saboya and Maubois, 2000). The applications of MF in the dairy industry are primarily the removal of microorganisms from skim milk, whey defatting, and casein enrichment (Saboya and Maubois, 2000). The MF permeate of cheese whey is lower in fat and microbial debris from starter culture than cheese whey, and also lower in annatto color if the cheese whey was from colored Cheddar (Saboya and Maubois, 2000).

Removal of fat and micellar caseins from milk results in milk serum proteins that are similar to the family of proteins found in cheese whey with the exception of the absence of the glycomacropeptide (**GMP**) fraction of κ-casein (Walstra et al., 1999). The difference in size between casein micelles (0.2 μm; Dalgleish and

Received January 24, 2013.
Accepted June 11, 2013.
[1]Corresponding author: allen_foegeding@ncsu.edu

Corredig, 2012) and serum proteins (0.01 μm for WPI; Roefs and de Kruif, 1994) allows the separation of these proteins using a ceramic membrane with a pore-size diameter of 0.1 μm (Saboya and Maubois, 2000). Permeate from MF of skim milk is clear and sterile, and it is an excellent starting material for production of serum protein concentrate (**SPC**) or isolates (Saboya and Maubois, 2000). Serum or whey proteins obtained by MF from raw milk have been referred to as native whey protein (Heino et al., 2007), milk microfiltrate protein (Britten and Pouliot, 1996; Maubois et al., 2001), virgin whey protein (Marcelo and Rizvi, 2008), and milk serum proteins (Nelson and Barbano, 2005).

Nelson and Barbano (2005) demonstrated the feasibility of removal of serum proteins from skim milk before Cheddar cheese making. A combination of MF and diafiltration with UF permeate was developed to remove 95% of serum proteins from milk before Cheddar cheese making without changing the mineral balance or NPN level in the aqueous phase of the milk. Because of differences in composition and processing effects, SPC from MF and WPC from cheese making could differ in functionality. Serum protein concentrates are not exposed to the enzymatic or chemical reactions of the cheese making process, thus potentially offering different levels of functional properties.

Whey proteins have many functional characteristics, including solubility, gelation, emulsification, and foaming. A few studies investigated the functional properties of microfiltered whey proteins compared with commercial products (Britten and Pouliot, 1996; Heino et al., 2007; Marcelo and Rizvi, 2008) but not when proteins were made from the same lot of milk.

Previous work (Evans et al., 2009, 2010) compared composition, sensory, and volatile components of 34% and 80% WPC and SPC made from the same lots of milk in 3 replications. Few sensory flavor differences were found in 34% WPC and SPC for both freeze-dried and spray-dried powders, despite differences in appearance and composition (Evans et al., 2009). Comparison of 80% WPC and SPC rehydrated powders yielded higher concentrations of lipid oxidation products and greater numbers of oxidation products in WPC (Evans et al., 2010). Comparison of 80% WPC and SPC with commercially produced products found higher levels of lipid oxidation products in commercial WPC products (Evans et al., 2010). Overall, flavor profiles and intensities of pilot plant–produced WPC and SPC were very similar for both 34% and 80% protein powders. Both pilot plant and commercially produced WPC had higher oxidized flavor compared with SPC, most likely because of the enzymatic and chemical reactions taking place in the cheese making process that preceded WPC production and the higher fat content of the WPC.

This paper is the third in a series with the goal of comparing quality characteristics and functional properties of SPC and WPC (34 and 80% protein) made from the same lot of milk. In addition to comparing pilot plant–produced SPC and WPC, commercial WPC made by 6 different companies were used as a second level of comparison for some properties. Solubility, turbidity, foaming, and gelation properties of 10% (wt/vol) protein suspensions were compared. The effects of spray and freeze drying were also examined.

MATERIALS AND METHODS

Materials

The SPC and WPC samples were made at Cornell University (Ithaca, NY). One lot of whole raw milk from the Cornell University dairy farm was divided into 2 portions. One portion was used to make Cheddar cheese and produce 34% WPC. Before cheese making, the whole milk was pasteurized at 72°C for 16 s. Once drained from the curds, the whey was pasteurized at 72°C for 16 s, before concentration via UF (Evans et al., 2009). The other portion of raw milk was centrifuged at 4°C to separate cream and skim milk, followed by skim milk pasteurization at 72°C for 16 s, and then used to produce 34% and 80% SPC. Production of SPC and WPC was replicated 3 times with different lots of milk. Commercial WPC (34% protein) samples were obtained from 6 different companies and analyzed under the same conditions for comparison with the samples produced in this study. Details of SPC and WPC production can be found in Evans et al. (2009, 2010).

Chemical Analyses

The WPC and SPC samples were analyzed for fat, total N, and NPN content using ether extraction (AOAC International, 2000; method 989.05, 33.2.26), Kjeldahl (AOAC International, 2000; method 991.20; 33.2.11), and Kjeldahl (AOAC International, 2000; method 991.21; 33.2.12), respectively. The GMP content (which is soluble in 12% TCA) of WPC was calculated as a difference in NPN content between WPC and SPC powders on a dry basis. Contents of Ca, P, K, and Na were determined using a standard dry ash method with inductively coupled plasma optical emission spectroscopy (ICP-OES) at the Department of Soil Science, North Carolina State University (Raleigh).

Solution Preparation

Samples of WPC or SPC (10% wt/vol protein) were hydrated in deionized water (80% of total volume) with