J. Dairy Sci. 101:1–10
https://doi.org/10.3168/jds.2017-13780

The effect of spray drying on the difference in flavor and functional properties of liquid and dried whey proteins, milk proteins, and micellar casein concentrates

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ABSTRACT

Traditionally most protein ingredients are sold as a powder due to transport ease and longer shelf life. Many high-protein powder ingredients such as milk protein concentrate with 85% protein and micellar casein concentrate have poor rehydration properties (e.g., solubility) after storage, which might limit their use. An alternative to the production of dried protein ingredients is the option to use liquid protein ingredients, which saves the cost of spray drying, but may also improve flavor and offer different functional properties. The objective of this study was to determine the effect of spray drying on the flavor and functionality of high-protein ingredients. Liquid and dried protein ingredients (whey protein concentrate with 80% protein, whey protein isolate, milk protein concentrate with 85% protein, and micellar casein concentrate) were manufactured from the same lot of milk at the North Carolina State University pilot plant. Functional differences were evaluated by measurement of foam stability and heat stability. Heat stability was evaluated by heating at 90°C for 0, 10, 20, and 30 min followed by micro-bicinchoninic acid and turbidity loss measurements. Sensory properties were evaluated by descriptive analysis, and volatile compounds were evaluated by gas chromatography-mass spectrometry. No differences were detected in protein heat stability between liquids and powders when spray dried under these conditions. Whey protein concentrate with 80% protein (liquid or spray dried) did not produce a foam. All powders had higher aroma intensity and cooked flavors compared with liquids. Powder proteins also had low but distinct cardboard flavor concurrent with higher relative abundance of volatile aldehydes compared with liquids. An understanding of how spray drying affects both flavor and functionality may help food processors better use the ingredients they have available to them.
Key words: dairy protein, spray drying, flavor, functionality

INTRODUCTION

High-protein ingredients have increased in popularity over the past decade because of the added nutritional, and health benefits (Tunick, 2008). The most popular forms of protein come from milk in the form of milk protein concentrates (**MPC**) and isolates (**MPI**), which are made up of casein and whey proteins in the normal ratio found in milk, and whey protein products, which are isolated from cheese whey (Agarwal et al., 2015). The main 2 protein products from the fluid whey stream are whey protein concentrate (**WPC**), 34 to 89% protein, and whey protein isolate (**WPI**), >90% protein (US Dairy Export Council, 2004). Micellar casein concentrate (**MCC**) is made by membrane fractionation of milk where milk serum proteins permeate through the membranes and are separated from caseins. The typical serum protein removal percentage in MCC lies in the range of 60 to 95%, which can create a range of MCC products (Beckman et al., 2010).

Protein has become more popular and profitable as a value-added nutrition ingredient (Tunick, 2008). Protein ingredients also have many useful functional properties, which include thermal stability, gelation, foam formation, and emulsification (de Wit, 1998). Protein is typically sold as a powder because it has a longer shelf life as well as reduced transportation costs. However, for a company that produces both ingredients and finished products, or a company that standardizes protein or milk solids with powder, it might be more advantageous to use liquid protein concentrates in consumer products as opposed to drying the protein first, then incorporating it into the final product.

Spray drying involves the atomization of a liquid into hot air chamber to remove water (Henning et al., 2006)

Received September 2, 2017.
Accepted November 16, 2017.
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and often includes preliminary heat-driven evaporator concentration under vacuum before spray drying. Spray drying is an expensive high-heat process and is the most common form of drying protein in the dairy industry in the United States. Higher heat processes have been associated with undesirable flavors caused by lipid oxidation, Maillard reaction products, and other volatile flavor formation (Smith et al., 2016a). Spray drying also reduces protein yield through mechanisms such as wall deposition, which can lead to reduced protein recovery and potential profit (Ozmen and Langrish, 2003). Several studies have evaluated or reviewed the literature as it pertains to the effect of spray drying parameters on particle size, particle morphology, surface free fat, and protein denaturation of milk powder, milk protein concentrates, and whey proteins (Gaiani et al., 2010; Fang et al., 2012; Schuck et al., 2013; Park et al., 2014b; Nikolova et al., 2015; Uluko et al., 2016). The process of spray drying causes some unavoidable losses in protein functionality due to difficulties with reconstitution as well as the dehydration process that occurs during spray drying can cause aggregation and denaturation (Augustin and Udabage, 2007). Using the liquid retentate, as opposed to spray drying, may then potentially increase protein yield as well as improve flavor, but have different functionality than a dried product. Previous studies have not, to our knowledge, compared the liquid concentrated protein retentate to the spray dried powder, and none to our knowledge, have considered the effect on flavor.

Flavors present in protein ingredients affect flavor of formulated foods (Morr and Ha, 1991; Lee and Morr, 1994; Drake, 2006; Childs et al., 2007). Protein ingredients are typically not included in ingredient applications for their flavor; therefore, the goal in ingredient processing is to produce a bland and clean flavored ingredient (Drake et al., 2009). Many processing operations, however, have an effect on the flavor of protein ingredients and can encourage off flavor development. Storage of whey or fluid milk at any step of the filtration process or evaporation can increase off-flavors (Whitson et al., 2010; Campbell et al., 2011; Park and Drake, 2016; Park et al., 2016a). Park et al. (2014b, 2016b) demonstrated that changing the feeds solids concentration and inlet temperature of the spray dryer affected off-flavor development in dried whey protein powder, skim milk powder, and MPC 70 (throughout, numbers indicate the percentage of protein). Even finished powder unit operations such as steam agglomeration and instantizing can increase off-flavor intensities (Wright et al., 2009; White et al., 2013). The flavor intensities of dried protein ingredients are low, but these low intensities are detected by consumers in ingredient applications and negatively affect acceptability (Caudle et al., 2005; Wright et al., 2009; Evans et al., 2010; Childs and Drake, 2010). Therefore, it is important to consider how each unit operation affects the flavor of the dried ingredient and how that will affect the final product application. The objective of this study was to determine the effect of spray drying on the flavor and functionality of WPC 80, WPI, MPC 85, and MCC.

MATERIALS AND METHODS

Protein Manufacture

All proteins were manufactured at the North Carolina State University Dairy Research Pilot Plant (Raleigh). Each protein was produced in triplicate.

WPC 80 Production

Raw whole milk, 380 kg, was obtained from the North Carolina State University Dairy Research and Education System. Milk was HTST pasteurized (720 kg/h) with a plate heat exchanger (model T4 RGS-16/2, SPX Flow Technology, Greensboro, NC) at 72°C with a hold time of 16 s. The milk was then cooled to 31°C and transferred to a cheese vat (Kusel Equipment, Watertown, WI). A standard colored Cheddar cheese-making procedure was then followed as described by Park et al. (2014a) but with the absence of annatto (norbixin) and an uncolored liquid whey was obtained. The liquid whey was passed through a sieve to remove cheese fines and HTST pasteurized under the same parameters as the milk, and fat-separated with a hot bowl centrifugal separator (model SI600E, Agri-Lac, Miami, FL).

Approximately 125 kg of whey was heated to 50°C and was concentrated with a UF system containing 10 polyethersulfone membrane cartridges (model P2B010V05, nominal cutoff = 10 kDa, surface area = 0.5 m^2, Millipore Inc., Billerica, MA) and a variable-speed peristaltic pump (model P2B010V05, Cole Parmer, Vernon Hills, IL), which was used to circulate the product as a batch process. Before UF, the membrane cartridges were rinsed of their storage solution (1 *N* NaOH) and a clean water flux was conducted and was typically about 35 L/h. A concentration factor of 5× and 34% protein of solids (wt/vol) was achieved and then diafiltration (**DF**) water was added. Deionized (**DI**) water was added to equal the original weight of the feed whey, followed by concentration to a solids content of 80% (wt/wt) of protein to produce liquid WPC 80. Total solids were measured by a rapid moisture analyzer (Smart Trac II, CEM Corp., Matthews, NC) and protein was measured with a mid-infrared analyzer during processing to monitor progress (Lactoscope model FTA, Delta Instruments, Drachten, the Netherlands).