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Short communication: The effect of liquid storage on the flavor of whey protein concentrate[1]

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ABSTRACT

Unit operations in dried dairy ingredient manufacture significantly influence sensory properties and, consequently, their use and consumer acceptance in a variety of ingredient applications. In whey protein concentrate (WPC) manufacture, liquid can be stored as whey or WPC before spray drying. The objective of this study was to determine the effect of storage, composition, and bleaching on the flavor of spray-dried WPC80. Liquid whey was manufactured and subjected to the following treatments: bleached or unbleached and liquid whey or liquid WPC storage. The experiment was replicated 3 times and included a no-storage control. All liquid storage was performed at 4°C for 24 h. Flavor of the final spray-dried WPC80 was evaluated by a trained panel and volatile compound analyses. Storage of liquids increased cardboard flavor, decreased sweet aromatic flavor, and resulted in increased volatile lipid oxidation products. Bleaching altered the effect of liquid storage. Storage of unbleached liquid whey decreased sweet aromatic flavor and increased cardboard flavor and volatile lipid oxidation products compared with liquid WPC80 and no storage. In contrast, storage of bleached liquid WPC decreased sweet aromatic flavor and increased cardboard flavor and associated volatile lipid oxidation products compared with bleached liquid whey or no storage. These results confirm that liquid storage increases off-flavors in spray-dried protein but to a variable degree, depending on whether bleaching has been applied. If liquid storage is necessary, bleached WPC80 should be stored as liquid whey and unbleached WPC80 should be stored as liquid WPC to mitigate off-flavors.
Key words: whey protein, flavor, bleaching, storage

Short Communication

Due to increased consumer demand for foods with greater protein content, whey proteins have become much more than a by-product of cheese manufacture. In 2014, over 244,000 t of whey protein concentrate (34–89% protein; **WPC**) was produced in the United States, an 8.1% increase from 2013 (USDA, 2015). Whey proteins are commonly used because of their unique nutritional and functional properties. The successful use of whey protein ingredients requires that they do not negatively affect the flavor of their ingredient applications. Due to delicate flavors in whey protein ingredients, off-flavors can become prominent and negatively affect consumer acceptance of food applications (Childs et al., 2007; Wright et al., 2009; Evans et al., 2010; Oltman et al., 2015).

Many of the off-flavors in WPC arise from the various unit operations applied to fluid whey to concentrate proteins. In the United States, annatto (norbixin) is an approved color additive in Cheddar cheese and its usage is consistent with good manufacturing practice (US FDA, 2015). The majority of the colorant is retained in the cheese but approximately 10% of annatto remains in the whey (Smith et al., 2014). This colorant is then concentrated along with the protein during manufacture of WPC or whey protein isolate (**WPI**) and must be removed by bleaching. Unit operations such as cheese manufacture, bleaching, spray drying, agglomeration, and instantization have all been demonstrated to influence the flavor of WPC or WPI (Wright et al., 2009; Campbell et al., 2011; White et al., 2013; Park et al., 2014a,b; Smith et al., 2015).

During the manufacture of WPC or WPI, liquid product may be stored for extended periods. This can be due to the need to ship product from one facility to another or to spray-drying capacities not meeting production capacities. Whitson et al. (2011) investigated how storage of liquid WPI before spray drying affected the flavor of WPI and WPC80. They observed that lipid oxidation products and off-flavors increased in both spray-dried Mozzarella WPC80 and Cheddar

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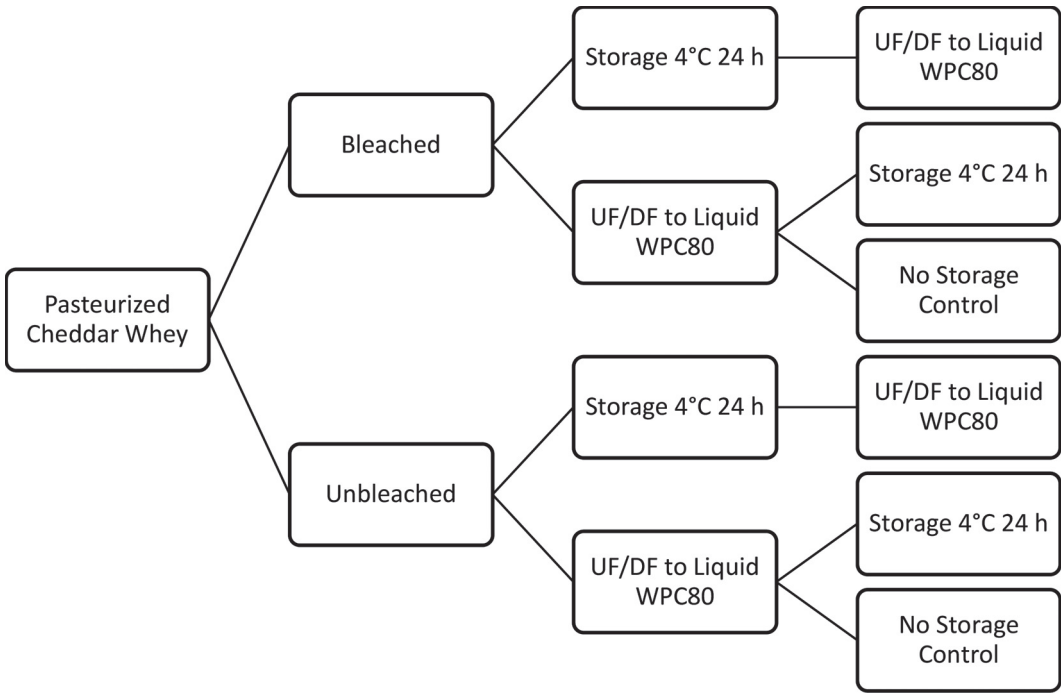

Figure 1. Diagram of experimental design. All samples were spray dried under identical conditions. This experiment was replicated 3 times. DF = diafiltration; WPC80 = whey protein concentrate with 80% protein.

WPI with increased storage of liquid protein product (liquid WPC80 or WPI). Liaw et al. (2010) demonstrated that lipid oxidation increased with storage of fluid whey but did not investigate whether or how fluid whey storage affected the flavor of the resulting WPC. To our knowledge, the role of bleaching and fluid composition during storage on the flavor of WPC80 has not been investigated. The objective of this study was to determine the effect of bleaching and fluid composition across liquid storage on the flavor of spray-dried WPC80.

Approximately 235 kg of raw whole milk was obtained from the North Carolina State University Dairy Education Unit (Raleigh). The milk was pasteurized at 72°C for 16 s with a plate heat exchanger (model T4 RGS-16/2, SPX Flow Technology, Greensboro, NC). Liquid Cheddar whey was manufactured as described by Park et al. (2014b). The whey was defatted with a centrifugal separator (model SI600E, Agri-Lac, Miami, FL) and pasteurized at 72°C for 15 s. The following treatments were then applied to manufacture of spray-dried WPC80: hydrogen peroxide bleach or no bleach and 24-h fluid whey storage or no storage. Half of the pasteurized whey was bleached with 250 mg/kg hydrogen peroxide (35% wt/vol, VWR International, Westchester, PA) for 1 h at 50°C, after which 20 mg/kg catalase was added (FoodPro CAT, Danisco, New Century, NJ). The other half of the whey was held at 50°C for 1 h before UF. Then, bleached or unbleached whey was concentrated and spray dried or concentrated and held for 24 h before spray drying. Six treatments (WPC80) were manufactured; a summary of the experimental design is shown in Figure 1.

Wheys (47 kg each) were concentrated to WPC80 by UF/diafiltration (**DF**) 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 in a batch process. Before UF, the membrane cartridges were cleaned as described by Park et al. (2014a). A concentration factor of 3× was achieved and then DF water was added to equal the original weight followed by concentration to a solids content of 15% (wt/wt) (12% protein, wt/wt) to produce liquid WPC80. Total solids were measured by a rapid moisture analyzer (Smart Trac II, CEM Corp., Matthews, NC) and protein was measured with a Sprint Rapid Protein Analyzer (CEM Corp.). Total time for each batch of UF/DF was approximately 1 h.

The liquid WPC80 produced from the no-storage controls and liquid whey storage treatments were spray dried immediately, whereas the liquid WPC80 storage treatments were spray dried after 24 h at 4°C (Figure 1). Spray drying was performed with a pilot-scale spray