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Invited Review: The effects of processing parameters on the flavor of whey protein ingredients

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ABSTRACT

Whey protein ingredients are used in a wide variety of products and are added primarily for nutritional benefits or functionality, not for flavor. However, the processes used to further refine fluid whey produce and encourage development of off-flavors that carry through to the final product. From the milk source to spray drying, each step contributes to the oxidation of lipids, which negatively affects flavor. An understanding of the sources of these flavor constituents and volatile compounds, as well as how they are formed during processing and handling, are important to eliminate or reduce undesirable flavors and for understanding how to best incorporate these ingredients into high-quality finished products.
Key words: whey, flavor, processing

INTRODUCTION

Liquid whey is a co-product of cheese manufacturing. Once considered a waste product, the demand for dried whey ingredients has steadily increased over the past decade to over 180 million metric tonnes produced per year (Smithers, 2015). Demand for whey protein ingredients owes to their unique nutritional and functional properties (Foegeding et al., 2002; Tunick, 2008).

Whey composition is dependent on cheesemaking. Whey can be distinguished as either sweet or acid whey, with a typical pH range of 6 to 6.3 and 4.3 to 4.6, respectively (Morr and Ha, 1993). Traditionally, sweet whey is produced by the addition of rennet to cheese milk, and acid whey by acidification by either fermentation of lactose into lactic acid by starter culture or direct addition of acid. Sweet whey has a higher fat content, which results from the starting milkfat of the cheese milk. Acid whey is higher in ash and lactic acid (Kosikowski and Mistry, 1997).

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Protein is currently the most valuable component of whey. The major proteins that contribute to the protein fraction of the whey stream are β-LG, α-LA, serum albumin, immunoglobulins, and protease peptone (Jayaprakasha and Brueckner, 1999). About 80% of the total whey protein is composed of β-LG and α-LA (Schmidt et al., 1984). Membrane technologies permit an increase in the protein content while reducing the carbohydrate, mineral, and water contents. Generally, the higher percentage of protein content, the higher the nutritional value of the product (Onwulata, 2008).

Whey proteins are added to a final product for added nutritional benefit or functionality, not for flavor. Whey proteins ideally have bland or no flavor; however, numerous published studies have demonstrated that whey protein and dried whey ingredients have flavor (Carunchia Whetstine et al., 2003; Mahajan et al., 2004; Carunchia Whetstine et al., 2005; Wright et al., 2006, 2009). Further, these flavors can carry over to finished products, which can limit applications of different dried dairy ingredients (Drake, 2006; Wright et al., 2009; Evans et al., 2010; Oltman et al., 2015).

The main tool used to characterize flavor of foods and ingredients is trained panel profiling or descriptive analysis (Drake, 2007). Trained panel profiling or descriptive sensory analysis can be a powerful tool for describing and differentiation of product flavors and identifying and quantifying specific flavors in products (Meilgaard et al., 1999; Drake, 2007). Panelists are highly trained (>100 h) and calibrated on reference materials that allow accurate and consistent results. Volatile compound analysis by GC provides information on specific volatile compounds that may contribute to flavor. Gas chromatography separates individual volatile compounds based on interaction with coating on a column (Kataoka et al., 2000). Gas chromatography-olfactometry splits the stream of separated volatile compounds from GC through an instrumental detector and a sniffer port, where a human sniffer identifies which volatiles compounds are odor active (Van Ruth and O'Connor 2001; d'Acampora Zellner et al., 2008). These tools allow researchers to investigate flavor and

flavor sources that are key tools in understanding how specific processing steps affect flavor. Both sensory analysis and GC-olfactometry methods have been reviewed previously (Van Ruth and O'Connor, 2001; Drake, 2007; Schiano et al., 2017).

Volatile compounds are responsible for flavors in dried whey ingredients. An understanding of the sources of these flavor constituents and volatile compounds, as well as how they are formed during processing and handling, are important to eliminate or reduce undesirable flavors and for understanding how to best incorporate these ingredients into high-quality finished products. This review will focus on the flavor of whey and whey protein concentrates and how whey ingredient flavor is affected by processing conditions.

WHEY PROCESSING

The advancement of membrane processing capabilities has led to a wide range of dried whey products with varying protein content. Membrane processing and whey protein ingredient manufacturing have been reviewed by Daufin et al. (2001) and Morr and Ha (1993). After whey has been separated from the cheese curd, the whey is clarified, separated, and pasteurized. In a colored cheese process, the whey is bleached to remove residual colorant that remains in the whey stream from the cheese milk (McDonough et al., 1968; Smith et al., 2014). Bleaching can be accomplished enzymatically or by addition of a chemical oxidizing agent (Kang et al., 2010). Filtration processes are then applied to concentrate the protein, followed by spray drying.

Different whey protein products (34–90% protein of the TS) exist for specific product applications (Morr and Foegeding, 1990). The most common techniques used for the membrane filtration of dairy products are microfiltration (**MF**), UF, nanofiltration, and reverse osmosis (**RO**). These different filtration technologies have key differences in terms of particle size, molecular weights, and the components that they separate (Daufin et al., 2001; Bylund, 2003; Pouliot, 2008). During filtration, 2 streams are produced: retentate and permeate. Retentate is the concentrate that is retained by the membrane, permeate is the filtrate that passes through the membrane (Bylund, 2003).

Microfiltration can be used to fractionate proteins, remove bacteria, further separate whey fat, and fractionate native milk fat globules (Fauquant et al., 2005; Michalski et al., 2006; Marcelo and Rizvi, 2008; Onwulata, 2008; Zulewska et al., 2009). Ultrafiltration separates macromolecules such as proteins and suspended particles. Ultrafiltration is commonly applied to separate protein from NPN, lactose, water, and minerals. Reverse osmosis uses a semipermeable membrane that allows water to pass through, but not salts, sugars, and small molecular compounds. The osmotic pressure on one side of the membrane increases greatly and if pressure is applied to that side, pure water can be achieved (Rosenberg, 1995). Nanofiltration fills the gap in pore size between UF and RO. The fact that this membrane process removes water and minerals makes this process very useful in demineralizing whey, milk, and the UF permeate of both milk and whey (Anonymous, 2000).

Whey Ingredients

Sweet whey powder is a dried product that contains all of the same components of whey in similar ratios to liquid sweet whey from the cheese vat. It typically is not fractionated by membrane filtration and usually contains 70% lactose, 1.5% fat, 12% protein, 4% moisture, and 8.5% other solids (US Dairy Export Council, 2004). Whey protein concentrates are obtained by removing nonprotein components to achieve higher protein percentages. Whey protein concentrates range from 34 to 90% (US Dairy Export Council. 2004). Ultrafiltration is typically used to achieve these higher protein percentages by reducing lactose, mineral, NPN, and water content.

Whey protein isolate (**WPI**) contains >90% protein on a dry weight basis. Microfiltration is used to remove excess lipid from sweet whey. Whey protein isolate is made from the permeate of the MF process; WPI can also be produced through ion exchange chromatography (Anonymous, 2003; Huffman 1996). Serum proteins (sometimes referred to as native whey protein) are separated by direct filtration of skim milk. Both ceramic and spiral-wound membranes can be used to separate casein and serum proteins with differing efficiencies (Zulewska et al., 2009; Beckman et al., 2010; Hurt et al., 2010; Adams and Barbano, 2013). Serum protein concentrates are created from the skim milk permeate from the MF. Serum protein concentrates and isolates are further concentrated through UF. Serum proteins have low levels of lipid, as they have already gone through an MF step to isolate the serum proteins from casein micelles.

Flavors in Whey

Flavors in liquid whey have been divided into dairy and nondairy flavors (Carunchia Whetstine et al., 2003; Drake, 2006). Dairy flavors are those found in fresh milk and whey and include sweet aromatic and cooked or milky flavors (Carunchia Whetstine et al., 2003). Nondairy flavors are atypical of dairy products and include cardboard, animal or wet dog, cucumber, and many others (Carunchia Whetstine et al., 2003).