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The effect of homogenization pressure on the flavor and flavor stability of whole milk powder[1]

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ABSTRACT

Flavor is one of the key factors that can limit the application and shelf life of dried dairy ingredients. Many off-flavors are caused during ingredient manufacture that carry through into ingredient applications and decrease consumer acceptance. The objective of this research was to investigate the effect of homogenization pressure on the flavor and flavor stability of whole milk powder (WMP). Whole milk powder was produced from standardized pasteurized whole milk that was evaporated to 50% solids (wt/wt), homogenized in 2 stages with varying pressures (0/0, 5.5/1.4, 11.0/2.8, or 16.5/4.3 MPa), and spray dried. Whole milk powder was evaluated at 0, 3, and 6 mo of storage at 21°C. Sensory properties were evaluated by descriptive analysis. Volatile compounds were analyzed by sorptive stir bar extraction with gas chromatography-mass spectrometry. Fat globule size in condensed whole milk and particle size of powders were measured by laser diffraction. Surface free fat, inner free fat, and encapsulated fat of WMP were measured by solvent extractions. Phospholipid content was measured by ultra-high-performance liquid chromatography–evaporative light scattering. Furosine in WMP was analyzed by ultra-high-performance liquid chromatography–mass spectrometry. Increased homogenization pressure decreased cardboard and painty flavors, volatile lipid oxidation compound concentrations, fat globule size in condensed milk, surface free fat, and inner free fat in WMP. Encapsulated fat increased and phospholipid-to-encapsulated fat ratio decreased with higher homogenization pressure. Surface free fat in powders increased cardboard flavor and lipid oxidation. These results indicate that off-flavors were decreased with increased homogenization pressures in WMP due to the decrease in free fat. To decrease off-flavor intensities in WMP, manufacturers should carefully evaluate these parameters during ingredient manufacture.
Key words: homogenization, flavor, whole milk powder

INTRODUCTION

Whole milk powder (**WMP**) is produced using fat standardization, pasteurization, evaporation, homogenization, and spray drying. The resulting powder must be between 26 and 40% fat and <5% moisture (USDEC, 2005). The shelf life of WMP is generally 6 to 9 mo when stored <27°C and <65% relative humidity (USDEC, 2005). Flavor of WMP is critical because it is the number one factor influencing consumer acceptance of WMP applications (Hough et al., 2002; Lloyd et al., 2009b). Typical flavors of fresh WMP include cooked or milky, milk fat, cooked, and caramelized, whereas off-flavors such as grassy, painty, and cardboard develop during storage due to lipid oxidation (Lloyd et al., 2009a,b). Due to its higher fat content, lipid oxidation in WMP occurs more readily than in nonfat dry milk. The flavor of WMP produced in the United States is highly variable, with lipid oxidation being the main source of off-flavors (Lloyd et al., 2009a). Sources of flavor variability among manufacturers of WMP are likely due to differences in how they are processed. Factors that affect lipid oxidation and shelf life of WMP include animal feed quality, raw milk storage, heat treatment, storage conditions, water activity, and packaging conditions (Hall and Lingnert, 1984; McCluskey et al., 1997; Stapelfeldt et al., 1997; Lloyd et al., 2009b).

During spray drying, fat migrates to the surface at the expense of protein and lactose due to its hydrophobic nature (Kim et al., 2009b). Free fat is defined as fat that is not entirely coated or stabilized by amphiphilic molecules (i.e., phospholipids or protein) or protected by amorphous carbohydrates or proteins during spray drying (Vignolles et al., 2007). Spray drying parameters significantly influence the amount of free fat on the surface of the whey protein ingredients, milk protein ingredients, and milk powders (Kim et al., 2009a;

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Vignolles et al., 2010; Park et al., 2014). Keogh and O'Kennedy (1999) observed that higher lactose-to-protein ratios decreased the aggregation of fat globules and free fat in spray-dried whey protein stabilized milk fat emulsions. Crystallization of lactose during storage increases free fat by increasing solvent accessibility to the fat (Saito, 1985). During WMP manufacture, homogenization is performed to decrease the fat globule size. Because homogenization of condensed whole milk before spray drying decreases fat globule size, it decreases the migration of fat to the surface of WMP (Vignolles et al., 2007). During homogenization, the milk fat globule membrane ruptures and milk proteins and phospholipids interact with the newly formed smaller fat droplets (Ye et al., 2004, 2008; Vignolles et al., 2007). Increased homogenization pressures have been reported to increase the amount of protein on the surface of the milk fat droplets in condensed whole milk (Ye et al., 2008). The increased protein on the surface of the fat droplets, along with the smaller size due to homogenization, decreases the amount of free fat in the spray-dried WMP (Tamsma et al., 1959). Spray drying conditions also cause a change in the fat droplet size as well as amount of adsorbed proteins on the fat globule surface (Ye et al., 2007; Vignolles et al., 2010).

Increased free fat has been associated with increased lipid oxidation in dried dairy ingredients (Keogh and O'Kennedy, 1999; Park et al., 2014). Because off-flavors in dried dairy ingredients are directly related to lipid oxidation, it is hypothesized that off-flavors increase with increased free fat of dairy powders (Park and Drake, 2014; Park et al., 2014). Keogh and O'Kennedy (1999) related free fat and fat globule size to flavor in spray-dried whey protein stabilized dairy emulsions with decreased free fat in general, resulting in decreased off-flavor levels. To our knowledge, previous studies regarding WMP homogenization conditions have focused on lipid oxidation rates rather than overall flavor and flavor stability. The objective of our work was to determine the effect of homogenization pressure of condensed whole milk (50% solids) on the flavor of WMP throughout shelf life.

MATERIALS AND METHODS

WMP Manufacture

Raw bovine whole milk (310 kg) and raw skim milk (80 kg) were obtained from the North Carolina State University Dairy Research and Education Unit. The whole milk was standardized to a milk SNF-to-fat ratio of 2.48 using skim milk. The percent fat and solids were measured using the Smart Turbo moisture/solids analyzer and Smart Trac II (CEM, Matthews, NC), with the percent SNF being calculated as TS − fat. The standardized milk was pasteurized at 73°C for 20 s using a plate heat exchanger (model T4 RGS-16/2, SPX Flow Technology, Greensboro, NC). The milk was subsequently cooled to 4°C and stored in a bulk tank with constant stirring until introduction into the evaporator.

Evaporation was performed on a single effect pilot-scale falling film evaporator. The milk was preheated to 50°C upon introduction into the evaporator. The calandria temperature was 71°C with a vacuum of 74.5 kPa. The condensed whole milk exiting the evaporator was 50% solids and at a temperature of 60°C. The solids content was confirmed using the Smart Turbo moisture/solids analyzer (CEM). The condensed whole milk was then homogenized with a 2 stage homogenizer (model NS2006H, GEA Niro Soavi, Parma, Italy) at one of the following pressures: 0/0, 5.51/1.38, 11.0/2.76, or 16.5/4.14 MPa at 60°C. This made treatments of 0, 6.9, 13.8, and 20.8 MPa. The order of treatments was completely randomized. The condensed whole milk was then spray dried with a pilot scale spray dryer (model Lab 1, Anhydro Inc., Soeberg, Denmark) using a 2-fluid nozzle operated at 172 kPa, with an inlet temperature of 200°C and an outlet temperature of 95°C. The entire experiment was replicated 3 times. The treatments are hereafter named 0-, 6.9-, 13.8-, and 20.8-MPa WMP based on the homogenization pressure applied to the condensed milk before spray drying.

Storage and Sampling

The fresh WMP was placed in Mylar bags (TF-4000, Impak Corp., Central City, SD; ~1 kg per bag) and heat sealed. Storage conditions were 21°C and 50% relative humidity. Whole milk powder was sampled at 0, 3, and 6 mo postmanufacture. A new bag was used for each sampling time point.

Proximate Analysis

Percent fat and moisture of the fresh WMP were measured using ether extraction (AOAC International 2000; method 932.06) and a vacuum oven (AOAC International, 2000; method 990.20) respectively.

Descriptive Sensory Analysis

Flavor of the WMP at all time points was evaluated using descriptive sensory analysis using the Spectrum method (Drake et al., 2003). The WMP was rehydrated to 10% SNF with deionized water using a hand-held blender as described by Lloyd et al. (2009b). Whole milk powder solutions were dispensed into 60-mL souf-