J. Dairy Sci. 99:1–13
http://dx.doi.org/10.3168/jds.2016-11692

The effect of spray-drying parameters on the flavor of nonfat dry milk and milk protein concentrate 70%[1]

Curtis W. Park, Mark A. Stout, and MaryAnne Drake[2]
Department of Food, Bioprocessing, and Nutrition Sciences, Southeast Dairy Foods Research Center, North Carolina State University, Raleigh 27695

ABSTRACT

Unit operations during production influence the sensory properties of nonfat dry milk (NFDM) and milk protein concentrate (MPC). Off-flavors in dried dairy ingredients decrease consumer acceptance of ingredient applications. Previous work has shown that spray-drying parameters affect physical and sensory properties of whole milk powder and whey protein concentrate. The objective of this study was to determine the effect of inlet temperature and feed solids concentration on the flavor of NFDM and MPC 70% (MPC70). Condensed skim milk (50% solids) and condensed liquid MPC70 (32% solids) were produced using pilot-scale dairy processing equipment. The condensed products were then spray dried at either 160, 210, or 260°C inlet temperature and 30, 40, or 50% total solids for NFDM and 12, 22, or 32% for MPC70 in a randomized order. The entire experiment was replicated 3 times. Flavor of the NFDM and MPC70 was evaluated by sensory and instrumental volatile compound analyses. Surface free fat, particle size, and furosine were also analyzed. Both main effects (30, 40, and 50% solids and 160, 210, and 260°C inlet temperature) and interactions between solids concentration and inlet temperature were investigated. Interactions were not significant. In general, results were consistent for NFDM and MPC70. Increasing inlet temperature and feed solids concentration increased sweet aromatic flavor and decreased cardboard flavor and associated lipid oxidation products. Increases in furosine with increased inlet temperature and solids concentration indicated increased Maillard reactions during drying. Particle size increased and surface free fat decreased with increasing inlet temperature and solids concentration. These results demonstrate that increasing inlet temperatures and solids concentration during spray drying decrease off-flavor intensities in NFDM and MPC70 even though the heat treatment is greater compared with low temperature and low solids.
Key words: nonfat dry milk, milk protein concentrate, process parameter, flavor

INTRODUCTION

Dairy powders have developed over the years as a way to extend the shelf life of milk through various drying techniques. Milk powders made from skim milk that contain less than 1.5% fat (wt/wt) are classified as either nonfat dry milk (**NFDM**) or skim milk powder (**SMP**; ADPI, 2015a). Milk retentate, milk permeate, and lactose can be used to adjust protein content to 34% in SMP but not in NFDM (ADPI, 2015a). Over 1 million t of SMP and NFDM are used annually as both an ingredient in food applications as well as for direct consumption (USDA, 2015). Milk protein concentrate (**MPC**) is any concentrated milk product with protein ranging from 40 to 90% (ADPI, 2015b). The flavor of NFDM and MPC is important because off-flavors negatively affect the consumer acceptance of ingredient applications (Caudle et al., 2005). Flavor variability has been documented in fresh NFDM from different manufacturers (Caudle et al., 2005; Drake et al., 2006) as well as MPC (Drake et al., 2009; Smith et al., 2016a) but currently no published studies have documented the role of unit operations on the flavor of MPC. Current available literature on the flavor of NFDM is limited to flavor properties throughout storage, key aroma compounds, and the effects of off-flavors in ingredient applications (Karagul-Yuceer et al., 2001, 2002; Drake et al., 2003; Caudle et al., 2005; Isleten and Karagul-Yuceer, 2006). Lipid oxidation compounds are the primary source of off flavors in NFDM and MPC stored at 21°C (Drake et al., 2006; Smith et al., 2016a).

Typical manufacture of NFDM includes fat separation, pasteurization, evaporation, and spray drying. For MPC, ultrafiltration is performed before concentration to remove the majority of lactose and soluble minerals.

Received July 2, 2016.
Accepted August 23, 2016.
[1]Use of names, names of ingredients, and identification of specific models of equipment is for scientific clarity and does not constitute any endorsement of product by authors, North Carolina State University, or the Southeast Dairy Foods Research Center.
[2]Corresponding author: mdrake@ncsu.edu

Concentration of MPC can be done either by nanofiltration or evaporation. The benefits of using a nanofiltration process include reduced product heating and improved solubility (Cao et al., 2015). Typical solids concentration for condensed skim milk during drying is 50% whereas for condensed MPC it is lower (around 30%). Manufacturers are limited on how much solids can be increased due to the high viscosity of condensed skim milk and condensed MPC (Velez-Ruiz and Barbosa-Canovas, 1998; Bienvenue et al., 2003). Spray drying involves atomization of milk into fine particles, which are mixed with hot air to remove the majority of the water. During drying, the temperature of the individual particles does not generally reach above 60°C due to evaporative cooling (Schuck, 2013). The spray-drying process not only affects the water content but also the powder structural and physiochemical characteristics (Vignolles et al., 2007).

Surface free fat (**SFF**), an important characteristic in dairy powders, is described as fat that is not entirely coated by amphiphilic molecules or protected by a matrix of carbohydrates and proteins during drying (Vignolles et al., 2007). The SFF in whole milk powders can alter important properties of the dried milk powder such as oxidative stability, wettability, dispersibility, solubility, flowability, shelf life, and ability to use in chocolate processing applications (Vignolles et al., 2007). Although NFDM and MPC have a low fat content, lipid oxidation plays a critical role in flavor and flavor stability of NFDM and MPC (Karagul-Yuceer et al., 2002; Caudle et al., 2005; Smith et al., 2016a). Control of SFF through changing processing parameters could potentially affect the flavor and flavor stability of NFDM and MPC (Park and Drake, 2014). Park et al. (2014) recently demonstrated that SFF influenced flavor stability of dried whey proteins and that SFF was affected by spray-drying parameters. Vignolles et al. (2010) also observed that SFF was affected by spray-drying temperatures, with decreasing SFF with increasing inlet temperatures.

Spray-drying parameters affect the flavor of whey protein concentrate (**WPC**; Park et al., 2014). Decreased off-flavor intensities and corresponding lipid oxidation products were observed with increased inlet temperatures and feed solids concentrations. Increased inlet temperatures may increase the heat treatment given to the dairy powder and decrease nutritional quality. To our knowledge, Maillard reaction products, such as furosine, have not been investigated in dried dairy ingredients spray dried under varying conditions. Given differences in composition and unit operations between WPC, MPC, and NFDM, it is important to investigate the influence of spray-drying parameters on the flavor of NFDM and MPC. The objective of this study was to determine the influence of feed solids concentration and inlet temperature on the flavor of NFDM and MPC 70% (**MPC70**).

MATERIALS AND METHODS

NFDM Production

Raw bovine skim milk (313 kg) was obtained from the North Carolina State University Dairy Research and Education Unit. The milk was HTST pasteurized at 73°C for 16 s with a plate heat exchanger (model T4 RGS-16/2, SPX Flow Technology, Greensboro, NC) and subsequently cooled to 4°C and stored until evaporation (<6 h). The pasteurized skim milk was evaporated to 50% solids (wt/wt) in a single stage falling film evaporator. The milk was preheated to 54°C and introduced to the evaporator operating at 71°C with 75 kPa vacuum. The condensed milk was then standardized with warm deionized water to either 30, 40, or 50% solids (wt/wt) and was approximately 50°C for <30 min before drying. Drying was performed with a spray dryer (model Lab 1, Anhydro Inc., Soeberg, Denmark) with a 2-fluid nozzle with compressed air, operated at an inlet temperature of 160, 210, or 260°C with a constant outlet temperature of 90°C. Outlet temperature was controlled with the feed flow rate into the spray dryer to keep a constant percent moisture in the resulting powders. The TS content in the condensed milk and the spray-dried NFDM was measured using the Smart Turbo moisture/solids analyzer (CEM, Matthews, NC). The order of treatments was completely randomized within 1 d of production. The entire experiment was replicated 3 times.

MPC70 Production

Raw bovine skim milk was obtained from the NC State University Dairy Research and Education Unit. The milk was pasteurized as described previously for NFDM production. The pasteurized skim milk was then subjected to UF using a pilot-scale unit (model Lab 46, Filtration Engineering, Champlin, MN). Two spiral-wound membranes were used (nominal cutoff 10 kDa, surface area 6.5 m^2 per element; Microdyn, Raleigh, NC) with a recirculation rate of 132 L/min. The skim milk was heated with a plate heat exchanger to 50°C before introduction into the UF unit. Ultrafiltration was performed in 2 stages with concentration factors of 3× and 4× in stages 1 and 2, respectively. After stage 1, diafiltration was performed by adding warm deionized water in an amount equaling 30% of the original weight of starting skim milk. Solids content of the liquid MPC70 was measured using the Smart Turbo