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Effect of temperature and concentration on benzoyl peroxide bleaching efficacy and benzoic acid levels in whey protein concentrate

T. J. Smith,* P. D. Gerard,† and M. A. Drake*[1]
*Department of Food, Bioprocessing and Nutrition Sciences, Southeast Dairy Foods Research Center, North Carolina State University, Raleigh 27695
†Department of Mathematical Sciences, Clemson University, Clemson, SC 29634

ABSTRACT

Much of the fluid whey produced in the United States is a by-product of Cheddar cheese manufacture and must be bleached. Benzoyl peroxide (BP) is currently 1 of only 2 legal chemical bleaching agents for fluid whey in the United States, but benzoic acid is an unavoidable by-product of BP bleaching. Benzoyl peroxide is typically a powder, but new liquid BP dispersions are available. A greater understanding of the bleaching characteristics of BP is necessary. The objective of the study was to compare norbixin destruction, residual benzoic acid, and flavor differences between liquid whey and 80% whey protein concentrates (WPC80) bleached at different temperatures with 2 different benzoyl peroxides (soluble and insoluble). Two experiments were conducted in this study. For experiment 1, 3 factors (temperature, bleach type, bleach concentration) were evaluated for norbixin destruction using a response surface model–central composite design in liquid whey. For experiment 2, norbixin concentration, residual benzoic acid, and flavor differences were explored in WPC80 from whey bleached by the 2 commercially available BP (soluble and insoluble) at 5 mg/kg. In liquid whey, soluble BP bleached more norbixin than insoluble BP, especially at lower concentrations (5 and 10 mg/kg) at both cold (4°C) and hot (50°C) temperatures. The WPC80 from liquid whey bleached with BP at 50°C had lower norbixin concentration, benzoic acid levels, cardboard flavor, and aldehyde levels than WPC80 from liquid whey bleached with BP at 4°C. Regardless of temperature, soluble BP destroyed more norbixin at lower concentrations than insoluble BP. The WPC80 from soluble-BP-bleached wheys had lower cardboard flavor and lower aldehyde levels than WPC80 from insoluble-BP-bleached whey. This study suggests that new, soluble (liquid) BP can be used at lower concentrations than insoluble BP to achieve equivalent bleaching and that less residual benzoic acid remains in WPC80 powder from liquid whey bleached hot (50°C) than cold (4°C), which may provide opportunities to reduce benzoic acid residues in dried whey ingredients, expanding their marketability.
Key words: benzoyl peroxide, benzoic acid, whey protein concentrate, bleaching

INTRODUCTION

Dried whey ingredients provide significant value to the dairy industry. They possess many useful functional properties, such as gelation, thermal stability, foam formation, and emulsification properties, and provide many health benefits, including exercise recovery, weight management, cardiovascular health, anti-cancer effects, anti-infection activity, wound repair, and infant nutrition (Foegeding et al., 2002; Miller, 2005; O'Connell and Flynn, 2007; Smithers, 2008). Much of the whey produced in the United States is a by-product of Cheddar cheese manufacture. Cheddar cheese in the United States is typically colored with annatto (norbixin), a carotenoid extracted from the seed of the *Bixa orellana* shrub (Scotter, 2009). Approximately 10% of annatto partitions into the liquid whey during Cheddar cheese manufacture (Smith et al., 2014).

To provide a colorless whey ingredient, colored liquid whey must be bleached; however, the use of chemical bleaching agents has detrimental effects, including off-flavor development, chemical residues, and protein functional changes (Listiyani et al., 2011; Jervis et al., 2012). There are currently 2 chemical bleaching agents approved for use in liquid whey in the United States, hydrogen peroxide (**HP**) and benzoyl peroxide (**BP**) (21CFR184.1366 and 21CFR184.1157, respectively). Bleaching of liquid whey has been extensively studied, and it has been consistently demonstrated that BP results in greater norbixin destruction and less lipid oxidation and subsequent off-flavors than bleaching

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[1]Corresponding author: maryanne_drake@ncsu.edu

with HP (Listiyani et al., 2012; Jervis et al., 2012; Fox et al., 2013; Jervis et al., 2015). Benzoyl peroxide reacts with oxidizable compounds in the liquid whey and is converted into water-soluble benzoic acid (**BA**). Benzoic acid residues are a concern because of restrictions in international markets, especially China. Because of the breakdown of BP into BA, BP is not an approved bleaching agent for whey ingredients in China or Japan (USDA 2013). In Canada, BP is allowed to be used as a bleaching agent in fluid whey not to be used in infant formula, at a maximum concentration of 100 mg/kg BP (CFIA, 2008).

The safety of BA has been extensively studied (Sharratt et al., 1964; Nair, 2001; Qi et al., 2009). Benzoic acid and its salt are used in the food industry as preservatives with antibacterial, yeast, and fungal properties (Chipley, 1993). Sieber et al. (1995) found native BA in dairy products, especially fermented dairy products, at concentrations as high as 50 mg/kg (Sieber et al., 1995), and Qi et al. (2009) reported BA concentrations in Chinese infant formula as high as 85 mg/kg and in milk powder as high as 110 mg/kg. Listiyani et al. (2011) reported concentrations in BP-bleached 34% whey protein concentrate (**WPC34**) of 272 and 634 mg/kg, depending on BP concentration used to bleach liquid whey at 60°C (50 and 100 mg/kg, respectively). In commercial 80% whey protein concentrate (**WPC80**) from BP bleached whey, 30 to 60 mg/kg BA were reported (Listiyani et al., 2011), but BP concentrations and conditions were not identified. Jervis et al. (2015) evaluated the effect of solids concentration at bleaching on residual BA. Benzoic acid concentrations in sweet whey powder (**SWP**) from BP-bleached (50 mg/kg BP) whey of 130 or 420 mg/kg were reported, depending on total solids concentration when bleached (6.7% solids and 14% solids, respectively). These studies suggest that parameters in addition to BP concentration affect residual BA in dried whey ingredients.

The Joint Expert Committee for Food Additives has set the acceptable daily intake for BA and its salts (benzoate calcium, potassium, and sodium), benzaldehyde, benzyl acetate, and benzyl alcohol at 0 to 5 mg/kg of BW (WHO, 1996). The Joint Expert Committee for Food Additives has also stated that no safety concern exists for BP in bleaching of whey when used at up to 100 mg/kg (JECFA, 2004). Benzoic acid is generally recognized as safe, but exposure to BA has been linked to eye, skin, and respiratory-tract irritation (Qi et al., 2009); skin sensitization (do Nascimento Filho et al., 2004); and nonimmunological contact reactions such as asthma, urticaria, metabolic acidosis, and convulsions (WHO, 2000; Tfouni and Toledo, 2002). Because of health concerns and international restrictions of BP use because of BA residues, it is important to investigate possible methods of reducing BA residues in dried whey protein ingredients. Benzoyl peroxide suspended in liquid medium, rather than powder, has recently come to the market and is commercially available. The objectives of this study were to compare the bleaching characteristics of commercially available soluble (liquid) and insoluble (powder) BP at different concentrations (5, 10, 25, 50 mg/kg BP) and temperatures (4 and 50°C), and to determine their effect on BA residues in WPC80 bleached at 4 and 50°C.

MATERIALS AND METHODS

Experimental Overview

Two experiments (experiments 1 and 2) were included in this study. The purpose of experiment 1 was to determine the effects of BP concentration and temperature on norbixin destruction in liquid whey using soluble or insoluble BP and to generate a response surface and prediction equation for each temperature–BP treatment. Liquid Cheddar whey was manufactured and bleached at 2 temperatures (4 and 50°C), using 2 commercial forms of BP at 4 concentrations (5, 10, 25, and 50 mg/kg). Samples were taken at 9 (50°C treatment; 1, 5, 10, 15, 20, 25, 30, 45, and 60 min) or 5 (4°C treatment; 1, 2, 4, 6, and 16 h) time points for norbixin analysis. Experiment 2 determined the effect of temperature and BP type (soluble or insoluble) on residual BA and flavor properties of WPC80. Conditions for experiment 2 were based on the results of experiment 1. Bleaching liquid whey with 5 mg/kg BP was selected for experiment 2. The prediction equations generated in experiment 1 predicted a norbixin destruction level of 90% using 5 mg/kg soluble BP at 50°C. A norbixin destruction level of 90% approximates the bleaching efficacy of BP treatments reported previously in literature (Listiyani et al., 2011; Jervis et al., 2012; Jervis et al., 2015). The prediction equations generated in experiment 1 also predicted that approximately 5 mg/kg soluble BP at 4°C would destroy 40% of norbixin in 1 h, which is equivalent to or greater than HP bleaching in previous literature (Jervis et al., 2012; Campbell et al., 2013; Jervis et al., 2015). The WPC80 powders were manufactured from liquid whey at 2 temperatures (4 and 50°C), with 5 mg/kg of each of the 2 commercial forms of BP.

Composition Analysis

The liquid whey and WPC80 powders were analyzed for TS, fat, and CP. Total solids were determined by vacuum oven drying (AOAC International, 2000; method number 990.20; 33.2.44), fat by ether extraction