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Short communication: The influence of solids concentration and bleaching agent on bleaching efficacy and flavor of sweet whey powder

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ABSTRACT

Recent studies have demonstrated the effect of bleaching conditions and bleaching agent on flavor and functional properties of whey protein ingredients. Solids concentration at bleaching significantly affected bleaching efficacy and flavor effects of different bleaching agents. It is not known if these parameters influence quality of sweet whey powder (SWP). The purpose of this study was to determine the effects of solids concentration and bleaching agent on the flavor and bleaching efficacy of SWP. Colored cheddar whey was manufactured, fat separated, and pasteurized. Subsequently, the whey (6.7% solids) was bleached, concentrated using reverse osmosis (RO) to 14% solids, and then spray dried, or whey was concentrated before bleaching and then spray dried. Bleaching treatments included a control (no bleaching, 50°C, 60 min), hydrogen peroxide (HP; 250 mg/kg, 50°C, 60 min), benzoyl peroxide (50 mg/kg, 50°C, 60 min), lactoperoxidase (20 mg/kg of HP, 50°C, 30 min), and external peroxidase (MaxiBright, DSM Food Specialties, Delft, the Netherlands; 2 dairy bleaching units/mL, 50°C, 30 min). The experiment was repeated in triplicate. Sensory properties and volatile compounds of SWP were evaluated by a trained panel and gas chromatography-mass spectrometry, respectively. Bleaching efficacy (norbixin destruction) and benzoic acid were measured by HPLC. Differences in bleaching efficacy, sensory and volatile compound profiles, and benzoic acid were observed with different bleaching agents, consistent with previous studies. Solids concentration affected bleaching efficacy of HP, but not other bleaching agents. The SWP from whey bleached with HP or lactoperoxidase following RO had increased cardboard and fatty flavors and higher concentrations of lipid oxidation compounds compared with SWP from whey bleached before RO. The SWP bleached with benzoyl peroxide after RO contained less benzoic acid than SWP from whey bleached before RO. These results indicate that solids concentration at bleaching and bleaching agent affect quality of SWP.
Key words: sweet whey, reverse osmosis, bleaching

Short Communication

Cheddar cheese is colored using the carotenoid annatto, which is primarily composed of norbixin (Smith et al., 2014). Of the added annatto, a portion of the norbixin (~10%) remains in the liquid sweet whey, imparting a yellow color (Smith et al., 2014). Dried whey ingredients that are both colorless and flavorless are desired to avoid unwanted color and flavor transfer to final food products. To obtain a colorless product, bleaching is a required step in whey ingredient manufacture. Bleaching parameters in whey production vary among manufacturers, but can occur at any point in the manufacturing process. Processing steps in manufacture of whey protein concentrate (WPC) with 34% protein (WPC34), WPC80, and whey protein isolate (WPI), including bleaching, impart off-flavors, which carry over to food or beverage applications (Croissant et al., 2009; Campbell et al., 2012; Listiyani et al., 2011; Jervis et al., 2012); thus, care should be taken to maximize final product quality.

Benzoyl peroxide (**BP**) and hydrogen peroxide (**HP**) are the 2 approved chemical bleaching agents used in the United States for bleaching of liquid whey and whey retentate. The use of BP for bleaching has declined in recent years due to concerns of some countries regarding benzoic acid residues, but remains an approved chemical bleaching agent, and chemical bleaching with HP or BP remain cost effective methods for bleaching. However, the nonspecific oxidation processes that reduce norbixin increase lipid oxidation products, which are the primary source of off-flavors in dried whey protein products (Whitson et al., 2010). Bleaching liquid whey or concentrated whey with HP produces higher levels of lipid oxidation and subsequent off flavors than BP (Croissant et al., 2009; Listiyani et al., 2011; Jervis et al., 2012; Fox et al., 2013). At optimal conditions in fluid whey, BP is a better bleaching agent than HP. In

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contrast, in 80% protein liquid retentate, HP destroyed more norbixin than BP (Fox et al., 2013). Li et al. (2012) examined the effects of bleaching at varying solids levels with HP at 250 mg/kg and reported bleaching 80% whey protein retentate produced greater bleaching efficacy than 34% whey protein retentate at equivalent solids, indicating that solids composition directly affected bleaching efficacy of HP.

Concerns over chemical bleaching agents have led to research into alternative bleaching methods. Enzymatic bleaching with the lactoperoxidase system (**LP**) is one alternative bleaching method (Bottomley et al., 1989; Campbell et al., 2012). Bleaching fluid whey with LP (20 mg/kg of HP) was more effective in norbixin destruction than chemical bleaching with HP (250 mg/kg of HP; LP >99% norbixin destruction at both 50 and 35°C vs. HP 46% at 50°C or 32% at 35°C; Campbell et al., 2012). The use of an external peroxidase (**EP**) has recently been approved by the Food and Drug Administration as an additional enzymatic bleaching agent for whey. External peroxidase facilitates enzymatic bleaching of whey similar to the LP system, but can account for variability in lactoperoxidase levels that may result from varying feeding regimens and processing steps (Seifu and Donkin, 2005; Campbell and Drake, 2014). In the case of LP, bleaching at higher protein concentration may facilitate bleaching by increasing concentrations of LP, as LP is concentrated by UF with other proteins. Higher solids in general may also facilitate bleaching with other agents simply due to a concentration effect: generated radicals have more ready access to available norbixin. However, previous studies have also suggested that bleaching at higher solids may also lead to higher concurrent concentrations of lipid oxidation compounds (Fox et al., 2013). The effect of bleaching fluid whey at various solids concentration levels is not yet fully understood in regards to the potential effect on both bleaching efficacy and flavor, and no published studies to our knowledge have evaluated the effect of bleaching on sensory and chemical properties of sweet whey powder (**SWP**). The objective of the current study was to examine the effect of bleaching of colored liquid whey at 2 concentrations of TS on the sensory and chemical properties of SWP.

Experimental Design

Liquid pasteurized, fat-separated cheddar whey was divided into 2 batches. The first batch was further divided into 5 sample groups based on bleaching method. These samples included 1 control (**CR**) and wheys bleached using HP, BP, LP, or EP at the solids of unconcentrated whey (approximately 6.7%). All 5 of the wheys were then concentrated to approximately 14% TS using reverse osmosis (**RO**) and spray dried. The second batch was concentrated to 14% TS and then separated into 5 sample groups (**CR14**, **HP14**, **BP14**, **LP14**, and **EP14**). These sample groups were then bleached at the higher TS concentration using the same 5 bleaching methods. Following bleaching and concentration, all sweet whey samples were cooled to 4°C and stored overnight. The following day, all samples were spray dried (Table 1); this experiment was replicated 3 times.

Table 1. Descriptions of sweet whey powder (SWP) treatments

Treatment[1]	Description
CR	Control before RO[2]
CR14	Control after RO
HP	Hydrogen peroxide before RO
HP14	Hydrogen peroxide after RO
BP	Benzoyl peroxide before RO
BP14	Benzoyl peroxide after RO
LP	Lactoperoxidase before RO
LP14	Lactoperoxidase after RO
EP	External peroxidase before RO
EP14	External peroxidase after RO

[1]CR = control (no bleaching), HP = bleaching with hydrogen peroxide (250 mg/kg); BP = bleaching with benzoyl peroxide (50 mg/kg); LP = bleaching with lactoperoxidase (hydrogen peroxide 20 mg/kg); EP = bleaching with external peroxidase (2 dairy bleaching units and hydrogen peroxide 20 mg/kg); CR14, HP14, BP14, LP14, and EP14 = wheys concentrated to 14% TS using RO and bleached as before.
[2]RO = reverse osmosis to 14% solids.

Sweet Whey Manufacture, Bleaching, and Concentration

Cheddar whey was manufactured from HTST (17 s at 72°C) pasteurized whole milk (approximately 1,400 kg), fat separated, and pasteurized following the methods of Campbell and Drake (2013). Fluid whey was then cooled to 50°C and divided into 2 batches weighing approximately 625 and 125 kg, respectively. Batch 1 (625 kg) was separated into 5 aliquots for bleaching, each approximately 125 kg. These 5 aliquots were bleached at TS concentrations of fluid whey (6.7% solids). All bleaching took place at 50°C (Fox et al., 2013). The HP (35% HP, Food Chemicals Codex grade; Columbus Chemical Industries Inc., Columbus WI) was added at 250 mg/kg to 1 aliquot and held for 60 min. This concentration was selected because it represents the midrange concentration of HP use for bleaching of whey (US Food and Drug Administration, 2009). The BP (Oxylite Type XX Benzoyl Peroxide 32%, Nelson Jameson, Marshfield, WI) was added to the second aliquot at a concentration of 50 mg/kg and