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Characterization of Dried Whey Protein Concentrate and Isolate Flavor

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ABSTRACT

The flavor of whey protein concentrates (WPC 80) and whey protein isolates (WPI) was studied using instrumental and sensory techniques. Four WPC 80 and 4 WPI, less than 3 mo old, were collected in duplicate from 6 manufacturers in the United States. Samples were rehydrated and evaluated in duplicate by descriptive sensory analysis. Duplicate samples with internal standards were extracted with diethyl ether. Extracts were then distilled to remove nonvolatile material using high vacuum distillation. Volatile extracts were analyzed using gas chromatography/olfactometry with post peak intensity analysis and aroma extract dilution analysis. Compounds were identified by comparison of retention indices, odor properties, and gas chromatography/mass spectrometry against reference standards. Whey proteins exhibited sweet aromatic, cardboard/wet paper, animal/wet dog, soapy, brothy, cucumber, and cooked/milky flavors, along with the basic taste bitter, and the feeling factor astringency. Key volatile flavor compounds in WPC 80 and WPI were butanoic acid (cheesy), 2-acetyl-1-pyrroline (popcorn), 2-methyl-3-furanthiol (brothy/burnt), 2,5-dimethyl-4-hydroxy-3-(2H)-furanone (maple/spicy), 2-nonenal (fatty/old books), (E,Z)-2,6-nonadienal (cucumber), and (E,Z)-2,4-decadienal (fatty/oxidized). This baseline data on flavor and flavor sources in whey proteins will aid ongoing and future research and will help to identify the most appropriate whey ingredients to use to control or minimize flavor variability in whey enhanced products.
(**Key words:** whey protein concentrate, whey protein isolate, flavor)

Abbreviation key: AEDA = aroma extract dilution analysis, **$\log_3$FD** = $\log_3$ flavor dilution, **GC/O** = gas chromatography/olfactometry, **RI** = retention index, **WPC** = whey protein concentrates, **WPI** = whey protein isolates.

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INTRODUCTION

Dried whey and dried whey products are important ingredients in the food industry. Although liquid whey is not often used as a food ingredient, production exceeded 39 million kg (86 million pounds) in 2004 (USDA, 2005). Liquid whey is further processed into dried whey powder, whey protein concentrates (**WPC**; 35 to 80% protein), and whey protein isolates (**WPI**; >90% protein). Dried whey proteins are commonly used as ingredients due to their exceptional functional characteristics including gelation and viscosity (Morr and Foegeding, 1990). Whey proteins also provide an excellent way to fortify foods with proteins and thus increase their overall nutritional value (Quach et al., 1999).

The flavor of whey is one of the limiting factors in its widespread usage. It has been suggested that off-flavors such as brothy, diacetyl, sourness, and bitterness are the main sensory attributes that limit whey protein usage in bland products (McGugan et al., 1979; Quach et al., 1999). As whey is processed into WPC 80 and WPI, there are many potential sources of flavor formation. Because liquid whey is pooled (sometimes from different types of cheese) before processing into WPC 80 and WPI, there are many sources of flavor variability. Swaisgood (1996) stated that volatile lipid oxidation products were the main sources of off-flavors in both liquid and dried whey, although whey contains only a small amount of lipid. Other studies have confirmed a wide variety of volatile lipid oxidation products in liquid whey and dried whey products, including methyl ketones, aldehydes, and free fatty acids (Hidalgo and Kinsella, 1989; Mills, 1993; Carunchia Whetstine et al., 2003a; Karagul-Yuceer et al., 2003a; Mahajan et al., 2004). Proteolysis is also an important flavor reaction in whey. Proteolytic enzymes, including chymosin, carry over into the whey and may promote the degradation of amino acids, leading to undesirable flavor formation (Holmes et al., 1977; Amundson, 1984). Variability in the type and concentration of free amino acids in whey has also been reported (Mavropoulou and Kosikowski, 1972; Mills, 1993) and may be a source of flavor variability in dried whey products. Proteins may also bind volatile flavor compounds during processing (Stevenson and

Chen, 1996), thereby contributing to flavor formation in the end product.

Previous studies (Carunchia Whetstine et al., 2003a; Karagul-Yuceer et al., 2003a) showed that metallic and cardboard flavors are present in liquid Cheddar whey. Furthermore, considerable variability in flavor and flavor volatiles existed in liquid Cheddar whey from different starter culture rotations and from different production facilities. Dried whey ingredients have been associated with oxidized, unpleasant flavors that are not pleasing to consumers (Morr and Ha, 1991; Branger et al., 1999). Few studies have specifically addressed the flavor of dried whey or whey proteins (Stevenson and Chen, 1996; Quach et al., 1999; Mahajan et al., 2004). Mahajan et al. (2004) characterized the aroma-active components from 2 samples of sweet whey powder. Sensory properties were not addressed. Other studies have optimized total volatile component analysis (not aroma-active components) (Quach et al., 1999) or evaluated processing methods to minimize volatile component entrapment (Stevenson and Chen, 1996). To our knowledge, the application of quantitative sensory analysis in conjunction with instrumental flavor volatile analysis on multiple whey protein samples has not been conducted. The objectives of this research were to identify and characterize sensory flavor and volatile aroma-active compounds that contribute to flavor in WPC 80 and WPI. Products from different domestic manufacturers as well as different cheese types were evaluated. A previously established defined sensory language for dried dairy ingredients (Drake et al., 2003) was applied by a trained sensory panel in conjunction with instrumental volatile analysis to characterize flavor and flavor variability in this important food ingredient.

MATERIALS AND METHODS

Whey Proteins

Whey protein concentrates (n = 7) and WPI (n = 8) (15 kg, commercially packaged) from different cheese types (Table 1) were received from different US manufacturers within 48 h of production. Duplicate samples were received from each manufacturer in the fall of 2004. Subsamples (500 g) were taken and stored in glass jars flushed with nitrogen, immediately frozen at –80°C, and analyzed within 3 mo of receipt. Whey protein concentrate and WPI samples were reconstituted to 10% solids using deodorized water (prepared by boiling 4 L of distilled water until its volume was decreased by one-third) and blended with a hand-held electric mixer for sensory and instrumental analyses.

Analyses of pH, moisture, fat, protein, and mineral were conducted on all whey proteins in duplicate using standard methods. The pH values were determined by rehydrating the powders and measuring the pH using a pH electrode. Fat content was determined by Mojonnier analysis (Mojonnier Bros. Co., Chicago, IL; Wehr and Frank, 2004). Moisture was determined by the vacuum oven method, and ash content was determined using a muffle furnace. Protein concentration was determined by the Kjeldahl method using a conversion factor of 6.38 to convert total N to protein concentration (Wehr and Frank, 2004). Mineral analysis (calcium, magnesium, potassium, sodium, and phosphate) was conducted using inductively coupled plasma atomic emission spectroscopy.

Table 1. Whey protein concentrate 80 (WPC) and whey protein isolates (WPI) used in the study.[1]

Sample	Manufacturer	Cheese type	Region of US[2]
WPC 80			
WPC 1	1	Primarily Mozzarella	Midwest
WPC 2	1	Primarily Mozzarella	Midwest
WPC 3	2	Mozzarella	Midwest
WPC 4	2	Mozzarella	Midwest
WPC 5	3	Mozzarella	West coast
WPC 6	4	Cheddar	West coast
WPC 7	4	Cheddar	West coast
WPI			
WPI 1	1	Primarily Cheddar	Midwest
WPI 2	1	Primarily Cheddar	Midwest
WPI 3	5	Cheddar	Midwest
WPI 4	5	Cheddar	Midwest
WPI 5	4	Cheddar	West coast
WPI 6	4	Cheddar	West coast
WPI 7	6	Cheddar	West coast
WPI 8	6	Cheddar	West coast

[1]All products were <3 mo old before analysis.

[2]Geographical region of United States in which the product was manufactured.

Descriptive Sensory Analysis

A trained sensory panel (n = 7) evaluated the flavor attributes of the reconstituted whey proteins using a previously published lexicon for dried dairy ingredients (Drake et al., 2003). The definitions and references for the terms used are given in Table 2. Panelists each received 100 h of training on aroma and flavor evaluation of dried dairy ingredients, including both WPI and WPC 80. Flavor and taste intensities were scaled using the 15-point universal intensity scale characterized by the Spectrum descriptive analysis method (Meilgaard et al., 1999; Drake and Civille, 2003). Consistent with Spectrum descriptive analysis training, panelists were presented with reference solutions of sweet, sour, salty, and bitter tastes to learn to consistently use the universal intensity scale (Meilgaard et al., 1999; Drake and Civille, 2003). Following consistent use of the Spectrum

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