Abstract

RUSSELL, TARA ALEXANDRA. Comparison of sensory properties of whey and soy protein concentrates and isolates (Under the direction of Dr. MaryAnne Drake).

Whey and whey components, particularly whey proteins, are now viewed as valuable ingredients due to recent discoveries of functionality and bioactive roles. The food/beverage industry has recently recognized the application and marketing benefits of soy protein. Characterization and comparison of the flavor properties of value-added ingredients such as whey and/or soy protein are needed to identify specific ingredient applications and marketing strategies. However, minimal research has been conducted in the comparison of sensory properties of whey and soy protein. The objectives of this study were to develop a sensory lexicon for whey and soy proteins, and to identify and compare the descriptive sensory properties of whey and soy proteins. Proteins were rehydrated [10 % solids, (w/v)] and evaluated in triplicate by a highly trained sensory panel (n=10) trained to use the developed language. Twenty-four descriptive sensory attributes were identified by a descriptive panel to evaluate appearance, flavor, and texture/mouthfeel. Following identification of the lexicon, twenty-two samples (14 whey proteins and 8 soy proteins) were selected for descriptive sensory analysis. Consumer testing was used to investigate consumer (n=147) perception of whey and soy protein. Results were analyzed by univariate and multivariate analysis of variance. Both whey and soy proteins were differentiated using the identified language ($p<0.05$). Different sensory attributes distinguished whey proteins from soy proteins. Consumer testing results revealed that consumers were knowledgeable of distinct health benefits of dairy and soy products. The lexicon developed has application in documentation of flavor of

products containing whey and/or soy protein concentrate or isolate, thus facilitating a common language for improved quality assurance within the food/beverage industry. Results os this study will also enhance ongoing research and product development with these nutritional and functional ingredients.

Comparison of sensory properties of whey and soy protein concentrates and isolates

by

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Biography

Tara Alexandra Russell was born on April, 19, 1976 in Canandaigua, New York to Rosemarie and Timothy Russell. Tara has two younger sisters, identical twins, Tiffany Russell and Amy Kimble, and a younger brother, Timothy Russell II.

Tara graduated from Canandaigua Academy in 1994. In pursuit of a career in the medical field, she graduated with a Bachelor of Science in Food science from North Carolina State University. After years of Business management in the medical field, she returned to NC State and found her passion for sensory analysis through her mentor Dr. MaryAnne Drake. Tara begun her graduate degree with the Department of Food Science at North Carolina State University in 2002, with an Interdisciplinary minor consisting of both Business and Statistics.

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Chapter 1. Introduction

In previous years, whey was an insignificant by-product of cheese making, used mainly in animal feed or discarded (National Dairy Council, 2003). With advances in technology and recent discoveries of functional and bioactive roles for whey, whey and whey components are now viewed as valuable ingredients. The recognition of whey as a source of unique physiological and functional attributes has increased incorporation of whey and whey components into a variety of foods. Whey protein concentrate (WPC) and whey protein isolate (WPI) are high protein, low-carbohydrate ingredients that are currently in demand due to increased awareness of nutrition and alternative methods for weight control. Dairy products, especially whey protein products, contain high concentrations of vitamins and minerals.

Many consumers have chosen to take more control over managing their health through diet, especially with the new diet techniques, such as low-carbohydrate high protein diets. Consumers desiring to lower their cholesterol levels through diet often turn to foods such as soy products. Soy protein is a functional ingredient that provides a wide range of functional and nutritional properties. Soy has a variety of health benefits; therefore, FDA approval of soy health claims has been a key driving force for an upward trend in soy consumption. Both soy protein concentrate (SPC) and soy protein isolate (SPI) are cost effective and offer unique amino acid profiles. Processing of SPC and SPI from soybeans is not as complex as processing WPC and WPI. However, both whey and soy proteins are abundant within the United States (U.S.).

The total number of consumers purchasing nutraceutical products such as whey is increasing. This new market growth of functional nutraceutical products includes a wide variety of foods from meal replacement bars to beverages. However, consumer trends are drifting towards nutraceutical products that offer an innovative taste (Williams, 2001). Characterization of flavor and flavor variability of whey and soy protein are crucial to development of products containing there ingredients. Consumer perception of these products is crucial to effectively design and market ingredient applications for whey and soy proteins.

Literature Review

Whey

Whey History

Whey is the greenish-yellow colored liquid which is drained off of the coagulated cheese curd during the cheese making process (Smithers et al., 1996). Whey, theoretically has a bland flavor (Laye et al., 1995) but rapidly oxidizes, forming stale off-flavors (Morr and Ha, 1991). Whey contains nearly half of all solids found in whole milk (Chandan, 1997). The majority of the solids found in whey are proteins, fat, minerals, and lactose (Table 1).

For years, the disposal of liquid whey was problematic and often discharged into local waterways, ocean/seas, and fields, or was used in animal feed (Smithers et al., 1996). Discharging whey into lakes and rivers removed the economic burden of disposing of whey in waste treatment facilities. Over the past few years, the Environmental Protection Act (EPA) has placed restrictions on land-spreading as a method for whey disposal, which is an incentive to find other uses for whey and whey products (Casper, 1999).

Whey cannot be used in liquid form so it is spray dried into whey powder (Smithers et al., 1996). The composition of whey powder can be further altered to concentrate specific whey components. These processes have resulted in various applications of whey making it economically convenient to use whey in human food since it contains a high concentration of protein. A popular but low financial return for manufacturing companies is the use of whey in animal feed.

Whey Production

The U.S. is recognized as the leading whey producer in the world (American Dairy Products Institute, 1998a). Since the 1970's, whey production in the United States has more than tripled (American Dairy Products Institute, 1998a). More than one quarter of the world's whey and lactose is manufactured at over 200 facilities in the U.S. (USDEC, 2003). The continuing long-term trend of U.S. whey exports attests to the high quality and increasing use of U.S. whey products. From 1998-2001, total U.S. dry whey exports grew 46% (USDEC, 2003). The U.S. is the top whey supplier in a large number of countries where the food and beverage manufacturing sector is dynamic and innovative. Each year, more than 80 billion liters of whey are produced worldwide (Smithers et al., 1996). deWit (1998) estimated that 700,000 tons of the true whey proteins produced worldwide are available for use as ingredients in food. The United States Export Dairy Council (USDEC, 2003) reported 5.6 tons of whey protein concentrates exported in 1996 compared to 24.5 tons exported in 2001 (Table 2). The cost of whey protein varies depending on milk prices. Currently, the demand for a higher protein, lower carbohydrate diet in the marketplace has further increased whey protein value. WPC80 (whey protein concentrate 80%) is valued at approximately $2.50/lb (Davisco Foods International, MN, 2004) and WPI is approximately $4.50/lb (Davisco Foods International, MN, 2004).

Types of Whey and Whey Products

There are many types of cheese, and thus there are many sources of whey. The latest technology allows suppliers to vary the protein, mineral, and fat levels in their whey products. U.S. whey suppliers can modify whey product composition and functionality through such technologies as demineralizing, crystallizing, or ultrafiltration. Whey products can range in protein levels from less than 12% to over 90%, and mineral levels between 1% and 28% (Table 3, USDEC, 2003). Modified whey products with enhanced functional and nutritional characteristics are also widely available and typically customized for optimal performance (USDEC, 2003). There are two basic types of liquid whey: sweet whey and acid whey. Various types of whey powders include sweet whey powder, acid whey powder, whey protein concentrate (WPC), WPC34, WPC50, WPC60, WPC75, WPC80, and whey protein isolate (WPI) (USDEC, 2003).

There are different whey products currently being manufactured, but liquid whey or whey powder was previously considered a by-product of the cheese making process. It was not until the 1970s that the use of liquid whey changed from being disposed of in the municipal water systems to use in food products (McDonough et al., 1974). Currently, most liquid whey is spray dried and used in a variety of food products (Varnam and Sutherland, 1994). Liquid whey contains approximately 93% water, 0.6% protein, (Huffman, 1996) and 0.05% fat (Smithers et al., 1996). The main functional component of liquid whey is the high level of calcium and B vitamins (Sienkiewicz and Riedel, 1990). Liquid whey and whey powders have relatively low protein content and limited functional properties so they are not used in food products as often as WPC or WPI (Varnam and Sutherland, 1994).

Two principal types of liquid whey are sweet whey and acid whey. Both originate from the manufacturing process of natural cheese or rennet casein. Both sweet whey powder and acid whey powder are made by drying fresh whey. Acid whey by definition has a pH of 5.1 or lower. Acid whey is a by-product of the manufacturing process of acid casein or directly acidified cheeses such as cottage and cream cheese (Mulvihill, 1992) and contains all the original constituents of acid whey except the water (USDEC, 2003). Acid whey is made by acidifying milk to a pH of 4.6, at which point the casein coagulates and precipitates. Acid whey is higher in mineral content, especially calcium phosphate than sweet whey. Acid whey can be used in snack foods, salad dressings, and frozen entrees. The protein content of acid whey is 11-13.5% which is similar to the range of sweet whey powder at 11-14.5% (Table 4) (USDEC, 2003).

Sweet whey is an off-white to cream-colored product and is manufactured by removing a substantial portion of water from fresh sweet whey; which is the whey separated from the production of renneted cheeses (American Dairy Products Institue, 1998a). Sweet whey is most commonly used in the food industry and has a pH of 5.8-6.3 and a titratable acidity of 0.1 (Varnam and Sutherland, 1994). Sweet whey powder has a fat content of 1-1.5% which is higher than acid whey powder (0.5-1%) (Table 4) (USDEC 2003). An equal amount of protein, 11-13.5% exists in both sweet whey and acid whey, however the lactose content is higher in sweet whey (63-75%).

Two other types of liquid whey are demineralized whey and reduced lactose whey. Demineralized whey, a reduced mineral whey, is obtained by the removal of a portion of minerals from pasteurized whey (USDEC, 2003). Demineralized whey is produced by separation techniques such as ion exchange (Varnam and Sutherland, 1994) and must not exceed 7% ash content (USDEC, 2003). The primary use of demineralized whey is for use in a food matrix where mineral content and concentration are crucial. Products in which demineralized whey is used include infant foods, diet food formulations, and prepared dried mixes. Reduced-lactose whey, also known as mineral concentrated whey, is a cream to dark cream-colored product and is manufactured by drying whey that has been treated to remove a portion of the lactose (American Dairy Products Institute, 1998a). The lactose content of the dry product is less than 60% (dry weight) and is removed by physical separation techniques such as precipitation, filtration or dialysis (American Dairy Products Institute, 1998a; USDEC, 2003). This type of whey has become increasingly popular as a nutritional ingredient in products such as powdered beverages, sauces, meats, baked goods and others (USDEC, 2003).

Liquid whey can be further processed into spray dried products such as whey protein concentrate (WPC), WPC34, WPC50, WPC60, WPC75, WPC80, and whey protein isolate (WPI). Whey protein that is concentrated to a protein content ranging from 35-80% is referred to as whey protein concentrate (WPC). WPC is white to light cream in color with a purportedly bland and generally clean flavor. Five WPC types exist, WPC 34, WPC 50, WPC 60, WPC 75, and WPC80. All types are produced by membrane separation processes whereby non-protein constituents are filtered out from pasteurized liquid whey (Figure 1) (USDEC, 2003) followed by a clarification process to remove any cheese fines. The whey is then evaporated to concentrate the solids before spray drying (Huffman, 1996). The finished dry product may contain 34 to 80% protein depending on the product (Table 4). The composition of non-fat dry milk is comparable to WPC34, and WPC34 has been used as a milk substitute. WPC50 contains 50-53% protein, 35% lactose, 5% fat, and 7% ash. WPC80 contains the greatest amount of protein, 80%, compared to the five types listed previously. WPC80 has a fat content of 4% to 8%. Production of WPC80 is essentially the same as WPC34 and WPC50, whereby protein is concentrated though physical separation techniques such as precipitation, filtration, ion exchange or dialysis. After the ultrafilteration step, a diafiltration step is added in the production of WPC80 for the purpose of concentrating the protein from 50% to 80% (Huffman, 1996). Acidity can also be adjusted in all types of WPC by the addition of safe and suitable pH ingredients (USDEC, 2003).

Another whey product is whey protein isolate (WPI). Like WPC, WPI is white to cream in color with a purportedly bland and generally clean flavor. The protein content of WPI is higher than WPC, containing no less than 90% protein. WPI has a lactose content of 0.5% which is lower than that of WPC 80%. WPI has a fat content of 0.5% to 1% and less than 1% lactose (USDEC, 2003). The USDEC (2003) recommends that after any type of processing, whey protein powder be stored in temperatures less than 27°C and in a dry, cool environment with a relative humidity less than 65%. The moisture content is approximately 4.5% for both WPC and WPI (Table 5) (USDEC, 2003). WPI is produced in a similar manner to WPC; however, two additional steps are needed. In the first step, whey undergoes a microfiltration process that reduces the fat content. In the second step, residual lactose is removed by lactose hydrolysis (USDEC, 2003). The individual components of liquid whey can also be marketed and include lactose, minerals, and specific proteins (lactoferrin, lactoperoxidase, glycomoacropeptide (GMP), α-lactoglobulin and β-lactoglobulin). The components of whey will be discussed in the next section, however liquid or spray dried whey permeate is also considered a type of whey.

Whey permeate (WP), a deproteinized lactose solution of whey (El-Salam, 1995), is composed of 59% lactose, 10% protein, and 27% ash (USDEC, 2003). WP primarily consists of lactose in a water solution with various minerals and soluble nitrogen

(Fitzpatrick and Smith, 2001; Fitzpatrick and O'Keefe, 2001; Geilman, 1992) and is a by-product of the production of WPC and WPI. WP can be in liquid or spray dried form, both having different compositions. Liquid WP is comprised of lactose (4.8%) and minerals (0.5%) (Macedo, 2002) and spray dried WP has 6.35-8.6% ash and 37% lactose (El-Salam, 1985). WP mineral content consists of sodium, potassium and citrate in concentrations similar to skim milk (El-Salam, 1985). The temperature at which WP is produced will vary the concentration of each mineral.

WP can also be called modified whey and consists of two major products, feed grade and food grade. Food grade permeate has a very low protein content of 3.5 to 8% but a range of 65 to 85% lactose (USDEC, 2003). WP accounts for approximately 90% of the liquid whey volume and WP from the production of WPC and WPI contains approximately 4% non-protein nitrogenous materials (Chandan, 1997). WP has a relatively high concentration of salts and non-protein-nitrogen (NPN, a protein derived from non protein sources), particularly if the permeate is from acid whey (Hardham, 1998). WP is a by-product of whey protein concentrate, a source of dairy solids consisting of 59% lactose, 10 % protein, and 27% ash (dry weight), and is obtained by the removal of protein, selected minerals and lactose from whey (Chapter 4, USDEC, 2003). WP is cost efficient and can be used as a replacement for many dairy solid applications such as sports drinks, bakery, and confectionary products (Von Elbe, 2001).

Components of Whey

The composition of whey protein products varies depending on several factors, including the source of the milk, production method, type of cheese, and manufacturer's specifications (Whey Protein Institute, 2003). Whey proteins consist of a number of individual protein components. Recent advancements in technology have enabled manufacturers to isolate and purify these proteins. Whey proteins have a high biological value (100) and the highest concentration of branched chain amino acids (BCAAs) from any natural food source (Table 6) (Pasin and Miller, 2000). The two major whey proteins are ß-lactoglobulin and α-lactalbumin (Dalgleish, 1997). The natural protein composition of liquid whey is 0% casein protein, 0.7% whey protein, 0.05 % fat, 0.7% ash, 4.9% lactose, and 6.35% total solids (Smithers et al., 1996). The major constituents of the protein present in whey includes: ß-lactoglobulin (54%), α-lactalbumin (21%) and lesser amounts of glycomacropeptides (GMP), bovine serum albumin (BSA), immunoglobulins, lactoferrin, lactoperoxidase and lysozymes (Kinsella, 1984; Smithers et al., 1996).

ß-Lactoglobulin is the most abundant protein in whey and makes up approximately 50-55% of the whey protein. It binds fat-soluble vitamins making them more available to the body and provides an excellent source of essential branched chain amino acids (BCAAs) (Francis and Wiley, 2000). These amino acids help prevent muscle breakdown and store glycogen during exercise. BCAAs may be required in some individuals with liver conditions such as cirrhosis. Hydrolyzed versions of ß-lactoglobulin are often used in infant formulas to reduce potential allergic reactions (USDEC, 2003).

α-lactalbumin is the second most abundant whey protein component and makes up approximately 20-25% of whey protein (Francis and Wiley, 2000). α-lactalbumin is a compact globular protein with 123 amino acid residues and four disulfide bridges (Cayot and Lorient, 1997). α-lactalbumin is high in the amino acid tryptophan, is an excellent source of essential amino acids, and is the primary protein found in human breast milk (Dalgleish et al, 1997;USDEC, 2003). One of the key benefits of α-lactalbumin is that it is the only whey protein component capable of binding calcium (DMI, 2003), making it essential for delivery of calcium to the fetus and infant.

Glycomacropeptide (GMP) is a minor protein component, comprising 15-20% of whey protein (Burrington, 2000; USDEC, 2003). It is produced during the production of renneted cheeses from the reaction of chymosin rennet with κ-casein (Pasin, 2000). GMP can be found in sweet whey but not acid whey since acid whey is formed when the pH is lowered to 4.6 causing isoelectric precipitation of casein rather than rennet hydrolysis (Walzem, 1999). GMP is a biologically active protein that positively affects the digestive system by suppressing the appetite. Therefore, GMP is considered to be a "digestion regulator". GMP promotes excretion of a pancreatic hormone called cholecystokinin, which causes a feeling of satiety (Walzem, 1999; Pasin, 2000; Burrington, USDEC 2003). Another positive effect of GMP is that it helps control and inhibit the formation of dental plaque and dental cavities (DMI, 2003).

Bovine serum albumin (BSA) consists of 582 amino acid residues with one free sulfhydryl group and 17 intramolecular disulfide bonds (Cayot and Lorient, 1997). Approximately 5-10% of whey protein is BSA, the smallest protein component of whey. Nevertheless, BSA has valuable fat binding properties (Francis and Wiley, 2000). BSA can be reversibly denatured by heat or by adding acid or base at 40-50°C (Cayot and Lorient, 1997). BSA also functions to bind fatty acids in the production of the antioxidant glutathione (Frank, 2001; Whey Protein Institue, 2001).

Lactoferrin, a minor protein component, makes up approximately 1-2% of whey protein. Lactoferrin is a cationic protein with an isoelectric point (pI) of 9 and is easily extracted from liquid whey by cation-exchange methods because other protein components of whey have pI's (isoelectric point) in the acidic range (Smithers et al., 1996). Functions and benefits of lactoferrin include protection against free radicals, promotion of cell growth, antioxidant action , and stimulation of the growth of *Bifidobacteria* (Von Elbe, 2001). Lactoferrin inhibits the growth of many harmful bacteria and fungi due to its ability to bind iron. Bacteria such as *E. coli* and *Salmonella* require iron as an essential nutrient to grow (DMI, 2003). Lactoferrin plays an important role in the human cellular defense system by regulating macrophage activity, by stimulating the proliferation of lymphocytes, (Frank, 2001; Pasin, 2000; Whey Protein Institute, 2003) and is a naturally occurring anti-oxidant in the human body (Whey Protein Institue, 2003). Immunoglobulins operate in conjunction with lactoferrin to provide a stronger human immune system. Currently, the major application for lactoferrin is in infant formula. The addition of lactoferrin enriches the formula, making it similar to breast milk (USDEC, 2003).

Immunoglobulins (Ig) are a major protein found in colostrum (Whey Protein Institute, 2003), the thin yellowish fluid secreted by the mammary glands at the time of parturition, and precedes the production of true milk. Immunoglobulins (Igs) are 10-15% of total whey protein. Three classes of bovine Igs are Ig G, Ig A, and Ig M. Immunoglobulins show higher denaturation temperatures than those of ß-lactoglobulin. A study by Cayot and Lorient (1997) found that Igs are very heat sensitive in the presence of BSA, probably due to the interaction with the free thiol group. Other minor protein constituents of whey protein are lactoperoxidase (0.5%) and lysozyme (>0.1%) (DMI, 2003). Lactoperoxidase is commonly known as a natural antimicrobial agent.

Processing Whey

Processing steps can alter the characteristics of whey products. These steps include heating, pH, and chemical treatments which can result in the modification of whey protein structure and functionality. Whey powder has a high mineral content, therefore a demineralization step must be used before whey can be used in many food and/or beverage applications. Removal of a portion of the minerals will yield demineralized whey, consisting of 11% fat, 70% lactose, 0.5% fat, and 3% moisture (USDEC, 2003). Demineralization can be conducted by a variety of different methods such as electrodialysis, diafiltration or ion exchange (Walzem, 2003; USDEC 2003). Once demineralization has occurred, concentration, crystallization, and spray drying are carried out to obtain the final product, demineralized whey powder (Walzem, 2003; USDEC, 2003).

Dried whey ingredients are manufactured after pasteurization and clarification of liquid whey (Laye et al., 1995). After clarification and pasteurization, liquid whey is cooled and held to stabilize the calcium phosphate complex. Much of the liquid whey produced cannot be used in its liquid form and is spray dried into whey powder (Smithers et al., 1996). The pH is adjusted to 6.0 in order to stabilize calcium phosphate and remove phospholipoproteins (Cayot and Lorient, 1997). Phospholipoproteins are released from the milk fat globule membrane into the whey during cheese making (Morr & Ha, 1991). These phopholipoproteins, along with small sized milk fat globules that are not removed from the whey, are concentrated along with protein in the retentate fraction during ultrafiltration (UF) of liquid whey. By removing the phopholipoproteins from cheese whey prior to UF and diafiltration (DF) in the manufacture of WPC and WPI, improvements are made in compositional and functional properties (Morr & Foegeding, 1990). Removal of lipids and other constituents allows for an increase in flavor stability and overall a better functional whey protein product.

There are several industrial methods suitable to selectively further concentrate the whey protein including, ultrafiltration (UF), ion exchange (IE), and microfiltration (MF). The most commonly used method is UF, where low molecular weight compounds such as lactose, minerals, non-protein nitrogen, and vitamins are filtered from the whey to form the permeate and the proteins are concentrated in the retentate (McDonough, 1974). During UF, whey is pumped or filtered through a low molecular weight membrane filtration unit which causes the whey to divide into the retentate (a protein concentrate) and a permeate (the lactose and mineral part) (Chandan, 1997; McDonough, 1974). Nearly all true protein, fat, and colloidal salts are retained in the retentate, while water-soluble vitamins and selected minerals are fractioned between the retentate and the permeate. The extent of this division depends on the initial composition, molecular weight and concentration of the components (Patel, 1997). The byproducts of whey protein production, i.e., lactose, minerals, non-protein nitrogen and vitamins, which are filtered from the whey, are together called permeate (McDonough, 1974).

The retentate (a protein concentrate) is comprised of protein, fat, colloidal salts, fat soluble vitamins, and selected minerals. After pasteurization, the retentate may be evaporated and then spray-dried. Spray drying is conducted at a lower temperature than milk spray drying to avoid protein denaturation (DMI, 2003). WPC is manufactured by spray drying the resulting products after the removal of sufficient non-protein constituents from pasteurized whey so that the finished dry product contains greater than 25% protein. The non-protein constituents are removed by physical separation techniques such as precipitation, filtration or dialysis. Safe and suitable pH-adjusting ingredients may be used to adjust the acidity of WPC.

WPI is obtained by removing sufficient non-protein constituents from whey so that the finished dry product contains no less than 90% protein (Burrington, 2000). WPI contains greater than 90% protein and typically contains less lactose than other whey ingredients, usually around 4% (Morr and Foegeding, 1990). The fat is first removed by microfiltration and the whey is then ultrafiltered and diafiltered to recover the minerals and lactose (deWit and Moulin, 2001). Two other processes, electrodialysis and ion exchange can be used. In addition to concentrating protein and fractionating whey into individual proteins, whey protein ingredients like WPC and WPI can be subjected to controlled enzyme hydrolysis in order to yield smaller protein fragments. A specific level of hydrolysis can be targeted for a specific functional benefit. As the level of hydrolysis increases, the digestibility, absorption, and retention of nitrogen increases and the allergenicity of the protein decreases (Burrington, 2000).

By the use of an ion exchange system, up to 100% of the minerals can be removed from the WPI (Varnam and Sutherland, 1994). A WPI produced by ion exchange tends to retain less calcium, phosphorus, potassium and greater sodium than WPI produced by microfiltration (Varnam and Sutherland, 1994). Microfiltered WPI contains the glycomacropeptide fraction, whereas WPI manufactured by ion exchange will not (Varnum and Sutherland, 1994). For WPI produced by ion exchange, during the pasteurization step, liquid whey is brought to acidic pH causing the whey proteins to be positively charged. The positively charged whey proteins are then pumped into a tank that contains negatively charged resin beads while all other components such as fat, lactose, and minerals, are removed. Once the resin is loaded with protein, the pH of the tank is made alkaline so the proteins detach from the resin and a very dilute whey protein is eluted, microfiltrated, diafiltered, and spray dried (Huffman, 1996).

Reverse osmosis (RO) is used to remove water and is a filtration step used in the production of many WPCs and WPIs. Reverse osmosis partially concentrates the whey prior to vacuum evaporation. Removal of lactose and minerals requires reverse osmosis and ultrafiltration processing (Smith et al., 1999; USDEC, 2003). Before the whey concentrate is spray dried, lactose crystallization is induced to decrease the hygroscopicity. Crystallization occurs in agitated tanks and takes anywhere from 4 to 24 hours. A fluidized bed may be used to produce large agglomerated particles with free-flowing, non-hygroscopic, no caking characteristics (Smith et al., 1999, USDEC, 2003; DMI, 2003).

A recent process to manufacture whey protein powder, patented by Invensys APV, is known as the Super Concentrated Whey (SCW) process (Anonymous, 2003). The SCW uses a specialized APV evaporator prior to crystallization of the lactose and spray drying. The process follows for a period of 10-15 hours, in order to achieve the correct level of crystallization before the liquid is spray dried. This method is known to be a highly efficient way of concentrating the whey to 68-70% protein (Anonymous, 2003).

Properties and Applications

Whey protein products such as WPCs and WPIs are highly functional groups of dairy ingredients widely used in various food applications (Foegeding et al., 2002). They are widely used as ingredients in foods due to their unique functional properties, i.e. emulsification, gelation, thickening, foaming, and fat and flavor binding capacity (Bryant and McClements, 1998). US whey products possess many different functional properties that lend themselves naturally to multiple applications as food ingredients. Over the years, utilization of whey proteins as functional ingredients has increased.

Kinsella (1984) described functional properties of whey proteins as physicochemical properties which govern the performance and behavior of proteins in food systems during processing, storage, preparation, and consumption. The functional properties of whey proteins affect the way the protein interacts with other components, especially when placed in a food application. A number of factors influence the functional properties of whey proteins such as the source of whey, protein content, treatment used during manufacturing, lipid, and mineral content. Whey proteins possess a wide range of functional properties such as fat and flavor binding, solubility, gelation, emulsification, and foaming (USDEC, 2003). Of the various whey protein powders that exist, WPI has a higher level of protein than WPC. Both WPC and WPI have astounding functional attributes such as emulsification, whipping, fat binding, solubility, heat setting/gelling properties, and water binding/thickening properties (McDonough et al., 1974).

WPC has many valuable functional properties as a food ingredient. WPC can modify properties in food such as flavor/texture, visual, hydration, surfactant, structural, textural, and rheological (DMI, 2003). The functional properties of whey protein concentrate are adversely affected by the residual lipid content of WPC (Morr and Ha, 1991). Whey proteins offer a wide range of potential functionality. WPC have lower protein content and are more limited in functionality than those of higher protein content such as WPI. Whey protein concentrates are typically very soluble though their water binding capacities are relative low (Smith et al., 1999; USDEC, 2003). Whey proteins remain soluble over a wide pH range and in particular near pH 4.5, so they may be used in acidic drinks as protein supplements. They may also bring emulsifying properties and turbidity to products (DMI, 2003).

The functional properties of whey proteins are often governed by a specific conformational state. Therefore, any modification or alteration affecting that state will affect the functionality (Mulvihill, 1992). Several factors that can cause protein denaturation are heat, pressure, interfacial forces, extreme pH changes, and organic solvents (Boye et al., 1997). Heat treatment is the most commonly used agent in food processing and the extent to which proteins unfold (denature), influences the overall functional and nutritional quality (Boye et al., 1997). BSA and Ig are the most heat sensitive of the whey proteins, based on solubility at pH 4.6 (Harper and Zadow, 1984). Moderate heat treatment of whey protein concentrate has shown to improve its foaming properties (Harper et al, 1984; Richert et al., 1974) and emulsification properties (Schmidt et al., 1984). The pH of a protein solution affects the denaturation temperature of proteins.

Whey Flavor

Whey itself has a purportedly bland and delicate flavor (Laye et al., 1993) which allows it to blend well with most products. Depending on the food application, whey protein can bring out already present flavors. When whey protein is heated, volatile sulfides are produced. Free amino acids are converted to flavorful compounds by heat and chemical interaction with other compounds. The release of the highly hydrophobic c-terminal end of casein and short chain fatty acid from milk triglycerides can impart bitterness and increase the rate of rancidity in dairy products (Shipe et al., 1984). Whey proteins provide a range of aromatic flavors to products. In beverages, whey is bland and the slight sweet flavor allows other fruit and chocolate flavors to come through. In soups and sauces, spice, and herb flavors are accentuated. Whey minerals also enhance dairy, meat, and savory foods (USDEC, 2003).

Off-flavors can form during the storage of spray dried whey products. Reactions that can contribute to off-flavors are Maillard browning and lipid oxidation. Ferretti and Flanagan (1971) found 55 different compounds that were formed during the accelerated storage (70°C and 75% relative humidity) of dried whey. The most abundant volatile compounds were maltitol, 2-acetylfuran, furfuryl alcohol, acetic acid, and dimethylsulfone. They also found 24 non-enzymatic reaction products in whey powder stored at 4°C for 3 years (Ferretti and Flanagan, 1971). These experiments demonstrated that degradative Maillard and lipid oxidation reactions occurred in low moisture, low lipid whey products.

Maillard browning occurs when there is a reducing sugar and a free amino group (BeMiller and Whistler, 1996). The Maillard reaction and Strecker degradation of alpha amino acids are responsible for the formation of heterocyclic compounds with distinct aromas and low odor thresholds. When the reducing sugar and free amino group react, many flavor compounds such as cooked and caramelized flavors are formed (Bemiller and Whistler, 1996). Even at refrigeration temperatures, Maillard reactions can occur, but at higher temperature the reactions occur more readily and volatiles are frequently formed during cooking. Also, Maillard reactions are commonly associated with foods that have been dehydrated by heat, such as dried whey powder (Whitfield, 1992). The rate and extent of Maillard reactions in dried whey and WPC can be controlled by alternating temperature, pH, storage time, addition or elimination of specific enzymes, and/or water activity (Morr & Ha, 1991). These reactions whether in liquid whey or spray dried whey protein products, produce undesirable off-flavors.

Badings et al. (1980) concluded that oxidation flavors were related to the breakdown of unsaturated fatty acids and were due to aldehydes and ketones (Badings et al., 1980). Lipid oxidation reactions were thought to initiate the deterioration of flavor in whey products through the formation of lipid oxidation products that contribute to off-flavors and the promotion of Maillard reactions (Tomaino et al., 2001). According to Morr and Ha (1991), aged, stale off-flavor is the single most important flavor criticism of dried whey and whey protein products. Two major factors, previously described, contribute to the formation of off-flavors in whey protein products, i.e., lipid oxidation and Maillard browning. Factors that may impact the development of off-flavors in WPC include: processing treatments, drying conditions, lipid oxidation and non-enzymatic browning reactions, and temperature conditions (Morr and Ha, 1991). WPC contains a variable amount of residual lactose and 3-7% lipid materials that are susceptible to chemical reactions resulting in the development of typical stale and aged off-flavors (Morr and Ha, 1991). Processing treatments such as chemical pretreatment, microfiltration, ultrafiltration, and diafiltration aid in removing materials (residual lactose and minerals) therefore improving flavor stability and functionality (Morr and Ha, 1991). There are numerous processing treatments that may impact the development of off-flavors in WPC and affect the composition of the whey and WPC. These include drying conditions, non-enzymatic browning reactions, and moisture and temperature conditions which affect the kinetics of the lipid oxidation and browing reactions during WPC storage (Morr and Ha, 1991; Morr and Foegeding, 1990).

Unlike WPIs, WPCs contain residual lactose, lipids, phospholipids, lipoproteins and metal ions, which makes them more susceptible to lipid oxidation and Maillard browning reactions (Morr and Ha, 1991). Morr and Ha (1991) discussed the contribution of off-flavors in WPC from chemical pathways such as Maillard browning and lipid oxidation. Mills (1993) identified compounds in fresh WPC which were products of lipid oxidation and Maillard browning reactions. The compounds identified by Mills (1993) in freshly prepared WPC were saturated and unsaturated aldehydes, methyl ketones, alcohols, alkyl pyrazines, and saturated fatty acids (Mills, 1993). In another study conducted by Mills and Broome (1998), 2,3-butanedione, 3-methyl butanal, 1-pentanone, pentanal, hexanal, 2-heptanone, heptanal, and benzaldehyde were isolated from WPC. They concluded that the volatile compounds identified could have arisen from such chemical pathways as Maillard browning, lipid oxidation, and thermal degradation of beta-keto fatty acids (Mills and Broome, 1998).

Advances in the technology of specific manufacturing methods for processing whey have solved many problems. Aged, stale off flavors were identified in dry whey protein concentrate (Morr and Ha, 1991). WPC products ideally exhibit a bland flavor immediately after drying, but develop a typically stale off-flavor during storage due to lipid oxidation and Maillard browning (Morr and Ha, 1991). Improved UF and DF technology is utilized to manufacture WPC with lower lactose content (<5% w/w) which effectively improves the flavor stability of WPC by reducing the amount of lactose available for Maillard browning reactions (Morr and Foegeding, 1990). Morr and Foegeding (1990) found commercial WPIs to exhibit a considerably higher flavor quality and functionality than WPCs (Morr and Foegeding, 1990). The poor flavor and relatively high lactose and mineral content of the WPCs represent a serious problem which limits their acceptance and use by the food industry (Morr and Foegeding, 1990).

Sensory Analysis

Sensory evaluation is a scientific discipline used to evoke, measure, analyze, and interpret reactions to characteristics of foods and materials perceived by the senses of sight, smell, taste, touch and hearing (Meilgaard et al., 1999). Sensory analysis methods are used in quality control, product development, marketing research, and development applications. The primary goal of sensory analysis is to conduct valid and reliable tests in producing data for which important and sound decisions can be made (Meilgaard et al., 1999). Lawless and Heymann (1999) identified the two primary areas of sensory analysis to be analytical and affective tests.

Analytical tests consist of discrimination tests, threshold determination, and descriptive analysis (Lawless and Heymann, 1999; Meilgaard et al., 1999). Discrimination tests consist of three different sub-categories all of which are based on the perceived differences between two products, e.g., paired-comparison, triangle testing, and duo-trio testing (Stone and Sidel, 1993; Lawless and Heymann, 1999). Discrimination tests are to be used when there is a slight or minimal difference between samples (Chambers and Wolf, 1996) and is applicable in product reformulation, product positioning, ingredient changes, and cost reduction changes (Chambers and Wolf, 1996; Marketing Research Methodological Foundations, 2003).

Threshold testing is a method to determine the strength or concentration of a stimulus required to produce effects on four different levels (Chambers and Wolf, 1996). The four different levels include detection threshold, recognition threshold, difference threshold, and terminal threshold (Chambers and Wolf, 1996). These methods are used in determining product acceptability, detecting product contaminants, and to assist in product formulation (Chambers and Wolf, 1996; Stone and Sidel, 1993).

Descriptive analysis is the description of both qualitative and quantitative sensory aspects of a product using trained panelists (Meilgaard et al., 1999). Qualitative aspects involve selecting the characteristics in a product (appearance, flavor, aroma and/or texture). Quantitative aspects involve intensity ratings of the characteristics of a product. Adults or children are the panelists used as an instrumentation source. Panelists are screened, selected, (approximately 6-15 people), and then trained. Descriptive panels usually require 50-100 hours of training prior to collecting and using panel data

(Meilgaard et al., 1999). After an extensive training, panelists have the expertise to evaluate aspects of a food product qualitatively and quantitatively.

Affective tests consist of two categories, qualitative tests and quantitative tests. Qualitative tests consist of focus groups, focus panels, or one-on-one interviews (in person, by phone, or by email) (Meilgaard et al., 1999). Quantitative tests consist of preference tests and acceptance tests (Meilgaard et al., 1999). Affective tests typically use consumers or panelists that are untrained for a particular product evaluation.

Sensory Analysis of Whey

Sensory analysis has been applied to whey products. A sensory study was performed by Morr and Foegeding (1990) on three commercial WPIs which were compared to eight commercial WPCs. The three WPIs exhibited a bland flavor with a slight indication of old whey powder off-flavor with 0-2 intensity on a 5-point scale. The eight WPCs exhibited a stale, old whey powder flavor with a 4-5 intensity rating on a 5-point scale. These results indicated that lipid and lactose concentration may be very important in controlling the flavor stability of WPCs and WPIs.

Formal descriptive sensory analysis has also been applied to liquid whey and dried whey ingredients. Carunchia Whetstine et al. (2003) and Karagul-Yuceer et al. (2003) used descriptive sensory analysis in conjunction with instrumental analysis to characterize the flavor of liquid whey. Drake et al. (2003) identified and developed a descriptive sensory language to profile the flavor of dried dairy ingredients, including WPC and WPI. Drake et al. (2003) found off flavors in WPC such as animal/wet dog, cardboard, metallic and high astringency intensities (Drake et al., 2003). Clearly, whey products are not necessarily mild and bland in flavor.

Health Benefits

Whey protein is a major component of the diet and is increasingly important to the human diet. Whey products are an excellent source of vitamins such as thiamin, riboflavin, pantothenic acid, and vitamin B6 and B12 (USDEC, 2003). Whey protein products range in the content of protein, minerals, and fat levels to ensure optimal performance and functionality. Incorporating whey proteins into food products provides exceptional nutritional benefits.

Whey and whey components contain a number of valuable minerals. These minerals help to enhance the functionality of whey proteins. These include monovalent sodium, potassium and chloride ions, magnesium, citrate and phosphate (Anonymous, 2001). Whey is also an excellent source of bioavailable calcium which prevents bone loss in both hypoestrogenic female athletes as well as post-menopausal women (Pasin and Miller, 2000).

WPCs have high protein levels and overall are very nutritious. Whey proteins are a good source of sulfur-containing amino acids which are proven to maintain antioxidant levels in the body (Pasin and Miller, 2000). The whey protein ß-lactoglobulin is an excellent source of essential and branched chain amino acids which are required in some individuals with liver conditions (USDEC, 2003). Incorporating whey products into the diet of those who suffer from cirrhosis may have a positive effect and overall health benefit. Hydrolyzed whey proteins have contributed to reducing the problem of infant allergic reactions associated with infant formula (USDEC, 2003).

Essential amino acids make-up over 60% of the total protein content of whey (Pasin, 2000). One method used to measure protein quality based on the amino acid requirements of humans is the Protein Digestibility Corrected Amino Acid Score (PDCAAS) which is endorsed by the USDA (Pasin and Miller, 2000). PDCAAS must follow a criteria that includes approximate nitrogen composition, essential amino acid profile, and true digestibility (Pasin and Miller, 2000; USDEC, 2003). According to the PDCAAS, the ideal protein has a value of 1.0 and meets all of the essential amino acid requirements of the human body (Pasin and Miller, 2000). Whey protein has a maximum score of 1.14 (Pasin and Miller, 2000). Whole egg and milk casein have scores of 1.0, soy protein has a value of 0.99, and wheat gluten 0.25 (Table 7) (Whey Protein Institute, 2001; Frank, 2001).

Soy

Soy History

Much of soybean history has recently been uncovered due to the attention that has been focused on studying the interrelationships between the domestication of plants and animals (Hymowitz, 1970). Soybeans are a native crop of eastern Asia (Wolf and Cowan, 1975). Domestication of the soybean is believed to have originated in the northern and central regions of China as long as 5000 years ago, with the first documented use of the plant by a Chinese emperor in 2838 B.C. (Liu, 1997). From China, soybean cultivation spread throughout Japan, Korea, and Southeast Asia, becoming an important source of food and medicine (Messina, 1995).

Soybeans were first brought to Europe in 1712, however utilization was limited by poor climate and soil conditions (Liu, 1997). It was not until their introduction to North America in 1765 by Samuel Bowen that the Western world began to realize the value of soybeans (Hymowitz, 1970). Other early importers included Benjamin Franklin, who sent soybean seeds from London to Philadelphia in 1770 (Hymowitz, 1970). Although the influx of soybeans increased throughout the 18^{th} century, it was not until the 19^{th} century that production of soybeans was widespread throughout North America. With the advancements in soybean oil processing in 1915, soybeans made the transition from a limited seed crop to a commercially viable commodity (Wolf and Cowan, 1975). During the 1920's, thousands of new varieties of soybean were brought to America from China, as demand increased (Liu, 1997). In 1939, US soybean production rose to over 90 million bushels annually and by the mid-1950's the US surpassed China as the global leader in soybean production and exportation (Liu, 1997). Historically, soy protein isolate was developed for making spun fibers for use in meat analogs and sometimes, restructured meats (Campbell 1981; Riaz 1999).

Soy Production

U.S. soybean production in harvest year 1999-2000 was 71.9 billion metric tons, 46.2% of the total world production (ADPI, 1998a). In 1999, the U.S. exported 32% of its total soybean production at a total value of $4.5 billion (Soya Bluebook, 2001). Since 1970, soybean production has been at least double that of any other oilseed, increasing in world oilseed production share from 32% in 1965 to over 50% in the 1980’s and 1990’s (Smith and Huyser, 1987; Soy and Oilseed Bluebook, 2001).

U.S. soybean and product exports increased to $6.66 billion in 2000 (USB, 2001). The two leading importers of U.S. soybeans are Japan, at $758 million, and Mexico, at $678 million (USB, 2001). In 2000, US farmers produced 2.770 billion bushels of soybeans, averaging a price of $4.40 per bushel. Soybean oil provides 80% of the fat and oil consumption in the U.S. (USB, 2001). In 1947, 85% of the soybean crops were harvested for seed processing in the production of soybean oil (Orthoefer, 1978). Within the last ten years, soybean oil was the major cash product of soybean production.

Soybean oil is the world’s leading vegetable oil and accounts for well over half of the fats and oils incorporated into food products in the U.S. Soybean oil can be found in salad oils, shortening and margarine, used for cooking, soap, paints, resins, and drying oil products (Scott and Aldrich, 1993; Orthoefer, 1978). Until recently, soybean oil was the primary high value product obtained from the soybean. Currently, a multitude of soy protein products are produced in addition to soybean oil.

Types of Soy Products

There are many varieties of soybean products produced throughout the US and internationally. Of the types of soybean products, other than oil, only four types are formed from the original soybean. The four major types are full-fat soy flour, defatted soy flour, soy protein concentrate (SPC), and soy protein isolate (SPI). During processing, the original soybean macrostructure is completely destroyed in each of the four forms. Therefore, all four forms vary in fat, carbohydrate, protein content and especially functionality (Cowan et al., 1973). The four groups are classified on a moisture-free basis, with SPI having the highest protein content (90-92%), SPC at 65-72%, and all soy flours ranging from 56-59% protein (Soy Protein Council, 1987). Isolated and concentrated soy proteins can be used in a wide variety of foods. Soy flours, soy protein concentrate, and soy protein isolate are the three basic types made from defatted soybean flakes (Scott and Aldrich, 1983).

The soybean is recognized as a valuable source of edible oil and an excellent source of protein for human and animals (Liener, 1994). Extracted flakes contain about 50% protein and are used as a source of protein in animal feed (Ferrier, 1975). SPC are originally spent soy flakes that have been grinded and sized to contain 65% or more protein, in addition to other components. These other components, carbohydrates and dietary fiber, have strong flavor compounds, flatulence-promoting sugars, and have been leached before drying (Lusas and Rhee, 1995). Further description of the leaching process will be discussed later. SPC and SPI, compared to soy flours, can be used in the same foods but SPC and SPI can be used in greater quantities due to their improved flavor, color, and high protein content (Kinsella, 1979).

Traditional soyfoods, those foods prepared from whole soybeans (Scott and Aldrich, 1983), are typically divided into two sub-categories of soy food types: non-fermented and fermented soy products. Traditional non-fermented soyfoods include soy milk, fresh green soybeans, whole dry soybeans, soy nuts, soy sprouts, whole-fat soy flour, and tofu (Goblitz, 1995). Soy nuts are typically dry roasted and characteristically eaten as a snack food. Soy sprouts, prepared by soaking, washing and sprouting of soybeans, are consumed as a vegetable throughout the year in many Asian countries and in the US are typically seen in soups, salads, and side dishes. Soymilk and tofu begin with the soaking of the whole soybeans, rinsing, grinding, and filtering. The insoluble residue is called okara and can be used in dishes or a fermentation step can be added to yield a product called tempeh (Liu, 1997). Further processing of the filtered soybean liquid produces soymilk. Tofu is made from processing the soymilk, then adding a coagulant to precipitate the protein from the soymilk. The precipitate is pressed into a solid, then dried, frozen or fried (Liu, 1997).

Traditional fermented soyfoods include: miso, tempeh, soy sauces, natto, and fermented tofu (Golbitz, 1995). Tempeh is a product produced from the fermentation of dehulled, boiled soybeans by *Rhizopus oligosporus*. This fermentation yields a cake-like product with a clean yeasty odor, covered completely by mycelium. Tempeh is usually a main dish or a meat substitute in a vegetarian or Asian diet. When it is sliced and deep-fried, it has a pleasant aroma, crunchy texture and nutty flavor (Liu, 1997). Miso, meaning fermented bean paste, is used as a base for soups or as a flavoring. Varieties of miso are rice miso, barley miso, and soybean miso. The production of miso starts with rice, barley, or soybeans that have been soaked, cooked, cooled, and inoculated with a mixure of strains of *Aspergillus orzae* and *Aspergillus soyae*. The product is fermented and ripened prior to blending and mashing to form the final product (Liu, 1997).

Components of Soy (Composition)

Soybeans are composed of approximately 37% protein, 18% oil, 15% soluble carbohydrate, 15% insoluble carbohydrate, and 14% moisture (Figure 2) (ASA, 2003). Humans can easily digest soy protein products. Approximately 92-100% of soy protein is digestible in humans (Riaz, 1999).

Amino acids are the building blocks of protein necessary for human growth and maintenance. Soy protein is a good source of all the essential amino acids except methionine and tryptophan. Eight essential amino acids can be found in soybeans some of which are not naturally produced in the human body but are important to human nutrition (ASA, 2003). The high lysine content of soy protein makes it a good complement to cereal proteins, which are low in lysine. Soybean protein does not have gliadin or glutenin, the unique proteins of wheat gluten. Gluten is the protein in wheat, which is required to form leavened bread. As a result, leavened breads can only be made from wheat and rye flours. Soy flour can be added to wheat flour in bread, but cannot replace all of the wheat flour. Soy proteins have a relatively high solubility in water or dilute salt solution at pH values below or above the isoelectric point. Soybeans are the highest natural source of dietary fiber, 4.6 grams (per 100 grams) (ASA, 2003). Soy flour and grits are the least refined forms of soy protein used for human consumption (Soy Protein Council, 1987). Soy flour and grits are obtained by grinding and screening defatted flakes to various sizes (Hettiarachy and Kalapathy, 1997). Soy flours are available in enzyme-active forms, which are non-heat treated. This form of soy flour contains active enzymes, which facilitates the natural bleaching of wheat flour for use in bakery applications. Soy flours are available in various degrees of water solubility, expressed as Protein

Dispersibility Index or Nitrogen Solubility Index (Lusas and Rhee, 1995). Per 100 gram sample, defatted soy flour contains 51.4 grams of protein, 33.9 grams of carbohydrate, 17.5 grams dietary fiber, and 1.22 grams of fat (USB, 2003). Uses of soy flour and grits include milk replacers, baked goods, pasta products, and infant formulas as well as additives to coarsely ground meat products, candies, confections, and desserts (Rakosky, 1974; Soy Protein Council, 1987).

SPC contains a minimum of 65% - 72% protein on a moisture-free basis (Lusas and Rhee, 1995). SPCs are essentially flours whereby water or alcohol-soluble components, including flatulence-promoting sugars and strong flavor compounds, are leached before drying (Lusas and Rhee, 1995). SPC, compared to soy flours, can be used in the same foods as flours but in greater quantities due to their improved flavor, color, and higher protein content (Kinsella, 1979). Soy concentrates are made of defatted soy meal, resulting in a very low amount of fat (1%) (Liu, 1997). An increased level of purification from soy flour to concentrates results in a compositional change, especially the protein and carbohydrate content (Liu, 1997). SPC on a moisture-free basis contain 65-72% protein, 0.5-1.0% fat, and 19-21% carbohydrate, 3.4-4.8% of which is crude fiber (Table 8) (Liu, 1997).

As the degree of purification increases from soy flour to isolates, the composition changes, especially the protein and carbohydrate content (Liu, 1997). In SPI both soluble and insoluble carbohydrates are removed causing an increase in protein content (Liu, 1997). SPI, on a moisture-free basis, contains 90-92% protein, 3-4% carbohydrate, 0.1-0.2 % of which is dietary fiber, and 0.5-1.0 % fat (Table 8) (Liu, 1997).

SPC and SPI are made from soy meal and contain very low amounts of fat (0.5-1%) (USB, 2001). Both SPC and SPI are the most refined forms of soy protein used as food sources. SPC and SPI are obtained by further processing defatted flakes and flour to remove the low molecular weight components which include the water soluble sugars, ash, and other minor constituents of defatted soy flakes or flour (Hettiarachy and Kalapathy, 1997; Liu, 1997). The major difference between SPC and SPI lies in the protein and carbohydrate value. SPC is less purified than SPI, and therefore SPC has a lower protein and a higher carbohydrate content (Soy Protein Council, 1987). The soluble carbohydrates are removed in soy concentrates whereas in isolates both insoluble and soluble carbohydrates are removed.

Properties and Applications

Soy protein ingredients must possess appropriate functional properties for food applications and consumer acceptability (Table 9) (Kinsella, 1979). These are the intrinsic physicochemical characteristics which affect the behavior of protein in food systems during processing, manufacturing, storage and preparation, including sorption, solubility, gelation, surfactancy, ligand-binding, and film formation. Until the development of soy protein concentrate and soy protein isolate in the late 1900's, the major reason for adding soy protein to foods in the US was for functionality rather than a source of dietary protein (Wolf and Cowan, 1975). SPC and SPI are used for nutritional and functional food applications in nearly all consumer food categories (Soy Protein Council, 1987). Functionality of SPC and SPI are related to surface-active properties, gelling abilities, and fat and water absorption (Orthoefer, 1978). The form of isolate used in a specific food application varies according to its characteristics such as solubility, gelation, emulsification, dispersibility, viscosity, and retort (Orthoefer 1978; Richert and Kolar, 1987; Soy Protein Council, 1987).

Solubility is one of the most important properties of a soy protein when used in a beverage application. Other requirements include that the protein should form a clear and translucent solution that is bland, possess low viscosity, and demonstrate stability over a wide range of pH, ionic strength and temperature conditions. The interactions of soy proteins with water are important in relation to dispersibility, water absorption and swelling, viscosity, gelation and surfactant properties. These properties directly influence the important functions of soy proteins in beverages (Kinsella, 1979). Other specific functional properties are crucial in other ingredient applications.

Processing of Soy

SPC is obtained by removing the water-soluble sugars, ash, and other minor constituents from defatted soy flakes or flour. There are three process to commercially prepare concentrates, i.e., acid leaching (isoelectric pH 4.5), aqueous ethanol (60-80%) extraction, and moist heat-water leaching (Figure 3) (ASA, 2003). All three processes differ by the method used to remove the low molecular weight components while insolubilizing major proteins (Hettiarachy and Kalapathy, 1997). In all three treatments protein becomes insolubilized while a portion of the carbohydrate remains soluble so that separation becomes possible by centrifugation. Solids containing mainly proteins and insoluble carbohydrates are then dispersed in water, neutralized to pH 7, and spray dried to produce soy concentrates. Most commercial soy concentrates are made by the aqueous alcohol extraction or acid leaching process (Liu, 1997).

Aqueous alcohol extraction is commonly employed for commercial production of soy protein concentrates. In this process, alcohol-soluble carbohydrate and minor flavor/odor compounds are extracted from defatted soy flour using a countercurrent stream of aqueous alcohol in a plateless column. The extracted wet flakes containing proteins and insoluble polysaccharides are continuously removed, desolventized, and dried to yield concentrates with bland flavor. The concentrates produced have low nitrogen solubility due to denaturation by alcohol (Liu, 1997).

In the acid-leaching process, defatted soy flakes are leached with water in a ratio of 20:1 at the isoelectric pH (pH 4.5) of soy proteins to remove soluble carbohydrate. This procedure takes 30-45 minutes at 40°C. The insoluble residue containing protein is separated by decanting or centrifugation, neutralizing to pH 7, and then spray dried. Soy protein concentrates with high nitrogen solubility and low microbial count can be produced using this process (Liu, 1997). For the leaching process, defatted soy flakes are heat treated to denature protein and are then insoluble in water. Soluble carbohydrate and salts are then removed from insoluble protein and polysaccharide material by water leaching. The product is then spray dried which yields soy protein concentrate (Liu, 1997).

SPI is the most refined product made from defatted soybean meal (Soy Protein Council, 1987). SPI is typically processed by solvent extraction, aqueous extraction, drying, and toasting. SPIs are commercially prepared from defatted soy meal by using aqueous or alkali extraction of proteins at a pH range of 7-10 (USB, 2003). By adjusting the pH to the isoelectric point of the proteins, the soy protein globulins are precipitated. The insoluble carbohydrates are removed by centrifugation followed by precipitation of soy protein at its isoelectric point. This process reversibly and then irreversibly modifies the solubility of the proteins (Liu, 1997). Initially soluble in pH 7.6 and 0.5 ionic strength buffer, the proteins are no longer completely soluble after isoelectric precipitation. The precipitated protein is separated by mechanical decanting, washed, and neutralized to a pH of 6.8, and then spray dried. The result is a highly purified form of soy protein with minimal beany flavor (Liu, 1997). Exposure to moderately high pH followed by readjustment to neutral pH has been found to activate soy protein and improve functional properties (Pour-El and Swenson, 1976). Isolates from different manufacturers are similar in their chemical compositions but dissimilar in physical properties because of processing variations (Liu, 1997). The source of the soy protein and process of manufacturing should be considered when evaluating SPI.

Both SPC and SPI can be manufactured by processes called thermoplastic extrusion and steam texturization. These texturizing processes are for use as meat extenders (Johnson et al., 1992). Dairy products and milk are often replaced by soy foods such as soy milk, tofu, soy protein, or other soy fractions used as dietary supplements. Soy protein powders are versatile in that the powder can be added to beverages, prepared as premixed beverages, and mixed with food. The form of isolate used in a specific food application varies according to its characteristics such as solubility, gelation, emulsification, dispersibility, viscosity, and retort treatment (Soy Protein Council, 1987).

Soybean Oil Extraction

Nearly all of the soybeans produced in the U.S. are processed in oil extraction plants (Ferrier, 1975). The general steps of oilseed extraction are oilseed preparation, solvent extraction, solvent and oil recovery, meal desolventizing, and finishing (Becker, 1978). Hexane is the accepted solvent for oil extraction of soybeans and oilseeds throughout the world. Modern soybean processing generally involves oil extraction by the use of hexane to produce crude soybean oil and defatted meal (Becker, 1978; Orthoefer, 1978). Solvent extraction of soybeans is a diffusion process in which the solvent (hexane) selectively dissolves miscible oil components (Proctor, 1997; Milligan, 1976). Solvent extraction primarily encompasses first the recovery of lipids from a seed structure which has been prepared to facilitate its penetration by a solvent, and second the diffusion of the lipid-solvent mixture or miscella to the surface of the solid (Milligan, 1976).

Oil processing begins with the cleaning, cracking and dehulling of dried soybeans. The cracked beans are then conditioned in a steam-jacketed cooker, a vertical stack type dryer or a rotary steam-tube dryer type (Mount et al., 1987). Next, conditioned, cracked beans are flaked by passing between horizontal, pressurized, smooth rollers producing flakes approximately 0.01-0.0015 inches thick (Proctor, 1997). Properly prepared flakes are essential to a consistent and high-quality extraction (Becker, 1978). Flaking is important prior to solvent extraction as solvent can much more readily flow through a bed of flakes than through a bed of soy meats or fine particles (Proctor, 1997).

After flaking, the flakes are transported to the extractor by enclosed mass-flow type conveyors designed to minimize flake breakage (Mount et al., 1987). The extractor is the heart of the process and must convey large volumes of solids, contact these solids with equally large volumes of circulating liquids, and efficiently separate liquids and solids in such a way as to minimize stage-to-stage carryover of liquid on solids (Milligan, 1978). During extraction, the miscella becomes richer in oil, resulting in the oil/hexane mixture obtained by flake extraction consisting of 70-75% oil and 25-30% hexane (Mount et al., 1987; Proctor, 1997). After extraction, the miscella is filtered to remove the suspended fines, and the solvent is stripped from the oil by a combination of thin film evaporators to ensure complete removal of solvent (Ortheofer, 1978). The oil, essentially free of solvent, is cooled to ambient temperature and pumped to storage (Mount et al., 1987).

Lecithin is the phospholipid fraction separated from soybean crude oil, containing phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, and phosphatidic acid (Liu, 1997). Lecithin is extracted from soybean oil and used for everything from pharmaceuticals to protective coatings. It is a natural emulsifier and lubricant. During processing, soybeans are cleaned, cracked, dehulled, and rolled into flakes (ASA, 2003). Once the soybean oil is removed, the remaining flakes can be processed into various edible soy protein products for human consumption and protein-enriched animal feed (ASA, 2003). Further processing produces high protein food ingredients such as soy protein concentrates and isolated soy protein. Currently, soybean oil remains the primary product of soy production in the US.

Flavor of Soy

Some flavor components in soybeans and soy protein concentrates are resistant to removal by methods such as distillation and extraction under normal conditions (Messina, 1997; Arai et al., 1966). One way to hide or help inactivate the soy protein flavor is the texture of a food product. In non-aqueous products, soy protein has a much smaller chance to interact with flavor compounds and the beany taste is less noticeable than in products where the soy protein is fully hydrated. Soy protein can be enrobed with fat to further mask the beany flavor (Gremli, 1974).

Due to the various methods of SPI processing - solvent extraction, aqueous extraction, drying and toasting - a common problem is the formation of lipid-derived off-flavors (Sessa, 1979). Soy proteins are notorious for containing a strong affinity for aldehydes which irreversibily bind to proteins. The binding to the protein causes a loss in olfactory effect and increases protein denaturation (Sessa, 1979). When a flavor compound is added to soy protein without heat treatment, a change in the flavor is noticed (Gremli, 1974). The change is due to the soy protein interfering with the added flavor. It interferes by suppressing or combining with the soy protein resulting in altered perception. In addition, some of the compounds of the original composition interact with the soy protein (Gremli, 1974).

It is important to understand which compounds will react with soy protein when placing SPI or SPC in a food matrix. Additionally, it is important to recognize if the overall reaction of soy protein is reversible or irreversible. Strong soybean-like flavors have been found when hydroperoxides were generated by the oxidative action of soy lipoxygenase, an indigenous soybean enzyme, on pure linoleic and linolenic acid (Sessa, 1979). Two components of off-flavors found in denatured soy protein concentrate were n-hexanal and n-hexanol (Arai et al., 1966). Enzymatic proteolysis in soy protein loosens the binding of the protein structure, which in turn releases the flavor compounds n-hexanal and n-hexanol (Arai et al., 1966). Volatile compounds such as n-hexanal and n-hexanol contribute to beany flavors; nonvolatile oxygenated fatty acids impart a bitter taste to soybeans. A study by Sessa (1979) demonstrated trihydroxy fatty acids generated by the action of soy lipoxygenases on linoleic acid generated a bitter taste at low concentrations.

More recently, Boatright and Crum (1997) identified an acid derivative, 2-pentyl pyridine, a flavor compound associated with roasted and fried foods, in SPI. 2-pentyl pyridine was found to be a major contributor of off-flavor in SPI, imparting a fish-like odor (Boatright and Crum, 1997). Zhou and Boatright (2000) found that the formation of 2-pentyl pyridine in SPI was due to a synthesis reaction of 2,4-decadienal and ammonium hydroxide during the processing of SPI. Compounds that contribute to the beany odor in SPI were studied by Boatright and Lei (1999), who found two additional odorants, dimethyl trisulphide, and trans-2-4-decadienal. The study concluded that the two chemical odorants found were described as fatty odors, characteristic of oxidized aroma. Overall, additional knowledge and research targeting the different off-flavors found in soy protein powders is needed to improve product formulation, leading to increased sales of products containing soy. The improvements in eliminating off-flavors in soy products would allow consumers to enjoy the many health benefits of soy.

Health Benefits and Deficits

Americans spend more than $60 billion dollars per year on prescription medications (FDA, 2003). Dietary and lifestyle changes that people institute themselves have increased in popularity and have the potential to naturally enhance overall health and well being. Soy protein could easily be promoted and implemented as a part of a daily diet by incorporating it into various food matrixes. Soybeans contain all three of the macronutrients required for good nutrition: protein, carbohydrate, and fats, as well as vitamins and minerals. Soybeans are the only plant food that contains complete protein along with all the essential amino acids (Johnson et al., 1992). The soybean amino acid composition is equivalent to that of meat, milk, or egg protein (Soy Protein Council, 1987).

An antinutritional factor of soybeans is phytate**.** Phytate is the calcium-magnesium-potassium salt of inositol hexaphosphoric acid commonly known as phytic acid (Liu, 1997). The phytate content of soybeans used in the diet increases the requirement for certain metallic minerals. Phytate decreases absorption of calcium and zinc in humans but it is partially eliminated in soybeans by treatment with heat, enzymatic hydrolysis, ion exchange chromatography, and pH control which occurs during soy isolate production (Groff and Gropper, 1999).

Soy proteins are high in the amino acids glycine and arginine, which decrease cholesterol and lower insulin levels (Burrington, 2000). The high protein content and amino acid structure of soy is a major health benefit (Messina, 1995). Soybeans provide all nine essential amino acids and a form of protein acceptable in most diets (Riaz, 1999). Soy protein isolate has a digestibility of 93-97%, which is among the highest of all soy products (Lusas, 1995; Liu, 1997). Soybeans, unlike other legumes, also have high levels of methionine (a sulfur-containing essential amino acid) and cysteine, therefore they easily meet the recommended level of protein for the human diet (Messina,1997).

Liener (1994) found that soy protein must undergo a specific amount of heat treatment in order to have full nutritional potential. Liener (1994) also identified the heat-labile anti-nutritional factors in untreated soybeans as protease inhibitors, lectins and anti-vitamins. Lectins, also known as hemaglutinins, have the ability to agglutinate red blood cells from various species of animals. Lectins have a high binding affinity for carbohydrates and a number of cell surfaces which may in part be responsible for the poor nutritive value of raw soybeans (Liener, 1994). Protease inhibitors such as the Kunitz trypsin inhibitor and the Bowman Birkman inhibitor, along with lectins are assumed to be responsible for growth depression. Feeding studies with mice indicated these compounds reduced protein digestibility (Leiner, 1994). Leiner (1994) stated the most effective means of inactivating these antinutritional components in soy protein is by heat treatment. Thus, processed forms of soy such as flour, SPC, and SPI are free of these compounds.

Soy isoflavones are commonly classified as a soy nutriceutical yielding many health benefits (Soy Protein Council, 1997). Isoflavones are a class of phytoestrogens which are estrogenic compounds in plants (Liu, 1997). The only significant dietary sources of isoflavones in the human diet are soybeans (Table 10) (Friedman and Brandon, 2001). Isoflavones are similar in structure to that of estrogen therefore classifying them as phytoestrogens. Isoflavones act as estrogens and anti-estrogens which make them well-suited for the diets of post-menopausal women (Friedman and Brandon, 2001). In recent years, studies have shown that soy products which have high isoflavone content may help reduce symptoms of menopause in women (Burrington, 2000; Leiner, 1994; Adlercreutz, 2000).

Kirk et al. (1998) designed a study to determine if isoflavones in SPI conferred protection from atherosclerosis, reduced total plasma cholesterol levels, and protected against lipoprotein oxidation in atherosclerosis susceptible mice. The study found that isoflavones from soy protein did provide protection in mice from atherosclerosis and reduced the total plasma cholesterol level. Recent research proposed that soy isoflavones have the potential to reduce LDL cholesterol in humans (Ho et al., 2000). A study by Hudnall (1999) found that a 1 oz. serving size of soy protein isolate yielded 57 mg of isoflavones, and a 1 oz. portion of soy protein concentrate yielded 12 mg of isoflavones. It was concluded that incorporating soybean products into the human diet is currently the most potent dietary tool for naturally treating hypercholesterolemia and reducing LDL cholesterol, without prescription medication (Hudnall, 1999; Sirtori et al., 1993).

Other advantages to consumption of soy in the human diet are soy protein itself (Messina, 1995). Soy proteins are thought to stimulate the liver to remove more cholesterol, especially LDL cholesterol, from the blood (Burrington, 2000). On October 26, 1999, the US Food and Drug Administration (FDA) recognized the cholesterol-lowering effects of soy protein and approved the use of a health claim. The health claim approved the relationship between the consumption of soy protein and reduced risk of coronary heart disease. Such health claims were made possible by the Nutrition Labeling and Education Act of 1990 (NLEA) which allowed for statements on food labels that associated a health benefit with a specific food component (FDA, 2004).

In 2000, the American Heart Association (AHA) also recognized that the consumption of soy protein significantly lowered low-density lipoproteins (LDL) and total cholesterol levels, therefore promoting a healthy heart. By lowering the total cholesterol level, this reduced the risk for cardiovascular disease (Friedman and Brandon, 2001). The health claim below can be utilized on a soy product or product containing soy protein that meets requirements including low saturated fat and low cholesterol with a minimum of 6.25g of soy protein per serving. The per serving level was determined by dividing the daily qualifying level (25g) by four to represent breakfast, lunch, dinner, and snack. The model health claim for foods containing soy protein which meets FDA regulations is as follows:

> (1) *Diets low in saturated fat and cholesterol that includes 25 grams of soy protein may reduce the risk of heart disease. One serving of _______ [name of food] provides _____ grams of soy protein* (Federal Register, 1999).
>
> (2) *25 grams of soy protein a day, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease. A serving of [name of food] provides ____ grams of soy protein* (Federal Register, 1999).

Soybeans are nutritionally wealthy with an abundance of other nutritional factors, which make them an ideal supplement to the human diet. Soybeans are also rich in antioxidants, which have a wide range of anti-aging and disease prevention properties. A study performed by Cowan et al. (1973) substituted soy protein for animal protein in human subjects and found a significant reduction in total cholesterol and low density lipoprotein (LDL) cholesterol within the blood plasma and serum. The study found that both hypercholesterolemia and atherosclerosis were primarily due to the animal protein used as the protein component of the diet. Investigation found that substituting isolated soy protein for the animal protein could prevent hypercholesterolemia and atherosclerosis (Carroll et al., 1995). A possible explanation for the cholesterol lowering effect of soy protein is the protein's ability to modulate the LDL receptor levels in the liver (Friedman and Brandon, 2001).

Food allergies occur in 4-6% of children, especially infants (Friedman and Brandon, 2001). Allergens associated with soybeans are of concern as soy products become more widely used (Leiner, 1994). Soy-based infant formulas are widely used for children who suffer from an allergy to cow's milk or to meet the infants dietary needs when breast milk is not available (Friedman and Brandon, 2001).

Cost of Soy

In 2000, soybeans represented 79% of U.S. exports and 54% of the world's soybean trade originated from the U.S. (USB, 2001). U.S. soybean and product exports were $6.66 billion in 2000 (USB, 2001). China is the largest single country customer for U.S. soybeans at $1.0 billion annually, followed by Japan at $758 million and Mexico at $678 million (USB, 2001). The Philippines is the largest customer for U.S. soybean meal at $122 million and Mexico and Korea are the largest U.S. customers of soybean oil, $39 million and $34 million, respectively (USB, 2001).

In 2000, the Soy Stats reported 74.5 million acres of soybeans were planted in the United States, resulting in 2.770 billion bushels of soybeans. Farmers in Louisiana earned $5.05 per bushel in 2000 and the two lowest paid soybean farmers, in the states of North

Dakota and Virginia, earned $4.20 per bushel (USB, 2001). The average price paid to farmers in 2000 was $4.40 per bushel, which is the lowest price paid since 1972 (USB, 2001). The largest amount of soybeans planted in the U.S. in 2000 was in Iowa which planted 10,700 acres of soybeans. Illinois planted 10,500 acres, the second largest amount of soybeans planted. Production in Minnesota was 293 million bushels; Illinois, 460 million bushels; and Iowa, 459 million bushels. Currently, soy flour sells for $0.25/lb, SPC for $0.90/lb, and SPI for $1.80/lb (The Solae Company, St. Louis, MO, 2004). The use of soy protein concentrate and isolates in simulated meat products has grown rapidly over the years therefore increasing the demand and value of soy (Wolf and Cowan, 1975).

Sensory Analysis of Soy

Sensory aspects of soy are an ongoing problem where sensory research often labels soy as having characteristics of "beany", grassy, and bitter flavors (Kinsella, 1979). Business and marketing techniques rely on the nutritional value, functionality, and price of soy protein to mask the flavor problems associated with soy (Schutte and Ouweland, 1979). Schutte and Ouweland (1979) addressed two major problems in soy protein materials, i.e., the off-flavors inherent to soy and the absence of attractive positive flavors such as those found in meat.

There is limited research to determine the sensory flavor properties and consumer perceptions of soy protein powders. Kalbrener et al. (1971) congregated a 17 member trained panel to evaluate odors and flavor of commercial soy protein products including soy flours, soy concentrates and isolates. Results showed that the most objectionable flavors were beany and bitter. The use of threshold analysis indicated that the undesirable taste constituents of soy were detectable and quite intense at very low concentrations (Kalbrener et al., 1971). A study on the sensory evaluation of soy concentrates and flours was performed by Cowan et al. (1973). The descriptions of the soy protein products were beany, bitter, nutty, and toasted. The attribute identified as beany was frequently reported as a predominant odor (Cowan et al., 1973).

As stated, the beany characteristic of soybeans is an unacceptable flavor that can limit application of soy proteins. Drake et al. (2000) investigated dairy yogurt fortification with soy protein concentrate. Sensory evaluation of yogurt with 1%, 2%, and 2.5% added SPC resulted in increases in soy flavor. Although the delicate flavor of fermented dairy was seen as promising in reducing the objectionable characteristic flavor of soy, levels of dairy flavor attributes were decreased with increased levels of added SPC (Drake et al., 2000).

An interesting study by Wansink et al. (2002) included 132 Indians and Pakistanis living in the US that participated in a taste profile study. Three groups of consumers were analyzed: people who ate soy primarily for taste-related reasons, those who ate it primarily for health-related reasons, and those who did not eat soy at all. Among the three groups of consumers analyzed, people who ate soy primarily for taste-related reasons were more likely to appreciate fine food from various cultures. The quantitative phase of the research indicated that soy was consumed due to health related reasons or because consumers tested liked the taste and texture of soy. The study provided evidence that soy is incorporated into various cultures and consumed not only for health related reasons but for its versatile flavor (Wansink et al., 2002).

Conclusion

Recently, fortified products have been a significant growth category for the food industry. Functional foods that include either whey protein or soy protein comprise a continuously growing product category. Consumers will be looking for products with ingredients that help control specific unwanted health symptoms as well as boost immunity. While nutraceutical and functional properties of whey and soy proteins are in demand, flavor will still ultimately drive consumer liking and product success. The objectives of this study are to identify and compare descriptive sensory properties of whey and soy protein products and to compare consumer acceptance and attitudes towards these products.

References

Adlecreutz, C.H.T., W. Mazur, P. Bartels, V.V. Elomma, S.S. Watanabe, K. Wahala, M. Landstrom, E. Lundin, A. Bergh, J.E. Damber, P. Aman, A.Widmark, A. Johansson, J.X. Zhang, G. Hallmans. 2000. Phytoestrogens and Prostate Disease. ASNS: *Journal of Nutrition*. 130:658S-659S

American Dairy Products Institue (ADPI). 1998a. Whey Products: Utilization and Production Trends. Chicago, IL.

American Dairy Products Institue (ADPI). 1998b. Ingredient Description Brochure. Dry Milks, Whey and Whey Products, Lactose. Chicago, IL.

American Soybean Association (ASA). 2004. "soy protein" www.asasoy.com

Anonymous. 2001. Do it with dairy. DMI. Whey. p. 1-3. www.doitwithdairy.com/infolib/ingspecsheet/factwhey.htm

Anonymous. 2003. Technical background article received on 5 May 2003 from Invensys APV. Efficient processing of whey and permeate. *ProcessingTalk*. www.processingtalk.com

Arai, S., H. Suzuki, M. Fujimaki, Y. Sukurai. 1966. Studies of Flavor Components in Soybeans. Part VI. Some Evidence for occurrence of protein-flavor binding. *Agricultural Biol. Chem*. 30 (10):364-369.

Badings, H.T., R. Neeter. 1980. Recent advances in the study of aroma compounds of milk and dairy products. *Netherlands Milk Dairy Journal*. vol. 34: 9-30.

Becker, W. 1978. Solvent Extraction of Soybeans. *J Am Oil Chem Soc* 55:754-761.

BeMiller, J.N., and R.L.Whistler. 1996. Carbohydrates. In *Food Chemistry*, 3rd Edition. Fennema, O.R. (Ed.). Marcel Decker. New York. p.175-176

Boatright, W.L., and A.D. Crum. 1997. Odor and flavor contribution of 2-pentyl pyridine to soy protein isolates. *J Am Oil Chem Soc* 74:1575-1581.

Boatright, W.L., and Q. Lei. 1999. Compounds contributing to the "beany" odor of aqueous solutions of soy protein isolates. *J Food Sci* 64:667-670.

Boye, J.I., C.Y. Ma, V.R. Harwalkar. 1997. Thermal denaturation and coagulation of proteins. In *Food Proteins and Their Applications*. Damodaran, S. and Paraf, A., Eds.; Marcel Dekker, Inc. New York, New York.

Bryant, C.M. and D.J. McClements. 1998. Molecular basis of protein functionality with special consideration of cold-set gels derived from heat-denatured whey. *Trends in Food Science and Technology*. 9:143-151.

Burrington, K. 2000. Nutritional and Beneficial Ingredients. *Food Product Design*. November 3000. p.1-12.

Cambell, M.F. 1981. Processing and product characteristics for textured soy flours, concentrates, and isolates. *J Am Oil Chem Soc* 58:336-338.

Carroll, K.K. and E.M. Kurowska. 1995. Soy Consumption and Cholesterol Reduction: Review of Animal and Human Studies. First International Symposium of the Role of Soy in preventing and treating chronic disease. Feb. 20-23, 1994, Mesa, A.Z. *Journal of Nutrition*. 125:594S-597S.

Casper, J. L., W. L. Wendorff, D. L. Thomas. 1999. Functional Properties of Whey Proteins Concentrates from Caprine and Ovine Specialty Cheese Wheys. *Journal of Dairy Science.* 82: 265-271.

Cayot, P. D., and Lorient. 1997. Structure-function relationships of whey proteins. In Food proteins and their applications. Damodaran, S. Paraf, A. Eds., Marcel Dekker, Inc. New York, New York. 1997.

Chambers IV, Edgar and M.B. Wolf, 1996. Sensory Testing Methods: Second Edition. ASTM, Pennsylvania.

Chandan, R. 1997. *Dairy-Based Ingredients*. Eagan Press Handbook Series. St. Paul, MN.

Cowan, J.C., J.J. Rackis, and W.J. Wolf. 1973. Soybean protein flavor components: a review. *J. Am. Oil Chem. Soc*. 50: 427a-444a.

Carunchia-Whetstine, M., J. Parker, M.A. Drake, and D.K. Larick. 2003. Determining flavor and flavor variability in commercially produced liquid Cheddar whey. *Journal of Dairy Science.* 86(2): 439

Dalgleish, D.G., V. Senaratne, S. Francois. 1997. Interactions between α-lactalbumin and β-lactoglobulin in the early stages of heat denaturation. *J. Agric. Food Chem*. 45: 3459-3464.

Davisco Foods International, MN. 2004 Personnal Correspondance.

DeMan, J.M. 1999. Proteins Chapter 3. In Principles of Food Chemistry. 3rd Edition. Aspen Publishers, Inc. Maryland. p.44-158

de Wit, J.N. and Moulin, J. 2001. Whey protein isolates: manufacture, properties, and applications. Industrial Proteins. vol 9 p.6-8
DMI. 2003. www.doitwithdairy.com. "whey protein". http://www.doitwithdairy.com/ingredients/wheycon/inwheycondef.htm

Drake, Dr. Maryanne. 2003. Personal correspondence.

Drake, M.A., Karagul-Yuceer, Y. K.R. Cadwallader, C.V. Civille. And P.S. Tong. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. *Journal of Sensory Studies*. 18:199-216.

Drake, M.A., X.Q. Chen, S. Tamarapu, and B. Leenanon. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. *Journal of Food Science*. 65(7):1244-1247.

El-Salam, M.H.A., S. El-Shibiny, and M.B. Mahfouz. 1985. Chemical composition and nutritive value of spray dried permeate powder. *Journal of the Society of Dairy Technology*. 38(2): 53-55.

FDA, 2004."nutrition labeling and education act" www.fda.gov

Federal Register, Food Labeling: Health Claims; Soy Protein and Coronary heart Disease United States Federal Register: Rules and Regulations (online). 1999. 64, 57699-57733.
http://frwebgate3.access.gpo.gov/cgbin/waisgate.cgi?WAISdocID┴84817666+0+0+0&WAISaction=retrieve.

Ferretti, A. and W.P. Flanagan. 1971. Volatile constituents of whey powder subjected to accelerated browning. *Journal of Dairy Science*. 54:1764-1768

Ferrier, L.K. 1975. Simple processing of whole soybeans. In *Soybean Production, Protection and Utilization*: proceedings of a conference for scientists of Africa, the Middle East, and South Asia, October 14-17, 1974. Addis Ababa, Ethiopia [Urbana] University of Illinois at Urbana-Champaign. P.179-188.

Fitzpatrick, J. J., and M.A.S. Smith. 2001. Effect of manganese on *Lactobacillus casei* fermentation to produce lactic acid from whey permeate. *Process Biochemistry.* 36 (7): 671-675.

Fitzpatrick, J. J., and U. O'Keefe. 2001. Influence of whey protein hydrolysate addition to whey permeate batch fermentations for producing lactic acid. *Process Biochemistry.* 37 (2):183-186.

Foegeding, E. A., J.P. Davis, D. Doucet, and M. McGuffey. 2002. Advances in modifying and understanding whey protein functionally. *Trends Food Science*. 13:151-159

Frank, Paula. 2001. "Finding the Whey". p. 1-3. www.legacy-meadowfresh.com/Finding_The_Whey.html

Friedman, M. and D.L. Brandon. 2001. Nutritional and Health Benefits of Soy Proteins. *Journal of Agricultural Food Chem*. 49:1069-1086.

Francis, F.J. and Wiley. 2000. "Whey: Composition, Properties, Processing and Uses". Wiley Encyclopedia of Food Science and Technology. 2nd Edition. New York. p.2652-2661.

Geilman, W.G., D. Schmidt, C. Herfurth-Kennedy, J. Path, and J.Cullor. 1992. Production of an Electrolyte Beverage From Milk Permeate. *Journal of Dairy Science.* 75: 2364-2369.

Goblitz, P. 1995. Traditional soyfoods: processing and products. *Journal of Nutrition*. 123(35):570-572

Groff and Gropper, 1999. Advance Nutrition and Human Metabolism. St. Paul, Wadsworth Publishing. 3rd Edition. p.

Gremli, H.A. 1974. Interaction of Flavor Compounds with Soy Protein. *Journal of Am. Oil Chem. Soc.* 51:95A-97A.

Harper, W.J. and J. Zadow. 1984. Heat induced changes in whey protein concentrates. *N.Z.J. Dairy Sci Technol*. 19:229-237.

Hettiarachy, N. and K. Kalapathy. 1997. Soybean Protein Properties. In: Liu K. Soybeans: Chemistry, Technology, and Utilization. New York: Chapman & Hall. p.412-441.

Ho S.C., J.L.F. Woo, S.S.F. Leung, A.L.K. Sham, T.H. Lam, E.D. Janus. 2000. Intake of soy products is associated with better plasma lipid profiles in the Hong King Chinese Population. *Journal of Nutrition*. 130:2590-2593.

Huffman, Lee M. 1996. Processing whey protein for use as a food ingredient. *Food Technology*. Vol 50 (Feb): 49-52

Hudnall, M.1999. Soy as superhero: Guardian against many maladies of aging. *Environmental Nutrition*.22(2): 1-2.

Hymowitz, T. 1970. On the domestication of the soybean. *Economic Botany*. October-December 1970. 24(4):408-421

Johnson, L.A., D.J. Meyers, D.J. Burden. 1992. Soy Protein's History, Prospects in food, Feed. Intl. New on Fats, Oils and Related Materials (INFORM), AOCS Press. 3:429-444.

Kalbrener, J.E., A.C. Eldridge, H.A. Moser, W.J. Wolf. 1971. Sensory evaluation of commercial soy flours, concentrates and isolates. *Cereal Chemistry*. 48:595-600.

Karagul-Yuceer, Y., M.A. Drake, K.R. Cadwallader. 2003. Aroma-active components of liquid Cheddar whey. *Journal of Food Science.* 68(4):1215-1219.

Kinsella, J.E. 1979. Functional Properties of Soy Proteins. *Journal of Am Oil Chem Soc* 56:242-257.

Kinsella, J.E. 1984. Milk proteins: Physicochemical and functional properties. CRC *Critical Reviews in Food Science and Nutrtition*. 21:197-262.

Kim, S-H., C.V. Moor, A. Seo, J.G. Surack.1989. Effect of whey pretreatment on composition and functional properties of whey protein concentrate. *Journal of Food Science*. 54:25-29

Kirk, E.A., P. Sutherland, F.A.Wang, A. Shait, and R.C. Leboeuf. 1998. Dietary isoflavones reduce plasma cholesterol atherosclerosis C57BL/6 mice but not LDL receptor deficient mice. *Journal of Nutrition*. 128:954-959

Lawless, H.T., and H. Heymann. 1999. *Sensory Evaluation of Food: Principles and Practices*. Aspen, Maryland.

Laye, I., Fitzgerald, G.F., Uniacke-Loew, T., Daly, C., Fox, P.F. 1993. The contribution of lactococcal starter proteinases to proteolysis in Cheddar cheese during ripening. *International Dairy Journal*. 76:2455-2467.

Liener, I.E. 1994. Implications of Antinutritional Components in Soybean Foods. *Critical Reviews in Food Science and Nutrition*. 34(1):31-67.

Liu, K. 1997. Chemistry and Nutritional Value of Soybean Components. In *Soybeans: Chemistry, Technology, and Utilization*. Liu K. Chapman & Hall: New York, NY. p.25-113.

Lusas, EW, Rhee, KC. 1995. Soy Protein Processing and Utilization. *In Practical Handbook of Soybean Processing and Utilization*, Erickson DR. (Ed). AOCA Press: Champaign, IL and United Soybean Board: St. Louis, MO. P.117-160.

Macedo, M.G. Lacroix, C., and Champagne, P. 2002. Combined effects of temperature and medium composition on exopolysaccride production by *Lactobacillus rhamnosus* RW-9595M in whey permeate based medium. *Biotechnology Progress* 18(2): 167-173.

McDonough, F.E., Hargrove, R.E., Mattingly, W.A., Posati, L.P., Alford, J.A. 1974. Composition and properties of why protein concentrates from ultrafiltration. *Journal of Diary Science*. 57:1438-1443.

Meilgaard, M. Civille, G.V, and Carr, B.T. 1999. Sensory Evaluation Techniques. 3rd Edition. CRC Press, Inc. Boca Raton, FL.

Messina, M. 2002. Symposium Highlights Significant Research on Soy and Human Health. United Soybean Board. The Soy Connection. 10(1) 1-6.

Messina, M. 1995. Modern Applications for an Ancient Bean: Soybeans and the Prevention and Treatment of Chronic Disease. First International Symposium on the Role of Soy in Preventing and Treating Chronic Disease. 1994. Feb. 20-23, Mesa, AZ. *Journal of Nutrition*. 125-567S-569S.

Messina, M. 1997. Soyfoods: Their Role in Disease Prevention and Treatment. In Soybeans: Chemistry, Technology, and Utilization. Lui K. Champan & Hall: New York, NY. p.443-477.

Milligan, E.D. 1976. Survey of Current Solvent Extraction Equipment. *J Am Oil Chem Soc* 53:286-290.

Mills, O.E. 1993. Flavor of whey protein concentrate. New Zealand Dairy Research Institute. In Food Flavors, ingredients, and composition: Proceedings of the 7th International Flavor Conference. Elsevier. New York. p.139-149.

Mills, O.E., Broome, A.J. 1998. Isolation of flavor compounds from protein material. In *Flavor Analysis: Development in Isolation and Characterization*. Mussinan, C.J. Morello, M.J. (Ed.) American Chemical Society. Washington, D.C. p.85-91.

Morr, C.V. and E.Y.W. Ha. 1991. Off-flavors of whey protein concentrates: A literature review. *International Dairy Journal*. 1:1-11.

Morr, C.V., and E.A. Foegeding. 1990. Composition and functionality of commercial whey and milk protein concentrates and isolate: A status report. *Food Technology*. 44: 100-111.

Mount, T.L., W.J. Wolf, and W.H. Martinez. 1987. Processing and Utilization. In *Soybeans: Improvement, Production and Uses*, 2nd Ed., Wilcox JR (Ed). American Society of Agronomy, Inc. Madison, WI. p819-866.

Mulvihill, D.M. 1992. Production, functional properties and stylization of milk protein products. In *Advance Dairy Chemistry*. Fox, P.F. Ed. Elsevier Science Publishers LTD. New York, NY. vol 1.

National Dairy Council. 2003. "whey protein" www.nationaldairycouncil.org

Ortheofer, F.T. 1978. Processing and Utilization. In *Soybean Physiology, Agronomy, and Utilization*. Norman AG. (Ed). Academic Press, Inc. p.219-246.

Pasin, G. and S.L. Miller. 2000. U.S. Whey Products and Sports Nutrition. U.S. Dairy Export Council. www.usdec.org p.1-18.

Patel, R. S., and V. V. Mistry. 1997. Physiochemical and Structural Properties of Ultrafiltered Buffalo Milk and Milk Powder. *Journal of Dairy Science*. 80:812-817.

Pour-El, A. and T.A. Swenson. 1976. Gelation parameters of enzymatically modified soy protein isolates. *Cereal Chem*. 53: 438-442.

Proctor, A.1997. Soybean Oil Extraction and Processing. In Soybeans: Chemistry, Techology, and Utilization. Liu K. Champan and Hall: New York, NY. p.297-346.

Riaz, M.N. 1999. Soybeans as Functional Foods. Cereal Foods World. 44:88-92.

Rakosky, J. 1974. Soy grits, concentrates and isolates in meat products. J Am Oil Chem Soc 51(1): 123A-127A.

Richert, S.H., C.V. Morr, C.M. Cooney. 1974. Effect of heat and other factors upon foaming properties of whey protein concentrates. *J. Food Science*. 39:42-48.

Richert, S.J., Kolar, C.W. 1987. Value of isolated soy protein in food products. In Cereals and Legumes in the Food Supply. Dupont J, Osmna EM (Eds). Iowa State University Press: Ames, IA. p.73-90.

Schmidt, R., V.S. Packard, H.A. Morris. 1984. Effect of processing on whey protein functionality. *J Dairy Sci*. 67:2723-2733.

Schutte L, and G.A.M. van den Ouweland. 1979. Flavor Problems in the Application of Soy Protein Materials. *J Am Oil Chem Soc* 56:289-290.

Scott, W.O., and S.R. Aldrich. 1983. Soybeans, Food, Feed and Future. In Modern Soybean Production, Scott WO, Aldrich SR. S & A Publications, Inc.: Champaign, IL. P209-219

Sessa, D.J. 1979. Flavor considerations of soy protein products. *Food Product Development*. Feb 1979 p.62-64.

Shipe, W.F., R. Bassette, D.D. Deane, W.L. Dunkley, E.G. Hammond, W.J. Harper, D.H. Kleyn, M.E. Morgan, J.H. Nelson, and R.A. Scanlan. 1978. Off flavors of milk: Nomenclature, standards, and bibliography. *J. Dairy Sci.* 61:855-869.

Sienkiewicz, T., C. Riedel. 1990. Whey and whey utilization possibilities for utilization in agriculture and foodstuffs products. Buersche Druckerei. Leipzig, Germany.

Sirtori, C.R., Even, R. and Lovati, M.R. 1993. Soybean protein diet and plasm cholesterol: from therapy to molecular mechanism. Ann. N.Y. *Acad. Sci*. 676:188.

Smith, K., K.J. Burrinton, J.H. Von Elbe. 1999. Whey Applications in Confections. Oral presentations for US Dairy Export Council.

Smith, K.J., and W. Huyser. 1987. World Distribution and Significance of Soybean. In Soybeans: Improvement, Production, and Uses. 2nd Ed., Wilson JR (Ed). American Society of Agronomy, Inc.: Madison, WI. p.1-22.

Smithers, G.W., J.F. Ballard, A.D. Copeland, K. J. De Silva, D.A. Dionysius, G.L. Francis, C.G. Paul, A. Griece, G.H. McIntosh, I.R. Mitchell, R.J. Pearce, G.O. Regester. 1996. New Opportunities from the Isolation and Utilization of Whey Proteins. Symposium: Advances in Dairy Foods Processing and Engineering. *Journal of Dairy Science.* 79:1454-1459.

Soya and Oilseed Bluebook. 2001. Soyatech, Inc.: Bar Harbor, ME. 2001.

Soy Protein Council. 1987. Soy Protein Products: Characteristics, Nutritional Aspects and Utilization. Soy Protein Council. Washington, D.C. 1987.

Stone, H.L. and J.L. Sidel. 1993. *Sensory Evaluation Practices*, 2nd Ed. Academic Press, San Diego.

The Solae Company. St. Louis, MO. Personal Correspondance. 2004

Tomaino, R.T., Parker J.D., and Larick D.K. 2001. Anaylsis of free fatty acids in whey products by solid-phase microextraction. Journal of Agriculture and Food Chemistry. 49:3993-3998.

USB, 2001. The 2001 edition of the Soy Stats by the United Soybean Board. www.unitedsoybean.org

USDEC, 2003. Reference manual for U.S. whey and lactose products. www.usdec.org

Varnam, A.H., and J.P. Sutherland. 1994. "Milk and milk products: Technology, Chemistry and Microbiology". Chapman and Hall, 1994. NY, NY. Chapters 1,4,7.
Von Elbe, J.H. 2001. Utilization of Whey Proteins in Confections. Presentation for US Dairy Export Council.
Walzem, R.D.L. 1999. Health Enhancing Properties of Whey Proteins and Whey Fractions. U.S. Dairy Export Council. P.1-7. www.usdec.org/pdffiles/manuals/7health.pdf.

Wansink, B. and JaeHak Cheong. 2002. Taste Profiles that correlate with soy consumption in developing countries. *Pakistan Journal of Nutrition*. 1(6):276-278

Whey Protein Institute. 2003. Benefits of Whey Proteins. www.wheyoflife.org/benefits.

Whitfield, F.B. 1992. Volatiles from interactions of Maillard reaction and lipids. *Critical Reviews in Food Science and Nutrition*. 31: 1-58.

Williams, L.A. Oct/Nov 2001. Trend setting drinks: The new developments and trends that will be shaping their industry in the years to come. *The World of Food Ingredients.* p.45-48, 50, 52.

Wolf, W.J., Cowan, J.C. 1975. Soybeans as a food source. CRC Press: Cleveland, OH.

Zhang, Y., W.J. Ritter, C.C. Barker, P.A. Traci, and C.T. Ho. 1994. Volatile formation by lipid-mediated Maillard reactions in model systems. In ACS Symposium 558-lipids in Food Flavors. C.T. Ho, T.G. Hartman (Ed.) p.49-60. *American Chemical Society*, Washington D.C.

Zhou, A. and W.L. Boatright. 2000. Precursors for formation of 2-pentyl pyridine in processing of soybean protein isolates. *J Food Sci* 65(7):1155-1159.

Manuscript

Comparison of sensory properties of whey and soy protein concentrates and isolates

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Abstract

In previous years, whey was treated as an insignificant by-product of cheese making, used mainly in animal feed or discarded. Whey and whey components, particularly whey proteins, are now viewed as valuable ingredients due to recent discoveries of functional and bioactive roles. Production and application of soy protein has also increased in recent years. Characterization and comparison of the flavor properties of these value-added ingredients is needed to identify specific ingredient applications and marketing strategies. The goal of this study was to develop a sensory lexicon for whey and soy proteins, and to subsequently identify and compare the descriptive sensory properties of whey and soy proteins. Consumer perception of these products was also investigated. Twenty-four descriptive sensory attributes were identified to evaluate appearance, flavor, and texture/mouthfeel. Following development of the lexicon, twenty-two samples (14 whey proteins and 8 soy proteins) were selected for descriptive sensory analysis. Proteins were rehydrated (10 % solids, (w/v)) and evaluated in triplicate by a highly trained sensory panel (n=10) trained to use the developed language. Results were analyzed by univariate and multivariate analysis of variance. Both whey and soy proteins were differentiated using the identified language ($p<0.05$). Different sensory attributes distinguished whey proteins from soy proteins. Consumers were knowledgeable of distinct health benefits of dairy and soy products. These results will enhance ongoing research and product development with these nutritional and functional ingredients.

Key Words: sensory analysis; whey protein concentrate; whey protein isolate; soy protein concentrate; soy protein isolate; descriptive analysis

Introduction

In previous years, whey was treated as an insignificant by-product of cheese making, used mainly in animal feed or discarded (National Dairy Council, 2003). With advances in technology and recent discoveries of functional and bioactive roles for whey, whey and whey components are now viewed as valuable ingredients. The recognition of whey as a source of unique physiological and functional attributes provides opportunity for the food industry to incorporate whey and whey components into a variety of foods. Both whey protein concentrate (WPC 80) and whey protein isolate (WPI) provide a high protein, low carbohydrate source which is currently in demand due to increased awareness of nutrition and alternative methods for weight control.

deWit and Moulin (2001) estimated that 700,000 tons of whey produced worldwide are used as ingredients in food. The United States Dairy Export Council (USDEC) reported 5.6 tons of whey protein concentrates exported in 1996 compared to 24.5 tons exported in 2001. The cost of whey protein varies depending on milk prices. Currently, the demand for a higher protein, low carbohydrate diet in the marketplace has further increased whey protein value. Whey protein concentrate (WPC) contains protein in concentrations less than 90% while whey protein isolates (WPI) contain a minimum of 90% protein. Spray dried whey powder costs approximately $0.25/lb while WPC80 is approximately $2.50/lb (Davisco Foods International, Le Sueur, MN, 2004) and WPI is approximately $4.50/lb (Davisco Foods International, Le Sueur, MN, 2004).

Whey protein products such as WPCs and WPIs are highly functional and nutritional groups of dairy ingredients widely used in various food applications (Foegeding et al., 2002). However, flavor of whey proteins can impact finished product quality and consumer acceptance. Drake et al. (2003) identified and developed a descriptive sensory language to profile the flavor of dried dairy ingredients, including WPC and WPI. They found wide flavor variability in whey proteins and off flavors such as animal/wet dog, cardboard, metallic and high astringency intensities.

Soy protein is an ingredient that also provides a wide range of functional and nutritional properties. Soy protein has health benefits, therefore, FDA approval of soy health claims has been a key driving force for an upward trend in soy consumption (FDA, 2004). Soy protein concentrate (SPC) and soy protein isolate (SPI) are the most refined forms of soy protein used as food sources. The major difference between SPC and SPI is in the protein and carbohydrate concentrates. SPC contains 60-80% protein while SPI contains equal or greater than 90% protein. The use of soy protein concentrates and isolates in food and beverage products has grown rapidly over the years increasing the demand and value of soy. Currently, soy flour sells for $0.25 per lb, SPC for $0.90/lb, and SPI for $1.80/lb (The Solae Company, St. Louis, MO, 2004). As with whey products, price increases with increasing protein content.

Sensory aspects of soy are an ongoing problem. Sensory research often labels soy as having sensory characteristics of “beany”, grassy, and bitter flavors (Kinsella, 1979). Business and marketing techniques use the nutritional value, functionality, and price of soy protein to mask the flavor problems associated with soy (Schutte and van den Ouweland, 1979). Drake et al. (2000) investigated dairy yogurt fortification with soy protein concentrate. The delicate flavor of fermented dairy products was seen as promising in reducing the objectionable characteristic flavor of soy protein; however levels of dairy flavor attributes were decreased with increased levels of added SPC

(Drake et al., 2000). There is a general lack of research on the sensory properties of soy proteins.

Both SPC and SPI are cost effective and offer unique amino acid profiles. Whey proteins, WPC80 and WPI also offer unique health and nutritional benefits. Processing of SPC and SPI from soybeans is not as complex as processing of WPC and WPI. However, both whey and soy proteins are abundant within the US. The total number of consumers purchasing nutraceutical products is on the rise (USB, 2004). Consumer trends are migrating towards nutraceutical products that offer an innovative taste. This new market growth of functional nutraceutical products includes a wide variety of foods from bars to beverages. Both whey and soy protein provide low carbohydrate and high protein. Characterization of flavor and flavor variability of both whey and soy protein is a key issue with the demand for great tasting healthy products. Consumer perception of these products is crucial to effectively design and market ingredient applications for whey and soy proteins. The objectives of this study were to identify and compare descriptive sensory properties of whey and soy protein products and examine consumer perception of whey and soy protein.

Materials and Methods

Sample Acquisition

Fifty-two samples (14 WPC80, 9 WPI, 9 SPC, and 20 SPI) were received from commercial suppliers in the United States and international sources between January and March 2004 (Table 1, 2). All products obtained were less than 1 month old at the time of receipt. All samples were stored at room temperature in the dark until analysis.

Sample Preparation

To avoid light oxidation, samples were prepared for sensory analysis with overhead lights off. The powders were reconstituted at 10% solids (w/v) in deodorized distilled water. Products were mixed with a Braun™ multiquick electric hand mixer (Gillette Commercial Operations, Boston, MA). Rehydrated samples were stored at 5°C in glass jars for 24 hours prior to sensory analysis. Products were removed from refrigeration 1 hour prior to test time. Approximately 30 ml of product were dispensed into 2 oz. plastic Sweetheart™ cups (Sweetheart Cup Co., Owings Mills, MD) with plastic lids and random 3-digit codes. Products were gently shaken prior to dispensing to avoid settling.

Lexicon Development

Sensory properties of the fifty-two collected WPC, WPI, SPC, and SPI were initially identified by 14 individuals who had extensive training (>75 hours each) with the descriptive analysis of dairy foods, including dried dairy ingredients. Samples were evaluated and preliminary attributes and definitions were identified (Table 3). Sensory properties identified included aroma, flavor, and texture/mouthfeel.

Descriptive Sensory Analysis

Twenty-two (22) commercial products (WPC80, WPI, SPC, and SPI) were selected for sensory analysis (Table 4). Samples were selected based on representative sensory properties and country of origin, such that an international sampling was obtained. Ten panelists were selected based on interest, time availability and knowledge of basic tastes as well as dairy associated flavors. Each panelist (10 females) had greater than 500 hours of previous descriptive analysis training involving basic tastes as well as dairy flavor identification and quantification using the Spectrum Method™ (Meilgaard et al, 1999). Panelists met for ten 2-hour training sessions to identify and discuss sensory properties of rehydrated whey and soy proteins using the identified lexicon. The lexicon was fine-tuned and the panelists were trained to identify and score attributes (Table 5). Products were evaluated individually by each panelist in an odor-free room dedicated to descriptive sensory analysis. The panelists were given distilled water and unsalted crackers to cleanse their palate between samples. Panelists did not swallow the samples to avoid saturation of the senses. Each product was evaluated in triplicate by each panelist in a randomized balanced block design.

Consumer Testing

Consumer testing incorporated a paper ballot questionnaire probing consumer perception of products containing whey and soy protein. The questionnaire was approved by the University Institutional Review Board. An informed consent form was signed by all participants (n=147) before taking the questionnaire. Consumers were faculty, staff, and students of North Carolina State University campus and employees at nearby businesses. They were recruited using email and fliers. Panelists received a $5.00 gift card for their participation. Panelists were asked questions to determine what type of "bar" products they normally purchased, the frequency of consumption of protein bars, level of knowledge about the use and function of proteins in food products, health benefits and product claims provided by soy products, health benefits and product claims provided by dairy products, purchase of food and/or beverage products that contain added protein, and type of food and/or beverage products likely to purchase and consume if high in protein. Consumers were also asked in separate questions to rank important attributes (most important to least important) when purchasing protein bars with labeled health claims and product features. Consumers were asked in separate questions to best indicate how they felt about the following statements: “cow’s milk is a healthy food”, “soy milk is a healthy food”, cow’s milk tastes good”, and “soy milk tastes good”. Consumers were asked to mark one of the following five possible answers: strongly agree, agree, neither agree nor disagree (don’t know), disagree, or strongly disagree.

Proximate Analysis

Proximate analysis (fat, moisture, protein, and ash) was conducted by a commercial facility, in duplicate on each of the 22 selected whey and soy proteins using standard methods. Fat content was determined by Mojonnier analysis (Mojonnier Bros. Co., Chicago, IL). Moisture was determined by vacuum oven, ash by muffle furnace, and protein by the Kjeldahl method. A conversion factor of 6.38 was used to convert total nitrogen to protein for whey protein and a 6.25 conversion factor was used for soy proteins.

Statistical Analysis

Statistical analysis was conducted using SAS (version 8.2, Cary, NC). Analysis of variance (PROC GLM) with means separation was used to compare attribute mean intensities. Principle component biplots (PROC PRINCOMP) were constructed to evaluate differences between whey and soy proteins and examine differences among whey and soy proteins individually. For consumer data, a rank test for a randomized complete block design was conducted (Friedman's rank test) to determine differences in mean consumer rank scores for ranked questions. For other consumer questions, frequencies were tabulated.

Results and Discussion

Proximate analysis results, provided by a commercial facility, indicated that fat, ash, and moisture varied among the whey and soy proteins (Table 6). As expected, fat contents were higher among SPC and WPC80 compare to SPI and WPI. Moisture and ash content also varied widely among and between whey and soy proteins. Three soy protein isolates SPI1, SPI2, and SPI4, did not fall within the defined content for protein isolates (which should be equal to or greater than 90% protein). Two whey protein isolates, WPI1 and WPI2, had average protein values less than 90%. The fat, ash and moisture content differed between the whey protein concentrates and whey protein isolates. The fat content of whey protein isolates was lower than whey protein concentrates. However, the average ash and moisture contents were similar. Similar trends in moisture and ash content were observed for SPC and SPI.

Among the WPC80 samples, WPC2 was documented on the certificate of analysis from the manufacturer to contain 75% protein. Proximate analysis results indicated that the mean protein value was 79.4%, therefore meeting the criteria of classification of WPC75. However, for the other WPC80 samples, WPC1, WPC3, WPC4, WPC5, and WPC6, the mean protein content was less than 80%. The mean protein content for all

WPIs except for samples WPI5, WPI7, and WPI8 was less than 90%. The mean moisture content of WPI3 was 6.1%, which exceeds the maximum of 4.5% moisture for WPI. All WPC samples were less than 8% fat, which is the standard recommended value by the USDEC (2003). However, WPI6 had a mean fat value of 6%, which exceeds the maximum 1% fat recommended by the USDEC (2003).

All SPC samples evaluated, except SPC2, had mean protein values greater than 70% which meets the standard definition by the American Soybean Association (ASA) (2004) for SPC (Table 6). The percent moisture content of SPC and SPI should be no more than 6%, (ASA, 2004). All soy protein samples were also within the 6% maximum ash value recommended by the ASA except SPC4, which had a mean ash value of 6.3%. In addition, all SPCs were within the standard maximum value of 3% fat. However, SPI1 had a mean value of 14.3% fat.

Analysis of variance of descriptive sensory results revealed many differences between and among whey and soy proteins (Table 7). In general, mean flavor intensities of rehydrated proteins were low (< 3.0). These intensities are typical for these types of products (Drake et al., 2003). Principle component analysis was conducted on whey and soy protein data sets individually and combined to more closely examine distinctive sensory differences within soy and whey proteins. For the whey and soy protein data combined, a cumulative of 72% of the data variability was explained by the first four principle components. Fifty-nine percent (59%) of the variability was explained on the first two components (Figure 1). PC1 explained 45% of the variability and was characterized by color, sweet aromatic, cereal, brothy, roasted, metallic/meat serum, flour paste, yeasty, sweet taste, viscosity, and chalkiness as determined by evaluating the eigenvector loadings (Table 8). PC2 described 14% of the variability and was characterized by cardboard/wet brown paper, animal/wet dog, soapy, salty taste, and astringency. PC3 and 4 explained an additional 13% of the variability (Figure 2). PC3 explained 7% of the variability and was characterized by opacity, fecal /dirty, and sour taste. PC4 explained 6% of the variability and was comprised of the attributes pasta, malty and bitterness (Table 8). Soy proteins and whey proteins were distinct from each other. In general, soy proteins were characterized by the flavor attributes flour, roasted, cereal, and high intensities of chalkiness and viscosity. In contrast, whey proteins were characterized by cardboard, brothy, and soapy flavors. These results indicate that soy and whey proteins have distinctive flavor differences. Several sensory attributes found in this study of whey and soy proteins have been used by previous researchers to describe other whey and/or soy products (Civille and Lyon, 1996; Carunchia-Whetstine et al., 2003; Drake et al., 2003; Friedeck et al., 2003).

Principal component analysis was also conducted on whey and soy protein data sets individually to more closely examine distinctive sensory differences within soy and whey proteins. In regards to whey proteins, a cumulative of 71% of the data variability was explained by the first four principle components. Fifty-one percent (51%) of the variability was explained by the first two components (Figures 3). PC1 explained 36% of the variability and was characterized by opacity, color, sweet aromatic, cardboard/wet paper, astringency, and viscosity (Table 9). PC1 primarily differentiated WPC80 from WPI while PC2, 3, and 4 differentiated individual whey proteins from one another. In general, WPI exhibited lower flavor intensities than WPC80. This characteristic has been documented in previous studies (Drake et al., 2003) and may be due to the lower fat and carbohydrate content of WPI compared to WPC80. PC2 described 15% of the variability and was characterized by pasta, animal/wet dog, and salty taste. PC3 and 4 explained a further 20% of the variability (Figure 4). PC3 explained 11% of the variability and was characterized by soapy, sweet taste, sour taste, and chalkiness. PC4 explained 9% of the variability and was comprised of the attributes cereal, brothy, metallic, and bitter taste (Table 9). Many of the primary flavors observed in the whey proteins (animal/wet dog, cardboard, sweet aromatic) have also been previously documented in liquid whey and other dried whey ingredients (Carunchia-Whetstine et al., 2003; Drake et al., 2003).

For soy proteins, 76% of the variability was explained on the first four principal components (Figure 5 and 6). PC1 explained 26% of the variability and was characterized by sweet aromatic, pasta, animal/wet dog, flour paste, fecal/dirty, yeasty, salty, viscosity and astringency (Table 10). PC2 described 19% of the variability and was characterized by opacity, cardboard, and brothy. PC3 explained 17% of the variability and was characterized by color, cereal, roasted, malty, and bitter. PC4 explained 14% of the variability and was comprised of the attribute sweet. Unlike whey proteins, where WPC80 and WPI were clearly distinguished, sensory properties of SPC and SPI were not distinct. Samples SPC1, SPC2 and SPI4 were characterized by low intensities of aromas and flavors. Flavors present in other soy proteins but absent in SPI4, SPC1 and SPC2 were fecal, yeasty, brothy, bitter taste, and sour taste. SPI3 had a distinct fecal note and SPC3 was more chalky (mean intensity 5.5) than the other soy protein samples. In contrast, sample SPI1 exhibited a higher viscosity and sweet aromatic than the other soy proteins. Similar attributes identified in these soy proteins were documented in soymilks (N'Kouka et al., 2004).

Correlation analysis was conducted on whey and soy combined as well as on whey and soy results individually. Analysis of the combined whey and soy data (Table 11) revealed the presence of a number of positive and negative correlations. Sweet aromatic was positively correlated with cereal, pasta, and flour flavors. Positive correlations were also present between cereal and flour flavors. The presence of cereal flavor was also strongly related to the presence of roasted, flour, and pasta, and an inverse relationship existed between cereal and both brothy and metallic flavors.

Correlation analysis of the whey sensory results alone (Table 12) revealed several correlations. Some of these relationships were not evident with the combined data. Opacity, sweet aromatic, color intensity, astringency, and viscosity were all correlated to each other. Therefore, samples that were higher in viscosity were more opaque and exhibited higher color intensities as well as higher intensities of sweet aromatic and astringency. Astringency was correlated to sweet aromatic and cardboard flavors. Soapy flavor was positively correlated to salty taste. Correlation analysis of the soy sensory results (Table 13) similarly revealed correlations, some of which were not present in the combined data set. Sweet aromatic and viscosity were correlated to pasta flavor. A positive relationship existed between animal and fecal, while an even stronger positive relationship existed between fecal and yeasty. Roasted and cereal flavors were also positively correlated.

The results from the consumer questionnaire showed that most participants purchased granola bars (69%) and cereal bars (47%) versus sports/nutritional bars (29%) (Table 14). Forty-nine percent of participants did not consume protein bars and/or meal replacement bars. However, 24% of consumers stated that they consumed protein bars at least once per month. Fifty-three percent of the consumers felt they had a moderate level of knowledge about the use and function of protein in foods. The majority of the consumers polled (68%) did not purchase food and/or beverages with added protein. Dairy products (61%) and meat products (69%) were most likely to be consumed and purchased if choosing a product high in protein. Key health claims that positively influenced bar purchase were “develops and maintains healthy bones”, “decreases chances of heart disease”, “decreases cancer risk”, “increases mental alertness”, and “prevents tooth decay” (Table 15). Weight control, immune system enhancement, development of lean muscle mass, and appetite reduction were not as important as these other health claims. Key product features for bars were “contains no animal fat” and “does not contain genetically modified ingredients” (Table 16).

Of the 147 consumers polled, the results indicated that consumer knowledge of health benefits and product claims of soy products centered on the high protein value of soy-based foods and/or beverages (65%). Fifty-eight percent indicated that soy was low fat/fat-free and forty-five percent indicated it was cholesterol free. In contrast, consumer perception of health benefits and products claims of dairy products were that they provide/develop and maintain healthy bones (88%) and contain calcium (80%). Sixty-three percent of the consumers agreed that dairy products have a great taste. The majority of the consumers polled indicated that “cow’s milk is a healthy food” (85% strongly agree and agree) and that “soy milk is a healthy food” (70% strongly agree and agree). Eighty-four percent (strongly agree and agree) of the consumers polled felt “cow’s milk tastes good”. However, for the statement “soy milk tastes good”, eighty-two percent of the consumers strongly disagreed, disagreed, or did not know if soy milk tastes good.

Conclusions

Descriptive analysis revealed differences among and between sensory properties of whey and soy proteins. Whey proteins (WPC and WPI) were characterized by the sensory attributes cardboard, brothy, metallic, and soapy. The intensities of these attributes were directly related to the type of protein such as concentrate versus isolate. Whey protein isolate sample WPI6 demonstrated a mean soapy intensity of 1.6, while whey protein concentrate WPC1 demonstrated a mean soapy intensity of 0.15. Soy proteins (SPC and SPI) were commonly characterized by the sensory attributes cereal, malty, flour paste, roasted, and these intensities were also related to the type of protein, concentrate verses isolate. Overall, consumers in this study perceived soy and dairy products as healthy foods and/or beverages, but different health benefits were associated with each product. Further, dairy products were generally perceived as better tasting than soy products.

References

American Soybean Association (ASA) 2004 "soy protein" www.asasoy.com

Carunchia-Whetstine, M., J. Parker, M.A. Drake, and D.K. Larick. 2003. Determining flavor and flavor variability in commercially produced liquid Cheddar whey. *Journal of Dairy Science.* 86(2): 439

Civille, G.V. and Lyon, B.G. (Eds). 1996. Aroma and flavor lexicon for sensory evaluation: terms, definitions, references, and examples. Madison, WI: American Society for Testing and Materials. p.158.

Davisco Foods International, Le Sueur, Minnesota. USA. 2004. Personnal Correspondance.

De Wit, J.N. and Moulin, J. 2001. Whey protein isolates: manufacture, properties, and applications. Industrial Proteins. vol 9 p.6-8

Drake, M.A., Karagul-Yuceer, Y. K.R. Cadwallader, C.V. Civille. And P.S. Tong. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. *Journal of Sensory Studies*. 18:199-216.

Drake, M.A., X.Q. Chen, S. Tamarapu, and B. Leenanon. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. *Journal of Food Science*. 65(7):1244-1247.

FDA, 2004."nutrition labeling and education act" www.fda.gov

Foegeding, E. A., J.P. Davis, D. Doucet, and M. McGuffey. 2002. Advances in modifying and understanding whey protein functionally. *Trends Food Science*. 13:151-159

Friedeck, K.G., Karagul-Yuceer, Y., and Drake, M.A. 2003. Soy protein fortication of a low-fat dairy based ice cream. *Journal of Food Science*. 68(9): 2651-2657.

Kinsella, J.E. 1979. Functional Properties of Soy Proteins. *Journal of Am Oil Chem Soc* 56:242-257.

Meilgaard, M. Civille, G.V, and Carr, B.T. 1999. Sensory Evaluation Techniques. 3rd Edition. CRC Press, Inc. Boca Raton, FL.

National Dairy Council. 2003. "whey protein" www.nationaldairycouncil.org

N'Kouka, K.D., Klein, B.P., and Lee, S.Y. 2004. Developing a Lexicon for Descriptive Analysis of Soymilks. *Journal of Food Science*. In Press.

Schutte, L. and van den Ouweland, G.A.M. 1979. Flavor Problems in the Application of Soy Protein Materials. *J Am Oil Chem Soc* 56:289-290.

The Solae Company, St. Louis, Missouri, USA. 2004. Personnal Correspondance.

USB (United Soybean Board), 2001. The 2001 edition of the Soy Stats by the United Soybean Board. www.unitedsoybean.org

USB. 2004. Consumer attitudes about nutrition: 2004-2005 National report. July 2004.

USDEC, 2003. Reference manual for U.S. whey and lactose products. www.usdec.org

Tables and Figures

for

Literature Review

Table 1: Composition of liquid whey

Composition of Whey

	Fluid Sweet Whey	Fluid Acid Whey	Dried Sweet Whey	Dried Acid Whey
Total Solid	6.35	6.50	96.5	96
Moisture	93.70	93.50	3.5	4
Fat	0.5	0.04	0.8	0.6
Protein	0.80	0.75	13.1	12.5
Lactose	4.85	4.90	75	67.4
Ash	0.50	0.80	7.3	11.8
Lactic Acid	0.05	0.40	0.2	4.2

***www.albalagh.net/halal/col4.shtml**

Table 2: United States exports of whey product by country

U.S. Exports of Product by Country in 2001

Whey Proteins	Volume (in metric tons)	% Change 2001 vs. 2000
Mexico	19,863	-31
South America	11,515	-16
Middle East/N Africa	472	-51
Japan	14,592	-3
Korea	7,440	-51
China	27,830	+20
Taiwan	10,061	+9
SE Asia	31,663	-11
World	**170,505**	**-9**

**Adapted from www.USDEC.org*

Table 3: Types of whey protein

Whey Type	Characteristic
Liquid Whey	Produced during cheese making
Whey Powder	Dried Whey
WPC34	34% protein
WPC35	35% protein
WPC50	50% protein
WPC80	80% protein
WPI	90% protein or greater
Reduced Lactose Whey	Less than 60% lactose
Demineralized Whey	Less than 7% ash
Acid Whey	pH of 5.1 or less
Sweet Whey	pH of 5.5 or higher

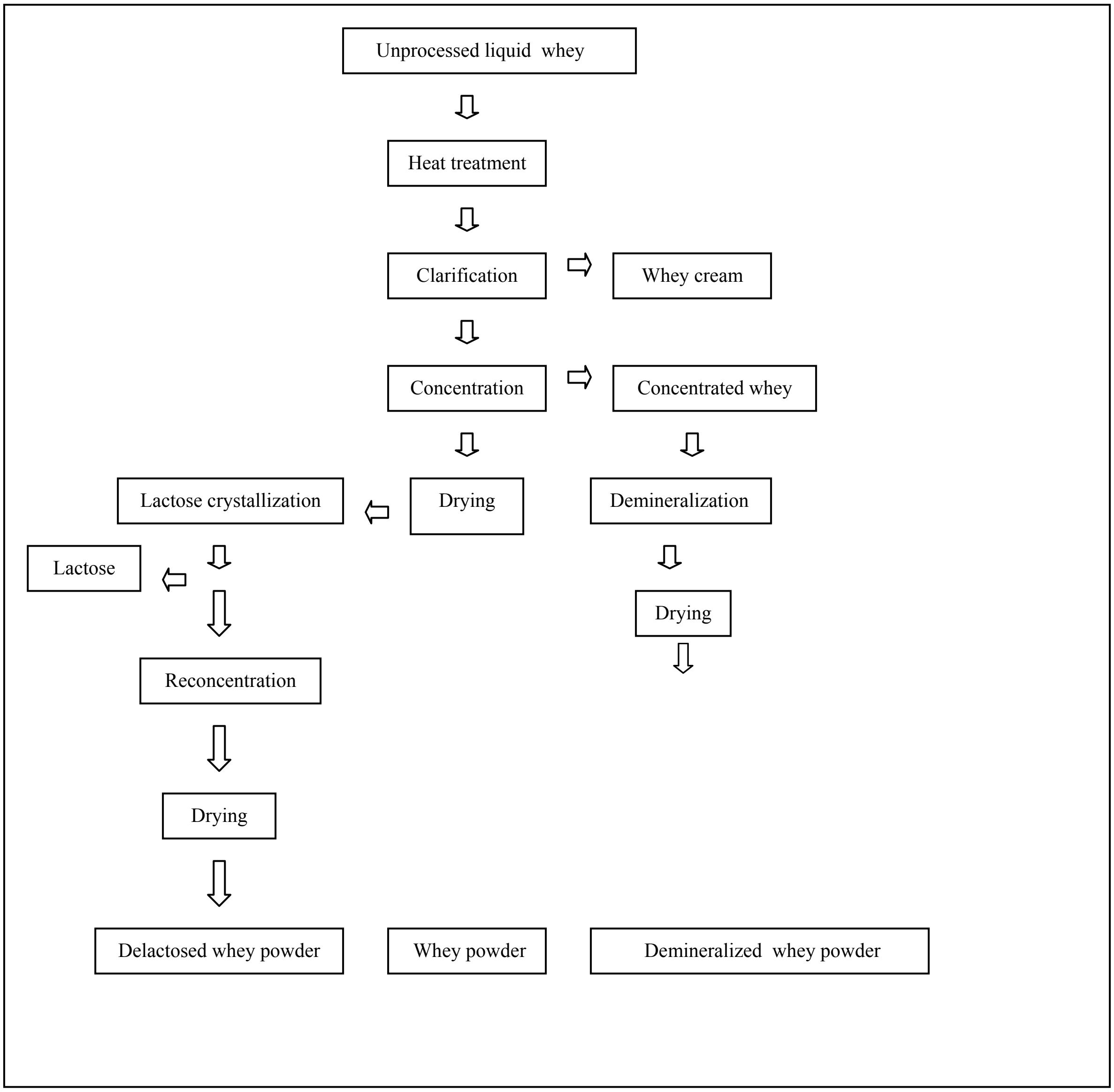
****Adapted from** *USDEC, Reference manual for U.S. whey and lactose products 2003,**

Table 4: Nutritional composition of whey protein products

Nutrient Ingredient	Units	Dry Sweet Whey[1]	Whey Protein Concentrate 34% WPC34[2]	Whey Protein Concentrate 80% WPC80[2]	Whey Protein Concentrate 80% Hydrolyzed	Whey Protein Isolate WPI[2]	Whey Protein Isolate Hydrolyzed
		Value per 100 grams of Edible Portion					
Proximates							
Water	g	3.19	3.93	4.11	4.00	4.50	4.50
Energy	kcal	353.00	369.00	412.00	400.00	371.00	360.00
Energy	kj	1476.00	1542.00	1722.00	1672.00	1550.00	1504.00
Protein	g	12.93	34.36	80.00	80.00	90.75	90.00
Total lipid (fat)	g	1.07	3.93	6.60	6.25	0.50	0.50
Carbohydrate, by difference*	g	74.46	50.80	5.31	6.00	0.87	0.50
Ash	g	8.35	6.99	3.98	3.75	3.38	4.50
Minerals							
Calcium, Ca	mg	796.00	569.00	423.00	400.00	600 mg	200.00
Iron, Fe	mg	0.88	0.89	1.20		5.00	5.00
Magnesium, Mg	mg	176.00	104.00	50.00	50.00	15.00	10.00
Phosphorus, P	mg	932.00	547.00	0.00	325.00	25.00	30.00
Potassium, K	mg	2080.00	1680.00	517.00			800.00
Sodium, Na	mg	1079.00	630.00	255.00	225.00	450.00	1000.00
Zinc, Zn	mg	1.97	0.21				
Copper, Cu	mg	0.07					
Manganese, Mn	mg	0.009	0.06				
Selenium, Se	mcg	27.20					

**Adapted from the USDEC, Reference manual for U.S. whey and lactose products, 2003*

Figure 1: **Processing of whey powders**



**Varnam & Sutherland, 1994*

Table 5: Composition of whey protein concentrate 80% (WPC80) and whey protein isolate (WPI)

Composition of WPC vs. WPI

WPC 80

Typical Composition*

Protein	80.0%–82.0%
Lactose	4.0%–8.0%
Fat	4.0%–8.0 %
Ash	3.0%–4.0%
Moisture	3.5%–4.5%

WPI

Typical Composition*

Protein	90.0%–92.0%
Lactose	0.5%–1.0%
Fat	0.5%–1.0%
Ash	2.0%–3.0%
Moisture	4.5%

**Adapted from www.USDEC.org , 2003*

Table 6: Branched chain amino acid content of key proteins

Protein Source	BCAAs g Per 100 g Protein
Whey Protein Isolate	26 g
Whey Protein Concentrate (80% Protein)	22.5 g
Egg White Powder	22 g
Milk Protein Isolate	20 g
Soy Protein Isolate	17 g

**US Dairy Export Council Reference Manual for US Whey and Lactose Products, 2003*

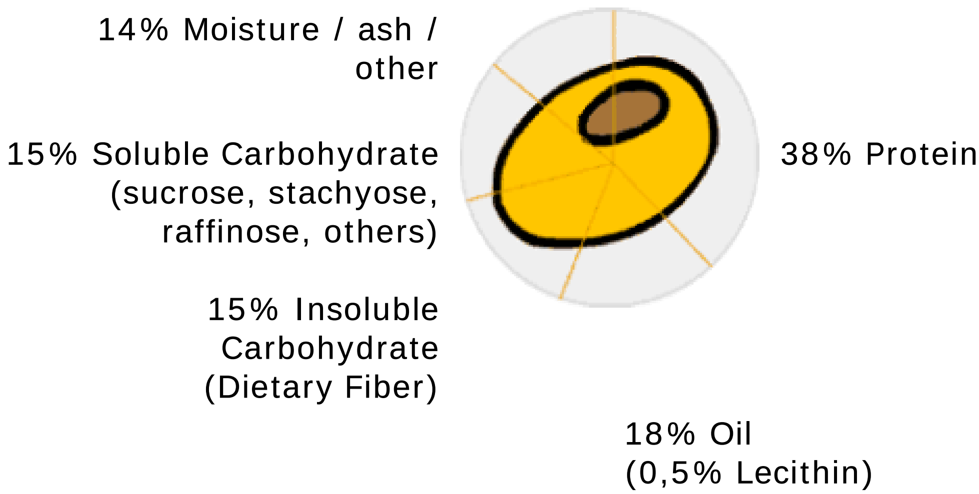
Table 7: *PDCAAS values of various proteins

Protein source	PDCAAS
Whey protein	1.14
Soy protein isolate	1.00
Milk protein isolate	1.00
Egg white powder	1.00
Casein	1.00
Ground beef	1.00
Canned lentils	0.52
Peanut meal	0.52
Wheat gluten	0.25

**PDCAAS = measures protein quality based on amino acid requirements of humans.*

Adapted Pasin and Miller 2000; USDEC Reference Manual for US Whey and Lactose Products, 2003

Figure 2: Composition of a soybean



*****_Adapted from www.asa-europe.org_

Table 8: Composition of commercial soy protein products

Composition	**Toasted Soybeans *(grams)***	***SPC *(per 100 grams)***	***SPI *(per 100 grams)***
Moisture	2	5.5	5
Protein	45	70	90
Fat	20	0.5	0.5
Carbohydrates	26.5	16.5	0
Crude Fiber	3	3.5	0.5
Ash	3.5	4	4

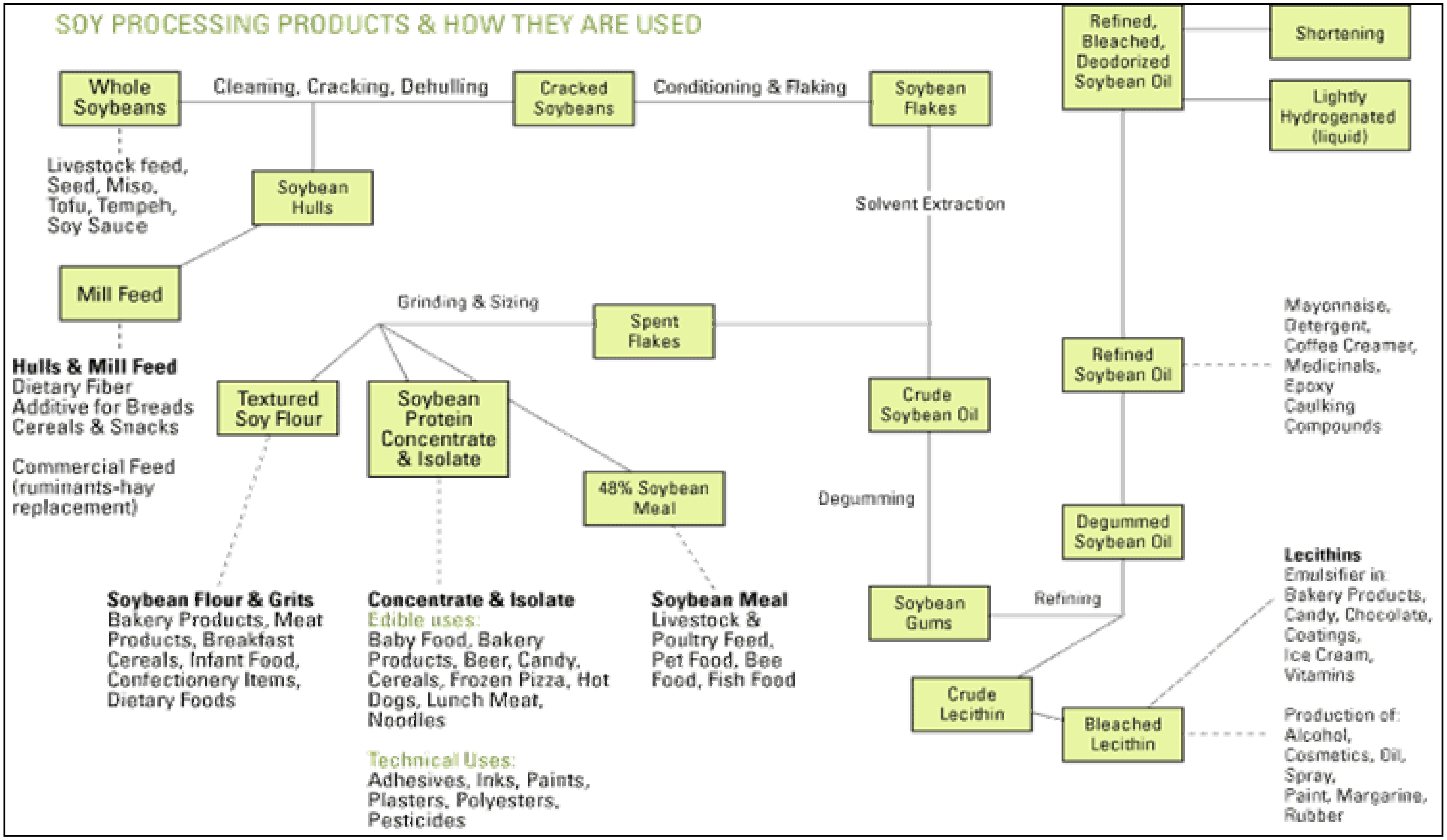
**SPC – soy protein concentrate SPI – soy protein isolate*
Adapted Gremli et al. 1974 and Kinsella J. 1979

Table 9: Functional properties of soy protein concentrate and soy protein isolate in food system

Type of soy protein	Functional Properties	Mode of Action	Food System
SPC, SPI	Soluility	Protein salvation pH dependent	Beverages
SPC	Water absorption and binding	Hydrogen-bonding and entrapment	Meats, sausages, breads, cakes
SPC, SPI	Viscosity	Thickening	Soups, gravy
SPC, SPI	Gelation	Protein matrix formation	Meats, cheese
SPC, SPI	Emulsification	Formation and stabilization of fat emulsions	Sausages, bologna, soup, cakes, icecream
SPC, SPI	Fat absorption	Binding of free fat	Meats, donuts
SPC, SPI	Flavor binding	Adsorption and entrapment	Simulated meats, bakery

**Adapted from Soya and Oilseed Bluebook, 2001*

Figure 3: Soy processing products



*Adapted from the American Soybean Association, 2003

Table 10: Composition in Soy Products

Soy Food	**Isoflavones *(milligrams)***	**Protein *(grams)***	**Serving size**
Mature soybeans	176	34	½ cup
Roasted soybeans	167	30	½ cup
Soy Protein Isolate	57	26	1 oz.
Soy Protein Concentrate	12	18	1 oz.
Soy Flour	44	8	¼ cup
Soy Milk	20	10	8 fl. oz
Textured Soy Protein	28	18	¼ cup

* Liu, 1997 and *Hudnall, M, 1999*

Tables and Figures

for

Manuscript

Table 1: Soy proteins acquired for initial sensory language development

Product Name	Product Type	Company	Manufacturing location
Supro EX33	SPI	The Solae Company	St. Louis, MO
Supro 500E	SPI	The Solae Company	St. Louis, MO
Promine DS	SPI	The Solae Company	St. Louis, MO
Procon 2000	SPI	The Solae Company	St. Louis, MO
Alpha 5812	SPC	The Solae Company	St. Louis, MO
Supro 670	SPI	The Solae Company	St. Louis, MO
Bunge NB	SPI	The Solae Company	Sao Paulo, Brazil
Bunge LH	SPI	The Solae Company	Sao Paulo, Brazil
Prolisse™ 500	SPI	Cargill Soy Protein Solutions	Wayzata, MN
ProFam 780	SPI	Archer Daniels Midland Company	Decatur, IL
ProFam930	SPI	Archer Daniels Midland Company	Decatur, IL
Arcon G	SPC	Archer Daniels Midland Company	Decatur, IL
Arcon F	SPI	Archer Daniels Midland Company	Decatur, IL
Arcon VF	SPC	Archer Daniels Midland Company	Decatur, IL
PFL	SPI	Archer Daniels Midland Company	Decatur, IL
ProFam 781	SPI	Archer Daniels Midland Company	Decatur, IL
Profam 825	SPI	Archer Daniels Midland Company	Decatur, IL
ProFam 873	SPI	Archer Daniels Midland Company	Decatur, IL
ProFam 891	SPI	Archer Daniels Midland Company	Decatur, IL
ProFam 892	SPI	Archer Daniels Midland Company	Decatur, IL
Arcon SM	SPC	Archer Daniels Midland Company	Decatur, IL
Arcon SJ	SPC	Archer Daniels Midland Company	Decatur, IL
Arcon S	SPC	Archer Daniels Midland Company	Decatur, IL
ISO 111 S800	SPI	Nutriant	Cedar Falls, Iowa
S5700	SPC	Nutriant	Cedar Falls, Iowa
SPI 500A	SPC	IFI	China
Solcon	SPC	Solbar Plant Extracts Ltd.	Ashdod, Israel
SPI 6000	SPI	Protient	Mountain Lake, MN
SPI 6400	SPI	Protient	Mountain Lake, MN

*SPC = soy protein concentrate, SPI = soy protein isolate

Table 2: Whey proteins acquired for initial sensory language development

Product Name	Product Type	Company	Manufacturing location
PowerPro®	WPI	Land O'Lakes Dairy Proteins	Perham, MN
Mel-O-Skim WP75	WPC75	Kerry Specialty Ingredients	Owen, WI
WPI 5849	WPI	Kerry Specialty Ingredients	Owen, WI
BiPro	WPI	Davisco Foods International, Inc.®	Eden Prairie, MN
WPC 80%	WPC80	Davisco Foods International, Inc.®	Eden Prairie, MN
Proliant 8000	WPC80	Proliant Inc.	Ames, IA
IsoChill 9000	WPI	Proliant Inc.	Ames, IA
Proliant 9000	WPI	Proliant Inc.	Ames, IA
Protient 8500	WPC80	Protient	Mountain Lake, MN
Protient 9000	WPI	Protient	Mountain Lake, MN
Protient 8000	WPC80	Protient	Mountain Lake, MN
WPI	WPI	Glanbia	Twin Falls, Idaho
WPC 80%	WPC80	Sorrento Lactalis, Inc.	Nampa, Idaho
WPC 80%	WPC80	CP International	Tulare, CA
WPC 80%	WPC80	Agri-Mark	Onalaska, WI
WPC 80%	WPC80	CalPro	Corona, California
Inpro 80 LF	WPC80 (defatted)	Vitalis Nutrition, Inc.	United Kingdom
Inpro 80	WPC80	Vitalis Nutrition, Inc.	Nampa, Idaho
Inpro 90 LF	WPI (defatted)	Vitalis Nutrition, Inc.	United Kingdom
Inpro 90	WPI	Vitalis Nutrition, Inc.	California
Alacen 392	WPC	NZMP	Wellington, New Zealand
Alacen 895	WPC	NZMP	Wellington, New Zealand
Alacen 53997	WPC	NZMP	Wellington, New Zealand

*WPC 80 = whey protein concentrate 80%, WPC75 = whey protein concentrate 75%, WPI = whey protein isolate 90%

Table 3: Initial whey and soy protein lexicon identified from roundtable discussion of 50 whey and soy proteins

Aromatics:

- Sweet aromatic/oatmeal
- Brothy/potato
- Mushroom/metallic
- Animal/wet dog
- Pasta water
- Cereal/grainy
- Doughy
- Cooked/milky
- Cardboard/wet paper
- Soapy
- Cucumber
- Fecal
- Catty
- Roasted/Nutty
- Dirty/Soil

Tastes:

- Sweet
- Sour
- Salty
- Bitter

Chemical Feeling Factors:

- Astringency

Texture/Mouthfeel:

- Chalkiness
- Thickness

Visual:

- Color intensity
- Opacity

Table 4: Products selected for descriptive sensory analysis

Product Code	Product Name	Company	Manufacturing location
WPC1	Inpro 80	Vitalis Nutrition, Inc.	Nampa, Idaho
WPC2	Mel-O-Skim WP75	Kerry Specialty Ingredients	Owen, WI
WPC3	8000	Proliant Inc.	Ames, IA
WPC4	WPC80	Agri-Mark	Onalaska, WI
WPC5	WPC80	Davisco Food International Inc.	Eden Prairie, MN
WPC6	Alacen 392	NZMP	Wellington, New Zealand
WPI1	5849	Kerry Specialty Ingredients	Owen, WI
WPI2	Inpro 90	Vitalis Nutrition, Inc.	California
WPI3	9000	Protient	Mountain Lake, MN
WPI4	WPC80	Glanbia	Twin Falls, Idaho
WPI5	Bipro	Davisco Food International Inc.	Eden Prairie, MN
WPI6	Alacen 59191	NZMP	Wellington, New Zealand
WPI7	Alacen 59337	NZMP	Wellington, New Zealand
WPI8	Alacen 895	NZMP	Wellington, New Zealand
SPC1	Arcon S	Archer Daniels Midland Company	Decatur, IL
SPC2	Arcon SM	Archer Daniels Midland Company	Decatur, IL
SPC3	S5700	Nutriant	Cedar Falls, Iowa
SPC4	Alpha 5812	The Solae Company	St. Louis, MO
SPI1	ISO 111	Nutriant	Cedar Falls, Iowa
SPI2	Prolisse	Cargill Soy Protein Solutions	Wayzata, MN
SPI3	ProFam 873	Archer Daniels Midland Company	Decatur, IL
SPI4	SPI6040	Protient	Mountain Lake, MN

*WPC 80 = whey protein concentrate 80%, WPC75 = whey protein concentrate 75%, WPI = whey protein isolate 90%, SPC = soy protein concentrate, SPI = soy protein isolate.

Table 5: Lexicon for whey and soy proteins (WPC80, WPI, SPC, and SPI)

Descriptor	Definition	Reference and Preparation
Sweet Aromatic	Sweet aromatic associated with cooked Oatmeal	Quaker oatmeal 50 g soaked in 500 ml water
[b]Cooked	Aromatic associated with cooked milk	Cooked milk, heat skim milk to 85º*C for 30 minutes
Pasta	Aromatic reminiscent of old fryer oil and/or biscuit dough, and pasta	Cooked pasta drained [2,4]-decadienal 20 ppm
Metallic/ Meat serum	Aromatics associated with metal or with juices of rare steak	Rare steak juice [1]-octen-[3]-one 20 ppm
[c]Cardboard/ Wet brown paper	Aroma associated with cardboard	1inch x 1inch cut brown paper bag boiled in water for 30 minutes, drained in water [pentanal]
[c]Animal/Wet dog	Knox unflavored gelatin	Dissolve one bag of gelatin (28g) in 16 oz. in water
Brothy	Aromatics associated with vegetable stock or boiled potatoes	Drained broth Food Lion® from white potato slices in glass jar
Cereal/Grain	Aromatics associated with grain	Crushed, blend, filter Cheerios® 50g in 16 oz water
Roasted	Aromatics associated with roasted unsalted soy nuts	Roasted unsalted soynuts Whole Foods® brand
[c]Fruity	Aromatics associated with different fruits	Fresh pineapple [ethyl hexanoate] 20 ppm
[c]Catty	Aromatics associated with tom-cat urine	[2]-mecapto-[2]-methyl-pentan-[4]-one 20 ppm
Soapy	Aromatics associated with medium chain fatty acids and soaps	Ivory® soap 50 g soaked in 500 ml water
Flour paste	Aromatic associated with flour paste	Gold Medal® all purpose flour 60g in 500 ml water
[b]Fecal/Dirty	Aromatic associated with animal excrement or dirt	Skatole or indole 20 ppm
Yeasty	Aromatics associated with fermenting Yeast	Fleishmanns® yeast packet 7g in 500 ml water
[d]Malty	Sweet slightly fermented or sour grain note	Ovaltine® regular malt 8 Tbsp in 500 ml water or Grape nuts® cereal (20g) in water 1000 ml
[a]Salty	Basic taste associated with salt	0.4% NaCl (salt) in water
[a]Sweet	Basic taste associated with sucrose	5% sucrose in water
[a]Sour	Basic taste associated with acid	0.08% citric acid in water
[a]Bitter	Basic taste associated with bitterness	0.08% caffeine in water
[a]Astringency	Trigeminal sensation of tongue drying	Black tea, soak 6 tea bags in 500 ml water for 10 min
Viscosity	Force required to move a spoon back And forth in product	Water = 1 Cream = 3

[a]Universal references in Meilgaard et al., 1999
[b]Drake et al., 2001
[c]Drake et al., 2003
[d]N'Kouka et al., 2004

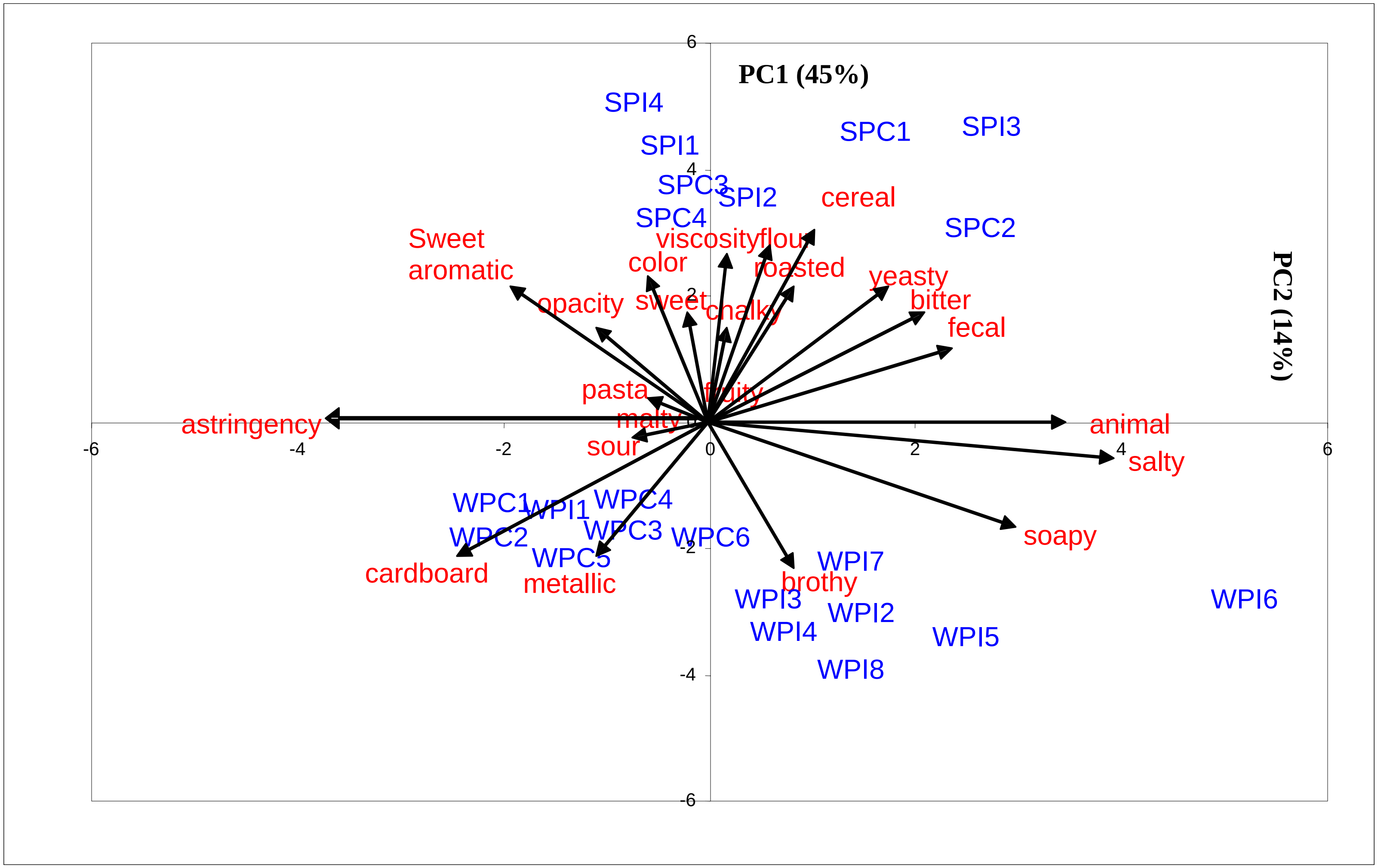
Table 6: Proximate analysis results for whey and soy proteins

Sample	Protein %	Moisture %	Ash %	Fat %
WPC1	78.4e	3.6o	2.8def	6.6b
	0.38	0.04	0.01	0.15
WPC2	79.4e	4.5i	2.8def	4.6e
	0.33	0.03	0.01	0.08
WPC3	79.4e	4.16k	2.89def	5.3d
	0.17	0.06	0.01	0.05
WPC4	77.6e	3.6o	2.7efg	4.5e
	0.30	0.02	0.04	0.06
WPC5	78.1e	3.6o	3.2de	5.4d
	1.1	0.01	0.08	0.06
WPC6	77.5ef	3.9m	2.9def	5.2d
	0.20	0.01	0.11	0.01
WPI1	85.7d	4.8g	2.8def	1.4j
	0.05	0.02	0.0	0.01
WPI2	87.0d	5.2e	2.7efg	0.1k
	0.04	0.01	0.0	0.01
WPI3	87.8cd	6.1a	2.4fg	0.32k
	0.29	0.05	0.04	0.11
WPI4	85.7d	2.5q	2.6efg	0.3k
	7.25	0.03	0.01	0.07
WPI5	94.4a	3.2p	2.1gh	0.1k
	0.09	0.04	0.01	0.01
WPI6	78.5e	4.1l	5.0b	6.0c
	0.33	0.01	0.06	0.10
WPI7	90.4bc	3.6n	2.9def	0.2k
	0.18	0.03	0.05	0.06
WPI8	92.7ab	4.7h	1.6h	0.22k
	0.08	0.01	0.03	0.14
SPC1	74.1g	4.9f	4.2c	1.33j
	0.29	0.01	0.01	0.06
SPC2	74.3fg	4.8g	4.2c	2.4h
	0.40	0.09	0.04	0.20
SPC3	67.8g	5.2e	2.4d	3.1f
	0.07	0.06	1.4	0.16
SPC4	77.6e	5.5d	6.3a	2.7g
	0.11	0.02	0.03	0.05
SPI1	79.0e	4.4j	3.2de	14.3a
	0.10	0.03	0.03	0.30
SPI2	85.9d	5.8c	6.0a	2.03i
	0.13	0.03	0.01	0.03
SPI3	90.6bc	3.9m	4.6bc	2.8g
	0.14	0.04	0.01	0.06
SPI4	85.1d	6.0b	5.9a	2.2hi
	0.06	0.01	0.01	0.01

Numbers in the top row for each sample represent the mean and numbers in the second row of each sample represent the standard deviation

Means within columns with different letters are significantly different ($p<0.05$)

Figure 1: Principal component biplot of descriptive analysis of whey and soy proteins (PC1 and PC2)

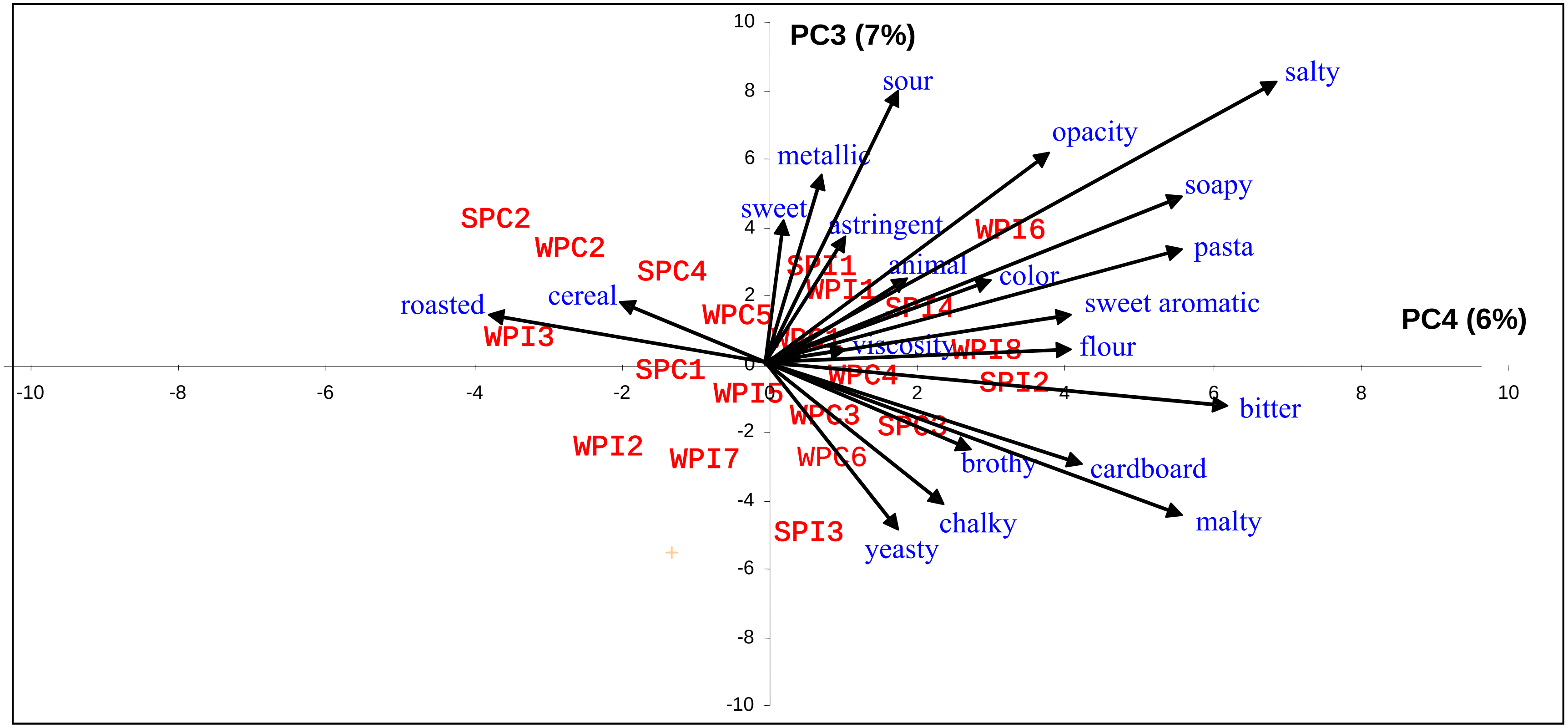


PC stands for principal component

Percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis

WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate, SPI = soy protein isolate

Figure 2: Principal component biplot of descriptive analysis of whey and soy proteins (PC3 and PC4)



PC stands for principal component

Percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis

WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate, SPI = soy protein isolate

Table 7: Mean values of descriptive sensory attributes for whey and soy proteins

Attribute	WPC1	WPC2	WPC3	WPC4	WPC5	WPC6	WPI1	WPI2	WPI3	WPI4	WPI5	WPI6	WPI7	WPI8	SPC1	SPC2	SPC3	SPC4	SPI1	SPI2	SPI3	SPI4	LSD
Opacity	14.0	14.2	14.1	13.5	14.3	14.1	13.3	3.0	10.4	4.6	4.7	12.3	5.9	8.1	14.4	14.9	14.6	14.0	14.8	14.5	14.8	14.9	1.38
Color	3.5	3.5	4.4	3.7	3.8	3.5	3.5	2.0	2.2	2.2	2.1	3.3	3.4	2.3	4.9	5.1	5.3	4.2	4.8	3.9	4.9	7.5	0.68
Sweet Aromatic Oatmeal	1.1	0.9	1.1	1.3	1.1	1.0	0.98	0.58	0.0	0.66	0.42	0.60	0.61	0.66	1.4	1.0	1.4	1.4	1.8	1.5	1.2	1.6	0.62
Cardboard	2.2	2.2	2.2	1.5	2.1	2.0	1.8	1.7	1.3	2.1	1.1	1.3	1.3	1.7	0.65	0.0	1.0	1.2	1.1	1.0	1.3	1.5	0.72
Cereal	0.0	0.59	0.0	0.0	0.0	0.63	0.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.0	1.9	1.8	2.2	1.5	1.9	2.1	0.59
Brothy	1.0	1.1	1.5	1.1	1.4	1.8	1.2	1.5	1.5	1.3	1.2	1.6	1.4	1.5	0.69	0.75	0.84	1.1	0.74	0.81	0.9	0.79	0.65
Roasted	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.88	0.73	1.0	1.0	0.59	0.98	0.92	0.43
Metallic	1.1	1.3	1.1	1.9	1.5	0.76	0.98	0.74	0.93	0.68	0.59	0.77	0.69	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.49
Fruity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09
Pasta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.76	0.0	0.0	0.57	0.34
Malty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.62	0.0	0.50	0.0	0.0	0.67	0.56	0.36
Animal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.54	0.0	0.0	0.0	0.0	0.17
Soapy	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.60	0.0	1.4	1.6	0.0	1.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.39
Flour paste	0.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.06	0.0	0.0	0.0	0.80	0.73	0.0	0.58	1.1	1.1	0.74	1.4	0.45
Fecal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.98	0.0	0.0	0.0	1.5	0.0	0.29
Yeasty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.56	0.0	0.35
Astringent	2.9	2.8	2.4	2.3	2.6	2.2	2.5	2.0	2.2	2.1	1.9	0.55	2.3	2.1	2.0	2.1	2.6	2.6	0.0	2.2	2.2	2.3	0.58
Sweet	0.70	0.61	0.61	0.96	0.0	0.0	0.52	0.70	0.50	0.62	0.0	0.50	0.67	0.50	0.82	0.72	0.52	1.1	0.88	0.85	0.70	0.88	0.50
Sour	0.62	0.55	0.0	0.54	0.0	0.0	0.90	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.54	0.0	0.0	0.0	0.0	0.45
Salty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.23
Bitter	0.74	0.0	0.61	0.50	0.0	0.0	0.0	0.54	0.0	0.0	0.57	0.90	0.0	0.88	0.90	0.77	0.69	1.0	0.90	1.8	1.6	0.94	0.98
Viscosity	1.5	1.5	1.4	1.3	1.5	1.7	1.2	0.90	1.0	1.1	1.0	0.90	1.06	0.92	5.16	4.0	4.3	2.8	5.8	4.5	4.2	5.3	1.1
Chalky	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.50	5.5	0.39	0.92	0.56	1.2	1.4	0.54

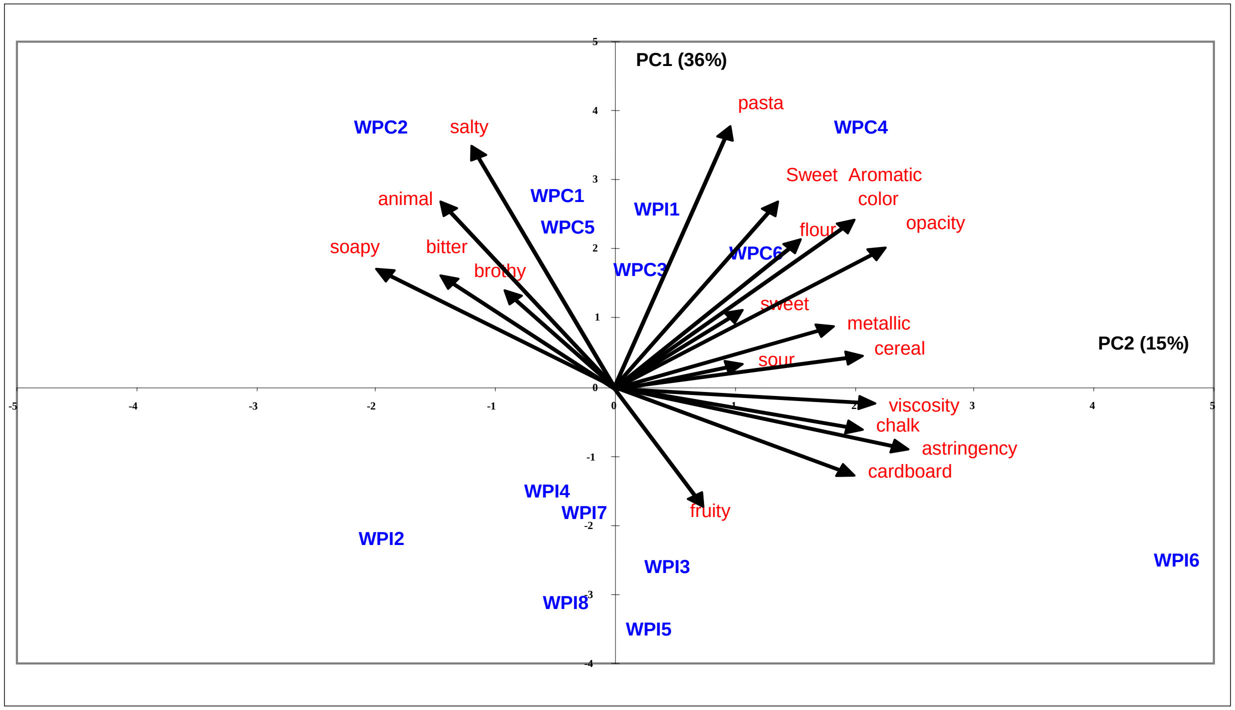
Attributes were scored on a 15 point numerical scale where 0 = absence of attribute and 15 = very high intensity of the attribute
WPC1-WPC6 = whey protein concentrate samples 1-6, WPI1-WPI7 = whey protein isolate samples 1-7, SPC1-SPC4 = soy protein concentrate samples 1-4
SPI1-SPI4 = soy protein isolate samples 1-4
LSD = least significant difference. Means in a row that differ by more than LSD are different ($p<0.05$)

Table 8: Eigenvector loadings of each attribute for whey and soy protein principle component analysis

Attribute	Factor 1	Factor 2	Factor 3	Factor 4
Opacity	0.19	-0.18	**0.26**	0.19
Color	**0.25**	-0.10	0.09	0.12
Sweet Aromatic Oatmeal	**0.25**	-0.24	0.07	0.20
Cardboard	-0.19	**-0.31**	-0.12	0.17
Cereal	**0.30**	0.02	0.03	-0.07
Brothy	**-0.25**	0.05	-0.13	0.10
Roasted	**0.29**	0.04	-0.01	-0.14
Metallic	**-0.23**	-0.21	0.10	0.06
Pasta	0.24	-0.05	0.19	**0.28**
Malty	0.01	-0.04	-0.09	**-0.28**
Animal wet dog	0.01	**0.34**	-0.26	0.01
Soapy	-0.18	**0.29**	0.27	0.27
Flour paste	**0.29**	0.01	0.04	0.13
Fecal	0.15	0.21	**-0.28**	-0.07
Yeasty	**0.23**	0.14	-0.18	0.06
Astringent	0.01	**-0.44**	0.06	0.02
Sweet	**0.18**	-0.09	0.05	-0.02
Sour	-0.02	-0.11	**0.35**	0.06
Salty	-0.06	**0.39**	0.35	0.30
Bitter	0.19	0.18	-0.07	**0.29**
Viscosity	**0.29**	-0.01	0.03	0.03
Chalky	**0.18**	-0.02	-0.15	0.12
Variance Explained[a]	44%	13%	7%	6%

[a]refers to percent variance explained
Numbers in bold are believed to be of primary importance

Figure 3: Principal component biplot of descriptive analysis of whey proteins (PC1 and PC2)



PC stands for principal component

Percentage following PC in parentheses explains amount of variability depicted by each principal component

WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate, SPI = soy protein isolate

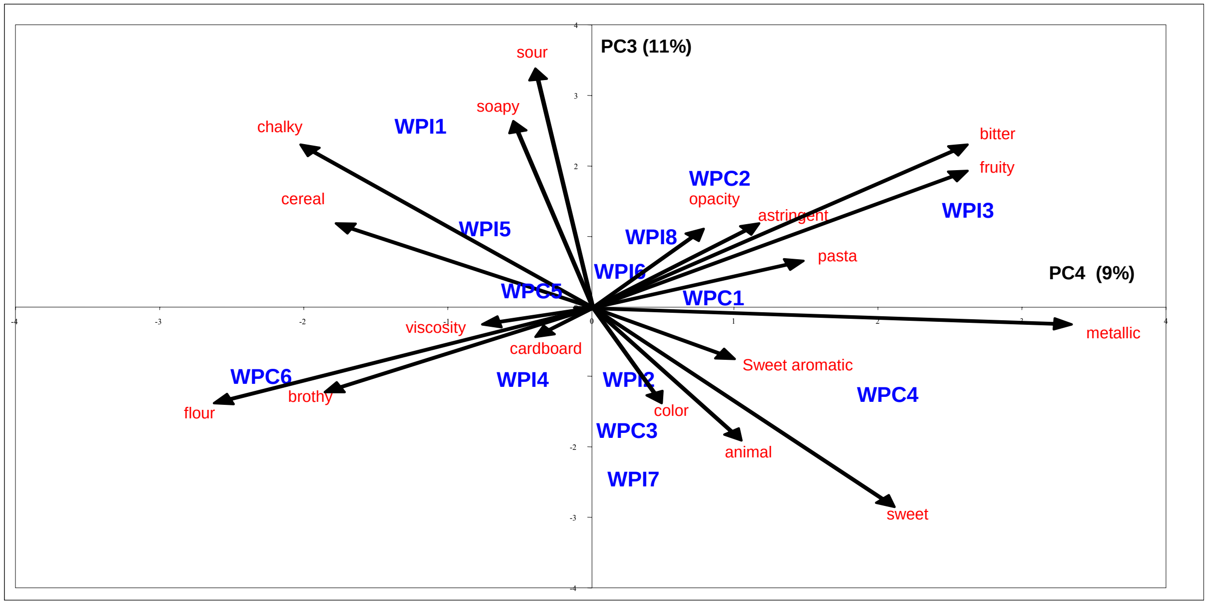
Table 9: Eigenvector loadings of each attribute for sensory analysis of whey proteins (WPC and WPI)

Attribute	Factor 1	Factor 2	Factor 3	Factor 4
Opacity	**0.29**	0.26	0.15	0.10
Color	**0.29**	0.22	-0.15	-0.01
Sweet Aromatic Oatmeal	**0.33**	0.17	-0.11	0.13
Cardboard	**0.26**	-0.11	-0.05	-0.09
Cereal	0.25	0.07	0.17	**-0.27**
Brothy	-0.13	0.18	-0.16	**-0.29**
Metallic	0.22	0.10	-0.03	**0.43**
Fruity	0.07	-0.22	0.26	**0.31**
Pasta	0.11	**0.47**	0.10	0.18
Animal wet dog	-0.19	**0.32**	-0.26	0.10
Soapy	-0.23	0.23	**0.35**	-0.07
Flour paste	0.19	0.27	-0.20	**-0.38**
Astringent	**0.30**	-0.12	0.14	0.15
Sweet	0.11	0.14	**-0.37**	0.25
Sour	0.13	0.05	**0.44**	-0.08
Salty	-0.15	**0.42**	0.14	-0.05
Bitter	-0.16	0.21	0.29	**0.34**
Viscosity	**0.33**	-0.01	-0.07	-0.13
Chalky	0.27	-0.03	**0.31**	-0.30
Variance Explained[a]	36%	15%	11%	9%

[a]refers to percent variance explained

Numbers in bold are believed to be of primary importance

Figure 4: Principal component biplot of descriptive analysis of whey proteins (PC3 and PC4)



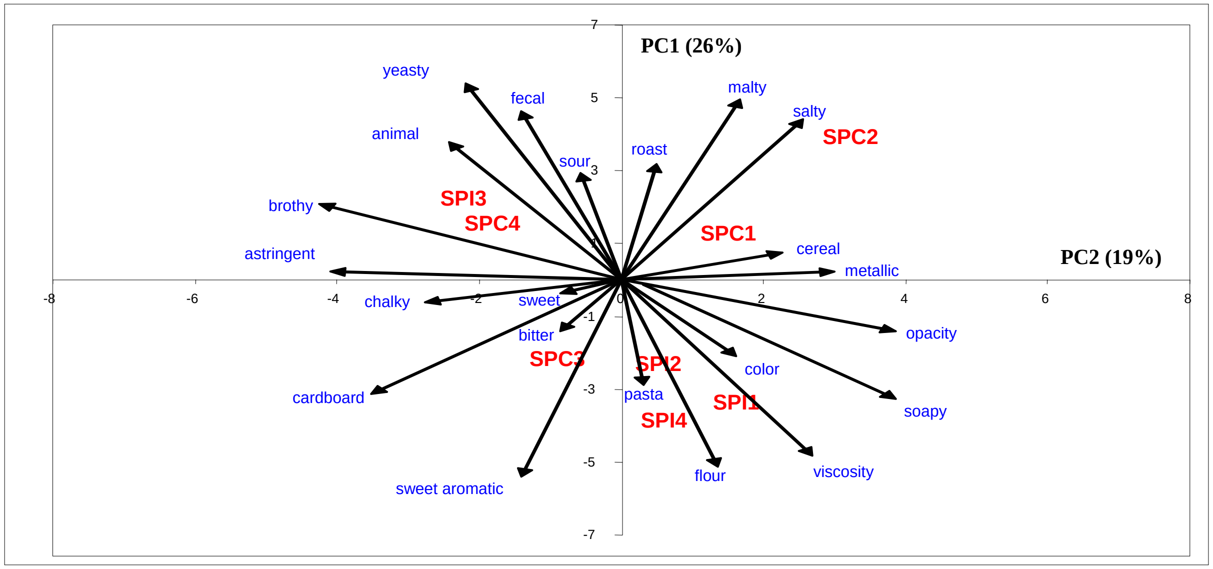
PC stands for principal component

Percentage following PC in parentheses explains amount of variability depicted by each principal component

WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate,

SPI = soy protein isolate

Figure 5: Principal component biplot of descriptive analysis of soy proteins (PC1 and PC2)



PC stands for principal component
Percentage following PC in parentheses explains amount of variability depicted by each principal component
WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate,
SPI = soy protein isolate

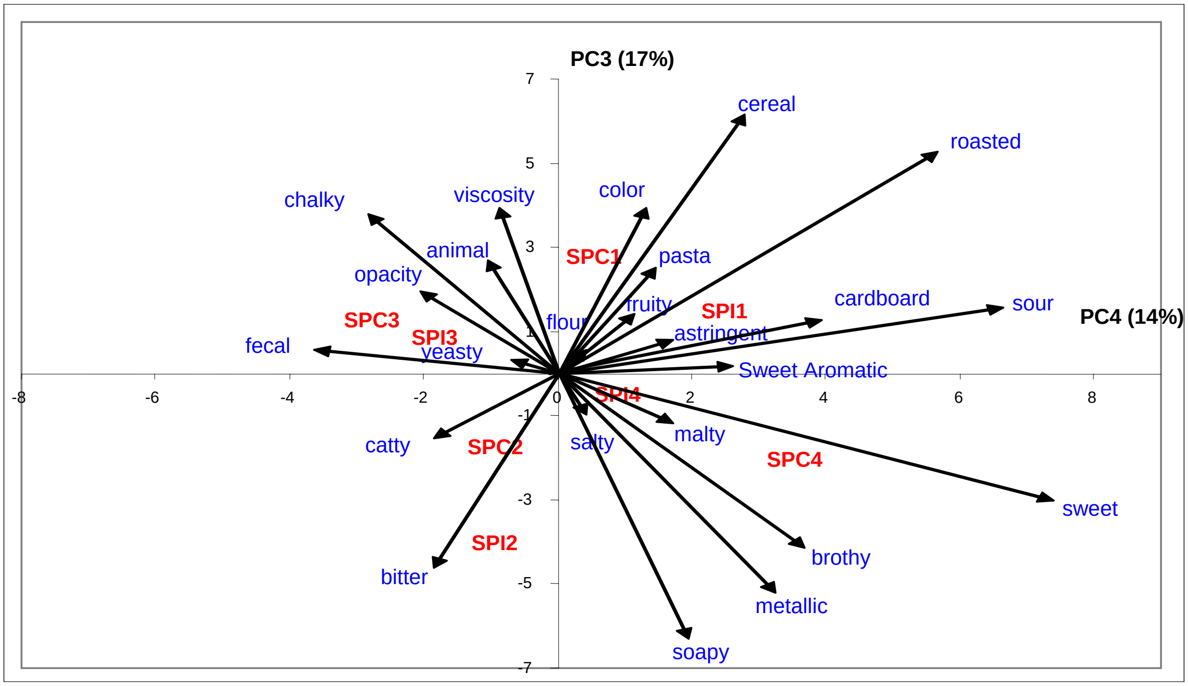
Table 10: Eigenvector loadings of each attribute for sensory analysis of soy proteins (SPC and SPI)

Attribute	Factor 1	Factor 2	Factor 3	Factor 4
Opacity	-0.08	**0.25**	0.11	-0.18
Color	-0.12	0.07	**0.20**	0.07
Sweet Aromatic Oatmeal	**-0.36**	-0.04	0.01	0.13
Cardboard	-0.12	**-0.29**	0.06	0.20
Cereal	0.03	0.15	**0.43**	0.16
Brothy	0.12	**-0.33**	-0.26	0.19
Roasted	0.15	0.03	**0.32**	0.31
Metallic	-0.01	0.19	**-0.31**	0.18
Pasta	**-0.30**	0.03	0.16	0.25
Malty	**0.26**	0.09	-0.04	0.13
Animal wet dog	**0.21**	-0.18	0.20	-0.05
Soapy	-0.17	0.20	**-0.37**	0.09
Flour paste	**-0.35**	0.07	0.06	-0.01
Fecal	**0.26**	-0.14	0.07	-0.12
Yeasty	**0.27**	-0.18	0.07	-0.07
Astringent	-0.01	**-0.32**	0.02	0.11
Sweet	-0.01	-0.01	-0.18	**0.48**
Sour	0.16	-0.01	0.14	**0.45**
Salty	**0.30**	0.25	-0.03	0.02
Bitter	-0.04	-0.09	**-0.29**	-0.14
Viscosity	**-0.28**	0.18	0.21	-0.05
Chalky	-0.07	-0.2	0.22	**-0.31**
% Variance Explained[a]	26%	19%	17%	14%

[a]*refers to percent variance explained*

Numbers in bold are believed to be of primary importance

Figure 6: Principal component biplot of descriptive analysis of soy proteins (PC3 and PC4)



PC stands for principal component

Percentage following PC in parenthesis explains amount of variability depicted by each principal component on each axis

WPC = whey protein concentrate, WPI = whey protein isolate, SPC = soy protein concentrate, SPI = soy protein isolate

Table 11: Correlations between descriptive sensory attributes of whey and soy proteins

	Opac	**Col**	**SwA**	**Card**	**Cer**	**Brot**	**Roas**	**Met**	**Fruit**	**Past**	**Anim**	**Soap**	**Flou**	**Ast**	**Swee**	**Sour**	**Salty**	**Bitt**	**Visc**	**Cha**
Opac	1.00	0.72	**0.78**	-0.13	0.57	-0.45	0.49	-0.16	0.19	0.61	-0.13	-0.38	0.52	0.46	0.33	0.17	-0.05	0.38	0.57	0.32
Col		1.00	**0.76**	-0.32	**0.78**	-0.65	0.73	-0.49	0.05	0.72	-0.09	-0.51	**0.81**	0.21	0.45	-0.06	-0.13	0.39	**0.81**	0.53
SwA			1.00	-0.25	**0.76**	-0.68	0.69	-0.36	0.02	**0.85**	-0.20	-0.62	**0.78**	0.32	0.64	0.01	-0.34	0.47	**0.81**	0.44
Card				1.00	-0.68	0.59	-0.65	0.68	-0.26	-0.45	-0.26	0.05	-0.59	0.50	-0.32	0.17	-0.17	-0.45	-0.60	-0.38
Cer					1.00	**-0.82**	**0.97**	**-0.80**	0.29	**0.77**	0.05	-0.54	**0.90**	-0.03	0.56	-0.01	-0.18	0.56	**0.95**	0.58
Brot						1.0	-0.78	0.55	-0.26	-0.64	0.10	0.47	**-0.78**	-0.11	-0.47	-0.12	0.25	-0.49	**-0.82**	-0.49
Roas							1.00	**-0.78**	0.29	0.71	0.13	-0.56	**0.83**	-0.04	0.62	-0.05	-0.19	0.54	**0.90**	0.49
Met								1.00	-0.09	-0.53	-0.16	0.28	**-0.78**	0.25	-0.32	0.17	0.01	-0.56	**-0.76**	-0.53
Fruit									1.00	0.02	-0.11	-0.14	0.05	0.08	0.04	0.12	-0.08	-0.18	0.18	-0.06
Past										1.000	-0.04	-0.30	**0.84**	0.00	0.54	0.01	0.0	0.46	**0.84**	0.42
Anim											1.00	0.07	-0.08	-0.41	0.01	-0.15	0.36	0.20	-0.01	0.01
Soap												1.00	-0.43	-0.41	-0.49	0.12	0.73	-0.10	-0.51	-0.35
Flou													1.00	-0.06	0.53	-0.13	-0.14	0.65	**0.96**	0.59
Ast														1.00	0.03	0.28	-0.40	-0.17	-0.04	0.16
Swee															1.00	0.07	-0.18	0.39	0.50	-0.01
Sour																1.00	0.10	-0.06	-0.13	-0.19
Salty																	1.00	0.15	-0.19	-0.12
Bitt																		1.000	0.60	0.20
Visc																			1.00	0.58
Cha																				1.00

Numbers in bold represent significant correlations ($p<0.05$)
Opac = opacity, Col = color, SwA = sweet aromatic, Card = cardboard, Brot = brothy, Met = metallic, Fruit = fruity, Past = pasta, Anim = animal wet/dog, Soap = soapy, Flou = flour paste, Fec = fecal, Yeas = yeasty, Ast = astringency, Swee = sweet, Bitt = bitter, Visc = viscosity, Cha = chalkiness

Table 12: Correlations between descriptive sensory attributes of whey proteins

	Opac	Color	SwA	Card	Cereal	Brothy	Met	Soap	Ast	Sweet	Sour	Salty	Bitter	Visc
Opacity	1.00	**0.79**	**0.83**	0.50	0.47	-004	0.59	-0.19	**0.68**	0.13	0.29	0.02	0.09	**0.73**
Color		1.00	**0.80**	0.49	0.45	-0.07	0.52	-0.43	**0.60**	0.28	0.04	-0.03	-0.31	**0.70**
Sweet Aromatic			1.00	**0.55**	0.51	-0.24	**0.78**	-0.53	**0.63**	0.46	0.23	-0.24	-0.29	**0.77**
Cardboard				1.00	0.25	0.01	0.26	-0.56	**0.67**	0.01	0.14	-0.28	-0.32	**0.67**
Cereal					1.00	-0.24	0.19	-0.33	0.36	0.18	0.63	-0.16	-0.38	0.51
Brothy						1.00	-0.38	0.20	-0.47	-0.20	-0.48	0.32	0.24	-0.10
Metallic							1.00	-0.29	0.42	0.40	0.14	-0.18	-0.15	0.41
Soapy								1.00	-0.53	-0.41	0.07	**0.73**	0.51	**-0.54**
Astringency									1.00	0.01	0.32	-0.39	-0.17	**0.73**
Sweet										1.00	0.06	-0.03	-0.19	0.13
Sour											1.00	0.08	0.07	0.05
Salty												1.00	0.41	-0.43
Bitter													1.00	-0.46
Viscosity														1.00

Numbers in bold represent significant correlations ($p<0.05$)
Opac = opacity, SwA = sweet aromatic, Card = carboard/wet paper, Roas = roasted, Met = metallic, An = animal wet/dog, Soap = soapy, Flour = flour paste, Ast = astringency, Visc = viscosity, Chalky = chalkiness

Table 13: Correlations between descriptive sensory attributes of soy proteins

	Opac	**Col**	**SwA**	**Card**	**Cer**	**Brot**	**Roas**	**Past**	**Malty**	**Anim**	**Flou**	**Fec**	**Yeas**	**Ast**	**Swee**	**Sour**	**Bitt**	**Visc**	**Cha**
Opac	1.00	0.59	0.02	0.08	0.17	-0.66	-0.23	0.15	0.24	-0.25	0.56	0.19	0.11	-0.34	-0.54	-0.19	-0.10	0.55	0.08
Col		1.00	0.08	0.49	0.31	-0.32	0.09	0.30	0.24	-0.24	0.68	-0.02	0.01	0.09	-0.16	0.23	-0.39	0.38	0.23
SwA			1.00	0.38	0.03	-0.39	-0.15	**0.89**	-0.62	-0.35	0.71	-0.58	-0.62	0.05	0.28	-0.18	0.13	0.66	0.01
Card				1.00	-0.08	-0.57	0.01	0.41	0.09	0.05	0.43	0.24	0.33	0.56	0.19	0.34	-0.01	0.04	0.16
Cer					1.00	-0.57	**0.85**	0.39	0.08	0.34	0.03	0.01	-0.03	-0.21	-0.06	0.49	-0.59	0.44	0.03
Brot						1.00	-0.13	-0.29	0.13	0.05	-0.44	0.18	0.36	0.65	0.49	0.32	0.17	-0.82	-0.09
Roas							1.00	0.18	0.33	0.55	-0.31	0.17	0.16	-0.09	0.31	0.75	-0.43	0.05	-0.24
Past								1.00	-0.45	-0.33	0.68	-0.53	-0.52	0.09	0.30	0.17	-0.24	**0.69**	-0.02
Malty									1.00	0.35	-0.30	0.67	0.59	-0.28	0.16	0.50	0.12	-0.30	-0.55
Anim										1.00	-0.48	**0.71**	0.55	-0.18	-0.14	0.16	0.26	-0.10	-0.01
Flou											1.00	-0.42	-0.48	-0.07	-0.09	-0.27	0.01	0.76	0.17
Fec												1.00	**0.93**	-0.03	-0.33	0.18	0.23	-0.31	-0.01
Yeas													1.00	0.29	-0.31	0.33	-0.03	-0.51	0.14
Ast														1.00	0.07	0.31	-0.44	-0.49	0.54
Swee															1.00	0.54	0.11	-0.19	-0.71
Sour																1.00	-0.53	-0.29	-0.33
Bitt																	1.00	0.04	-0.38
Visc																		1.00	0.03
Cha																			1.00

Numbers in bold represent significant correlations ($p<0.05$)

Opac = opacity, Col = color, SwA = sweet aromatic, Card = cardboard, Brot = brothy, Met = metallic, Fruit = fruity, Past = pasta, Anim = animal wet/dog, Soap = soapy, Flou = flour paste, Fec = fecal, Yeas = yeasty, Ast = astringency, Swee = sweet, Bitt = bitter, Visc = viscosity, Cha = chalkiness

Table 14: Demographic information and consumer knowledge of soy and whey protein and protein products (n = 147)

Type of "bar" products purchased*	69% granola bars 23% sports/nutritional bars 38% chocolate bars 47% cereal bars 4% other
Frequency of protein bar or meal replacement bar consumption	46% I do not consume 24% At least once per month 16% At least 2-3 times per month 3% At least once per week 8% Two or more times per week 2% At least once per day 1% More than one time per day
Level of knowledge about the use and function of proteins in food products	9% None 31% Low 53% Moderate 7% Extensive
Health benefits and product claims soy products provide*	42% Helps to develop lean body mass and muscles 29% Regulate appetite/satiety 37% Weight control 30% Enhances immune defenses 2% Prevents cavities 48% Decreases chances of heart disease 32% Decreases menopausal symptoms 12% Increase mental alertness 33% Develops and maintains healthy bones 37% Decreases chances of developing cancer 58% Low in fat/fat-free 45% Cholesterol free 42% Lactose free 24% Contains calcium 65% High in protein 33% Low in carbohydrates 20% Great taste

Health benefits and product claims dairy products provide*	51% Rich in essential amino acids for lean body mass/muscle 21% Regulate appetite/satiety 24% Weight control 39% Enhances immune defenses 39% Prevents cavities 17% Decrease chances of heart disease 8% Decrease menopausal symptoms 7% Increase mental alertness 88% Develops and maintains healthy bones 18% Decrease chances of developing cancer 32% Low in fat/fat-free 13% Cholesterol free 10% Lactose free 80% Contains calcium 44% High in protein 17% Low in carbohydrates 63% Great taste 20% Does not contain genetically modified ingredients
Purchase of food and/or beverage products that contain added protein	32% Yes 68% No
Type of food and/or beverage products likely to purchase and consume if high protein*	47% Breakfast cereal 48% Protein bars 17% Soy milk 61% Dairy products 14% Baked goods 18% Soy products 23% Snack products 42% Smoothies/shakes 16% Coffee based beverages 15% Soup 48% Cow's milk 69% Meat products 49% Legumes 18% Frozen entrees 5% Other
Consumer perception on statement "Cow's milk is a healthy food"	28% Agree strongly 57% Agree 10% Neither agree or disagree 3% Disagree 3% Disagree strongly
Consumer perception on statement "Soy milk is a healthy food"	20% Agree strongly 50% Agree 30% Neither agree or disagree 0% Disagree 1% Disagree strongly

Consumer perception on statement "Cow's milk tastes good"	39% Agree strongly 45% Agree 5% Neither agree or disagree 8% Disagree 2% Disagree strongly
Consumer perception on statement "Soy milk tastes good"	8% Agree strongly 12% Agree 46% Neither agree or disagree 25% Disagree 11% Disagree strongly

*Indicates panelists were allowed to choose more than more category so percentages do not add up to 100%

Table 15: Rank score of health claims that influence purchase intent of protein bars

Factor	Mean ranking
Develops and maintains healthy bones	4.2E
Weight control	5.3BC
Decreases chances of heart disease	4.5DE
Enhances immune defenses	4.9CD
Helps to develop lean body mass and muscle	6.8A
Decreases chances of developing cancer	4.3E
Suppresses/reduces appetite	5.6B
Protects teeth from decay	4.6DE
Increase metal alertness	4.4DE

*Panelists were instructed to rank each choice in order, most important = 1; least important = 10
ranks followed by different letters are different ($p<0.05$)

Table 16: Ranking score of product features that influence purchase intent of protein bars

Factor	Mean ranking
Contains no animal fat	3.8E
Free from trans fatty acids	4.5D
Cholesterol free	7.5A
High in protein	4.7CD
Low in fat/fat-free	7.6A
Does not contain genetically modified ingredients	3.4E
Contains no soy products	5.2C
Low in carbohydrates	4.6CD
Contains calcium	6.1B
Lactose free	7.2A

*Panelists were allowed to rank each choice in order, most important = 1; least important = 1

+Ranks followed by different letters are different (p<0

Appendix

Appendix

Table 1 : Codes for whey and soy protein samples

Treatment	Product code	Company Name	Product name
1	SPI1	Nutriant	ISO 111
2	SPI3	ADM	ProFam 873
3	SPC1	ADM	Arcon S
4	SPC4	Solae	Alpha 5812
5	WPI1	Kerry	5849
6	WPI2	Inovatech	Inpro 90
7	WPC1	Inovatech	Inpro 80
8	WPC4	Agrimark	WPC80
9	WPI4	Glanbia	WPC80
10	WPI6	Alacen	59191
11	WPI3	Protient	9000
12	WPC3	Proliant	8000
13	WPI5	Davisco	Bipro
14	SPI2	Cargill	Prolisse
15	WPC2	Kerry	Mel-O-skim
16	WPI8	Alacen	895
17	WPI7	Alacen	59337
18	SPI4	Protient	SPI6040
19	WPC6	Alacen	392
20	SPC3	Nutriant	S5700
21	SPC2	ADM	Arcon SM
22	WPC5	Davisco	WPC80

Table 2: Descriptive scoring ballot and references for evaluation

<u>Basic Taste References</u> (30 ml per 2 oz. sample cup)
Salty: 0.2% NaCl (salt) in water = 1
Sweet: 2% sucrose in water = 2, 5% sucrose in water = 5
Sour: 0.05% citric acid in water = 2, 0.08% citric acid in water = 5
Bitter: 0.05% caffeine = 2, 0.08% caffeine = 5

Warm-up: R1 (whey protein concentrate 80%)

Attribute	Intensity
Sweet Aromatic	2
Brothy/Potato/Mushroom	1
Cardboard/Wet brown paper	3
Astringency	3.5

Warm-up: R2 (soy protein concentrate)

Attribute	Intensity
Sweet Aromatic	3
Brothy/Potato/Mushroom	2.5
Fecal/Dirty	3.5
Malty	1
Astringency	4.5
Bitter	5

<u>Terms</u>

Opacity - the degree to which the liquid is opaque.
Very opaque (whole milk) = 15 Not opaque(water) =0

Color Intensity - the intensity or strength of the color from light to dark.
No color = 0 (clear) Dark intense color = 15 (black)

Aroma - swirl sample cup prior to evaluation; evaluate the intensity of the aroma in the headspace of the sample cup.

Flavor - swirl sample cup prior to evaluation and expectorate sample.

Viscosity - the force required to slurp the sample off of a spoon.
Water = 1 Heavy Cream = 3
Maple Syrup = 6.8 Condensed milk = 14

Astringency - mouth drying intensity after swallowing or expectorating sample

Chalkiness - presence or absence of particles in mouth

Table 3: WPC, WPI, SPC, and SPI Descriptive Ballot

Tasting order____
Name_________________________
Panelist # _____________________

COLOR/APPEARANCE

Opacity

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
not opaque — very opaque

Color intensity

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
No Color — dark intense color

AROMA

Sweet Aromatic/Oatmeal

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none — high

FLAVOR

Cardboard/Wet brown paper

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none — high

Cereal/Grain/Toasted

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none — high

Brothy/Potato/Mushroom

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none — high

Roasted/Nutty/Burnt

|____|____|____|____|____|____|____|____|____|____|____|____|____|____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none — high

Metallic/ Meat Serum

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Fruity

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Pasta/Dough/Fatty

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Malty

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Catty

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Animal/Wet dog

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Soapy

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Fecal/Dirty

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Yeasty

|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|____|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Flour paste
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

FEELING FACTORS

Astringency
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

BASIC TASTES

Sweet taste
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Sour taste
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Salty taste
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Bitter taste
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

TEXTURE/MOUTHFEEL

Viscosity
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Chalkiness
|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|_____|___|
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
none high

Table 4: U&A questionnaire

1. What type of "bar" product do you normally purchase? You may select (√) more than one response.

	Granola bars
	Sports/Nutritional bars
	Chocolate bars
	Cereal bars
	Other ____________________

2. How often do you consume protein bars or meal replacement bars? Please select (√) one response.

	I do not consume
	At least once per month
	At least 2-3 times per month
	At least once per week
	Two or more times per week
	At least once per day
	More than one time per day

3. If you were to purchase a protein bar how important would the following HEALTH claims be to you? Please rank the features from MOST IMPORTANT to LEAST IMPORTANT (***MOST IMPORTANT = 1; LEAST IMPORTANT = 9***).

RANKING

	Helps to develop lean body mass and muscles
	Suppress/reduces appetite
	Weight control
	Enhances immune defences
	Protects teeth from decay
	Decreases chances of heart disease
	Increases mental alertness
	Decreases chances of developing cancer
	Develops and maintains healthy bones

4. If you were to purchase a protein bar how important would the following PRODUCT FEATURES be to you? Please rank the features from MOST IMPORTANT to LEAST IMPORTANT (***MOST IMPORTANT = 1; LEAST IMPORTANT = 10***).

RANKING

	Low in fat/fat-free
	Cholesterol free
	Lactose free
	Contains calcium
	Contains no soy products
	High in protein
	Low in carbohydrates
	Free from trans fatty acids
	Contains no animal fat
	Does not contain genetically modified ingredients

5. What is your level of knowledge about the use and function of proteins in food products? Please select (√) one response.

	None
	Low
	Moderate
	Extensive

6. Please select the health benefits and product claims that you believe SOY PRODUCTS can provide. You may select more than one choice.

Please tick (√) all that apply	**Health Benefits**	Please tick (√) all that apply	**Product Claims**
	Helps to develop lean body mass and muscles		Low in fat/fat-free
	Regulate appetite/satiety		Cholesterol free
	Weight control		Lactose free
	Enhances immune defences		Contains calcium
	Prevents cavities		High in protein
	Decreases chances of heart disease		Low in carbohydrates
	Decreases menopausal symptoms		Great taste
	Increases mental alertness		Does not contain genetically modified ingredients
	Develops and maintains healthy bones		
	Decreases chances of developing cancer		

7. Please select the health benefits and product claims that you believe DAIRY PRODUCTS can provide. You may select more than one choice.

Please tick (√) all that apply	**Health Benefits**	Please tick (√) all that apply	**Product Claims**
	Rich in essential amino acids for lean body mass/muscle		Low in fat/fat-free
	Regulate appetite/satiety		Cholesterol free
	Weight control		Lactose free
	Enhances immune defences		Contains calcium
	Prevents cavities		High in protein
	Decreases chances of heart disease		Low in carbs
	Decreases menopausal symptoms		Great taste
	Increases mental alertness		Does not contain genetically modified ingredients
	Develops and maintains healthy bones		
	Decreases chances of developing cancer		

8a. Do you specifically choose food and beverage products that contain added protein (e.g. protein bars, shakes, etc)?

	Yes
	No

8b. If you answered YES in Question 6a, why do you specifically choose food and beverage products that contain added protein?

____

____

9. What food or beverage products would you be most likely to consume if you were to purchase a high protein food or beverage? You may select more than one choice.

Please tick (√) all that apply	
	Breakfast cereal
	Protein bars
	Soy milk
	Dairy products (e.g. cheese, yoghurt)
	Baked goods
	Soy products (e.g. tofu)
	Snack products (e.g. chips, pretzels)
	Smoothies/shakes
	Coffee based beverages (e.g. lattes)
	Soup
	Milk (cow)
	Meat products (e.g. lean red meat, chicken, fish, pork)
	Legumes (e.g. beans, peas)
	Frozen entrees
	Other ___________________________

10. Please indicate how you feel about the following statement “Cow’s milk is a healthy food”.

	agree strongly
	agree
	neither agree nor disagree (don’t know)
	disagree
	disagree strongly

11. Please indicate how you feel about the following statement “Soy milk is a healthy food”.

	agree strongly
	agree
	neither agree nor disagree (don’t know)
	disagree
	disagree strongly

12. Please indicate how you feel about the following statement “Cow’s milk tastes good”.

	agree strongly
	agree
	neither agree nor disagree (don’t know)
	disagree
	disagree strongly

13. Please indicate how you feel about the following statement “Soy milk tastes good”.

	agree strongly
	agree
	neither agree nor disagree (don’t know)
	disagree
	disagree strongly

Table 5: NC State University IRB form

SUBJECT CONSENT TO PARTICIPATE IN CONSUMER SURVEY
I agree to participate in a consumer survey for the Department of Food Science at North Carolina State University. I understand that participation is voluntary and that I may withdrawal my participation at any time. I also understand that information I provide is confidential and that results with not be associated with my name. I understand that I will not be required to consume any food or beverage for this survey.
______________________________   ***PRINT YOUR NAME***
______________________________ ______________________________   ***SIGN YOUR NAME*** ***DATE***