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Comparative sensory evaluation of soy protein isolates extracted from full-fat and defatted flours using natural and conventional synthetic extraction chemicals

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Abstract

As consumer interest in natural food, in which no synthetic chemicals are used, is increasing, a traditional soy protein isolate (SPI) was prepared from full-fat flour, using amaranth (*Amarathus tricolor* L.) ash and lemon (*Citrus limon*) extracts as alternatives to NaOH and HCl, respectively. Spectrum™ descriptive analysis revealed some distinctive characteristics of the traditional SPI compared to those of conventional and commercial SPIs. Principal component analysis (PCA) results accounted for 90.11% of the samples variability on a two dimensional component space based on the attribute eigenvector loadings of ≥ 0.3, and associated the traditional SPI with opacity, pasta, sweet, sour, and bitter (principal component 1, 55.14%), but not color, cardboard, cereal, brothy, ashy, astringent, salty, and viscosity, which were also characteristic to the conventional and commercial SPIs (principal component 2, 36.53%). That's the traditional SPI had comparatively no unique characteristic that would affect its application in food systems.

Introduction

Soy protein isolate (SPI), a soybean derivative protein powder, is one of the most important products in food processing as well as many other industrial uses. Its preference is attributed to its ability to enhance nutritional (especially protein) and functional qualities of food products to which it is used as an ingredient (Kinsella, 1979; Mariotti *et al.*, 1999; L'hocine *et al.*, 2006). SPI has been added to baked foods, breakfast cereals and meat products among others. It can also be made into a nutritious drink once added to water. A soybean product qualifies to be called a protein isolate only if it contains at least 90% crude protein (N x 6.25) on dry basis (Codex Alimentarius Commision, 1996). To achieve this purity, conventional technique of processing SPI involves use of synthetic chemicals such as n-hexane, ethanol, sodium hydroxide (NaOH) and hydrochloric acid (HCl) (Kinsella, 1979). Some of these chemicals have well known risks if handled without adequate knowledge, and have created skepticism among health-conscious food consumers. Although health risks of such chemicals are still under debate, the number of consumers that opt for more natural or traditional products is fast growing (Soil Association, 2012). Dickson-Spillmann *et al.* (2011) reported that laypeople view chemicals as either safe or dangerous, and think that even minor doses of chemicals are likely to cause harm. To such people, 'synthetic equals dangerous'. The challenge lies on identifying natural and food-based reagents and chemicals that would produce similar or improved results as the synthetic ones. For this reason, food scientists have recently shown interest in traditional methods of food processing in order to understand and improve them.

Although rarely documented, for centuries people have traditionally used ash and lemon extracts as alkali and acid sources in food preparation, among other uses. In countries like Malawi, amaranth (*Amaranth hybridus*) plant is the most preferred source of ash for food alkali due to its pH strength and safety for consumption. However, not much if any has been done to explore the effects of these traditional chemicals in food processing. Up to now, studies that report use of the ash extract or in combination with lemon extract for the preparation of any protein isolate can hardly be found. At this time, when consumers are increasingly becoming skeptical about consuming food processed using synthetic chemicals, exploring these traditional chemistries may be considered a favorable option. Not only would it address the fear of consuming synthetic chemicals, but also enhance food processing at grass-root level, where most of the

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people in developing countries are found. The major drawback to the use of most traditional chemicals is the organoleptic effects they may have on the final product. Unfortunately, very little information, if any is available that characterize their sensory evaluation effect.

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 (Stone and Sidel, 1993). 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 the production of data for which important and rational decisions can be made (Meilgaard *et al.*, 1999).

There are several techniques and or instruments developed for the sensory evaluation of food. The selection of specific method of analysis to be used depends on a number of factors, which include its appropriateness with reference the characteristics of the product at hand, and advantages and disadvantages of the test. In most cases, a mixture of them is used to develop deeper understanding of consumer acceptance of a food product. Lawless and Heymann (1999) identified the two primary areas of sensory analysis to be analytical and affective tests.

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

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

Descriptive analysis describes both qualitative and quantitative sensory aspects of a product using trained panelists (Meilgaard *et al.*, 1999). In qualitative aspects the characteristics in a product such as appearance, flavor, aroma and/or texture are selected. 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. Affective tests typically use consumers or panelists that are untrained for a particular product evaluation.

Sensory aspects of soy products are an ongoing problem where sensory research often labels soy as having characteristics of “beany”, grassy, and bitter flavors. Business and marketing techniques rely on the nutritional value, functionality, and price of soy protein to mask the flavor problems associated with soy products. There is a number of sensory evaluation studies conducted on 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. The results showed that the most objectionable flavors were beany and bitter. Cowan *et al.* (1973) evaluated soy concentrates and flours. The resultant descriptions were beany, bitter, nutty, and toasted. In the following studies, still the attribute “beany” was frequently reported as a predominant odor, which is an unacceptable flavor that can limit application of soy proteins. Drake *et al.* (2003) identified and developed a descriptive sensory language to profile the flavor of dried dairy ingredients; including whey protein concentrate (WPC) and whey protein isolate (WPI). Later, Carunchia *et al.* (2005) applied the sensory language in conjunction with instrumental analysis to document flavor and flavor chemistry of selected fresh WPC and WPI. Russell *et al.* (2006) compared whey and soy proteins in terms of sensory aspects where consumers detected distinction between the two. Nevertheless, there is still limited research to determine the sensory properties and consumer perceptions of soy protein powders as raw materials prepared using different processing techniques. Lexicons for raw ingredients are powerful tools for product development and can also be used to pinpoint flavor sources by interfacing with flavor chemistry results, to trace flavors into ingredient applications, and to interpret consumer responses (Drake and Civille, 2003; Drake, 2004). Description of flavor and flavor variability of both differently processed soy proteins is a key issue with the demand for great tasting healthy products; and a sensory language to distinguish these products would not only be useful for precise communication for product developers and marketers, but also serve as a platform to interpret instrumental volatile component studied on these proteins and to potentially trace flavors into ingredient applications. The aim of this study therefore, was to examine descriptive sensory characteristics of SPIs prepared using these amaranth ash and lemon extracts as natural chemicals with comparison to those of conventionally and commercially prepared SPIs.

Materials and Methods

Materials

Four SPI samples namely; natural chemical full fat flour (NCFF), synthetic chemical full fat flour (SCFF), natural chemical defatted flour (NCDF) and synthetic chemical defatted flour (SCDF) were prepared in the vegetable protein laboratory using full-fat (FF) or defatted flour (DF), with either the natural chemicals (NC) or synthetic ones (SC), by modified method of Li *et al.* (2007). The final neutralized protein was freeze dried, sealed in polythene bags and stored at room temperature in the dark until further analysis. Three commercial SPI samples were obtained from a local soybean protein companies in Shandong, China and were also stored in sealed polythene bags at room temperature in the dark. All products were less than 3 months old at the time of analysis. Distilled or deionized water was used in sample preparation and all laboratory procedures.

Sample preparation

To avoid light oxidation, samples were prepared for sensory analysis under darkness according to the method of Drake *et al.* (2003) with modification. The SPI powders were suspended at 10% solids (w/v) in distilled water, on a magnetic stirrer. The rehydrated samples were stored at 4°C in beaker rapped in aluminum foil for 24 h prior to sensory analysis. The suspensions were removed from refrigeration 1 h prior to analysis time. After shaking to avoid settling, approximately 30 mL of the product were poured into clear transparent odorless plastic cups with plastic lids and randomly labeled with 3-digits codes.

Table 1. Sensory language used to describe the soy protein isolates

Descriptor	Definition	Reference
Sweet aromatic	Sweet aromatic associated with cake mixor grains such as oatmeal	Quaker oatmeal, 50 g soaked in 500 mL water Vanilla cake mix
Pasta/doughy	Aromatic reminiscent of biscuit dough and cooked pasta	Cooked drained pasta, 2, 4-decadienal, 20 ppm on filter paper in sniff jar
Metallic/meat serum	Aromatics associated with metals or with juices of raw or rare beef	Aroma of fresh raw beef steak or ground beef or juices from seared beef steak
Cardboard/wet brown paper[a]	Aromatics associated with wet cardboard and brown paper	2 cm × 2 cm piece of brown paper bag boiled in water for 30 min
Animal/wet dog[a]	Aromatics associated with wet animal hair	Knox unflavored gelatin, dissolve one bag of gelatin (28 g) in two cups of distilled water
Brothy	Aromatics associated with vegetable stock or boiled potatoes	Drained broth from canned white potatoes
Cereal/grain	Aromatics associated with cereals and grains	Cheerios, 50 g in 200 mL water
Roasted	Aromatics associated with roasted nuts	Roasted, unsalted soynuts
Fruity[b]	Aromatics associated with different fruits, particularly pineapple	Fresh pineapple, ethyl hexanoate, 20 ppm on filter paper in sniff jar
Catty[b]	Aromatics associated with tom cat urine	[2]-mercapto-[2]-methyl-pentan-[4]-one, 20 ppm on filter paper in sniff jar
Soapy	Aromatics associated with medium chain fatty acids and soaps	White unscented soap bar, 50 g soaked in 500 mL water
Flour paste	Aromatics associated with white flour paste	All-purpose white flour, 60 g in 500 mL water
Fecal/dirty	Aromatics associated with animal excrement	Skatole or indole, 20 ppm on filter paper in sniff jar
Yeasty	Aromatics associated with fermenting yeast	Freeze-dried yeast packet, 7 g in 500 mL water
Yeasty		
Malty[c]	Sweet fermented aromatic associated with dried sprouted grains	Grape nuts cereal, 20 g in 500 mL water
Salty[d]	Basic taste elicited by salts	2% NaCl solution
Sweet[d]	Basic taste elicited by sugars	5% sucrose solution
Sour[d]	Basic taste elicited by acids	1% citric acid solution
Bitter[d]	Basic taste elicited by various compounds including caffeine and quinine	0.5% caffeine solution
Astringency[d]	Chemical feeling factor characterized by a drying or puckering of the oral tissues	Soak 6 black tea bags in 500 mL water for 10 min
Opacity	Visual term referring to the degree of opacity of the rehydrated protein solution	Water = 0 Whole fat fluid milk = 12
Color intensity[d]	Visual term referring to the intensity of the color of the rehydrated solution from light to dark	
Viscosity[d]	Attribute evaluated in the mouth, place product in mouth(approximately 1 tsp), evaluate the rate of flow across the tongue	Water = 1 Heavy cream = 3 Sweetened condensed milk = 12
Chalky	Attribute evaluated in the mouth, place product in mouth (approximately 1 tsp), evaluate the amount of particulates	Whole fat fluid milk = 0 Sour cream with instant cream of wheat cereal added = 5

[a]Drake, Karagul-Yuceer, Cadwallader, Civille, Tong (2003); [b]Drake and others 2001, [c]N'Kouka, Klein and Lee (2004); [d]Universal references in Meilgaard and others (1999). Adopted from Russell, Drake and Gerard (2006).

Lexicon development

Twenty-three relevant descriptors were identified from lists of lexicon described by previous studies (Drake *et al.*, 2003; Friedeck *et al.*, 2003; N'Kouka *et al.*, 2004) (Table 1). The sensory properties to be identified include aroma, flavor and color intensity.

Descriptive sensory analysis

Ten panelists (5 males and 5 females) comprising of food science students from various countries of origin were selected based on interest, availability, and knowledge of basic tastes as well as previous sensory analysis experience. These panelists did not participate in generating the initial lexicon. The Spectrum™ descriptive analysis technique, which utilizes a universal intensity scale for descriptor scaling (Drake and Civille, 2003; Meilgaard *et al.*, 1999) was used. By this method, panelists score intensities in the same manner across all attributes and all products. The advantages to this descriptive analysis technique are that 1 panel can be readily trained on multiple products, since one intensity scale is used, different types of products can be directly compared, and panel scaling is less prone to drift with time (Drake and Civille, 2003). Prior to the evaluation, the panelists met for a briefing session to identify and discuss sensory properties of rehydrated soy proteins using the identified lexicon. Samples were evaluated individually by each panelist in a positive air pressure, odor-free room dedicated to descriptive sensory analysis. The panelists were given distilled water to cleanse their palate between samples. Panelists did not swallow the samples to avoid saturation of the senses.

Statistical analysis

Statistical analysis was conducted using EXSTAT analytical software (XLSTAT-Pro 2012.1 for Windows, Addinsoft, New York, USA). Analysis of variance (ANOVA) with least significant difference (LSD) mean separation was conducted to determine whether there were differences among samples, panelists, replications, or interactions for each attribute. Attributes that were not detected in any particular SPI sample was eliminated from the subsequent analysis. Correlation analysis was conducted to determine the relationships among the attributes. Principal component analysis (PCA) with varimax rotation was used to identify redundant attributes and determine which terms best described each sample, and the PCA biplots provided a visual representation of which terms were related and described the samples.

Results and Discussion

Proximate analysis

The results of proximate analysis showed that all the SPI products met the minimum required protein content of 90% dry weight basis, and their other component were within the levels recommended by CODEX Alimetarius (1996) with ash and crude lipids significantly higher ($P < 0.05$) in samples prepared with the traditional chemicals (NCFF and NCDF) and those prepared from full fat flour (NCFF and SCFF), respectively (Chamba *et al*., 2013).

Descriptive analysis

Determination of descriptive sensory attributes

The mean attribute scores for the seven samples are presented in Table 2. In general, the intensity scores for all descriptive attributes, except opacity, were low, falling between 0 and 5 on a 15-point universal Spectrum™ descriptive analysis scale. These low intensity scores are characteristic to many rehydrated dry ingredients such as powdered dairy products, which primarily range between 0 and 4 (Drake *et al*., 2003).

It can be noted from the table that attributes such as metallic, fruity/lemony and soapy were not present in all the SPI samples. Thus, although these attributes are used in the evaluation of other dry ingredients,

Table 2. Mean values of sensory attributes of the six soy protein isolate samples

Attribute	NCFF	SCFF	NCDF	SCDF	CSPI1	CSPI2	CSPI3	LSD
Opacity	14.90	14.40	10.30	8.20	14.50	14.00	13.40	0.47
Color	5.53	4.32	5.75	3.34	5.07	3.10	2.80	0.59
Sweet A. Oat*.	1.45	1.87	1.60	2.76	1.00	1.50	1.98	0.57
Cardboard	1.66	2.20	1.30	2.85	1.41	1.84	2.11	0.61
Cereal	3.32	5.50	1.50	6.42	1.67	3.45	4.20	0.61
Brothy	1.12	1.25	0.79	1.7	0.81	0.67	0.50	0.51
Roasted	1.60	3.20	0.76	2.4	0.85	1.50	1.80	0.55
Metallic[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
Fruity/Lemon[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
Pasta	0.97	1.50	0.00	0.00	0.00	0.00	0.00	0.47
Ashy	1.53	2.00	1.12	2.48	1.22	1.65	1.98	0.61
Malty	0.25	0.20	0.00	0.00	0.00	0.00	0.00	0.48
Animal	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.45
Soapy[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA
Flour paste	3.20	4.20	0.65	3.50	2.00	0.98	0.10	0.50
Fecal	0.00	0.00	0.00	0.00	0.50	0.00	0.98	0.43
Astringent	1.50	1.30	1.72	0.97	1.75	0.85	0.88	0.59
Sweet	0.92	0.85	0.68	0.77	0.72	0.80	0.75	0.48
Sour	0.08	0.11	0.00	0.00	0.00	0.00	0.00	0.48
Salty	0.15	0.00	0.20	0.00	0.12	0.00	0.00	0.58
Bitter	0.57	0.82	1.66	2.01	0.97	0.89	0.91	0.47
Viscosity	5.50	6.30	13.00	3.20	11.80	3.01	3.60	0.57
Chalky	0.12	0.22	0.20	0.10	0.28	1.62	1.46	0.47

Attributes were scored on a 15-point universal Spectrum™ scale, where 0 = absence of attribute and 15 = very high intensity of the attribute (Meilgaard, Civille, and Carr, 1999). aAttribute not detected. LSD = Least squares standard deviation; CSPI1 = soy protein isolate for meat with high gelling property; CSPI2 and CSPI3 = the other two commercial soy protein isolate with low gelling property. Sweet A. Oat* = sweet aromatic oatmeal.

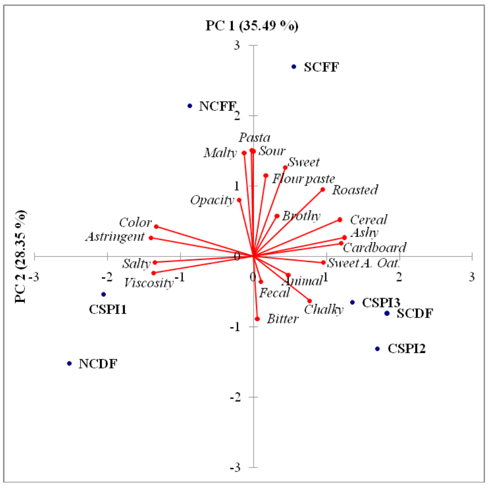

Figure 1. Principal component biplot of descriptive analysis of the cumulative soy proteins isolates (NCFF, SCFF, NCDF, SCDF, CSPI1, CSPI2, CSPI3)

they are not relevant in the description of soy protein isolates and therefore were not considered in the subsequent analyses. Animal/wet dog and fecal accounted for only in one of the three commercial samples and were also not detected in the rest. Malty and sour with very low values were predominant in the laboratory samples prepared from full fat flour (NCFF and SCFF), while salty was detected mainly in those prepared with traditional (natural) chemicals (NCFF and NCDF). Impurities from the full fat flour and the higher ash content, respectively, might had contributed to the presence of these attributes. Despite the use of lemon extract in the preparation of some of the samples, fruity/lemony attribute was not detected in any one of them. The findings of

Table 3. Correlations of descriptive sensory attributes of the six SPI samples

	Opac	Col	SwA	Card	Cer	Brot	Roas	Past	Ash	Malt
Opac	1.00	0.33	**-0.73**	**-0.54**	-0.42	**-0.53**	-0.18	**0.49**	**-0.48**	**0.57**
Col		1.00	**-0.77**	**-0.82**	**-0.76**	-0.14	**-0.61**	0.26	**-0.84**	0.39
SwA			1.00	**0.97**	**0.92**	**0.69**	**0.77**	-0.07	**0.95**	-0.22
Card				1.00	**0.98**	**0.68**	**0.88**	0.09	**1.00**	-0.06
Cer					1.00	**0.72**	**0.95**	0.27	**0.99**	0.12
Brot						1.00	**0.73**	**0.46**	**0.64**	0.37
Roas							1.00	**0.53**	**0.90**	0.39
Past								1.00	0.11	**0.98**
Ash									1.00	-0.04
Malt										1.00

	Ani	FloP	Fec	Astr	Swe	Sou	Salt	Bitt	Visc	Cha
Opac	0.02	-0.07	0.16	0.31	**0.45**	**0.50**	0.26	**-0.99**	0.18	0.16
Col	**-0.73**	0.08	**-0.45**	**0.99**	-0.06	0.28	**0.95**	-0.23	**0.90**	**-0.74**
SwA	0.24	0.37	-0.10	**-0.80**	0.12	-0.10	**-0.82**	**0.63**	**-0.79**	0.15
Card	0.27	**0.45**	-0.09	**-0.87**	0.31	0.06	**-0.91**	0.43	**-0.90**	0.22
Cer	0.19	**0.57**	-0.18	**-0.83**	**0.48**	0.24	**-0.90**	0.29	**-0.91**	0.16
Brot	**-0.51**	**0.88**	**-0.75**	-0.24	**0.46**	**0.45**	-0.36	**0.47**	-0.40	**-0.55**
Roas	0.05	**0.72**	-0.30	**-0.71**	**0.69**	**0.51**	**-0.82**	0.06	**-0.86**	0.05
Past	**-0.51**	**0.82**	**-0.62**	0.13	**0.92**	**1.00**	-0.04	**-0.54**	-0.16	**-0.44**
Ash	0.31	0.43	-0.04	**-0.89**	0.35	0.08	**-0.94**	0.36	**-0.93**	0.28
Malt	**-0.56**	**0.75**	**-0.62**	0.26	**0.89**	**0.99**	0.11	**-0.60**	-0.04	**-0.48**
Ani	1.00	**-0.63**	**0.92**	**-0.65**	-0.28	**-0.52**	**-0.55**	-0.08	**-0.48**	**0.92**
FloP		1.00	**-0.82**	-0.05	**0.77**	**0.81**	-0.21	0.01	-0.30	**-0.62**
Fec			1.00	-0.33	**-0.48**	**-0.62**	-0.22	-0.16	-0.12	**0.83**
Astr				1.00	-0.19	0.15	**0.98**	-0.19	**0.95**	**-0.67**
Swe					1.00	**0.92**	-0.32	**-0.55**	**-0.47**	-0.16
Sou						1.00	-0.01	**-0.55**	-0.14	**-0.45**
Salt							1.00	-0.14	**0.97**	**-0.57**
Bitt								1.00	-0.05	-0.21
Visc									1.00	**-0.52**
Cha										1.00

Bolded coefficients represent significant correlations ($P < 0.05$). Opac = opacity, Col = color, SwA = sweet aromatic, Card = cardboard, Cer = cereal, Brot = brothy, Roas = roasty, Past = pasta, Ash =ashy, Malt = malty, Ani = animal wet/dog, FloP = flour paste, Fec = fecal, Astr = astringency, Swe = sweet, Sou = sour, Salt = salty, Bitt = bitter, Visc = viscosity, and Cha = chalky.

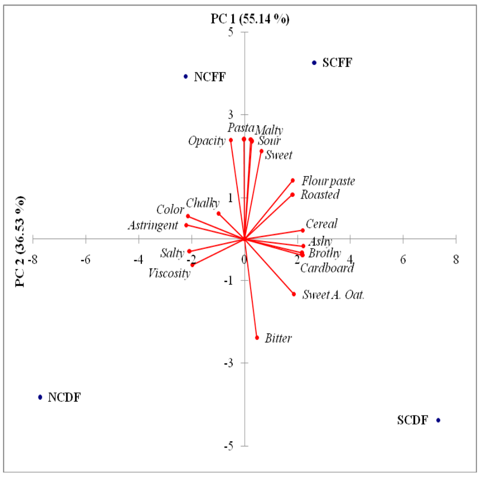

Figure 2. Principal component biplot of descriptive analysis of the soy proteins isolates prepared from different flours (NCFF, SCFF, NCDF, SCDF)

this study, in general, were in consistent with those earlier reported by Russell *et al.* (2006) using a similar analytical instrument, with slight differences in the specific attribute scores. These variations may be attributed to different SPI products and the data collecting panels involved. It is obvious that no matter how well trained they may be, two different groups of people may not have exactly the same observations.

Principal component analysis

To further understand the association among the variables, the attribute data scores were correlated, and principle component analysis (PCA) was conducted on two datasets (All SPIs and the laboratory made SPIs). Performing PCA helps to reduce redundancy among variable which correlate with one another. The resultant structural pattern is made clearer when rotated. In this analysis, it was assumed that the factors were orthogonal; therefore, principal components (PCs) were drawn after varimax rotation (Brown, 2009). The results of the correlation test among the attributes are presented in Table 3. For all the SPI samples, the significant correlations ($P < 0.05$) accounted for 55.26% (28.95% negative and 26.31% positive) of the total correlation coefficients.

The PCA results for the cumulative SPIs dataset, a two dimensional component space accounted for 63.84% of the samples variability as shown in Figure 1. Based on their eigenvector loadings of ≥ 0.3 (Kline, 2002), the first principal component (PC 1) explained 35.49% of the variability and was mainly characterized by 12 of the 20 attributes namely; color, sweet aromatic oatmeal, cardboard, cereal, roasted, animal, ashy, sweet, astringent, salty, viscosity and chalky. These characteristics significantly ($p < 0.05$) associated with 3 of the 7 samples (NCDF, SCDF and CSP1). The second principal component (PC 2, 28.35%) linked 10 attributes (opacity, cereal, brothy, roasted, pasta, malty, flour paste, sweet, sour, and bitter, chalky) to NCFF, SCFF and CSPI3.

The two sample groups separated by the two PCs reveal a distinction between the SPIs prepared from defatted flour and those from full-fat flour rather that those prepared from different chemicals. Unfortunately, no study could be found to verify these findings. Nevertheless, sensory evaluation of soy-based dry ingredients has been reported. Rassell *et al.* (2006) compared various whey protein concentrate (WPC), whey protein isolate (WPI), soy protein concentrate (SPC) and SPI using the similar instrument, where differences among these products were observed. Their finding on SPIs is in consistent with those observed in this study, except for a few attributes. During the development of soymilk lexicon by N'Kouka *et al.* (2004), the panelists also detected the similar attributes. It was also reported that soy milk prepared in the laboratory differed from the commercial ones. In this study, chalky attribute was only detected in 2 of the 3 commercial SPI, while fecal was detected in only one of them. For the rest of the attributes, no special distinction was observed between the commercial and the laboratory prepared SPIs.

In order to further understand the variations between the samples prepared from different starting materials (full-fat flour and defatted flour), principal component analysis was also performed on them together. Their variability was explained by the

90.11% of a two dimensional component space (Figure 2). The PC 1 (55.14%) comprised of samples from the defatted flour (NCDF and SCDF), which were specially characterized by color, cardboard, cereal, brothy, ashy, astringent salty and viscosity, where as PC 2 (36.53%) characterized the remaining two samples with opacity, pasta, sweet, sour and bitter as special attributes. The overlap of sweet aromatic oatmeal, roasted and flour paste flavors was observed between the two sample groups.

The characteristics associated with defatted flour SPIs may be attributed to the effects of defatting solvents (n-haxane and or 95% alcohol) interactions with some compound in the soy flour. It was also observed that although color attribute was much associated with these two products (NCDF and SCDF), they were not linked to opacity as compared to the full-fat based products. Thus opacity attribute may be linked to the interaction of lipids and proteins to form an emulsion system in the final product. Nevertheless, the level of opacity observed in the full-fat based products fell within the ranges observed in some commercial SPI products (Rassell *et al*., 2006).

Conclusion

Descriptive sensory evaluation of the soy protein isolates prepared using amaranth ash and lemon extracts (traditional SPI product) revealed some differences from the conventional and commercial products. Among others, opacity, pasta, sweet, sour and bitter attributes were more associated with the traditional SPI product. While color, cardboard, cereal, brothy, ashy, astringent, salty and viscosity were not very much associated with it, although they were characteristic to the conventional as well as commercial SPI products. Nevertheless, it is not expected that the traditional SPI would introduce a unique characteristic if used in the food system, considering that the attributes associated with it had also been reported in all the other similar products.

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