ABSTRACT

LAWRENCE, STEPHANIE ELIZABETH. Cross-Cultural Preference Mapping of Soymilk. (Under the direction of MaryAnne Drake.)

Soymilk consumption has increased tremendously in the last 15 years, but the advent of other plant based milks has increased competition. The objective of this study was to determine and compare drivers of liking for unflavored soymilk with different U.S. consumer groups. A category survey of 26 commercial soymilks was conducted. A highly trained panel (n=7) documented appearance, mouthfeel and flavor attributes of the soymilks. Twelve representative soymilks were then selected for evaluation by consumers from three age/cultural categories (n=75 each category; Caucasian/African American females 18-30 y; Asian females 18-30 y; Caucasian/African American females 40-64 y). Consumers evaluated overall liking and liking and intensity of specific attributes. Results were evaluated by analysis of variance, followed by internal and external preference mapping. Age had no effect on overall liking, while ethnicity did (Caucasian/African American vs. Asian)($p<0.05$). Caucasians/African Americans differentiated soymilks more than Asians and assigned a wider range of liking scores than Asians (2.1-7.2 vs. 4.0-6.1).Three consumer clusters were identified. Cluster 1 (n=71) was comprised of more Asians than Clusters 2 and 3 ($p<0.05$), while Clusters 2 and 3 had more Caucasians and African Americans ages 40-64 y. Cluster 3 also had more Caucasians and African Americans ages 18-30 y than Cluster 1. Sweet taste with vanilla/vanillin and sweet aromatic flavors and higher viscosity were preferred by most consumers and differences between consumer clusters were primarily in drivers of dislike. Drivers of dislike were not identified for Cluster 1 consumers while Clusters 2 and 3 consumers (n=84, n=80) disliked beany, green/grassy and meaty/brothy flavors and astringency. Cluster 3 ($n=80$) consumers scored all soymilks higher in liking ($p<0.05$) than Cluster 2 consumers, and were willing to overlook disliked attributes with the addition of sweet taste, whereas the Cluster 2 consumers were not. These findings can be utilized to produce soymilks with attributes that are well liked by target consumers and to tailor attributes to reach different segments of the population that have not yet been accommodated.

Cross-Cultural Preference Mapping of Soymilk

by
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BIOGRAPHY

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Literature Review

Soymilk Introduction

Soymilk, a beverage made by soaking and grinding soybeans in water then filtering, is a widely consumed beverage often positioned in Western markets as a substitute for more traditional Western beverages such as dairy milk. To make soymilk, a 1:10 ratio on a dry weight basis of soybeans to water is necessary, though soymilk can be made with as little as 8 parts water (Kuo and others 2013). The soybeans must be soaked, drained, then ground to a soybean slurry. Once a soybean slurry is obtained, it must be cooked to inactivate anti-nutritional enzymes, then be filtered to remove residue before it can be considered soymilk (Min and others 2006). Soymilk is lactose and cholesterol free, and has been shown to reduce or prevent incidences of various cancers, diabetes, high blood pressure, kidney disease and osteoporosis. However, consumers may not be willing to sacrifice sensory components for potential health benefits (Day N'Kouka and others 2004; Villegas and others 2009). Great efforts have been made to improve and conserve the quality and sensory attributes of soymilk, but a common problem for Western consumers in the acceptance of soymilk is that its sensory profile does not match that of the product that it is substituting (dairy milk) (Day N'Kouka and others 2004; Villegas and others 2009). Soy protein flavors are significantly different from flavors found in dairy proteins (Russell and others 2006). Factors that affect the flavor and sensory characteristics of soymilk should be addressed to better understand how to improve consumer acceptance.

Soybean Nutrient Composition

The soybean, also known as the soya or soja bean, is a legume from a plant that is native to Eastern Asia, the wild form of which is still found in China and Korea (Singh 2010; Kuo and others 2013). The soybean has been of great importance as a food in China and Japan for centuries (Kuo and others 2013). In the United States, over 800 varieties of soybeans with varying characteristics have been tested by the Department of Agriculture. Soybeans were originally grown as a forage crop (Page 1924). The soybean is known for its high protein content (up to 46%) and fat content (up to 24%, Page 1924; Singh 2010). The nutritional composition of the soybean is roughly 41.0% protein, 20.0% fat, 5.3% ash, 2.7-3.9% crude fiber and 25% carbohydrate (Kellor 1971; Mustakes 1971; Krishna and others 2003). Soybeans contain all the essential amino acids (Singh 2010). In Asia, soybeans are used to make foods such as soy sauce, soymilk, soy paste, tempeh, miso, tofu, etc., but in Western countries soybeans are most often processed to soybean meal (from which soy protein originates) and seed oil (Liu 1997; Singh 2010). Due to their high protein and fat content, soybeans, especially in Western countries, are now grown worldwide specifically for their high protein and oil content (Singh 2010; Medic and others 2014). In 2011/2012 over half of the soybeans grown (54%) in the U.S. were crushed for use by the domestic oil industry (USDA 2015).

The composition of the soybean varies depending on the geographical region where it is grown. For example, while the soybeans in the United States have the highest quality protein (the highest concentration of total essential amino acids), Chinese and Brazilian varieties have higher protein content than U.S. soybeans, varying from 42.14%-44.9% for Chinese varieties, 35.5%-39.3% protein for Brazilian varieties and 34.8%-37.1% for U.S.

varieties (Thakur and Hurburgh 2007; Karr-Lilienthal and others 2004), and Argentinian cultivars (varying between 32.6%-33.3% protein) have the lowest amount of protein (Thakur and Hurburgh 2007; Grieshop and Fahey 2001) (Table 1). Fiber content in the soybean is consistent, and does not vary depending on geographical location. Amount of oil, however, does vary, and Chinese soybeans have the lowest amount of oil (Karr-Lilienthal and others 2004; Grieshop and Fahey 2001). On average, U.S. cultivars average approximately 41.3% protein and 19.1% oil, while Japanese and South Korean soybeans average 44.5% protein and 18.1% oil (Medic and others 2014). The variation seen between the soybeans of different geographical regions is due to the different genetic backgrounds of the soybeans.

Not only is variability in composition seen between different countries, but it is also seen in different regions within countries. In the United States, consistent state and regional differences amongst soybean composition are found. In Northern and Western regions of the U.S. (North and South Dakota, Minnesota, Iowa and Wisconsin) soybeans with a greater amount of oil (0.2-0.5%) are found (Medic and others 2014). In addition to their greater amount of oil, soybeans from this region in the United States have less protein (1.5-2.0%) than southern states such as Texas, Arkansas, Louisiana, Mississippi, Tennessee, Kentucky, Alabama, Georgia, and North and South Carolina (Medic and others 2014). Generally warmer climates produce soybeans that have less linoleic and linolenic acids, but contain higher amounts of oleic acid (Medic and others 2014). This is important to note because linoleic and linolenic acids are more susceptible to oxidation by lipoxygenase (LOX) than oleic acid (Sessa 1979).

A positive correlation exists between growing temperature and oil content, such that the warmer the climate, the greater the amount of oil, and the lower the amount of sucrose

(Medic and others 2014). Total protein content of soybeans is not affected by temperature. With the increase in temperature, a 3.5x increase of methionine is also observed (Medic and others 2014). Isoflavones (soybean phytoestrogens) are very sensitive to growing temperature, and so as growing temperature increases from 25°C to 38°C isoflavones decrease 13.6-18.2 times (Medic and others 2014).

Soil moisture plays an important role in the size, amount, and nutritional characteristics of the soybean. If there is a water deficit at the beginning of the soybean growing season then fewer soybeans will be produced. Consequently, if there is a water deficit at the middle or end of the soybean growing season, the soybeans will be small in size. With a deficit in water during soybean growth, there is a decrease in the amount of protein in the soybeans (Medic and others 2014).

Linoleic acid is the fatty acid that is most plentiful in commodity soybeans, followed by oleic, palmitic, linolenic and stearic acids (Medic and others 2014; Penalvo and others 2004). Linoleic and linolenic acids are essential fatty acids that cannot be produced by mammals, so they must be acquired through diet. Since most fatty acids in soybean and soy products are unsaturated, they are more vulnerable to oxidation (Penalvo and others 2004). Due to high linolenic acid (three double bonds) content, soybean oil can be unstable and have a tendency to oxidize and develop off flavors. To decrease the number of unsaturated double bonds, soybean oil is often hydrogenated, thereby increasing stability and decreasing the likelihood of oxidation and development of off-flavors (Medic and others 2014).

Carbohydrates (most of which are found in the seed coat) account for approximately 35% of the dry seed weight of soybeans. The seed coat dry weight is comprised of 86% carbohydrates. About half of the carbohydrates found in soybeans are soluble sugars such as sucrose, raffinose and stachyose, while the other half is in the form of cell-wall polysaccharides (cellulose and pectin) (Medic and others 2014). Raffinose and stachyose are oligosaccharides that are extensively found in beans, and due to their inability for humans to digest them, intestinal bacteria turn them into carbon dioxide, methane and hydrogen (the primary constituents of intestinal gas), which cause flatulence (Naczk and others 1997; Price and others 1988).

Soybean Production and Processing

World production of soybeans reached 263.7 million metric tons in 2010/2011, and there has been an increase in production (more than double that of 1992/1993) due to the increase in demand and crop yield for food and fuel needs (Medic and others 2014). The United States is the largest soybean producer in the world, producing 34% of the world's soybeans (Medic and others 2014), and has been the leader in soybean production for more than 60 years (Wilcox, 2004). Following the United States in soybean production is Brazil (29%), Argentina (19%) and China (6%)(Medic and others 2014; Singh 2010, Wilcox 2004).

Currently soybeans are crushed and put through an extraction process with organic solvents (usually hexane) (Rosenthal and others 1996; Singh 2010) in order to make oil and defatted flakes. The defatted soybean flakes are further processed to produce soy flours, which contain 56-59% protein, soy protein concentrates (SPC), which contain 65-72% protein, and soy protein isolate (SPI), which contains 90-92% soy protein (Cowan and others 1973; Soy Protein Council 1987) (Figure 1). Mechanical oil expellers are used less than solvent extraction since more oil is left in the defatted flakes when mechanical expellers are used. Due to the flammability of hexane, other solvents have been explored, such as ethanol, isopropanol and CO_2 (Liu 1997; Singh 2010). Of the explored hexane alternatives for solvent extraction, CO_2 shows the most potential due to the fact that it is plentiful, non-reactive, inexpensive, non-toxic, and not detrimental to the environment (Singh 2010). About 55% of the oil is used as a cooking or salad oil, a quarter is used as baking and frying fats, about 4% is used as an ingredient in margarines, 11% as a substrate for biodiesel production and 7% for other food and industrial uses (Singh 2010; Medic and others 2014). Other uses for soybean oil include the making of soap, shampoo, detergents, paints, resins, ink, candles, crayons, electrical insulation, plastic and waterproof cement (Scott and Aldrich 1993; Liu 1997). Soy lecithin, which is the phospholipid fraction of soybean oil, is further made into products that include anti-foaming agents, viscosity modification agents, pharmaceuticals, dispersing agents and protective coatings (Liu 1997).

Defatted flakes are made when soybeans are cracked and conditioned and pressed through rollers to produce flakes that are approximately 0.01-0.0015 inches thick that then go through solvent extraction to remove oil (Proctor 1997). Defatted flakes can then be ground to soybean meal, which provides a high quality source of protein for animal feed in addition to being used to produce texturized vegetable protein, soy concentrates and soy isolates (Singh 2010; Medic and others 2014). The texturized vegetable protein, soy concentrates and soy isolates are often used as a value-added food ingredient in meats and meat substitutes, baked goods, whipped toppings, infant formulas, protein drinks, etc. (Liu 1997; Singh 2010; Medic and others 2014) (Table 2).

The majority of soymilk manufacturers use U.S. grade No. 2 yellow soybeans to make soymilk. Yellow soybeans are the most widely available, but green and black varieties exist, as well (Soyfoods Association of North America 2015b). This could be due to several factors, however, research has shown that many Westerners dislike beany/grassy soymilk flavor, and a comparison of soymilk produced from black soybeans versus from yellow soybeans has shown that it is more difficult to remove soy odors in black soybeans than it is to remove the odors in yellow soybeans (Zhang and others 2012). De-hulling (removal of the outer seed coat or hull) of soybeans is necessary. The de-hulling is performed by a heat treatment, which breaks the bond between the hulls and the cotyledons. The soybean is then cracked open, and the hulls are separated from the cotyledon, usually by air aspiration. The de-hulling of the soybeans results in less beany flavor, a whiter soymilk, better protein recovery, and reduced oligosaccharides (Chen 1989).

To ensure consistency in soymilk quality and to aid soymilk manufacturers in reducing variability in the product, some Asian countries have implemented national standards for soymilk. The national standard of protein for soymilk in mainland China is 2.0%, while in Taiwan it is 2.6%, in Japan 3.8%, in Singapore and Thailand 2.0% and in France 3.6% (Liu and Chang 2012). As of 2012, no federal standards for soymilks have been implemented in the United States, however, the Soyfoods Association of America voluntarily created a standard for soymilk composition and labeling in the United States. Due to the creation of standards by the Soyfoods Association of America, the current protein standard for soymilk in the United States is 3.0% (Liu and Chang 2012).

Sensory Properties of Soybeans, Soybean Oil and Soy Protein

Soymilk is a water extract of soybeans, obtained by soaking soybeans then wet grinding and filtering. Yu-Ying Li, a Chinese man who was living in Paris, was given the first patent (British) for soymilk production in 1910. Vitasoy, established in Hong Kong in

1940 by K.S. Lo, is one of the most successful commercial soymilk production companies. Vitasoy is now produced by the Hong Kong Soya Bean Product Co. Ltd, and it is not marketed as a milk substitute, but as a soymilk soft drink (Chen 1989). Popularity of Vitasoy was evident in that it surpassed Coca Cola to be the best selling soft drink in Hong Kong in 1974. Soymilk consumption in Taiwan has also been high, and President Enterprises Corporation in Taiwan produces several flavors of soymilk (of which egg, milk and strawberry are the most popular) to cater to the high amount of consumption (Chen 1989).

Culturally created flavor preferences are developed by association of flavors from the mothers' diet, which is passed to the baby by way of amniotic fluid, and again from breast milk. Early flavor experiences are developed further through foods consumed as an infant and into childhood (Mennella and Beauchamp 1991, 1993, 1999, 2002, 2005). Fondness of soymilk can be seen in people of Asian origin who were accustomed to drinking soy as the main "milk-type" beverage, whereas people from Western societies who grew up drinking cow milk developed a preference for the flavor of cow milk (Keast and Lau 2006).

Traditionally, Japanese consumption of soymilk wasn't very high due to their aversion to its beany flavor, which has been reduced with modern food processing technology. Chinese accept the beany flavor of soymilk, but Westerners (Wansink 2003; Wright and others 2001; Keast and Lau 2006), Japanese (Endo and others 2004; Mizutani and Hashimoto 2004), Indians (Dahuja and Madaan 2003; Deshpande and others 2008) and others do not have a tolerance for beany flavor (Chen 1989). A study that looked at the flavor profiles of soymilks across different cultures revealed that Australian soymilks were characterized by milky, astringent and salty attributes, whereas Asian soymilks were characterized by beany, cooked beans, sweet and pandan attributes (Keast and Lau 2006).

Further analysis revealed that Australian soymilks had on average 50 mg/ 100 mL of salt to soymilk, while the Asian soymilks added on average 5 mg or less salt per 100 mL of soymilk. Conversely, Asian soymilks contained an average of 7.5 mg/100 mL of sucrose to soymilk while the Australian soymilks had an average of 1.3 g/ 100 mL of sucrose to soymilk, and it is for this reason that Asian soymilks are sweeter than Australian soymilks (Keast and Lau 2006). In Australia where cow milk is the dominant form of milk consumed, Australians have developed a predilection for milk beverages that most closely reflect cow milk (Keast and Lau 2006).

Though soymilk is available in a variety of flavors, plain and vanilla are the most popular flavors in the United States (Chambers and others 2006). Since Americans have been shown to prefer the taste of bland soymilks, efforts have been made to control off flavors such as beany, rancid, grassy and painty (Torres-Penaranda and others 1998; Villegas and others 2009; Nelson and others 1976). One way to control off flavors is to inactivate lipoxygenase (LOX), an enzyme naturally present in soybeans. Beany off-flavors are rapidly produced when the lipoxygenase in soybeans is exposed to moisture and temperatures below its inactivation (Nelson and others 1976; Macleod and Ames 1988). Soybean lipoxygenases catalyze the oxidation of fatty acids with *cis*, *cis*-1, 4-pentadiene structure (usually linoleic and α-lineoleic acids) to hydroperoxides, which then form beany or "painty" flavors during their decomposition (Chen 1989, Medic and others 2014) (Figure 2). Singlet oxygen develops into linoleic acid, which is allegedly responsible for hexanal which is the beany flavor that is unacceptable to Westerners (Macleod and Ames 1988; Tran and others 1992; Torres-Penaranda and Reitmeier 2001; Day N'Kouka and others 2004; Gerde and White 2008). While hexanal accounts for approximately 25% of total volatiles contributing to beany flavor, hexanol, 2-pentylfuran and pentanal have also been identified as major contributors to beany flavor (Min and others 2006; Wang and others 1998; Takahashi and others 1979; Wilkens and Lin 1970).

The original process of making soymilk involved soaking then grinding the soybeans in water, before filtering and then heating, but this resulted in a high painty (linseed oil) odor and flavor. With the soaking and blanching of soybeans in 0.5% sodium bicarbonate, grinding, heating to 93°C, homogenizing, neutralizing, pasteurizing and then re-homogenizing, a bland flavored soymilk can be created with a 99% recovery of protein and 90% recovery of total solids (Figure 3). The blanching step inactivates lipoxygenase, minimizing off-flavors (Nelson and others 1976; Medic and others 2014). In addition to inactivation by heat treatment, lipoxygenase (LOX) can also be inactivated by adjusting the pH to <3.0 or >10.0 (Chen 1989). LOX inactivation has been shown to result in complete disappearance of hexanal (a possible source of off aromas), along with reduction in bitterness, astringency and beany flavor (Torres-Penaranda and Reitmeier 2001). In order to eradicate off-flavors, western agronomists have developed some lipoxygenase-free cultivars (Gerde and White 2008). While sensory characteristics of soymilk have improved with the use of lipoxygenase-free cultivars, other soy-containing foods such as meat, bread and beverage products did not have improvement in sensory characteristics due to auto-oxidation of oil, and it is for this reason that lipoxygenase-free cultivars are not widely used (Murphy 2008; Gerde and White 2008).

Nutritional Benefits of Soybeans and Soy Products

Relative to alternative protein sources, soymilk is comparatively inexpensive (Lozano and others 2007; Singh 2010). Soymilk contains 7 grams of protein per 8 ounce serving (Soyfoods Association of North America 2015a) and dairy milk contains 8 grams of protein per 8 ounce serving (CDC 2012). In addition to cost, the quality of protein reflected in its digestibility is important, and roughly 92-100% of soy protein can be digested by humans (Riaz 1999). Soybeans are the only plant that contains all essential amino acids and complete protein (Johnson and others 1992; Liu 1997). There have been several discoveries on soymilk benefits to human health, and with the 1999 FDA-approved claim of the health benefits of soy protein, consumption of soymilk in the United States has increased (FDA 1999; Zhang and others 2012). Research has shown that soybean phytoestrogens contribute to the amelioration of menopausal hot flashes, vaginal dryness, osteoporosis, and other post-menopausal issues (Holt 1998; Connie 1999). Other health benefits provided by consuming soymilk is the lowering of atherogenic lipid fraction (a reduction in the formation of fatty plasma in arteries) in blood. Soymilk significantly reduces plasma total cholesterol and low-density lipoprotein cholesterol in healthy men and women (Onuegbu and others 2011). Additionally, previous studies on hyperlipidemic men demonstrated a steady decrease of blood lipid profile from soy protein consumption (Weidner and others 2008; Wong and others 1998). Other research has shown that the consumption of approximately 47g of soy protein per day results in the lowering of total blood circulating cholesterol by 9.3%, reduction of low-density lipoprotein cholesterol by 12.3%, and a reduction in triacylglyerol by 10.5% (Anderson and others 1995).

Nitric oxide (produced by inducible nitric oxide synthase), is considered to be a mediator of inflammation, as it allows for the destruction or growth inhibition of infected bacteria, tumor cells, parasites and fungi (Schmidt and Walter 1994). The production of too much nitric oxide has also been associated with the development of diseases such as cancer, diabetes, cardiovascular disease and renal disease (Beckman and Koppenol 1996; Cooke and Dzau 1994). Nitric oxide production of lipopolysaccharide-treated cells was reduced by 83% with soymilk extract or 60-68% with fermented soymilk extract at a concentration of 500 μg/mL (Liao and others 2010). Prostaglandin E_2 is produced at inflammation sites by cycloxygenase 2, and is what is responsible for pain, stiffness and swelling associated with inflammation (Liao and others 2010). Prostaglandin E_2 sways tumor expansion and represses the immune response to malignant cells. Inflammatory diseases such as rheumatoid arthritis and pulmonary fibrosis, which are caused by the production of too many inflammatory mediators, can be restrained or stopped altogether if the excessive production of these mediators is halted. Soymilk reduces prostaglandin E_2 production in lipopolysaccharide-induced cells (Liao and others 2010). Inflammatory mediators such as nitric oxide, prostaglandin E_2, interleukin-6 and interleukin-1β are suppressed by the addition of soymilk and/or fermented soymilk to lactic acid bacteria and bifidobacteria (Liao and others 2010), thus regular consumption of soymilk or fermented soymilk may decrease risk of cardiovascular diseases and chronic inflammatory diseases.

In addition to soymilk's ability to reduce inflammation, it has also been shown to be an effective skin lightener. For aesthetic reasons there are several skin lighteners available on the market, which include retinoids, hydroquinones, melanocyte-cycotoxic agents, and tyrosinase inhibitors, but their results can be dissatisfying, as they can cause skin irritation and be lacking in effectiveness (Jimbow and Jimbow 1998; Amer and Maged 2009). Fresh soymilk (soymilk that has not been heat denatured or pasteurized) contains the proteinase inhibitors Kunitz trypsin inhibitor (also known as Soybean Trypsin Inhibitor (STI)) and Bowman-Birk protease inhibitor (BBI), which prevent protease-activated receptor 2 (PAR-2) from activating (Paine and others 2001). PAR-2 is a kind of transmembrane G-protein coupled receptor that is expressed in keratinocyes (not in melanocytes) and it plays a role in regulating skin pigmentation through melanocyte-keratinocyte activity (Ebanks and others 2009). PAR-2 works by either increasing or decreasing melanosome transfer, thus modifying skin pigmentation. The proteinase inhibitors in soymilk lower keratinocyte phagocytosis by inhibiting PAR-2, and as such are able to reversibly lighten skin (Paine and others 2001). It is for this reason that Soybean Trypsin Inhibitor (STI) is currently used in cosmeceutical moisturizers, facial and body care products for its skin-lightening effects (Draelos 2007; Parvez and others 2006).

The ability to depigment is also carried over in hair, as well. Fresh (not heat-treated) soymilk, if applied to skin daily, can lighten hair color and decrease rate of hair growth along with decreasing the dimensions of the hair shaft (Seiberg and others 2001). Tyrosinase and Tyrosinase related protein-1 (TRP-1) levels are decreased and duration of their expression during the hair cycle is shortened with soymilk treatment (Seiberg and others 2001). The amount and duration of tyrosinase and TRP-1 correlate with the amount and duration of melanogenesis (Seiberg and others 2001). Since the levels of tyrosinase and TRP-1 are decreased and the duration of their expression is shortened by treatment with soymilk, there is a reduced level and shortened duration of melanogenesis, creating lighter hair color. Reduced length and thickness of hair shafts were noted from soymilk-treated hair, and length of time before hair regrowth was also augmented from the topical use of fresh soymilk (Seiberg and others 2001). Total reversibility of the effects of soymilk on hair was noted post treatment (Seiberg and others 2001).

Studies have also been conducted on the effects of soymilk on prevention of bone loss. Currently, estrogen or hormone replacement therapy is used to treat osteoporosis, but when used long-term, these increase the risk of breast and uterine cancer (Scharbo-Dehaan 1996). For this reason, soy protein and soy isoflavones (phytoestrogen originating from plants, Kuo and others 2013) have become an interest (Lydeking-Olsen and others 2004). The soy isoflavones selectively bind to estrogen receptors (Kuiper and others 1996; Kuiper and others 1997) and produce the same end products that are associated with reduced bone turnover (Williams and others 1998; Rassi and others 2001; Cho and others 2002; Chen and others 2002). Soymilk with isoflavones stops bone loss in the lumbar spine, and works even better than progesterone therapy, which just slows bone loss (Lydeking-Olsen and others 2004). Soy has a helpful effect on bone, and soymilk-based diets have even shown to increase calcium absorption (Arjmandi and others 1998a), and prevent femoral and vertebral bone loss in rats (Arjmandi and others 1996; Arjmandi and others 1998b). Studies by Lydeking-Olsen and others (2004) demonstrated that soy protein itself had a calcium sparing effect, and that the addition of at least 15g protein/day of soy foods to a diet could have a sparing effect on calcium loss (with an emphasis on sparing effect for cortical bone) for postmenopausal women.

Isoflavones, which are soy phytoestrogens with hormone-like effects, have piqued interest recently due to their antioxidant effects, ability to aid in prevention of cardiovascular diseases, osteoporosis, cancers, type 2 diabetes and menopausal symptoms (Anderson and

Garner 1997; Holt 1998; Greenberg and Newton 1998; Setchell 1998; Setchell and Cassidy 1999; Messina and Hughes 2003; Prakash and others 2007; Banerjee and others 2008). Due to the importance that isoflavones play on relaying health benefits to the people that consume soy, studies have been conducted to look at soymilk preparation methods that yield higher amounts of isoflavones in the end product. A study by Kuo and others (2013) examined the physicochemical differences between blended soymilks, filtered soymilks and media milled soymilks. Filtered soymilks represent the soymilks that are commercially available, and have received a heat treatment. A media mill is obtained from a stirred ball mill, used in paint and pharmaceutical industries, and can create nano/submicrometer particles. Results of produced soymilks show that aglycones, which have the most biological effect, were highest in the media-milled soymilk (more than twice the amount found in filtered soymilk). There was a total isoflavone loss across all soymilks of 10-13% after heating. Among the blended, media-milled and filtered soymilks, filtered soymilk had the greatest loss of aglycones (approximately 65%) (Kuo and others 2013).

Antinutritional Components of Soybeans

Food producers are now trying to incorporate more soy into the human diet in order for people to be able to receive the health benefits associated with soybeans (Medic and others 2014). While soy products are becoming more widely used, over 15 proteins in soybeans have been identified that cause allergies and allergenic responses in humans (Medic and others 2014). Storage proteins, of which glycinin and β-conglycinin are the major ones found in soybeans, account for approximately 65-80% of total seed protein (Medic and others 2014). The allergenic responses, however, are caused by the lower abundance proteins, several of which are antimetabolic and can cause gastric reactions and atopic eczema (Herman 2005). Some of the proteins that have been found to cause allergies include Gly m Bd 30K (Ogawa and others 1993; Ogawa and others 2000), proteins Gly m IA and Gly m IB, which are found in the hull of the seed (Gonzalez and others 1992), the α-subunit of β-conglycinin (Ogawa and others 1995), lectins and soybean trypsin inhibitors (Medic and others 2014). Lectins are hemagglutinins, which inhibit animal growth through the prevention of nutrient absorption. Allergens from soybeans are of concern because soy products are becoming increasingly consumed by a wider population (Leiner 1994), and because between 4-6% of children have food allergies. Soy-based baby formula usage has increased for babies who are allergic to dairy milk or for whom breast milk is not accessible (Friedman and Brandon 2001). There are some soybean cultivars with fewer allergens, such as Kunitz, which has no Kunitz trypsin inhibitor, and Kyu-kei 305, which has no 28 K protein, α- and β-subunit of β-conglycinin (Fukushima 2001; Bernard and others 2001).

Antinutritional properties of soybeans include the trypsin inhibitor, hemagglutinins, urease and flatulence (Singh 2010). The trypsin inhibitors, hemagglutinins (lectins) and urease all prevent nutrient absorption and inhibit growth (Wiriyaumpaiwong and others 2006). Although the Bowman-Birk trypsin inhibitor is thought to guard against cancer (Danji 2000; Messina 2002), it is also shown to be responsible for growth inhibition, hyperplasia, reduced digestibility of proteins and pancreatic hypertrophy (Yanatori and Fujita 1976; Medic and others 2014). The protease inhibitors (Bowman-Birk trypsin-chymotrypsin inhibitor and Kunitz trypsin inhibitor) make up approximately 6% (and up to 25%) of soybean protein (Singh 2010; Medic and others 2014). Protease inhibitors function by inhibiting pancreatic enzymes in animals that have one stomach, causing diminished digestibility of proteins and pancreatic hypertrophy (Medic and others 2014).

Heating and its effects on soymilk and soymilk nutritional content has been investigated (Van Buren and others 1964). Heat is necessary to inactivate harmful enzymes such as trypsin inhibitors (Liener 1958; Singh 2010), although even post heat treatment 10-20% of the trypsin inhibitors remain (Friedman and Brandon 2001). During heating of soymilk, urease was more quickly inactivated than trypsin inhibitor, but when dry beans were steamed, the trypsin inhibitor was inactivated more quickly than urease (Van Buren and others 1964). Since urease inactivates more quickly than trypsin inhibitor, the presence of urease in soymilk is a sign of insufficient heat treatment (Van Buren and others 1964). The lack of urease, however, does not indicate that the soymilk has been properly and sufficiently heated. Heat can also cause adverse chemical changes, which may give way to the damage of amino acids and vitamins (Poliseli-Scopel and others 2013).

In addition to affecting nutritional properties of soymilk, heat processing affects the odors and flavors in soymilk. Lozano and others (2007) showed that intensities of overall aroma, sulfur flavor, diacetyl, potato and roasted flavors increased as processing temperature increased. Furthermore, heat may cause browning reactions to take place and lead to the development of cooked flavor (Kwok and Niranjan 1995).

Heating also affects color and color changes in soymilk. Color plays an important role in soymilk acceptance. Studies have shown that cultures that have a preference for cow milk tend to create soymilk to mimic the color of cow's milk (Keast and Lau 2006). The primary compounds responsible for color in soymilk are polyphenols and carotenoids (Taira and others 1985; Katayama and Tajima, 2003), though color can also be affected by protein aggregates, lipid content and droplet size concentration (Chantrapornchai and others 1998; Chanamai and McClements, 2001). UHT heating yields a more yellow and saturated color compared to soymilk produced with less heat (90°C for 10 minutes) (Lozano and others 2007). The yellowness in soymilks can be a result of Maillard reactions caused from heat treatment, which also produce a more yellow soymilk (Macleod and Ames 1988). Color saturation of soymilk has been concluded to be directly influenced by amount of process time (Kwok and others 1999), because the biggest increase in saturation was observed with longer contact with heat (143 °C/59 s) as opposed to shorter contact with higher temperatures (154 °C/29 s) (Lozano and others 2007).

Examination of storage effects on soymilk color, pH, flavor and lipoxygenase activity has also been conducted. Lozano and others (2007) documented a decrease in overall aroma, sulfur and potato flavor with increased storage time. Achouri and others (2007) established that as storage time increased, total volatile recovery decreased, with the greatest decline (88% volatile loss) occurring in the first few months. Storage time did not have a significant impact on pH ($p < 0.05$), however color of soymilk darkened as storage time increased (Achouri and others 2007). As storage time of soymilk increased, lipoxygenase activity decreased, which can yield a soymilk with less beany flavor and ultimately greater acceptance in western countries (Achouri and others 2007).

While flavor masking technology is also a viable option to control off flavors, many processing methods have been explored to optimize sensory characteristics of soymilk. Cold extraction and soaking with potash produces soymilks with high sensory panel scores, compared to other methods of making soymilk, such as hot extraction, soaking and blanching, soaking with sodium bicarbonate or delayed filtration (Tunde-Akintunde and others 2009). Compared to room-temperature grinding to produce soymilk, the hot and cold grinding methods produced soymilk with significantly fewer off-flavors. Combing both hot grinding and two-phase UHT (ultra high temperature), most off-flavors can be reduced to the point of below detection threshold (Zhang and others 2012). Although hot grinding can inactivate 99% of lipoxygenase activity compared to cold-grinding, it produces soymilk with a lower amount of protein and solids than other grinding methods (Zhang and others 2012).

Sensory Properties of Soy Protein and Soymilk

Many studies have been conducted to examine flavors found in cheese and dairy products such as Heisserer and Chambers (1993), Drake and others (2001), Drake and others (2003) and Retiveau and others (2005), fewer studies have been conducted to examine flavors found in soy proteins and soymilks. A study by Russell and others (2006) demonstrated significant differences between the sensory properties of soy proteins and dairy proteins. Some studies using sensory descriptive analysis have been carried out to examine and characterize the sensory properties of soy protein and soymilk. Lexicon development is often employed to find terms to apply to products to differentiate and describe them. Since there is a wide variety of soymilks on the market, including shelf stable, refrigerated and powdered forms, there is a need to characterize their sensory properties in order to set them apart from each other and describe them.

A study in 2007 by Lozano and others used terms such as sweet aromatic, cereal/grain, sulfur, flour paste and metallic to describe soymilks, while a study by Chambers and others (2006) had other terms including almond, banana, milky, molasses, nona-lactone, brown, butter rum, cardboard, fruity, green/peapod, nutty, overall grain, oats, wheat, processed, rancid, raw, starch-like, sweet aromatics and vanilla/vanillin. Various studies have been conducted to address the wide variety of the soymilks on the market, so soymilk lexicon development has also been established from studies by Day N'Kouka and others (2004) and Torres-Penaranda and Reitmeier (2001).

Many studies discuss the "beany" aroma and flavor of soymilk, which is purportedly caused by the lipoxygenase enzyme. The beany flavor is sometimes described as "green" or "raw soy" (Day N'Kouka and others 2004), and is the sensory attribute to which many Westerners have an aversion. It is this particular attribute that production companies try to eliminate in soymilk to reach a wider consumer base.

Cross Cultural Studies on Soymilk

Studies have been conducted with more than 35 different soymilks to look for differences and similarities in nutritional content and physicochemical properties as they relate to sensory characteristics. Eighty percent of commercial soymilks assessed had a viscosity of 3.0-7.5 cP. The variation in the viscosities was likely due to the addition of gums or thickening agents, which were found in 92% of soymilks (Liu and others 2013). Consumers in Spain and Brazil preferred higher viscosities and sweeter soymilks (Villegas and others 2009; Terhaag and others 2013). It is important to look at cross-cultural preferences of products in order to formulate products specifically targeted to reach a global audience. As soymilk sales and popularity has continued to rise, researching cross-cultural preferences of soymilk has become an even greater necessity. Unfortunately, research on cross-cultural studies and drivers of liking for soymilks is extremely limited. A cross-cultural study on liking of soy-based snack foods was conducted to examine preferences of a group of consumers living in India versus the preferences of a group of U.S. surrogates (Neely and others 2010). Significant liking differences were noted amongst the U.S. group, whereas there were no significant differences in liking of the soy-based snack products in the Indian consumer group (Neely and others 2010). Jones and others (2008) observed differences in New Zealand and U.S. consumer views and opinions of soy and dairy products. While only very small differences in knowledge and opinions of soy and dairy products existed between the two groups, New Zealanders, who typically consume more dairy and less soy than their American counterparts, preferred dairy protein, while American consumers had no preference between soy and dairy protein (Jones and others 2008). More research needs to be conducted to specifically examine cross-cultural preferences and drivers of liking for soymilk. The objective of this thesis was to conduct a cross-cultural study to examine the drivers of soymilk liking for Asian women and for Caucasian and African American women.

References

Achouri A, Boye JI, Zamani Y. 2008. Soybean variety and storage effects on soymilk flavour and quality. Int J Food Sci and Technol 43:82-90.

Amer M, Maged M. 2009. Cosmeceuticals versus pharmaceuticals. Clinics in Derm 27.5:428-430.

Anderson JJB, Garner SC. 1997. The effects of phytoestrogens on bone. Nutr Res 17:1617-1632.

Anderson JW, Johnstone BM, Cook-Newell ME. 1995. Meta-analysis of the effects of soy protein intake on serum lipids. N Engl J Med 333:276-282.

Arjmandi BH, Birnbaum R, Goyal NV, Getlinger MJ, Juma S, Alekel L, Hasler CM, Drum ML, Hollis BW, Kukreja SC. 1998a. Bonesparing effect of soy protein in ovarian hormone-deficient rats is related to its isoflavone content. Am J Clin Nutr 68:364S-368S.

Arjmandi BH, Alekel L, Hollis BW, Amin D, Stacewicz-Sapuntzakis M, Guo P, Kukreja SC. 1996. Dietary soybean protein prevents bone loss in an ovariectomized rat model of osteoporosis. J Nutr 126:161-167.

Arjmandi BH, Getlinger MJ, Goyal NV, Alekel L, Hasler CM, Juma S, Drum ML, Hollis BW, Kukreja SC. 1998b. Role of soy protein with normal or reduced isoflavone content in reversing bone loss induced by ovarian deficiency in rats. Am J Clin Nutr 68:1358S-1363S.

Banerjee S, Li Y, Wang Z, Sarkar FH. 2008. Multi-targeted therapy of cancer by genistein. Cancer Lett 269:226-242.

Beckman JS, Koppenol WH. 1996. Nitric oxide, superoxide, and peroxynitrite: The good, the bad, and the ugly. Am J Physiol, Cell Physiol. 271:C1424-C1437.

Bernard R, Nelson R, Cremens C.1991. USDA soybean genetic collection: isoline collection. Soybean Genet Newsl 18:27-57.

Burrington K. 2000. Nutritional and beneficial ingredients. Food Prod Des. November 2000. p 1-12.

CDC. 2012. Protein. Centers for Disease Control and Prevention, Atlanta, GA, USA. http://www.cdc.gov/nutrition/everyone/basics/protein.html Accessed 2015 May 27.

Chambers E, Jenkins A, Mcguire BH. 2006. Flavor properties of plain soymilk. J Sens Stud 21.2:165-179.

Chanamai R, Mcclements DJ. 2001. Prediction of emulsion color from droplet characteristics: dilute monodisperse oil-in-water emulsions. Food Hydrocolloids 15:83-91.

Chantrapornchai W, Clydesdale FM, Mcclements DJ. 1998. Influence of droplet size and concentration on the color of oil-in-water emulsions. J Agric Food Chem 46:2914-2920.

Chen S. 1989. Principles of soymilk production. In Lusas EW, Erickson DR, Nip WK, editors. Food uses of whole oil and protein seeds. American Oil Chemists' Society, Champaigne, Illinois. p 40-86.

Chen X, Anderson JJB. 2002. Effects of isoflavones on osteoblast proliferation and differentiation. J Nutr 132.3:616S.

Cho Y, Chung S, Cho K, Shin H, Kim N, Kang SA, Choue R. 2002. Black bean (*rhynchosia molubilis,* Yak-Kong) exerts a prominent estrogenic effect on the proliferation of human MG-63 osteoblastic cells. J Nutr 132:614S.

Connie W. 1999. Soy and osteoporosis. Proceedings of the World Soybean Research Conference—VI. University of Illinois, Urbana-Champaign, IL. p 428.

Cooke JP, Dzau VJ. 1997. Nitric oxide synthase: role in the genesis of vascular disease. Annu Rev Med 48:489-509.

Cowan JC, Rackis JJ, Wolf WJ. 1973. Soybean protein flavor components: a review. J Am Oil Chem Soc 50:427a-444a.

Dahuja A, Madaan TR. 2003. Estimation of parameters responsible for the generation of off-flavor in some Indian varieties of soybeans. Plant Foods for Human Nutr 58.3:1-8.

Day N'kouka K, Klein BP, Lee S-Y. 2004. Developing a lexicon for descriptive analysis of soymilks. J Food Sci 69.7:259-263.

Danji F. 2000. Recent progress in research and technology for processing and utilization of soybean. Proceedings of III International Soybean Processing and Utilization Conference, Tsukuba, Tokyo, Japan. p 11-16.

Deshpande S, Bargale PC, Jha K. 2008. Suitability of soymilk for development of shrikhand. Food Sci Tech 45.3:284-286.

Draelos ZD. 2007. Skin lightening preparations and the hydroquinone controversy. Derm Ther 20:308-313.

Drake MA, McIngvale SC, Cadwaller KR, Civille GV. 2001. Development of a descriptive sensory language for cheddar cheese. J Food Sci 66:1422-1427.

Drake MA, Karagul-Yuceer Y, Cadwaller KR, Civille GV, Tong PS. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. J Sens Stud 18:199-216.

Ebanks JP, Wickett RR, Boissy RE. 2009. Mechanisms regulating skin pigmentation: the rise and fall of complexion coloration. Int J Mol Sci 10:4066-4087.

Endo H, Ohno M, Tanji K, Shinada S, Kaneko K. 2004. Effect of heat treatment on the lipid peroxide content and aokusami (beany flavor) of soymilk. Food Sci and Tech Res 10.3:328-333.

FDA. 1999. Food labeling: health claim; soy protein and coronary heart disease. Final Rule. Fed Regist 64.206:57700-57733.

Friedman M, Brandon DL. 2001. Nutritional and health benefits of soy proteins. J Ag Food Chem 49:1069-1086.

Fukushima D. 2001. Recent progress in research and technology on soybeans. Food Sci Technol Res 7:8-16.

Gerde J, White PJ. 2008. Lipids. In Johnson L, White P, editors. Soybeans: chemistry, production, processing and utilization. AOCS Press, Urbana. p 193-227.

Gonzalez R, Polo F, Zapatero L, Caravacaj F, Carreira J. 1992. Purification and characterization of major inhalant allergens from soybean hulls. Clin Exp Allergy 22:748-755.

Greenberg P, Newton HH. 1998. The whole soy cookbook. New York, NY: Three River Press.

Grieshop CM, Fahey GC. 2001. Comparison of quality characteristics of soybeans from Brazil, China, and the United States. J Agric Food Chem 49:2669-2763.

Heisserer DM, Chambers E. 1993. Determination of the sensory flavor attributes of aged natural cheese. J Sens Stud 8:121-132.

Herman E. 2005. Soybean allergenicity and suppression of the immunodominant allergen. Crop Sci 45:462-467.

Holt S. 1998. Soy revolution—the food of the next millennium. M. Evans and Company, New York, NY.

Hwang SH, Hong JH. 2013. Sensory drivers of goso flavor in soymilk: understanding a complex traditional Korean sensory attribute. Food Qual and Pref 29:113-125.

Iwuoha CI, Umunnakwe KE. 1997. Chemical, physical and sensory characteristics of soymilk as affected by processing method, temperature and duration of storage. Food Chem 59.3:373-79.

Jimbow K, Jimbow M. 1998. Chemical, pharmacological and physical agents causing hypomelanoses. In Norlund JJ, Boissy RE, Hearing VJ, King RA, Ortonne J-P, editors. The pigmentary system. Oxford University Press. p 621-627.

Johnson LA, Meyers DJ, Burden DJ. 1992. Soy protein's history, prospects in food, feed. Inform 3.4:429-444.

Jones VS, Drake MA, Harding R, Kuhn-Sherlock B. 2008. Consumer perception of soy and dairy products: a cross-cultural study. J Sens Stud 23.1:65-79.

Karr-Lilienthal LK, Grieshop CM, Merchen NR, Mahan DC, Fahey Jr GC. 2004. Chemical composition and protein quality comparisons of soybeans and soybean meals from five leading soybean-producing countries. J Agric Food Chem 52:6193-6199.

Katayama O, Tajima M. 2003. Shokuhin to iro [Color of food]. Change in Color of Food. Korin, Tokyo. p 71-117.

Keast RSJ, Lau JJ. 2006. Culture-specific variation in the flavor profile of soymilks. J Food Sci 71.8:S567-S572.

Keller RL. 1971. Soy flour and grits for use in food products. J Amer Oil Chem Soc 48:481-493.

Krishna A, Singh G, Kumar D, Agarwal K. 2003. Physico-chemical characteristics of some new varieties of soybean. J Food Sci and Tech 40:490-492.

Kuiper GG, Enmark E, Pelto-Huikko M, Nilsson S, Gustafsson JA. 1996. Cloning of a novel receptor expressed in rat prostate and ovary. Proc Natl Acad Sci 93:5925-5930.

Kuiper GG, Carlsson B, Grandien K, Enmark E, Haggblad J, Nilsson S, Gustafson JA. 1997. Comparison of the ligand binding specificity and transcript tissue distribution of estrogen receptors alpha and beta. Endocrinology 138:863-870.

Kuo H-Y, Chen S-H, Yeh A-I. 2014. Preparation and physicochemical properties of whole-bean soymilk. J Agric Food Chem 62:742-749.

Kwok KC, Macdougall DB, Niranjan K. 1999. Reaction kinectics of heat-induced colour changes in soymilk. J Food Eng 40:15-20.

Kwok KC, Niranjan K. 1995. Review: effect of thermal processing on soymilk. Int J Food Sci Tech 30:263-295.

Liao C-L, Huang H-Y, Sheen L-Y, Chou C-C. 2010. Anti-inflammatory activity of soymilk and fermented soymilk prepared with lactic acid bacterium and bifidobacterium. J Food Drug Anal 18.3:202-210.

Liener IE. 1958. Processed plant protein foodstuffs. In: Altschul AM, editor. Chap 5. Academic Press, New York.

Liener IE. 1994. Implications of antinutritional components in soybean foods. Crit Rev Food Sci Nutr 34.1:31-67.

Liu K. 1997. Argonomic characteristics, production and marketing. In: Liu K. Soybeans: chemistry, technology and utilization. 1st ed. New York, NY: Chapman & Hall. p 20.

Liu Z-S, Chang SKC. 2013. Nutritional profile and physicochemical properties of commercial soymilk. J Food Proc and Pres 37.5:651-661.

Lozano PR, Drake M. Benitez D, Cadwallader KR. 2007. Instrumental and sensory characterization of heat-induced odorants in aseptically packaged soy milk. J Agric Food Chem 55.8:3018-3026.

Lydeking-Olsen E, Beck-Jensen J-E, Setchell KDR, Holm-Jensen T. 2004. Soymilk or progesterone for prevention of bone loss: a 2 year randomized, placebo-controlled trial. Eur J Nutr 43:246-257.

Macleod G, Ames J. 1988. Soy flavor and its improvement. Crit Rev Food Sci Hum Nutr 27:219-400.

Medic J, Atkinson C, Hurburgh Jr. CR. 2014. Current knowledge in soybean composition. J Am Oil Chem Soc 91.3:363-384.

Mennella JA, Beauchamp GK. 1991. Maternal diet alters the sensory qualities of human milk and the nursling’s behavior. Pediatrics 88:737-744.

Mennella JA, Beauchamp GK. 1993. The effects of repeated exposure to garlic-flavored milk on the nursling’s behavior. Pediat Res 34:805-808.

Mennella JA, Beauchamp GK. 1999. Experience with a flavor in mother’s milk modifies the infant’s acceptance of flavored cereal. Dev Psychobiol 35:197-203.

Mennella JA, Beauchamp GK. 2002. Flavor experiences during formula feeding are related to preferences during childhood. Early Hum Dev 68:71-82.

Mennella JA, Beauchamp GK. 2005. Understanding the origin of flavor preferences. Chem Senses 30: i242-243.

Messina M. 2002. Soya and health. Extension Pamphlet, American Soybean Association and United Soybean Board, New Delhi, India.

Messina M, Hughes C. 2003. Efficacy of soyfoods and soybean isoflavone supplements for alleviating menopausal symptoms is positively related to initial hot flush frequency. J Med Food 6:1-11.

Min S, Yu Y, Yoo S, St. Martin S. 2006. Effect of soybean varieties and growing locations on the flavor of soymilk. J Food Sci 70.1:C1-C11.

Mizutani T, Hashimoto H. 2004. Effect of grinding temperature on hydroperoxide and off-flavor contents during soymilk manufacturing process. J Food Sci 69.3:112-116.

Murphy P. 2008. Soybean proteins. In: Johnson L, White P, Galloway R, editors. Soybeans: chemistry, production, processing, and utilization. Urbana, IL: AOCS Press. p 229-269.

Mustakes GC. 1971. Full fat and defatted soy flour for human nutrition. J Amer Oil Chem Soc 48:815-819.

Naczk M, Amarowicz R, Shahidi F. 1997. Alpha-Galactosides of sucrose in foods: composition, flatulence-causing effects, and removal. ACS Symposium Series 662:127-151.

Neely EA, Lee Y, Lee S-Y. 2010. Cross-cultural comparison of acceptance of soy-based extruded snack foods by U.S. and Indian consumers. J Sens Stud 25.s1:87-108.

Nelson AI, Steinberg MI, Wei LS. 1976. Illinois process for preparation of soymilk. J Food Sci 41.1:57-61.

Ogawa T, Tsuji H, Bando N, Kitamura K, Zhu YL, Hirano H, Hishikawa K. 1993. Identification of the soybean allergenic protein, Gly m Bd 30K, with the soybean seed 34-kDa oilbody-associated protein. Biosci Tiotechnol Biochem 57:1030.

Ogawa T, Bando N, Tsuji H, Nishikawa K, Kitamura K. 1995. Alpha-subunit of beta-conglycinin, an allergic protein recognized by IgE antibodies of soybean-sensitive patients with atopic dermatitis. Biosci Biotechnol Biochem 59:831-833.

Ogawa T, Samoto M, Takahashi A. 2000. Soybean allergens and hypoallergenic soybean products. J Nutr Science and Vit 46.6:271-279.

Onuegbu AJ, Olisekodiaka JM, Onibon MO, Adesiyan AA, Igbeneghu CA. 2011. Consumption of soymilk lowers atherogenic lipid fraction in healthy individuals. J Med Food14.3:257-260.

Page HJ. 1924. The soybean. Nature 113.2849:813-815.

Paine C, Sharlow E, Liebel F, Eisinger M, Shapiro S, Seiberg M. 2001. An alternative approach to depigmentation by soybean extracts via inhibition of the PAR-2 pathway. J Invest Derm 116:587-595.

Parvez S, Kang M, Chung H-S, Cho C, Hong M-C, Shin M-K, Bae H. 2006. Survey and mechanism of skin depigmenting and lightening agents. Phytother Res 20:921-934.

Penalvo JL, Castilho MC, Silveira MIN, Matallana MC, Torija ME. 2004. Fatty acid profile of traditional soymilk. Eur Food Res Technol 219:251-253.

Poliseli-Scopel FH, Gallardo-Chacon JJ, Juan B, Guamis B, Ferragut V. 2013. Characterisation of volatile profile in soymilk treated by ultra high pressure homogenisation. Food Chem 141:2541-2548.

Prakash D, Upadhyay G, Singh BN, Singh HB. 2007. Antioxidant and free radical-scavenging activities of seeds and agri-wastes of some varieties of soybean (Glycine max). Food Chem 104:783-790.

Price KR, Lewis J, Wyatt GM. Fenwick GR. 1988. Review article flatulence—causes, relation to diet and remedies. Die Nahrung 32.6:609-626.

Proctor A. 1997. Soybean oil extraction and processing. In: Liu K. Soybeans: chemistry, technology, and utilization. New York, NY: Chapman and Hall. p 297-346.

Rassi CM, Lieberherr M, Chaumaz G, Pointillart A, Cournot G. 2001. Daidzen inhibits osteoclast differentiation and activity in vitro. Ann Nutr Metab 45:230.

Retiveau A, Chambers DH, Esteve E. 2005. Developing a lexicon for the flavor description of French cheeses. Food Qual Prefer 16:517-527.

Riaz MN. 1999. Soybeans as functional foods. Cereal Foods World 44:88-92.

Rosenthal A, Pyle DL, Niranjan K. 1996. Aqueous and enzymatic processes for edible oil extraction. Enzyme Microb Technol 19:402-420.

Russell TA, Drake MA, Gerard PD. 2006. Sensory properties of whey and soy proteins. J Food Sci 71.6:S447-S455.

Scharbo-Dehaan M. 1996. Hormone replacement therapy. Nurse Pract 21:1-13.

Schmidt HHHW, Walter U. 1994. NO at work. Cell 78:919-925.

Scott WO, Aldrich SR. 1983. Soybeans, food, feed and future. In: Scott WO, Aldrich SR, editors. Modern Soybean Production. Champaign, IL: S & A Publications, Inc. p 209-219.

Seiberg M, Liu J-C, Babiarz L, Sharlow E, Shapiro S. 2001. Soymilk reduces hair growth and hair follicle dimensions. Exp Dermatol 10:405-413.

Sessa DJ. 1979. Biochemical aspects of lipid-derived flavors in legumes. J Amer Oil Chem 27.2:234-239.

Setchell KDR. 1998. Phytoestrogens: the biochemistry, physiology, and implications for human health of soy isoflavones. Am J Clin Nutr 68:1333S-1346S.

Setchell KDR, Cassidy A. 1999. Dietary isoflavones: biological effects and relevance to human health. J Nutr 129:758S-767S.

Singh G. 2010. The soybean: botany, production and uses. Chap 1, p 1-20. Chap. 16, p. 345-356. Chap. 18, pp. 404-409. 1st ed. CAB International, Oxfordshire, UK.

Soy Protein Council 1987. Soy protein products: characteristics, nutritional aspects and utilization. Soy Protein Council. Washington, D.C.

Soyfoods Association Of North America. 1996. Voluntary standards for the composition and labeling of soymilk in the United States. Soyfoods Association of America, Washington, DC, USA. http://www.soyfoods.org/soy-products/soy-standards. Accessed 2015 March 27.

Soyfoods Association Of North America. 2015a. Soy for Heart Disease. Soyfoods Association of North America, Washington DC, USA. http://www.soyfoods.org/nutrition-health/soy-for-healthy-living/soy-for-heart-disease/soy-protein-content-chart. Accessed 2015 May 27.

Soyfoods Association Of North America. 2015b. Whole soybeans, soy products. Soyfoods Association of North America, Washington, DC, USA. http://www.soyfoods.org/soy-products/soy-fact-sheets/whole-soybeans-fact-sheet. Accessed 2015 March 27.

Taira H, Toriu H, Saito M. 1985. Quality of soybean seeds grown in Japan: varietal differences in total carotenoids content and color of soybean seeds grown in Nagano Chushin agricultural experiment station. Rep Natl Food Res Inst 47:92-104.

Takahashi N, Saski R, Chiba H. 1979. Enzymatic improvement of food flavor IV: oxidation of aldehydes in soybean extracts by aldehyde oxidase. Agric Biol Chem 43:2557-2561.

Terhaag MM, Almeida MB, Benassi MT. 2013. Soymilk plain beverages: correlation between acceptability and physical and chemical characteristics. Food Sci Technol 33.2:387-394.

Thakur M, Hurburgh CR. 2007. Quality of US soybean meal compared to the quality of soybean meal from other origins. J Am Oil Chem Soc 84:835-843.

Torres-Penaranda AV, Reitmeier CA. 2001. Sensory descriptive analysis of soymilk. J. Food Sci 66.2:352-56.

Torres-Penaranda AV, Reitmeier CA, Wilson LA, Fehr WR, Narvel JM. 1998. Sensory characteristics of soymilk and tofu made from lipoxygenase-free and normal soybeans. J Food Sci 63.6:1084-1087.

Tran QK, Takamura H, Kito M. 1992. Dried soy milk with low content of n-hexanal. Biosci Biotech Biothem 56:519-520.

Tunde-Akintunde TY, Souley A. 2009. Effect of processing methods on quality of soymilk. Pakistan J of Nutr 8.8:1151-56.

USDA. 2015. Soybeans: supply, disappearance, and price, US, 1980/81-2012/13. http:usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1290. Accessed 2015 15 May.

Van Buren JP, Stein-Kraus KH, Hackler LR, El Rawi I, Hand DB. 1964. Heat effects on soymilk. J Agric Food Chem 12.6:524-528.

Villegas B, Carbonell I, Costell E. 2009. Acceptability of milk and soymilk vanilla beverages: demographics consumption frequency and sensory aspects. Food Sci and Tech Int 15.2:203-10.

Wang AH, Dou J, Macura D, Durance TD, Nakai S. 1998. Solid phase extraction for GC analysis of beany flavours in soymilk. Food Res Int 30:503-511.

Wang B, Xiong YL, Wang C. 2001. Physicochemical and sensory characteristics of flavored soymilk during refrigeration storage. J Food Qual 24:513-526.

Wansink B, Cheong JH. 2002. Taste profiles that correlate with soy consumption in developing countries. Pakistan J of Nutr 1.6:276-278.

Wansink B. 2003. Overcoming the taste stigma of soy. J Food Sci 68:2604-2606.

Weidner C, Krempf M, Bard J, Cazaubiel M, Bell D. 2008. Cholesterol-lowering effect of soy drink enriched with plant sterols in a French population with moderate hypercholesterolaemia. Lipid Health Dis 7:35-42.

Wilcox JR. 2004. World distribution and trade of soybean. In Boerma HR, Specht J, editors. Soybeans: improvement, production and uses. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc., Madison, WI. p 1-14.

Wilkens WF, Lin FM. 1970. Gas chromatographic and mass spectral analyses of soybean milk volatiles. J Agric Food Chem 18:333-336.

Williams JP, Jordan SE, Barnes S, Blair HC. 1998. Tyrosine kinase inhibitor effects on avian osteoclastic acid transport. Am J Clin Nutr 68:1369S-1374S.

Wiriyaumpaiwong S, Soponronnarit S, Prachayawarakorn S. 2006. Drying and urease inactivation models of soybean using the two-dimensional spouted bed technique. Drying Tech 24:1673-1681.

Wong WW, Smith EO, Stuff JE, Hachey DL, Heird WC, Pownell HJ. 1998. Cholesterol-lowering effect of soy protein in normocholesterolaemic and hypercholesterolaemic men. Am J Clin Nutr 68:1385S-1389S.

Wright L, Nancarrow C, Kwok P. 2001. Food taste preferences and cultural influences on consumption. Br Food J 103:348-357.

Yanatori Y, Fujita T. 1976. Hypertrophy and hyperplasia in the endocrine and exocrine pancreas of rats fed soybean trypsin inhibitor or repeatedly injected with pancreozymin. Archives of Histology, Japan 39:67-69.

Zhang Y, Guo S, Liu Z, Chang SKC. 2012. Off-flavor related volatiles in soymilk as affected by soybean variety, grinding, and heat-processing methods. J of Agricultural and Food Chem 60:7457-7462.

TABLES

Table 1. Percentage of protein and oil in soybeans of the top 4 soybean producing countries

	United States	Brazil	Argentina	China
Protein (%)	34.8-41.58**	35.5-40.86**	32.6-33.3*	42.14-44.9*
Oil (%)	15.1-18.7**	13.6-18.66**	14.1-19.1*	12.9-17.25*

**ranges are from 2 different studies*
***ranges are from 3 different studies*

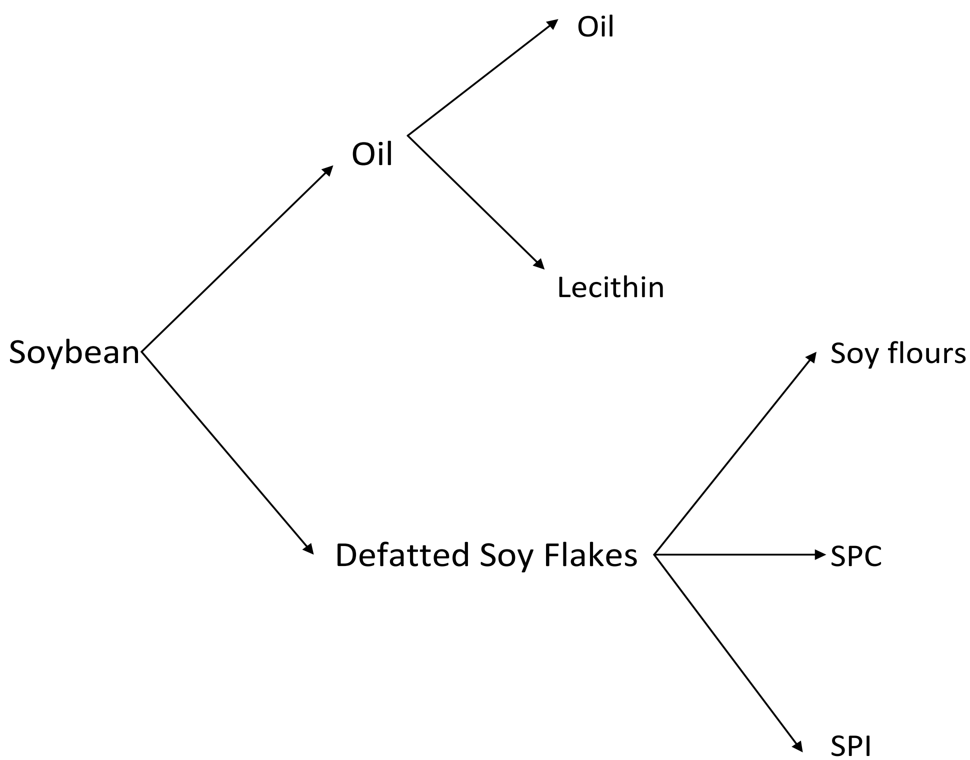
Thakur and Hurburgh 2007; Karr-Lilienthal *et al*. 2004; Grieshop and Fahey 2001

Table 2. Products made from soybean oil, lecithin, flours, concentrates and isolates

Products Made from Soybean Oil	Products Made from Soybean Lecithin	Products Made from Soy Flours, Concentrates and Isolates
Salad oil	Anti-foaming agents	Packaging Films
Shortening and Margarine	Dispersing agents	Adhesives
Paints	Viscosity modification	Fermentation aids
Resins	Pharmaceuticals	Water-based paints
Ink	Protective Coatings	Particle boards
Candles		
Crayons		
Soap		
Shampoos		
Detergents		
Electrical Insulation		
Lubricants		
Linoleum backing		
Pesticide carriers		
Fungicides		
Plastics		
Waterproof Cement		
Putty		

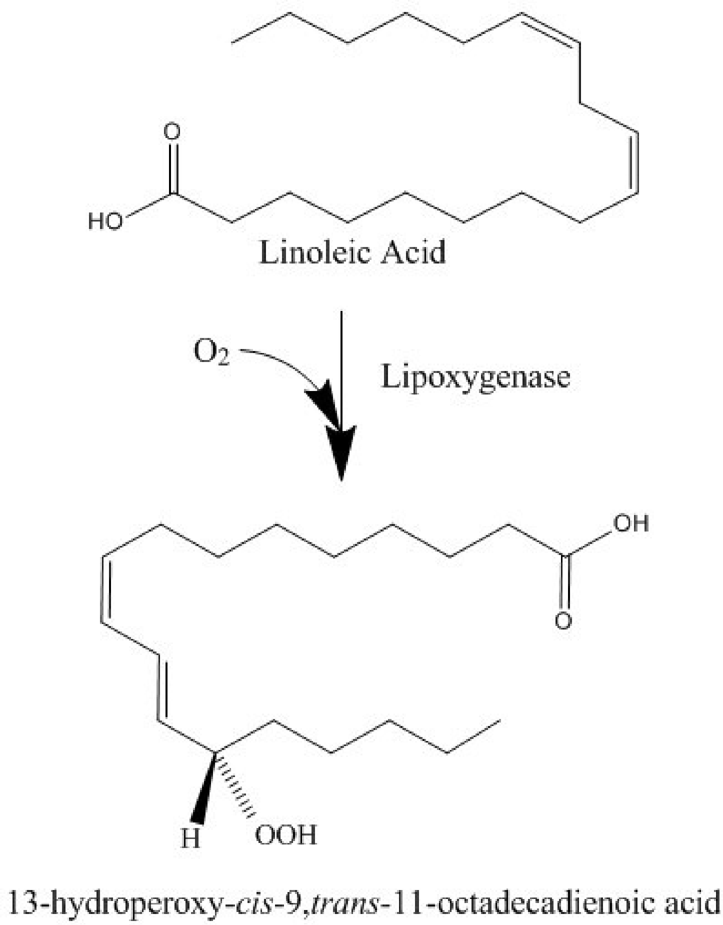
Soyfoods Association of North America 2015b; Liu 1997; Scott and Aldrich 1993

FIGURES



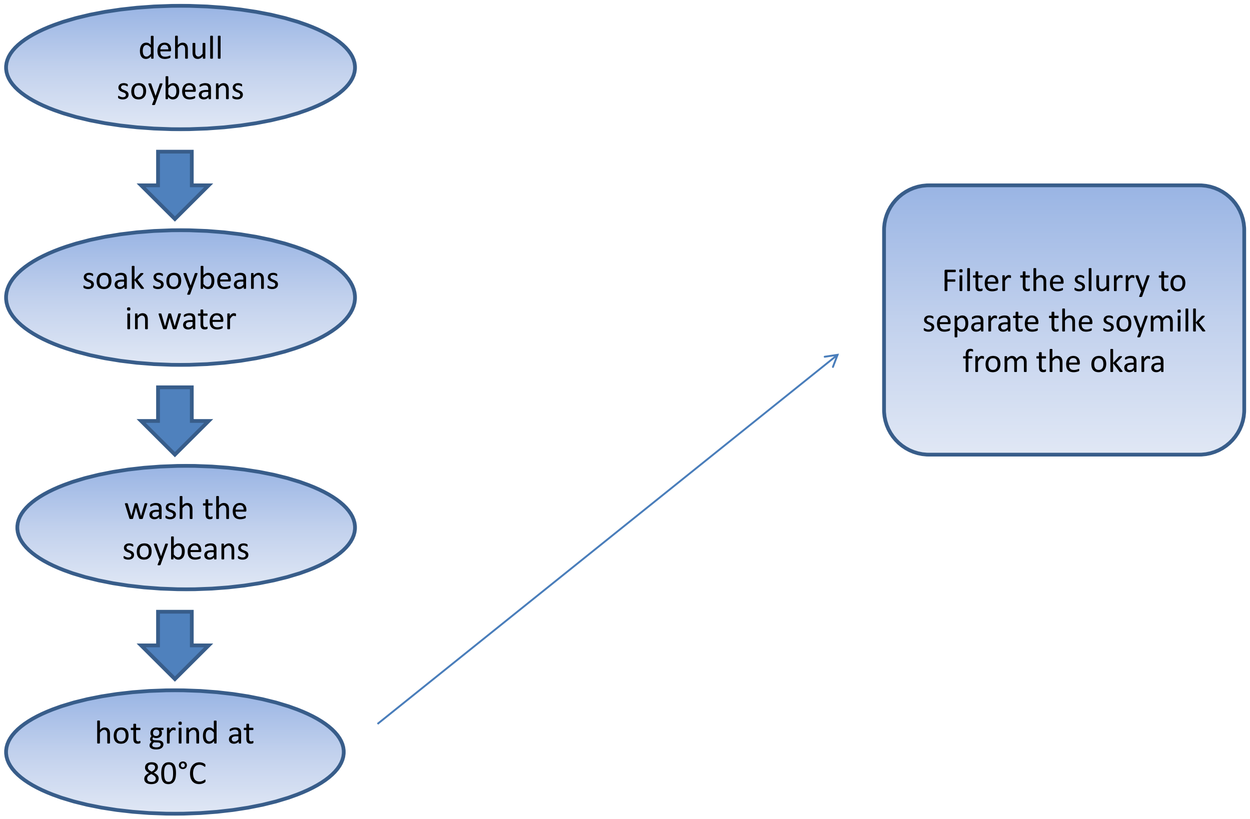
Soy Protein Council 1987; Cowan *et al*. 1973

Figure 1. Products of Soybean Processing



Taken from Liu 1997

Figure 2. Lipoxygenase catalized oxygenation of linoleic acid to produce 13-hydroperoxy-*cis*-9,*trans*-11octadecadienoic acid



Nelson *et al*. 1976

Figure 3. The process for making soymilk

CHAPTER 2

Cross-Cultural Preference Mapping of Soymilk

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ABSTRACT

Soymilk consumption has increased tremendously in the last 15 years, but the advent of other plant based milks has increased competition. The objective of this study was to determine and compare drivers of liking for unflavored soymilk with different U.S. consumer groups. A category survey of 26 commercial soymilks was conducted. A highly trained panel (n=7) documented appearance, mouthfeel and flavor attributes of the soymilks. Twelve representative soymilks were then selected for evaluation by consumers from three age/cultural categories (n=75 each category; Caucasian/African American females 18-30 y; Asian females 18-30 y; Caucasian/African American females 40-64 y). Consumers evaluated overall liking and liking and intensity of specific attributes. Results were evaluated by analysis of variance, followed by internal and external preference mapping. Age had no effect on overall liking, while ethnicity did (Caucasian/African American vs Asian)($p<0.05$). Caucasians/African Americans differentiated soymilks more than Asians and assigned a wider range of liking scores than Asians (2.1-7.2 vs. 4.0-6.1).Three consumer clusters were identified. Cluster 1 (n=71) was comprised of more Asians than Clusters 2 and 3 ($p<0.05$), while Clusters 2 and 3 had more Caucasians and African Americans ages 40-64 y. Cluster 3 also had more Caucasians and African Americans ages 18-30 y than Cluster 1. Sweet taste with vanilla/vanillin and sweet aromatic flavors and higher viscosity were preferred by most consumers and differences between consumer clusters were primarily in drivers of dislike. Drivers of dislike were not identified for Cluster 1 consumers while Clusters 2 and 3 consumers (n=84, n=80) disliked beany, green/grassy and meaty/brothy flavors and astringency. Cluster 3 (n=80) consumers scored all soymilks higher in liking ($p<0.05$) than Cluster 2 consumers, and were willing to overlook disliked attributes with the addition of sweet taste, whereas the Cluster 2 consumers were not. These findings can be utilized to produce soymilks with attributes that are well liked by target consumers and to tailor attributes to reach different segments of the population that have not yet been accommodated.

KEYWORDS:

Soymilk, descriptive analysis, acceptance testing, cross-cultural, preference mapping

INTRODUCTION

Soymilk, a water extract of soybeans obtained by soaking soybeans then wet grinding and filtering, has seen a remarkable increase in sales over the last few decades. Sales of soymilk increased from $500 million in 2001 to $622 million in 2003 (Savitry and Prakash, 2004) and then grew at a rate of 61% from 2003 to 2008 (Suppavorasatit and others 2013) with $1 billion in sales (Soyfoods Association of North America 2015). Increases in demand can be for several reasons, including the health benefits of soy protein and the use of soymilk as a lactose-free alternative to dairy milk. Studies on soymilk have demonstrated health benefits of soy isoflavones (phytoestrogens) for reduction or prevention of various cancers, diabetes, high blood pressure, kidney disease and osteoporosis (Messina and Hughes, 2003; Prakash and others 2007; Banerjee and others 2008; Villegas and others 2009) as well as health benefits of soy protein for its reduction of blood lipid profile (Weidner and others 2008; Wong and others 1998), lowering of cholesterol (Anderson and others 1995), and prevention of bone loss (Lydeking-Olsen and others 2004). While soymilk sales have dramatically increased from previous years, it is still purchased by less than 13% of households in the United States (Dharmasena and Capps, 2014). Determination of what sensory attributes drive consumer liking of soymilk among different consumer groups can help to clarify consumer desires and identify improvements to reach a wider consumer audience.

The analytical sensory properties of soymilks and soy protein have been documented (Russell and others 2006; Chambers and others 2006; Day N' Kouka and others 2004; Torres-Penaranda and Reitmeier 2001). Russell and others (2006) evaluated sensory profiles of whey proteins and soy proteins. Distinct flavors were associated with each protein. Soy proteins were characterized by cereal, roasted, malty and flour paste flavors. Day N' Kouka and others (2004) identified 31 sensory terms to describe soymilks, including vanilla, cooked grain, green, nutty, starchy and bran. Keast and Lau (2006) examined flavor characteristics of Australian soymilks and Asian soymilks. Australian soymilks were characterized by milky flavor, astringency and salty taste, while the Asian soymilks were characterized by beany, cooked bean, pandan flavors, and sweet taste.

Consumer liking of soymilks has also been investigated in studies by Nti and Larweh (2003), Hinze and others (2004), Villegas and others (2009), Palacios and others (2010) and Terhaag and others (2013). Nti and Larweh (2003) conducted a consumer acceptance test in Ghana to determine the most desirable flavors for soymilk. They reported that the addition of any flavor (vanilla, banana, coffee or chocolate) improved the overall acceptability of the soymilks. Hinze and others (2004) evaluated knowledge and acceptability of soymilk by adults in low versus high socio-economic regions in Cape Town, South Africa. They concluded that adults living in the high socio-economic region had more knowledge about soymilk, but there was no difference in acceptability or frequency of use between the low and the high socio-economic classes. Villegas and others (2009) conducted a study in Spain on acceptability of vanilla milk versus vanilla soymilk and the influence of consumer demographics, habits, and sensory properties. The vanilla milks were more acceptable than the vanilla soymilks, and higher liking was attributed to increased vanilla flavor, sweet taste, and higher viscosity than the soymilks. Consumer demographics and habits had no impact on beverage preference. Terhaag and others (2013) applied internal preference mapping of soymilks in a study on consumers in Brazil, and related the soymilks to their physicochemical characteristics. The most desirable characteristics of soymilk were darker color, higher viscosity, higher protein content and higher vanilla flavor.

Palacios and others (2010) conducted a consumer acceptance test with U.S. children ages 8-16 y with unflavored and chocolate flavored lactose-free dairy milk versus unflavored and chocolate flavored soymilk. The study included Caucasian, African American, and Hispanic children. Lactose-free dairy milk was liked more than soymilk in both flavor categories by children. Ethnicity did not impact liking. To our knowledge no study has addressed preference mapping of soymilks with different U.S. consumer groups. The objective of this study was to determine the sensory attributes that drive liking of unflavored soymilks among different U.S. consumer groups. Descriptive analysis of soymilks followed by consumer acceptance testing with Asian and Caucasian/African American U.S. consumers was conducted.

MATERIALS AND METHODS

Experimental Overview

Sensory properties of twenty six commercial plain (unflavored) soymilks were evaluated by descriptive analysis. Instrumental color measurements were also conducted. Subsequently, a consumer acceptance test was conducted with selected soymilks with 235 consumers representing Caucasian/African American females age 18-30 y, Caucasian/African American females 40-64 y, and Asian females age 18-30 y.

Soymilks

Forty five commercial soymilks (flavored and unflavored) were obtained from local supermarkets and specialty stores in Raleigh, NC for trained panel lexicon development and calibration. Twenty six unflavored soymilks were selected based on availability and market share. The 26 profiled soymilks included shelf stable (n=12) and refrigerated (n=14), both regular (n=24) and light (n=2) original flavor soymilks, 19 of which were sweetened, and 7 of which were unsweetened. Soymilks were stored at 4°C until evaluation. Selected soymilks (n=26) were purchased in triplicate on different occasions (ca 3 weeks apart) and subjected to analytical sensory and instrumental evaluations to ensure that representative evaluations were conducted.

Color Measurement

Soymilks were gently mixed and approximately 8 mm of each was dispensed into 60 mm x 15 mm disposable, sterile, polystyrene petri dishes (Corning Incorporated, Corning, NY, USA). Sample preparation was conducted with overhead lights off to avoid any light oxidation of the samples. A Konica Minolta Chroma Meter model CR-410 was used to measure the L*, a*, b* values (Liu and Chang 2013). Measurements were taken in triplicate. Whiteness was calculated using the formula L*-3b* (Rawdkuen and others 2004; Park 2005; Digre and others 2011; Park and others 2013).

Descriptive Analysis

The descriptive panel was comprised of eight trained panelists, all female, ages 22-45 y and were all employed by North Carolina State University. Each panelist had a minimum of 65 h of prior descriptive analysis training on food flavor and mouthfeel/texture attributes using the Spectrum™ method (Meilgaard and others 2007). Supplementary training (approximately 75 30 min sessions) was devoted to soymilk lexicon development/refinement, and calibration. The lexicon was adapted from the lexicon of Day N' Kouka and others (2004). Additional attributes were added (Table 1). During the development and refinement of the terms, panelists conversed and assigned definitions and references for each attribute. An array of commercial soymilks and other foods were used for lexicon development and refinement. Analysis of variance of results from practice sessions was used to determine that the panel and panelists could generate reproducible data and differentiate soymilk sensory properties.

Soymilks were evaluated at room temperature (20°C). Soymilks were gently shaken and 85 mL was dispensed into coded 118 ml plastic soufflé cups and lidded. Sample preparation was conducted with overhead lights off to avoid any light oxidation of the samples. At the beginning of each evaluation session, panelists were calibrated with a commercial warm up sample that panelists had previously characterized. Panelists then evaluated no more than 5 soymilks per session to prevent fatigue. Panelists expectorated samples. Between samples, panelists rinsed with spring water and or unsalted crackers. A 2 min wait time between samples was enforced. The order of presentation of samples was randomized to account for presentation and carryover effects. Opacity and viscosity were evaluated in separate sessions from flavor to prevent interactions. Each beverage was evaluated in separate sessions in triplicate by each panelist. Data were collected on paper ballots or with Compusense five v5.6 (Compusense, Guelph, Ontario, Canada).

Consumer Acceptance Testing

Twelve representative soymilks were selected for consumer testing based on market share and examination of descriptive sensory analysis principal component biplots. A target number of 225 consumers were recruited from the database of more than 7,500 maintained by the NCSU Sensory Service Center (Raleigh, NC). Consumers were recruited with an online screener using SSI Web (Sawtooth Software Version 8.3.2, Orem, UT). All consumers drank soymilk at least once per week, and were consumers of original flavor soymilk. Additional recruitment criteria included consumers from three age/ethnicity categories: Caucasian/African American females 18-30 y, Asian females 18-30 y, and Causasian/African American females 40-64 y. Participants were recruited for two days of testing and received a $35 gift card at the end of both days of testing.

The test was conducted across two days, with consumers evaluating 6 soymilks per day. Soymilks were served at 4°C. The samples were presented monadically with a balanced partial presentation of samples randomized across consumers for both days. Approximately 120 mL of soymilk was poured into 207 mL plastic tumblers labeled with three-digit codes. Consumers were instructed to cleanse their palate by rinsing with deionized water and taking a bite of unsalted cracker during an enforced 2 minute rest between each sample. Compusense Five version 5.6 (Compusense, Guelph, Canada) was used for data collection.

Consumers were asked to first evaluate appearance, aroma and color liking before tasting the soymilks. Consumers then evaluated overall liking, flavor, sweetness, thickness and aftertaste liking using a 9-point hedonic scale where 1= dislike extremely and 9= like extremely. Just-about-right (JAR) questions were asked for color, flavor, sweetness and thickness using a 5-point scale where 1 and 2= too little, 3= just about right, 4 and 5= too much. Purchase intent was asked on a 5-point scale where 1 and 2= would not buy, 3= might/might not buy, 4 and 5= would buy. Consumers were also allowed an option to write in comments for specific likes or dislikes.

Statistical Analysis

Statistical analyses were conducted using XLStat (version 2014.6.04, Addinsoft; Paris, France). Descriptive analysis data were analyzed by analysis of variance (ANOVA) followed by principal component analysis using the correlation matrix. A 3-way analysis of variance

(ANOVA) was performed on consumer liking data with ethnicity, age group and soymilk treatments as variables to determine interactions. Just-about-right scores were analyzed with chi-square analysis. Purchase intent was analyzed by Kruskal-Wallis with Dunn's post hoc non-parametric test.

Cluster analysis was performed on consumer liking scores prior to preference mapping using agglomerative hierarchical clustering (AHC) and k-means clustering. Panelists with similar responses were placed into groups. A 2-way ANOVA with means separation (Fishers least significant difference) was performed on consumer liking data with cluster and soymilk treatments as variables to determine interactions. Internal and external preference mapping were subsequently conducted on 9 soymilks instead of 12, as no distinct differences ($p>0.05$) in the overall liking means were observed for the other 3 soymilks. This result implied that what contributed to the drivers of liking of each cluster was characterized with the remaining 9 soymilks. Internal preference mapping was then conducted on soymilks with cluster liking scores. External preference mapping was conducted on descriptive analysis means and consumer liking scores for each cluster using external preference mapping and partial least squares regression. All statistical analyses were performed at a 95% confidence interval.

RESULTS AND DISCUSSION

Twenty four sensory attributes were identified and defined for soymilks. The developed lexicon contained overall aroma intensity, 16 aromatics, 4 basic tastes, viscosity, opacity and 1 chemical feeling attribute (Table 1). The lexicon for soymilk contained some descriptors and references previously defined by Day N' Kouka and others (2004), but many attributes were unique. The greatest additions to the lexicon (16 terms) were aromatic descriptors. Aromatic terms used from Day N' Kouka and others (2004) included green/grassy, potato, vanilla, nutty and malty. In the current study, the terms "nutty" and "malty" were merged for clarification based on panelist discussions during training sessions. Although the term "beany" was omitted from Day N' Kouka and others (2004) for its perceived ambiguity, it has often been used to describe soy products by others (Civille and Lyon 1996; Torres-Penaranda and others 1998; Carrao-Panizzi and others 1999; Torres-Penaranda and Reitmeier 2001; Vara-Ubol and others 2004; Chambers and others 2006; Keast and Lau 2006; Lozano and others 2007) and also was added to the current lexicon by panelists.

The lexicon was developed from the 45 evaluated soymilks, which included some flavored soymilks, fortified soymilks, and specialty store brands. Our objective was focused on original flavor, non-fortified soymilks. For this reason, some attributes identified in the lexicon were not present in the 26 evaluated soymilks. The seven aromatics and two basic tastes not present in the 26 evaluated soymilks were identified in at least one commercial soymilk during the initial lexicon training and calibration sessions. The terms not present in the 26 evaluated soymilks are likely unique to specialty brands (malty/nutty, hay, carrots, vitamin, molasses, potato, salty and umami) or perhaps loss of shelf life (fermented, fatty/oxidized). Many of those terms were also used to describe soy products in other studies such as malty or nutty (Day N'Kouka and others 2004; Keast and Lau 2006; Russell and others 2006), hay (Keast and Lau 2006), molasses (Chambers and others 2006), potato (Day N'Kouka and others 2004), oxidized or rancid (Hwang and Hong 2013; Chambers and others 2006; Day N'Kouka 2004), salty (Chambers and others 2006; Keast and Lau 2006) and umami (Hwang and Hong 2013).

The 26 soymilks were differentiated by the identified lexicon. All soymilks had varying intensities ($p<0.05$) of overall aroma impact, beany flavor, sweet taste and astringency (Table 2). Meaty/brothy flavor and bitter taste were found almost exclusively in shelf stable soymilks (Table 2, Figure 1). This could be due to the higher heat treatment received by shelf stable soymilks compared to refrigerated soymilks. Most refrigerated soymilks were characterized by sweet aromatic and fruity flavors (Table 2, Figure 1). Diacetyl flavor was present exclusively in one brand of soymilks (Table 2). These flavors (sweet aromatic, vanilla/vanillin, diacetyl) are likely due to specific flavoring systems/masking agents used by the various suppliers. The light soymilks were lowest in opacity (Table 2).

Principal component (PC) analysis of the trained panel data explained 51% of the variability on PCs 1 and 2 (Figure 1). Principal component 1 (31%) was comprised of vanilla/vanillin, which was positively loaded on PC 1, and beany, green/grassy, meaty/brothy, astringency and bitter taste, which were all negatively loaded on PC 1. Principal component 2 (20%) was comprised of sweet aromatic and cereal/oatmeal flavors, which were positively loaded on PC 2, and overall aroma impact and diacetyl flavor, which were negatively loaded on PC 2. Sweet aromatic was the predominant aromatic in soymilks 431, 280, 426, 142, 130, 689, 808 and 585. Chambers and others (2006) also reported that sweet aromatic flavor was present in all ready-to-drink soymilks that they profiled, and in higher intensities than most other attributes. Although most sweet aromatic flavor is likely due to flavoring/masking systems, Russell and others (2006) also reported low intensities of sweet aromatic flavor in rehydrated soy protein concentrates and isolates. Soymilks 603, 309, 716, 748, 832, 351, 764 and 108 (6/8 of which were shelf stable) displayed meaty/brothy flavor (a flavor previously reported in soy sauces by Cherdchu and others (2013)). Soymilks 561 and 084, different soymilks of the same brand, were characterized by diacetyl and vanilla/vanillin flavors, and were also the only soymilks with no detectable cereal/oatmeal flavor. Beany flavor was present in all soymilks, but in varying intensities ($\overline{x}$ =1.0-3.8), which is corroborated by the findings of Chambers and others (2006), who also reported beany flavor in all of the non-powdered forms of soymilks that they profiled.

Opacity of the soymilks was measured on a 0 to 15 point product-specific scale, and ranged between 9.5-14.7 (Table 2). The light soymilks 130 and 084 had the lowest opacity with 9.5 and 10.5 values, respectively. Color measurement of the soymilks was also conducted and reported in CIELAB format (Table 3). Whiteness of the soymilks ranged from 11.86-41.46, with soymilk 084 having the lowest value for whiteness, and soymilks 748 and 309 having the highest value for whiteness (Table 3). Based on market share and analytical sensory properties, representative soymilks 084, 130 (light soymilks), 561, 955, 459, 832, 585, 748, 716, 309, 603 and 426 (3 shelf stable, 9 refrigerated, 3 unsweetened, 9 sweetened) were selected for consumer testing.

Consumer Acceptance Testing

A total of 235 consumers participated in the acceptance test. Soymilks were differentiated by consumers in appearance and flavor/texture attributes (Table 4). Soymilks 585 and 561 (shelf stable sweetened and refrigerated sweetened, respectively) received the highest overall liking scores, along with the highest flavor, sweetness and aftertaste liking scores (Table 4). Soymilk 585 scored higher than 561 in thickness liking (Table 4). Soymilk 084 (light, refrigerated sweetened) also received high scores for overall liking, flavor, sweetness, thickness and aftertaste liking relative to other soymilks (Table 4), indicating that consumers preferred soymilks characterized by vanilla/vanillin, diacetyl and sweet taste. Conversely, soymilks 309 and 748 were the least liked by all consumers (Table 4). These soymilks were characterized by beany, green/grassy, and meaty/brothy flavors, bitter taste and astringency (Table 2, Figure 1).

Soymilks 309,426,585,603 and 748 received the highest JAR (Just About Right) scores for color, and soymilks 084, 130 and 561 were penalized for being too dark (Table 4). Instrumental whiteness of soymilk was not an important attribute, as correlation analysis revealed an insignificant correlation (r^2=0.048, $p>0.05$) between instrumentally measured whiteness of soymilk and color liking scores. Additionally, the overall liking scores of soymilk indicated that soymilk preference was determined not by color, but by the flavor/taste of the soymilk, as 561 and 084 were among the lowest scored soymilks in terms of color liking, but were among the top 3 most liked soymilks (Table 4). The color of soymilks was diverse, as confirmed by l* a* b* values, and varied from a pale yellow/tan to a dark yellow/tan. Future work should address determination of the ideal color/shade of soymilks for consumers.

Soymilks 084, 561 and 585 scored the highest in flavor JAR, and were also the most highly liked soymilks by all consumers, indicating that flavor was a very important attribute to the consumers (Table 4). Soymilks 309, 459 and 748 were all penalized for not having enough flavor. The highest JAR scores for sweetness were given to soymilks 084, 130, 426, 561 and 585 (Table 4). Soymilks 309, 459 and 748 were penalized for not being sweet enough. The soymilks with the best thickness JAR scores were soymilks 084, 426, 561, 585 and 603 (Table 4). Soymilks 130, 603 and 748 were penalized for not being thick enough. The fact that soymilk 603 scored at parity with the other soymilks for highest JAR score but was also penalized for not being thick enough shows that there was a split opinion on this soymilk by consumers, which can also be seen in Table 6 among cluster liking by soymilk.

A 3-way analysis of variance (ANOVA) was performed on consumer liking data with ethnicity, age group and soymilk treatments to determine interactions. Age had no impact on soymilk liking ($p>0.05$), but there were ethnicity effects ($p<0.05$). Asians scored soymilks differently ($p<0.05$) than Caucasians/African Americans (Figure 2), with the exception of soymilk 603. The mean liking scores for Caucasians and African Americans ranged from 2.0-7.2, while the mean liking scores for Asians ranged from 4.0-6.1. The tendency for Asians to use a smaller range of the hedonic scale than Westerners has been documented in studies by Yeh and others (1998), Prescott and others (2002) and Yao and others (2003). Of the consumers that participated in the consumer acceptance test, 21.7% were not U.S. citizens, though approximately three fourths of those (74.5%) had been living in the United States for at least 6 months, which is the time after acculturation would have occurred. Yeh and others (1998) determined that Asians are less likely to use extreme ends of the hedonic scale, regardless of residency in the U.S. or duration of stay.

Consumer segmentation was conducted on overall liking scores to examine specific consumer preferences and drivers of liking for soymilk. Three clusters were identified. Cluster analyses were verified by evaluating soymilk attributes and liking of each soymilk by clusters. Cluster 1 (C1) was comprised of more Asians than Cluster 2 (C2) and Cluster 3 (C3) ($p<0.05$), while Clusters 2 and 3 had more Caucasians and African Americans 40-64 y than Cluster 1 ($p<0.05$). Cluster 3 also had more Caucasians and African Americans 18-30 y than Cluster 1 ($p<0.05$). Soymilk usage questions were analyzed by cluster and also revealed differences in usage of soymilk and preferences of flavor (Table 5). All consumers drank soymilk at least once a week and 25.0% of C2 consumers used soymilk as an added ingredient to smoothies, indicating more diversity in their use and consumption of plant milks. All clusters consumed the same amount of shelf stable, refrigerated, sweetened and unsweetened soymilk relative to each other ($p>0.05$), but clusters 2 and 3 also consumed more vanilla and chocolate flavored soymilk than C1 consumers, who preferred original flavor ($p<0.05$)(Table 5).

The soymilk by cluster interaction indicated that consumers in different clusters liked soymilks differently and further verified the clusters (Figure 4, Table 6). Soymilk 309 was scored higher by C1 than by C2 or C3 (Figure 4, Table 6). Soymilk 309 was characterized by higher overall aroma impact, beany, meaty/brothy and green/grassy flavors, bitter taste, astringency, lower viscosity and low sweet taste intensity (Figure 1, Table 2). Soymilks 459 and 748 were scored higher by C1 and C3 than by C2 (Figure 4, Table 6). Soymilks 459 and 748 were characterized respectively by cereal/oatmeal and beany flavors, bitter taste and astringency, and cereal/oatmeal, beany, green/grassy and meaty/brothy flavors, lower viscosity, bitter taste, astringency and low sweet taste (Figure 1, Table 2). This indicates that C1 and C3 consumers were much more accepting of unsweetened soymilks with high cereal/oatmeal and beany flavors than C2 consumers. C1 consumers were more accepting of soymilk 309 than C3 consumers, but scored 459 and 748 the same as C3 consumers, indicating that C1 consumers were more tolerant of soymilks with high overall aroma than C3 consumers. Soymilk 603 was scored much higher by C3 than by C1 or C2 (Figure 4, Table 6). Soymilk 603 was characterized by higher overall aroma impact, beany and meaty/brothy flavors, bitter taste, high sweet taste and astringency. This indicates that C3 consumers were more tolerant of attributes that they generally disliked as long as the soymilk was sweetened. There were some soymilks that C1 consumers liked more than other clusters and some soymilks that C3 consumers liked more than other clusters, but there was not a single soymilk that C2 consumers liked more than the other two clusters, indicating that C2 consumers were more selective in the soymilks that they liked compared to the other two clusters (Figure 4).

Internal Preference Mapping

Internal preference mapping was conducted on the consumer data to clarify likes or dislikes for specific soymilks (Figure 3). The variability explained by the first two factors was 59% (Figure 3). The best liked characteristics of the most liked soymilks (soymilks 561 and 585) were the flavor, sweetness and viscosity. "Nothing" was selected as what was disliked most for these samples by 23.4% (sample 561) and 31.5% (sample 585) of consumers, confirming their high acceptability. Samples 309 and 459 were the least liked by consumers and the most undesirable characteristics for both samples were the flavor (62.1%, 63.4%), the lack of sweetness (29.8%, 27.2%), and the aftertaste (17.4%, 15.3%). Samples 426 and 459 were the most viscous soymilks (Table 2), and viscosity was the most liked attribute for both of these soymilks (35.7%, 36.2%), indicating a consumer preference towards more viscous soymilks.

Soymilks 748 and 309 were among the top rated soymilks in color liking (Table 4), and color was their most liked attribute (33.6% and 34.9% respectively), with those consumers commenting specifically on how much they liked the "white" color of the soymilks. While instrumental whiteness measurements indicate that soymilks 748 and 309 were not white in color as instrumentally measured, they had higher whiteness values than the rest of the soymilks, and so they might have appeared white relative to other soymilks.

Additionally, these soymilks had the lowest b* value, showing that these soymilks were less yellow in color than the other soymilks. This indicates that consumers have a preference towards soymilks that are lighter and less yellow in color. This coincides with the findings of Terhaag and others (2013) who also found that consumers did not appreciate darker colored soymilks. Cluster 2 (C2) and Cluster 3 (C3) consumer responses were highly loaded on the positive axis of PC1, indicating their distaste for samples 309, 459, 603 and 748 (Figure 3). Cluster 1 (C1) also showed more concentrated responses towards samples 561, 585, 084 and 130, but these consumers were more spread out across the graph near all other soymilks, demonstrating that C1 consumers found most soymilks more appealing than C2 and C3 consumers (Figure 3).

External Preference Mapping and Partial Least Squares Regression

External preference mapping and partial least squares regression (PLS) were conducted on the consumer data. On the external preference maps (Figures 5-8), soymilks loading highly on the F1 axis were characterized by vanilla/vanillin flavor. Soymilks loading negatively on the F1 axis were characterized by beany, green/grassy and meaty/brothy flavors, and bitter taste and astringency. Soymilks loading positively on the F2 axis were characterized by sweet aromatic and cereal/oatmeal flavors, while the soymilks loading negatively on the F2 axis were characterized by high overall aroma and diacetyl flavor. Preference mapping of the clusters (Figure 5) confirmed the attributes that drove liking and disliking for each cluster. Cluster 1 (C1; n=71) consumers liked vanilla/vanillin, diacetyl, sweet taste and higher viscosity (Figure 6). There were no distinct drivers of dislike for C1 consumers, who preferred moderate flavors. Cluster 1 consumers preferred soymilks that were not too beany, not too meaty/brothy, not too green/grassy, not too cereal/oatmeal, not too bitter, and not too astringent (Figure 6). Cluster 2 (C2; n=84) consumers also liked vanilla/vanillin, diacetyl, sweet taste and higher viscosity (Figure 7). Drivers of dislike for C2 were high overall aroma impact, beany, cereal/oatmeal, green/grassy, meaty/brothy, bitter taste and astringency (Figure 7). Cluster 3 (C3; n=80) consumers liked vanilla/vanillin, diacetyl, sweet taste and higher viscosity (Figure 8). Drivers of dislike for C3 were identical to C2 consumers: high overall aroma impact, beany, cereal/oatmeal, green/grassy, meaty/brothy, bitter taste and astringency (Figure 8). What differentiated C2 consumers from C3 consumers is that C3 consumers were passionate about soymilk and sweetness was a big driver of liking for them. C2 consumers, while they also liked soymilk, were consumers of other plant milks as well, sweet taste was a driver of liking, but not as critically so as it was for C3 consumers, and C2 consumers on a whole preferred flavored soymilks.

Partial least squares regression of the clusters (Figure 9) confirmed the conclusions drawn from the external preference maps. Universal drivers of liking were vanilla/vanillin and diacetyl flavors, sweet taste and higher viscosity. For all three clusters the top scoring soymilks were 585, 561 and 084, which reinforces the findings that universal drivers of liking for unflavored soymilks are vanilla/vanillin, diacetyl, sweet taste and higher viscosity. Clusters were differentiated mainly by their dislikes. While C1consumers preferred original flavor soymilk and disliked high intensities of beany, meaty/brothy, green/grassy, cereal/oatmeal, bitter taste, and astringency, the differences between C2 and C3 consumers were a bit more obscure. Primary differences between C2 and C3 consumers were the usage and the extent to which they disliked certain attributes. C2 consumers were very selective in the soymilks that they liked and disliked, scoring all of the original flavored soymilks that they tasted between a 1.6 and a 6.6 (Table 6). C2 consumers preferred flavored soymilks, used soymilk as an "ingredient" in other foods such as smoothies, and were consumers of other plant milks, as well (Table 5). C3 consumers were passionate about soymilk, giving an average score of 7.7 to their favorite soymilk (Table 6). While the attribute dislikes for C3 were the same as those for C2 (beany, meaty/brothy, green/grassy, cereal/oatmeal, bitter taste and astringency), sweet taste was such a driver of liking for C3 (Figure 9) that disliked attributes could be overlooked (soymilk 603, Table 6). Findings from this study coincide with studies by Wansink (2003) and Wright and others (2001), who have also found that consumers dislike beany flavor. Sweet taste was found to be a driver of liking for soymilks in studies of Spanish consumers by Villegas and others (2009) and Brazilian consumers by Terhaag and others (2013). Additionally, just as vanilla was shown to be an appreciated attribute in this study, Villegas and others (2009) and Nti and Larweh (2003) also found that vanilla flavor in soymilk was a desirable attribute for consumers in Spain and Ghana. This is the only study to our knowledge that examines soymilk drivers of like and dislike across cultures with Caucasian and African American U.S. consumers and Asian consumers.

While some soymilks were well liked by the consumers on a whole, there were many soymilks that were disliked. Knowing what attributes of soymilk that consumers like and what drives dislike of soymilk can help product developers create a product that is well-liked. The results from this study indicate that consumers like soymilks that are characterized by vanilla/vanillin and sweet aromatic flavor, sweet taste and higher viscosity. Clusters of consumers were differentiated by what they disliked. A soymilk to target Cluster 1 consumers would be mild in flavor, avoiding high overall aroma, high beany, meaty/brothy, cereal/oatmeal and green/grassy flavors, and avoiding high bitter taste and astringency. An original flavor soymilk to target Cluster 2 consumers, who prefer flavored soymilks, would have vanilla/vanillin and sweet aromatic flavor, sweet taste and higher viscosity, and no beany, meaty/brothy, green/grassy or cereal/oatmeal flavors, would be void of bitter taste and astringency. Cluster 3 consumers, who are passionate about soymilk and driven by sweet taste, also would like a soymilk with vanilla/vanillin and sweet aromatic flavors, sweet taste and higher viscosity and no beany, meaty/brothy, green/grassy or cereal/oatmeal flavors, and would be void of bitter taste and astringency.

CONCLUSION

Age had no effect on U.S. consumer liking of soymilk, but ethnicity did have an effect. Asians did not use the full range of the hedonic scale, and all overall liking scores were centered around the middle of the scale, while Caucasian and African American U.S. consumers used a much wider range of the hedonic scale. Color was not a key driver for consumer liking but color differences in color liking were documented and may be an area of future work. Universal drivers of liking were vanilla/vanillin and sweet aromatic flavor, sweet taste and a higher viscosity with differences among consumers for sweet taste intensity and tolerance for beany and cereal flavors and bitter taste. These findings can aid product developers to create a soymilk that is appealing to a wide population, and also to reach segments of the population that have not yet been accommodated.

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REFERENCES

Anderson JW, Johnstone BM, Cook-Newell ME. 1995. Meta-analysis of the effects of soy protein intake on serum lipids. N Engl J Med 333:276-282.

Banerjee S, Li Y, Wang Z, Sarkar FH. 2008. Multi-targeted therapy of cancer by genistein. Cancer Lett 269:226-242.

Carrao-Panizzi MC, Beleia AD, Prudencio-Ferreira SH, Oliveira MCN, Kitamura K. 1999. Effects of isoflavones on beany flavor and astringency of soymilk and cooked whole soybean grains. Pesq Agropec Bras 34.6:1045–52.

Cherdchu P, Chambers E, Suwonsichon T. 2013. Sensory lexicon development using trained panelists in Thailand and the U.S.A.: soy sauce. J Sens Stud 28.3: 248-255.

Civille GV, Lyon BG, editors. 1996. Aroma and flavor lexicon for sensory evaluation: terms, definitions, references, and examples. West Conshohocken, PA: American Society for Testing and Materials. p 158.

Chambers E, Jenkins A, Mcguire BH. 2006. Flavor properties of plain soymilk. J Sens Stud 21.2:165-179.

Day N'kouka K, Klein BP, Lee S-Y. 2004. Developing a lexicon for descriptive analysis of soymilks. J Food Sci 69.7:259-263.

Dharmasena S, Capps Jr O. 2014. Unraveling demand for dairy-alternative beverages in the United States: The case of soymilk. Agr and Res Econ Rev 43.1:140-157.

Digre H, Erikson U, Skaret J, Lea P, Gallart-Jornet L, Misimi E. 2011. Biochemical, physical and sensory quality of ice-stored Atlantic cod (*Gadus morhua*) as affected by pre-slaughter stress, percussion stunning and AQUI-S™ anaesthesia. Eur Food Res Technol 233:447-456.

Hinze A, Karg C, Van Zyl M, Mohamed N, Steyn NP. 2004. The acceptability of different types of soymilks available in Cape Town in consumers from high and low socio-economic areas. Int J Cons Stud 28.1:40-48.

Hong JH, Yoon EK, Chung SJ, Chung L, Cha SM, O'Mahony M, Vickers Z, Kim KO. 2011. Sensory characteristics and cross-cultural consumer acceptability of *bulgogi* (Korean traditional barbecued beef). J Food Sci 76:S306–S313.

Hwang SH, Hong JH. 2013. Sensory drivers of goso flavor in soymilk: understanding a complex traditional Korean sensory attribute. Food Qual and Pref 29:113-125.

Keast RSJ, Lau JJ. 2006. Culture-specific variation in the flavor profile of soymilks. J Food Sci 71.8:S567-S572.

Kim Y-K, Jombart L, Valentin D, Kim K-O. 2013. A cross-cultural study using Napping®: Do Korean and French consumers perceive various green tea products differently? Food Res Int 53:534-542.

Liu Z-S, Chang SKC. 2013. Nutritional profile and physicochemical properties of commercial soymilk. J Food Proc and Pres 37.5:651-661.

Lozano PR, Drake MA, Benitez D, Cadwallader KR. 2007. Instrumental and sensory characterization of heat-induced odorants in aseptically packaged soy milk. J Agric Food Chem 55.8:3018-3026.

Lydeking-Olsen E, Beck-Jensen J-E, Setchell KDR, Holm-Jensen T. 2004. Soymilk or progesterone for prevention of bone loss: A 2 year randomized, placebo-controlled trial. Eur J Nutr 43:246-257.

Meilgaard M, Civille GV, Carr BT. 2007. Descriptive analysis techniques. In: Meilgaard M, Civille GV, Carr BT, editors. Sensory evaluation techniques, 4th ed. Boca Raton, FL: CRC Press. P 173-186.

Messina M, Hughes, C. 2003. Efficacy of soyfoods and soybean isoflavone supplements for alleviating menopausal symptoms is positively related to initial hot flush frequency. J Med Food 6:1-11.

Neely EA, Lee Y, Lee S-Y. 2010. Drivers of liking for soy-based Indian-style extruded snack foods determined by U.S. and Indian consumers. J Food Sci 75:S292–S299.

Nti CA, Larweh PM. 2003. Production and sensory characteristics of flavoured soymilk samples. Int J Cons Stud 27.3:181-184.

Park JH, Kang SN, Shin D, Hur IC, Kim IS, Jin SK. 2013. Antioxidant activities of *Achyranthes japonica* Nakai extract and its application to the pork sausages. Asian-Australas J Anim Sci 26.2:287-294.

Park JW. 1994. Functional protein additives in surimi gels. J Food Sci 59:525-527.

Park JW. 2005. Codex code for frozen surimi. In: Park JW, editor. Surimi and surimi seafood. Boca Raton, FL: Taylor and Francis group. p 869-885.

Palacios OM, Badran J, Spence L, Drake MA, Reisner M, Moskowitz HR. 2010. Measuring acceptance of milk and milk substitutes among younger and older children. J Food Sci 75.9:S522-S526.

Prakash D, Upadhyay G, Singh, BN, Singh HB. 2007. Antioxidant and free radical-scavenging activities of seeds and agri-wastes of some varieties of soybean (Glycine max). Food Chem 104:783-790.

Prescott J, Young O, O'Neill L, Yau NJN, Stevens R. 2002. Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. Food Qual Pref 13:489-495.

Rawdkuen S, Benjakul S, Visessanguan W, Lanier TC. 2004. Chicken plasma protein: Proteinase inhibitory activity and its effect on surimi gel properties. Food Res Int 37.2:156-165.

Russell TA, Drake MA, Gerard PD. 2006. Sensory properties of whey and soy proteins. J Food Sci 71.6: S447-S455.

Savitry A, Prakash M. 2004. Sing a song of soy. Prepared Foods 4:25-28.

Soyfoods Association Of North America. 2015. Sales by Product Type, 1996-2011. Soyfoods Association of North America, Washington, DC, USA. http://www.soyfoods.org/wp-content/uploads/SANA-sales-data-1996-2011-for-web.pdf. Accessed 2015 March 27.

Suknark K, Mcwatters K, Phillips RD. 1998. Acceptance by American and Asian consumers of extruded fish and peanut snack products. J Food Sci. 63:721–725.

Suppavorasatit I, Lee SY, Cadwallader KR. 2013. Effect of enzymatic protein deamidation on protein solubility and flavor binding properties of soymilk. J Food Sci 78.1:C1-C7.

Terhaag MM, Almeida MB, Benassi MT. 2013. Soymilk plain beverages: correlation between acceptability and physical and chemical characteristics. Food Sci Technol 33.2:387-394.

Torres-Penaranda AV, Reitmeier CA. 2001. Sensory descriptive analysis of soymilk. J. Food Sci 66.2:352-56.

Torres-Penaranda AV, Reitmeier CA, Wilson LA, Fehr WR, Narvel JM. 1998. Sensory characteristics of soymilk and tofu made from lipoxygenase-free and normal soybeans. J Food Sci 63.6:1084-1087.

Vara-Ubol S, Chambers E, Chambers DH. 2004. Sensory characteristics of chemical compounds potentially associated with beany aroma in foods. J Sens Stud 19:15–26.

Villegas B, Carbonell I, Costell E. 2009. Acceptability of milk and soymilk vanilla beverages: demographics consumption frequency and sensory aspects. Food Sci and Tech Int 15.2: 203-10.

Wansink B. 2003. Overcoming the taste stigma of soy. J Food Sci 68:2604-2606.

Weidner C, Krempf M, Bard J, Cazaubiel M, Bell D. 2008. Cholesterol-lowering effect of soy drink enriched with plant sterols in a French population with moderate hypercholesterolaemia. Lipid Health Dis 7:35-42.

Wong WW, Smith EO, Stuff JE, Hachey DL, Heird WC, Pownell HJ. 1998. Cholesterol-lowering effect of soy protein in normocholesterolaemic and hypercholesterolaemic men. Am J Clin Nutr 68:1385S-1389S.

Wright L., Nancarrow C., Kwok P. 2001. Food taste preferences and cultural influences on consumption. Br Food J 103:348-357.

Yao E, Lim J, Tamaki K, Ishii R, Kim K-O, O'Mahony M. 2003. Structured and unstructured 9-point hedonic scales: a cross cultural study with American, Japanese and Korean consumers. J Sens Stud 18:115-139.

Yeh LL, Kim KO, Chompreeda P, Rimkeeree H, Yau NJN, Lundahl DS. 1998. Comparison in use of the 9-point hedonic scale between Americans, Chinese, Koreans, and Thai. Food Qual Pref 9.6:413-419.

TABLES

Table 1. Sensory attributes for soymilks

Terms	*Definition*	*References*
Overall Aroma Intensity	The overall orthonasal impact of the sample	
Vanilla /vanillin[1]	Aromatics associated with vanilla extract and artificial vanilla	Pure vanilla extract diluted to a ratio of 1:8 with spring water, 4-Hydroxy-3-methoxybenzaldehyde
Diacetyl	Aromatics associated with diacetyl, characteristically buttery	Diacetyl, 20ppm on filter paper in a sniff jar
Beany	Aromatic characteristic of raw and cooked bean & bean products	Arrowhead Mills soy beans, Kroger butter beans
Sweet Aromatic	Aromatics of sweet solutions or very sweet foods that are not vanilla/vanillin	Sweetened condensed milk, γ-octa or nonalactone, shredded coconut
Fruity	Aromatics associated with different fruits	Propyl hexanoate and related esters/pyrazines, fresh pineapple, Welch's white grape pear juice
Cereal/Oatmeal	Sweet aromatic reminiscent of cooked oatmeal, flour paste and grains	Cooked plain oatmeal
Fatty/Oxidized	Aromatic commonly associated with oxidized fats and oils	2,4 decadienal, 20 ppm on filter paper in sniff jar, canola oil aged 14 days at 60°C
Green/Grassy[1]	Aromatics associated with fresh cut grass	Hexanal, fresh cut grass
Meaty/brothy	Aromatics associated with canned chicken or beef	Canned chicken, canned Vienna Sausages
Hay	Aromatics associated with dried grass or hay	Kaytee natural Timothy hay, Dried grass (*Pennisetum clandistenum*)
Fermented	Sour aromatics of fermented foods	Belgian ale, yogurt
Carrots	Aroma of carrots	Fresh cut carrots, canned carrots
Vitamin	Flavor of vitamin-rich foods	Crushed unflavored multivitamin tablet
Potato[1]	Flavor and aftertaste of boiled potato	20 ppm methional, unpeeled white potato cubes boiled until soft, dehydrated instant potato flakes
Molasses	Dark top notes that are characteristic of molasses	Grandma's brand molasses
Malty/nutty[1]	Sweet fermented aromatic associated with dried sprouted grains, aromatic associated with roasted nuts and coffee beans	Methylbutanal, 20 ppm on filter paper in a sniff jar, Grape Nuts cereal, 20g in 500 ml water, dihydromethylcyclopentapyrazine, roasted pecans or cashews
Sweet[1]	Fundamental taste sensation elicited by sugars	2% Sucrose solution = 2
Salty[1]	Fundamental taste sensation elicited by salts	0.35% NaCl solution = 2
Umami	Fundamental taste sensation elicited by monosodium glutamate (msg)	0.5% Monosodium glutamate solution = 3
Bitter[1]	Fundamental taste sensation elicited by caffeine, quinine	0.05% Caffeine solution = 2
Astringent[1]	Drying/puckering sensation of any of the mouth surfaces	Strong black tea, 0.05% alum solution=5
Viscosity	Amount of force required to slurp 1 tsp liquid from a spoon over the lips	Fat free milk vs. whole milk vs. cream Water=1, heavy cream=3, sweetened condensed milk=12
Opacity	Visual term denoting the degree of opacity	Water=0, Whole fat fluid milk=12

[1]Terms were adapted from Day N Kouka and others (2004).

Table 2. Means of soymilk attributes

Sample	Overall Aroma	Sweet Aromatic	Vanilla/ Vanillin	Diacetyl	Beany	Cereal/ Oatmeal	Fruity	Green/ Grassy	Meaty/ Brothy	Sweet	Bitter	Astringent	Viscosity	Opacity
Refrigerated, sweetened														
561	3.4	ND	2.8	1.6	1.9	ND	ND	ND	ND	2.8	ND	1.8	2.0	13.2
017	2.5	1.9	1.0	ND	2.2	2.3	ND	0.8	ND	2.4	ND	2.6	1.9	13.3
955	3.8	2.4	1.9	ND	1.7	1.3	ND	ND	ND	2.9	ND	2.1	1.8	12.7
142	3.0	2.1	1.3	ND	1.6	1.9	1.6	ND	ND	3.2	ND	2.8	1.9	13.8
426	2.9	1.9	0.9	ND	2.5	2.7	0.8	ND	ND	3.3	ND	2.5	2.5	14.4
689	2.9	2.2	1.4	ND	1.5	2.0	ND	ND	ND	2.9	ND	1.9	2.0	13.5
716	3.8	1.4	1.1	ND	3.8	1.7	ND	1.0	1.5	6.8	ND	3.2	1.7	13.3
323	3.3	3.0	1.3	ND	1.0	1.5	ND	ND	ND	3.2	ND	2.7	1.5	12.6
808	2.2	1.6	1.1	ND	2.1	2.1	ND	ND	ND	2.7	ND	2.3	1.8	12.9
Light, refrigerated sweetened														
130	2.8	2.3	1.2	ND	1.7	2.3	1.4	ND	ND	2.8	ND	2.8	1.8	9.5
084	3.2	ND	1.9	1.6	2.0	ND	ND	ND	ND	2.6	ND	2.1	1.8	10.5
Refrigerated, unsweetened														
459	2.5	1.2	0.9	ND	2.5	2.3	ND	ND	ND	1.0	0.6	3.3	2.3	14.7
309	3.6	1.1	ND	ND	3.7	1.8	ND	0.7	1.0	1.0	0.6	3.2	1.6	14.5
280	2.1	1.4	0.7	ND	1.8	2.7	ND	ND	ND	1.3	ND	2.5	1.7	14.4
Shelf stable, sweetened														
351	3.7	1.1	0.8	ND	3.0	2.3	ND	ND	1.6	6.0	0.7	2.3	1.7	12.7
603	3.6	ND	ND	ND	3.4	1.5	ND	ND	3.2	4.7	0.7	3.2	1.6	13.3
832	3.2	1.3	0.5	ND	2.7	2.2	ND	0.7	1.8	3.0	0.7	3.3	2.2	14.6
764	3.0	0.6	ND	ND	3.0	2.8	ND	ND	1.9	2.1	ND	2.9	1.9	14.7
108	3.2	1.3	1.3	ND	2.5	1.7	ND	ND	1.9	2.6	0.6	2.1	1.7	14.3
296	2.8	0.5	1.3	ND	2.0	1.9	2.1	ND	ND	3.3	ND	2.1	1.9	13.8
924	2.9	1.9	0.9	ND	1.9	1.8	1.9	ND	0.9	2.9	ND	2.4	1.8	13.7
585	2.3	2.1	2.3	ND	1.1	1.4	ND	ND	ND	4.5	ND	2.2	1.8	13.9
059	2.1	1.1	ND	ND	2.0	1.5	ND	0.9	ND	2.8	ND	2.3	1.7	14.2
Shelf stable, unsweetened														
748	3.0	0.7	ND	ND	3.0	2.4	0.8	0.7	1.5	1.2	1.3	3.5	1.6	14.6
277	2.6	1.3	1.3	1.0	2.0	1.9	ND	ND	ND	1.5	ND	2.6	1.8	14.3
431	2.5	1.9	1.2	ND	1.6	2.0	2.1	ND	ND	1.0	0.6	2.8	1.7	13.9
LSD	0.21	0.23	0.22	0.10	0.21	0.22	0.14	0.11	0.18	0.18	0.12	0.17	0.07	0.44

LSD – least significant difference, means within a column that differ by LSD are different ($P < 0.05$).
ND= Not Detected
Flavor attributes were scored using a 0 to 15 point universal intensity scale (Drake and Civille, 2003; Meilgaard and others 2007).
Viscosity and Opacity were scored using a 0 to 15 point product specific scale.

Table 3. Color and whiteness measurement of soymilks

Soymilk	L*	a*	b*	Whiteness
561	77.08	-1.26	17.58	24.34
017	77.70	-0.33	13.73	36.51
955	78.81	-0.61	17.26	27.03
142	76.64	0.20	14.98	31.70
426	76.86	-1.53	16.82	26.40
689	75.71	1.71	13.93	33.92
716	74.73	-0.64	12.44	37.41
323	75.45	0.49	14.05	33.30
808	74.53	-1.26	15.69	27.46
130	69.65	2.32	15.28	23.81
084	70.36	-0.15	19.50	11.86
459	78.17	0.00	14.44	34.85
309	77.58	-0.80	12.04	41.46
280	76.07	-0.45	14.61	32.24
351	74.35	0.55	13.73	33.16
603	74.7	0.39	13.31	34.77
832	75.25	-0.17	15.46	28.87
764	67.14	1.45	13.84	25.62
108	74.66	1.31	16.35	25.61
296	71.37	0.24	18.35	16.32
924	74.45	-0.90	16.32	25.49
585	74.77	-0.64	18.47	19.36
59	76.49	-0.79	16.65	26.54
748	73.55	1.44	12.39	36.38
277	76.42	0.45	15.29	30.55
431	73.29	-0.28	16.70	23.19
LSD	0.118	0.053	0.054	0.277

L* measures lightness, L*=0 indicates darkest black, L*=100 indicates brightest white
a*measures green/red, negative values indicate green color, positive values indicate red color, a*=0 indicates neutral gray
b* measures blue/yellow, negative values indicate blue color, positive values indicate yellow color, a*=o indicates neutral gray
Whiteness (L*-3b*) is on a 0-100 scale, where 100 indicates the whitest white
LSD – least significant difference, means within a column that differ by LSD are different (*P* < 0.05)

Table 4. Mean soymilk liking scores across all consumers (n=235)

Soymilk Code		084	130	309	426	459	561	585	603	748
Aroma Liking		5.9cde	5.6ef	4.9hi	5.7de	5.7def	6.1bc	6.0cd	5.1gh	5.4fg
Overall Appearance Liking		5.7g	5.7g	6.3cde	6.4bcd	6.3bcde	6.0f	6.6ab	6.1ef	6.5bc
Color Liking		5.5g	5.7f	6.4bcd	6.3bcde	6.4bc	5.7f	6.3bcd	6.1de	6.5ab
Color JAR	Too Light	3.8%b	9.4%ab	9.4%ab	4.3%b	2.6%b	2.6%b	5.5%b	6.0%b	19.1%a
	Just About Right	50.2%d	58.3%bcd	78.7%a	70.6%abc	77.4%a	57.4%cd	74.5%ab	72.8%abc	72.3%abc
	Too Dark	46.0%a	32.3%abc	11.9%de	25.1%bcd	20.0%cde	40.0%ab	20.0%cde	21.3%cd	8.5%e
Overall Liking		6.3bc	5.7d	2.7j	5.2e	3.4i	6.6ab	6.8a	4.8f	3.8h
Flavor Liking		6.3bc	5.7d	2.7j	5.2e	3.5i	6.6ab	6.9a	4.8f	3.9h
Sweetness Liking		6.3abc	5.9cde	2.9i	5.7e	3.5h	6.6a	6.5a	5.0f	3.7h
Thickness Liking		6.5bc	5.9ef	5.2h	6.2cde	5.5gh	6.6b	7.0a	6.0def	5.5gh
Flavor JAR	Not Enough Flavor	21.3%b	31.5%b	60.0%a	24.3%b	60.4%a	17.4%bc	6.8%c	22.1%b	59.1%a
	Just About Right	63.4%ab	51.1%bc	17.0%e	46.4%bc	21.7%e	72.8%a	74.5%a	42.6%cd	26.4%de
	Too Much Flavor	15.3%bc	17.4%bc	23.0%abc	29.4%ab	17.9%bc	9.8%c	18.7%bc	35.3%a	14.5%c
Sweet Taste JAR	Not Sweet Enough	21.7%b	31.5%b	87.7%a	26.0%b	81.7%a	16.6%b	5.1%c	22.1%b	78.3%a
	Just About Right	63.0%ab	59.1%ab	11.5%c	60.4%ab	17.4%c	69.8%a	62.1%ab	49.4%b	21.7%c
	Too Sweet	15.3%bc	9.4%c	0.9%d	13.6%c	0.9%d	13.6%c	32.8%a	28.5%ab	0.0%d
Thickness JAR	Not Thick Enough	15.7%bc	31.5%a	34.5%a	7.7%c	16.2%bc	10.6%bc	9.8%bc	21.3%ab	36.2%a
	Just About Right	76.6%abc	65.1%c	62.6%c	73.2%abc	70.2%bc	81.3%ab	86.0%a	74.9%abc	63.0%c
	Too Thick	7.7%abc	3.4%c	3.0%c	19.1%a	13.6%ab	8.1%abc	4.3%bc	3.8%bc	0.9%c
Aftertaste Liking		5.8bc	5.5cd	3.3h	4.9ef	3.9g	6.0ab	6.1a	4.6f	4.2g

*Data represents n=235 consumers
*Different letters in a row indicate significant differences (p<0.05)
*Aroma Liking, Overall Appearance Liking, Color Liking, Overall liking, Flavor Liking, Sweetness Liking, Thickness Liking and Aftertaste Liking were scored on a 9 pt scale where 1 = dislike extremely and 9 = like extremely
*Purchase intent was scored on a 5 pt scale where 5 = definitely would buy it; 3 = might or might not buy it; and 1 = definitely would not buy it
*All JAR questions were rated using 5 pt scales where 1 = much too little, 3 = just right, and 5 = much too much.
* For all JAR questions the percentage of consumers that selected these options is presented

Table 5. Soymilk Flavor Preferences and Usage of Clusters

Question	Response	C1	C2	C3
Of the plant based milks that you consume, which do you consume THE MOST?	Soymilk	86.3%ab	76.1%b	90.5%a
	Almond milk	8.2%ab	19.3%a	6.8%b
	Coconut milk	0.0%a	3.4%a	2.7%a
	Plant milk blend	1.4%a	0.0%a	0.0%a
	Rice milk	1.4%a	1.2%a	0.0%a
	Flax milk	0.0%a	0.0%a	0.0%a
	Other	2.7%a	0.0%a	0.0%a
How often do you drink soymilk?	Every day	21.9%a	21.6%a	23.0%a
	A few times a week	56.2%a	59.1%a	60.8%a
	Once a week	21.9%a	19.3%a	16.2%a
	Once a month	0.0%a	0.0%a	0.0%a
	Once every few months or less	0.0%a	0.0%a	0.0%a
How do you most often consume soymilk?	Over cereal	28.8%a	22.7%a	32.4%a
	In a glass	60.4%a	51.1%a	47.3%a
	In a smoothie	9.6%b	25.0%a	16.2%ab
	In a recipe	0.0%a	1.2%a	1.4%a
	Other	1.4%a	0.0%a	2.7%a
When you purchase soymilk, do you usually purchase shelf stable or refrigerated soymilk?	Shelf Stable	12.3%a	19.3%a	8.1%a
	Refrigerated	87.7%a	80.7%a	91.9%a
When you purchase soymilk, do you usually purchase sweetened or unsweetened?	Sweetened	52.1%a	47.7%a	60.8%a
	Unsweetened	47.9%a	52.3%a	39.2%a
Which flavors of soymilk do you consume? (CHECK ALL THAT APPLY)	Original (plain)	100.0%a	100.0%a	100.0%a
	Vanilla	61.6%b	81.8%a	73.0%ab
	Chocolate	35.6%b	60.2%a	51.4%ab
	Other	6.8%a	6.8%a	6.8%a
Which is your preferred flavor of sweetened soymilk?	Original (plain)	44.7%a	19.0%b	26.7%ab
	Vanilla	44.7%a	57.2%a	51.1%a
	Chocolate	10.6%a	23.8%a	22.2%a
	Other	0.0%a	0.0%a	0.0%a
Which is your preferred flavor of unsweetened soymilk?	Original (Plain)	85.7%a	54.3%b	75.9%ab
	Vanilla	14.3%b	45.7%a	24.1%ab

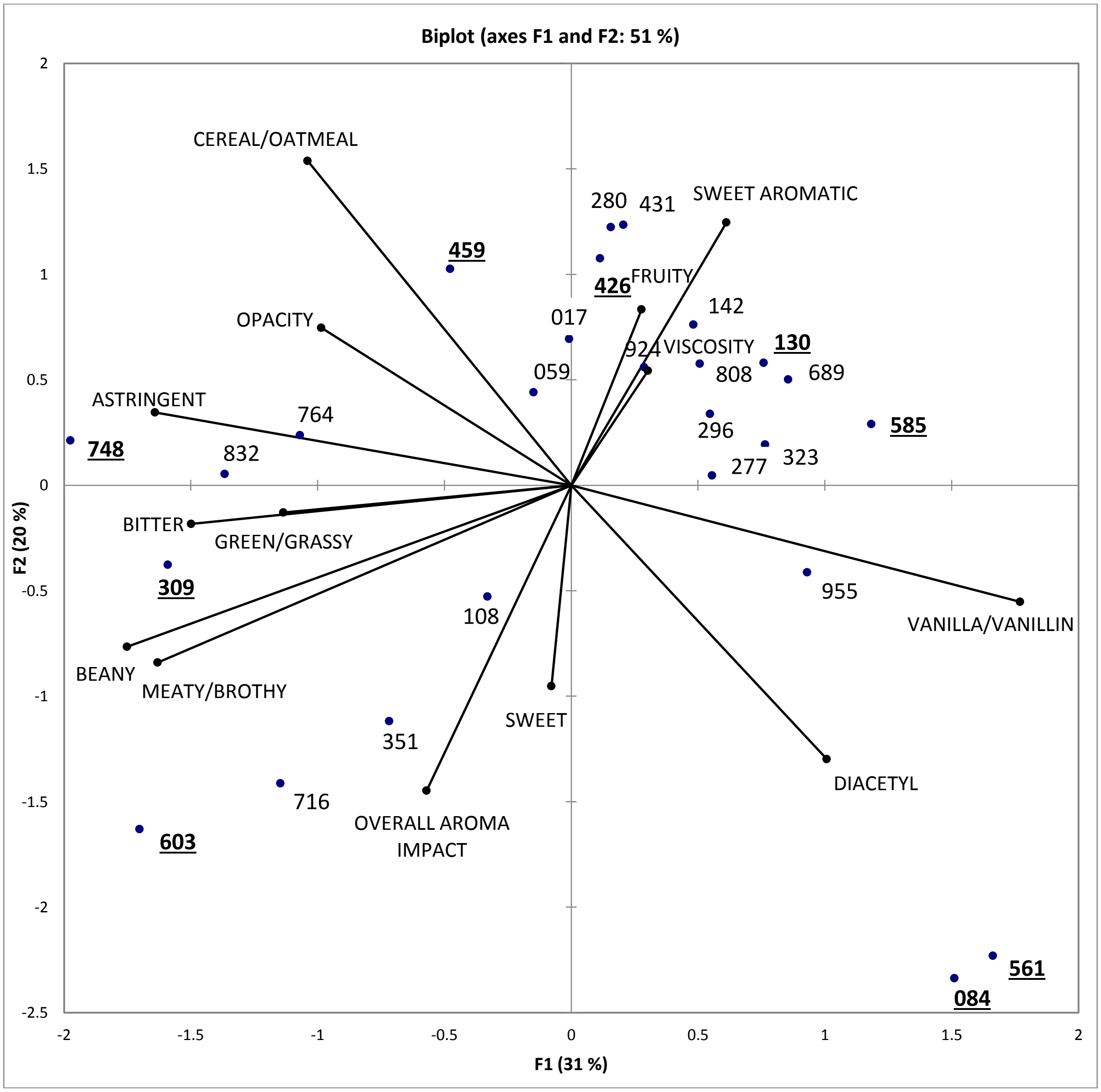
Numbers in columns represent the percentage of consumers in each cluster that chose that option
Check all that apply questions may equal more than 100%
Highlighted rows are to point out differences
Letters in a row that are different signify significant differences ($p<0.05$)

Table 6. Overall liking means for each cluster

Sample	C1	C2	C3
084	5.4c	6.3b	7.0a
130	4.9c	5.5b	6.5a
309	4.1a	1.6c	2.6b
426	5.1b	4.1c	6.6a
459	4.0a	2.6b	3.9a
561	5.8c	6.6b	7.2a
585	6.2b	6.5b	7.7a
603	3.6b	3.5b	5.9a
748	4.3a	3.0b	4.0a

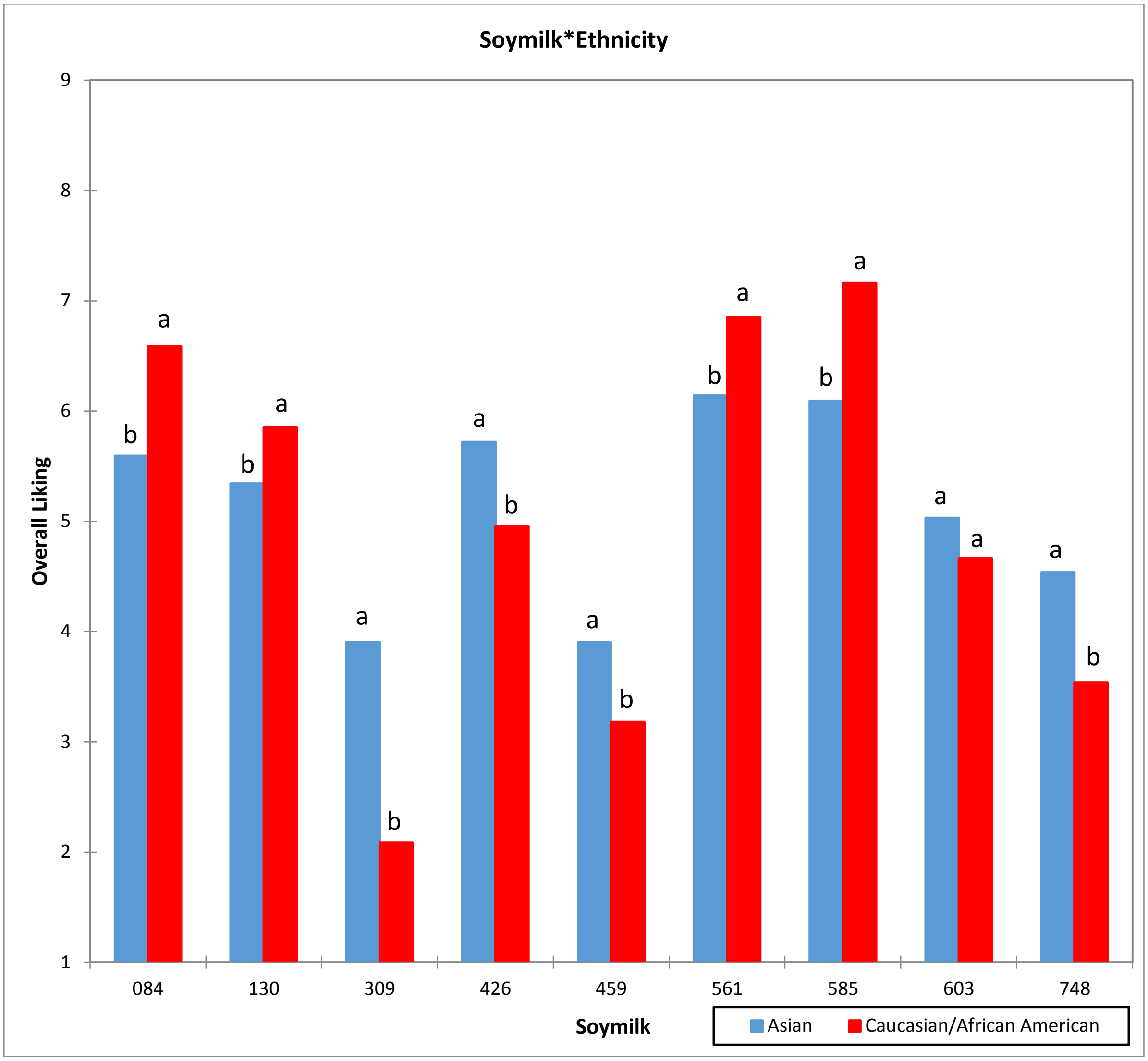
Overall liking was scored on a 9-point hedonic scale where 1=dislike extremely and 9= like extremely
Means in a row with different letters are statistically different ($p<0.05$)

FIGURES



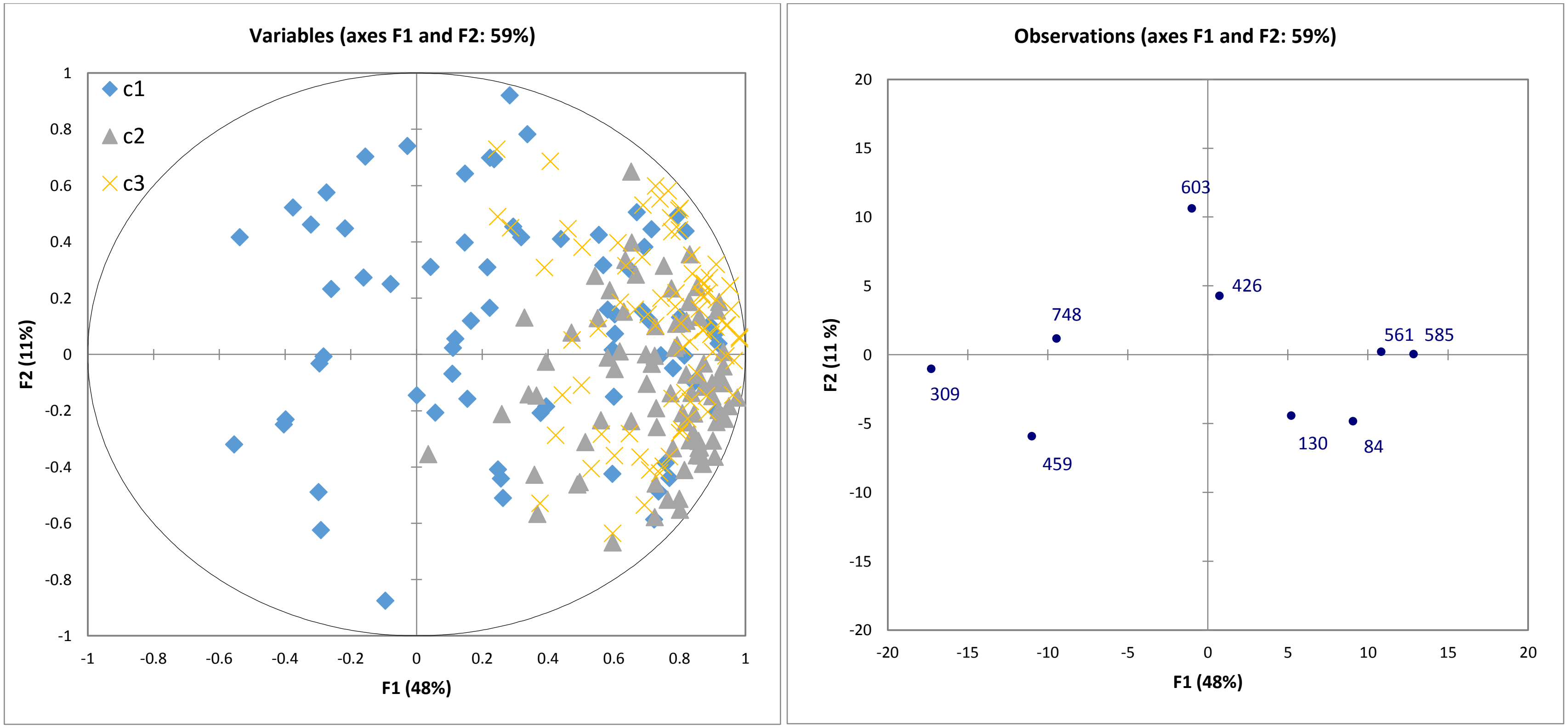
Samples that were used in the consumer acceptance test are underlined and bolded.

Figure 1. Principal component (PC) analysis biplot of trained panel sensory attributes of soymilks



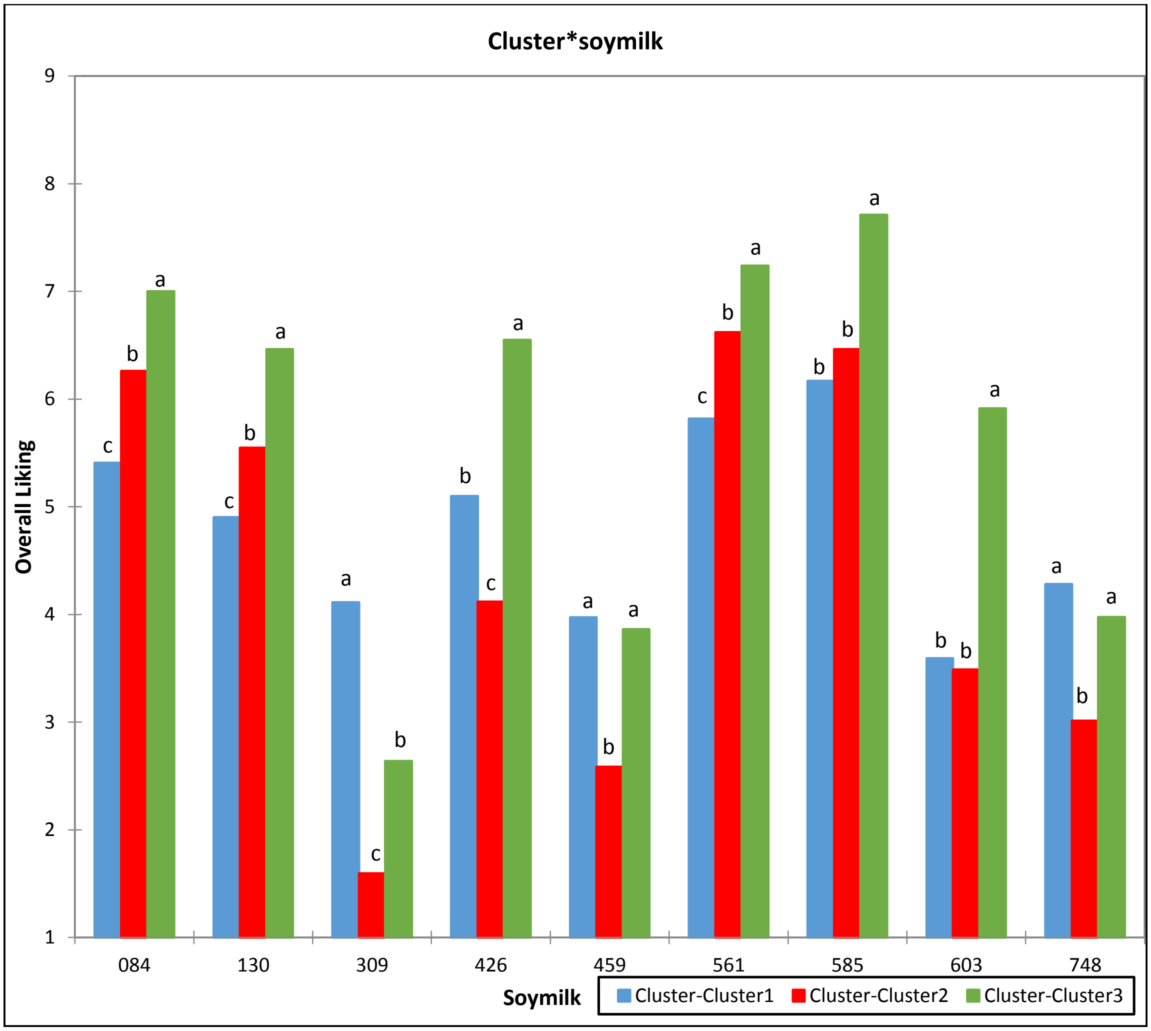
Means not sharing a common superscript are different ($P < 0.05$)
Statistical lettering applied between demographics for each soymilk

Figure 2. Mean soymilk liking scores across all consumers sorted by ethnicity



C1= Cluster 1; C2= Cluster 2; C3=Cluster 3

Figure 3. Internal preference mapping of soymilks



Means not sharing a common superscript are different (*P* < 0.05)
Statistical lettering applied between clusters for each soymilk, lettering does not apply within clusters.

Figure 4. Mean soymilk liking scores by consumer clusters

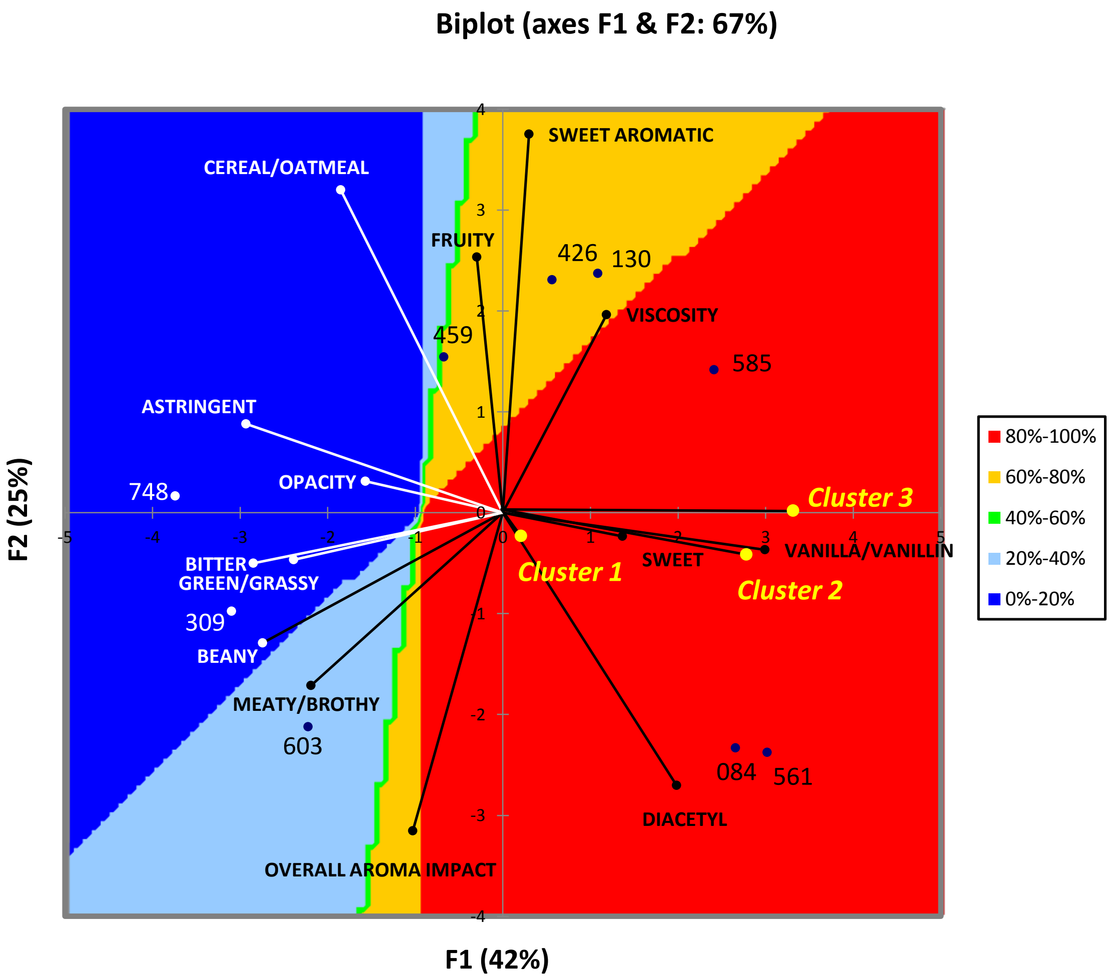


Figure 5. External preference map of all clusters, differences in shading indicate the percent probability that a product or attribute is liked

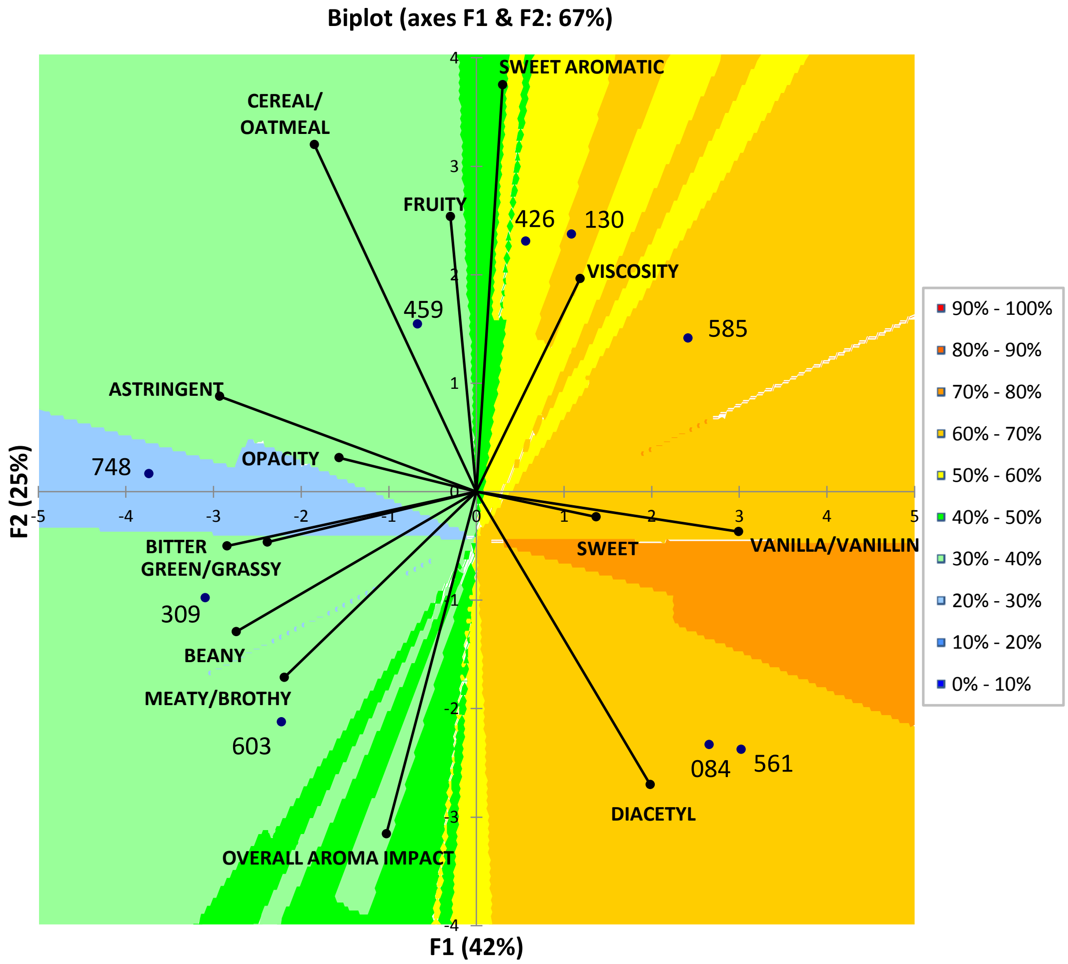


Figure 6. External preference map of Cluster 1, differences in shading indicate the percent probability that a product or attribute is liked

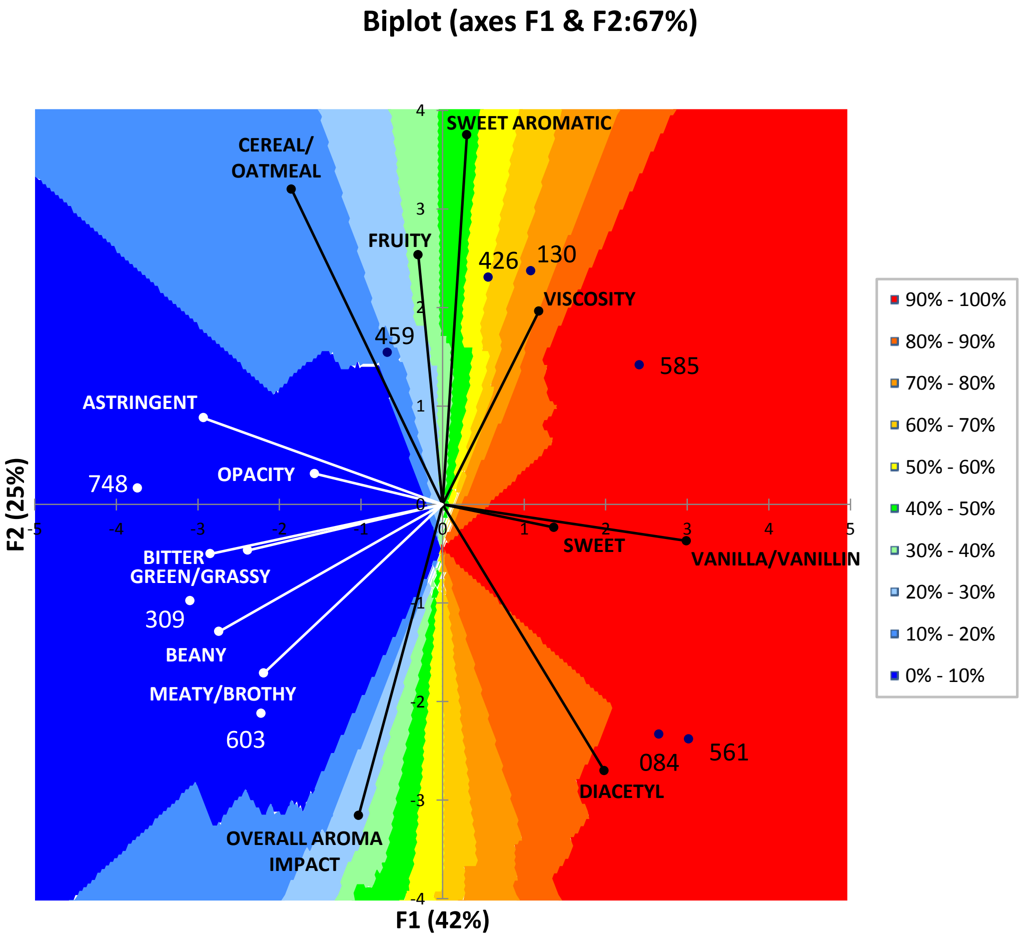


Figure 7. External preference map of Cluster 2, differences in shading indicate the percent probability that a product or attribute is liked

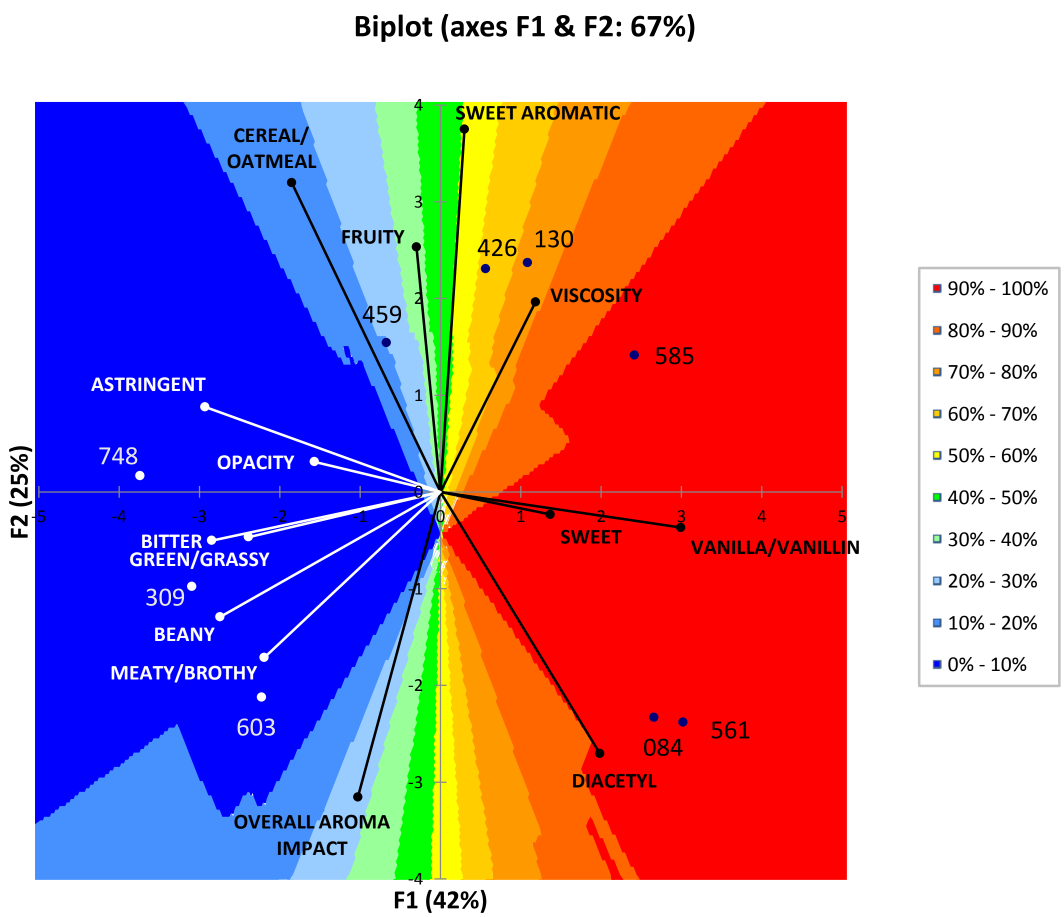


Figure 8. External preference map of Cluster 3, differences in shading indicate the percent probability that a product or attribute is liked

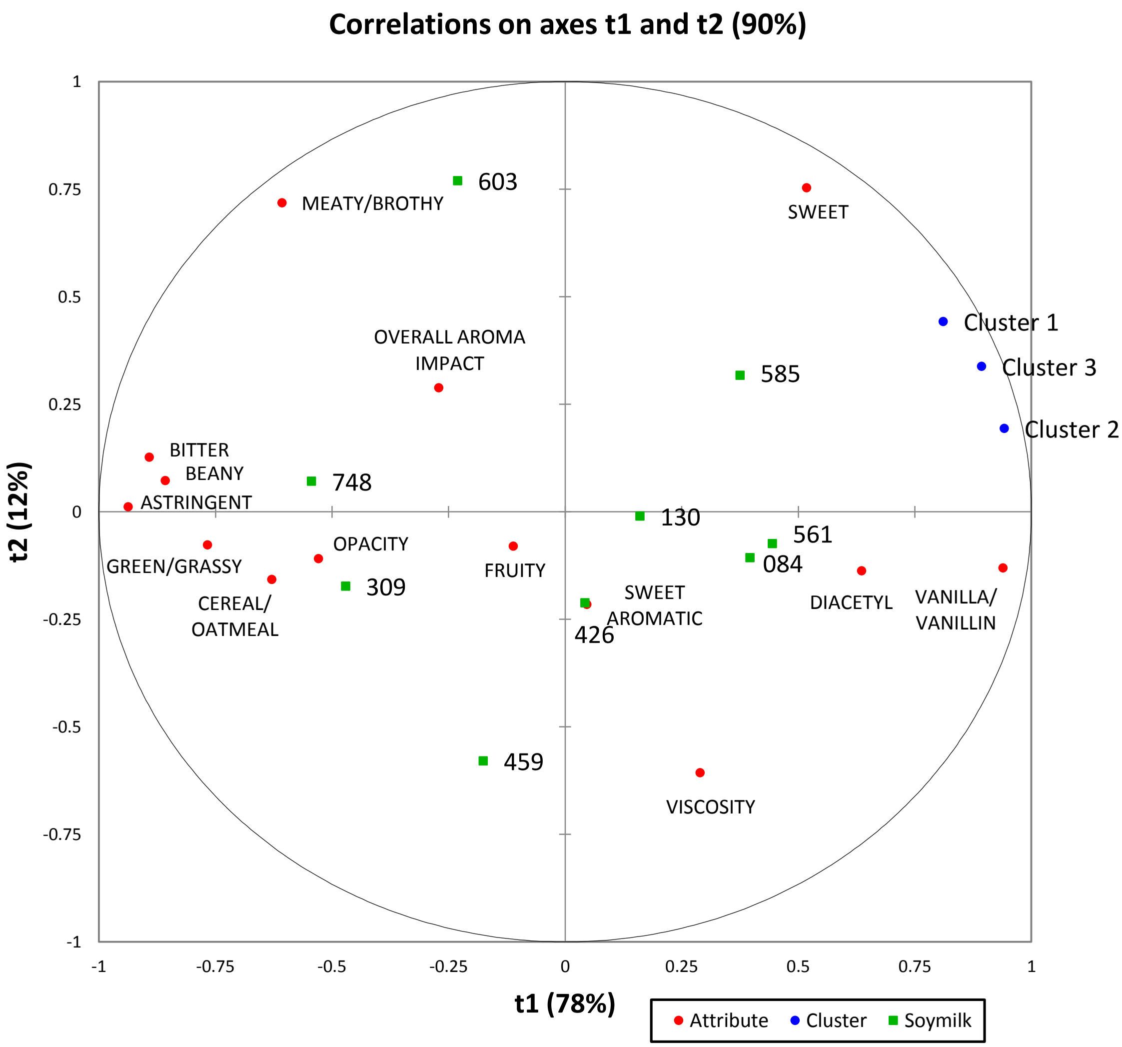


Figure 9. Partial least squares regression biplot of soymilks by cluster

APPENDICES

Appendix A

Additional Tables of Chapter 2

Table 1. Internal Preference Mapping Comment Tallies on Likes and Dislikes

Soymilk	Most Liked Attribute	% Responses	Least Liked Attribute	% Responses
084	Flavor	49.4	Flavor	25.5
	Viscosity	33.2	Color	23.4
	Sweetness	25.1	Sweetness	21.3
130	Flavor	43.4	Flavor	34.0
	Viscosity	31.5	Viscosity	26.0
	Sweetness	22.1	Sweetness	18.7
309	Color	34.9	Flavor	62.1
	Aroma	27.7	Sweetness	29.8
	"Nothing"	24.7	Aftertaste	17.4
426	Viscosity	35.7	Flavor	43.4
	Flavor	27.7	Sweetness	21.3
	Sweetness	25.1	"Nothing"	16.7
459	Viscosity	36.2	Flavor	63.4
	Color	34.5	Sweetness	27.2
	"Nothing"	15.7	Aftertaste	15.3
561	Flavor	55.7	"Nothing"	23.4
	Sweetness	31.1	Color	20.2
	Viscosity	25.1	Sweetness	18.3
585	Flavor	52.3	"Nothing"	31.5
	Viscosity	34.5	Sweetness	28.5
	Sweetness	30.2	Flavor	12.8
603	Viscosity	34.5	Flavor	46.8
	Flavor	28.5	Sweetness	29.8
	Color	26.8	Aftertaste	17.9
748	Color	33.6	Flavor	51.5
	Viscosity	33.6	Sweetness	34.9
	Flavor	24.3	Viscosity	18.3

% Responses indicates the percentage of consumers that specified that attribute as something they liked or disliked for the selected soymilk