SENSORY CHARACTERISTICS AND CLASSIFICATION OF COMMERCIAL AND EXPERIMENTAL PLAIN YOGURTS

by

MARISSA BROWN

B.S., University of Delaware, 2008

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Food Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2010

Approved by:

Major Professor
Dr. Delores Chambers
Department of Human Nutrition

Abstract

This research aimed to determine the sensory characteristics of commercially-available plain yogurts and examine how three "more sustainable" prototypes compared. Three experimental non-fat set-style yogurts were provided – one control and two samples that differed in fermentation time. These shortened fermentation times could result in energy reductions and potentially substantiate a “sustainable” marketing claim, a concept gaining traction with consumers. Twenty-six commercially-available yogurts varying in percent milk fat, milk type (organic or conventional), and processing (set-style, stirred, or strained/Greek-style) were also included. Using descriptive sensory analysis, a six-person highly-trained panel scored the intensity of 25 flavor, six texture, four mouthfeel, and two mouthcoating attributes on a 15-point numerical scale. Three replications were conducted, and all samples were tested at least 10 days prior to the end of their shelf-lives. The samples differed for 19 flavor and all texture, mouthfeel, and mouthcoating attributes. Cluster analysis indicated approximately seven flavor and five texture (texture, mouthfeel, and mouthcoating combined) clusters, resulting in 15 unique combinations of flavor and texture. Although no legal definitions exist for “sustainable,” the prototypes’ sensory characteristics were comparable to those of top-selling yogurts indicating potential market viability. This research also demonstrated potential growth opportunities. Despite the current diversity, several combinations of flavor and texture were not represented.

Table of Contents

List of Figures

List of Tables

Acknowledgements

First things first:

This material is based upon research supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2008-38420-18754. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

And on a personal note:

I would like to first thank the students and faculty of the Food Industry Management Enhancement Program (FIMEP) – Tori, Carly, Amber, Dr. D, Dr. V, and Dr. Schmidt.

Tori, Carly, and Amber, as I said before in my personal narrative of the experience, you all were not only my fellow collaborators, you were my friends. Thank you so much for both your companionship and inspiration. I truly do not know how I would have fared in graduate school or this collaborative venture without you all. Working with you all pushed my boundaries personally and professionally, and I am such a better person because of it.

Dr. D, Dr. V, and Dr. Schmidt – thank you for your guidance, patience, and encouragement throughout the past two years, and thank you for taking a chance on this program and on me as a part of it. Despite its inherent challenges, I appreciate absolutely everything that came out of it. I know the skills and knowledge I gained in FIMEP will continue to prove themselves invaluable as I begin my career.

To the staff and students at the Sensory Analysis Center – thank you for your gracious assistance with the execution of this project. Whether it was labeling cups, preparing references, or serving samples when I was in with the panel, every little bit helped (and made such a hectic time in my life seem just a little less hectic)!

To the panel – you all are amazing. Thank you for maintaining such positive attitudes and enthusiasm while tasting so many, um, “extreme” samples. Your passion for your work made it a pleasure working with and learning so much from all of you.

To Dr. Chambers and Dr. K – thank you for your help along the way and for taking the time to answer my myriad of questions. You two contributed just as much to my success here at Kansas State as anybody else.

Finally, to my family, friends, ΣAI sisters, and band section-mates – thank you for continuously supporting me over the past two years, keeping me sane, and getting my mind off sensory science and statistics every once in a while.

.

CHAPTER 1 - Review of Literature

Life is half delicious yogurt, half crap, and your job is to keep the plastic spoon in the yogurt – Scott Adams, author

Origins and history

Yogurt is a vast food category with a long and rich history. Like other fermented foods, such as wine and cheese, yogurt was probably discovered by complete accident, and its exact origins are unknown. However, its early history is likely interwoven with the general history of agriculture (Kosikowski and Mistry 1997). Neolithic humans shifted "from food gathers to food producers" around 15,000-10,000 BC, began domesticating animals, and started to practice milking (Tamime and Robinson 1999). Herdsmen would milk their cows, sheep, or goats, and either consume it themselves while they were away from villages or transport it from their pastures to more populated areas in order to sell it. In the instances where the milk required transportation, they would use natural bags or containers such as animal's stomachs or emptied gourds (Tribby 2009).

Unbeknownst to the herdsmen, these bags provided ideal conditions for producing yogurt. Raw milk contains its own inherent cultures, and contamination by air, from the animal, animals' feed, herdsmen's hands, or the bag itself could have introduced additional bacteria (Tamime and Robinson 1999). The environment inside the bag paired with the warm climate outside the bag resulted in a coagulated dairy product uniquely different from milk (Tannahill 1988). Because of its flavor and texture, it could be utilized in dishes differently than milk, and because it was fermented, it could be stored for longer periods of time, an important characteristic in early societies (Chandan 2006). Milk during these times would sour and coagulate not too long after milking, but yogurt and cultured milk products were convenient, versatile, and long-lasting.

Despite its generally-accepted overall origin, yogurt's exact geographical origin is often a point of contention (Rašić and Kurmann 1978). Most sources indicate that it came from the Middle East and Central Asia (Tamime and Robinson 1999). Archeological evidence "associated with the Sumerians and Babylonians of Mesopotamia, the Pharoes of northeast Africa, and Indo-Aryans of the Indian subcontinent" supports this conclusion (Chandan 2006). Although civilizations around the world eventually developed their own unique fermented milk products (Table 1.1), it appears that the cultures living in Western Asia were the first to refine the process (Davidson 1999).

Table 1.1 Yogurt and fermented yogurt-like products throughout the world

Traditional name	Country
Busa	Turkestan
Chal	Turkmenistan
Cieddu	Italy
Dahi, dadhi, dudhee, dahee	Indian subcontinent
Donskaya, varenetes, kurugna, ryzhenka, guslyanka	Russia
Ergo	Ethiopia
Filmjolk, fillbunke, filbunk, surmelk, taettemjolk, tettemelk	Sweden, Norway
Gioddu	Sardinia
Gruzovina	Yugoslavia
Iogurte	Brazil, Portugal
Jugurt, eyran, ayran	Turkey
Katyk	Transcaucasia
Kissel mleka, naja, yaourt	Balkans
Kurunga	Western Asia
Leban, laban, laban rayeb	Lebanon, Syria, Jordan
Mast, dough, doogh	Iran and Afghanistan
Mazun, matzoon, matsun, matsoni, madzoon	Armenia
Mezzoradu	Sicily
Pitkapiima, viili	Finland
Roba, rob	Iraq
Shosim, sho, thara	Nepal
Shrikhand	India
Skyr	Iceland
Tarag	Mongolia
Tarho, taho	Hungary
Urgotnic	Balkan mountains
Yakult	Japan
Yiaourti	Greece
Ymer	Denmark
Yoghurt, yogurt, yaort, yourt, yaourti, yahourth, yogur, yaghourt	Rest of the world
Zabady, zabade	Egypt, Sudan

Sources: Tamime and Deeth 1980, Accolas *et al.* 1978, Kosikowski and Mistry 1997, Tamime and Robinson 1999, Chandan 2006

As transportation and trade became more sophisticated, this food, once exclusive to Turkey, the Balkans, and Western Asia, spread throughout Europe and later grew in popularity. In *History of Food*, author Toussaint-Samat (1992) tells the story of yogurt's entry into France in 1542. Francis I, the king at the time, fell ill, and only after he ate yogurt provided by a Turkish doctor did he seem to get better. About a century later in 1625, English travel writer Samuel Purchas mentioned Turkish yogurt in his book *Pilgrimes* (Ayto 2002). Finally, scientist Ilya Metchnikov truly brought interest in yogurt to the European masses (Rašić and Kurmann 1978). Metchnikov worked with fellow scientist Louis Pasteur at the Pasteur Institute in Paris in the early 1900s, studying microbiology and immunology. In his 1907 book *The Prolongation of Life: Optimistic*

Studies, he noted that Bulgarians seemed to live remarkably longer lives, and unlike other Europeans, they ate large quantities of yogurt and other fermented milk products. He received the Nobel Prize in Medicine in 1908, and because of his research's publicity, yogurt's popularity increased across the continent (Tribby 2009).

The next two decades saw sweeping advancement in yogurt manufacturing. Two major yogurt companies were established: Danone in 1919 and Colombo and Sons Creamery in 1929 (Dannon 2010, General Mills 2010). Isaac Carasso, a Spanish immigrant from the Balkans, founded Danone. The company drew upon the recent discoveries concerning yogurt (including Metchnikov's work) and, in their own words, "perfected the first industrial manufacturing process by combining the traditional method of making yogurt with the pure cultures that had been isolated in Paris" (Dannon 2010). Ten years later, Carasso's son Daniel, for whom the company was named, established Danone in France, and Armenian immigrants Sarkis Colombosian and Rose Krikorian formed Colombo and Sons Creamery in Andover, Massachusetts, United States. Daniel Carasso later came to the United States during World War II and set up Dannon Milk Products, Inc., the American incarnation of Danone.

Until this point, yogurt consumption in the United States was still relatively limited to immigrants and those who were exposed to it from family, friends, neighbors, or travel. However, similar to how Metchnikov's book created positive publicity in Europe, another scientific book featuring yogurt thrust it into the American spotlight. Dr. Benjamin Gayelord Hauser published a book entitled *Look Younger, Live Longer* that celebrated whole foods and natural eating, including the benefits of yogurt. An excerpt of the book was included in the October 1950 issue of Reader's Digest, and this release, coupled with Dannon's new fruit-on-the-bottom variety of yogurt, created a surge in yogurt sales during the mid-20th century (Mariani 1999; Dannon 2010). Yogurt maintained its image as a health food for several decades and continued to grow in popularity in the late 20th century as consumer awareness of its health benefits increased. After much technological advancement, it was eventually established as a common American household food item by the close of the century.

Legal standards and regulations

As yogurt became increasingly sophisticated with time, regulations needed to be put in place to govern what can be put into it and how it must be treated. Domestic and international government agencies have placed legal definitions and standards on yogurt, and non-government organizations have set forth optional guidelines to further differentiate products in the market.

Domestic and international standards

The U.S. Code of Federal Regulation defines yogurt as:

> The food produced by culturing one or more of the optional dairy ingredients… with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (CFR 2009)

Prior to adding the starter cultures, yogurt may be homogenized, and it must be pasteurized or ultra-pasteurized. These pasteurization options serve the same purpose; they differ simply in the temperature and length of time of treatment. As mentioned in the definition, optional dairy ingredients that may be used are “cream, milk, partially skimmed milk, or skim milk, used alone or in combination” (CFR 2009). Other optional ingredients that may be used include:

> Concentrated skim milk, nonfat dry milk, buttermilk, whey, lactose, lactalbumins, lactoglobulins, or whey modified by partial or complete removal of lactose and/or minerals, to increase the nonfat solids content of the food concentrated (CFR 2009).

A variety of sweeteners, such as sucrose, high-fructose corn syrup, and honey may also be used. In addition to the ingredients allowed in yogurt, the CFR also sets guidelines for the percentage of milk fat required in order for the yogurt to be labeled as whole milk, low-fat, or nonfat (Table 1.2). Federal regulations do not limit the upper end of whole milk yogurts, though. All yogurts, regardless of milk fat percentage, must contain at least 8.25% milk solids not-fat and have a titratable acidity of at least 0.9%. Similar rules regarding processing and ingredients also apply to both low-fat and nonfat yogurts. All food additives, such as flavors, colors, and preservatives, “generally regarded as safe" (GRAS) can also be added to yogurts. USDA specifications define that yogurt "shall possess a pleasant, clean acid flavor [and] be free from undesirable flavors such as: bitter, rancid, oxidized, stale, yeasty and unclean" (USDA 2001). They also specify that yogurts "shall possess a firm, custard-like body with a smooth, homogeneous texture" (USDA 2001).

Table 1.2 Percent milk fat regulations for yogurts

Category	Percent milk fat
Whole milk	No less than 3.25%
Low-fat	No less than 0.5%, but no more than 2.0%
Nonfat	No more than 0.5%

Source: CFR 2009

The Codex Alimentarius Commission of the Food and Agriculture Organization (FAO) and World Health Organization (WHO) set broader international standards for yogurt in the *Codex Standard for Fermented Milks* (2003). This document simply requires that yogurt be the result of a fermentation by *Streptococcus thermophilus* and *Lactobacillus delbruekii* ssp. *bulgaricus* cultures, and contain a minimum of 2.7% milk protein, less than 15% milk fat, and at least 0.6% titratable acidity. If a claim regarding live microorganisms is made on the package, the Codex specifies that at least 10^6 colony forming units (CFU) per gram must be present.

Domestic regulations

Following the passage of the Organic Foods Production Act in 1990, all foods, including yogurts, that meet the necessary standards could officially be labeled as *organic* and use the U.S. Department of Agriculture (USDA) organic seal (Figure 1.1). Multi-ingredient foods like yogurt

> [M]ust contain (by weight or fluid volume, excluding water and salt) not less than 95 percent organically produced raw or processed agricultural products. Any remaining product ingredients must be organically produced, unless not commercially available in organic form, or must be nonagricultural substances or nonorganically produced agricultural products produced consistent with the National List [7 CFR 205.605] (CFR 2010)

Organically labeled products, in addition to the regulations on ingredients, cannot be genetically engineered or undergo processing methods such as ionizing radiation treatment (USDA 2008). The USDA accredits agents, and these agents can confirm the qualifications of manufacturers interested in having their product(s) certified as “USDA organic.” This procedure includes providing a written plan (ingredients used, how the products are processed) and undergoing on-site inspections (USDA 2008). Yogurts can also be labeled *natural*; however, no legal definition exists for this term. Generally speaking, natural yogurts tend to have no added preservatives, stabilizers, or artificial colors (Chandan and O’Rell 2006), but these practices are not regulated by any government or trade organizations.

Figure 1.1 USDA's organic seal
Source: USDA 2008

Optional standards and regulations

The CFR allows additional heat treatment steps after culturing than can extend the final product’s shelf-life. However, in doing so, this process destroys the active microorganisms. Thus, the National Yogurt Association (NYA), a non-profit trade organization, established the *Live & Active Cultures* seal (Figure 1.2). Yogurt manufacturers may elect to include this seal on their products indicating that there are “at least 100 million cultures per gram at the time of manufacture” (National Yogurt Association 2010). Including this seal on product packaging is purely voluntary, so although some products may meet the necessary standards, their packaging may not necessarily carry this mark.

Figure 1.2 National Yogurt Association's Live & Active Culture seal
Source: National Yogurt Association 2010

In 2009, the United States Food and Drug Administration proposed a change in the yogurt standard of identity due “in part, to a citizen petition submitted by the National Yogurt Association” (FDA 2009). The NYA suggested that minimum requirements be set for bacterial culture levels, similar to the standards necessary for their voluntary labeling program. This issue has proponents on both sides, and no decision regarding the proposed changes has been made at this time.

Figure 1.3 Dairy Management, Inc.'s REAL® seal
Source: Dairy Management, Inc. 2010

Other optional labeling standards for yogurt include the REAL® seal established by Dairy Management, Inc. (Figure 1.3) and kosher labeling seals. The REAL® seal, like the *Live & Active Cultures* seal, is a voluntary program used to distinguish what the respective organizations deem as “quality” products; in this case, the REAL® seal distinguishes real dairy products from simulated dairy products. Products carrying the REAL® seal must be made in the United States, be at least 51% cow’s milk, and not contain specific ingredients such as casein/caseinates (Dairy Management, Inc. 2009). Like the USDA organic seal, manufacturers must undergo certification in order to use the REALA® seal. Many rabbinical organizations exist that are qualified to carry out certification based upon Jewish kosher food laws, and each of these organizations identify products that they certified using different symbols (Frye 2006).

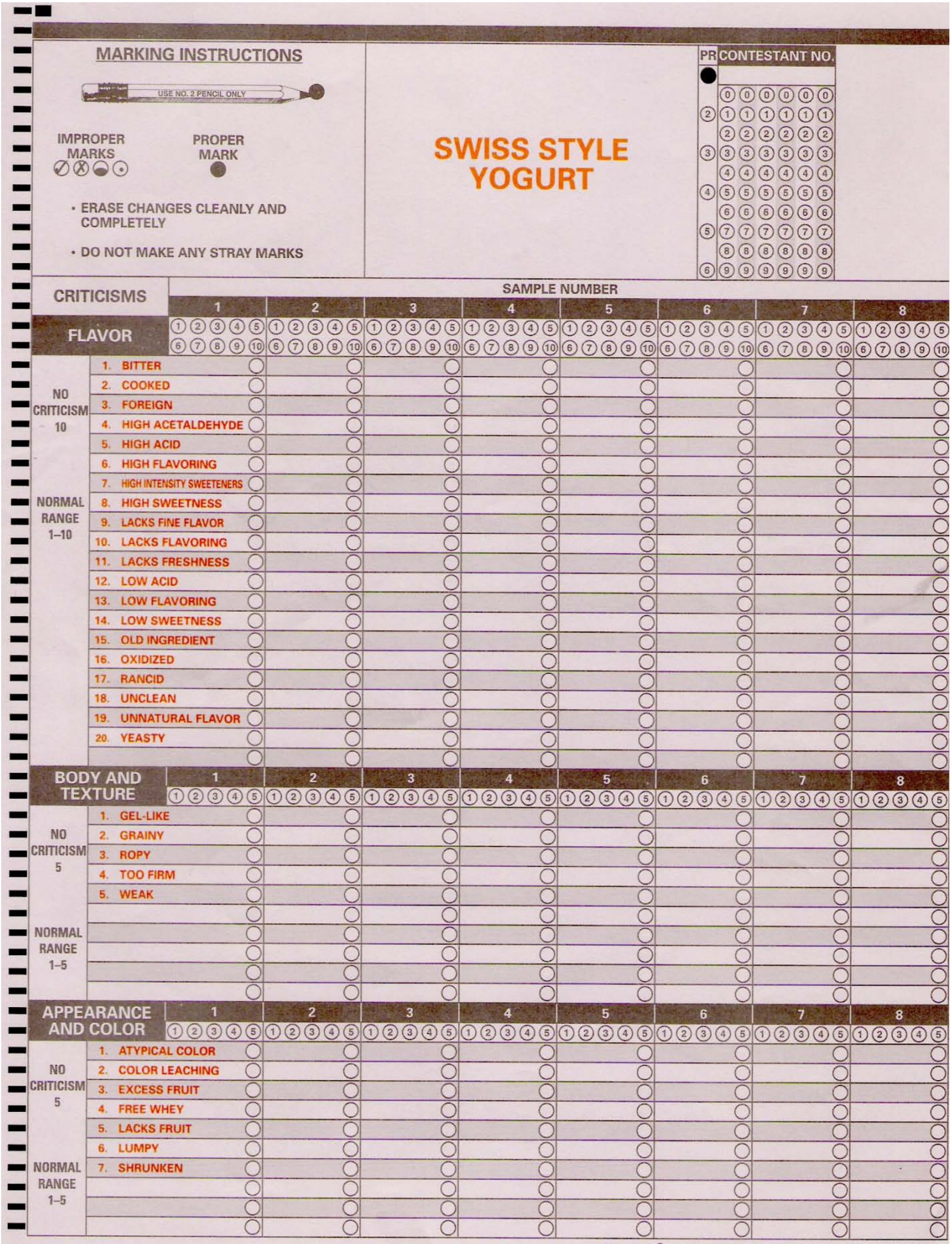
Methods of evaluating yogurt

Plain yogurt is generally consumed with other foods, used as an ingredient, or used as the base for other yogurt products. According to Harper (1991), plain yogurt "must be of the highest quality to ensure the optimal quality of the final fruit-flavored yogurt." Sensory quality of dairy products is vital since the best ingredients make the best final products, and quality drives consumer acceptance (Drake 2007). Quality and consistency evaluations emerged in the early 1900s as means of grading dairy products, but as the field of sensory science developed throughout the latter half of the 20th century, objective analytical methods were increasingly adopted instead.

Traditional dairy quality judging

In the past, traditional dairy score cards have been used to assess cultured dairy products, such as yogurts. These evaluations focus on identifying defects and rely on the perception of expert panelists that have been trained exclusively in the area of dairy products. Because these types of procedures can be carried out quickly on many samples, traditional dairy quality judging serves as a useful tool for analyzing products at the factory-level (Drake 2007). Trained judges can swiftly identify defective products and ensure that they do not reach consumers.

Traditional dairy quality assessors grade products based on the presence/absence of particular negative quality attributes by comparing the quality of the product to a hypothetically defect-free ideal (Clark and Costello 2009). In American Dairy Science Association (ADSA) scorecard evaluations of Swiss-style yogurts, these defects include: gel too firm, weak, shrunken, ropy, atypical color, color leaching, lacks fruit, excess fruit, lumpy, high acetaldehyde, bitter, cooked, atypical (foreign), high acid, low flavoring, lacks fine flavor, lacks freshness, low sweetness, low acid, old ingredient, oxidized (light-activated), rancid, high flavoring, high sweetness, unnatural flavor, and unclean (Tribby 2009). Figure 1.4 illustrates a recent scorecard for Swiss-style yogurt.


MARKING INSTRUCTIONS

USE NO. 2 PENCIL ONLY

IMPROPER MARKS

PROPER MARK

· ERASE CHANGES CLEANLY AND COMPLETELY

· DO NOT MAKE ANY STRAY MARKS

SWISS STYLE YOGURT

PR CONTESTANT NO.

CRITICISMS

SAMPLE NUMBER 1 2 3 4 5 6 7 8

FLAVOR

NO CRITICISM 10

NORMAL RANGE 1–10

1. BITTER
2. COOKED
3. FOREIGN
4. HIGH ACETALDEHYDE
5. HIGH ACID
6. HIGH FLAVORING
7. HIGH INTENSITY SWEETENERS
8. HIGH SWEETNESS
9. LACKS FINE FLAVOR
10. LACKS FLAVORING
11. LACKS FRESHNESS
12. LOW ACID
13. LOW FLAVORING
14. LOW SWEETNESS
15. OLD INGREDIENT
16. OXIDIZED
17. RANCID
18. UNCLEAN
19. UNNATURAL FLAVOR
20. YEASTY

BODY AND TEXTURE

NO CRITICISM 5

NORMAL RANGE 1–5

1. GEL-LIKE
2. GRAINY
3. ROPY
4. TOO FIRM
5. WEAK

APPEARANCE AND COLOR

NO CRITICISM 5

NORMAL RANGE 1–5

1. ATYPICAL COLOR
2. COLOR LEACHING
3. EXCESS FRUIT
4. FREE WHEY
5. LACKS FRUIT
6. LUMPY
7. SHRUNKEN

Trans-Optic® by NCS EM-41764-3:654321 ED04 Printed in U.S.A.

Figure 1.4 ADSA yogurt quality scorecard

The inherent issues associated with such evaluations stem from the fact that they measure quality. Unlike objective sensory intensity ratings, quality “is more elusive and poses considerable difficulty in establishing the frame of reference, definition, measurement, and interpretation” (Bodyfelt 1981). The terminology used to describe quality may be outdated or ill-defined, and it often does a poor job of fully and aptly describing the sensory characteristics of dairy products (Bodyfelt 1981). Based on traditional dairy judging, two products with completely different flavors and textures could hypothetically receive the same quality scores as long as their characteristics place them the same degree from ideal (Drake 2007). Furthermore, assessors using these types of scorecards may not penalize defects consistently since the scales are not balanced or equally spaced (Drake 2007). This scale structure and language eliminates the possibility of using statistical methods to analyze results and makes it challenging, if not impossible, to correlate the results to consumer acceptance data (Claassen and Lawless 1992; Lawless and Claassen 1993). Without explicit quantitative values of specific sensory descriptors, it becomes difficult to ascertain consumer drivers of liking.

Descriptive sensory analysis

Descriptive sensory analysis, as defined by *The Manual on Descriptive Analysis Testing for Sensory Evaluation* (Hootman 1992), is “a sensory method by which the attributes of a food or product are identified and quantified, using human subjects who have been specifically trained for this purpose.” These analyses can include, but are not limited to, flavor, aroma, taste, and texture. Several major methodologies have been developed within this category of sensory analytical testing: Flavor Profile Method (Cairncross and Sjöstrom 1950; Sjöstrom 1954; Caul 1957; Keane 1992), Texture Profile Method (Brandt, Skinner, and Coleman 1963; Szczesniak 1963; Szczesniak, Brandt, and Friedman 1963; Muñoz *et al.* 1992), Quantitative Descriptive Analysis/QDA® (Stone *et al.* 1974; Stone and Sidel 1992, Stone 1992), Spectrum™ Descriptive Analysis (Muñoz and Civille 1992; Meilgaard *et al.* 2007), and Free-Choice Profiling (Langron 1983; Thomson and MacFie 1983; Williams and Arnold 1984; Williams and Langron 1984). Other methods combine characteristics of one or more of these methods. These hybrid methods are generally referred to as just that – hybrid descriptive analysis methods – since they lack specific or proprietary names. All of these techniques provide quantitative information about sensory attribute intensities, but their exact approaches to panel training, language development, and scaling differ. A brief comparison of these methods with respect to their major distinguishing factors is located in Table 1.3.

Table 1.3 A comparison of major descriptive sensory analysis methodologies

Method	Panel	Language development	Evaluation procedures
Flavor Profile	4-6 panelists *highly-trained* in language and methodology	*Technical* terminology with specific definitions and reference standards agreed upon by panelists	Variable sized scale; panelists use the same scaling then discuss to come to a *consensus*
Texture Profile	6-10 panelists *highly-trained* in language and methodology	*Technical* terminology with specific definitions and reference standards agreed upon by panelists	Variable sized scale; panelists use the same scaling then discuss to come to a *consensus*
Quantitative Descriptive Analysis (QDA®)	8-15 panelists *semi-trained* (product users or likers with sensory discriminating abilities and understanding of methodology)	*Consumer* terminology with specific definitions and reference standards agreed upon by panelists	15-cm line scale; panelists rate intensities according to their *own scale*
Spectrum™ method	12-15 panelists *highly-trained* in language and methodology	*Technical* terminology from a standardized lexicon of terms	15-point scale; panelists use the same *universal scaling*
Free-choice profiling	Larger number of *untrained* consumers (number varies)	*Consumer* terminology with inconsistent definitions	Variable sized scale determined by panelists; panelists rate intensities according to their *own scale*
Hybrid method*	6 panelists *highly-trained* in language and methodology	*Technical* terminology with specific definitions and reference standards agreed upon by panelists (and researcher)	15-point scale; panelists use *attribute-specific* scaling to individually evaluate samples (no consensus)

Sources: Meilgaard *et al.*2007, Lawless and Heymann 1999, Hootman 1992
* Indicates the methodology used for this study

Ideally a descriptive sensory analysis panel should function like a scientific instrument, providing objective, accurate, precise, and reproducible quantitative measurements of the variables of interest (Drake 2007). Unlike traditional dairy judging, these sensory science methodologies base their scaling on sound psychological and physiological theories of human responses to external stimuli (Drake 2007). Thus many of the shortcomings of traditional dairy judging – unbalanced scales, inconsistent ratings among assessors, inability to statistically analyze evaluations, and inability to correlate to consumer responses – are fulfilled by using descriptive sensory analysis methods.

Studies of yogurt using descriptive sensory analysis methods did not seem to emerge until the early 1990s. Before then, most sensory evaluation studies of yogurt tended to use the traditional defect-oriented quality judging approach (Richter 1979; McGill 1983; Tamime *et al.* 1987). Yogurt sales in the United States started to slow down in the late 1980s; therefore researchers, wanting to better understand correlations between sensory quality and consumer acceptance, began running studies using descriptive analysis to examine yogurt flavor, texture, appearance, and aroma (Harper *et al.* 1991).

Initial descriptive terms for yogurt included acetaldehyde, cooked milk, caramel, milky, buttery, cheesy, yeasty, salty, sweet, sour, astringent, and bitter (Barnes *et al* 1991, Harper *et al.* 1991). Barnes *et al.* (1991) looked purely at the flavor of commercially-available stirred strawberry and lemon yogurts. They collected descriptive data and correlated it to consumer liking scores for the same samples. Based on their findings, it was concluded that fruit-flavored yogurts could be distinguished primarily on fruity/sweet character and plain/sour flavor, and consumers tended to score fruitier, sweeter samples higher for liking.

Harper *et al.* (1991) carried out a corollary study using plain yogurts rather than fruit-flavored ones. They looked at 17 commercial samples – 7 nonfat, 9 low-fat, and 1 full-fat and found that the samples varied greatly in sourness. Astringent, salty, sweet, cooked milk, buttery, bitter, and yeasty flavor attributes were also reported to be significant. A subsequent multivariate analysis of the data revealed three principal components that described the variability in yogurt flavor: (1) salty, yeasty, sweet, buttery, and astringent; (2) sourness and overall intensity; (3) bitter and cooked milk. Based on consumer ratings of the samples, plain yogurts with high sweetness and milkiness and low sourness, acetaldehyde, saltiness, and astringency were most liked.

Descriptive vocabulary applied to the broader category of fermented milk products was also researched in the early 1990s. In addition to some of the previously-published terms, the lexicons for these studies included flavor attributes, such as rancid, creamy, lemon, and chemical, and an array of texture attributes, including firmness, creamy, thick, slimy, curdy, mouth-coating, and chalky (Muir and Hunter 1992, Hunter and Muir 1992). These studies not only expanded the language of yogurt descriptive analysis, but they expanded the applications of it. The 24 products tested in these studies varied in percent milk fat (0.2-10.3%), milk source (cow, ewe), processing (fromage frais, set-style, strained, Greek-style), and brand. All 32 attributes tested were found to be significant; however, based on multivariate analyses, Muir and Hunter determined that five major characteristics could be used to differentiate yogurts: acidity, curds and whey character, sweetness, creamy character, and chalkiness. Many studies have been carried out to better understand what contributes to creamy perception in foods, and it has been found that it is in fact a confounded term that includes both flavor and texture perceptions (Mela 1988; Lawless and Clark 1992; Kilcast and Clegg 2002). Therefore, this term is not suitable in descriptive sensory analysis lexicons.

The transition from traditional dairy judging to sensory analysis methodology continued in the 1990s and 2000s. Rohm *et al.* (1994) used Quantitative Descriptive Analysis (QDA®) to examine the effect of starter cultures on plain set-style yogurt flavor and texture. Panelists assessed laboratory-prepared prototypes on initial total aroma, visual surface smoothness, texture firmness when penetrated, flavor intensity, acidity, mouthfeel smoothness, viscosity, ropiness, and liking. Significant differences were found in the prototypes with respect to all sensory attributes except texture firmness. Since this particular method uses consumer-based language, the terminology was less technical and specific and would not be appropriate for use with a trained panel.

Ott *et al.* (2000) used descriptive analysis to correlate instrumental measurements to sensory intensity measurements. Similar to Hunter and Muir's research, it was reported that yogurt flavor was significantly affected by pH. Increased pH led to increased sweet dairy-like flavors and decreased sourness, astringency, and bitterness. Drake *et al.* (2000) used descriptive analysis in addition to microbiological and instrumental measurements to better understand the effect of soy protein fortification in yogurts. The language used for evaluation (sour, sweet, astringency, dairy aroma, dairy flavor, soy aroma, color, free whey, chalky, ropy, and thickness) was relatively similar to those of previous yogurt studies using descriptive sensory analysis.

Folkenburg and Martens (2003) used descriptive analysis to examine the effects of percent milk fat (0.1, 3.5, and 5.3%), culture (three types from Chr. Hansen, Hørsholm, Denmark), and added non-fat dry milk (0 and 2%) in plain stirred yogurts in a full factorial experimental design. A nine-person panel assessed the 18 samples on language derived from Muir and Hunter's research (1992) and found that all three factors – percent milk fat, culture, and added non-fat dry milk – can affect flavor, odor, and texture. Some combinations of cultures and non-fat dry milk concentrations could result in similar texture to one that has high fat content. In recent studies, others have also used descriptive analysis methods to make connections between physical properties, such as rheology, viscosity, and other texture data, and the sensory perception of texture (Kora *et al.* 2003, Sodini *et al.* 2004, Martin *et al.* 2005, Janhøj *et al.* 2006, Ares *et al.* 2007).

The culminating result of terminology development for yogurt descriptive analysis was a comprehensive lexicon published in 2008 by Coggins and others at Mississippi State University. Of 61 identifiable appearance, flavor, aroma, and texture attributes, 37 terms significantly differentiated between yogurt products. Their findings indicated that of the four sensory modalities, "taste and texture were more effective at differentiating yogurt treatments than aroma and appearance" (Coggins *et al.* 2008). The issue with this newer lexicon is that many of their terms are product-based rather than sensory perception-based. This lexicon includes flavor attributes such as cream cheese and buttermilk that, like creaminess, are confounded terms that include more than one specific flavor attribute.

Regardless of how well researchers understand yogurt sensory characteristics, consumers ultimately drive the market; they make the purchase decisions that determine the successful products from the failures. Sensory quality factors into these decisions, but characteristics such as price, brand, label claims, nutrition, health promises, and endorsements can also contribute and influence their buying behavior (Vickers 1993; Lucklow *et al.* 2005).

Varieties and classifications

Variability between types of yogurt stems from the ingredients, how they were made, and what has been added (Tamime and Robertson 1999). Various processing steps can affect flavor and texture. Yogurt can be made from nonfat, low-fat, and full fat milk, or additional cream can be added to yield even higher milk fat contents. Protein and carbohydrate stabilizers can affect both flavor and texture (Chandan and O'Rell 2006). Vitamins and minerals can be added to fortify yogurts, and preservatives may be added to further lengthen their shelf-lives. Figure 1.5 illustrates major distinguishing characteristics in the yogurt category.

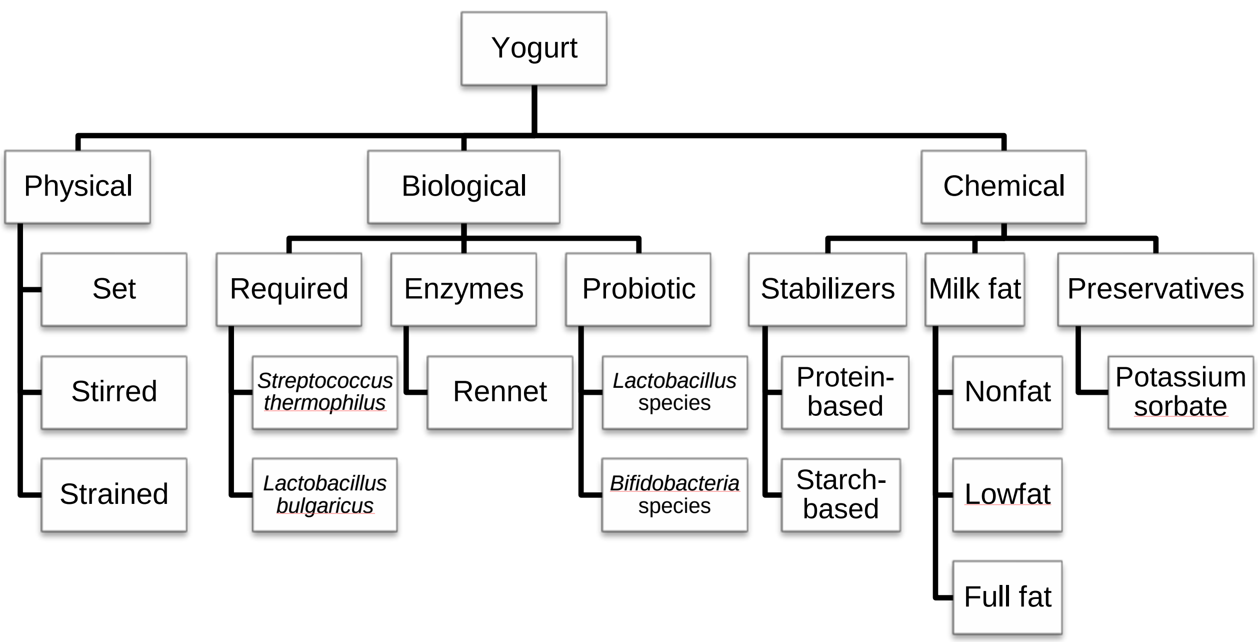


Figure 1.5 Major distinguishing characteristics of yogurt

Sources: Tamime and Robinson 1999 and Chandan 2006

Processing and storage effects

Yogurt can vary greatly depending on the ingredients used and what has been added, but much of the production remains the same regardless of the characteristics of the final product. The major steps involved with making yogurt – blending, pasteurizing, homogenizing, cooling, culturing, incubating, and cooling – are outlined in Table 1.4. Depending on the style of yogurt, inoculated yogurt mix may be pumped into individual cups before incubation, or it may coagulate in a vat before undergoing additional stirring. These processes yield set-style and stirred-style yogurts, respectively, and they differ in texture because of the gel structure. Set-style yogurts preserve the gel structure; whereas stirred-style yogurts destroy the coagulated curds. Stirred yogurts generally have a "smoother body and less gel-like texture" in comparison to set-style ones (Chandan and O'Rell 2006).

Table 1.4 Generalized procedures for yogurt production

Processing step	Action
Blending	Standardizes yogurt mix by dissolving and dispersing dry ingredients into liquid phase
Pasteurizing	Eliminates pathogenic bacteria, reduces the other microorganisms present, inactivates milk enzymes, denatures proteins (necessary step legally)
Homogenizing	Mechanically reduces milk fat globules to smaller sizes, helps disperse and activate some stabilizers (not legally necessary)
Cooling and culturing	Cools down to optimal incubation temperatures and introduces the yogurt cultures
Incubating	Cultures multiply, ferment lactose, and produce lactic acid; proteins precipitate and/or coagulate at the lowered pH (4.4-4.6)
Cooling	Stops culture growth and subsequent lactic acid production

Sources: Tamime and Robinson 1999, Chandan 2006, and Tribby 2009

After the gel has set, yogurt can also undergo a concentration step to become what is known as strained or Greek-style yogurt. Traditionally, the finished product is strained through cheesecloth for an extended period of time. The whey is subsequently drained out, and the yogurt curd increases in total solids and percent milk fat (Tamime and Robinson 1999). These types of yogurts are known for their "remarkably thick viscous body" (Chandan and O'Rell 2006). Over time new technologies, such as ultrafiltration or centrifugation, have eclipsed this traditional process since they improve both efficiency and sanitation (Chandan and O'Rell 2006). Additional ingredients such as nonfat milk solids can also be added to achieve this thickened texture without undergoing a physical concentration step (Chandan and O'Rell 2006).

Once yogurt has reached its desired pH, generally around 4.6, it should be stored in refrigerated conditions. These temperatures, although they slow down acid production, do not completely prevent changes from occurring. Salvador and Fiszman (2004) studied whole and skimmed artificially-sweetened strawberry-flavored set-style yogurts stored at 10 °C for 15, 35, 49, 63, 77, and 91 days. They reported increased syneresis and firmness in both the whole and skimmed yogurts over time and increased acidity and astringency for the skimmed yogurts. Isleten and Karagul-Yuceer (2006) found increased firmness of various nonfat yogurts over the course of a 12-day period at 5 °C. The findings of Kumari *et al.* (2008) seemed to agree with both of these previous studies. Their research demonstrated significant changes in plain yogurt flavor and texture over an 8-week period at 4.4, 7, and 10 °C, particularly with respect to overall flavor intensity and sourness.

Ingredient and composition effects

A variety of ingredients can be added to stabilize, sweeten, flavor, color, fortify, and extend the shelf-life of yogurt. However, only stabilizers, vitamin and mineral fortifications, and preservatives are generally seen in plain yogurts. Since yogurt at its most basic level starts with essentially just milk and cultures, yogurts with these added ingredients will vary in their sensory characteristics.

Both proteins and starches can be used as stabilizers, and in the process of stabilizing the yogurt gel, also provide a thickening functionality. Milk powders increase the protein content of yogurts and can increase "the viscosity, gel strength, and ability to retain the whey of the yogurt" (Sodini and Tong 2006). However, due to the processing of these milk powders, flavors such as cooked, sweet aromatic, cereal, animal/wet dog, potato/brothy, cardboard, sweet, salty, and astringent can arise (Drake *et al.* 2003). Other unique flavors such as caramelized, burnt, animal/barny, vitamin/rubbery, free fatty acid, earthy/musty, bitter, and sour were seen in some, but not all, of skim milk powders (Drake *et al.* 2003).

Whey, caseinates, and soy proteins can also be used. They are cheap; however, they can often cause deleterious effects in texture, flavor, and appearance at higher levels. Drake *et al.* (2003) reported that whey proteins and caseinates exhibited higher animal/wet dog, brothy, cardboard, and astringent flavors than skim milk powders. The research of Isleten and Karagul-Yuceer (2006) indicated that sodium caseinate-fortified yogurts had higher animal-like flavor than the control. Added soy proteins thickened yogurts in a study conducted by Drake *et al.* (2000), but they also increased soy aroma, soy flavor, and chalkiness. These samples with added soy proteins were also reported to be less sweet (Drake *et al.* 2000). Tribby (2009) reported that dried milk powders, whey proteins, and starch-based stabilizers can cause stale and/or storage off-flavors.

Vitamins such as vitamin A or vitamin D may be added, but little research has been conducted to determine their effect on flavor and texture. Additional calcium fortification has been shown not to affect sensory characteristics (Singh and Muthukumarappan 2007). Potassium sorbate is often used as a mold and yeast-inhibitor to increase the shelf-life of products; however, it too can cause off-flavors (Tribby 2009). Tribby (2009) described its flavor as “atypical and objectionable…[detected as] a burn on the middle of the tongue”.

Trends in innovation and sales

Sales of yogurt products saw substantial increases in the 1970s and 1980s, and despite the slowing rates of the past several years, sales continue to rise at gradual pace. The appeal of yogurt stems from the fact that is a highly versatile food that can be enjoyed eaten on its own or in a variety of cooking applications.

Functional food trends

Plain yogurt, a good source for protein, calcium, and other vitamins and minerals (if fortified), can be eaten as is, or it can be enhanced by adding other ingredients. For those watching their caloric and fat intakes, it can also be used as low-fat substitute for mayonnaise, heavy cream, whipped cream, or sour cream in certain recipes.

Yogurt has been established as a beneficial health food for some time, but with increasing interest in functional foods, the addition of probiotics seemed to be the next logical step. Although *Lactobacillus bulgaricus* and *Streptococcus thermophilus* are the only cultures required to meet the yogurt standard of identity, other cultures can be used. These microflora include, but are not limited to, *Lactobacillus acidophilus*, *Bifidobacteria infantis*, and *Bifidobacteria longum*. Extensive research has been undertaken to understand how to incorporate these strains into yogurts and how these cultures affect human health. It should be noted, however, that not all probiotic bacteria have clinically demonstrated health benefits. Shah (2006) reports that

> A number of health benefits are claimed in favor of probiotic organisms including antimicrobial properties, control of gastrointestinal disorders, improvement in lactose metabolism, anticarcinogenic properties, and reduction in serum cholesterol.

Along with probiotic products, the functional food trend has created more interest and demand for products with specific claims such "immunity boost," "lower cholesterol," "lower blood pressure," "digestive health," "organic," and "natural" (Table 1.5) According to a November 2008 Mintel report, these specialty yogurts grew 169% from 2003 to 2008 and now account for 11% of the market share (up from 10% in 2005) in the U.S. Similarly, products with organic and natural claims constitute 12% of all yogurt sales.

Table 1.5 Top 10 product claims in recent new product launches

Product claims	2005	2006	2007	2008	2009	Total
Low/no/reduced fat	94	111	146	150	95	596
Kosher	24	38	111	119	67	359
Vitamin/mineral fortified	40	34	62	40	39	215
Low/no/reduced calorie	38	33	41	47	32	191
Organic	11	9	37	51	31	139
All natural	10	11	42	37	23	123
Low/no/reduced sugar	13	20	33	31	9	106
Functional – digestive	0	17	4	56	27	104
Low/no/reduced allergen	6	1	13	47	25	92
No additives/preservatives	4	4	46	10	27	91

Source: Mintel 2009

Brand trends

A more recent November 2009 Mintel report indicates that category growth can be increasingly attributed to small premium brands and private labels. Group Danone and General Mills (Yoplait) combined own about 71% of the market share (Figure 1.6). Investments in innovation and marketing have led to popular line extensions such as Dannon Light & Fit, Activia Light, Dan-o-nino, Yoplait Light, YoPlus, and Yoplait Fiber One, but growth was only modest. From August 2008-2009, Group Danone and General Mills grew by about 4.2% and 2.0%, respectively; whereas small brands like The Greek Gods and Fage Total grew by nearly 17%, and private labels grew by about 5.2%. Even now, after the economic recession in the United States, innovation in new product launches is still lead by organic, natural, and functional food trends.

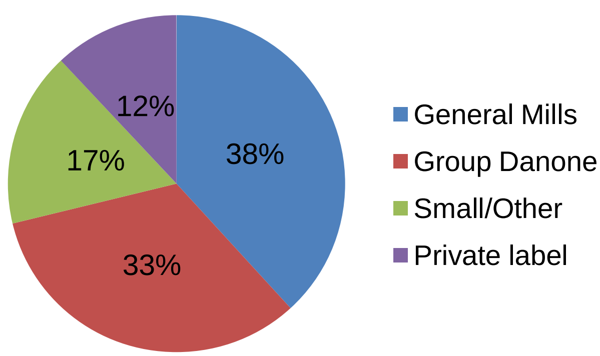


Figure 1.6 Division of yogurt market share by brand
Source: Mintel 2009

Organic and sustainability trends

As opposed to the term *organic* no specific set of standards exist that define a sustainable product, although the idea of sustainability is not a new concept. The term is mentioned in United Nations documents dating as far back as the 1980s. The Brundtland Commission of the United Nations (1987) defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Since then, the idea of sustainability has surfaced in both the public and private sectors in reference to anything from agriculture and environment to social policies and manufacturing processes.

In 1996, environmental author Bill McKibben said that "[the term] 'sustainability' is doomed because it does not refer to anything familiar." However, interest in and awareness of environmental issues has increased since this time (Mintel 2010), and the idea of sustainability has gained traction as a result. The idea of sustainability can be exemplified by the actions of one individual, but it can also be seen in the policies passed by a government or changes made in a business. The term is now also being used as a brand, label, and/or distinction in order to market and sell specific consumer goods. However, as McKibben warned, the term is rather vague and is still not widely understood. According to a 2008 report by The Hartman Group, "though widely used in business circles, the term 'sustainability' is little used in consumer circles." In a survey of 971 consumers, 70% indicated that they were interested in products that save energy or natural resources, but other components of sustainability were also evaluated (Mintel 2010). The terms used to define sustainability and the actual means in which it is implemented and/or practiced are not analogous; thus these uncertainties have led to consumer confusion and skepticism towards the green movement (Mintel 2010). Especially with respect to the green movement in the food industry, consumers still relate the terms organic, natural, and sustainable to each other, even though they are distinct terms with different definitions and regulations (Mintel 2010).

Research has been done to explore the effects of organic practices on the sensory characteristics of products such as chicken breast, steak, tomatoes, bread, rice, wine, and olive oil (Jahan *et al.* 2005; Walshe *et al.* 2006; Thybo *et al.* 2006; Annett *et al.* 2007; Champagne *et al*. 2007; Morlat and Symoneaux 2008; Ninfali *et al.* 2008). However, very little to no research has been done to explore the resulting sensory characteristics of products developed using new sustainable technologies and how they differ from those using conventional practices. Sales of "green" products slowed down some due to the economic troubles in the United States in the late 2000s, but Mintel Market Research predicts that the market will pick up in 2010 and continue to increase as the economy improves. Furthermore, the behavior of consumers committed to the green lifestyle seems to stay consistent regardless of the economic climate (Mintel 2010). Therefore new introductions to the market with the value-added benefit of being "more sustainable" could benefit from this increased interest in "green" products. It is necessary, however, to determine how these potential new products compare to those already available to consumers.

Research objectives

Background of the program and research

The Food Industry Management Enhancement Program (FIMEP) was an experiment in Master's-level graduate education at Kansas State University (Manhattan, Kansas, U.S.A.) that was supported by a United State Department of Agriculture (USDA) National Needs Fellowship Grant. The primary purpose of the program was to "train managers for the food industry who can understand, appreciate and operate effectively outside their core area of expertise" (Amanor-Boadu *et al.* 2008). As defined by the project proposal, the students in the program would gain a greater understanding of the food industry's complexity and develop professional skills necessary for success in increasingly collaborative work environments.

Graduate students from three academic disciplines – sensory science, food science, and agricultural business – worked on a collaborative research project pertaining to the food industry. During the program's first year (August 2008-May 2009), the students decided upon sustainability as their research theme then focused on the dairy foods industry, specifically yogurt production. The overall cohort goal was to develop a more sustainable yogurt that was viable within the current yogurt market. Each student's thesis project then examined specific research objectives within that goal that related to her specific academic discipline. Due to the collaborative nature of this research, pieces of each student's project overlapped. In the case of this project, three sustainable yogurt prototypes produced by another student in the program were evaluated as part of this study's sample set.

Specific research objectives

The objectives of this research were thus to (1) generate a thorough lexicon for plain yogurts that captures the full range of sensory characteristics evident in the category; (2) by using this new language, compare the sensory properties of a wide range of commercially-available plain yogurts; and (3) compare sensory properties of three sustainable plain yogurt prototypes to the commercially-available samples.

References

Accolas, JP, Deffontaines, JP, Aubin, F. 1978. Le lait et les produits laitiers en République Populaire de Mongolie. Le Lait. 58:278-286.

Amanor-Boadu, V., Schmidt, K, Chambers, D. 2008. Food industry management enhancement program. United State Department of Agriculture: National Institute of Food and Agriculture. Accession: 0212574. Project: KS600838.

Annette, LE, Spaner, D, Wismer, WV. 2007. Sensory profiles of bread made from paired samples of organic and conventionally grown wheat grain. J Food Sci 72:S254-S260.

Ares, G, Gonçalvez, Pérez, C, Reolón, Segura, N, Lema, P, Gámbaro. 2007. Influence of gelatin and starch on the instrumental and sensory texture of stirred yogurt. Int J Dairy Tech 60:263-269.

Ayto, J. 2002. Yoghurt. In: Ayto, J, author. An A-Z of Food & Drink. Oxford: Oxford University Press. p 273.

Barnes, DL, Harper, SJ, Bodyfelt, FW, McDaniel, MR. 1991. Correlation of descriptive and consumer panel flavor ratings for commercial prestirred strawberry and lemon yogurts". J Dairy Sci 74:2089-2099.

Bodyfelt, FW. 1981. Dairy product score cards: are they consistent with principles of sensory evaluation?. J Dairy Sci 64:2303-2308.

Brandt, MA, Skinner EZ, Coleman, JA. 1963. The texture profile method. J Food Sci 28:404-409.

Cairncross, SE, Sjöstrom, LB. 1950. Flavor profiles—a new approach to flavor problems. Food Technology 4:308-311.

Caul, JF. 1957. The profile method of flavor analysis. Adv Food Res 7:1-40.

Champagne, ET, Bett-Garber, KL, Grimm, CC, McClung, AM. 2007. Effects of organic fertility management on physicochemical properties and sensory quality of diverse rice cultivars. Cereal Chemistry 84:320-27.

Chandan, RC. 2006. History and consumption trends. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 3-15.

Chandan, RC. 2006. Manufacture of various types of yogurt. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 211-236.

Chandan, RC, O'Rell, KR. 2006. Principles of yogurt processing. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 195-209.

Clark, S, Costello, M. Dairy products evaluation competitions. In: Clark, S, Costello, M, Drake, MA, Bodyfelt, F, editors. The sensory evaluation of dairy products. 2nd ed. New York: Springer. p 43-71.

Claassen, M, Lawless HT. 1992. Comparison of descriptive terminology system for sensory evaluation of fluid milk. J. Food Science 57, 596-600.

Code of Federal Regulations (CFR) [Internet]. Product composition. Title 7-Agriculture. Part 205-National Organic Program. Section 205.301. Washington, DC: U.S. Department of Agriculture [Accessed 2010 Mar 17]. Available from: http://edocket.access.gpo.gov/cfr_2010/janqtr/pdf/7cfr205.301.pdf.

Code of Federal Regulations (CFR) [Internet]. Yogurt. Title 21-Food and drugs. Part 131. Section 131.200. Washington, DC: U.S. Department of Agriculture [Accessed 2010 Mar 17]. Available from: http://edocket.access.gpo.gov/cfr_2009/aprqtr/pdf/21cfr131.200.pdf.

Code of Federal Regulations (CFR) [Internet]. Lowfat Yogurt. Title 21-Food and drugs. Part 131. Section 131.203. Washington, DC: U.S. Department of Agriculture [Accessed 2010 Mar 17]. Available from: http://edocket.access.gpo.gov/cfr_2009/aprqtr/pdf/21cfr131.203.pdf.

Code of Federal Regulations (CFR) [Internet]. Nonfat Yogurt. Title 21-Food and drugs. Part 131. Section 131.206. Washington, DC: U.S. Department of Agriculture [Accessed 2010 Mar 17]. Available from: http://edocket.access.gpo.gov/cfr_2009/aprqtr/pdf/21cfr131.206.pdf.

Codex Standard for Fermented Milks. Codex Standard 243-2003 [Internet]. World Health Organization, 2003. [Revised 2008; Accessed 2010 Mar 17]. Available from: http://www.codexalimentarius.net/download/standards/400/CXS_243e.pdf

Coggins, PC, Schilling, MW, Kumari, S Gerrard, PD. 2008. Development of a sensory lexicon for conventional milk yogurt in the United States. J Sensory Stu 23: 671-687.

Dairy Management, Inc: guidelines for use of the Real® Seal [Internet]. [Accessed 2010 Mar 17]. Available from: http://www.realseal.com/Documents/Guidelines-for-use-of-the-REAL-Seal.pdf.

Dairy Management, Inc: Real® Seal [Internet]. [Accessed 2010 Mar 17]. Available from: http://www.realseal.com/.

Dannon: Our Heritage [Internet]. [Accessed 2010 Mar 17]. Available from: http://dannon.com/about_company.aspx.

Davidson, A. 1999. Yogurt. In: Davidson, A, author. The Oxford Companion to Food. Oxford: Oxford University Press. p 859.

Drake, M.A. 2007. Invited review: sensory analysis of dairy foods. J Dairy Sci 90: 4925-4937.

Drake, MA, Chen, XQ, Tamarapu, S, Leenanon, B. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. J Food Sci 65:1244-1247.

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

Folkenberg, DM, Martens, M. 2003. Sensory properties of low fat yoghurts. Part B: Hedonic evaluations of plain yoghurts by consumers correlated to fat content, sensory profile and consumer attitudes. Milchwissenschaft 58:154-157.

Food and Drug Administration (FDA): Milk and Cream Products and Yogurt Products; Proposal to Revoke the Standards for Lowfat Yogurt and Nonfat Yogurt and to Amend the Standard for Yogurt [Internet]. Washington, D.C.: Federal Register Vol. 74, No. 10; 2009 Jan 15 [Accessed 2010 Mar 17]. Available from: http://aboutyogurt.com/AboutYogurt08/files/ccLibraryFiles/Filename/000000000030/1.15.09_Proposed%20Rule%20FDA-2000-P-0126.pdf

Frye, CP. 2006. Regulations for product standards and labeling. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 57-71.

General Mills. Colombo: Our Story [Internet]. [Accessed 2010 Mar 17]. Available from: http://www.colomboyogurt.com/OurStory.aspx.

Harper, SJ, Barnes, DL, Bodyfelt, FW, McDaniel, MR. 1991. Sensory ratings of commercial plain yogurts by consumer and descriptive panels. J Dairy Sci 74:2927-2935.

The Hartman Group: Sustainability, the rise of consumer responsibility. The Hartman Group; 2009 Jan [Accessed 2009 Feb 10]. Available from: http://www.hartman-group.com/downloads/Sustainability2009-ExecSummary.pdf.

Hatchwell, LC. 1996. Implications of fat on flavor. In: McGorrin, RJ, Leland, JV, editors. Flavor-food interactions. Washington, DC: American Chemical Society. p 14-23.

Hootman, RC, editor. 1992. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. 52 p.

Hunter, EA, Muir, DD. 1993. Sensory properties of fermented milks: objective reduction of an extensive sensory vocabulary. J Sensory Studies 8:213-227.

Isleten, M, Karagul-Yuceer, Y. 2006. Effects of dried dairy ingredients on physical and sensory properties of nonfat yogurt. J Dairy Sci 89:2865-2872.

Jahan, K., Paterson, A., Piggott, JR. 2005. Sensory quality in retailed organic, free range, and corn-fed chicken breast. Food Research Int 38:495-503.

Janhøj, T, Blangsted Petersen, C, Bom Frøst, Ipsen, R. 2006. Sensory and rheological characterization of low-fat stirred yogurt. J Text Stu 37:276-299.

Keane, P. 1992. The flavor profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 1-14.

Kilcast, D, Clegg S. 2002. Sensory perception of creaminess and its relationship with food structure. Food Qual and Pref 13:609-623.

Kora EP, Latrille E, Souchon I, Martin N. 2003. Texture–flavor interactions in low fat stirred yogurt: How mechanical treatment, thickener concentration and aroma concentration affect perceived texture and flavour. J Sens Stud 18:367–390.

Kosikowski, FV, Mistry, VV. 1997. Cheese and Fermented Milk Foods – Origins and Principles. Vol. 1. Westport: FV Kosikowski. p 87-108.

Kumari, S, Coggins, PC, Wilson, JC, Rowe, D. 2008. Combined effects of storage time and temperature on sensory characteristics of plain yogurt. Abstract. HortScience 43:628.

Langron, SP. 1983. The application of Procrustes statistics to sensory profiling. In: Williams, AA, Atkin, RK, editors. Sensory quality in foods and beverages: definition, measurement, and control. Chichester: Horwood. p 89-95.

Lawless, HT, Claassen, MR. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. J Food Sci 58:108-112.

Lawless, HT, Clark, CC. 1992. Psychological biases in time-intensity scaling. Food Technology 11:81 -90.

Lawless, HT, Heymann, H. 1999. Sensory evaluation of food. New York: Springer. 837 p.

Lucklow, T., Moskowitz, HR, Beckley, J, Hirsch, J, Genchi, S. 2005. The Four Segments of Yogurt Consumers: Preferences and Mind-Sets. J Food Products Marketing 11:1-22.

Mariani, JF. 1999. Yogurt. In: Mariani, JF, author. The Encyclopedia of American Food and Drink. New York: Lebhar-Friedman Books. p 355-356.

Martin, FL, Parker, A, Hort, J, Hollowood, TA, Taylor, AJ. 2005. Using vane geometry for measuring the texture of stirred yogurt. J Text Stu 36:421-438.

McGill, AEJ. 1983. Evaluation and prediction of the consumer acceptability of commercially manufactured yogurt. South African J Dairy Tech 15:139-140.

McKibben, Bill. 1996. Buzzless Buzzword. The New York Times. 1996 Apr 10, Section A, p. 19, column 2. Accessed through LexisNexis® Academic.

Meilgaard, MC, Civille, GV, Carr, BT. 2007. Sensory evaluation techniques. 4th ed. Boca Raton: CRC Press. 448 p.

Mela, DJ. 1988. Sensory assessment of fat content in fluid dairy products. Appetite 10:37-44.

Mintel: Yogurt and yogurt drinks – US – November 2008 [Internet]. [Accessed 2010 Jan 27]. Available from: http://academic.mintel.com.

Mintel: Yogurt– US – November 2009 [Internet]. [Accessed 2010 Feb 17]. Available from: http://academic.mintel.com.

Mintel: Green living– US – February 2010 [Internet]. [Accessed 2010 Mar 31]. Available from: http://academic.mintel.com.

Morlat, R, Symoneaux, R. 2008. Long-term additions of organic amendments in a Loire Valley vineyard on a calcareous sandy soil. III. effects on fruit composition and chemical and sensory characteristics of cabernet franc wine. American J Enology and Viticulture 59:375-386.

Muir, DD, Hunter, EA. 1992. Sensory evaluation of fermented milks: vocabulary development and the relations between sensory properties and composition and between acceptability and sensory properties. J Soc Dairy Tech 45:73-80.

Muñoz, AM, Civille, GV. 1992. The spectrum descriptive analysis method. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 22-34.

Muñoz, AM, Szczesniak, AS, Einsten, MA, Schwartz, NO. 1992. The texture profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 35-50.

National Yogurt Association: Live & Active Culture Yogurt [Internet]. [Accessed 2010 Mar 17]. Available from: http://aboutyogurt.com/index.asp?bid=5.

Ninfali, P, Bacchiocca, M, Biagiotti, E, Esposto, S, Servili, M, Rosati, A, Montedoro, G. 2008. A 3-year study on quality, nutritional and organoleptic evaluation of organic and conventional extra-virgin olive oils. J Amer Oil Chem Soc 85:151-158.

Ott, A, Hugi, A, Baumgartner, M, Chaintreau, A. 2000. Sensory investigation of yogurt flavor perception: mutual influence of volatiles and acidity". J Agric Food Chem 48: 441-450.

Rašić, JL, Kurmann, JA. 1978. History and growth. In: Rašić, JL, Kurmann, JA, authors. Yoghurt, scientific grounds, technology, manufacture and preparations. Copenhagen: Rašić, JL, Kurmann, JA. p 11-17.

Richter, RL. 1979. Results of the 1978 American dairy products scoring clinic. Cult Dairy Prod J 13:15-17.

Rohm, H, Kovac, A, Kneifel W. 1994. Effects of starter cultures on sensory properties of set-style yoghurt determined by quantitative descriptive analysis. J Sensory Stu 9:171-186.

Salvador, A, Fiszman, SM. 2004. Textural and sensory characteristics of whole and skimmed flavored set-type yogurt during long storage. J Dairy Sci 87:4033-4041.

Shah, NP. 2006. Probiotics and fermented milks. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 341-354.

Singh, G, Muthukumarappan, K. 2007. Influence of calcium fortification on sensory, physical and rheological characteristics of fruit yogurt. LWT Food Sci Tech 41:1145-1152.

Sjöstrom, LB. 1954. The descriptive analysis of flavor. In: Peryam, D, Pilgrim, F, Peterson, M, editors. Food acceptance testing methodology. Chicago: Quartermaster. p 25-61.

Sodini, I, Remeuf, F, Haddad, S, Corrieu, G. 2004. The relative effect of milk base, starter, and process on yogurt texture: a review. Critical Rev in Food Sci Nut 44:113-137.

Sodini, I, Tong, PS. 2006. Milk and milk-based dairy ingredients. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 167-178.

Stone, H. 1992. Quantitative descriptive analysis (QDA). In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials (ASTM). p 15-21.

Stone, H, Sidel, JL, Oliver, S, Woolsey, A, Singleton, RC. 1974. Sensory evaluation by quantitative descriptive analysis. Food Technology 28:24-34.

Stone, H, Sidel, JF. 1993. Sensory evaluation practices. 2nd ed. Orlando: Academic Press, Inc. p 206-240.

Szczezsniak, AS. 1963. Classification of textural characteristics. J Food Sci 28:385-389.

Szczezsniak, AS, Brandt, MA, Friedman, HH. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. J Food Sci 28:397-403.

Tamime, AY, Davies G, Hamilton, MP. 1987. The quality of yoghurt on retail sale in Aryshire. Part II. Organoleptic evaluation. Dairy Ind Int 52:40-41.

Tamime, AY, Deeth, HC. 1980. Yoghurt: technology and biochemistry. J Food Protection 43:939-977.

Tamime, AY, Robinson, RK. 1999. Yoghurt Science and Technology. 2nd ed. Cambridge: Woodhead Publishing. 606 p.

Tannahill, R. 1988. Food in history. New York: Three Rivers Press. 448 p.

Thompson, DMH, MacFie, HJH. 1983. Is there an alternative to descriptive sensory assessment? In: Williams, AA, Atkin, RK, editors. Sensory quality in foods and beverages: definition, measurement, and control. Chichester: Horwood. p 96-107.

Thybo, AK, Edelenbos M, Christensen LP, Sorensen JN, Thorup-Kristensen, K. 2006. Effect of organic growing systems on sensory quality and chemical composition of tomatoes. LWT Food Sci Tech 39:835-843.

Toussaint-Samat, M. 1992. The history of dairy produce. In: Bell, A, translator. A History of Food. Malden: Blackwell Publishing. p 113-124.

Tribby, D. Yogurt. In: Clark, S, Costello, M, Drake, MA, Bodyfelt, F, editors. The sensory evaluation of dairy products. 2nd ed. New York: Springer. p 191-223.

United Nations: report of the world commission on environment and development [Internet]. General Assembly Resolution 42/187; 1987 Dec 11. [Accessed 2010 Mar 31]. Available from: http://www.un.org/documents/ga/res/42/ares42-187.htm.

U.S. Department of Agriculture (USDA). USDA specifications for yogurt, nonfat yogurt and lowfat yogurt [Internet]. Washington, DC: U.S. Department of Agriculture; 2001 Jan 19 [Accessed 2010 Mar 17]. Available from: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3004551.

U.S. Department of Agriculture (USDA). National Organic Program Background and History Fact Sheet. Washington, DC: U.S. Department of Agriculture; 2002 Oct [Updated 2008 Apr; Accessed 2010 Mar 17]. Available from: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3004443&acct=nopgeninfo.

Vickers, ZM. 1993. Incorporating tasting into a conjoint analysis of taste, health claim, price and brand for purchasing strawberry yogurt. J Sensory Stu 8:341–352.

Walshe, BE, Sheehan EM, Delahunty, CM, Morrissey, PA, Kerry, JP. 2006. Composition, sensory and shelf life stability analyses of Longissimus dorsi muscle from steers reared under organic and conventional production systems. Meat Science. 73:319-325.

Williams, AA, Arnold, GM. 1984. A new approach to sensory analysis of foods and beverages. In: Adda, J, editor. Progress in flavour research. Proceedings of the 4th Weurman Flavour Research Symposium. Amsterdam: Elsevier. p 35-50.

Williams, AA, Langron, SP. 1984. The use of free choice profiling for examination of commercial ports. J Sci Food and Agr 35:558-568.

CHAPTER 2 - Materials and Methods

I opened-up a yogurt, underneath the lid it said, "Please try again" because they were having a contest that I was unaware of. I thought maybe I opened the yogurt wrong, or maybe Yoplait was trying to inspire me: "Come on Mitchell, don't give up! An inspirational message from your friends at Yoplait, fruit on the bottom, hope on top."
– Mitch Hedberg, comedian

Samples

Prototype samples

Three prototypes, two "more sustainable" samples and a control sample, were prepared in a food-grade laboratory at Kansas State University (Manhattan, Kansas, U.S.A.). The "more sustainable" samples were developed using novel production methods that were demonstrated to reduce fermentation time (Boomgaarden and Schmidt 2009). All prototypes were plain, nonfat, set-style yogurts.

Commercially-available samples

Fifty-four commercially-available plain yogurt samples were purchased from a variety of retailers located within a 125 radius of Kansas City, Kansas, U.S.A. (Table 2.1). The yogurts differed in percent milk fat, milk type (organic or conventional), physical processing (set-style, stirred, or strained/Greek-style), and brand. A complete listing of all 54 samples is located in Appendix A.

Five experts, two graduate students and three faculty members involved in the study, tasted all the samples in order to identify samples with standard or unique sensory characteristics which would represent the entire scope of the plain yogurt category. This process can be carried out by either "a descriptive panel or personnel familiar with the product category's sensory characteristics" as long as the objectives of the screening are met (Muñoz *et al.* 1996). These objectives include representing all the variables of interest and eliminating redundancies and products outside the defined category (Muñoz *et al.* 1996). Typically this number ranges from 12-30 samples.

Table 2.1 Retail locations where commercially-available samples were purchased

Store name	Ownership	Classification	Location
The Community Mercantile	Consumer-owned	Cooperative	901 Iowa Street Lawrence, KS 66044
Cosentino's Price Chopper	Retailer-owned (Associated Wholesale Grocers, Kansas City, KS)	Cooperative	3700 West 95th Street Shawnee Mission, KS 66206
Dillon's	The Kroger Company	Supermarket	130 Sarber Lane Manhattan, KS 66502
Dillon's	The Kroger Company	Supermarket	1000 Westloop Place Manhattan, KS 66502
Dillon's	The Kroger Company	Supermarket	1740 Massachusetts Street Lawrence, KS 66044
Hy-Vee	Employee-owned (Hy-Vee, West Des Moines, IA)	Cooperative	601 3rd Place Manhattan, KS 66502
Ray's Apple Market	Retailer-owned (Associated Wholesale Grocers, Kansas City, KS)	Cooperative	222 North 6th Street Manhattan, KS 66502
Wal-Mart	Wal-Mart Stores, Inc.	Supercenter	101 Bluemont Avenue Manhattan, KS 66502
Whole Foods Market	Whole Foods Market, Inc.	Natural and organic food supermarket	7401 West 91st Street Overland Park, KS 66212
Whole Foods Market	Whole Foods Market, Inc.	Natural and organic food supermarket	6621 West 119th Street Overland Park, KS 66209

In this first tasting, samples were simply grouped as "standard," "different," or somewhere in between. Non-cow's milk yogurts, such as soy, goat, and coconut, had radically different flavors compared to the rest of the plain yogurt category. Thus the experts felt that these samples should not be included in the study. Inclusion of these samples would require additional sensory terminology specific to them. For example, beany is a flavor associated with soymilk (Chambers *et al.* 2006) but not normally with cow's milk. Additional terms would only lengthen the final lexicon and cause difficulties when analyzing the results. The sensory space would be inclusive of a much wider variety of flavor and texture, making subtle differences between cow's milk yogurts more difficult to ascertain in the presence of non-cow's milk yogurts. Muñoz *et al.* (1996) emphasize the importance of establishing clear category boundaries, hence why the researchers proceeded forward with only cow's milk yogurts. From these remaining samples, the experts identified a series of potential options.

A second, slower, and more methodical tasting was held to specifically examine the samples by categorical grouping (i.e. Greek-style, set-style, conventional, and organic). Within each category, each fat level was tasted, and similar samples were indentified. When redundancies of sensory characteristics were detected, additional eliminations were made while keeping overall brand representation as a consideration. The final list of samples determined from this second approach was identical to the list developed after the first tasting. A third and final tasting was held to confirm the decisions made at the conclusion of the previous two tastings.

Table 2.2 lists the final 29 samples selected for testing, organized by percent milk fat. Samples specifically identified on their packaging as organic or Greek-style/strained are also indicated. These samples represented a snapshot of the entire U.S. plain yogurt category. By categorical classification alone, they covered each combination of percent milk fat, milk type (organic or conventional), and physical processing (set-style, stirred, and Greek-style/strained). This sample set also included top-selling category leaders, private label store-brands, and smaller, independent brands. They selected samples also covered an extensive range of flavors and textures, so as to capture the full variety of sensory characteristics evident within the whole category without any redundancies. A sample set size of 29 included enough samples so that overall trends could be examined, and clusters could be determined and few enough samples that the entire study could be easily managed and completed in a reasonable timeframe.

New samples were purchased and new prototypes were produced for each of the three independent evaluations. All samples were stored in a 4 °C walk-in refrigerator (Jamison Built Doors, Hagerstown, Maryland, U.S.A.) until testing. The prototypes were approximately 10 days old when evaluated, and all market samples were evaluated at least 10 days prior to the end of their labeled shelf-lives.

Table 2.2 Classifications of the samples evaluated

Milkfat category	Percent milkfat	Organic	Greek	Brand
Nonfat	**<0.05**	X		Stonyfield
Nonfat	**<0.05**	X		Wallaby
Nonfat	**<0.05**	X	X	Stonyfield
Nonfat	**<0.05**		X	The Greek Gods
Nonfat	**<0.05**		X	Fage
Nonfat	**<0.05**		X	Siggi's
Nonfat	**<0.05**			Belfonte
Nonfat	**<0.05**			Cascade Fresh
Nonfat	**<0.05**			Dannon
Nonfat	**<0.05**			Hy-Vee
Nonfat	**<0.05**			Best Choice
Nonfat	**<0.05**			Great Value (8 oz)
Nonfat	**<0.05**			Great Value (32 oz)
Nonfat	**<0.05**			Weight Watchers
Nonfat	**<0.05**			Control prototype
Nonfat	**<0.05**			Lemon prototype
Nonfat	**<0.05**			Citric acid prototype
Low-fat	**1.0**			Anderson Erikson
Low-fat	**1.0**	X		Private Selection
Low-fat	**1.0**	X		Seven Stars Farm
Low-fat	**1.5**	X		Nancy's
Low-fat	**1.5**			Dannon
Low-fat	**2.0**	X		Wallaby
Low-fat	**2.0**		X	Fage
Whole milk	**3.5**	X		Nancy's
Whole milk	**3.5**			Dannon
Whole milk	**5.0**	X		Cultural Revolution
Whole milk	**8.8**		X	Voskos
Whole milk	**20.0**		X	Cascade Fresh

Panelists

Samples were evaluated by a six-person highly-trained descriptive panel at the Sensory Analysis Center (Kansas State University, Manhattan, Kansas, U.S.A.). Prior to this study, each panelist had completed over 120 hours of general training in descriptive sensory analysis methodology. This training comprised of exercises involving a variety of foods and beverages, including dairy foods. All conditions set by the Kansas State University Committee on Research Involving Human Subjects (Institutional Review Board) were met for this study.

Orientation and lexicon development

Ten 90-minute orientation sessions were held prior to testing, for a total orientation period of 15 hours. The first part of orientation focused on exposing the panelists to the wide variety of yogurts included in the study. The panelists tasted samples one-at-a-time, independently wrote all of the sensory descriptors that they perceived, and then participated in group discussions moderated by the principal researcher. Predominant flavor attributes were identified and further clarified when confusion arose. More subtle, harder-to-describe flavors were also discussed. The first few sessions helped the panelists understand the scope of different attributes necessary to describe yogurt flavor and texture and the breadth of these attributes within the category.

The following sessions focused on evaluation procedures and lexicon development. An initial lexicon was presented that included previously-published terminology from studies of fermented milks and yogurt (Barnes *et al.* 1991; Harper *et al.* 1991; Muir and Hunter 1992; Hunter and Muir 1993; Drake *et al.* 2000; Ott *et al.* 2000; Coggins *et al.* 2008). Other lexicons from descriptive studies of fluid milk (Claassen and Lawless 1992; Lawless and Claassen 1993; Frost *et al.* 2001; Francis *et al.* 2005), ultrapasteurized milk (Chapman *et al.* 2000, Oupadissakoon *et al.* 2009), cheese (Heisserer and Chambers 1993; Drake *et al.* 2001; Retiveau *et al.* 2006; Talavera-Bianchi and Chambers 2008), soymilk (Torres-Penaranda and Reitmeier 2001; Day N' Kouka *et al.* 2004; Chambers *et al.* 2006), and ice cream (Thompson *et al.* 2009) were also considered during terminology development. Many attributes, definitions, and references remained the same; however, a few changes were made.

Since the predominant flavors in yogurt are dairy and sour notes, special attention was given to these attributes and their scales. The overall dairy and dairy fat scales were expanded so that low intensity samples would be rated lower and higher intensity samples would be rated higher, thus better capturing subtle intensity differences in the samples. The sour attributes were organized in such a way that the different sour flavors (ex. lactic, acetaldehyde, etc.) were components to an overall sour score. This structure was created in order to better compartmentalize the variety of sour flavors present in yogurt. The goal was to separate out as many of the flavors as possible into individual attributes in order to avoid having confounded terms that were inclusive of more than one sensory perception.

At this point during orientation and lexicon development, the principal researcher consulted with experts in the field of dairy science that were familiar with the technical language associated with yogurt evaluations. Both experts also had experience in traditional dairy quality judging and the language used in those settings. This conversation served to validate the language developed by the panel and ensure that all important yogurt-related terminology was included. Based on this meeting, the flavor descriptor acetaldehyde was added to the lexicon. This term, although initially unfamiliar to the descriptive panel, is consistent in dairy science-focused evaluations of yogurt and refers to the green apple flavor associated with fresh yogurts (Harper *et al.* 1991; Tribby 2009).

Other clarifications were made regarding some of the dairy and off-flavors. Diacetyl flavor is another important dairy science term, and it was captured in the lexicon as the term buttery since the compound diacetyl is commonly associated with buttery flavor (Drake 2001). Rancid off-flavors such as cardboard and oxidized were also discussed. In dairy science, the singular terms rancid and oxidized are used, where the term rancid refers to flavors resulting from hydrolytic rancidity, and the term oxidized refers to flavors resulting from light-activated oxidation (Tribby 2009). Hydrolytic rancidity is the process in which triglycerides are hydrolyzed into free fatty acids and glycerol. This cleavage can either occur due to high temperatures (chemical hydrolysis) or enzymes, specifically lipase (enzymatic hydrolysis) (Schmidt 2000). Since the yogurts were not exposed to temperatures necessary for chemical hydrolysis (between 225-280 °C), any hydrolytic rancidity in the samples would likely be attributed to enzymatic hydrolysis (Schmidt 2000). The flavor of these free fatty acids was captured in the flavor attributes butyric (butyric acid) and goaty (caproic, caprylic, and capric acids). The flavors due to light-activated oxidation, or autoxidation, were captured in the lexicon as cardboard and plastic (Tribby 2009).

The last few orientation sessions with the panel focused on finalizing the references and becoming comfortable and confident using the established lexicon and data collection procedures. Many of the panelists were accustomed to using solely paper ballots; therefore they required some practice using the data collection equipment and software. At this time, the panelists evaluated several practice samples and were able to compare and discuss their scores so that any confusion with the language or scales could be clarified. Examples of confusion that was clarified included the texture attribute degree of dissolving and its scale. A low score for degree of dissolving indicated a low degree of dissolving. However, several of the panelists were reversing the scale and giving samples with a low degree of dissolving a high score. After discussion, the panelists understood how to use the scale properly, and they were able to make notes of these clarifications to keep with them during evaluation in case they forgot. By the end of orientation, the panel was also able to eliminate several references that were either redundant or unnecessary. The final lexicon used for evaluation included 25 flavor, four texture, four mouthfeel, and two mouthcoating attributes (Table 2.3 and Table 2.4).

Table 2.3 Flavor attributes and definitions used for evaluation

Attribute	Definition	Reference
Dairy flavors		
Overall dairy[A]	The general term for aromatics associated with products made from cow's milk	Carnation Instant Nonfat Dry Milk = 3.0 (flavor) Dillon's Skim Milk = 5.0 (flavor) Dillon's 2% Milk = 8.0 (flavor) Dillon's Whole Milk = 9.0 (flavor)
Dairy fat[AB]	The oily aromatics reminiscent of milk or dairy fat	Carnation Instant Nonfat Dry Milk = 1.0 (flavor) Dillon's Skim Milk = 2.5 (flavor) Dillon's 2% Milk = 4.0 (flavor) Dillon's Whole Milk = 5.5 (flavor) Dillon's ½ and ½ = 7.5 (flavor) Hiland Sour Cream = 8.5 (flavor)
Buttery[B]	The aromatics commonly associated with natural, fresh, slightly salted butter	Land O'Lakes Unsalted Butter = 7.0 (flavor)
Cooked[B]	The combination of brown flavor notes and aromatics associated with heated milk	Heated Whole Milk = 4.5 (flavor)
Processed	The dry, powdery impression found in non-fat dry milk/buttermilk solids	Jell-O Fat Free Tapioca Pudding Snack = 4.5 (flavor) Carnation Instant Nonfat Dry Milk = 7.5 (flavor)
Butyric[AB]	An aromatic that is sour and cheesy, reminiscent of baby vomit	DiGiorno Grated Romano Cheese = 6.0 (aroma) DiGiorno Grated Romano Cheese = 9.0 (flavor) Butyric acid (character reference)
Whey	Sweet, slight brown, dry aromatic impression associated with processed dairy products	Frigo Lowfat Ricotta Cheese = 5.5 (flavor)
Off-flavors		
Animalic[B]	A combination of aromatics associated with farm animals and the inside of a barn.	5,000 ppm 1-phenyl-2-thiourea in propylene glycol
Cardboard[C]	Aromatic associated with cardboard and paper	Cardboard in water = 7.5 (aroma)
Filler[A]	The impression of a thickening substance added to the base product (e.g. starch)	Jello Instant Pudding & Pie Filling Vanilla Flavor = 4.5 (flavor)
Goaty[B]	An aromatic that is pungent, musty, and somewhat sour, reminiscent of wet animal hair (fur).	Kraft 100% Grated Parmesan Cheese = 5.0 (flavor) Private Selection Feta Cheese = 8.0 (flavor) Hexanoic acid in propylene glycol
Grain-like	Brown aromatics that are musty, dusty, and malty. May include sweet, sour, and slightly fermented	Post Grape Nuts = 11.0 (flavor)
Lemon	The citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatics associated with lemon	McCormick Pure Lemon Extract in milk = 4.0 (flavor)
Moldy	The combination of aromatics generally associated with molds; they usually are earthy, dirty, stale, musty, and slightly sour	10,000 ppm 2-ethyl-1-hexanol in propylene glycol Kraft Mild Cheddar Cheese = 3.0 (flavor)

Oil-like	The aromatics commonly associated with oil, excluding dairy fat and milkfat	Cool Whip = 5.0 (flavor)
Plastic	An aromatic associated with plastic polyethylene containers or food stored in plastic	Ziploc Bag in Covered Snifter = 3.5 (aroma)
Oxidized	Aromatic commonly associated with oxidized fat and oils, may include painty and fishy	Microwaved Wesson Vegetable Oil = 7.0
Sharp/sour flavors		
Sharp/bite[B]	The total impact of the flavor notes associated with the combination of aromatics that are sour, astringent, and pungent	Kraft Mozzarella Cheese = 3.5 (flavor) Kraft Mild Cheddar Cheese = 6.5 (flavor)
Overall sour	The overall perception of sourness that includes sour taste and sour aromatics	Hiland Sour Cream = 4.5 (flavor) Dillon's Cultured Lowfat Buttermilk = 8.0 (flavor)
Lactic	The slightly citrus-like sour aromatic of cultured dairy products	0.2% lactic acid solution = 3.0 (flavor) 0.4% lactic acid solution = 6.0 (flavor) 0.6% lactic acid solution = 9.0 (flavor) 0.8% lactic acid solution = 11.0 (flavor)
Acetaldehyde[D]	The delicate, green apple-like sour aromatic of cultured dairy products	2 ppm acetaldehyde in Dillon's 2% Milk = 2.5 (flavor) Green Apple Jolly Rancher = 12.0 (flavor)
Sour[AB]	Fundamental taste sensation of which lactic acid and citric acid are typical	0.025% citric acid solution = 2.5 0.035% citric acid solution = 3.5 0.080% citric acid solution = 5.0 0.100% citric acid solution = 7.0 0.150% citric acid solution = 9.5 0.200% citric acid solution = 12.5
Basic tastes		
Sweet[AB]	Fundamental taste sensation of which sucrose is typical	1% sucrose solution = 1.0 2% sucrose solution = 2.0
Salty[AB]	Fundamental taste sensation of which sodium chloride is typical	0.15% sodium chloride solution = 1.5 0.20% sodium chloride solution = 2.5
Bitter[AB]	Fundamental taste sensation of which caffeine or quinine are typical	0.010% caffeine solution = 2.0 0.020% caffeine solution = 3.5 0.035% caffeine solution = 5.0

[A] Language used by Thompson *et al.* 2009
[B] Language used by Rétiveau *et al.* 2005
[C] Language used by Chambers *et al.* 2005
[D] Language used by Harper *et al.* 1991

Table 2.4 Texture, mouthfeel, and mouthcoating attributes used for evaluation

Attribute	Definition	References
Texture		
Firmness[A]	The force required to compress the sample between the tongue and palate	Jello Instant Pudding & Pie Filling Vanilla Flavor = 3.0 Hiland Sour Cream = 4.5 Philadelphia Cream Cheese = 10.0
Smoothness	Degree to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy	Musselman's Apple Butter = 6.0 Duncan Hines Creamy Home Style Classic Vanilla Icing = 10.0 Hiland Sour Cream = 14.0
Thickness	A measure of the consistency of the product when manipulating sample on roof of mouth with tongue	Eagle Brand Sweetened Condensed Milk = 5.0 Jello Instant Pudding & Pie Filling Vanilla Flavor = 9.0 Hiland Sour Cream = 14.0
Degree of dissolving	The amount of sample that dissolves rather than remains as a semi-solid, after 6 manipulations with the tongue disregarding particles. Use ½ teaspoon	Hiland Sour Cream = 3.5 Jello Instant Pudding & Pie Filling Vanilla Flavor = 7.5
Mouthfeels		
Astringent[B]	Puckering or a tingling sensation on the surface and/or edges of the tongue or mouth	0.025% alum solution = 1.5 0.050% alum solution = 2.5 0.100% alum solution = 5.0
Tooth etch[B]	The sensation of abrasion and drying of the surfaces of the teeth	0.1% alum solution (astringent 5.0 cup) = 4.0 Diluted Welch's Grape Juice = 6.0
Fat feel[A]	Refers to the intensity of the oily feeling in the mouth when the product is manipulated between the tongue and the palate; perceived fat content	Dillon's ½ and ½ = 8.0
Chalky mouthfeel[A]	The measure of the dry, powdery sensation in the mouth	Jello Instant Pudding & Pie Filling Vanilla Flavor = 4.0 Eagle Brand Sweetened Condensed Milk (¼ tsp) = 7.5 HIland Sour Cream = 10.0
Mouthcoatings		
Fatty mouthcoating	The amount of fat/oily film left on surfaces of mouth after swallowing or expectorating	Land O' Lakes Unsalted Butter = 5.0 Dillon's ½ and ½ = 6.0 Cool Whip = 7.5
Chalky mouthcoating	A measure of the dry, powdery sensation in the mouth after swallowing or expectorating	Eagle Brand Sweetened Condensed Milk (¼ tsp) = 7.5 Hiland Sour Cream = 10.0 Duncan Hines Creamy Home Style Classic Vanilla Icing = 14.0

[A] Language used by Thompson *et al.* 2009
[B] Language used by Chambers *et al.* 2005

Experimental design

In addition to the blind servings during the orientation period, panelists saw each sample three times, once each for three independent replications of the sample set. The samples were not identical from one evaluation to the next since the commercially-available samples were purchased and the prototypes were produced new each time. However, for the design, it was assumed that the differences were negligible, thus each evaluation was treated as a replication. The serving orders were completely randomized within each replication, with some adjustments being made to minimize position, order, and carry-over effects.

Carry-over and other context effects are well-documented phenomena in sensory evaluation (Lawless and Heymann 1999). Because they can cause biases in evaluation, randomization is recommended in order to "ensure that sample order is counterbalanced as far as possible" (Lawless and Heymann 1999). Due to the number of samples involved with this study, a completely counterbalanced design was not possible; however, considerations were made in order to minimize these effects. Particularly sour or chalky samples were generally placed in the last position of each testing day in order to prevent subsequent samples from being scored higher or lower due to carry-over. Serving orders were also adjusted so that the same sample was not always seen in the same position (ex. first, last, etc.) during the testing day or relative position (ex. first day, last day, etc.) during each replication.

Muñoz *et al.* (1996) recommends that all samples be tested as approximately the same age. Salvador and Fiszman (2004), Isleten and Karagul-Yuceer (2006), and Kumari *et al.* (2008) all reported significant changes in plain yogurt flavor and texture over time, primarily increased firmness and sourness. Therefore, samples with earlier ends of shelf-lives, as indicated on their packaging, were placed earlier in the presentation order, in an effort to keep these changes from affecting the evaluation. All prototypes were evaluated at approximately 10 days old, and all commercially-available samples were evaluated at least 10 days prior to the end of their indicated shelf-lives. The full experimental design is located in Appendix B.

Evaluation procedures

Samples were removed from the walk-in refrigerator and monitored with a temperature probe an hour before evaluation. Samples were tempered to approximately 10 °C, as it was determined that attributes could better be assessed at a slightly-above refrigeration temperature. Lawless and Heymann (1999) reported that volatile flavors can be perceived better in 15 °C fluid milk than 4 °C; however, Francis *et al.* (2005) found that temperature did not significantly affect the flavor and texture evaluation of nonfat and whole milks. Rašić and Kurmann (1978) reported that "cold perception disturbs the taste perception" in yogurt evaluation. Drake *et al.* (2000) and Isleten *et al.* (2006) described tempering yogurt samples to 15 and 10 °C, respectively. Opinions on appropriate serving temperatures of dairy products seem to differ; therefore, it was decided to evaluate samples at a temperature slightly above refrigeration temperature and below room temperature – 10 °C.

Immediately before serving, the top layer of yogurt and whey were scraped off and discarded, making sure to scrape around the edges where the lid meets the container using white, odorless plastic spoons (Dart® S6BW; Dart Container Corporation, Mason, Minnesota, U.S.A.). This step was taken to ensure that samples were uniform, a general good practice in all sensory testing. Next, a fresh spoon was used to scoop 2 oz. portions into clear, odorless 3.25 oz cups (P325; Solo Cup Company, Lake Forest, Illinois, U.S.A.) which were labeled with random three-digit blinding codes. Cardello and Segars (1989) reported that sample size affected texture scores; thus, it was imperative that approximately the same sample sizes were served to the panel.

Set and stirred yogurts vary in their processing methods and textures. Excessive stirring of yogurt can cause casein and whey to separate (known as syneresis), further leading to changes in consistency and viscosity (Rašić and Kurmann 1978). Additional stirring affects the yogurt gel and can result in a "smoother body and less gel-like texture" in comparison to set-style ones (Chandan and O'Rell 2006). Thus in order to preserve the gel structure and texture of the samples, the portions were scooped using only one or, when necessary, two dips into the container.

Samples were served monadic sequentially, with each member of the panel seeing the same sample at the same time. Samples were evaluated using a hybrid descriptive analysis method adapted from the Flavor Profile Method (Cairncross and Sjöstrom 1950; Sjöstrom 1954; Caul 1957; Meilgaard *et al.* 1991; Keane 1992) and Texture Profile Method (Brandt, Skinner, and Coleman 1963; Szczesniak 1963; Szczesniak, Brandt, and Friedman 1963; Muñoz *et al.* 1992). The intensity of each attribute was scored based on a 15-point numerical scale with 0.5 point increments where 0.0 = none, 0.5 – 5.0 = slight, 5.5 – 10.0 = moderate, and 10.5 – 15.0 = high. References for each attribute were used as scale anchors to calibrate   the scores (Lawless and Heymann 1998; Muñoz and Civille 1998; Meilgaard *et al.* 2007). Expectoration of samples was encouraged but not required.

Each panelist scored the products independently and recorded their scores electronically (Compusense® five 4.6 and Compusense® Commuter 2.0, Compusense Inc., Guelph, Ontario, Canada, 2005). The panelists were also provided with paper ballots as a preventative back-up in case computer files were lost or damaged and as a cross-reference in case they accidentally entered scores incorrectly. The paper ballots also helped the panelists focus on the sample evaluation by allowing them to score attributes in whichever order they preferred. They then transferred their scores from the paper ballot to the computer while they waited on the next sample. A copy of the paper ballot is located in Appendix C.

Panelists were provided deionized, carbon-filtered water, unsalted crackers, and Reduced Fat Triscuits (Nabisco, East Hanover, New Jersey, U.S.A.) for palate cleansing. The panel completed between four to five samples during each 90 minute session, averaging about 17 minutes per sample (including short breaks between each to minimize carry-over effects). Twenty total sessions were held over a seven-week period, and evaluation sessions occurred on weekdays during the same midmorning timeslot. The second replication directly followed the first replication; however, a period of three weeks separated the second replication from the third replication. A single-day 90 minute reorientation period was held prior to the third replication to refresh panelists with the terminology, references, and scales. The full experimental design is located in Appendix B.

Statistical analysis

The data were analyzed using a combination of univariate and multivariate statistical methods (SAS®, 2008, version 9.2; SAS Institute Inc., Cary, N.C., USA). Analyses of variance (ANOVA) were carried out for each attribute (Muñoz *et al.* 1996; Lawless and Heymann 1998; Meilgaard *et al.* 2007). The sample effect was tested using the sample by replication interaction as the testing term. For attributes in which the sample effect was significant ($\alpha = 0.05$), pairwise comparisons of the sample means were tested using the least significant difference (LSD) method. Relationships among the descriptive attributes were determined using correlation analysis, and significance was determined using Pearson's test.

Principal components analysis (PCA) and cluster analysis (CA) were employed to further explore the relationships among samples with respect to their statistically significant attributes (Muñoz *et al.* 1996; Lawless and Heymann 1998; Meilgaard *et al.* 2007). Separate principal component analyses were carried out for the samples' mean flavor attribute scores and mean texture attribute scores. The variance-covariance matrix was used for both analyses since the attributes were all scored using the same scale (Johnson 1998). Eigenvalues and scree plots were used to decide the number of principal components. The eigenvectors were used to determine the characteristics of each principal component.

Principal components scores were then used in the CA. Samples were hierarchically grouped by flavor and texture following Ward's and average methods, respectively. Cubic clustering criteria, pseudo-Hotelling's T^2 statistics, and tree diagrams were used to decide the number of clusters for each analysis (Johnson 1998). The characteristics of each cluster were determined by their location within the principal component space. The code used to carry out all analyses is located in Appendix D, and the evaluation criteria used for the multivariate analyses are located in Appendices E and F.

References

Barnes, DL, Harper, SJ, Bodyfelt, FW, McDaniel, MR. 1991. Correlation of descriptive and consumer panel flavor ratings for commercial prestirred strawberry and lemon yogurts". J Dairy Sci 74:2089-2099.

Brandt, MA, Skinner EZ, Coleman, JA. 1963. The texture profile method. J Food Sci 28:404-409.

Boomgaarden, TA, Schmidt, KA. 2009. Effect of acidulant addition on yogurt fermentation. Dairy Research 2009: Report of Progress. Manhattan: Kansas State University Research and Extension. p 52-55.

Cairncross, SE, Sjöstrom, LB. 1950. Flavor profiles—a new approach to flavor problems. Food Technology 4:308-311.

Cardello, AV, Segars, RA. 1989. Effects of sample size and previous mastication on texture judgments. J. Sensory Stu. 4:177–215.

Caul, JF. 1957. The profile method of flavor analysis. Adv Food Res 7:1-40.

Chambers, E IV, Jenkins, A, McGuire, BH. 2006. Flavor properties of plain soymilk. J Sensory Stu 21:165-179.

Chandan, RC, O'Rell, KR. 2006. Principles of yogurt processing. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 195-209.

Chapman, KW, Lawless, HT, Boor, KJ. 2001. Quantitative descriptive analysis and principal component analysis for sensory characterization of ultra pasteurized milk. J Dairy Sci 84:12-20.

Claassen, M, Lawless HT. 1992. Comparison of descriptive terminology system for sensory evaluation of fluid milk. J. Food Science 57, 596-600.

Coggins, PC, Schilling, MW, Kumari, S Gerrard, PD. 2008. Development of a sensory lexicon for conventional milk yogurt in the United States. J Sensory Stu 23: 671-687.

Day N' Kouka, KD, Klein, BP, Lee, SY. 2004. Developing a lexicon for descriptive analysis of soymilks. J Food Sci 67:259-263.

Drake, MA, Chen, XQ, Tamarapu, S, Leenanon, B. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. J Food Sci 65:1244-1247.

Drake, MA, McIngvale, SC, Gerrard, PD, Cadwallader, KR, Civille, GV. 2001. Development of a descriptive language for Cheddar cheese. J Food Sci 66:1422-1427.

Francis, LL, Chambers, DH, Kong, SH, Milliken, GA, Jeon, IJ, Schmidt, KA. 2005. Serving temperature effects on milk flavor, milk aftertaste, and volatile compound qualification in nonfat and whole milk. J Food Sci 70:413-418.

Frost, MB, Dijksterhuis, G, Martens, M. 2001. Sensory perception of fat in milk. Food Qual Pref 12:327-336.

Harper, SJ, Barnes, DL, Bodyfelt, FW, McDaniel, MR. 1991. Sensory ratings of commercial plain yogurts by consumer and descriptive panels. J Dairy Sci 74:2927-2935.

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

Hunter, EA, Muir, DD. 1993. Sensory properties of fermented milks: objective reduction of an extensive sensory vocabulary. J Sensory Studies 8:213-227.

Isleten, M, Karagul-Yuceer, Y. 2006. Effects of dried dairy ingredients on physical and sensory properties of nonfat yogurt. J Dairy Sci 89:2865-2872.

Johnson, DE. 1998. Applied multivariate methods for data analysts. Pacific Grove: Duxbury Press. 567 p.

Keane, P. 1992. The flavor profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 1-14.

Kumari, S, Coggins, PC, Wilson, JC, Rowe, D. 2008. Combined effects of storage time and temperature on sensory characteristics of plain yogurt. Abstract. HortScience 43:628.

Lawless, HT, Claassen, MR. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. J Food Sci 58:108-112.

Lawless, HT, Heymann, H. 1999. Sensory evaluation of food. New York: Springer. 837 p.

Meilgaard, MC, Civille, GV, Carr, BT. 2007. Sensory evaluation techniques. 4th ed. Boca Raton: CRC Press. 448 p.

Muñoz, AM, Chambers, E IV, Hummer, S. 1996. A multifaceted category research study: how to understand a product category and its consumer responses. J Sensory Stu 11:261-294.

Muñoz, AM, Civille, GV 1998. Universal product and attribute specific scaling and the development of common lexicons in descriptive analysis. J Sensory Stu 13:57-75.

Muñoz, AM, Szczesniak, AS, Einsten, MA, Schwartz, NO. 1992. The texture profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 35-50.

Muir, DD, Hunter, EA. 1992. Sensory evaluation of fermented milks: vocabulary development and the relations between sensory properties and composition and between acceptability and sensory properties. J Soc Dairy Tech 45:73-80.

Ott, A, Hugi, A, Baumgartner, M, Chaintreau, A. 2000. Sensory investigation of yogurt flavor perception: mutual influence of volatiles and acidity". J Agric Food Chem 48: 441-450.

Oupadissakoon, G, Chambers, DH, Chambers, E IV. 2009. Comparison of the sensory properties of ultra-high-temperature (UHT) milk from different countries. J Sensory Stu 24:427-440.

Rašić, JL, Kurmann, JA. 1978. Yoghurt, scientific grounds, technology, manufacture and preparations. Copenhagen: Rašić, JL, Kurmann, JA. 466 p.

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

Salvador, A, Fiszman, SM. 2004. Textural and sensory characteristics of whole and skimmed flavored set-type yogurt during long storage. J Dairy Sci 87:4033-4041.

Schmidt, K. 2000. Lipids: Functional Properties. In: Christen, GL, Smith, JS, editors. Food chemistry: principles and applications. West Sacramento: Science Technology System. p 97-113.

Sjöstrom, LB. 1954. The descriptive analysis of flavor. In: Peryam, D, Pilgrim, F, Peterson, M, editors. Food acceptance testing methodology. Chicago: Quartermaster. p 25-61.

Szczezsniak, AS. 1963. Classification of textural characteristics. J Food Sci 28:385-389.

Szczezsniak, AS, Brandt, MA, Friedman, HH. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. J Food Sci 28:397-403.

Talavera-Bianchi, M, Chambers, DH. 2008. Simplified lexicon to describe flavor characteristics of Western European cheese. J Sensory Stu 23:468-484.

Thompson, KR, Chambers, DH, Chambers, E IV. 2009. Sensory characteristics of ice cream produced in the U.S.A. and Italy. J Sensory Stu 24:396-414.

Torres-Penaranda, AV, Reitmeier, CA. 2001. Sensory descriptive analysis of soymilk. J Food Sci 66:352-356.

Tribby, D. Yogurt. In: Clark, S, Costello, M, Drake, MA, Bodyfelt, F, editors. The sensory evaluation of dairy products. 2nd ed. New York: Springer. p 191-223.

CHAPTER 3 - Sensory characteristics and classification of commercial and experimental plain yogurts

Make [food] simple and let things taste of what they are - Curnonsky, author

Abstract

This research aimed to determine the sensory characteristics of commercially-available plain yogurts and examine how three "more sustainable" prototypes compared. Three experimental non-fat set-style yogurts were provided – one control and two samples that differed in fermentation time. These shortened fermentation times could result in energy reductions and potentially substantiate a “sustainable” marketing claim, a concept gaining traction with consumers. Twenty-six commercially-available yogurts varying in percent milk fat, milk type (organic or conventional), and processing (set-style, stirred, or strained/Greek-style) were also included. Using descriptive sensory analysis, a six-person highly-trained panel scored the intensity of 25 flavor, six texture, four mouthfeel, and two mouthcoating attributes on a 15-point numerical scale. Three replications were conducted, and all samples were tested at least 10 days prior to the end of their shelf-lives. The samples differed for 19 flavor and all texture, mouthfeel, and mouthcoating attributes. Cluster analysis indicated approximately seven flavor and five texture (texture, mouthfeel, and mouthcoating combined) clusters, resulting in 15 unique combinations of flavor and texture. Although no legal definitions exist for “sustainable,” the prototypes’ sensory characteristics were comparable to those of top-selling yogurts indicating potential market viability. This research also demonstrated potential growth opportunities. Despite the current diversity, several combinations of flavor and texture were not represented.

Introduction

Yogurt is a vast category with a long and rich history. At its most basic level, yogurt is a fermented milk product cultured with the lactic acid-producing bacteria *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. The cultures metabolize the lactose in the milk and produce lactic acid, which coagulates the proteins, thus creating the characteristic yogurt gel.

Sensory quality of dairy products, including yogurt, is vital since the best ingredients make the best final products, and quality drives consumer acceptance (Harper *et al.*

1991; Drake 2007). Traditional dairy quality judging initially emerged to address the need of evaluating yogurt quality, but as the field of sensory science developed, objective analytical methods were increasingly adopted as an alternative (Richter 1979; Bodyfelt 1981; McGill 1983; Tamime *et al.* 1987). In order to better understand quality, researchers began using descriptive sensory analysis methods to evaluate yogurts' flavor, texture, appearance, and aroma. The information provided by these types of studies was both useful alone and when correlated to instrumental analyses and/or consumer studies of liking and acceptance (Claassen and Lawless 1992; Lawless and Claassen 1993).

Initial descriptive terms for yogurt included acetaldehyde, cooked milk, caramel, milky, buttery, cheesy, yeasty, salty, sweet, sour, astringent, and bitter (Barnes *et al* 1991, Harper *et al.* 1991). Further studies of the entire category of fermented milk products expanded the descriptive language used to evaluate yogurts. These lexicons included flavor attributes, such as rancid, creamy, lemon, and chemical, and texture attributes, such as firmness, creamy, thick, slimy, curdy, mouth-coating, and chalky (Muir and Hunter 1992, Hunter and Muir 1992). Coggins *et al.* (2008) developed a comprehensive yogurt lexicon based on this previous research. Of 61 identifiable appearance, flavor, aroma, and texture attributes, 37 terms significantly differentiated between yogurt products, and their findings indicated that taste and texture differentiated yogurt samples more aptly that appearance or aroma.

Despite its simplicity, even the texture and flavor of plain yogurt, without any added sweeteners or flavors, can vary greatly depending on the ingredients, what has been added, and how it was made. The milk itself can vary in milk fat percentage, and it can come from either conventional or organic sources. Coggins *et al.* (2008) reported that no differences were found in the sensory characteristics of organic and conventional yogurts. Research on commercial fluid milk by Fillion and Arazi (2002) demonstrated this same pattern.

Ingredients, such as milk proteins, whey proteins, and a variety of starches, can be added to stabilize yogurt gels. They are cheap; however, they can often cause deleterious effects on texture, flavor, and appearance at higher concentrations. Drake *et al.* (2003) reported that whey proteins and caseinates exhibited higher animal/wet dog, brothy, cardboard, and astringent flavors than skim milk powders. The research of Isleten and Karagul-Yuceer (2006) indicated that sodium caseinate-fortified yogurts had higher animal-like flavor than the control. Added soy proteins thickened yogurts in a study conducted by Drake *et al.* (2000), but they also increased soy aroma, soy flavor, and chalkiness.

These stabilizers, along with other fortifications such as vitamin and minerals, can also alter the nutritional profile. Additional calcium fortification has been shown to not affect sensory characteristics; however, little research has been carried out to determine the effect of other vitamins and minerals on flavor and texture (Singh and Muthukumarappan 2007). Added preservatives or additional heat treatment steps can increase the shelf-life, but they too can affect the final product's sensory properties. Potassium sorbate, an effective mold and yeast-inhibitor, is often associated with negative, atypical flavor (Tribby 2009).

Sales of yogurt products saw substantial increases in the 1970s and 1980s, and despite the slowing rates of the past several years, sales continue to rise at gradual pace with new products being introduced each year. Recently, increased interest and demand for functional foods and more "natural" foods have led to many new products with specific claims such "immunity boost," "lower cholesterol," "lower blood pressure," "digestive health," "organic," and "natural" (Mintel 2008). The market has also seen considerable growth among both smaller and private-label brands (Mintel 2009).

As opposed to the term "organic," no specific set of standards exist that define a sustainable product; however, the trend towards "green" living and consumer social responsibility has increased in recent years (Mintel 2010). Sales of "green" products slowed down some due to the economic troubles in the United States in the late 2000s, but market research indicates that the market will pick up in 2010 and continue to increase as the economy improves (Mintel 2010). Furthermore, the behavior of consumers committed to the green lifestyle seems to remain consistent regardless of the economic climate (Mintel 2010). Therefore, new introductions to the market with the value-added benefit of being “more sustainable” could benefit from this increased interest in “green” products. It is necessary, however, to determine how these potential new products compare to those already available to consumers. Therefore, the objectives of this research were to (1) generate a thorough lexicon for plain yogurts that captures the full range of sensory characteristics evident in the category; (2) by using this new language, compare the sensory properties of a wide range of commercially available plain yogurts; and (3) compare sensory properties of three sustainable plain yogurt prototypes to the commercially-available samples.

Materials and methods

Samples

Fifty-four commercially-available plain yogurt samples were purchased from a variety of retailers located within a 125 mile radius of Kansas City, Kansas, U.S.A (Appendix A). The yogurt samples differed in percent milk fat, milk type (organic or conventional), physical processing (set-style, stirred, or strained/Greek-style), and brand. Five experts, two graduate students and three faculty members, tasted all of the samples in order to identify samples with standard or unique sensory characteristics which would represent the entire scope of the plain yogurt category. The sample selection procedure followed the steps outlined by Muñoz *et al.* (1996) for category review studies. After eliminating any redundancies, 26 representative samples were selected for evaluation. Once purchased, the samples were stored in a 4 °C walk-in refrigerator (Jamison Built Doors, Hagerstown, Maryland, U.S.A.) until testing.

Three prototypes, two “more sustainable” samples and a control, were prepared in a food-grade laboratory at Kansas State University (Manhattan, Kansas, U.S.A.). The “more sustainable” samples were developed using novel production methods that were demonstrated to reduce fermentation time (Boomgaarden and Schmidt 2009). The prototype samples were stored in the same walk-in refrigerator as the commercially-available samples until testing. New commercially-available samples were purchased and new prototypes were produced for each of the three independent evaluations. The prototypes were approximately 10 days old when evaluated, and all commercially-available samples were evaluated at least 10 days prior to the end of their labeled shelf-lives. All 29 samples (26 commercially-available plus the three prototypes) are presented in Table 3.1.

Table 3.1 Classifications of the samples evaluated

Milk fat category	Percent milk fat	Organic	Greek/ strained	Brand	Number
Nonfat	**<0.05**	X		Stonyfield	24
Nonfat	**<0.05**	X		Wallaby	28
Nonfat	**<0.05**	X	X	Stonyfield Oikos	21
Nonfat	**<0.05**		X	The Greek Gods	15
Nonfat	**<0.05**		X	Fage	14
Nonfat	**<0.05**		X	Siggi's	23
Nonfat	**<0.05**			Belfonte	2
Nonfat	**<0.05**			Cascade Fresh	4
Nonfat	**<0.05**			Dannon	8
Nonfat	**<0.05**			Hy-Vee	18
Nonfat	**<0.05**			Best Choice	3
Nonfat	**<0.05**			Great Value (8 oz)	17
Nonfat	**<0.05**			Great Value (32 oz)	16
Nonfat	**<0.05**			Weight Watchers	29
Nonfat	**<0.05**			Control prototype	11
Nonfat	**<0.05**			Lemon prototype	12
Nonfat	**<0.05**			Citric acid prototype	10
Lowfat	**1.0**			Anderson Erikson	1
Lowfat	**1.0**	X		Private Selection	22
Lowfat	**1.0**	X		Seven Stars Farm	25
Lowfat	**1.5**	X		Nancy's	19
Lowfat	**1.5**			Dannon	7
Lowfat	**2.0**	X		Wallaby	27
Lowfat	**2.0**		X	Fage	13
Whole milk	**3.5**	X		Nancy's	20
Whole milk	**3.5**			Dannon	9
Whole milk	**5.0**	X		Cultural Revolution	6
Whole milk	**8.8**		X	Voskos	26
Whole milk	**20.0**		X	Cascade Fresh	5

Panelists and lexicon development

Samples were evaluated by a six-person highly-trained descriptive panel at the Sensory Analysis Center (Kansas State University, Manhattan, KS, U.S.A.). All measures set forth by the Kansas State University Committee on Research Involving Human Subjects (Institutional Review Board) were met for this study. Prior to this study, each panelist had completed over 120 hours of general training in the descriptive sensory analysis methodology which included exposure to dairy products. Ten 90-minute orientation sessions were held prior to testing for a total orientation period of 15 hours.

An initial lexicon was presented that included previously-published terminology from studies of fermented milks and yogurt (Barnes *et al.* 1991; Harper *et al.* 1991; Muir and Hunter 1992; Hunter and Muir 1993; Drake *et al.* 2000; Ott *et al.* 2000; Coggins *et al.* 2008). Other lexicons from descriptive studies of fluid milk (Claassen and Lawless 1992; Frost *et al.* 2001; Francis *et al.* 2005), ultrapasteurized milk (Chapman *et al.* 2000, Oupadissakoon *et al.* 2009), cheese (Heisserer and Chambers 1993; Drake *et al.* 2001; Retiveau *et al.* 2006; Talavera-Bianchi and Chambers 2008), soymilk (Torres-Penaranda and Reitmeier 2001; Day N' Kouka *et al.* 2004; Chambers *et al.* 2006), and ice cream (Thompson *et al.* 2009) were also considered during terminology development. Experts in dairy science were also consulted to ensure that the language was actionable for product developers/dairy scientists.

During these orientation discussions, many of the previous attributes, definitions, and references remained the same; however, a few changes were made. The overall dairy and dairy fat scales were expanded so that low intensity samples would be rated lower, and higher intensity samples would be rated higher, thus better capturing subtle differences in the samples. The sour attributes were organized in such a way that the different sour flavors (ex. lactic, acetaldehyde, etc.) were components to an overall sour score. The final lexicon used for evaluation included 25 flavor, four texture, four mouthfeel, and two mouthcoating attributes (Table 3.2 and Table 3.3).

Table 3.2 Flavor attributes and definitions used for evaluation

Attribute	Definition	Reference
Dairy flavors		
Overall dairy[A]	The general term for aromatics associated with products made from cow's milk	Carnation Instant Nonfat Dry Milk = 3.0 (flavor) Dillon's Skim Milk = 5.0 (flavor) Dillon's 2% Milk = 8.0 (flavor) Dillon's Whole Milk = 9.0 (flavor)
Dairy fat[AB]	The oily aromatics reminiscent of milk or dairy fat	Carnation Instant Nonfat Dry Milk = 1.0 (flavor) Dillon's Skim Milk = 2.5 (flavor) Dillon's 2% Milk = 4.0 (flavor) Dillon's Whole Milk = 5.5 (flavor) Dillon's ½ and ½ = 7.5 (flavor) Hiland Sour Cream = 8.5 (flavor)
Buttery[B]	The aromatics commonly associated with natural, fresh, slightly salted butter	Land O'Lakes Unsalted Butter = 7.0 (flavor)
Cooked[B]	The combination of brown flavor notes and aromatics associated with heated milk	Heated Whole Milk = 4.5 (flavor)
Processed	The dry, powdery impression found in non-fat dry milk/buttermilk solids	Jell-O Fat Free Tapioca Pudding Snack = 4.5 (flavor) Carnation Instant Nonfat Dry Milk = 7.5 (flavor)
Butyric[AB]	An aromatic that is sour and cheesy, reminiscent of baby vomit	DiGiorno Grated Romano Cheese = 6.0 (aroma) DiGiorno Grated Romano Cheese = 9.0 (flavor) Butyric acid (character reference)
Whey	Sweet, slight brown, dry aromatic impression associated with processed dairy products	Frigo Lowfat Ricotta Cheese = 5.5 (flavor)
Off-flavors		
Animalic[B]	A combination of aromatics associated with farm animals and the inside of a barn.	5,000 ppm 1-phenyl-2-thiourea in propylene glycol
Cardboard[C]	Aromatic associated with cardboard and paper	Cardboard in water = 7.5 (aroma)
Filler[A]	The impression of a thickening substance added to the base product (e.g. starch)	Jello Instant Pudding & Pie Filling Vanilla Flavor = 4.5 (flavor)
Goaty[B]	An aromatic that is pungent, musty, and somewhat sour, reminiscent of wet animal hair (fur).	Kraft 100% Grated Parmesan Cheese = 5.0 (flavor) Private Selection Feta Cheese = 8.0 (flavor) Hexanoic acid in propylene glycol
Grain-like	Brown aromatics that are musty, dusty, and malty. May include sweet, sour, and slightly fermented	Post Grape Nuts = 11.0 (flavor)
Lemon	The citric, sour, astringent, slightly sweet, peely, and somewhat floral aromatics associated with lemon	McCormick Pure Lemon Extract in milk = 4.0 (flavor)
Moldy	The combination of aromatics generally associated with molds; they usually are earthy, dirty, stale, musty, and slightly sour	10,000 ppm 2-ethyl-1-hexanol in propylene glycol Kraft Mild Cheddar Cheese = 3.0 (flavor)

Oil-like	The aromatics commonly associated with oil, excluding dairy fat and milkfat	Cool Whip = 5.0 (flavor)
Plastic	An aromatic associated with plastic polyethylene containers or food stored in plastic	Ziploc Bag in Covered Snifter = 3.5 (aroma)
Oxidized	Aromatic commonly associated with oxidized fat and oils, may include painty and fishy	Microwaved Wesson Vegetable Oil = 7.0
Sharp/sour flavors		
Sharp/bite[B]	The total impact of the flavor notes associated with the combination of aromatics that are sour, astringent, and pungent	Kraft Mozzarella Cheese = 3.5 (flavor) Kraft Mild Cheddar Cheese = 6.5 (flavor)
Overall sour	The overall perception of sourness that includes sour taste and sour aromatics	Hiland Sour Cream = 4.5 (flavor) Dillon's Cultured Lowfat Buttermilk = 8.0 (flavor)
Lactic	The slightly citrus-like sour aromatic of cultured dairy products	0.2% lactic acid solution = 3.0 (flavor) 0.4% lactic acid solution = 6.0 (flavor) 0.6% lactic acid solution = 9.0 (flavor) 0.8% lactic acid solution = 11.0 (flavor)
Acetaldehyde[D]	The delicate, green apple-like sour aromatic of cultured dairy products	2 ppm acetaldehyde in Dillon's 2% Milk = 2.5 (flavor) Green Apple Jolly Rancher = 12.0 (flavor)
Sour[AB]	Fundamental taste sensation of which lactic acid and citric acid are typical	0.025% citric acid solution = 2.5 0.035% citric acid solution = 3.5 0.080% citric acid solution = 5.0 0.100% citric acid solution = 7.0 0.150% citric acid solution = 9.5 0.200% citric acid solution = 12.5
Basic tastes		
Sweet[AB]	Fundamental taste sensation of which sucrose is typical	1% sucrose solution = 1.0 2% sucrose solution = 2.0
Salty[AB]	Fundamental taste sensation of which sodium chloride is typical	0.15% sodium chloride solution = 1.5 0.20% sodium chloride solution = 2.5
Bitter[AB]	Fundamental taste sensation of which caffeine or quinine are typical	0.010% caffeine solution = 2.0 0.020% caffeine solution = 3.5 0.035% caffeine solution = 5.0

[A] Language used by Thompson *et al.* 2009
[B] Language used by Rétiveau *et al.* 2005
[C] Language used by Chambers *et al.* 2005
[D] Language used by Harper *et al.* 1991

Table 3.3 Texture, mouthfeel, and mouthcoating attributes used for evaluation

Attribute	Definition	References
Texture		
Firmness[A]	The force required to compress the sample between the tongue and palate	Jello Instant Pudding & Pie Filling Vanilla Flavor = 3.0 Hiland Sour Cream = 4.5 Philadelphia Cream Cheese = 10.0
Smoothness	Degree to which the sample feels smooth and free of lumps/particulates as opposed to lumpy, rough, grainy, gritty, and/or sandy	Musselman's Apple Butter = 6.0 Duncan Hines Creamy Home Style Classic Vanilla Icing = 10.0 Hiland Sour Cream = 14.0
Thickness	A measure of the consistency of the product when manipulating sample on roof of mouth with tongue	Eagle Brand Sweetened Condensed Milk = 5.0 Jello Instant Pudding & Pie Filling Vanilla Flavor = 9.0 Hiland Sour Cream = 14.0
Degree of dissolving	The amount of sample that dissolves rather than remains as a semi-solid, after 6 manipulations with the tongue disregarding particles. Use ½ teaspoon	Hiland Sour Cream = 3.5 Jello Instant Pudding & Pie Filling Vanilla Flavor = 7.5
Mouthfeels		
Astringent[B]	Puckering or a tingling sensation on the surface and/or edges of the tongue or mouth	0.025% alum solution = 1.5 0.050% alum solution = 2.5 0.100% alum solution = 5.0
Tooth etch[B]	The sensation of abrasion and drying of the surfaces of the teeth	0.1% alum solution (astringent 5.0 cup) = 4.0 Diluted Welch's Grape Juice = 6.0
Fat feel[A]	Refers to the intensity of the oily feeling in the mouth when the product is manipulated between the tongue and the palate; perceived fat content	Dillon's ½ and ½ = 8.0
Chalky mouthfeel[A]	The measure of the dry, powdery sensation in the mouth	Jello Instant Pudding & Pie Filling Vanilla Flavor = 4.0 Eagle Brand Sweetened Condensed Milk (¼ tsp) = 7.5 HIland Sour Cream = 10.0
Mouthcoatings		
Fatty mouthcoating	The amount of fat/oily film left on surfaces of mouth after swallowing or expectorating	Land O' Lakes Unsalted Butter = 5.0 Dillon's ½ and ½ = 6.0 Cool Whip = 7.5
Chalky mouthcoating	A measure of the dry, powdery sensation in the mouth after swallowing or expectorating	Eagle Brand Sweetened Condensed Milk (¼ tsp) = 7.5 Hiland Sour Cream = 10.0 Duncan Hines Creamy Home Style Classic Vanilla Icing = 14.0

[A] Language used by Thompson *et al.* 2009
[B] Language used by Chambers *et al.* 2005

Experimental design

In addition to the blind servings during the orientation period, panelists saw each sample three times, once each for three replications of the sample set. The serving orders were completely randomized within each replication, with some adjustments being made to minimize position, order, carry-over, and shelf-life effects (Appendix B). Particularly sour or chalky samples were generally placed in the last position of each testing day in order to prevent subsequent samples from being scored higher or lower due to carry-over. Serving orders were also adjusted so that the same sample was not always seen in the same position (ex. first, last, etc.) during the testing day or relative position (ex. first day, last day, etc.) during each replication. Significant changes in plain yogurt flavor and texture, primarily increased firmness and sourness, over time has been reported (Salvador and Fiszman 2004; Isleten and Karagul-Yuceer 2006; Kumari *et al.* 2008). Therefore in an effort to keep these changes from affecting the evaluation, samples with earlier ends of shelf-lives were placed earlier in the presentation order. All prototypes were evaluated at approximately 10 days old, and all commercially-available samples were evaluated at least 10 days prior to the end of their labeled shelf-lives.

Evaluation procedures

Opinions on appropriate serving temperatures of dairy products seem to differ (Rašić and Kurmann 1978; Drake *et al.* 2000; Francis *et al.* 2005; Isleten *et al.* 2006). Therefore, the samples were tempered to approximately 10 °C, between refrigeration and room temperatures, before evaluation. Immediately before serving, the top layer of yogurt and whey were scraped off and discarded, making sure to scrape around the edges where the lid met the container using a white, odorless plastic spoon (Dart® S6BW; Dart Container Corporation, Mason, Minnesota, U.S.A.). A fresh spoon was used to scoop 2 oz. portions into clear odorless 3.25 oz cups (P325; Solo Cup Company, Lake Forest, Illinois, U.S.A.) which were labeled with random three-digit blinding codes. In order to preserve the gel structure and texture of the samples, the portions were scooped using only one or, when necessary, two dips into the container immediately preceding serving.

Samples were served monadic sequentially, with each member of the panel seeing the same sample at the same time. Samples were evaluated using a hybrid descriptive analysis method adapted from the Flavor Profile Method (Cairncross and Sjöstrom 1950; Sjöstrom 1954; Caul 1957; Keane 1992) and Texture Profile Method (Brandt *et al.* 1963; Szczesniak 1963; Szczesniak *et al.* 1963; Muñoz *et al.* 1992). The intensity of each attribute was scored based on a 15-point numerical scale with 0.5 point increments, and references for each attribute were used as scale anchors to calibrate the scores. Expectoration of samples was encouraged but not required, and the panelists were provided distilled, deionized water, unsalted crackers, and Reduced Fat Triscuits (Nabisco, East Hanover, NJ, U.S.A.) for palate cleansing.

For each evaluation, panelists scored samples independently and recorded their scores electronically (Compusense® five 4.6 and Compusense® Commuter 2.0, Compusense Inc., Guelph, Ontario, Canada, 2005). Paper ballots were used as a back-up (Appendix C). The panel evaluated 4-5 samples during each 90 minute session, and twenty total sessions were held over a seven-week period. Evaluation sessions occurred on weekdays during the same midmorning timeslot. The second replication directly followed the first replication; however, a period of three weeks separated the second replication from the third replication. A single-day 90 minute reorientation period was held prior to the third replication to refresh panelists with the terminology, references, and scales.

Statistical analysis

Analyses of variance (ANOVA) were carried out for each attribute, using the sample by replication interaction as the testing term. For attributes in which the sample effect was significant ($\alpha = 0.05$), pairwise comparisons of the sample means were tested using the least significant difference (LSD) method. Relationships among the descriptive attributes were determined using correlation analysis, and significance was determined using Pearson's test. Separate principal component analyses using the variance-covariance matrix were carried out for the samples' mean flavor attribute scores and mean texture attribute scores. Samples were then hierarchically clustered by flavor and texture following Ward's and average methods, respectively.

Results and discussion

Effectiveness of the lexicon

The yogurt samples differed for 29 out of the 35 total attributes. Significant differences between samples were found for 19 of the 25 flavor attributes: overall dairy, dairy fat, buttery, cooked, butyric, whey, animalic, cardboard, goaty, lemon, moldy, plastic, oxidized, sharp/bite, overall sour, lactic, sour, sweet, and bitter flavor attributes (Table 3.4). Samples did not differ with respect to processed, filler, grain-like, oil-like, acetaldehyde, and salty flavors. The samples were significantly different for all of the texture, mouthfeel, and mouthcoating attributes (Table 3.4).

Table 3.4 P-values from the analyses of variance for each sensory attribute

Attribute	P-value	Attribute	P-value
Overall dairy (f)	0.0053*	Overall sour (f)	<0.0001*
Dairy fat (f)	0.0079*	Lactic (f)	<0.0001*
Buttery (f)	0.0318*	Acetaldehyde (f)	0.7973
Cooked (f)	0.0005*	Sour (f)	<0.0001*
Processed (f)	0.1641	Sweet (f)	0.0003*
Butyric (f)	0.0008*	Salty (f)	0.2648
Whey (f)	0.0127*	Bitter (f)	<0.0001*
Animalic (f)	<0.0001*	Firmness (t)	<0.0001*
Cardboard (f)	0.0016*	Smoothness (t)	<0.0001*
Filler (f)	0.3496	Thickness (t)	<0.0001*
Goaty (f)	0.0014*	Degree of dissolving (t)	<0.0001*
Grain-like (f)	0.1505	Astringent (t)	<0.0001*
Lemon (f)	<0.0001*	Tooth etch (t)	0.0011*
Moldy (f)	0.0033*	Fat feel (t)	0.0020*
Oil-like (f)	0.0512	Chalky mouthfeel (t)	<0.0001*
Plastic (f)	0.0329*	Fatty mouthcoating (t)	0.0211*
Oxidized (f)	0.0007*	Chalky mouthcoating (t)	0.0003*
Sharp/bite (f)	<0.0001*		

(f) indicates a flavor attribute, and (t) indicates a texture, mouthfeel, or mouthcoating attribute
Attributes indicated with an asterisk (*) are significant at the α=0.05 level.

Analysis by flavor attributes

Ten of the 19 significant attributes were present in all the samples above threshold (intensity > 0.5) levels; whereas the other nine attributes were present only in some of the samples above threshold levels (Table 3.6). The 10 attributes that were present in all of the samples included overall dairy, dairy fat, cooked, whey, cardboard, sharp/bite, overall sour, lactic, sour, and bitter. Yogurt is primarily characterized by its dairy and sour flavors; thus these results were expected. Previous studies of plain yogurt flavor (Harper *et al.* 1991; Muir and Hunter 1992; Coggins *et al.* 2008) also indicated that dairy and sour flavors were defining sensory characteristics of yogurt.

However, the approach to defining the dairy flavor and sour flavor differed from those studies to the present study. To capture dairy flavor, Harper *et al.* (1991) used cooked milk, milky, buttery, and cheesy as descriptors; Muir and Hunter (1992) used buttery and creamy, and Coggins *et al.* (2008) used sour cream, cream cheese, buttermilk, baby vomit, and milky. Creaminess has been demonstrated to be a complex of flavor and texture, so the term is not particularly helpful in studies using descriptive analysis methods (Civille and Lawless 1986; Mela 1988; Richardson and Booth 1993; Kilcast and Clegg 2002). Descriptors, such as sour cream, cream cheese, buttermilk, and milky, may prove challenging to other people involved with the product research process (ex. product developers) since they are related to a specific product rather than a specific sensory response.

This study endeavored to capture the full range of dairy flavors including the fatty/creaminess (represented as dairy fat), diacetyl (represented as buttery), brown (represented as cooked and whey), short chain fatty acid (represented as butyric), and non-fat dry milk powderiness (represented as processed) aspects. These aspects all contribute to the overall impression perceived as dairy flavor; therefore they were structured into a hierarchical scale under the main attribute *overall dairy*. Higher intensities of these contributing attributes were reflected in higher overall dairy scores. Within this ladder of terms, special attention was given to the attribute *dairy fat*. Oupadissakoon *et al.* (2009) structured the scale with nonfat milk (less than 0.5% milk fat) = 0.0 and half-and-half (about 10% milk fat) = 5.0 on a 15-point scale. The present study encompassed products ranging from less than 0.5% milk fat to about 20%, so this scale needed to allow for those differences. Therefore, the scale was expanded so that half-and-half represented a 7.5 on the 15-point dairy fat scale. Based on the structure of the scale, correlations would naturally exist between the constituents and the overall dairy term. Significant positive correlations were observed between overall dairy, dairy fat, and buttery (Table 3.6). These findings were consistent with previous research.

Drake (2001) found that mild dairy flavors, such as dairy fat, cooked, whey, and buttery (diacetyl), were closely related to one another, yet still remained distinct flavors.

To capture sour flavor, Harper *et al.* (1991) used acetaldehyde and sour as descriptors; Muir and Hunter (1992) used sour/acid and lemon, and Coggins *et al.* (2008) used lactic acid along with the product-specific sour dairy flavors already mentioned. Since sour flavor is such a quintessential component of yogurt flavor, special attention was also given to this scale. A hierarchical scale, similar to that of dairy flavor, was structured. This *overall sour* scale comprised of lactic, acetaldehyde, and fundamental sour taste descriptors. Significant positive correlations were observed between overall sour, lactic, sour, and bitterness (Table 3.6). The correlations between the sour attributes were understandable based on the scale structure. Sour-bitter confusion is a commonly-documented sensory phenomenon; however, in trained panelists, this confusion is highly unlikely. Rather, proteases in yogurt break down proteins leaving peptides that are perceived as bitter on the tongue (Maehashi and Huang 2009). The attributes remained independent descriptors, but they were significantly related due to the innate processes that occur during the aging of fermented foods (Maehashi and Huang 2009).

No significant correlations were observed between the other sour attributes and acetaldehyde, though (Table 3.7). Acetaldehyde, although important to yogurt flavor, was not significant in the analysis of variance. This insignificance could be due to two possibilities: (1) the age of the samples and (2) confusion of the panelists. Acetaldehyde is generally more predominant in younger/fresher yogurts, and it is slowly predominated by lactic acid as the product ages. The commercially-available samples were likely much older than the three prototype samples, so their sour flavor probably came mostly from lactic acid instead. Coggins *et al.* (2008) found that the attribute *green*, one way of describing the flavor of acetaldehyde, was not helpful in differentiating samples. The fact that this term was added late in the orientation period and was previously unknown to the panelists could have contributed to its insignificance as well. As demonstrated by Chambers *et al.* (2004), many descriptive terms can be easily and quickly learned, but others require more time in order to fully understand and recognize when using in evaluations. Perhaps further training on this specific term and its characteristic sensory response could have improved the panelists' ability to identify and rate its intensity in the samples.

The reference for sour taste was citric acid solution; whereas the reference for lactic was lactic acid solution. Lactic acid has been used as a sour taste reference in other studies, and the correlation between these two attributes was 0.94. Based on this correlation, it appears that these terms were rather redundant, and only one was needed to describe the sour taste/lactic flavor sensory response. In addition to the hierarchical sour attributes, overall sour, lactic, and sour taste were significantly correlated to sharp/bite flavor (Table 3.6). Sharp/bite flavor comprises of sour, astringent, and pungent impressions, thus this correlation was understandable. The sharp/bite term did not necessarily contribute any extra understanding about the flavor of yogurt that was not captured by other attributes, hence although it significantly differentiated the samples, it was probably not necessary to evaluate yogurt flavor.

The attributes animalic, buttery, butyric, goaty, lemon, moldy, plastic, oxidized, and sweet were present above threshold levels in some, but not all, of the samples (Table 3.5). Of these nine attributes, sweet, goaty, and butyric were seen most often, with 18, 14, and 12 samples, respectively, having average intensities above 0.5. The other attributes (animalic, buttery, lemon, moldy, plastic, and oxidized) were observed in less than one-third of the samples. Butyric, animalic, and goaty attributes were highly correlated with one another (Table 3.6). The references for butyric and goaty flavor were both fatty acids – butyric and hexanoic/caproic acids, respectively. Animalic was characterized as the aroma of 1-phenyl-2-thiourea. Although 1-phenyl-2-thiourea is structurally different from butyric and hexanoic/caproic acids, its aromatic impression is somewhat similar. Looking at the definitions of animalic and goaty, it is evident that similarities persist due to the overlap of animal-related aromatics.

Lemon, although considered a somewhat sour aromatic, was not correlated to any of the sour flavors (overall sour, lactic, acetaldehyde, and basic sour taste) (Table 3.6). During panel orientation, it was emphasized that the lemon attribute was to be used specifically for rating lemon flavor perception, and all sour flavors should be rated using the specific sour flavor attributes. The panel seemed to be able to make these distinctions aptly, based on the lack of correlations. Plastic and oxidized flavors were significantly correlated to one another and to cardboard flavor. These flavors were all indicative of rancidity; therefore, these correlations are to be expected (Tribby 2009).

Analysis by texture attributes

All of the texture, mouthfeel, and mouthcoating attributes were significant. Firmness and thickness texture attributes were positively correlated, and they were both negatively correlated with degree of dissolving. These trends are to be expected; thicker samples will tend to be firmer, and these thicker, firmer samples will take longer to dissolve in the mouth, indicated by lower intensity scores for degree of dissolving (Folkenberg *et al.* 2006; Janhøj *et al.* 2006). Astringent and tooth etch mouthfeels were positively correlated with each other and with overall sour, lactic, sour taste, sharp/bite, and bitter flavors (Ott *et al.* 2000).

Fatty mouthfeeling and fatty mouthcoating were correlated to one another and with dairy fat and butter flavors (Kilcast and Clegg 2002; Janhøj *et al.* 2006). Chalky mouthfeeling and chalky mouthcoating were also positively correlated to one another. These correlations, too, were understandable since they in essence provided the same type of information about fattiness and chalkiness, respectively. They simply captured the impression of these characteristics in the mouth during ingestion and after swallowing. Despite high correlations between the texture, mouthfeel, and mouthcoating attributes, there do not seem to be any redundancies. However, depending on the specific objectives of the study, both the mouthfeeling and mouthcoating attributes of each impression, fatty and chalky, may not be necessary.

Table 3.5 Attribute means for yogurt samples

Yogurt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	LSD
Overall dairy	6.0	4.3	3.9	4.9	3.7	4.3	5.3	5.4	5.6	4.7	4.8	4.8	5.8	4.4	4.8	5.0	3.4	5.1	4.6	5.0	4.8	4.9	3.4	4.8	3.6	6.3	6.0	5.2	4.1	1.5
Dairy fat	2.6	1.7	1.6	1.7	1.9	2.0	2.2	2.3	2.4	1.9	2.1	1.9	3.6	2.2	2.0	1.7	1.4	1.9	1.6	2.4	2.0	2.2	2.0	1.8	0.8	3.8	2.3	2.0	1.2	1.1
Buttery	0.7	0.2	0.2	0.2	0.3	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.7	0.3	0.3	0.4	0.1	0.3	0.2	0.6	0.2	0.4	0.1	0.3	0.0	1.4	0.5	0.3	0.1	0.6
Cooked	2.7	2.1	1.9	2.0	1.9	2.2	2.4	2.5	2.6	2.3	2.4	2.6	2.2	2.3	2.4	2.3	2.2	2.4	2.0	2.1	2.3	2.3	1.2	2.2	1.6	2.1	2.8	1.9	2.3	0.5
Processed	2.1	3.6	3.4	2.5	3.5	3.4	2.4	2.5	2.3	2.8	3.1	2.5	2.7	2.8	2.4	3.0	3.1	2.3	2.1	2.4	2.9	2.8	3.4	2.5	2.9	2.3	1.7	2.9	2.9	1.1
Butyric	0.4	2.6	1.3	0.3	0.9	1.9	0.3	0.7	0.1	0.1	1.0	0.0	0.4	0.2	0.2	0.2	0.1	1.1	0.8	0.6	0.2	0.2	1.8	0.1	0.1	0.3	0.6	0.4	0.8	1.1
Whey	2.0	1.6	1.9	2.4	1.8	2.4	2.0	2.7	2.1	2.9	2.3	2.2	1.6	2.3	2.6	1.9	2.5	2.3	2.5	2.1	2.8	1.6	1.7	1.9	1.8	2.0	1.4	1.5	2.4	0.8
Animalic	0.1	1.6	1.6	0.1	0.1	1.2	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.1	0.1	0.0	0.7	0.0	0.2	0.1	0.1	2.1	0.0	0.1	0.0	0.0	0.0	0.5	0.9
Cardboard	0.6	2.4	2.1	1.2	2.3	1.5	0.9	0.9	0.9	1.3	1.4	1.0	1.2	1.6	0.8	1.1	1.6	0.8	0.8	0.8	1.5	1.3	2.1	1.0	1.6	0.7	0.9	0.9	1.5	0.9
Filler	1.9	2.7	2.7	2.4	2.6	2.5	2.4	2.3	2.1	2.6	2.8	2.5	2.0	2.6	2.5	2.6	2.2	1.9	2.1	2.0	2.8	2.5	2.9	3.0	2.6	1.7	1.7	1.7	2.6	1.0
Goaty	0.4	1.6	1.5	0.5	0.8	2.3	0.4	0.4	0.7	0.2	1.1	0.1	0.5	1.8	0.8	0.8	0.5	1.5	0.4	0.5	0.3	0.2	1.4	0.1	0.3	0.2	0.6	0.4	1.0	1.0
Grain-like	0.2	0.3	0.2	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.0	0.1	0.2	0.2	0.2	1.0	0.3	0.1	0.2	0.2	0.5	0.2	0.2	0.2	0.1	0.3	0.1	0.1	0.4
Lemon	0.4	0.2	0.1	1.1	0.9	0.0	0.4	0.2	0.6	0.1	0.1	1.9	0.3	0.1	0.5	0.2	0.1	0.3	0.7	0.4	0.2	0.4	0.1	0.2	0.2	0.1	0.3	2.6	0.4	0.6
Moldy	0.1	1.0	0.9	0.4	1.5	1.5	0.1	0.2	0.6	0.1	0.4	0.2	0.4	0.4	0.2	0.4	0.9	0.3	0.3	0.1	0.3	0.1	0.9	0.0	0.4	0.3	0.3	0.3	0.4	0.7
Oil-like	0.9	1.2	1.5	1.4	2.5	1.4	1.0	0.4	1.5	1.3	0.9	1.1	0.4	0.3	0.7	0.9	1.3	0.9	0.8	0.5	1.5	1.0	0.6	1.5	1.5	1.4	1.3	1.0	1.3	1.0
Plastic	0.1	0.7	1.4	0.2	2.4	0.5	0.1	0.0	0.4	0.1	0.1	0.1	0.3	0.1	0.2	0.2	0.6	0.2	0.3	0.1	0.4	0.2	0.3	0.2	0.5	0.4	0.2	0.2	0.6	1.0
Oxidized	0.1	0.5	1.1	0.1	1.6	0.7	0.4	0.1	0.2	0.4	0.3	0.6	0.5	0.2	0.1	0.2	0.4	0.3	0.1	0.2	0.6	0.3	0.6	0.5	1.0	0.4	0.1	0.2	0.2	0.6
Sharp/bite	4.2	4.2	4.5	5.1	5.9	4.9	4.0	3.7	3.1	2.2	4.3	2.6	3.3	4.1	5.0	3.8	3.9	4.8	5.9	5.9	5.1	3.5	6.8	3.2	3.6	3.7	4.2	3.7	4.3	1.5
Overall sour	6.0	6.2	6.5	6.6	8.6	5.8	5.6	5.2	5.1	4.2	6.3	4.4	4.9	5.5	7.3	5.9	5.5	6.4	9.0	8.8	6.9	5.3	9.3	5.3	5.4	5.5	6.6	5.8	6.6	1.5
Lactic	2.4	2.3	2.1	2.6	3.6	2.0	2.2	1.8	1.7	1.4	2.0	1.4	1.6	1.4	2.6	1.9	2.4	2.2	3.6	3.3	2.1	1.8	4.3	1.7	1.9	1.8	2.2	2.3	2.7	1.1
Acetaldehyde	0.7	1.6	1.1	1.1	1.0	1.1	1.1	0.8	0.6	0.7	1.3	0.7	1.2	0.9	0.9	1.8	1.4	0.9	0.8	1.1	1.4	1.4	0.8	1.1	0.9	0.8	1.1	0.8	1.3	1.0
Sour	4.3	4.2	4.8	4.8	7.1	3.9	3.7	3.4	3.6	2.9	4.4	3.3	3.4	3.6	5.1	3.9	3.9	4.6	7.1	6.1	4.9	4.0	7.4	3.8	4.0	3.8	4.4	4.1	4.6	1.3
Sweet	1.1	0.4	0.4	0.5	0.3	0.4	0.8	0.8	0.8	0.9	0.6	1.0	0.7	0.4	0.5	0.9	0.6	0.7	0.4	0.3	0.4	0.7	0.1	0.7	0.6	1.0	1.2	0.7	0.4	0.4
Salty	2.3	1.9	1.8	1.8	2.1	2.1	1.7	1.8	1.7	1.9	1.9	1.8	1.7	1.5	1.8	1.8	2.1	2.1	1.8	2.4	1.9	1.9	1.7	1.6	1.5	1.8	1.9	1.6	1.8	0.5
Bitter	2.8	3.3	3.4	2.8	3.9	3.4	3.0	2.9	2.4	2.2	2.8	2.3	2.6	2.7	3.1	2.7	2.9	3.1	3.6	3.4	3.1	2.4	4.3	2.8	2.9	2.5	2.7	2.9	3.1	0.7
Firmness	2.6	3.3	3.6	3.9	7.2	3.1	3.7	3.3	2.6	3.1	3.9	3.6	5.5	6.8	3.7	2.9	2.5	2.7	4.1	4.7	4.2	3.5	7.2	4.6	2.6	4.8	2.2	1.5	3.4	1.1
Smoothness	12.6	12.6	12.8	9.1	13.3	7.3	8.1	8.0	8.5	6.7	10.4	7.5	12.5	11.9	7.7	12.9	12.1	12.0	8.7	9.7	10.9	11.3	12.4	8.1	8.8	12.5	11.0	12.5	6.2	2.0
Thickness	7.2	8.4	9.6	9.7	14.0	7.3	8.9	8.3	6.7	7.7	9.7	8.8	12.9	13.5	9.4	6.7	5.7	7.5	9.6	10.6	10.2	9.1	13.1	9.4	6.5	12.1	5.1	3.4	8.3	2.0
Degree of dissolving	7.4	5.0	4.8	6.3	3.1	7.1	6.3	6.8	8.0	6.9	5.4	6.3	3.4	3.3	6.7	7.2	8.9	8.1	6.4	5.1	5.7	6.7	3.5	6.5	8.4	4.9	8.2	10.6	7.0	1.5
Astringent	2.7	3.0	3.1	3.0	4.4	2.8	2.5	2.6	2.1	1.6	2.6	1.9	2.6	2.8	4.1	2.7	2.7	3.2	3.9	3.7	3.9	2.5	5.1	2.5	2.4	2.4	2.8	3.1	3.0	1.1
Tooth etch	5.0	5.0	5.2	5.2	6.1	4.9	4.3	5.0	3.6	4.0	4.9	4.1	5.5	5.4	5.9	4.9	4.6	5.3	5.7	5.7	6.1	4.0	7.1	4.6	4.7	3.9	5.0	4.9	5.8	1.3
Fat feel	2.2	1.4	1.4	1.5	2.0	1.8	1.6	1.3	1.8	1.8	1.6	1.9	3.0	1.7	1.0	1.3	0.9	1.3	1.5	2.0	1.3	1.7	0.8	1.4	0.8	3.9	1.8	1.3	1.2	1.1
Chalky mouthfeel	6.0	5.7	6.7	6.5	6.1	5.4	5.6	6.5	5.5	5.3	6.5	5.4	9.1	9.5	7.4	7.0	6.5	6.9	6.4	7.0	6.6	5.4	10.3	6.3	6.8	4.5	6.9	7.0	8.1	2.0
Fatty mouthcoating	1.3	1.2	1.1	1.0	1.9	1.2	1.0	0.8	1.2	1.4	1.1	1.1	1.9	1.4	0.8	0.8	0.8	0.7	0.9	1.3	1.0	1.2	0.7	1.1	0.8	2.9	1.5	1.1	1.1	0.9
Chalky mouthcoating	6.1	5.6	6.5	6.8	6.0	5.5	5.6	7.0	5.9	5.4	6.8	5.6	9.3	9.9	7.6	6.8	6.8	7.1	6.9	6.9	6.8	5.4	10.2	7.1	7.2	4.3	6.8	6.8	7.8	2.2

The corresponding brand names and classifications for the numbered samples (1-29) are located in Table 3.1

Table 3.6 Correlations of the flavor attributes

Attribute	Dairy fat	Buttery	Cooked	Processed	Butyric	Whey	Animalic	Cardboard	Filler	Goaty	Grain-like	Lemon	Moldy	Oil-like	Plastic	Oxidized	Sharp/bite	Overall sour	Lactic	Acetaldehyde	Sour	Sweet	Salty	Bitter
Overall dairy	***0.75***	***0.73***	0.64	***-0.73***	-0.34	-0.09	-0.48	***-0.77***	***-0.66***	-0.37	-0.29	0.13	-0.57	-0.27	-0.48	-0.57	-0.36	-0.33	-0.40	-0.22	-0.40	***0.71***	0.07	-0.57
Dairy fat	1.00	***0.85***	0.30	-0.37	-0.12	-0.16	-0.20	-0.39	-0.50	-0.15	-0.25	-0.07	-0.20	-0.31	-0.21	-0.24	-0.15	-0.17	-0.22	-0.22	-0.20	0.38	0.09	-0.29
Buttery		1.00	0.27	-0.43	-0.17	-0.19	-0.25	-0.46	-0.57	-0.21	-0.24	-0.10	-0.22	-0.12	-0.15	-0.20	-0.21	-0.21	-0.26	-0.16	-0.25	0.52	0.21	-0.35
Cooked			1.00	-0.56	-0.35	0.25	-0.52	-0.56	-0.30	-0.16	0.04	0.02	-0.43	-0.12	-0.36	-0.50	-0.48	-0.47	-0.55	-0.04	-0.54	***0.67***	0.21	***-0.66***
Processed				1.00	0.53	-0.12	0.58	***0.88***	0.62	0.50	0.13	-0.11	***0.71***	0.29	0.56	0.64	0.18	0.11	0.17	0.45	0.16	-0.58	-0.02	0.45
Butyric					1.00	-0.22	***0.85***	0.57	0.21	***0.74***	-0.05	-0.24	0.64	0.01	0.32	0.27	0.50	0.41	0.41	0.21	0.38	-0.47	0.30	0.65
Whey						1.00	-0.21	-0.20	0.18	-0.03	0.11	-0.17	-0.14	-0.07	-0.21	-0.25	0.01	-0.06	-0.10	-0.19	-0.09	-0.10	0.13	-0.12
Animalic							1.00	0.63	0.37	***0.71***	-0.03	-0.28	0.56	-0.03	0.25	0.34	0.44	0.34	0.35	0.15	0.33	-0.52	0.09	0.62
Cardboard								1.00	0.63	0.51	0.16	-0.21	***0.75***	0.37	***0.67***	***0.70***	0.29	0.23	0.27	0.37	0.30	-0.63	-0.06	0.52
Filler									1.00	0.24	-0.03	-0.31	0.23	0.19	0.21	0.43	0.12	0.09	0.04	0.36	0.13	-0.50	-0.23	0.26
Goaty										1.00	0.04	-0.32	0.64	-0.09	0.23	0.17	0.38	0.22	0.13	0.18	0.16	-0.46	0.13	0.44
Grain-like											1.00	-0.24	0.23	0.17	0.09	-0.01	0.00	-0.10	0.02	0.32	-0.09	-0.04	0.28	-0.04
Lemon												1.00	-0.14	0.10	0.00	-0.07	-0.11	-0.04	0.05	-0.30	0.03	0.12	-0.19	-0.11
Moldy													1.00	0.47	***0.75***	0.64	0.40	0.29	0.35	0.16	0.35	-0.50	0.17	0.58
Oil-like														1.00	***0.71***	0.63	-0.04	-0.02	0.04	0.05	0.08	-0.03	0.07	0.09
Plastic															1.00	***0.81***	0.32	0.33	0.36	0.12	0.42	-0.40	0.16	0.51
Oxidized																1.00	0.15	0.11	0.14	0.07	0.23	-0.37	-0.04	0.42
Sharp/bite																	1.00	***0.95***	***0.88***	0.07	***0.92***	***-0.72***	0.35	***0.89***
Overall sour																		1.00	***0.93***	0.03	***0.98***	***-0.67***	0.31	***0.86***
Lactic																			1.00	-0.04	***0.94***	-0.61	0.32	***0.86***
Acetaldehyde																				1.00	-0.05	-0.19	0.14	0.06
Sour																					1.00	***-0.67***	0.26	***0.86***
Sweet																						1.00	-0.02	***-0.78***
Salty																							1.00	0.21
Bitter																								1.00

Numbers underlined and italicized represent significant correlations ($p < 0.0001$)

Table 3.7 Correlations of the texture attributes

Attribute	Firmness	Smoothness	Thickness	Degree of dissolving	Astringent	Tooth etch	Fat feel	Chalky mouthfeel	Fatty mouthcoating	Chalky mouthcoating
Overall dairy	-0.27	0.03	-0.14	0.16	-0.40	-0.41	0.65	-0.30	0.45	-0.29
Dairy fat	0.26	0.28	0.37	-0.35	-0.14	-0.16	***0.86***	-0.04	***0.72***	-0.06
Buttery	0.08	0.24	0.21	-0.19	-0.27	-0.33	***0.91***	-0.30	***0.81***	-0.34
Cooked	-0.41	-0.23	-0.31	0.27	-0.53	-0.45	0.25	-0.35	0.08	-0.31
Processed	0.27	0.25	0.19	-0.31	0.26	0.27	-0.31	0.16	-0.12	0.10
Butyric	0.15	0.22	0.12	-0.30	0.41	0.40	-0.14	0.11	-0.09	0.05
Whey	-0.06	-0.56	0.02	0.07	-0.06	0.04	-0.15	-0.13	-0.25	-0.04
Animalic	0.21	0.22	0.17	-0.32	0.41	0.41	-0.26	0.29	-0.22	0.22
Cardboard	0.43	0.31	0.34	-0.47	0.35	0.37	-0.29	0.26	-0.05	0.21
Filler	0.40	-0.21	0.36	-0.42	0.18	0.26	-0.46	0.18	-0.35	0.21
Goaty	0.19	0.19	0.14	-0.27	0.27	0.34	-0.19	0.33	-0.15	0.29
Grain-like	-0.22	0.16	-0.26	0.28	-0.07	-0.18	-0.31	-0.14	-0.29	-0.09
Lemon	-0.21	-0.02	-0.27	0.34	-0.01	-0.11	-0.03	-0.12	-0.03	-0.13
Moldy	0.28	0.29	0.20	-0.30	0.36	0.30	-0.08	0.05	0.09	0.01
Oil-like	-0.07	-0.03	-0.09	0.09	-0.04	-0.19	0.02	-0.51	0.22	-0.53
Plastic	0.33	0.34	0.29	-0.34	0.37	0.26	0.02	-0.09	0.25	-0.15
Oxidized	0.37	0.24	0.33	-0.37	0.21	0.16	-0.03	-0.06	0.16	-0.09
Sharp/bite	0.47	0.23	0.40	-0.37	***0.92***	***0.83***	-0.23	0.38	-0.17	0.34
Overall sour	0.43	0.21	0.36	-0.33	***0.92***	***0.79***	-0.23	0.35	-0.14	0.30
Lactic	0.38	0.17	0.26	-0.22	***0.86***	***0.73***	-0.27	0.32	-0.18	0.26
Acetaldehyde	-0.04	0.28	-0.01	-0.11	0.04	0.10	-0.21	0.05	-0.14	0.00
Sour	0.49	0.22	0.40	-0.36	***0.91***	***0.76***	-0.21	0.32	-0.11	0.28
Sweet	-0.54	-0.04	-0.48	0.46	***-0.72***	***-0.71***	0.39	-0.47	0.26	-0.46
Salty	-0.10	0.16	-0.05	0.00	0.17	0.15	0.15	-0.27	0.04	-0.32
Bitter	0.45	0.23	0.34	-0.36	***0.88***	***0.79***	-0.34	0.37	-0.22	0.32
Firmness	1.00	0.23	***0.95***	***-0.90***	0.52	0.53	0.24	0.47	0.34	0.47
Smoothness		1.00	0.20	-0.27	0.30	0.22	0.19	0.22	0.26	0.15
Thickness			1.00	***-0.95***	0.42	0.44	0.38	0.34	0.43	0.35
Degree of dissolving				1.00	-0.37	-0.43	-0.36	-0.33	-0.41	-0.31
Astringent					1.00	***0.90***	-0.30	0.50	-0.17	0.45
Tooth etch						1.00	-0.32	***0.71***	-0.22	***0.67***
Fat feel							1.00	-0.30	***0.91***	-0.34
Chalky mouthfeel								1.00	-0.24	***0.98***
Fatty mouthcoating									1.00	-0.29
Chalky mouthcoating										1.00

Numbers underlined and italicized represent significant correlations ($p < 0.0001$)

Characterization and classification of the samples

Analysis by flavor attributes

The 19 significant flavor attributes reduced to two underlying principal components (Figure 3.1). The first principal component (PC 1) explained the greatest amount of total variability in flavor (about 61.3%), primarily sour/sharp flavors. The second principal component (PC 2) explained the other major sources of flavor variability in the samples (about 14.8%), dairy aromatics and generally undesirable off-flavors.

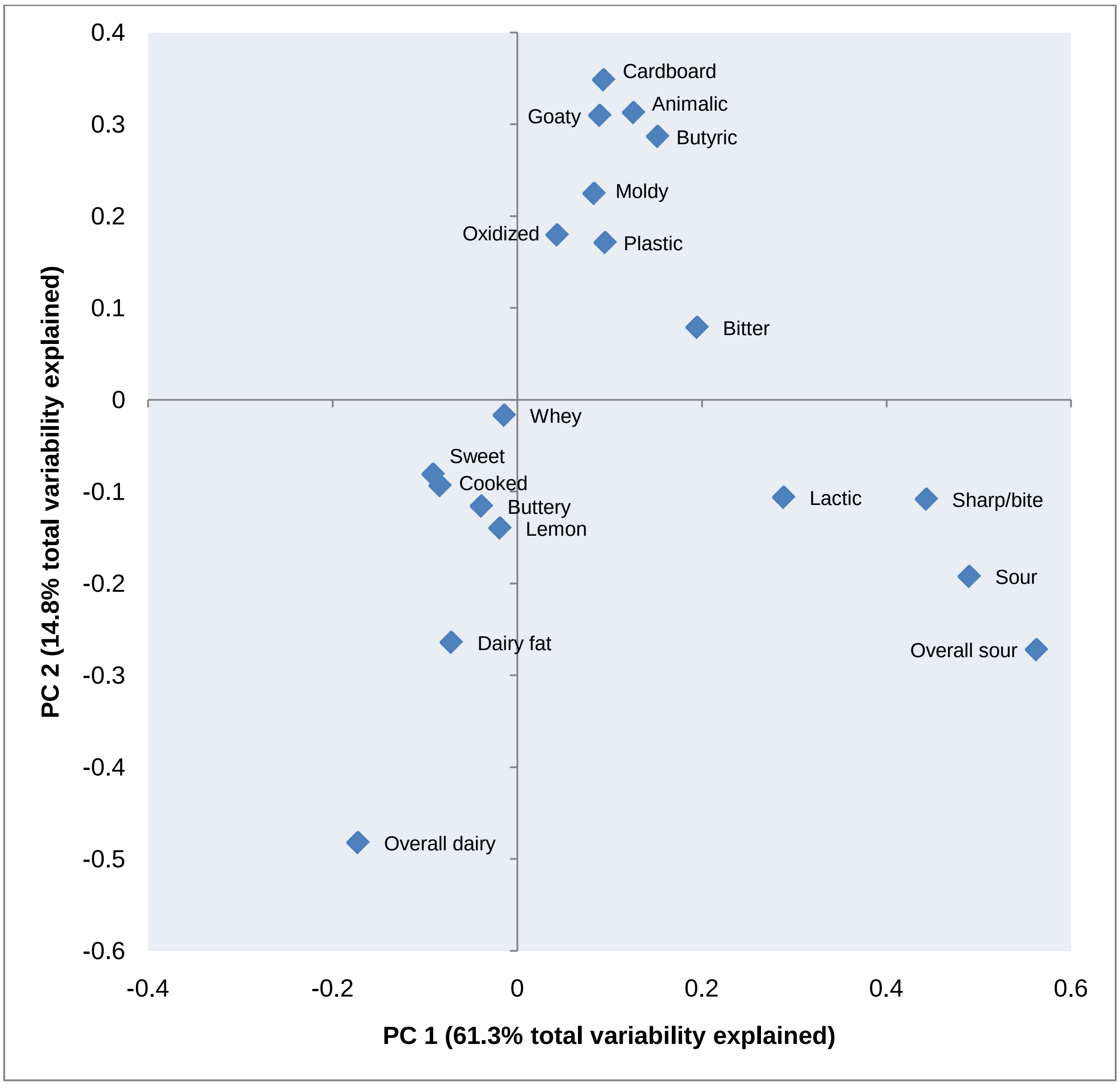


Figure 3.1 Loadings of the significant flavor attributes onto the two PCs

Based on their PC 1 and PC 2 scores, the 29 samples were segmented into seven clusters (Figure 3.2). Overall Cluster 1 samples were the least sour; they also had minimal to moderate dairy and off-flavors. This cluster contained category leaders Dannon and Stonyfield's nonfat varieties along with the prototypes preacidified with lemon juice (Experimental Lemon) and citric acid (Experimental Citric Acid). Both prototypes had slightly less intense sour and dairy flavors than the popular market samples, but of the two prototypes, the Experimental Lemon more closely resembled them. Wal-Mart's Great Value Nonfat packaged in the 32 oz container (Great Value 32 oz) also fell into this cluster. Despite the added stabilizers indicative of other private label store-brand products, Great Value 32 oz had a flavor similar to the products it strives to undercut. It was one of the sourest samples in this cluster, but its dairy flavors were close to those of Stonyfield Nonfat. Although they were low, its off-flavors were slightly higher than those of Dannon and Stonyfield's nonfat products.

Along with Stonyfield Nonfat, this cluster contained two other organic products – Private Selection, a low-fat store-brand product, and Wallaby, a nonfat small-brand product. The flavor of Private Selection and Stonyfield appeared to be similar, but the dairy flavors in Wallaby Nonfat were more intense. Overall, the fact that the milk for these products came from an organic source did not seem to result in uniquely different flavor. These three organic samples clustered with conventional big brands, small brands, and private label store-brands. All three percent milk fat levels of Dannon (nonfat, low-fat, and full fat) clustered into this grouping. This finding indicated that within the scope of the entire plain yogurt category, increased percent milk fat did not seem to drastically change the flavor. Dannon Whole Milk had the highest overall dairy score of the three; however, it was not statistically different from the low-fat and nonfat. Coggins *et al.* (2008) found a similar lack of effects for milk type (organic versus conventional) and percent milk fat on the flavor of yogurts. Fage 2% had the most intense dairy flavors within this cluster, but again these differences were not statistically significant. Interestingly, though, it was the only Greek-style yogurt in this cluster. This finding seems to indicate that thicker texture, a characteristic indicative of these types of products, might lead to higher perceived dairy fat. Studies pertaining to the perception of creaminess have found that thicker textures can often lead to higher perceived milk fat (Mela 1988; Kilcast and Clegg 2002).

Cluster 2 samples were similar to the samples in the lower half of Cluster 1; the major difference between these samples was that the Cluster 2 samples were sourer. The Greek Gods, a nonfat conventional Greek-style yogurt had both the most intense sour and dairy flavors in this cluster. Like Cluster 1, this cluster contained organic and conventional products. Stonyfield Oikos, an organic nonfat Greek-style yogurt, was slightly less sour than The Greek Gods with less intense dairy flavors. Once again, the fact that this product was organic did not seem to impart any unique flavors.

Cluster 3 samples were moderately sour with minimal to moderate dairy and off-flavors. All samples in this cluster were either low-fat or nonfat. Four of the samples, Seven Stars, Great Value 8 oz, Fage 0%, and Weight Watchers, were characterized by low dairy flavors. The remaining two samples, Experimental Control and HyVee, were distinguished by sourer flavors. Unlike the Great Value sample in Cluster 1, Great Value 8 oz was fortified with vitamin A and vitamin D and had added whey protein. Like the private-label store-brand samples in Cluster 4, these added ingredients seemed to result in more intense off-notes like cardboard flavor. This finding is in agreement with previous research. Drake *et al.* (2003) reported that whey proteins exhibited higher animal/wet dog, brothy, cardboard, and astringent flavors. Fage 0%, unlike its low-fat counterpart in Cluster 1, had less intense dairy flavors and more intense sour and off-flavors. In particular, Fage 0% seemed to have a goaty note that was absent in Fage 2%. Based on these findings, the higher percent milk fat might have been able to mask some off-flavors (Hatchwell 1996). Weight Watchers was the sourest sample within this cluster. It was also characterized by low dairy flavors and slight off-flavors, primarily cardboard. HyVee and Experimental Control had the highest dairy flavors in this cluster. Their dairy flavors were similar to Cluster 1 samples; however, their sourer flavors placed them in Cluster 3.

Cluster 4 samples were fairly sour with intense off-flavors. The sourness of samples in this cluster were similar to those of Clusters 2 and 3; the major difference between these clusters was that Cluster 4 samples tended to have more intense off-flavors such as cardboard, animalic, butyric, goaty, moldy, and plastic. Belfonte, a nonfat conventional yogurt produced by a Kansas City-based dairy, had the highest off-flavors. It was characterized primarily by cardboard and goaty flavors, but it also had subtle moldy, plastic, and oxidized notes. Best Choice, another nonfat conventional yogurt, had the next highest off-flavors. Like the Belfonte, Best Choice's off-flavors were mostly cardboard and goaty; however, its animalic, plastic, and oxidized notes were slightly above threshold levels too.

Both of these products had ingredients not seen in most of the other samples – mainly whey protein and potassium sorbate. They both had additional stabilizers too; however, these ingredients were found in samples outside this cluster. Based on this knowledge, it appeared that the whey protein and potassium sorbate had a profound effect on flavor. Tribby (2009) reported that dried milk powders, whey proteins, starch-based stabilizers, and potassium sorbate can cause stale and/or storage off-flavors in yogurts. The other sample in Cluster 4, Cultural Revolution 5%, was categorically unlike the other two. It was organic with a much higher percent milk fat; at about 5% milk fat, it was one of the highest among all of the samples evaluated. Cream was added to the milk to get the higher percentage, and it was "gently processed and never homogenized" according to the package. Rather than scoring high in dairy flavors, it scored low with high off-flavors. Unlike the other two samples in this cluster, though, it was difficult to ascertain the source of these off-flavors.

Cluster 5 samples were moderately sour with high dairy flavors and low off-flavors. This cluster contained two low-fat products and one high fat product. Anderson Erikson was a low-fat conventional yogurt, and Wallaby Low-fat was a low-fat organic yogurt. Once again, it appeared that milk type had no direct effect on yogurt flavor since these conventional and organic products clustered together. The third sample in Cluster 5, Voskos Traditional, was a whole milk (about 8.8% milk fat) conventional Greek-style yogurt. This percent milk fat was much higher than the two low-fat samples; however, the intensity of its dairy flavors, of which dairy fat is a component, was relatively similar. Voskos Traditional's overall dairy and dairy fat flavor intensities were statistically equivalent to those of Anderson Erikson, but it possessed a unique buttery note. Its sour flavors also differed; it was the least sour product in the cluster.

Cluster 6 samples were very sour with higher dairy flavors. These samples were sourer than those of Cluster 3, and their dairy flavors were more intense than those of Cluster 2. The two samples in this cluster were produced by the same company: Nancy's. One is an organic low-fat product; whereas the other is an organic whole milk product. Again, the difference in percent milk fat did not seem to affect the intensity of dairy flavors. It was difficult to determine the reason(s) why these samples were sourer than most of the other commercially-available samples evaluated, though. The experimental design provided for evaluations at a variety of points during its shelf-life, so these differences probably cannot be attributed to increased sourness at the end of shelf-life. Rohm *et al*. (1994) reported differences in acidity flavor due to cultures; however since these samples were purchased and not produced on-site, information about the specific cultures and how they compare to those of the other samples remains unknown.

Cluster 7 samples were very sour with moderate off-flavors and low dairy flavors. Siggi's, a conventional nonfat yogurt, was labeled as "Icelandic-style skyr" on its packaging, and the Cascade Fresh product was merely identified as "Mediterranean-style yogurt" on its label. Skyr is a fermented milk product similar to strained/Greek-style yogurts. After coagulation, the curd is strained to remove excess whey; however rennet is added in addition to the typical yogurt cultures in order to coagulate the milk proteins. Thus skyr is technically a cheese rather than a yogurt, although it is placed in the same section as yogurts in retail locations. Based on the packaging, it is uncertain what Cascade Fresh means by "Mediterranean-style yogurt," but it too has added enzymes, as indicated by its ingredient list. The enzymes in Cascade Fresh Mediterranean-style were not specifically identified, but Siggi's does list vegetable rennet on their ingredient list. It was difficult to determine the exact chemical effect that these enzymes had on the flavor compounds, but both of these samples demonstrated intense sour and off-flavors.

Figure 3.2 Flavor clusters with respect to the two principal components

Analysis by texture attributes

The 10 texture attributes reduced to three underlying principal components. The first principal component (PC 1) explained the greatest amount of total variability in texture (about 59.6%), thick/firm texture. The second principal component (PC 2) explained the next greatest amount of total variability (about 20.0%), smooth texture. Finally the third principal component (PC 3) primarily explained variability due to chalkiness (about 14.4%); however, the remaining attributes (astringent, tooth etch, fat feel, and fatty mouthcoating) also loaded onto this principal component.

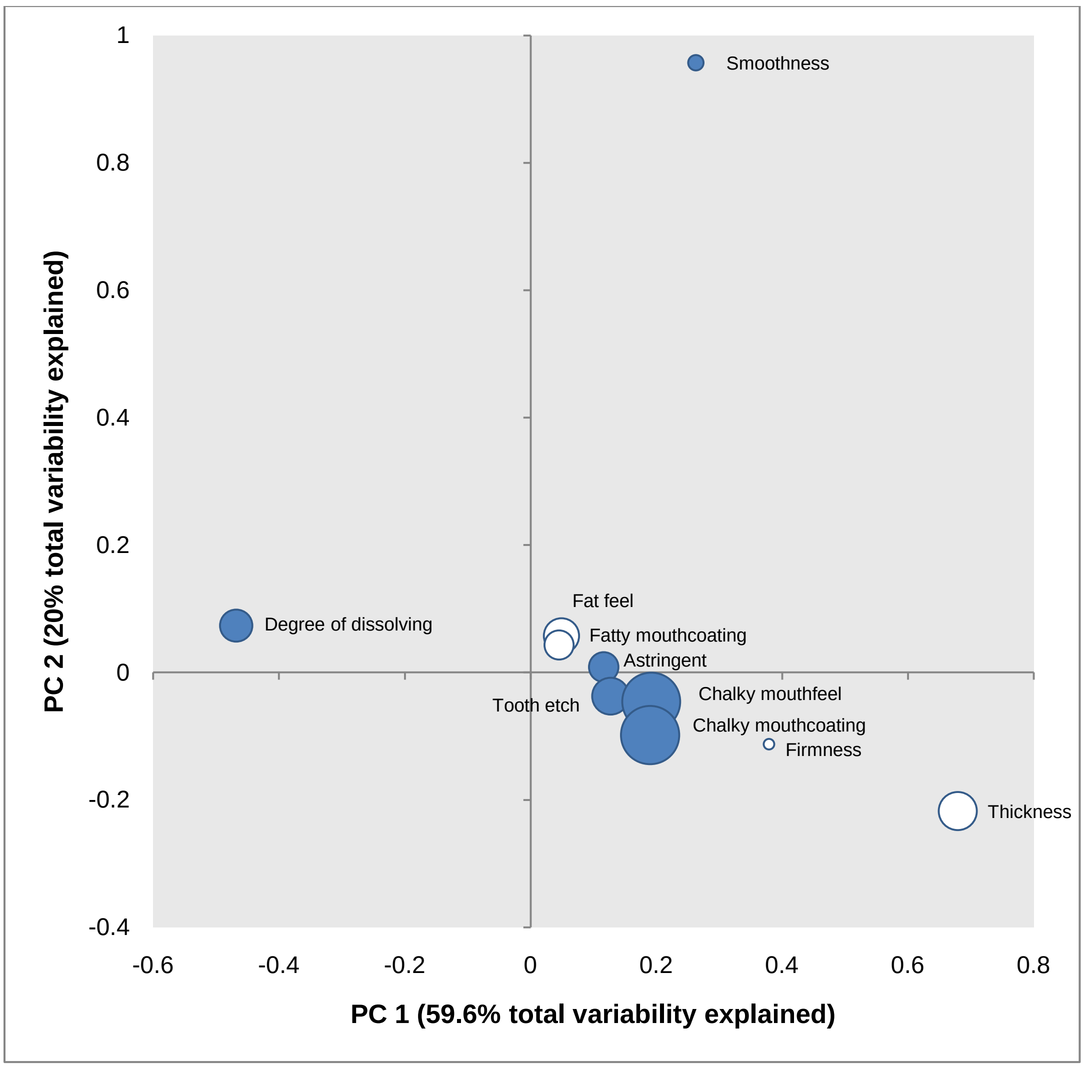


Figure 3.3 Loadings of the significant texture attributes onto the three PCs

Based on their PC 1, PC 2, and PC 3 scores, the 29 samples were segmented into five clusters (Figure 3.4). Cluster 1 samples were moderately thick, somewhat gritty/lumpy, and slightly chalky with low fat feel. This cluster contained category leaders Dannon and Stonyfield's nonfat varieties along with all three prototype samples. With the exception of Cultural Revolution 5%, all of these samples were set-style. These findings seem to indicate that most of the traditional set-style yogurts (Dannon Nonfat, Dannon Lowfat, Dannon Whole Milk, Weight Watchers, Stonyfield Nonfat, and the experimental prototypes) were moderately thick and smooth. Cascade Fresh Nonfat, Experimental Control, Nancy's Organic Nonfat, and Nancy's Organic Low-fat, were the only exception to this trend. They too were traditional set-style yogurts, but they were bit thicker than most of the other set-styles.

Cluster 2 samples were moderately thick, very smooth and absent of particles/lumps, and slightly chalky with low fat feel. The textures of Cluster 2 samples were similar to Cluster 1 samples, except that Cluster 2 samples were much smoother. With the exception of Great Value 32 oz, all of these samples were stirred -style. These findings were consistent with known textural differences between set-style and stirred-style yogurts. Chandan and O'Rell (2006) stated that stirred yogurts generally have a "smoother body and less gel-like texture" in comparison to set-style ones. The smooth samples in this cluster happened to be mostly store-brands. Best Choice and Belfonte were the thickest and least smooth samples in the cluster; whereas HyVee, Great Value 32 oz, and Anderson Erikson were less thick and slightly smoother. Wallaby Low-fat had similar smoothness to the store-brands, but it was thinner.

Cluster 3 samples were very thick and firm, relatively smooth, and very chalky with low fat feel. All three samples in this cluster were strained/Greek-style. Strained/Greek-style yogurts are known for their thicker texture, so these findings were to be expected (Chandan and O'Rell 2006). Cluster 4 samples were thick and firm, rather smooth, low in chalkiness, and high in fat feel. The two samples in this cluster were also strained/Greek-style, but they differed from those in Cluster 3 because they were not nearly as chalky. The source of this chalkiness remains unknown. Whereas the added enzymes in Siggi's and Cascade Fresh Mediterranean-style distinguished their flavors from other samples, it did not seem to have an effect on the chalkiness. These two samples were some of the thickest and firmest evaluated, but Siggi's was chalky while Cascade Fresh Mediterranean-style was not.

Surprisingly, some samples that were not strained/Greek-style had thicker, firmer texture than those that were. Nancy's Organic Whole Milk and Best Choice, both set-style yogurts, were found to be thicker and firmer than the specifically labeled Greek-style Stonyfield Oikos, Voskos Traditional, and The Greek Gods. The other Nancy's sample, Nancy's Organic Low-fat, was also rather thick, firm, and smooth with a texture similar to Stonyfield Oikos. The Greek Gods, although advertised as Greek-style, did not seem to possess the same thickness and firmness of the other Greek-style samples. Six regular yogurts – Nancy's Organic Whole Milk, Best Choice, Nancy's Organic Low-fat, Experimental Control, Belfonte, and Cascade Fresh Nonfat – were thicker and firmer. In terms of thick and smooth texture, it seemed to most resemble Cascade Fresh Nonfat.

Cluster 5 comprised of only one sample, Wallaby Nonfat. It was very runny, smooth, somewhat chalky, and low in fat feel. This sample's texture was similar to Wallaby Low-fat in Cluster 2, but it was runnier and smoother. Since milk fat can increase the viscosity of dairy products, this decreased thickness and firmness might be due to the decreased percent milk fat.

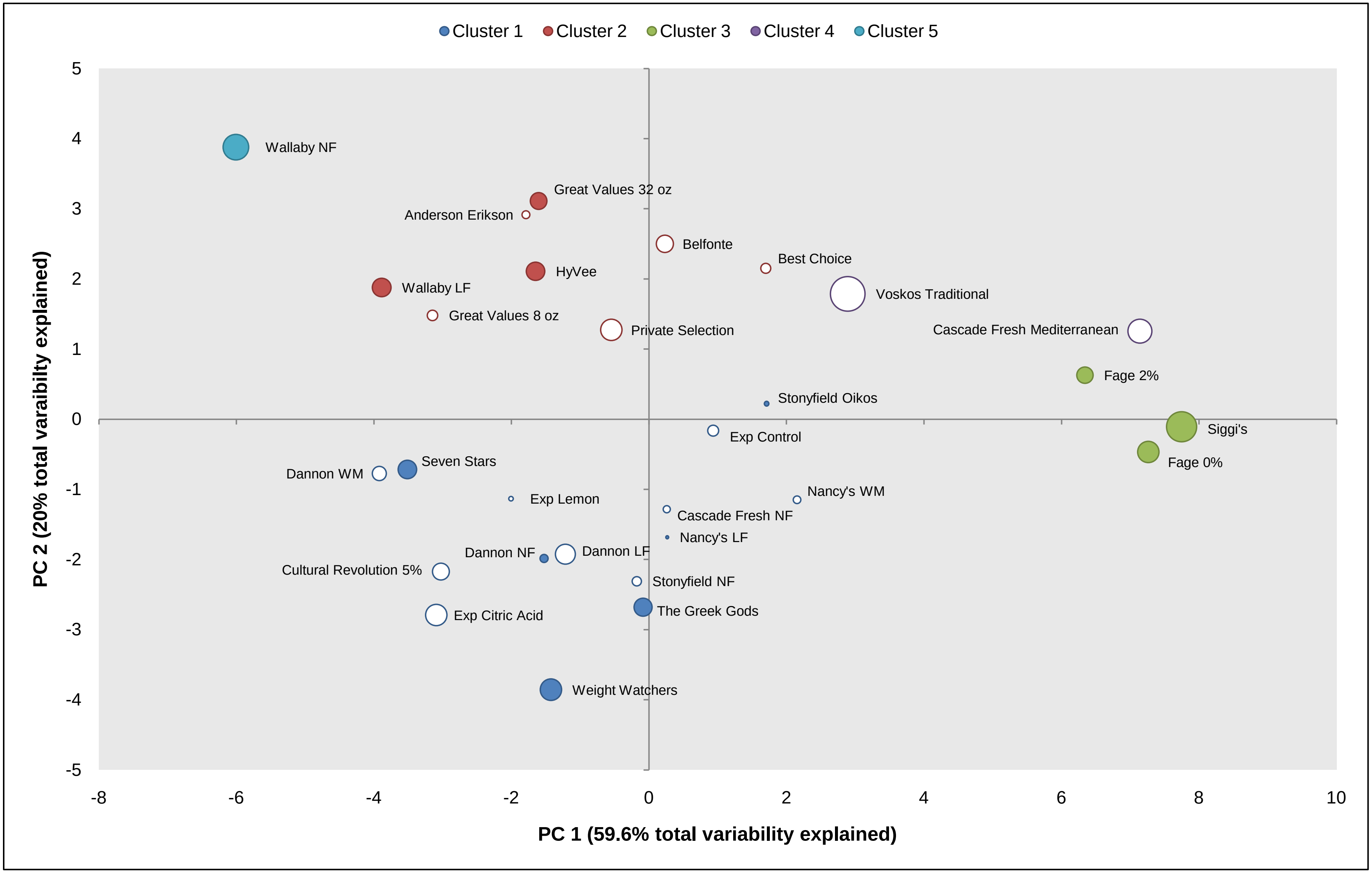


Figure 3.4 Texture clusters with respect to the three principal components

Analysis of flavor and texture combinations

In total based on the seven flavor and five texture clusters, there were 15 unique combinations of flavor and texture (Table 3.8). The prototypes preacidified with citric acid and lemon shared similar flavor and texture to all three Dannon varieties and Stonyfield Nonfat. The second through fifth combinations shared similar textures to this first group; however, they varied in sour, dairy, and off-flavors. The sixth through ninth combinations shared the same smooth, slightly thick texture (texture Cluster 2), but again, subtle differences in flavor existed. The last six combinations displayed unique sets of flavor and texture, unparalleled by any other samples in this study.

Table 3.8 Combinations of flavor and texture clusters

Label	Flavor	Texture
Dannon Lowfat	1	1
Dannon Nonfat	1	1
Dannon Whole milk	1	1
Experimental Citric Acid	1	1
Experimental Lemon	1	1
Stonyfield Nonfat	1	1
Cascade Fresh Nonfat	2	1
The Greek Gods	2	1
Stonyfield Oikos	2	1
Experimental Control	3	1
Seven Stars	3	1
Weight Watchers	3	1
Cultural Revolution 5%	4	1
Nancy's Lowfat	6	1
Nancy's Whole milk	6	1
Great Value 32 oz	1	2
Private Selection	1	2
Great Values 8 oz	3	2
HyVee	3	2
Belfonte	4	2
Best Choice	4	2
Anderson Erikson	5	2
Wallaby Lowfat	5	2
Fage 2%	1	3
Fage 0%	3	3
Siggi's	7	3
Voskos Traditional	5	4
Cascade Fresh Mediterranean	7	4
Wallaby NF	1	5

Conclusions

Yogurt flavor was described by a combination of sour, dairy, and uncharacteristic off-flavors, and texture was described predominantly by thickness, firmness, smoothness, and chalkiness. Twenty-nine of the 35 attributes significantly differentiated the samples; however, depending on the objectives of the study, all of these terms may not be necessary. Based on flavor, the samples grouped into seven clusters, and based on texture, they grouped into five clusters. When flavor and texture clusters were combined, there were 15 unique combinations illustrated by these 29 representative samples. Overall, this study exemplified the vast array of products available in the current yogurt market. Differences in milk type (organic or conventional) and percent milk fat did not seem to affect the flavor and texture. Added ingredients such as whey protein and potassium sorbate introduced off-flavors such as cardboard. Differences in physical processing (set, stirred, or strained/Greek-style) affected texture. Set-style and stirred samples generally had similar thickness and firmness; however stirred samples were smoother. Strained/Greek-style yogurts were the thickest and firmest in the category, but some set-style yogurts were thicker and firmer than some samples specifically identified as Greek-style. Overall, the “more sustainable” prototypes closely resembled both the flavor and texture of category leaders, thus demonstrating their potential viability within the plain yogurt market.

References

Barnes, DL, Harper, SJ, Bodyfelt, FW, McDaniel, MR. 1991. Correlation of descriptive and consumer panel flavor ratings for commercial prestirred strawberry and lemon yogurts”. J Dairy Sci 74:2089-2099.

Bodyfelt, FW. 1981. Dairy product score cards: are they consistent with principles of sensory evaluation?. J Dairy Sci 64:2303-2308.

Boomgaarden, TA, Schmidt, KA. 2009. Effect of acidulant addition on yogurt fermentation. Dairy Research 2009: Report of Progress. Manhattan: Kansas State University Research and Extension. p 52-55.

Brandt, MA, Skinner EZ, Coleman, JA. 1963. The texture profile method. J Food Sci 28:404-409.

Cairncross, SE, Sjöstrom, LB. 1950. Flavor profiles—a new approach to flavor problems. Food Technology 4:308-311.

Caul, JF. 1957. The profile method of flavor analysis. Adv Food Res 7:1-40.

Chambers, DH, Allison, AA, Chambers, E IV. 2004. Training effects on performance of descriptive panelists. J Sensory Stu 19:486-489.

Chambers, E IV, Jenkins, A, McGuire, BH. 2006. Flavor properties of plain soymilk. J Sensory Stu 21:165-179.

Chandan, RC, O'Rell, KR. 2006. Principles of yogurt processing. In: Chandan, RC, White, CH, Kilara, A, Hui, YH, editors. Manufacturing Yogurt and Fermented Milks. Ames: Blackwell Publishing. p 195-209.

Chapman, KW, Lawless, HT, Boor, KJ. 2001. Quantitative descriptive analysis and principal component analysis for sensory characterization of ultra pasteurized milk. J Dairy Sci 84:12-20.

Civille, GA, Lawless, HT. 1986. Comparison of descriptive terminology systems for sensory evaluation of fluid milk. J Food Sci 1:217-236.

Claassen, M, Lawless HT. 1992. Comparison of descriptive terminology system for sensory evaluation of fluid milk. J. Food Science 57, 596-600.

Coggins, PC, Schilling, MW, Kumari, S Gerrard, PD. 2008. Development of a sensory lexicon for conventional milk yogurt in the United States. J Sensory Stu 23: 671-687.

Day N' Kouka, KD, Klein, BP, Lee, SY. 2004. Developing a lexicon for descriptive analysis of soymilks. J Food Sci 67:259-263.

Drake, MA. 2007. Invited review: sensory analysis of dairy foods. J Dairy Sci 90: 4925-4937.

Drake, MA, Chen, XQ, Tamarapu, S, Leenanon, B. 2000. Soy protein fortification affects sensory, chemical, and microbiological properties of dairy yogurts. J Food Sci 65:1244-1247.

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

Drake, MA, McIngvale, SC, Gerrard, PD, Cadwallader, KR, Civille, GV. 2001. Development of a descriptive language for Cheddar cheese. J Food Sci 66:1422-1427.

Fillion, L, Arazi, S. 2002. Does organic food taste better? A claim substantiation approach. Nut Food Sci 32:153-157.

Folkenberg, DM, Dejmek, P, Skriver, A, Guldager, HS, Ipsen, R. 2006. Sensory and rheological screening of exopolysaccharide producing strains of bacterial yoghurt cultures. Int Dairy J 16:111-118.

Francis, LL, Chambers, DH, Kong, SH, Milliken, GA, Jeon, IJ, Schmidt, KA. 2005. Serving temperature effects on milk flavor, milk aftertaste, and volatile compound qualification in nonfat and whole milk. J Food Sci 70:413-418.

Frost, MB, Dijksterhuis, G, Martens, M. 2001. Sensory perception of fat in milk. Food Qual Pref 12:327-336.

Hatchwell, LC. 1996. Implications of fat on flavor. In: McGorrin, RJ, Leland, JV, editors. Flavor-food interactions. Washington, DC: American Chemical Society. p 14-23.

Harper, SJ, Barnes, DL, Bodyfelt, FW, McDaniel, MR. 1991. Sensory ratings of commercial plain yogurts by consumer and descriptive panels. J Dairy Sci 74:2927-2935.

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

Hunter, EA, Muir, DD. 1993. Sensory properties of fermented milks: objective reduction of an extensive sensory vocabulary. J Sensory Studies 8:213-227.

Isleten, M, Karagul-Yuceer, Y. 2006. Effects of dried dairy ingredients on physical and sensory properties of nonfat yogurt. J Dairy Sci 89:2865-2872.

Janhøj, T, Blangsted Petersen, C, Bom Frøst, Ipsen, R. 2006. Sensory and rheological characterization of low-fat stirred yogurt. J Text Stu 37:276-299.

Keane, P. 1992. The flavor profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 1-14.

Kilcast, D, Clegg S. 2002. Sensory perception of creaminess and its relationship with food structure. Food Qual and Pref 13:609-623.

Kumari, S, Coggins, PC, Wilson, JC, Rowe, D. 2008. Combined effects of storage time and temperature on sensory characteristics of plain yogurt. Abstract. HortScience 43:628.

Lawless, HT, Claassen, MR. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. J Food Sci 58:108-112.

McGill, AEJ. 1983. Evaluation and prediction of the consumer acceptability of commercially manufactured yogurt. South African J Dairy Tech 15:139-140.

Maehashi, K, Huang, L. 2009. Bitter peptides and bitter taste receptors. Cellular and molecular life sciences 66:1661-1671.

Mela, DJ. 1988. Sensory assessment of fat content in fluid dairy products. Appetite 10:37-44.

Mintel: Yogurt and yogurt drinks – US – November 2008 [Internet]. [Accessed 2010 Jan 27]. Available from: http://academic.mintel.com.

Mintel: Yogurt– US – November 2009 [Internet]. [Accessed 2010 Feb 17]. Available from: http://academic.mintel.com.

Mintel: Green living– US – February 2010 [Internet]. [Accessed 2010 Mar 31]. Available from: http://academic.mintel.com.

Muñoz, AM, Chambers, E IV, Hummer, S. 1996. A multifaceted category research study: how to understand a product category and its consumer responses. J Sensory Stu 11:261-294.

Muñoz, AM, Szczesniak, AS, Einsten, MA, Schwartz, NO. 1992. The texture profile. In: Hootman, RC, editor. Manual on descriptive analysis testing for sensory evaluation. Baltimore: American Society for Testing and Materials. p 35-50.

Muir, DD, Hunter, EA. 1992. Sensory evaluation of fermented milks: vocabulary development and the relations between sensory properties and composition and between acceptability and sensory properties. J Soc Dairy Tech 45:73-80.

Ott, A, Hugi, A, Baumgartner, M, Chaintreau, A. 2000. Sensory investigation of yogurt flavor perception: mutual influence of volatiles and acidity". J Agric Food Chem 48: 441-450.

Oupadissakoon, G, Chambers, DH, Chambers, E IV. 2009. Comparison of the sensory properties of ultra-high-temperature (UHT) milk from different countries. J Sensory Stu 24:427-440.

Rašić, JL, Kurmann, JA. 1978. Yoghurt, scientific grounds, technology, manufacture and preparations. Copenhagen: Rašić, JL, Kurmann, JA. 466 p.

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

Richardson, NJ, Booth, DA. 1993. Multiple physical patterns in judgements of the creamy texture of milks and creams. Acta Psychologica 84:92-101.

Richter, RL. 1979. Results of the 1978 American dairy products scoring clinic. Cult Dairy Prod J 13:15-17.

Rohm, H, Kovac, A, Kneifel W. 1994. Effects of starter cultures on sensory properties of set-style yoghurt determined by quantitative descriptive analysis. J Sensory Stu 9:171-186.

Salvador, A, Fiszman, SM. 2004. Textural and sensory characteristics of whole and skimmed flavored set-type yogurt during long storage. J Dairy Sci 87:4033-4041.

Schmidt, K. 2000. Lipids: Functional Properties. In: Christen, GL, Smith, JS, editors. Food chemistry: principles and applications. West Sacramento: Science Technology System. p 97-113.

Singh, G, Muthukumarappan, K. 2007. Influence of calcium fortification on sensory, physical and rheological characteristics of fruit yogurt. LWT Food Sci Tech 41:1145-1152.

Sjöstrom, LB. 1954. The descriptive analysis of flavor. In: Peryam, D, Pilgrim, F, Peterson, M, editors. Food acceptance testing methodology. Chicago: Quartermaster. p 25-61.

Szczesniak, AS. 1963. Classification of textural characteristics. J Food Sci 28:385-389.

Szczesniak, AS, Brandt, MA, Friedman, HH. 1963. Development of standard rating scales for mechanical parameters of texture and correlation between the objective and the sensory methods of texture evaluation. J Food Sci 28:397-403.

Talavera-Bianchi, M, Chambers, DH. 2008. Simplified lexicon to describe flavor characteristics of Western European cheese. J Sensory Stu 23:468-484.

Tamime, AY, Davies G, Hamilton, MP. 1987. The quality of yoghurt on retail sale in Aryshire. Part II. Organoleptic evaluation. Dairy Ind Int 52:40-41.

Thompson, KR, Chambers, DH, Chambers, E IV. 2009. Sensory characteristics of ice cream produced in the U.S.A. and Italy. J Sensory Stu 24:396-414.

Torres-Penaranda, AV, Reitmeier, CA. 2001. Sensory descriptive analysis of soymilk. J Food Sci 66:352-356.

Tribby, D. Yogurt. In: Clark, S, Costello, M, Drake, MA, Bodyfelt, F, editors. The sensory evaluation of dairy products. 2nd ed. New York: Springer. p 191-223.

Appendix A - Initial sample set at the start of the study

Brand	Product	Organic?	Greek?	Location
365	Whole	No	No	91st St. Whole Foods Market
365	Nonfat	No	No	91st St. Whole Foods Market
365 Organic	1.5% lowfat	Yes	No	91st St. Whole Foods Market
365 Organic	Nonfat	Yes	No	91st St. Whole Foods Market
Anderson Erikson	1% lowfat	No	No	Price Chopper Overland Park
Belfonte	Nonfat	No	No	Price Chopper Overland Park
Brown Cow	1% lowfat	No	No	119th St. Whole Foods Market
Brown Cow	Nonfat	No	No	91st St. Whole Foods Market
Brown Cow Greek-style	Nonfat	No	Yes	119th St. Whole Foods Market
Cascade Fresh	Nonfat	No	No	91st St. Whole Foods Market
Cascade Fresh Mediterranean-style	Whole	No	Yes	The Merc Co-Op Lawrence
Chobani	Nonfat	No	Yes	91st St. Whole Foods Market
Dannon	1.5% lowfat	No	No	Price Chopper Overland Park
Dannon	Whole	No	No	Price Chopper Overland Park
Fage	Whole	No	Yes	91st St. Whole Foods Market
Fage	2% lowfat	No	Yes	91st St. Whole Foods Market
Fage	Nonfat	No	Yes	91st St. Whole Foods Market
Horizon Organic	Nonfat	Yes	No	91st St. Whole Foods Market
HyVee	Nonfat	No	No	HyVee Manhattan
Kolona Organics Cultural Revolution	Whole	Yes	No	HyVee Manhattan
Kolona Organics Cultural Revolution	2% lowfat	Yes	No	HyVee Manhattan
Kroger Blended	1% lowfat	No	No	Dillons Lawrence
Kroger Blended	Nonfat	No	No	Dillons Lawrence
Kroger Private Selection	1% lowfat	Yes	No	Dillons Lawrence
Mountain High	Nonfat	No	No	119th St. Whole Foods Market
Mountain High	Whole	No	No	119th St. Whole Foods Market
Nancy's	1.5% lowfat	No	No	91st St. Whole Foods Market
Nancy's	Nonfat	No	No	91st St. Whole Foods Market
Nancy's Organic	1.5% lowfat	Yes	No	The Merc Co-Op Lawrence
Nancy's Organic	Soy	Yes	No	119th St. Whole Foods Market
Nancy's Organic	Whole	Yes	No	91st St. Whole Foods Market
Nancy's Organic	Nonfat	Yes	No	91st St. Whole Foods Market
Redwood Hill Goat Farm	Whole	No	No	91st St. Whole Foods Market
Seven Stars Farm Organic	1% lowfat	Yes	No	The Merc Co-Op Lawrence
Siggis Icelandic-style skyr	Nonfat	No	Yes	91st St. Whole Foods Market
Silk Live!	Soy	No	No	91st St. Whole Foods Market
Stonyfield Organic	1% lowfat	Yes	No	91st St. Whole Foods Market
Stonyfield Organic	Nonfat	Yes	No	91st St. Whole Foods Market
Stonyfield Organic Oikos	Nonfat	Yes	Yes	91st St. Whole Foods Market
Stonyfield Organic YoBaby	Whole	Yes	No	91st St. Whole Foods Market

Brand	Product	Organic?	Greek?	Location
The Greek Gods	Whole	No	Yes	119th St. Whole Foods Market
The Greek Gods	Nonfat	No	Yes	91st St. Whole Foods Market
Turtle Mountain So Delicious	Coconut	No	No	91st St. Whole Foods Market
Turtle Mountain So Delicious	Soy	No	No	119th St. Whole Foods Market
Voskos	Whole	No	Yes	91st St. Whole Foods Market
Voskos	2% lowfat	No	Yes	91st St. Whole Foods Market
Voskos	Nonfat	No	Yes	91st St. Whole Foods Market
Wallaby Organic	2% lowfat	Yes	No	91st St. Whole Foods Market
Wallaby Organic	Nonfat	Yes	No	The Merc Co-Op Lawrence
Weight Watchers	Nonfat	No	No	Price Chopper Overland Park
White Mountain Bulgarian-Style	Nonfat	No	No	91st St. Whole Foods Market
White Mountain Bulgarian-Style	Whole	No	No	91st St. Whole Foods Market
Whole Soy & Co.	Soy	Yes	No	91st St. Whole Foods Market
Wildwood Organics	Soy	Yes	No	HyVee Manhattan

Appendix B - Presentation order and experimental design

Product	Rep 1	Rep 2	Rep 3
Anderson Erikson 1% Lowfat Plain	24	11	20
Belfonte Nonfat Plain	21	3	18
Best Choice Nonfat Plain	25	14	21
Cascade Fresh Mediterranean-style	29	18	3
Cascade Fresh Nonfat Plain	18	25	5
Cultural Revolution Complete 5%	22	4	13
Dannon Lowfat Plain	19	8	24
Dannon Nonfat Plain	27	10	14
Dannon Whole Milk Plain	8	17	6
Experimental Citric Acid	28	19	4
Experimental Control	23	15	10
Experimental Lemon	16	21	27
Fage 0%	14	22	9
Fage 2%	6	5	19
Great Value Fat Free Plain (32 oz)	1	13	28
Great Value Fat Free Plain (8 oz)	17	29	22
HyVee Fat Free Plain	15	26	7
Nancy's Organic 1.5% Lowfat Plain	12	23	1
Nancy's Organic Whole Milk Plain	9	20	11
Private Selection Organic Lowfat Plain	10	16	25
Seven Stars Farm Organic Lowfat Plain	4	27	29
Siggi's Icelandic-style skyr Fat Free Plain	3	9	23
Stonyfield Organic Fat Free Plain	5	28	16
Stonyfield Organic Oikos Greek-style	26	12	8
The Greek Gods Nonfat	2	24	15
Voskos Traditional	20	7	12
Wallaby Organic Lowfat Plain	11	2	26
Wallaby Organic Nonfat Plain	7	6	17
Weight Watchers Nonfat Plain	13	1	2

Date	Product	Code	Replication	Serve Time
Monday 9/28/2009	Great Value Fat Free Plain (32 oz)	354	1	9:10
	Stonyfield Organic YoBaby Simply Plain	754	1	9:32
	The Greek Gods Nonfat	297	1	9:54
	Siggi's Icelandic-style skyr Fat Free Plain	818	1	10:16
Tuesday 9/29/2009	Seven Stars Farm Organic Lowfat Plain	714	1	9:10
	Moutain High Whole Milk Plain	757	1	9:32
	Brown Cow Nonfat Plain	853	1	9:54
Wednesday 9/30/2009	Stonyfield Organic 1% Lowfat Plain	903	1	9:10
	Stonyfield Organic Fat Free Plain	774	1	9:32
	Fage 2%	796	1	9:54
	Wallaby Organic Nonfat Plain	555	1	10:16
Thursday 10/1/2009	Dannon Whole Milk Plain	796	1	9:10
	Nancy's Organic Whole Milk Plain	408	1	9:31
	Private Selection Organic Lowfat Plain	218	1	9:52
	Wallaby Organic Lowfat Plain	859	1	10:13
Friday 10/2/2009	Nancy's Organic 1.5% Lowfat Plain	587	1	9:10
	Weight Watchers Nonfat Plain	825	1	9:31
	Fage 0%	177	1	9:52
	HyVee Fat Free Plain	107	1	10:13
Monday 10/5/2009	Experimental Lemon	156	1	9:10
	Great Value Fat Free Plain (8 oz)	803	1	9:31
	Cascade Fresh Nonfat Plain	336	1	9:52
	Dannon Lowfat Plain	651	1	10:13
Tuesday 10/6/2009	Voskos Traditional	149	1	9:10
	Belfonte Nonfat Plain	579	1	9:27
	Cultural Revolution Complete 5%	581	1	9:44
	Experimental Control	873	1	10:01
	Anderson Erikson 1% Lowfat Plain	948	1	10:18
Wednesday 10/7/2009	Best Choice Nonfat Plain	136	1	9:10
	Stonyfield Organic Oikos Greek-style	557	1	9:27
	Dannon Nonfat Plain	188	1	9:44
	Experimental Citric Acid	977	1	10:01
	Cascade Fresh Mediterranean-style	527	1	10:18

Date	Product	Code	Replication	Serve Time
Thursday 10/8/09	Weight Watchers Nonfat Plain	704	2	9:10
	Wallaby Organic Lowfat Plain	219	2	9:27
	Belfonte Nonfat Plain	583	2	9:44
	Cultural Revolution Complete 5%	678	2	10:01
	Fage 2%	552	2	10:18
Friday 10/9/09	Wallaby Organic Nonfat Plain	607	2	9:10
	Voskos Traditional	708	2	9:27
	Dannon Lowfat Plain	351	2	9:44
	Siggi's Icelandic-style skyr Fat Free Plain	695	2	10:01
	Dannon Nonfat Plain	617	2	10:18
Monday 10/12/09	Anderson Erikson 1% Lowfat Plain	437	2	9:10
	Stonyfield Organic Oikos Greek-style	931	2	9:27
	Great Value Fat Free Plain (32 oz)	664	2	9:44
	Best Choice Nonfat Plain	568	2	10:01
	Experimental Control	990	2	10:18
Wednesday 10/14/09	Private Selection Organic Lowfat Plain	804	2	9:10
	Dannon Whole Milk Plain	141	2	9:31
	Cascade Fresh Mediterranean-style	237	2	9:52
	Experimental Citric Acid	374	2	10:13
Thursday 10/15/09	Nancy's Organic Whole Milk Plain	768	2	9:10
	Experimental Lemon	483	2	9:27
	Fage 0%	277	2	9:44
	Nancy's Organic 1.5% Lowfat Plain	262	2	10:01
	The Greek Gods Nonfat	455	2	10:18
Friday 10/16/09	Cascade Fresh Nonfat Plain	596	2	9:10
	HyVee Fat Free Plain	693	2	9:27
	Seven Stars Farm Organic Lowfat Plain	624	2	9:44
	Stonyfield Organic Fat Free Plain	694	2	10:01
	Great Value Fat Free Plain (8 oz)	734	2	10:18

Date	Product	Code	Replication	Serve Time
Monday 11/9/09	Nancy's Organic 1.5% Lowfat Plain	573	3	11:20
	Weight Watchers Nonfat Plain	964	3	11:38
	Cascade Fresh Mediterranean-style	982	3	11:56
Tuesday 11/10/09	Experimental Citric Acid	869	3	10:50
	Cascade Fresh Nonfat Plain	891	3	11:07
	Dannon Whole Milk	716	3	11:24
	HyVee Fat Free Plain	366	3	11:41
	Stonyfield Organic Oikos Greek-style	554	3	11:58
Wednesday 11/11/09	Fage 0%	363	3	10:50
	Experimental Control	843	3	11:07
	Nancy's Organic Whole Milk Plain	353	3	11:24
	Voskos Traditional	820	3	11:41
	Cultural Revolution Complete 5%	906	3	11:58
Thursday 11/12/09	Dannon Nonfat Plain	127	3	10:50
	The Greek Gods Nonfat	645	3	11:07
	Stonyfield Organic Fat Free Plain	560	3	11:24
	Wallaby Organic Nonfat Plain	290	3	11:41
	Belfonte Nonfat Plain	872	3	11:58
Friday 11/13/09	Fage 2%	126	3	10:50
	Anderson Erikson 1% Lowfat Plain	163	3	11:07
	Best Choice Nonfat Plain	372	3	11:24
	Great Value Fat Free Plain (8 oz)	294	3	11:41
	Siggi's Icelandic-style skyr Fat Free Plain	639	3	11:58
Monday 11/16/09	Dannon Lowfat Plain	398	3	10:50
	Private Selection Organic Lowfat Plain	773	3	11:07
	Wallaby Organic Lowfat Plain	812	3	11:24
	Experimental Lemon	282	3	11:41
	Great Value Fat Free Plain (32 oz)	338	3	11:58
	Seven Stars Farm Organic Lowfat Plain	623	3	12:15

Appendix C - Ballot used for evaluations

The margins of this ballot, when used, were adjusted so that it printed onto one page.

Panelist: ______________________ Date: ____________

	Code	Code	Code	Code	Code
Flavor aromatics					
Overall dairy					
Dairy fat					
Buttery					
Cooked					
Processed					
Butyric					
Whey					
Animalic					
Cardboard					
Filler					
Goaty					
Grain-like					
Lemon					
Moldy					
Oil-like					
Oxidized					
Plastic					
Sharp/bite					
Overall sour					
Lactic					
Acetaldehyde					
Sour					
Sweet					
Salty					
Bitter					
Texture, mouthfeels and mouthcoatings					
Firmness					
Smoothness					
Thickness					
Degree of dissolving					

Astringent					
Tooth etch					
Fat feel					
Chalky mouthfeel					
Fatty mouthcoating					
Chalky mouthcoating					

Appendix D - SAS code for data analysis

To calculate overall attribute means for each sample:

```
data results;
merge yogurt.rep1 yogurt.rep2 yogurt.rep3;
by product rep;
drop product;
run;

proc sort data=results;
by product rep panelist;
run;

proc means data=yogurt.results mean std maxdec=2;
var overall_dairy--chalky_mouthcoating;
class sample;
output out=yogurt.means mean(overall_dairy--chalky_mouthcoating)=
overall_dairy dairy_fat buttery cooked processed butyric whey
animalic cardboard filler goaty grain_like lemon moldy oil_like
plastic     oxidized sharp_bite overall_sour lactic acetaldehyde
sour sweet salty bitter firmness smoothness thickness degree_of_dissolving
astringent tooth_etch fat_feel chalky_mouthfeel fatty_mouthcoating
chalky_mouthcoating;
run;

proc sort data=yogurt.results;
by sample rep panelist;
run;
```

To do the analysis of variance for each attribute:

```
proc glm data=yogurt.results;
class sample rep panelist;
model overall_dairy--chalky_mouthcoating=panelist sample rep
panelist*sample panelist*rep sample*rep/ss3;
test h=sample rep e=sample*rep;
means sample/LSD lines e=sample*rep;
run;
```

To determine the correlations between the attributes:

```
proc corr data=yogurt.means cov out=yogurt.corr;
var overall_dairy--chalky_mouthcoating;
run;
```

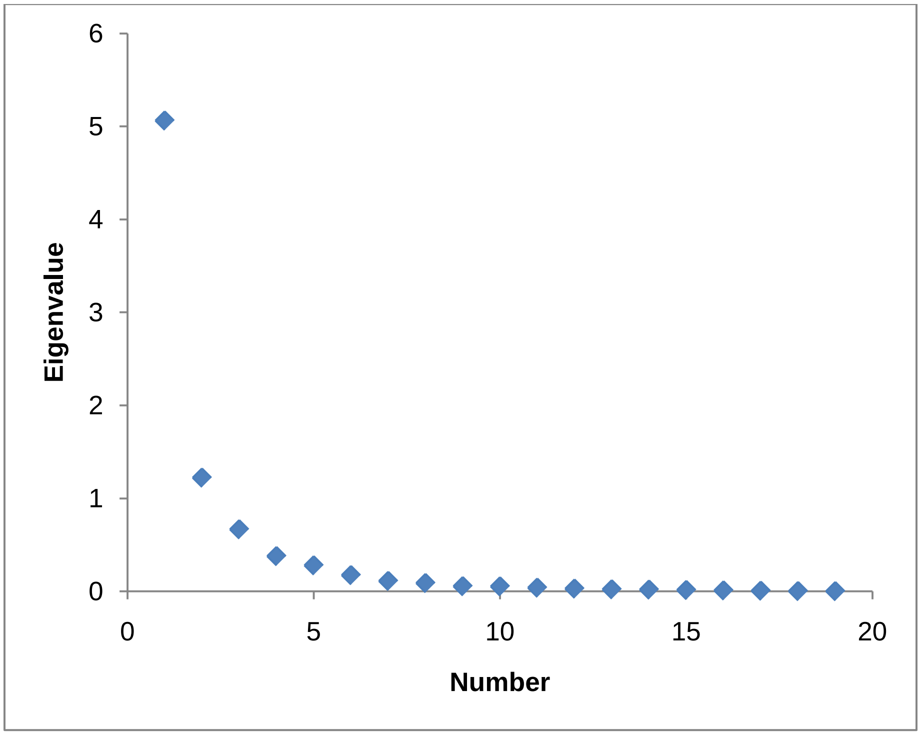
To do the principal component and cluster analysis of the significant flavor attributes:

```
data yogurt.flavmean;
set means;
keep sample--bitter;
run;

data yogurt.flavmeansig;
set yogurt.flavmean;
drop processed filler grain_like oil_like acetaldehyde salty;
run;

proc princomp data=yogurt.flavmeansig out=yogurt.flavpcsig covariance;
var overall_dairy--bitter;
ods output eigenvalues=yogurt.flavevalsig eigenvectors=yogurt.flavevecsig;
run;

ods graphics;
proc cluster data=yogurt.flavpcsig s standard method=ward noprint
ccc pseudo outtree=yogurt.flavtree;
var prin1 prin2;
id sample;
run;
ods graphics close;

proc tree data=yogurt.flavtree out=yogurt.flavtreeout nclusters=7;
copy prin1 prin2;
id sample;
run;

ODS RTF;
proc print data=yogurt.flavtreeout;
var sample cluster;
run;
ODS RTF CLOSE;

proc plot data=yogurt.flavtreeout;
plot prin2*prin1=cluster;
run;
```

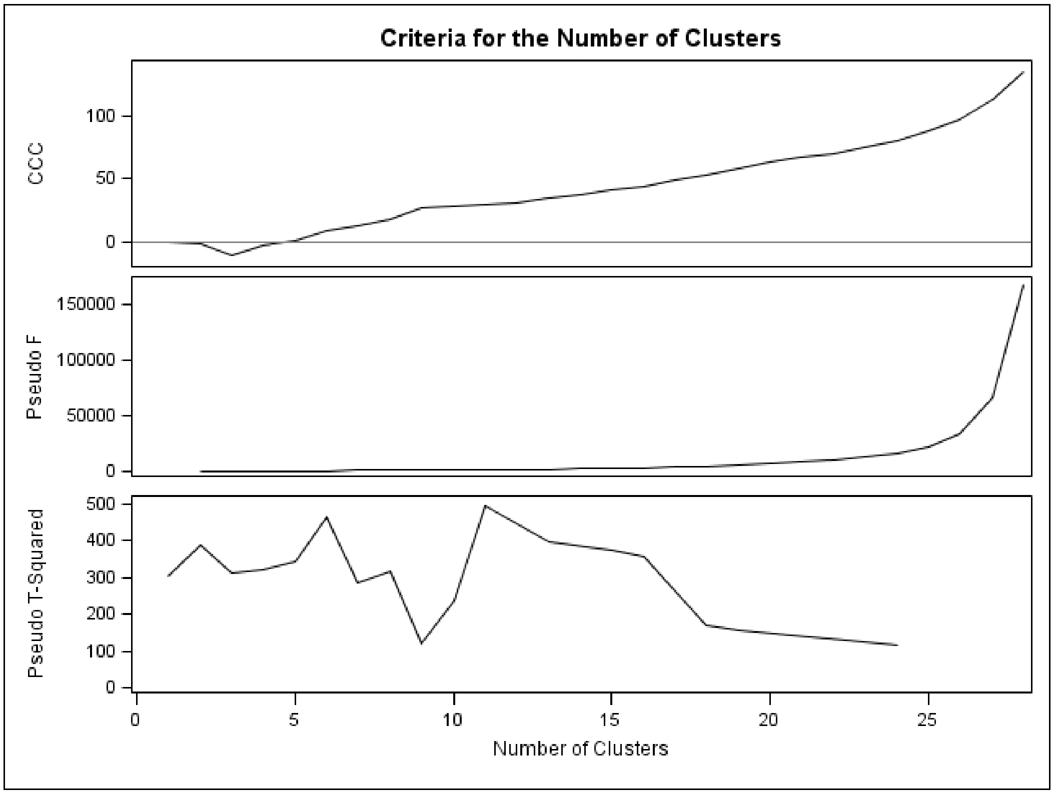
To do the principal component and cluster analysis of the significant texture attributes:

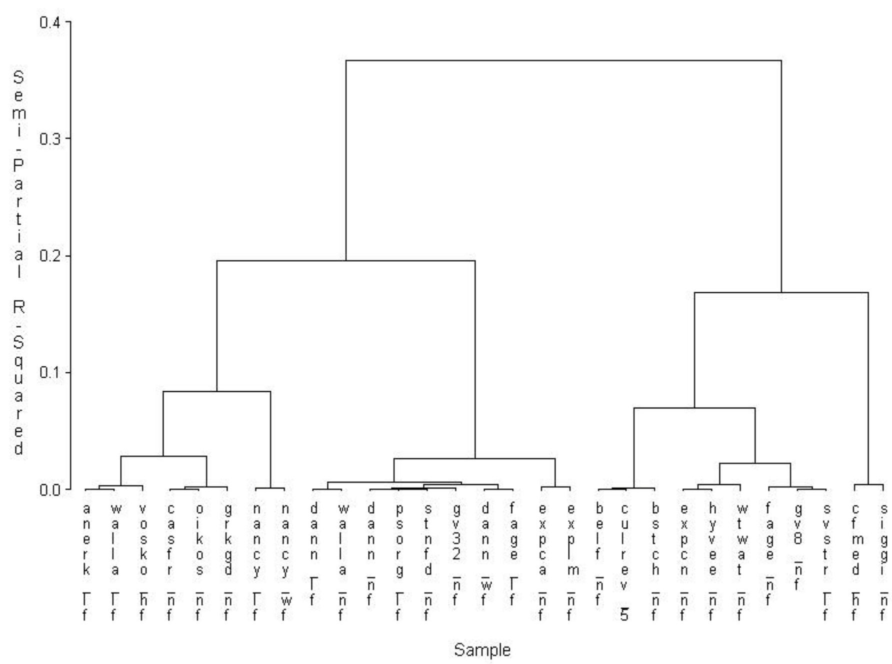
```
data yogurt.texmean;
set means;
keep sample firmness—chalky_mouthcoating;
run;

proc princomp data=yogurt.texmean out=yogurt.texpcs covariance;
var firmness--chalky_mouthcoating;
ods output eigenvalues=yogurt.texeval eigenvectors=yogurt.texevec;
run;

ods graphics;
proc cluster data=yogurt.texpcs s standard method=average
ccc pseudo outtree=yogurt.textree;
var prin1 prin2 prin3;
id sample;
run;
ods graphics close;

proc tree data=yogurt.textree out=yogurt.textreeout nclusters=5;
copy prin1 prin2 prin3;
id sample;
run;

ods rtf;
proc print data=yogurt.textreeout;
var sample prin1 prin2 prin3 cluster;
run;
ods rtf close;

proc plot data=textreeout;
plot prin2*prin1=cluster;
run;
```

Appendix E - Decision criteria for flavor analyses

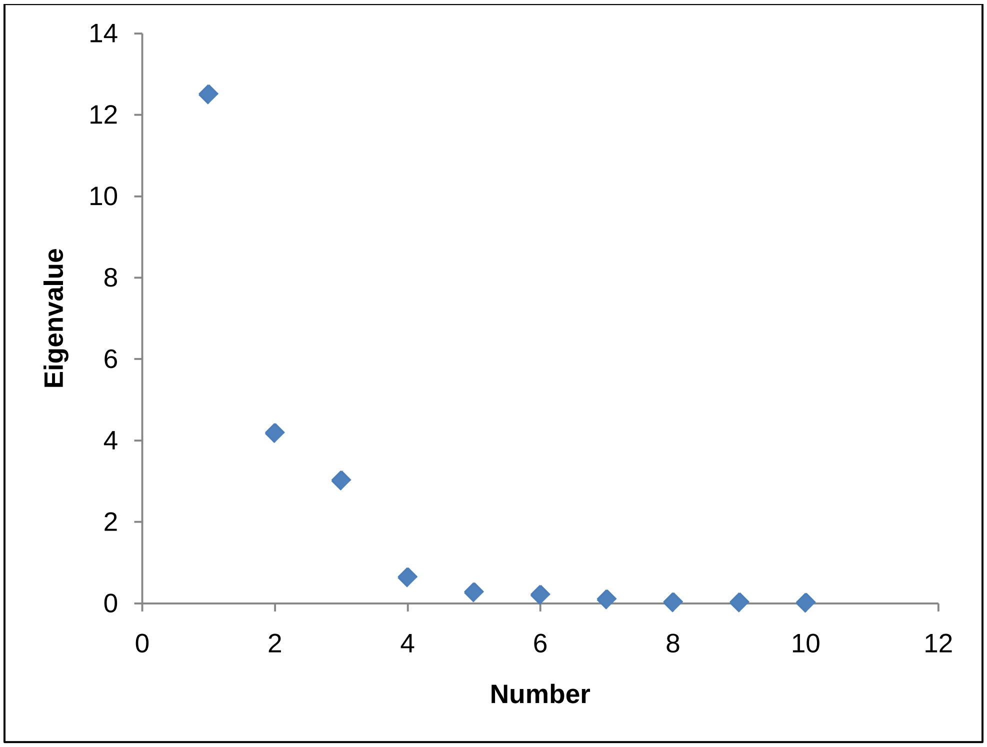


Number	Eigenvalue	Proportion of total variability explained	Cumulative proportion of total variability explained
1	5.0633	0.6133	0.6133
2	1.2236	0.1482	0.7616
3	0.6680	0.0809	0.8425
4	0.3797	0.0460	0.8885
5	0.2805	0.0340	0.9225
6	0.1753	0.0212	0.9437
7	0.1125	0.0136	0.9573
8	0.0900	0.0109	0.9682
9	0.0561	0.0068	0.9750
10	0.0542	0.0066	0.9816
11	0.0402	0.0049	0.9865
12	0.0301	0.0037	0.9901
13	0.0225	0.0027	0.9928
14	0.0195	0.0024	0.9952
15	0.0153	0.0019	0.9970
16	0.0108	0.0013	0.9984
17	0.0074	0.0009	0.9992
18	0.0035	0.0004	0.9997
19	0.0027	0.0003	1.0000

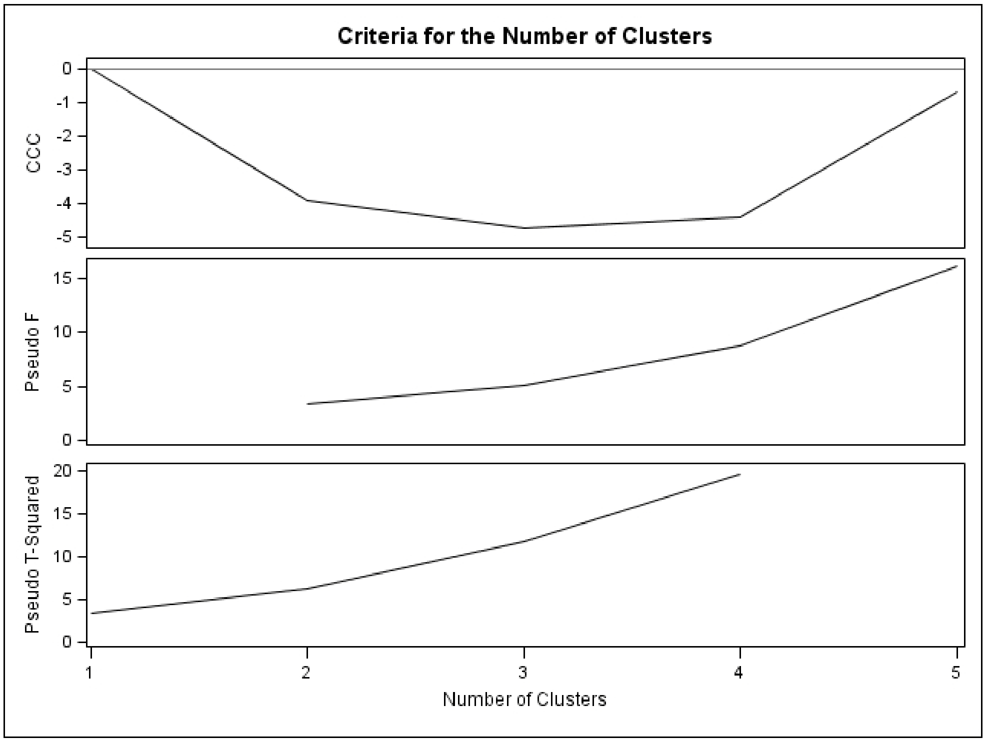

Criteria for the Number of Clusters
CCC
100
50
0
Pseudo F
150000
100000
50000
0
Pseudo T-Squared
500
400
300
200
100
0
0
5
10
15
20
25
Number of Clusters

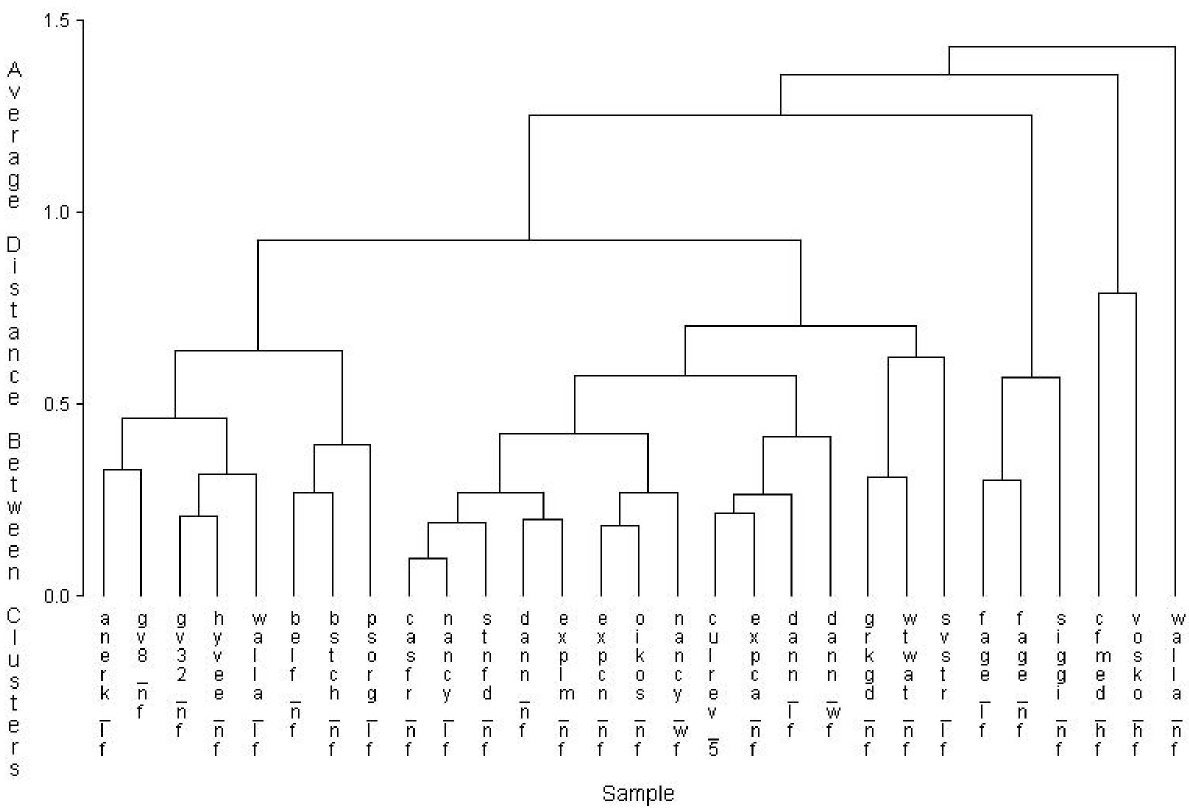

Semi-Partial R-Squared
0.4
0.3
0.2
0.1
0.0
Sample

Appendix F - Decision criteria for texture analyses



Number	Eigenvalue	Proportion	Cumulative
1	12.5036356	0.5962	0.5962
2	4.1821925	0.1994	0.7957
3	3.0172033	0.1439	0.9395
4	0.6376943	0.0304	0.9699
5	0.2704389	0.0129	0.9828
6	0.2065307	0.0098	0.9927
7	0.0956748	0.0046	0.9973
8	0.0240192	0.0011	0.9984
9	0.0206711	0.001	0.9994
10	0.0128584	0.0006	1


Criteria for the Number of Clusters
CCC
0
-1
-2
-3
-4
-5
Pseudo F
15
10
5
0
Pseudo T-Squared
20
15
10
5
0
1
2
3
4
5
Number of Clusters


Average Distance Between Clusters
1.5
1.0
0.5
0.0
anerk_lf
gv8_nf
gv32_nf
hyvee_nf
walla_lf
belf_nf
bstch_nf
psorg_lf
casfr_nf
nancy_lf
stnfd_nf
dann_nf
explm_nf
expcn_nf
oikos_nf
nancy_wf
culrev_5
expca_nf
dann_lf
dann_wf
grkgd_nf
wtwat_nf
svstr_lf
fage_lf
fage_nf
siggi_nf
cfmed_hf
vosko_hf
walla_nf
Sample