ABSTRACT

CROISSANT, ADAM EDWARD. Evaluation of Chemical Properties and Consumer Perception of Fluid Milk from Conventional and Pasture-Based Production Systems. (Under the direction of Dr. MaryAnne Drake.)

The purpose of this research was to compare the chemical and sensory properties of pasture-based (PB) and conventional fluid milk and to determine the influence of feed on consumer acceptance of fluid milk. Fluid milk was collected throughout the 2006 growing season from two herds; one fed on a PB diet and one fed on a total mixed ration (TMR), conventional diet. Sensory analyses, descriptive profiling, difference testing, and consumer testing were conducted on pasteurized product in separate sessions. Instrumental volatile analysis and fatty acid composition were also conducted. Instrumental and sensory analysis differentiated the PB and TMR milks ($p<0.05$). PB milks contained higher percentages of unsaturated fatty acids, including CLA. Trained panelists documented higher intensities of sweet aromatic, grassy, and cowy/barny flavors in PB milks compared to TMR milks. Consumers were not able to consistently differentiate between PB and TMR milks, which had no effect on overall consumer acceptance. These results indicate distinct flavor and compositional differences between TMR and PB milks, but that these differences do not impact consumer acceptance. These findings are crucial issues to consider and optimize for the growing interest in grazing feed systems.

Evaluation of chemical properties and consumer perception of fluid milk from conventional and pasture-based production systems

by

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Biography

Adam Edward Croissant was born in the middle of a bunch of Illinois cornfields to Joyce and Philip Croissant. Adam was raised the youngest child of three by his mother and stepfather, Arthur Moak, who still reside in LaSalle, Illinois. His brother, Cory, has just moved to South Carolina with his wife, Delane, and three children. His sister, Jenifer Vowels, resides in Indianapolis, Indiana, with her husband, Matt, and daughter, Jocelyn.

Adam graduated from LaSalle-Peru Township High School in June 1997 and began a degree at Illinois Valley Community College. It was there he realized that medicine did not interest him as much as science generally intrigued him. He attended several conferences and was exposed to the vast pool of knowledge of which he had yet to learn. After graduating with an Associate of Science in August 1999, Adam enlisted in the Illinois Army National Guard and made his way to Champaign, IL. One year into his studies, Adam realized that he wanted to spend his life working on "bigger things" than biochemistry would allow. At the suggestion of a friend, he took an introductory food science course and was hooked. He was a science guy and liked to eat and cook and rationalized that people always have to eat so food science would be the way to go.

Only months after meeting his future wife, Adam graduated from the University of Illinois at Champaign-Urbana with a BS in Biochemistry in August 2002 and was commissioned as a 2LT in the Army Reserve Chemical Corps. From there, he braved the bitter cold in Nowhere, Missouri for six months of training before making his way to NC State to work on whey protein powders. He was there for six months before being called up to command his detachment in Iraq. Adam served in Iraq in the Joint Command Headquarters for 11 months in 2004 and returned home just in time for Christmas. He

worked a very rewarding job as a substitute teacher while waiting to rejoin the MAD lab in 2005. Dr. Drake graciously accepted him back and easily convinced him to stay on for a Ph.D. On March 3, 2007, Kristin Saunders happily accepted his marriage proposal. They are to be married on August 11, 2007, nearly five and a half years after first meeting.

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Not many graduate students can appreciate the experiences of the MAD lab, but the ones that have made it through are much better for it. Everyone in the MAD lab deserves hugs and thanks for tasting the many milk samples with minimal whining. The author is especially grateful to MaryAnne Drake for her patience and for the extra kick(s) when self-motivation faltered.

The author's grandparents fostered respect and admiration with whomever they encountered and provided a template for the type of person he aspires to be. The author received his voracious appetite for knowledge from his mother who returned to school three times to continue her education after her divorce while raising three very strong and opinionated children. The author cannot imagine North Carolina without his fiancée, Kristin, and is thankful every day that she still puts up with him. And Parker the dog kept us laughing when there was little reason to smile.

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Literature Review

Milk Overview

In the United States and other Western cultures, dairy products are largely traditional and a recommended nutritional group (Boland et al., 2001). Consumers value the sensory characteristics and prize the indulgence factors of some high fat dairy products such as ice cream or the incorporation of some aged cheeses with their wine. Food prices are becoming a smaller proportion of rising disposable income (USDA-ERS, 2006) and consumers in the United States have come to expect inexpensive food. According to the US Government Accountability Office, GAO, (2004) volatility in farm prices of milk has yielded relatively stable retail prices of fluid milk. Recently, the cost of feed grains has risen dramatically, due in large part to the increased interest in corn as an alternative fuel. Corn is a major constituent of animal feed. To overcome these trends, dairy farmers are looking to produce value-added products. One such product is organic milk and organic dairy products, specifically from milk produced using a pasture-based feeding system.

Per capita milk consumption has seen a decline in recent years (IDFA, 2005). The general trend towards skimmed and low fat milks follows consumer interest in "healthier" foods. Cheese and fluid milk and cream accounted for nearly 70% of the milk supply utilization in 2004 with 39.7% and 33%, respectively. Milk competes with all other beverages on the market including sports drinks, bottled (including flavored) water, soft drinks, and a number of energy drinks.

The largest direct competitor of fluid milk is soy milk. Soy milk has seen annual growth rates of 15-25% over the last five years, with total sales of $917 million in 2004

(Beverage Marketing Corp., 2005). Several trends have and will continue to influence the sales of soy milk. The approval by the FDA in 1999 to allow soy products to be marketed as a "cholesterol-reducing food" spurred consumer interest. The Adkins diet introduced soy milk to many consumers who had never before tasted the beverage. The leading brands of soy milk are made with organic soybeans, offering consumers an organic *and* a non-dairy alternative to milk (Ferrier and Lewandowski, 2002). Large percentages of minorities are estimated to be lactose intolerant. Soybeans are viewed as a healthy, renewable resource that is satisfying to environmentally conscious consumers. Also worth mention are other dairy alternatives with much less market share such as almond milk, rice milk, and soy fruit beverages. These products coupled with soy milk combined for sales surpassing $1 billion in 2004 (Beverage Marketing Corp., 2004).

Standard of Identity: Fluid Milk

The standard of identity for fluid milk is: the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more cows. Milk in the final package form for beverage use shall have been pasteurized or ultra-pasteurized. If added, vitamin A must be added at a concentration of 2000 IU vitamin A/quart. Vitamin D, if added, requires a minimum concentration of 400 IU vitamin D/quart (Code of Federal Regulations, 2004). Lower fat and nonfat milks are subject to the requirements of the general standards for nutrient claims set forth by the Food and Drug Administration (FDA) (National Dairy Council, 2005). Whole milk shall contain not less than 8.25 percent milk solids not fat and not less than 3.25 percent milk fat. Reduced fat or lowfat milk shall contain either 0.5%, 1%, or 2% milk fat. Reduced fat milk contains 2% milk fat. 1% and 0.5% lowfat milk contain

1% and 0.5% milk fat, respectively. Fat-free or skim milk contains less than 0.5% milk fat (Federal Register, Nov. 1996).

Organic fluid milk adheres to the same standard of identity as conventionally produced fluid milk. Organic milk also adheres to the FDA general standards for nutrient claims. However, the organic certification follows the guidelines and restrictions set forth by the Organic Foods Production Act (1990) and the USDA National Organic Program.

Milk Composition

Milk is a unique fluid primarily composed of water, lipids, proteins, and carbohydrates. The composition varies between species, but cows' milk is consumed more than milk from other species. The average composition of cows' milk can be found in Table 1 (Varnum and Sutherland, 2001). The carbohydrate, lactose, is the most abundant solid component of milk. Lactose is a disaccharide of α-D-glucose and β-D-galactose existing in 3 forms, α-lactose monohydride and α- and β-lactose anhydrous forms. The primary role of lactose in milk is in the colligative properties (osmotic pressure, freezing point depression, and boiling point elevation) (Varnum and Sutherland, 2001). Lactose also provides a source of energy, aids in calcium absorption, and provides a sweet taste to milk.

Milk proteins are becoming increasingly important in the food industry. There are two types of proteins found in milk; whey proteins and caseins. Caseins account for most (>80%) of the total protein composition of milk. They are globular proteins made up of 5 subdivisions, α_{s1}, α_{s2}, β-, γ- , κ-caseins (Varnum and Sutherland, 2001). Milk caseins form a micelle structure with each other and with calcium phosphate. This structure is responsible for the high protein content of milk, generally not expected in a liquid. Many of the changes in milk during processing involve changes and interactions of the casein micelles. Whey

proteins are globular, consisting of β-lactoglobulins (54%) and α-lactalbumins (20-25%), protease-peptones (2-10%), blood-derived proteins, bovine serum albumin, and immunoglobulins (Kinsella, 1986). Compared to caseins, whey proteins are more heat sensitive, less sensitive to calcium, and can engage in thiol-disulfide interchange to form disulfide linked dimers or polymers (Kinsella, 1986). Whey proteins do not strongly aggregate and do not readily interact with other proteins. Typical thermal processing of milk may denature β –lactoglobulin (β-Lg), which is irreversible. α-lactalbumin (α-Lg) undergoes a reversible denaturation except at very high temperatures (Swaisgood, 1996).

The properties of milk proteins relate to the behavior of milk during processing. The reactions of most importance are those which involve destabilization of the protein micelles. These reactions can be both desirable (κ-casein undergoes selective proteolysis in the manufacture of Cheddar cheese) and undesirable (casein aggregation during age thickening of concentrated milks). The functional properties of casein and whey reflect the amino acid sequence and thus the conformational structure of the proteins. In the case of casein, its ampiphilic nature imparts good surface active properties and thus the functional properties of whipping/foaming and emulsification (Varnum and Sutherland, 2001).

Table 1: Average composition of cow's milk

Component	Percentage	Percentage of Solids
Lactose	4.8	37.5
Fat	3.7	28.9
Protein	3.4	26.6
Non-protein Nitrogen	0.19	1.5
Ash	0.7	5.5

Varnum and Sutherland (2001)

The fat phase of milk plays an important role in determining its flavor and palatability in foods. Dairy fats are particularly palatable due to the large number of small molecular size lipids and short chain fatty acids and their derivatives which contribute to flavor, aroma, and mouth feel (Varnum and Sutherland, 2001). Milk fat is a complex element of milk composition. The aqueous phase of the milk is greatly affected by fat content. Density differences enable milk fat to be separated from the fluid phase during processing. Milk fat provides energy and provides a solvent for fat-soluble vitamins (A, D, E, and K). Milk fat is predominantly composed of triacylglycerols, accounting for nearly 98% of milk fat (Varnum and Sutherland, 2001). The remaining milk fat consists of small amounts of di- and monoacylglycerols and free fatty acids along with phospholipids, cholesterol, and cerebrosides as well as trace amounts of fat soluble vitamins, and flavor components. Lipid molecules form large spherical globules surrounded by a phospholipid layer, the milk fat globule membrane. The globule membrane stabilizes the hydrophobic lipid in the aqueous environment of milk. Approximately 85% of milk cholesterol and 60% of milk phospholipids are located within the milk fat globule membrane.

Several hundred fatty acids (FA) have been identified in milk fat triacylglycerols. However, 15 fatty acids account for 95% of those present in milk triacylglycerols. All bovine milk fats are comprised of eight even-numbered saturated FA's (4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, and 18:0); two odd-numbered saturated FA's (15:0 and 17:0); dienes and trienes (18:2 and 18:3) and three monounsaturated FA's (14:1, 16:1, and 18:1). The proportion of each FA varies with phase of lactation and diet (Varnum and Sutherland, 2001).

Table 2: Average lipid composition of milk

Lipid	% by weight
Triacylglycerols	97-98
Diacylglycerols	0.3-0.6
Monoacylglycerols	0.02-0.04
Free fatty acids	0.1-0.4
Free sterols	0.2-0.4
Sterol esters	trace
Phospholipids	0.2-1.0
Hydrocarbons	trace

Varnum and Sutherland, 2001

Conjugated linoleic acid (CLA) refers to the mixture of 8 geometric isomers of linoleic acid. In dairy products, >80% of CLA is the *cis-9, trans-11*-octadecadienoic acid (*c9, t11*-18:2) isomer (Chin et al., 1992). The c*9, t11*-18:2 isomer is assumed to be the most important CLA isomer in terms of anticarcinogenic activity because it is the only isomer incorporated into the phospholipid fraction of rat tissue (Ip et al., 1990). CLA has been demonstrated to act as a potent anticarcinogenic agent in mice and human cancer cells (Schultz et al., 1992a; Schultz et al., 1992b). CLA is formed as an intermediate product during biohydrogenation of linoleic acid to stearic acid in rumenic animals (Chin et al., 1992). Animal foods have a higher concentration of CLA when compared to foods of vegetable origin. Among animal products, CLA contents are generally higher in ruminant tissues and dairy products are recognized as major dietary sources of CLA (Lin et al., 1995).

Studies have shown that CLA concentration is significantly higher in pasture-grazing cows compared to herds fed total mixed rations (TMR) (Jahreis et al., 1997; Kelly et al., 1998; Dhiman et al., 1999; White et al., 2001). Kelly et al. (1998) showed substantial increases in CLA concentration when cows were switched from a TMR diet to a grazing-only diet. They also observed considerable variation in milk fat CLA concentration among

individual cows. This increase in CLA and other branched-chain fatty acid content with pasture-feeding demonstrates a more intense activity of rumen bacteria when cows are fed on pasture (Lin et al., 1995). However, CLA content in milk fat is affected by a number of factors including breed (Soyeurt et al., 2006), type and source of dietary carbohydrate, forage to concentrate ratio, level of intake, and intake of unsaturated fatty acids as well as seasonal variations (Parodi, 1977; Reil, 1963). While CLA content is significantly higher in milk from grazing cows, milk yield decreases when compared to conventional-fed cows (Kelly et al., 1998).

Pasture feeding regimens result in milk fat containing higher concentrations of polyunsaturated FA's and therefore make the milk more susceptible to lipid oxidation (Barrefors et al., 1995; Bugaud et al., 2001; Timmons et al., 2001). However, these same milks have been shown to contain higher levels of the antioxidants β-carotene, lutein, and zeaxanthine. Studies have shown that antioxidants can be transferred from the cow feed to the milk and thereby improve the oxidative stability of milk (Barrefors et al., 1995; Granelli et al., 1998). These compounds have been shown to delay protein oxidation in milk (Havemose et al., 2004). Protein oxidation is responsible for the early noticeable oxidative flavors in fluid milk while lipid oxidation becomes the dominating source later (Marsili, 1999). There is no single contributor to the development of oxidative flavors in milk. Previous work has shown the importance of several factors including the ratios of α-tocopherol, β-carotene, and polyunsaturated fatty acids (such as CLA) (Granelli et al., 1998; Barrefors et al., 1995) and the degree of fatty acid unsaturation (Granelli et al., 1998) in the prevention or onset of oxidation in fluid milk. Campbell et al. (2003) incorporated purified CLA into reduced fat milk to artificially enhance CLA levels. Substantial sensory defects

including a blue tint and a grassy/vegetable flavor were observed indicating that natural feeding regimens currently offer the best option for increasing CLA levels in dairy products.

Other milk components of importance are minerals, vitamins, urea, and enzymes. The principal minerals of milk are calcium, magnesium, potassium, and sodium. Milk is an important source of dietary calcium, contributing to healthy bone and tooth development. Urea is an important factor in determining the stability of unconcentrated milk. The concentration of milk urea is controlled by blood urea, which in turn is largely influenced by diet (Varnum and Sutherland, 2001). Urea levels are expected to be higher in pasture-fed cows (Bargo et al., 2002).

Milk also contains a large number of enzymes important in determining the stability of milk during storage. Proteases and lipases affect the flavor and protein stability of milk. The major proteinase of milk is plasmin. Plasmin is highly heat stable at the pH of fluid milk and retains substantial activity after pasteurization (Varnum and Sutherland, 2001). Lipoprotein lipase is the major lipolytic enzyme in milk. The enzyme is present in large quantities in fresh milk. The milk fat globule protects milk fat against lipolysis due to lipoprotein lipase. The enzyme is heat-labile and, therefore, of little importance in heat treated milk. Pasteurization, or heating of milk, is required to inactivate lipase before homogenization to avoid lipolysis. Oxidoreductases also affect flavor, especially in the lipid fraction. Lactoperoxidase, an oxidoreductase, is present in high concentrations in milk. This enzyme may catalyze the oxidation of unsaturated fatty acids, producing an oxidized taste (Varnum and Sutherland, 2001). Although alkaline phosphatase is of no importance to milk stability, it is widely known in respect to milk. Alkaline phosphatase is almost completely

inactivated by pasteurization. This enzyme serves as an index of proper heat pasteurization (Varnum and Sutherland, 2001).

Effects of Pasture on Milk Flavor

Volatile compounds can be transferred to milk through inhaled air, from the digestive tract by direct absorption, or by rumen gases (Urbach, 1990). Diet can influence the composition of volatile compounds in milk, either by interacting with rumen metabolism (Urbach, 1990) or by transferring odor-active molecules (Buchin et al., 1999). Protected denomination of origin (PDO) cheeses have distinctive sensorial characteristics linked not only to the processes involved in cheesemaking but the feed associated and available in the area and thus the milk. Modifications to the original characteristics of the milk is restricted if not forbidden. The color of milk can also be influenced by diet. Seasonal variation in color is related to changes in the β-carotene concentration (Kosikowski and Mistry, 1997). Due to the variation in seasonal availability of certain types of forage throughout the year, there is potential for variance in all sensory aspects of pasture-based milk.

Bendall (2001) concluded that the same volatile compounds are found in milk regardless of feed source and that the difference in flavor comes from differing concentrations of these volatile compounds. However, volatile compound results are very much dependent on the extraction recovery technique applied. Several studies have also reported unique aroma-active compounds in milk from pasture not present in total mixed ration (TMR) milk (Carpino et al., 2004; Moio, 1996). These compounds are generally, but not exclusively, terpenes. Terpenes are secondary metabolites of plants (Mariaca et al., 1997). Xylenes may also come from the degradation of plant material (Molimard and Spinnler, 1996). The composition of pasture also influences compounds of microbial origin.

Branched aldehydes and ethyl esters result from microbial metabolism of amino acids, fatty acids and carbohydrates of milk (Buchin et al., 1999).

Methyl esters were found to be characteristic of pasture milk (Povolo et al., 2006). One can also expect to find higher levels of several groups of aromatic compounds including nitrogen heterocycles, linolenic acid oxidation products, lactones, phenolics and phytol derivatives (Bendall, 2001). Several nitrogen heterocycles have been linked to grassy flavors (Khiari, 1997). Pasture-derived milk has also been reported to contain greater concentrations of both indole and skatole (Urbach, 1990). Variation in fatty acid oxidation products are expected given the established differences in fatty acid content of pasture vs. TMR milks. Fatty acids, Strecker esters, sulfur compounds, *ä*-lactones, terpenes, diacetyl and related compounds, and Strecker degradation products are expected at lower concentrations in milk (Bendall, 2001).

Milk Processing

Pasteurization is required of all fluid milk intended for retail sale (Code of Federal Regulations, 1998). Although, states may allow the sale of raw milk directly from the farm. Raw milk is transported and stored at refrigeration temperatures, up to 4 days. A heating step is required to help ensure the safety of milk and to prolong shelf life. Three time/temperature combinations have been approved for milk pasteurization in the United States. Low temperature-long time (LTLT) pasteurization, also called vat pasteurization, is carried out at a minimum of 62.8°C for 30 minutes. High temperature-short time pasteurization (HTST) is 71.1°C for 15 seconds. Both of these are equivalent processes for the elimination of pathogenic bacteria in milk. HTST pasteurization is the most common practice in commercial processes. Pasteurized milk is not sterile and requires refrigeration to further

prolong shelf life. Demand for a shelf stable milk product was met in many countries by ultra-heat-treated (UHT) milk. Processing conditions vary between countries from 130-150°C for 1-4 seconds. The US requires UHT milk to be heated at 137.7° for 2 seconds. UHT milk is microbiologically stable at room temperature when packaged aseptically, but is more likely to have chemical deterioration due to the high temperature of processing (Varnum and Sutherland, 2001). Stale or oxidized flavors have also been attributed to UHT milk (Perkins et al., 2005). Milk is homogenized to reduce the size of the fat globule, stabilizing the fat within the aqueous phase. Without this processing step the fat globules settle at the top of the milk, known as creaming.

Pasteurization has a history in the United States. In 1924, the Public Health Service developed the Standard Milk Ordinance to be voluntarily adopted by state and local milk control agencies. The goal of the Standard Milk Ordinance was to provide guidelines for the safe processing and handling of milk to decrease the incidence of foodborne disease associated with dairy products. After 33 revisions, the ordinance is now called the Grade "A" Pasteurized Milk Ordinance (PMO). This ordinance regulates the production, transportation, processing, handling, sampling, examination, labeling, and sale of Grade "A" milk and milk products, as well as the inspection of dairy farms, plants, and transfer stations. If adopted by state or local agencies, PMO violators are subject to legal actions, which are recommended in the revised ordinance (Grade "A" Pasteurized Milk Ordinance, U.S. Dept. of Health and Human Services and U.S. Food and Drug Administration, 2003 Revision).

Sensory Analysis

Microbial quality, shelf life, and shelf stability have been and will remain key ways to define quality (Boor, 2001). However, flavor is a crucial concept of quality (Drake, 2004).

There are three main types of sensory analysis for dairy products and ingredients: grading/judging, analytical tests, and affective tests. Grading/judging is used to measure the quality of a product as good or bad. Analytical tests are used to quantify the amounts of certain attributes, and affective tests are used to assess the consumer acceptability or preference of an attribute or a product (Lawless and Heymann, 1998). The use of sensory techniques to measure quality of dairy products dates back many years, to the early use of these products. In the early twentieth century, trade names and brand names were developed for the first time, and each was given a quality grade by the USDA. The original purpose of dairy grading and judging was to determine if a product had good "eating quality", versus the product passing chemical and physical evaluation standards. In judging and grading, a judge rates a product based on a score card (Bodyfelt et al., 1988). An example of a dairy judging score card can is shown in Figure 2. The long history of these analyses emphasizes the importance of sensory quality.

Grading and judging are based on the characteristic "goodness" of a food. An overall flavor and/or texture quality score is generated based on the presence/absence of specific pre-determined defects. These two techniques function well to assess gross quality. However, grading/judging are not accurate tools in assessing the full range of flavors or textures associated with foods for several reasons. The tests are subjective and defect-oriented, which means that rather than assessing a flavor attribute for intensity, the attribute is rated good or bad and can vary between judges. Further, what is good or bad to a trained judge does not necessarily translate to consumer like or dislike. Judging and grading data are not continuous and cannot be analyzed statistically for this same reason (Drake et al., 2001).

More recently, descriptive sensory analysis has begun to take the place of grading and judging. These methods seek to profile a food on all of its characteristics, which is different than quality judging. These types of analyses are used to evaluate the quality of a product, compare products to each other, and to understand consumer responses to different products (Murray et al., 2001). Murray et al. (2001) described the several different descriptive sensory analysis techniques, including the Flavor Profile Method, Texture Profile Method, Quantitative Descriptive Analysis, Quantitative Flavor Profiling Technique, and the Spectrum Method. For each method, a descriptive panel is screened to test performance skills and then trained at some level. The panel either develops a sensory language for the product they are testing or adopts a language that has already been developed for such products. Training occurs in reference to the language, with attributes being described by a specific definition as well as a reference solution or taste (Table 3). No judgment is made to "good" or "bad", rather, all flavors or textures are identified and their intensities are quantified.

To accurately describe flavors in dairy products, a lexicon or sensory language is developed that identifies a descriptor for a flavor, explains the descriptor, and provides a reference for that descriptor. An example of a full lexicon can be found in Table 4: A descriptive lexicon for Cheddar cheese (Drake et al., 2001). A developed lexicon allows sensory research to be more objective, and terms to be standardized. A lexicon is produced by first generating a rough language by round table discussion of experienced tasters and a range of representative products. Other panelists are trained on the existing descriptors, and encouraged to volunteer new descriptive terms. The panel is presented with possible

references and collectively chooses the best reference for each descriptor (Drake and Civille, 2003).

Flavor profiling, developed at Arthur D. Little and Co., was the first documented method of descriptive sensory analysis (Cairncross and Sjöstrom, 1950). The panel consists of four to six judges trained specifically for the product they are evaluating. Texture profiling is based on flavor profiling, but involves descriptive analysis of texture. Trained panelists evaluate texture from first bite until the food is completely chewed. Quantitative descriptive analysis (QDA) is a method that was developed based on flavor profiling, but also addressed problems or issues of flavor profiling. QDA was developed by Stone and Sidel in the 1970's at Tragon Co. In QDA, the language is "everyday" and non-technical. References are only used if a problem with a term is encountered. The panel leader is not an active member of the panel, but is trained in leading these types of panels and acts as a facilitator. QDA uses a panel of 8-12 people who are trained on the descriptors. The data from these panels is both quantitative and qualitative. Quantitative flavor profiling (QFP) is a modified version of QDA that uses a standardized, technical language (Murray et al., 2001). Also, in QFP, references are used to demonstrate the language and concepts. The Spectrum method is a widely used technique, developed by Gail Vance Civille of Sensory Spectrum, Inc. in the 1970's. This technique relies on references, specialized training, and multi-product evaluation. Eight to 12 panelists are highly trained on attributes that are non-product specific. References are provided for each term, and do not change if the panel evaluates another product, though some may be added as new attributes are defined. These are the descriptive analysis methods that are widely used today, and descriptive analysis is the most useful tool in providing information on sensory attributes of food (Murray et al,

2001). These techniques differ but their goal is the same; to enable a group of individuals to perform in unison as an instrument to document sensory properties of foods or materials.

Another type of sensory testing that generates quantitative data is affective testing. These tests involve consumers rather than trained panelists and are conducted in a manner that uses terms representative of the way consumers would describe a food rather than a developed lexicon used for descriptive sensory analysis. Affective tests measure intensity of a flavor attribute, degree of liking of a flavor attribute, and overall liking of a product. The overall preference between products can also be determined (Lawless and Heymann, 1999).

Instrumental Analysis of Flavor:

The human nose is the most sensitive instrument used for flavor evaluation and cannot be replaced by instrumentation. However, to fully understand flavor, descriptive sensory analysis needs to be accompanied by instrumentation to identify and characterize the compounds responsible for the flavor and aroma in foods. There are several ways to analyze flavors in food. The first step is to identify the compounds present in the food matrix, so those compounds must be extracted for analysis. Methods for extraction of volatile compounds from foods are numerous and include direct solvent extraction, distillation, and headspace analysis techniques including purge-and-trap headspace analysis, static headspace analysis, and headspace solid-phase microextraction (SPME). For solid matrices, direct solvent extraction is the simplest method for extracting volatiles. A highly volatile organic solvent, such as diethyl ether, is combined with the food matrix and, after several mixing cycles, the solvent along with the extracted volatile compounds are collected from the solid or aqueous phase by density separation. The volatile compounds can then be distilled. High vacuum distillation is a common method for further concentration of volatile compounds.

This method applies a vacuum to decrease the boiling point so that very little heat is applied, greatly reducing or eliminating artifacts. The concentrated solvent extract is then injected onto a gas chromatograph (GC) for separation and identification (Milo and Reineccius, 1997).

Solid-phase microextraction (SPME) is a technique used for rapid, solventless extraction or preconcentration of volatile and semi-volatile organic compounds from product headspace. This extraction technique utilizes the principle of partitioning the organic component of a sample between a bulk aqueous or vapor phase and the thin polymeric films coated onto fused silica fibers in an apparatus specifically designed for this technique (Harmon, 1997). This technique is advantageous to other extraction methods because the method remains the same for liquid, solid, and gaseous samples. As this is an equilibrium technique, careful consideration is necessary to optimize and control many factors including: agitation, temperature, volume of sample/headspace, and pH. Early use was concentrated in environmental research, but SPME has become increasingly popular for use in food analyses. SPME can be used without heat resulting in little to no artifact formation. The SPME device is a modified syringe that allows the plunger to be held at a specific length for extended periods of time while inside the sample vials and the GC injector port. The barrel of the syringe is a stainless steel port containing the silica fiber, which is coated with either a liquid or solid. Several types of fibers are available and their use depends on the application The fiber is introduced into the headspace and analytes establish equilibrium and adsorb onto the fiber. Analytes are desorbed onto a GC column for separation and identification of the headspace volatiles of the sample.

Gas chromatography/mass spectrometry (GC/MS) is the most common method used to separate and identify volatile compounds. The GC/MS method combines chromatographic separation with a multi-channel detector to produce qualitative and quantitative information. After a small sample is injected onto the GC, the volatiles travel through a coiled column where individual compounds are separated based on their specific chemical properties. The separated compounds then enter the MS where they are bombarded by electrons to produce ion fragments. Different compounds will produce different characteristic ion fragments. The fragmentation patterns can be compared to chemical standards and existing databases to identify which compounds are present in the food (Huston, 1997). There are two basic types of MS: quadrupole and ion trap. The quadrupole MS utilizes a quadrupole electric field to affect the motion of ions. An ion trap MS stores and concentrates ions prior to mass analysis, and, therefore is more sensitive than a quadrupole apparatus (Huston, 1997).

In contrast to MS detection, the flame ionization detector (FID) has become the most commonly used detector for gas chromatography. Several factors contribute to this popularity. The FID responds to virtually all organic compounds with favorable sensitivity. The detector response is not affected by moderate changes in flow, pressure, or temperature. The FID does not respond to common carrier gas impurities such as CO_2 and water under normal operation. The linear range of an FID extends to about seven orders of magnitude (10^7). The FID is composed of a small hydrogen-air diffusion flame burning at the end of a jet, to which the eluted components from the column are directed with carrier gas. As the organic components reach the flame, electrically charged species are formed. The charged species are collected at an electrode set above the flame, producing an increase in current proportional to the amount of carbon in the flame. The organic materials eluting from the

column undergo degradation reactions in this hydrogen-rich region, forming a group of single carbon species. As the two gas flows mix at the reaction zone (with oxygen available) CHO^+ and e^- are formed. The CHO^+ reacts rapidly with water produced in the flame to generate hydronium ions. These ions are the primary positive carrying species. The process occurs approximately once every 100,000 carbon atoms introduced into the flame. This serves as an almost quantitative counter of carbon atoms being burned. Therefore, the FID response is proportional to the number of carbon atoms rather than the compound weight or moles present (Colon and Baird, 2004). The FID is also inexpensive compared to MS detectors. However, characteristic patterns specific to one particular compound are not generated by the FID making it less useful in compound identification compared to the MS detector.

Several other GC detectors exist. The choice of detector is dependent on several factors including limit of detection, sensitivity, linear range, and selectivity of response. Thermal conductivity detectors (TCD) are a nondestructive detection system that respond to differences in the thermal conductivity of the carrier gas due to the presence of the eluted components. While the TCD has largely been replaced by ionization detectors, it remains useful in the determination of gaseous substances that are difficult to detect such as CS_2, COS, H_2S, SO_2, and CO_2. The electron-capture detector (ECD) is another popular gas detector using a β-emitter radioactive source to produce electrons on collision with the carrier gas and effluents, producing a measurable standing current. The thermionic detector (TID), also known as the nitrogen-phosphorous detector (NPD), is based on the phenomenon that a metal anode emits positive ions when heated in gas. Thermionic detectors are commonly used for detection of organic compounds containing nitrogen and phosphorous atoms. The

helium ionization detector (HID) forms metastable helium species with the effluent and are subjected to an electric field whereupon current change is measured. The flame photometric detector (FPD) is based on the monitoring of the intensity of the light emission of species that have been excited in a flame. The components of the effluent of the chromatographic column are decomposed and then excited to a higher electronic state in a hydrogen-rich flame. These species emit light characteristic of the heteroatoms introduced into the flame (Colon and Baird, 2004). Table 5 contains a summary of typical characteristics of common GC detectors.

Though instrumental analysis and descriptive sensory analysis are powerful tools on their own, they are even more powerful when used in combination. By relating instrumental data to descriptive sensory data, researchers are able to determine which compounds are responsible for specific flavors in food (Drake and Civille, 2003). This goal is challenging because instruments may detect many compounds that are present at levels below the human threshold and therefore do not contribute to the flavor of the food. Likewise, there are flavor-active components that contribute to food flavor at concentrations below instrumental detection. Differentiating the small number of compounds that are present in foods above the human threshold from those that are not becomes challenging when there are so many volatile compounds in the product (Drake and Civille, 2003). One such method that assists in linking instrumental data to the sensory perception of flavor is gas chromatography-olfactometry (GC/O). This method of evaluating odor-active compounds involves splitting the GC effluent between a traditional detector and a human nose. This technique provides additional confirmation of compound identity, and aids the determination of aroma quality of individual compounds and their significance to the flavor of a food. The procedure for GC/O

combines gas chromatography with a human sniffer to determine what compounds are released from the column, aroma quality, and at what intensity the odor of the compound is found. The human sniffer records the aroma and intensity as compounds elute and a chromatogram is established by the traditional detector, usually an FID (Maria et al., 1994). A table can then be generated identifying the retention time (RT) or retention index (RI) of a compound and its aroma quality and intensity. Retention indices are calculated using an n-alkane series (Van den Dool and Kratz, 1963). For calculation of RI, these compounds are defined as 100 times the number of carbon atoms in the molecule. For example, n-hexane, n-heptane, and n-octane are 600, 700, and 800 respectively. The eluted compounds are then compared to these standards and assigned their respective RI. Retention indices are more stable and comparable across time, machine, and location than RT values. Table 6 shows an example of this type of table.

The use of GC/O has been applied to several dairy products (Bendall, 2001; Carunchia Whetstine et al., 2003; Friedrich and Acree, 1998; and Karagul-Yuceer et al., 2002, 2003, 2004). Friedrich and Acree (1988) reported that seven common odor-active compounds could be identified in raw milk. Those were dimethylsulphone, ethyl butanoate, ethyl hexanoate, heptanal, indole, nonanal, and 1-octen-3-ol. Fifteen compounds were detected in milk after it was heated, and four of those were unique to the heated milk only. Those four compounds were hexanal, 2-nonanone, benzothiazole and δ-decalactone. Other odor-active volatile compounds were found to be common in other dairy products, such as cheese and fermented products (Friedrich and Acree, 1988). Several aroma-active compounds were found in skim milk powder by GC/O (Karagul- Yuceer et al., 2001,2002).

Thirty-eight aroma-active compounds were identified by GC/O included p-cresol, skatole, octanoic acid, nonanoic acid, decanoic acid, and dodecanoic acid.

Organic Products

With the demand for organic products on a continued upward trend, many farmers are considering the opportunities and benefits of value-added milk in organic dairy products. According to the Organic Trade Association (2006), the organic non-foods product categories, such as personal care and nutritional supplements, experienced sales of $744 million in 2005 for a 32.5% increase over the previous year. The organic food industry grew 16.2% in 2005 for nearly $13.8 billion in sales. This represents 2.5% of total food sales in the US, an increase from 0.8% in 1997. Organic foods have shown consistent growth rates of nearly 20% since 1990 compared to a 2-4% increase in total US food sales. The organic industry predicts an annual growth rate of 18% through 2008 (Organic Trade Association, 2004). Organic foods are estimated to reach $22 billion in sales by 2010 (Scheel, 2003). Organic farming, in general, can create additional incomes as well as maintain rural employment. While small farms may be at a financial disadvantage in regards to organic conversion (Buragas, 2005), unfavorable agricultural locations such as mountainous regions may be revived by the adoption of organic farming (Rosati and Aumaitre, 2004).

Both the US Senate and House of Representatives have recognized the role that organic products will play in coming years. Each side has established working groups to deal with organic-based legislature. Cost-share provisions are being implemented to help farmers offset the costs of certification and transition to organic (USDA, 2004). Dozens of agencies outside the US have been approved as certifiers of organic products and negotiations are on-going for equivalency agreements promoting international organic trade. Retailers are

introducing and expanding organic products every day. Retail chains are producing their own private label organic products, further stabilizing the organic market (Haumann, 2004).

The current trends show many markets are unable to keep up with demand for organic dairy products. Demand for organic dairy products has far surpassed industry expectations (Buragas, 2005). Organic dairy products saw a 20.3% growth rate for total sales of $1.38 billion in 2003. Fruits and vegetables continue to make up the bulk of organic food sales, accounting for nearly half of all sales in 2003. Organic dairy products represented 13% of total sales of the same year. Prepared foods and beverages accounted for 13% and 15%, respectively. Organic meat, fish, and poultry experienced the greatest growth rate at 77.8% (Organic Trade Association, 2004).

Organic Production Regulations

The Organic Foods Production Act of 1990 (OFPA) was passed to establish national standards governing the marketing of certain agricultural products as organically produced products, assure consumers that organically produced products meet a consistent standard, and to facilitate commerce in fresh and processed food that is organically produced (USDA National Organic Program, 2004). Organic farms/operations are annually inspected and certified by a nationally approved certifying agent.

Organic regulations can be found in the Code of Federal Regulations, Title 7 Part 205. 7 CFR Part 205 states,

"Livestock products that are to be sold, labeled, or represented as organic must be from livestock under continuous organic management from the last third of gestation or hatching. Milk or milk products must be from animals that have been under continuous organic

management beginning no later than 1 year prior to the production of the milk or milk products that are to be sold, labeled, or represented as organic.

The producer of an organic livestock operation must provide livestock with a total feed ration composed of agricultural products, including pasture and forage, that are organically produced and, if applicable, organically handled: Except, that, nonsynthetic substances and synthetic substances allowed under 7 CFR, Part 205.603 may be used as feed additives and supplements. The producer of an organic operation must not:

(1) Use animal drugs, including hormones, to promote growth;
(2) Provide feed supplements or additives in amounts above those needed for adequate nutrition and health maintenance for the species at its specific stage of life;
(3) Feed plastic pellets for roughage;
(4) Feed formulas containing urea or manure;
(5) Feed mammalian or poultry slaughter by-products to mammals or poultry; or
(6) Use feed, feed additives, and feed supplements in violation of the Federal Food, Drug, and Cosmetic Act.

The producer of an organic livestock operation must establish and maintain livestock living conditions which accommodate the health and natural behavior of animals, including access to outdoors, shade, shelter, exercise areas, fresh air, and direct sunlight suitable to the species, its stage of production, the climate, and the environment."

Access to pasture is required for ruminant animals. This portion of the requirements has become a point of contention for many organic milk producers. Several large dairy operations allow herds to roam the land but little to no energy is obtained from fresh forage on this acreage. Organic feed is trucked in to feed the cows. Some organizations believe this is not the intent of the regulations and that to be organic, cows must obtain energy from fresh forage when available. These organizations want more specific language regarding the role of pasture to the organic dairy cow. Parasiticides and antibiotics are allowed in very limited use and will generally not allow for that cow's milk to be labeled as organic. Land used to

produce organic crops must have had no prohibited substances applied for three years before harvest.

It should be noted that while organic farming should assure lower levels of drugs, pesticides, and the absence of genetically modified organisms (GMO), organic products may have a higher risk of fecal contamination from animal manure (Rosati and Aumatitre, 2004; Mukherjee et al., 2004). These risks are influenced by several factors including manure compost time and application prior to harvest. However, organic products have not been found to pose a greater risk of pathogenic contamination than conventional products (Mukherjee et al., 2004; Phillips and Harrison, 2005).

Organic Labeling

The goal of the USDA's organic labeling program is consumer recognition of the green and white USDA label "certified organic" (Fig 1). A consistent, uniform set of standards and labels means more information for the consumer as well as consistency among certifiers, producers, and handlers. The USDA groups organic products into four categories (USDA, 2002). The categories are 100% organic, 95-100% organic, 70-95% organic, and less than 70% organic. Only those products with at least 95% organic ingredients are allowed to use the USDA organic seal. Products with at least 70% organic ingredients may make the claim that the product is made with organic ingredients anywhere on the packaging. Products with less than 70% may only list organic ingredients in the information panel on the side of the package and may not make the claim anywhere else.

Fig 1. *USDA Organic* Seal

Consumer Perceptions and Attitudes Towards Organic Products

A review of the literature on consumer perceptions and attitudes towards organic foods shows that there is no single factor or demographic driving the organic movement. According to Hill and Lynchehaun (2002), key influential factors when considering organic milk purchase are:

- knowledge of organic products (including price justification and definitions of organic)
- food scares (including pesticide and fertilizer residues as well as disease)
- safety of children (related to food scares)
- societal trends towards healthier eating
- health and welfare of animals
- environmental impact of organic products
- personal health and welfare
- price
- availability
- taste or flavor
- product quality

Due to the current price premiums on organic foods, affluent households are more likely to purchase organic food products. However, the presence of high household income does not mean the consumer is willing to purchase these products or knows enough information to justify the purchase. According to Davies et al. (1995), women with disposable income and children are the most committed purchasers of organic food. This correlates in that women are the primary purchasers of food for a household and tend to do more research and be more concerned with health. Organic food has received much press coverage throughout the world and is therefore on the minds of consumers. This attention has made organic products appealing as a fashionable item or a fad for some consumers (Hill and Lynchehaun, 2002). Organic products have made it past the "hippy era" and made it into the mainstream (Jensen and Smith, 2000).

Several studies have shown that consumers identify taste as a primary factor in purchase decisions for food products (Yiridoe et al., 2004; Boland et al., 2001; Kirk and Slade, 2002; Hill and Lynchehaun, 2002). However, it has also been shown that consumers do not choose organic foods for better taste. When queried, a consumer may likely state that flavor is a major reason for purchasing organic products but cannot tell the difference between organic and conventional products when tested (Kirk and Slade, 2002).

Consumers also contemplate price and product availability in addition to health and nutritive value considerations. Limited availability is an obstacle for non-organic purchasing consumers. More consumers would purchase organic products if they were more readily available (Yiridoe et al., 2004 and Davies et al., 1995). Price is of great importance in the decision **not to buy** organic milk. Consumers are generally not willing to pay a price premium above 20% although specific markets have been found to be exceptions to this

claim (Yiridoe et al., 2004). Although consumers rank appearance, taste, and quality higher than price; price will remain the determining factor in whether they buy fruits and vegetables (Bounty Fresh, LLC, 2002). This assumption can be carried over for dairy products as well.

The belief that organic food is better for you can lead to the belief that the food is actually better quality and has better sensory characteristics. There is little or no consistent data proving that organic foods are a healthier product than their conventional counterparts, other than the lack of pesticide residues on organic products. There is also no evidence that legal amounts of pesticide residues are harmful. Organic products are generally perceived as a premium product. As such, organic products are not much more expensive than other premium products available in the market (Hill and Lynchehaun, 2002).

According to the National Center for Health Statistics, more than 30 percent of Americans are considered obese. The American Obesity Association estimates that 127 million Americans are overweight, 60 million are obese, and 9 million are severely obese based on body mass index (BMI) scores of 25-30, 30, and 40+ respectively. The number of obese children and teens ages 6-19 has more than tripled in the last twenty-five years. The annual medical costs of being overweight and obese are estimated to exceed $115 billion (Finkelstein et al., 2004). These figures do not include soft factors such as absenteeism and decreased productivity caused by obesity. The adverse health effects of obesity are numerous and continue to be identified. These disturbing trends have been broadcast over all media outlets in countless variations, triggering some consumers to start thinking about living a healthier lifestyle and eating more nutritious, healthy foods. Organic products fit this "healthy" profile.

Environmental concerns

The large number of studies of the environmental impact of organic milk production shows a variance in methods, calculations, and conclusions (deBoer, 2003). Methane (CH_4) production accounts for more than half of global warming gases on dairy farms. Methane emissions decrease by increasing production levels and feed digestibility. Switching to organic production will increase methane production because of lower milk production levels and increased use of roughage. Organic dairy farming does reduce the eutrophication potential (EP) by potentially reducing the leaching of nitrates (NO_3^-) and phosphates (PO_4^-) due to lower use of fertilizer. Eutrophication is the process whereby water bodies receive excess nutrients stimulating excessive plant growth (also known as an algal bloom) reducing dissolved oxygen in the water (US Dept Interior, 2005). Organic dairy farming has the potential to decrease carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions, thereby reducing global warming potential (GWP). Carbon dioxide emissions result mainly from combustion of fossil fuels at the farm and the production and transport of fertilizer and concentrates. Organic production is expected to use less fossil fuel per ton due to lack of artificial fertilizers and lower levels of concentrates in the cow's feed. Nitrous oxide reduction can be achieved by lower fertilization rates. However, global warming potential has not been shown to be proven lower due to higher methane production from organic versus conventional farming and both methods produce nearly equal rates of CO_2 emissions (deBoer, 2003).

Until recently, organic dairy products were not a major player in the organic food arena. Fruits and vegetables still make up nearly half the organic food sales in the US (Organic Trade Association, 2004). Horizon Organic Holdings Corp (Longmont, CO) was

the first national distributor of organic milk in the US. Horizon's sales swelled by 650% in 1993 thanks, in part, to the negative consumer reaction to the FDA approval of Monsanto's (St. Louis, MO) recombinant bovine growth hormone (rBGH) (Palmeri, 1998) with the trade name "Posilac". A vast majority of popular and trade press articles that addressed the rise of organic milk mention rBGH as the driving factor behind the increased demand seen in the organic milk market (DuPuis, 2000).

Recombinant bovine growth hormone (rBGH)

Bovine growth hormone (BGH; also known as bovine somatotrophin or BST) is a naturally occurring protein hormone produced in the pituitary gland of all cattle. The function of BGH is to direct energy from the cow's feed to meet physical demands such as milk production in adult cows and growth in calves. Bovine growth hormone is present in trace amounts in all cows milk, both organic and conventional. Bovine growth hormone concentrations in milk are not representative of BGH concentrations in the body of the cow as the hormone is burned up in order to produce milk. Growth hormones are species specific; therefore, the human body does not recognize BGH and simply digests the protein in the stomach as with all other proteins.

Through the use of recombinant DNA technology, an exact copy of the natural hormone can be produced for subcutaneous injection into cattle in order to enhance milk production. Recombinant bovine somatotrophin (rBST; also known as recombinant bovine growth hormone or rBGH) is indistinguishable from natural BST (Washington Dept Agriculture, 2005). Furthermore, because BGH is naturally present in cows and their milk, the FDA has ruled that milk from cows treated with rBGH is no different than milk from non-treated cows. Therefore, there can be no requirement to list rBGH as an ingredient

because it does not change milk from its natural state. As previously stated, with trace amounts of BGH present in all milk, to label fluid milk as "rBGH-free" is a violation of the FDA labeling laws. Distributors may, however, label their products as being derived from cows not treated with rBGH.

One can not ignore rBGH when discussing organic dairy products. While the European Union and Canadian government have not approved rBGH for use, neither organization has refuted the facts and findings. In the terms of this discussion, "rBGH-free" means milk produced without the injection of bovine growth hormone. An important point to note is that rBGH-free does not necessarily mean that milk is organic. Consumers may incorrectly assume that they are the same. All organic milk is rBGH-free but not vice versa. Consumers have long believed that milk is wholesome and pure. There remains an incorrect belief by some consumers that the injection of rBGH exposes the consumer to foreign, artificial product without their consent (Grobe and Bouthhitt, 1995).

Utilizing supermarket scanner data Dhar and Foltz (2005) showed that organic milk benefits by competition with rBGH-free milk. Consumers derive significant benefits from the ability to purchase both rBGH-free milk and organic milk. Competitive effects of organic milk, rBGH-free milk, and unlabeled (conventionally-produced) milk lower the overall prices of milk in general. Some consumers demonstrate a willingness-to-pay for rBGH-free milk but not organic. The price premiums may run up to $2 per gallon for rBGH-free and an additional $1 per gallon for organic milk over conventionally produced milk. Data shows that the organic market share is steadily growing while the rBGH-free market peaked in 1998 and is in decline (Dhar and Foltz, 2005). Several hypotheses exist as to the cause of this trend including consumers upgrading from rBGH-free to organic for its added

benefits at a low cost, comparatively speaking, and that risk perception over rBGH has decreased with increased information available. This trend may reverse in the future. Starbucks and Safeway Corp have recently declared that they will no longer use milk from cows treated with rBGH. This movement by these companies has created a ripple in the dairy industry. California Dairies, Inc., California's largest milk co-op responded by eliminating external application of rBGH by their co-op members. Dean Foods, the largest dairy processor and distributor in the US, no longer accepts milk treated with rBGH in several of its processing plants in the New England area.

Objectives

With the continued interest and growing popularity of organic dairy, transitioning to pasture-fed or organic dairy farms may be a lucrative decision for North Carolina dairy farmers. Grazing cows portray a healthy image of milk and may increase health benefits via increases in unsaturated fatty acids and conjugated linoleic acid content. The possibility of organic dairy production for North Carolina has been a source of interest due to inquiries from a processing company within the state as well as from a national organic cooperative looking for more local sources of fluid milk for the growing demand in North Carolina and elsewhere in the Southeast. While most North Carolina dairy farms are not expected to make a move towards organic milk, there could be a real marketing opportunity for those that do. Because pasture-based dairy systems vary in the types of forage that are grown, it is very important to characterize the effect of such variations on milk composition and flavor characteristics. The objectives of this study are to compare the flavor and shelf life of pasture-based and conventional fluid milk; and to compare consumer perception and market

potential for pasture-based and/or organic dairy products. Such data will be very useful to dairy producers considering the transition to organic production.

Figure 2: Example of dairy grading scorecard for dried milk

Product: _____ SAMPLE NO. Date: _____

Flavor	Criticism Score								
	Acid								
	Astringent								
	Bitter								
No Criticism 10	Chalky								
	Cooked								
	Feed								
	Fermented								
Unsalable 0	Flat								
	Foreign								
	Gluey								
	Metallic								
Normal Range	Neutralizer								
1-5	Oxidized/Tallowy								
	Rancid (Lipolysis)								
	Salty								
	Scorched								
	Stale								
	Storage								
	Unclean/Utensil								
	Weedy								
Physical									
No Criticism 5	Dry Product:								
Unsalable 0	Caked								
Normal Range	Dark Particles								
1-5	Lumpy								
	Unnatural Color								
	Reconstituted								
	Product:								
	Churned Particles								
	Dark Particles								
	Grainy								
	Undispersed Lumps								
Package 5	Score								
No Criticism 5	Ruptured Vapor								
Unsalable 0	Barrier								
Normal Range	Soiled								
1-5	Unsealed								

Flavor Criticism Score									
Laboratory									
	Fat (%)								
	Moisture (%)								
	Titratable Acidity								
	(% Lactic Acid)								
	Solubility Index (ML)								
	Bacterial Estimate								
	(Per Gram)								
	Coliform (Per Gram)								
	Direct Microscopic								
	Clump Count (Per G)								
	Scorched Particles (MG)								
	Dispersibility (Modified								
	Moats-Dabbah Method,%)								
No Criticism 5	Phospahatase test								
	Micrograms Phenol/ML								
	Undenatured Whey Protein								
	Nitrogen (MG/G)								
	Oxygen Content (%)								
Unsalable 0	Copper (PPM)								
	Iron (PPM)								
	Vitamin A (I.U.)								
	Vitamin D (I.U.)								
	Alkalinity of Ash								
Normal Range 1-5	(ML/ 100 G)								
	Protein Content (%)								
	Mesh (Screen %)								
	Ash, Phosphorus Fixed (%)								
	Lead (PPM)								
	Yeast and Mold (Per 0.1 G)								
	Thermophiles (Per G)								
	Reducing Sugars (As								
	Lactose %)								
	Staphylococcus								
	(Coagulase Positive)								
	Salmonella (In 100 G)								

SIGNATURES: _____ _____ _____

Bodyfelt et al., 1988

Table 3. Preparation of reference materials for descriptive sensory evaluation of nonfat dried milk

Descriptor	Reference	Preparation
Cooked/sulfurous	-Heated milk	-Heat pasteurized skim milk to 85ºC for 45 min
Caramelized/butterscotch	-Autoclaved milk -Caramel syrup	- Autoclave whole milk at 121º for 30 min - Dilute 1 tablespoon of caramel syrup in 400mL skim milk
Sweet aromatic/cake mix	-Pillsbury-White cake mix -vanillin	-dilute 5mg of vanillin in skim milk
Cereal/grass-like	-breakfast cereals (corn flakes, oat and wheaties)	-soak one cup cereal into three cups milk for 30 min and filter to remove cereals
Barny	-*p*-cresol	-20 ppm in skim milk
Brothy/potato-like	-Kroger-Canned white potato slices -methional	-remove the sliced potatoes from the broth -few drops of 20 ppm methional in methanol in sniffing jars
Animal/gelatin-like/wet dog	-Knox-unflavored gelatin	-dissolve 28g of gelatin in 2 cups of distilled water
Milk fat/lactone	-Heavy cream -delta dodecalactone	40 ppm on filter paper
Fried fatty/painty	-(E,E)-2,4-decadienal	-2 ppb in skim milk
Fishy	-Fresh fish with skin -Canned tuna juice	
Mushroom/metallic	-fresh mushroom	-slice fresh mushroom in skim milk for 30 min and filter to remove mushroom slices
Papery/cardboard	-cardboard paper	-oak pieces of cardboard paper in skim milk overnight
Burnt/charcoal	-over toasted bread slice	
Vitamin/rubber	- Enfamil- liquid Polyvisol vitamins	
Diacetyl	-diacetyl	-Diacetyl, 20 ppm on filter paper
Earthy/musty	-potting soil, odor reminiscent of damp basement	
Sweet taste	-sucrose	-5% sucrose solution
Salty	-NaCl	-2% NaCl solution
Sour	-citric acid	-1% citric acid solution

Table 3 continued.

Descriptor	Reference	Preparation
Bitter	-caffeine	-0.5% caffeine solution
Umami	-monosodium glutamate	-1% MSG in water
Astringent	-tea	-soak 6 tea bags in water for 10 min

Karaguul-Yuceer, 2003

Table 4. Descriptive lexicon for Cheddar cheese

Term	Definition	Reference
Cooked	Aromatics associated with cooked milk	Skim milk heated to 85ºC for 30 min
Whey	Aromatics associated with Cheddar whey	Fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	Diacetyl, 20ppm
Milk fat/Lactone	Aromatics associated with milk fat	Freash coconut meat, heavy cream, δ dodecalactone, 40ppm
Fruity	Aromatics associated with different fruits	Fresh pineapple
Sulfur	Aromatics associated with sulfurous compounds	Boiled mashed egg
Free fatty acid	Aromatica associated with short chain fatty acids	Butyric acid, 20ppm
Brothy	Aromatics associated with boiled meat or vegetable stock	Canned potatoes, qylers low sodium beef broth cubes, methional, 20ppm
Nutty	The nut-like aromatic associated with different nuts	Lightly toasted unsalted nuts, wheat germ, unsalted wheat thins, roasted peanut oil extract
Catty	Aroma associated with tom-cat urine	2 mercapto-2 methyl-pentan-4-one, 20ppm
Cowy/phenolic	Aromas associated with barns and stock trailer, indicative of animal sweat and waste	p-cresol, 160ppm, bandaids
Age**	Flavors indicated age in Cheddar cheese	Aged Cheeddar cheese (1 y or longer)
Yeasty*	Aromatics associated with fermenting yeast	Raw yeast dough, yeast in 3% warm sucrose water
Moldy/Musty*	Aromas associated with molds and/or freshly turned soil	2-ethyl-1-hexnol, potting soil
Methyl Ketone/ bleu*	Aroma associated with blue-veined cheeses	2-octanone, 40ppm
Oxidized*	Aroma associated with oxidized fat	2,4 decadienal, 20ppm
Waxy/Crayon*	Aromatics associated with medium chain fatty acids	Capric acid lauric acid or decanoic acid, 100mg/mL

Table 4 continued.

Term	Definition	Reference
Fecal*	Aroma associated with complex protein decomposition	Indol, skatole, 20ppm
Bell pepper*	Aroma associated with freshly cut green vegetables	Methoxy pyrazines, 5ppb
Rosy/Floral	Aroma associated with flowers	2-phenethylamine, 20ppm
Scorched*	Aroma associated with extreme heat treament of milk proteins	Milk heated to 121°C for 25 min
Bitter	Fundamental taste sensation elicited by caffeine, quinine	Caffeine (0.08% in water)
Salty	Fundamental taste sensation elicited by salts	Sodium chloride (0.5% in water)
Sweet	Fundamental taste sensation elicited by sugars	Sucrose (5% in water)
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08% in water)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	MSG (1% in water)
Prickle/bite*	Chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water

*Indicates term was not frequently encountered in Cheddar cheese
**Data analysis indicated term is redundant and is a combination of several terms.
Chemical references prepared in 95% ethanol
(Drake et al., 2001)

Table 5. Summary of several typical characteristics for common GC detectors

Detector	Selectivity	Limits of detection (LOD)	Linear Range
Thermal conductivity detector (TCD)	Responds if thermal conductivity is different from carrier gas (Universal)	1 ng/mL	10^5
Flame ionization detector (FID)	Organic compounds	1 pg(C)/s	10^7
Electron-capture detector	Electron-capturing compounds such as halogens	10 fg/s (lindane)	10^4
Nitrogen-phosphorous detector (NPD) or thermionic detector	N- and P-containing compounds	1 pg N/s 0.5 pg P/s	10^4
Flame photometric detector (FPD)	P- and S- containing compounds	50 pg S/s 2 pg P/s	10^3 10^4
Photoionization detector (PID)	Aromatics	5 pg C/s	10^7
Electrolytic (Hall) conductivity detector (ELCD)	Halogens and S	1 pg CL/s 5 pg S/s	10^6 10^4
Atomic emission detector (AED)	Element sensitive	0.1-50 pg/s depending on the element	10^4

Table 6. Neutral/basic aroma-active compounds of goat cheese identified during GC/O

		Mean intensities[a]			RI[c]		
Nr.	Compound	Cheese 1	Cheese 2	Odor[b]	DB-Wax	DB-5	Method of Identification[d]
1	Diacetyl	3.00(4/4)	3.65(4/4)	Buttery	937	623	RI,odor,MS
2	Acetoin	1.50(3/4)	1.40(3/4)	Buttery		730	RI,odor
3	Methyl 2-methybutanoate	ND	2.25(4/4)	Butterscotch	1006	787	RI,odor,MS
4	Hexanal	1.50(2/4)	2.25(4/4)	Green grassy	1020	787	RI,odor
5	3-methyl thiophene	3.30(3/4)	4.30(4/4)	Sweet/ plastic	1026		RI,odor
6	Unknown	ND	1.90(3/4)	Ammonia	1099		
7	2-pentanol	ND	2.60(4/4)	Minty	1120	959	RI,odor,MS
8	Unknown	ND	2.00(3/4)	Geranium	1140	831	
9	1-hexen-3-one	1.70(3/4)	3.25(3/4)	Cooked/ vegatable	1153		RI,odor
10	Octanal	1.25(3/4)	ND	Sweet/citrus		1023	RI,odor,MS
11	Heptanal	3.70(3/4)	3.55(4/4)	Fatty	1181	916	RI,odor,MS
12	1-hepten-3-one	ND	1.50(3/4)	Mushroom	1218	883	RI,odor
13	1-octen-3-one	4.00(4/4)	3.90(4/4)	Mushroom	1249	991	RI,odor
14	2-heptanol	1.50(4/4)	2.00(4/4)	Mushroom	1254	926	RI,odor,MS
15	2-acetyl-1-pyrroline	3.00(4/4)	2.05(4/4)	Popcorn	1285	939	RI,odor
16	(Z)-1,5-octadien-3-one	3.50(3/4)	3.60(4/4)	Geranium	1312	997	RI,odor
17	Unknown	2.00(2/4)	1.30(3/4)	Earthy/ Chocolate	1074		
18	Nonanal	2.50(4/4)	3.75(4/4)	Hay/sweet	1378	1107	RI,odor,MS
19	Unknown	ND	2.25(4/4)	Horsehair	1125		
20	Methional	5.25(4/4)	4.75(4/4)	Potato	1392	925	RI,odor,MS
21	2,5-dimethyl-3-ethylpyrazine	ND	2.50(4/4)	Potato	1441	1084	RI,odor
22	2-nonanone	2.75(3/4)	2.00(1/4)	Vitamin/ sour	1450	1096	RI,odor,MS
23	(Z,Z)-3,6-nonadienal	3.20(3/4)	ND	Fatty		1116	RI,odor
24	Unknown	4.60(4/4)	1.00(2/4)	Floral	1470	1150	
25	(E)-2-nonenal	3.30(4/4)	3.65(4/4)	Cucumber	1525	1170	RI,odor,MS
26	(E,Z)-2,6-nonadienal	4.25(2/4)	ND	Hay/fatty	1565	1186	RI,odor
27	Unknown	2.75(4/4)	2.20(3/4)	Vitamin/ minty	1199		
28	2-undecanone	2.50(2/4)	3.20(2/4)	Floral		1285	RI,odor,MS
29	(E)-2-decenal	2.65(3/4)	2.50(4/4)	Hay/fatty	1585	1267	RI,odor
30	(Z)-2-decenal	3.55(4/4)	2.85(4/4)	Fatty	1596	1246	RI,odor

Table 6 continued.

Mean intensities[a]					RI[c]		
Nr.	Compound	Cheese 1	Cheese 2	Odor[b]	DB-Wax	DB-5	Method of Identification[d]
31	Benzothiazole	4.00(2/4)	ND	Plastic/ Rubber	1572		RI,odor,MS
32	Unknown	ND	3.35(4/4)	Coconut	1260		
33	(E,E)-2,4-nonadienal	1.50(3/4)	2.75(2/4)	Fatty	1609	1217	RI,odor
34	Unknown	5.50(4/4)	3.30(4/4)	Fatty/fried	1687	1354	
35	(E,E)-2,4-decadienal	2.50(4/4)	2.45(4/4)	Fried	1700	1304	RI,odor
36	Unknown	4.00(2/4)	3.35(3/4)	Fatty/waxy	1738		
37	2-acetyl-2-thiazoline	2.85(4/4)	2.00(1/4)	Popcorn	1763	1106	RI,odor
38	Dodecanal	2.20(3/4)	2.61(4/4)	Floral	1765	1387	RI,odor,MS
39	Unknown	3.35(2/4)	2.15(4/4)	Coconut/ hay	1434		
40	Decanal	2.15(3/4)	4.25(2/4)	Fatty/hay	1771	1267	RI,odor
41	Indole	3.50(2/4)	1.75(2/4)	Musty	1796	1254	RI,odor
42	γ –Butyrolactone	2.00(1/4)	2.35(4/4)	Coconut		1313	RI,odor,MS
43	γ –Dodecalactone	ND	ND	Coconut		1684	RI,odor,MS
44	Unknown	2.50(4/4)	3.35(4/4)	Goaty/waxy		1371	
45	3-Methyl indole (skatole)	3.45(4/4)	4.10(4/4)	Fecal/ mothball		1440	RI,odor
46	Geraniol	2.35(3/4)	1.75(2/4)	Grassy/ floral	1863	1278	RI,odor,MS
47	γ –Octalactone	3.90(4/4)	4.40(4/4)	Coconut		1547	RI,odor,MS
48	Vanillin	ND	2.50(4/4)	Vanilla	1899	1412	RI,odor
49	δ -decalactone	2.85(3/4)	1.85(4/4)	Peach	1972	1518	RI,odor,MS
50	γ –decalactone	2.00(1/4)	1.00(1/4)	Peach	2103	1508	RI,odor
51	Unknown	3.20(3/4)	3.70(4/4)	Peach	1725		
52	o – Aminoacetophenone	2.50(4/4)	3.95(4/4)	Grape	2281	1346	RI,odor
53	δ –Dodecalactone	2.95(4/4)	5.00(1/4)	Coconut		1733	RI,odor,MS

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Chapter 2

Manuscript 1

Evaluation of chemical properties and consumer perception of fluid milk from conventional and pasture-based production systems

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Key words: milk, flavor, pasture, SPME, descriptive analysis, sensory, fatty acid

Abstract

The continued popularity of organic and natural foods has generated interest in organic milk, and use of pasture for dairy cattle is a requirement for organic production. This process may increase health benefits of fluid milk via increases in unsaturated fatty acid content including conjugated linoleic acid (CLA). Because pasture-based systems vary in types of forage, it is important to understand the impact of feed on the composition and flavor of fluid milk.

The objectives of this study were to compare chemical and sensory properties of pasture-based (PB) and conventional fluid milk and to determine their influence on consumer acceptance. Fluid milk was collected throughout the 2006 growing season from two herds; one fed on a PB diet and one fed on a total mixed ration (TMR), conventional diet. Sensory analyses, descriptive profiling, difference testing, and consumer testing were conducted on pasteurized product in separate sessions. Instrumental volatile analysis and fatty acid composition were also conducted.

Instrumental and sensory analysis differentiated the PB and TMR milks. Pasture-based milks contained higher percentages of unsaturated fatty acids, including conjugated linoleic acid. Trained panelists documented higher intensities of sweet aromatic, grassy, and cowy/barny flavors in PB milks compared to TMR milks. Volatile compound analysis by solid-phase microextraction (SPME) and gas chromatography/mass spectrometry (GC/MS)

separated PB and TMR milk samples. However, analyses showed no compounds unique to either sample. All identified compounds were common to both samples. Consumers were unable to consistently differentiate between PB and TMR milks, which had no effect on overall consumer acceptance. These results indicate distinct flavor and compositional differences between TMR and PB milks, but that these differences do not impact consumer acceptance. These findings are crucial issues to consider and optimize for the growing interest in grazing feed systems.

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Introduction

The dairy industry has seen great changes in production, products, and processing of fluid milk in the past 15 yr. The total number of dairy farms has decreased while the number of cows per herd and milk production per cow has increased significantly (Blayney, 2002). An overall decrease in fluid milk consumption has been offset by increased consumption of other dairy products such as cheese and yogurt and increased applications of dried dairy ingredients. Fluid milk price volatility and an increasing gap in the farm-retail price asymmetry (GAO, 2004) are of increased concern for dairy farmers. To remain competitive, many dairy farmers must look for a value-added approach to dairy operations. One such approach is pasture-feeding of cows and the possibility of a transition to organic milk production.

Consumer interest in the organic and natural food sector is growing with current demand for organic products in the United States exceeding supply (Buragas, 2005; OTA, 2006). The organic food market has shown an annual growth of 15 to 21% since 1997, and organic dairy products experienced a 23.6% increase in 2005, resulting in $2.1 billion in sales or 15% of the total organic food market (OTA, 2006). Local analysis of the Raleigh/Durham/Chapel Hill, NC retail grocery market showed a premium of $2 to $3 per gallon for organic milk over conventional milk and $1-2/gallon premium on milk from cows not treated with recombinant bovine somatotrophin (rBST) hormone. There are no available compound data that addresses the premium farmers receive for organic milk, but current supply and demand of organic dairy products has preserved a strong and more consistent price paid to farmers for organic fluid milk.

With the demand for organic products on a continued upward trend, many farmers are considering the opportunities and benefits of value-added milk in pasture-based dairy farming. Pasture-feeding of cows portrays a healthy image which may provide marketing opportunities and lends itself to organic certification. Pasture-based feeding systems on dairy farms may provide increased health benefits for the consumer and economic benefits for the farmer. Significant increases in concentrations of conjugated linoleic acid (CLA) and unsaturated fatty acids exist in milk from pasture-grazing cows compared to cows fed total mixed rations (Jahreis et al., 1997; Kelly et al., 1998; Dhiman et al., 1999; White et al., 2001). Conjugated linoleic acid (CLA) serves as a potential anticarcinogenic agent (Ip et al.,

1991; Chin et al., 1992) while increased intake of unsaturated fats has been linked to improved cardiovascular health (Hu and Willett, 2002). The lower milk output of grazing cows can be offset by lower feed and capital costs (White et al., 2002) and the potential for premiums on a value-added product.

Fluid milk flavor is delicate and bland with sweet aromatic, cooked (pasteurized product), and feed flavors and a sweet and slightly salty taste. Fresh, pasteurized milk is characterized by sweet aromatic, cooked, and milk fat notes that are influenced by processing conditions and milk fat concentration, respectively. While many factors contribute to the popularity of organic foods, flavor remains a fundamental concern. Milk composition and flavor variations have been attributed to feed, seasonal variation, and breed. Because pasture-based dairy systems vary in the types of forage that are grown, it is essential to characterize the effect of such variations on milk composition and flavor characteristics. Previous research has evaluated volatile compounds in milk flavor from conventional and pasture-based systems. Flavor compounds from feeds may be transferred to milk from the cow via inhalation, digestion, and rumen gases (Shipe et al., 1962). Feed composition influences compounds of plant origin and microbial origin which may be transferred to the milk (Buchin et al., 1999). Several groups of compounds are believed to contribute to the flavor profile of pasture-based milk including terpenes, linolenic acid oxidation products, phenolics, phytol derivatives, and nitrogen heterocycles (Bendall, 2001). Numerous studies have explored the composition of milk from different breeds and feeding systems (Khanal et al., 2005; Bauman, et al., 2001; Lawless et al., 1999), however, there is a lack of solid analytical sensory analysis and consumer testing directly comparing pasture-based fluid milk to total mixed ration (traditional feed lot feeding) fluid milk. The objective of this study was to compare chemical properties, trained sensory panel profiles, and consumer perception of fluid milk from cows fed pasture-based (PB) or total mixed ration (TMR) diets. Fluid milk was collected from two herds, each containing Jersey and Holstein breeds. Milk was collected from each breed individually at both sites and analyzed to determine fatty acid profiles, volatile content, solids composition, color, sensory profiles and consumer acceptance.

Materials and Methods

Sample collection. Fresh whole milk was collected from two dairy research units: North Carolina State University Dairy Education Unit, Raleigh, NC (farm one) and the Center for Environmental Systems, Goldsboro, NC (farm two). Each herd included Jersey and Holstein breeds. Farm one represented a facility where cows were fed on a total mixed ration (TMR) with no pasture, and farm two represented a facility where cows were fed approximately 60% of their diet from pasture supplemented with 30% ground corn and 10% whole cottonseed. The TMR consisted of corn silage, alfalfa haylage, grain concentrate 10% crude protein (CP) (soybean meal/ground corn/minerals), whole cottonseed, soybean hulls, pelleted corn gluten, Nutrimax bypass (vitamin and mineral supplement, QAF Feeds, Corowa, NSW), cottonseed hulls, and grain concentrate 10% CP (soybean meal/ground corn/minerals). The composition of total ration for TMR and the 5 forage species in this study are listed in Table 1. The experimental design was a 2 by 2 factorial arrangement of treatments with two breeds (Holstein, Jersey) and two feeding systems (TMR, pasture). Feeding system was confounded by herd location as the TMR and pasture-based rations were fed to separate herds at different locations about 80 km apart. However, both herds were state owned with similar genetics across herds within the two breeds.

Milk was collected from each farm in the morning and afternoon milkings on successive days. Fluid milk was collected from farm one at the morning milking and farm two in the afternoon. The following day, milk was collected from farm two in the morning and farm one in the afternoon. Three to six cows were milked for each sampling. Dairy cows were attached to automatic milking devices and milk was collected from the milk line before flowing into the bulk milk tank. Cows were separated by breed and the milking lines were cleaned between samples. Milk (38.6 kg) was placed into cleaned and sanitized lidded stainless steel 38 L cans and packed on ice for transport back to North Carolina State University, Raleigh, NC. Transport time was 20 minutes for farm one and 60 minutes for farm two. The temperature of the milk was < 12°C upon arrival at NCSU. Milk was immediately placed at 3°C and reached < 5°C within 4 h of collection. 200mL samples were collected and frozen at -20°C for fatty acid analysis, and samples were taken for microbial

and compositional analysis. The rest of the raw milk was processed within 36 h. A total of 10 collections from each breed at each farm (20 collections total per location) were taken in duplicate from both farms across the 2006 growing season.

Feed analyses. Grab samples of pasture were collected randomly from the areas grazed at farm two to fill a one gallon zip-closure bag. Grab samples were obtained in a manner to simulate the selection of the grazing cow to provide a representative sample. Samples were taken by hand-tearing the top 7 to 10 cm of pasture leaves (White et al., 2001). Pasture species were identified on the farm at the time of collection. Table 2 identifies the grass species grazed on by PB cows and the months in which they were collected. Dry samples, consisting of TMR from farm one and ground corn and cottonseed from farm two, were each placed in one gallon zip-closure bags. Feed samples were gathered at each milking and sent to the North Carolina Department of Agriculture & Consumer Services, Food & Drug Protection Division, Forage Laboratory, Raleigh, NC for protein, moisture, and fiber analysis. Samples were dried in an oven at 80°C for a minimum of 15 h. The samples were ground after drying, using a Retsch ZM 100 and Retsch ZM 200 mill with a 1-mm sieve (Arthur Thomas Co., Philadelphia, PA). Ground samples were analyzed for crude protein (CP) by Dumas combustion (LECO FP-428, LECO Corporation, St. Joseph, MI) and for acid detergent fiber (ADF) by wet chemistry digestion (Ankom 200, Ankom Technology Corp., Fairport, NY). Net energy lactation (NEL) was determined by using the Cornell regression equations (Mertens, 1973).

Solids composition. Total solids and total fat of fluid milk were analyzed using the Smart™ System 5 moisture/solids analyzer with SmartTrac rapid fat analysis (CEM, Matthews, NC). Solids nonfat (SNF), density, and protein were analyzed using the Lacticheck™ ultrasound milk analyzer (P&P International Ltd, Hopkinton, MA).

Microbial analyses. The Petrifilm™ plate count (PAC) method was used to estimate the microbial content in fluid milk samples. Coliform counts and aerobic plate counts (APC) were taken for each raw and pasteurized sample using Petrifilm™ plastic films (3M, St. Paul, MN) and 0.1 % (w/w) peptone water as the diluent. Preliminary incubation counts (PI) on

raw milk were taken to evaluate sanitary practices at the farm and in processing/handling of the raw milk (Laird et al., 2004). For the PI test, raw milk was held at 13°C for 18 h before plating with appropriate dilutions on APC Petrifilms.

Fluid milk processing. Raw milk was standardized to 1.5% milk fat by gravity separation and skimming. The upper milk fat layer was drawn off. The cream and resulting milk were analyzed with the Smart^{TM} System 5 moisture/solids analyzer with SmartTrac rapid fat analysis (CEM, Matthews, NC). Cream was added back to the milk using the Pearson square calculation (Arbuckle, 1977) to reach 1.5% milk fat. Twenty-five kg of each fluid milk sample were batch-pasteurized within 36 h of collection. Milk was heated to 65.5°C and held for 30 min. Samples were then homogenized at 13.8 x 10^6 Pa and cooled to 5°C prior to refrigeration.

Solid phase micro-extraction. Volatile compounds of raw and pasteurized milk were collected using solid phase micro extraction (SPME) and identified by gas chromatography-mass spectrometry (GC-MS). Sample (20 g) and 2 g of NaCl were placed in a 40 mL amber vial with PTFE/Silicone septa (Supelco, Bellefonte, PA) with a stir bar. 2-methyl-3-heptanone was used as an internal standard at a concentration of 206 ppm. The vial was heated at 40°C for 30 minutes. A 2 cm-50/30µm film thickness DVB/Carboxen™/PDMS Stableflex™ SPME fiber (Supelco, Bellefonte, PA) was exposed for 60 min with continuous stirring. Analytes were desorbed onto the column through a splitless injector at 250°C. Samples were run on a Varian (Saturn 2000) Mass Spectrometer attached to a Varian gas chromatograph (Model CP 3380, Varian, Walnut Creek, CA) equipped with a 30 m, 0.25 mm ID, 0.25 µm film thickness DB-5 column (Restek US, Bellefonte, PA). The oven temperature was held at 40°C for 2 min, then increased to 200°C at a rate of 10°C min-1 and held for 15 min. Helium was used as a carrier gas at a flow rate of 0.4 mL min-1. The fiber was removed from the injector after 5 min. Relative abundance was calculated using the peak area of the volatile compound and the peak area and known concentration of the internal standard. Chemical standards (dimethyl sulfide, 2-butanone, acetic acid, 2-pentanone, 3-pentanone, toluene, 2-hexanone, hexanal, butanoic acid, 2-furanmethanol, 2-heptanone, heptanal, 3-octenol, octanal, hexanoic acid, limonene, 2-nonanone, nonanal,

maltol, octanoic acid, nonanoic acid, 2-undecanone, indole, n-decanoic acid, indole, 3-methyl, δ-decalactone, dodecanoic acid, δ-dodecalactone, tetradecanoic acid, n-hexadecanoic acid, oleic acid, octadecanoic acid) were obtained from Supelco (Bellafonte, PA).

Fatty acid analyses and color. Milk fat was extracted from raw milk using the AOAC Choloroform-Methanol extraction method for fat in foods (Deutsch, 1990). Fatty acids were methylated with 14% boron trifluoride in methanol (Bannon et al., 1982) and injected onto a split injector at 220°C with a split flow rate of 50:1. A Perkin Elmer Autosampler XL (Wellesley, MA) with an RT-2560, 100 m, 0.25 mm ID, 0.2mm film thickness column (Restek, Bellefonte, PA) terminating at a flame-ionization detector (FID) was used for separation. The oven temperature was held at 100°C for 2 min, then increased to 250°C at a rate of 3°C min^{-1} and held for 4 min. Helium was used as a carrier gas at a flow rate of 40 psi. Fatty acids were identified by comparison of retention times with those of authentic standards (Sigma Aldrich, St. Louis, MO). Color was measured using a Minolta Chroma meter (CR-300 series) with DP-301 data processor (Ramsey, NJ). Ten mL of milk were placed in the top of a Falcon 60 mm x 15 mm polystyrene petri dish for triplicate measurements. The equipment was calibrated before each session with a factory-supplied calibration plate. The Hunter Lab color scale was used.

Descriptive sensory analysis. All sensory testing was conducted in accordance with the NCSU Institutional Review Board for Human Subjects guidelines. Evaluation of milk flavor was conducted using a trained descriptive sensory panel and an established flavor language (Table 3). Panelists (n=10) each had more than 100 h of previous experience with the sensory analysis of dairy products using the Spectrum™ descriptive analysis method (Meilgaard et al., 1999). Before this study, panelists participated in 20 h of additional training on organic and reduced-fat fluid milk flavor with the identified sensory language. During training, panelists evaluated and discussed conventional and organic pasteurized and ultrapasteurized milks in order to ensure panel consistency and understanding of the lexicon. Pasteurized fluid milk (30 mL) was placed in three-digit-coded, 60 mL lidded cups (Sweetheart Cup Company, Owings Mills, MD). Preparations were conducted with overhead lights off to avoid exposure to light. Samples were prepared 24 h in advance and refrigerated

at 4°C. Samples were then tempered to 15°C before analysis. Samples were evaluated in duplicate by each panelist using paper ballots in a randomized balanced block design.

Difference testing. Difference testing was conducted using a triangle difference test to determine if consumers could detect differences between fluid milk from conventional and pasture-based systems. Milk from Jersey and Holstein breeds were evaluated individually; difference tests compared feeding systems, not breeds. A total of 40 triangle tests were conducted, representing 20 time points and 2 breeds. Triangle tests were conducted at each collection time point on pasteurized milk. Milks were served at 4°C in three-digit-coded 180 mL polystyrene cups with opaque lids and straws to ensure that color variation was not a source of difference. Samples were evaluated individually in dedicated sensory booths using Compusense *five* v4.6 (Guelph, Ontario, Canada) and presented in a randomized balanced order. Participants (n=50 at each time) were recruited via e-mail, classified advertisements, and flyers. All participants were screened for allergies to dairy products. Subjects were given ambient temperature de-ionized water to cleanse their palates between samples. Demographic information as well as milk usage information was collected before tasting. Subjects received food treats and a gift card for their participation.

Consumer acceptance testing. Acceptance testing with milk consumers was conducted on different days from difference testing. Self-reported milk consumers were recruited via e-mail, classified advertisements, and flyers. Milk preparation and presentation were identical to difference testing. Consumers (n=75 at each time) were provided with the four milks monadically in a randomized balanced order of presentation and were asked to evaluate overall liking, flavor liking, and texture/mouth feel liking. Attributes were scored using a 9-point hedonic scale where 1= “dislike extremely” and 9 = “like extremely”. Samples were evaluated individually in dedicated sensory booths using Compusense *five* v4.6 (Guelph, Ontario, Canada)

Statistics. Proximate analysis, sensory and instrumental results were analyzed using the XLSTAT statistical software (version 2006.3, Addinsoft, New York, NY). Two-way analysis of variance was conducted to explore the impact of breed and feeding regimen.

Fisher's least significant difference (LSD) post hoc was conducted as a post hoc test. Principal component analysis was also conducted to determine how the treatments (breed, feeding regimen) and individual collections were differentiated from each other across sensory and instrumental measurements.

Results and Discussion

Proximate analyses. There were no significant interactions between treatment*breed, breed*time, or treatment*time (Table 4). By the Hunter Lab L*a*b* color scale (Figure 1), the milks were differentiated by breed ($P<0.01$) and treatment ($P<0.05$) on the b* axis. A positive value on the b* axis represents a more yellow color. This corresponds to the higher cream content found in Jersey milk compared to Holsteins. A more yellow color in pasture milks is expected due to the ingestion of fresh forage, which has been shown to increase the concentration of carotenoids (Kosikowski and Mistry, 1997; Hulshof et al., 2006) in milk. β-carotene serves as the primary carotenoid contributing to the color of milk fat (Panfili et al., 1994).

Milk collection time differentiated the milks by milk fat ($P<0.01$) and density ($P<0.01$). Milk collected in the morning was denser, 1.0320 compared to 1.0313 g cm^{-1}, than milk collected in the afternoon. Milk collected in the afternoon contained higher milk fat, 4.09% to 3.68%, compared to milk collected in the afternoon. Differences in both density and milk fat can be attributed to the longer time period between the afternoon and morning milking on both farms. Longer intervals between milking produce lower milk fat content (Ayadi et al., 2004). An increase in milk fat concentration is expected to increase the density of the milk. Milk fat content was also differentiated by breed ($P<0.01$) and treatment ($P<0.01$). Previous studies have observed higher values for milk fat and % protein in Jersey cows (White et al., 2001). Pasture-fed cows produced milk with a lower milk fat content ($P<0.01$), consistent with previous studies (White et al., 2001, Bargo et al., 2002) and lower % total solids ($P<0.01$).

Free fatty acids. Table 5 summarizes fatty acid (FA) concentrations by percentage of total fatty acids. Analysis showed significant differences ($P<0.01$) in percentage saturated, unsaturated, and monounsaturated fatty acids by breed and treatment. Pasture-based milk

contained higher concentrations of CLA and a lower ratio of saturated:unsaturated fatty acids. Conjugated linoleic acid is a mixture of octadecanoic acid isomers with two conjugated double bonds. The main CLA component of milk fat is the *cis-9, trans-11* isomer, representing 75 to 90% of the total CLA (Chin et al., 1992). Feed has been shown to have a significant effect on milk fat composition (Bauman et al., 2001; Ellis et al., 2006). Pasture-based milks analyzed in this study contained nearly 60% greater CLA concentration and 45% more *trans-11* 18:1, a CLA intermediate (Griinari et al., 1999) that has been shown to increase levels of CLA upon ingestion (Banni et al., 2001). Pasture-based milk had a lower ratio of saturated:unsaturated fatty acids (1.70 versus 2.05; $P<0.01$). This result was consistent with previous work comparing pasture and TMR milk (Schroeder et al., 2005). Saturated fatty acids have been associated with increased risk of coronary heart disease (CHD) (Hu et al., 1999) making the lower ratio of saturated:unsaturated FA in PB milk more beneficial for health. Levels of monounsaturated fatty acids (MUFA) showed significant differences by breed ($P<0.01$) and treatment ($P<0.01$). Pasture-based milk was 3 percentage points higher than TMR milk in MUFA, an increase of 10%. Pasture-based milk was 0.5 percentage points higher in polyunsaturated fatty acids (PUFA) compared to TMR milk, which corresponds to findings by Ellis and others (2006). Holstein milk contained 3 percentage points greater concentrations of MUFA compared to Jersey milk.

Volatile compounds. Figure 2 presents a principal components analysis (PCA) biplot of 32 compounds identified in both PB and TMR milks by SPME and GC-MS. Principal components (PC) 1 and 2 accounted for 80.6% of the variability between samples. Table 6 shows the compound concentrations calculated by relative abundance to an internal standard. No compounds were unique to either breed or feeding regimen, in agreement with the findings of Bendall (2001). Using solvent-assisted flavor evaporation (SAFE) with nasal impact frequency (NIF), Bendall (2001) found that of the 71 compounds identified by gas chromatography-olfactometry (GC-O), only one compound was unique, γ-12:2 lactone. It has been suggested that this compound may be formed from microbiological activity in the rumen. Nasal impact frequency uses untrained panelists for GC-O analysis and derives an NIF-value by the ratio of sniffers that detect each compound. This method is not directly quantifiable; however, differences in NIF-values of multiple samples imply different

concentrations of the compound (Pollien et al., 1997). Compounds identified and classified by chemical class were: 11 carboxylic acids, 6 ketones, 4 aldehydes, 3 aromatic hydrocarbons, 2 lactones, 2 nitrogen compounds, 2 lactones, 1 terpene, 1 alcohol, and 1 sulfur compound. Indole and skatole have been associated with pasture-based milk (Urbach, 1990) and the grassy and mothball flavors also associated with pasture-based cheeses. The SPME method used in this research did not extract indole if present in the milk samples at levels to separate TMR and PB milks. However, skatole was present in higher levels in the PB milk samples.

Descriptive analysis. Significant differences were noted in the flavor profiles of the milk from the 2 different feeding systems (Table 7, Figure 3), similar to volatile compound differences. No significant differences were found by breed or the treatment*breed interaction in any of the attributes tested. Conventional milk was characterized by a sweet feed/malty flavor, higher sweet aromatic flavor and sweet taste than PB milks, and no grassy or fecal/mothball flavors. Milk from grazing cows was characterized by a low but distinct salty taste and grassy and fecal/mothball flavors. As shown in the principal components biplot (Figure 3) PB and TMR milks were clearly differentiated along PC1. The PB milks fall near the vectors for grassy, fecal/mothball, and salty while the TMR milks fall near the vector representing feed/malty, sweet taste, and sweet aromatic. Principal components 1 and 2 accounted for 98% of the variability in the samples.

A search of literature revealed no previous research comparing flavor of PB milk with conventional milk using descriptive analysis (QDA). Numerous studies have been performed comparing the volatile fraction of cows' milk from varying feeds (Bendall, 2001; Bugaud et al., 2001; Toso et al., 2002) as well as cheese (Buchin et al., 1999; Carpino et al., 2004). Drake et al. (2005) reported that Cheddar cheeses from New Zealand were characterized by grassy and mothball flavors compared to cheeses from the U.S. and Ireland. They hypothesized this distinct flavor was due to the pasture-based dairy industry in New Zealand.

In the current study, trained panelists were able to differentiate milks by feeding regimen. We found no previous attempt to relate sensory analysis to the flavor compounds identified in fluid milk from different feed types. Fillian and Arazi (2002) attempted to compare several commercial organic and conventional milks, though they were unable to

differentiate the samples based on sensory characteristics. The authors first compared organic and conventional orange juice by quantitative descriptive analysis and consumer acceptance testing. Results showed that organic juices were preferred by consumers. The same methods were applied to organic milk in an attempt to determine if better taste applied to all organic products as many such claims relate to the entire organic food sector. For milks, few statistical differences were found with no distinct grouping of milks. Organic milk is not defined by the composition of the feed, but rather the origin and production processes. It is not a requirement in the US (USDA, 2006) or the European Union (EU) (DEFRA, 2006) that organic cows are fed on a pasture-based diet alone; although access to pasture is a requirement during the grazing seasons. As the origin of feed for these milks tested is not known, no conclusions can be drawn from the panelists' inability to differentiate the milks in this study.

Consumer difference and acceptance testing. A total of 20 separate triangle tests were conducted for each breed, representing each collection time point. Consumers were able to distinguish the different sample with significance ($P<0.05$) on only 7 occasions (35% of total tests) when comparing milk from TMR Jersey cows to PB Jersey cows. Panelists were able to distinguish the different sample with significance ($P<0.05$) on only 7 occasions when comparing TMR Holstein milk to PB Holstein milk. Ryegrass and Bermuda varieties were positively identified more often than other species but these 2 species also comprised 14 of the 20 collections. There were no distinct seasonal tendencies associated with the ability of consumers to differentiate the samples. No relation was found between the positively identified samples from the difference tests and the subsequent acceptance testing performed the next day. The ability to differentiate milks did not have a significant effect ($P<0.05$) on the hedonic scores. As shown in table 8, there were no significant differences ($P<0.05$) in overall liking and texture liking between the four milk samples. Pasture Holstein milk scored significantly lower in flavor liking than TMR Holstein milk (5.88 vs. 6.12; $P<0.05$), but was not different from PB jersey and TMR Jersey milk. Although there were no significant differences between the intensities of grassy and fecal/mothball flavors by trained panel profiles, PB Holstein milk had higher intensities (0.2 points in both attributes) of these attributes compared to PB Jersey milk and perhaps this contributed to lower flavor liking

scores from consumers. It should be noted that a lower flavor liking score did not have a significant effect on the overall liking scores of PB Holstein milk. One objective of this study was to determine the effects of a pasture-based feeding system on the consumer acceptance of fluid milk. These results show that the consumer was unable to routinely identify differences between samples. Furthermore, distinct differences documented by trained panelists (a lack of grassy and fecal/mothball flavors in TMR milk and a lack of feed/malty flavor in PB milks) did not have an effect on overall consumer liking. Differences noted by trained panelists are not always detected by untrained consumers. Further, sensory differences may exist but may not affect consumer acceptance. Trained panel profiling was conducted at 15°C to maximize panelists' ability to discern milk flavors. In contrast, difference and consumer testing was conducted at 7°C which is indicative of a temperature that consumers normally consume milk. The lower temperature may have masked flavor differences due to decreased volatility of compounds and this may also explain lack of difference and lack of difference in acceptance.

Khanal et al. (2005) compared milk and cheese produced by TMR, pasture, and TMR plus pasture feeding regimens using acceptance testing with panelists that had previous experience in dairy judging and grading. No significant differences were reported in overall liking, color, flavor, or mouth feel for milk or cheese. Panelists were given chemical references with limited training (2 sessions) on use of a cheese flavor language. Panelists identified differences in the milks, with the pasture and pasture plus TMR products scoring higher in cowy and barny attributes. The results of Khanal et al. (2005) are consistent with the results of this study, however, direct comparison cannot be made as panelists were essentially untrained and different scaling was used.

Debate continues over the nutritional, compositional, and sensory properties of organic vs. conventional foods. Much of the focus has concentrated on produce and grains. Bourn and Prescott (2002) discussed 209 articles comparing the nutritional value, sensory quality, and food safety of organic and conventional food production systems. While there are reports that organic products maintain superior sensory quality over conventionally produced food, results are inconsistent. Of the 150 studies reviewed by Woese et al. (1997), only 9 studies involved dairy products with the focus being on composition and nutritive value as opposed to sensory quality. Assessing the current comparative research of organic

and conventional foods, it is not prudent to apply any general statements of one production system's quality over the other. Results are convoluted by several factors including the application of a wide range of methods and study duration, variance in definitions of terms such as organic and quality, and lack of proper controls for direct comparison (Siderer et al., 2005). An important consideration when comparing animal products from organic and conventional systems is the source of feed. The current study represents the flavor profile expected from fluid milk produced on a pasture-based dairy farm with similar feeding practices as a certified organic farm.

Conclusions

Milks from pasture-fed cows and from cows fed a diet of total mixed ration were differentiated by descriptive sensory analysis, proximate analysis, and volatile compound profiles. Milks were not consistently differentiated by difference testing or by consumer acceptance scores. This research shows that the feeding regimens compared did not play a factor in the consumer acceptance of fluid milk flavor. While many factors are responsible for the increasing demand in organic dairy products, flavor and nutrition are consistently given as significant reasons for the purchase of organic foods. With higher CLA and unsaturated fatty acid concentrations and lower saturated fatty acid concentration, PB milk may provide a better nutritional profile than TMR milk. While no statement can be made verifying the belief by some consumers that organic food tastes better, this study shows that a pasture-based feeding system for the production of fluid milk does not adversely affect consumer acceptance.

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Table 1. Formulation and nutrient content of total ration fed to TMR and PB cows (calculated)

	TMR	Annual ryegrass	Matua bromegrass	Sorghum-Sudan	Bermuda grass	Fescue/ Clover
Formulation, % of total ration DM						
Corn Silage	37	-				
Alfalfa Haylage	16	-				
Grain Concentrate 10%CP (Soybean Meal/ Ground Corn/Minerals)	15	-				
Whole Cottonseed	12	10	10	10	10	10
Soybean Hulls	7	-				
Cottonseed Hulls	2	-				
Pelleted Corn Gluten	5	-				
Bypass blend[1]	3	-				
Ground corn	-	30	30	30	30	30
Fresh forage	-	60	60	60	60	60
Nutrient content, DM basis[2]						
DM, %	53.2 ± 4.5	47.3 ± 2.2	47.4	49.1 ± 3.1	51.3 ± 3.8	48.5
CP, %	18.0 ± 2.1	17.4 ± 3.5	17.9	14.2 ± 1.0	14.9 ± 2.1	12.0
ADF, %	25.7 ± 2.6	19.1 ± 3.0	19.0	24.5 ± 1.4	24.4 ± 1.1	29.2
NE_L, Mcal/lb	0.69 ± 0.02	0.76 ± 0.05	0.76	0.69 ± 0.02	0.71 ± 0.01	0.63

[1] Blend of poultry byproduct meal, meat and bone meal, flash-dried blood meal, hydrolyzed poultry feathers, and fish meal (Nutrimax Inc., Greensboro, NC).
[2] Standard deviation values are presented in parentheses

Table 2. Forage identification of grass species fed to pasture cows

Time collected	Forage species	Latin names
March-April	Ryegrass	*Lolium multiflorum*
March	Matua grass	*Bromus willdennowii*
March	Clover/Fescue	*Festuca arundinacea/ Trifolium repens*
April-May	Sorghum-Sudan	*Sorghum bicolor*
May-August	Bermuda	*Cynodon dactylon*
September-October	RyeGrass	*Lolium multiflorum*

Table 3. Descriptive sensory language for fluid milk

Term	Definition	Reference
Milk fat/Lactone[1]	Aromatics characteristic of milk fat, lactones, and coconut	fresh coconut meat, heavy cream, δ-dodecalactone 40 ppm
Cooked[1]	Aromatics associated with cooked milk	skim milk heated to 85°C for 30 min
Sweet Aromatic[2]	Aromatics associated with materials having a sweet taste	Molasses, vanilla, caramelized sugar
Cowy/Barny/ Phenolic[1]	Aromas associated with barns and stock trailers, indicative of animal sweat and waste	bandaids, p-cresol 160 ppm
Fecal/Mothball[1]	Aroma associated with complex protein decomposition	indole, skatole 20 ppm
Grassy[2]	Green, sweet aromatics associated with cut grass	Fresh cut grass, hay, cis-3-hexenol 50 ppm
Feed/Malty/ Silage[2]	Aromatics associated with mixture of grains and fermented hay and cattle feed	corn silage, malt extract, fresh kilned malt
Sweet[2]	Fundamental taste sensation elicited by sugars	sucrose (5% in water)
Salty[2]	Fundamental taste sensation elicited by sodium salt	sodium chloride (0.3% in water)
Astringency[2]	Chemical feeling factor on the tongue/oral cavity described as puckering/dry	alum (1% in water)

1 Reference taken from Drake et al., 2001
2 Reference taken from Civille and Lyons, 1996

Table 4. Means of compositional analysis of pasture-based and conventional whole milk by breed and treatment

	TMR Jersey	Pasture Jersey	TMR Holstein	Pasture Holstein	SEM	Treatment	Breed	Time (AM/PM)
						P		
Fat, %	4.54[a]	4.04[b]	3.75[b]	3.20[c]	0.39	0.01	0.01	0.01
Total solids, %	13.72[a]	13.16[b]	12.43[c]	11.85[d]	0.48	0.01	0.01	NS
Protein, %	3.64[a]	3.63[a]	3.49[b]	3.49[b]	0.05	NS	0.01	NS
SNF, %	9.59[a]	9.58[a]	9.21[b]	9.23[b]	0.13	NS	0.01	NS
Density, g/cm	1.0318[a]	1.0322[a]	1.0310[b]	1.0316[ab]	0.001	NS	0.01	0.01
Hunter color, L	87.48[a]	88.23[a]	88.94[a]	87.93[a]	4.46	NS	NS	NS
Hunter color, a	-1.80[ab]	-2.37[b]	-0.89[a]	-1.60[ab]	0.92	NS	NS	NS
Hunter color, b	5.32[a]	7.34[a]	2.07[c]	3.85[bc]	1.75	0.05	0.01	NS

[a-d] Means within rows with different letters are statistically different ($p<0.05$)

NS – not significant ($p>0.05$)

SEM – standard error of the mean

Table 5. Means for % fatty acid (FA) composition by treatment and breed group

Fatty acid	TMR Jersey	Pasture Jersey	TMR Holstein	Pasture Holstein	SEM	Treatment	Breed	Interaction
	% of total fatty acids					P		
$C_{4:0}$	1.01[a]	0.98[a]	0.98[a]	0.86[a]	0.14	NS	NS	NS
$C_{6:0}$	1.34[a]	1.25[ab]	1.20[a,b]	1.07[b]	0.16	NS	NS	NS
$C_{8:0}$	1.09[a]	1.01[ab]	0.93[a,b]	0.86[b]	0.13	NS	0.05	NS
$C_{10:0}$	2.69[a]	2.45[ab]	2.27[b]	2.16[b]	0.26	NS	0.05	NS
$C_{12:0}$	3.15[a]	2.76[ab]	2.59[b]	2.53[b]	0.33	NS	0.01	NS
Total short chain FA	9.63[a]	8.76[ab]	8.29[bc]	7.76[c]	0.81	NS	0.05	NS
$C_{14:0}$	9.89[a]	9.13[ab]	9.17[ab]	8.64[b]	0.69	NS	NS	NS
$C_{14:1}$	1.22[b]	1.23[b]	1.19[b]	1.35[a]	0.10	NS	NS	NS
$C_{16:0}$	30.61[a]	27.08[b]	29.86[a]	26.63[b]	1.44	0.01	NS	NS
$C_{16:1}$	1.61[c]	1.76[b,c]	1.84[b]	2.27[a]	0.21	NS	0.05	NS
Total medium chain FA	44.44[a]	40.32[b]	43.1[a]	40.08[b]	1.92	0.05	NS	NS
$C_{18:0}$	15.45[ab]	17.09[a]	14.34[b]	14.48[b]	1.48	NS	NS	NS
trans-11, $C_{18:1}$	2.12[c]	3.07[ab]	2.42[bc]	3.53[a]	0.68	0.01	NS	NS
cis-9, $C_{18:1}$	20.84[c]	22.52[b]	23.44[b]	24.87[a]	1.21	0.05	0.05	NS
$C_{18:2}$	2.88[c]	3.04[b,c]	3.48[a,b]	3.69[a]	0.47	NS	0.05	NS
CLA[1]	0.67[c]	1.07[a,b]	0.79[b,c]	1.24[a]	0.25	0.01	NS	NS
$C_{18:3}$	0.14[a]	0.43[a]	0.11[a]	0.10[a]	0.41	NS	NS	NS
$C_{20:0}$	0.16[a]	0.15[a]	0.15[a]	0.15[a]	0.04	NS	NS	NS
$C_{22:0}$	0.12[a]	0.09[ab]	0.10[a]	0.07[b]	0.03	NS	NS	NS
$C_{24:0}$	0.12[b]	0.12[b]	0.17[ab]	0.27[a]	0.11	NS	NS	NS
Total long chain FA	44.37[c]	49.05[ab]	47.21[b]	50.67[a]	1.97	0.05	0.05	NS
Saturated FA[2]	67.62[a]	64.13[b]	63.62[b]	59.80[c]	2.04	0.01	0.01	NS
Unsaturated FA[3]	30.97[c]	34.16[b]	35.07[b]	38.85[a]	2.03	0.01	0.01	NS
MUFA[4]	26.97[c]	29.57[b]	30.07[b]	33.18[a]	1.53	0.01	0.01	NS
PUFA[5]	4.00[b]	4.59[ab]	5.01[ab]	5.71[a]	0.94	NS	NS	NS
Unknown	1.42[a]	1.75[a]	1.39[a]	1.35[a]	0.57	NS	NS	NS
Ratios								
	2.20[a]	1.89[b]	1.83[b]	1.56[c]	0.05	0.01	0.01	NS
Long chain:short	4.76[c]	5.75[bc]	5.89[ab]	6.78[a]	1.49	0.01	0.01	NS

1 *cis*-9, *trans*-11 and *trans*-10, *cis*-12 $C_{18:2}$ isomers only. Conjugated linoleic acid

2 Sum of $C_{4:0}$,$C_{5:0}$, $C_{6:0}$, $C_{8:0}$, $C_{10:0}$, $C_{11:0}$, $C_{12:0}$, $C_{13:0}$, $C_{14:0}$, $C_{15:0}$, $C_{16:0}$, $C_{17:0}$, $C_{18:0}$, $C_{19:0}$, $C_{20:0}$, $C_{22:0}$, $C_{23:0}$, $C_{24:0}$ fatty acids, saturated fatty acids

3 Sum of $C_{10:1}$, $C_{12:1}$, $C_{13:1}$, $C_{14:1}$, $C_{15:1}$, $C_{16:1}$, $C_{17:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, $C_{18:2}$, $C_{18:3}$, $C_{20:4}$ fatty acids, unsaturated fatty acids

4 Sum of $C_{10:1}$, $C_{12:1}$, $C_{13:1}$, $C_{14:1}$, $C_{15:1}$, $C_{16:1}$, $C_{17:1}$, $C_{18:1}$, $C_{20:1}$, $C_{22:1}$, $C_{24:1}$ fatty acids, monounsaturated fatty acids

5 Sum of $C_{18:2}$, $C_{18:3}$, $C_{20:4}$ fatty acids, polyunsaturated fatty acids

6 Ratio of saturated fatty acids: unsaturated fatty acids

[a-d] Means within rows with different letters are statistically different ($p<0.05$)

NS – not significant ($p>0.05$)

SEM – standard error of the mean

Table 6. Mean relative abundance (ppm) for selected compounds in fluid milk from pasture-based (PB) and total mixed ration (TMR) feeding systems

Relative Abundance (SEM)	Treatment	TMR Jersey	PB Jersey	TMR Holstein	PB Holstein
dimethyl sulfide	Compound 1	2.26 ± 1.27	1.03 ± 0.72	2.42 ± 1.67	0.72 ± 0.48
2-butanone	Compound 2	11.35 ± 8.62	4.33 ± 2.36	12.26 ± 9.11	5.72 ± 3.19
acetic acid	Compound 3	0.53 ± 0.31	1.89 ± 3.55	4.27 ± 6.51	4.71 ± 5.19
2-pentanone	Compound 5	1.32 ± 0.78	1.10 ± 0.55	1.45 ± 1.15	0.86 ± 0.32
3-pentanone	Compound 6	0.54 ± 0.29	0.19 ± 0.12	0.48 ± 0.25	0.22 ± 0.14
toluene	Compound 7	0.68 ± 0.27	2.28 ± 1.38	0.82 ± 0.72	2.52 ± 1.35
2-hexanone	Compound 8	0.50 ± 0.03	0.09 ± 0.05	0.06 ± 0.03	0.06 ± 0.03
hexanal	Compound 9	0.35 ± 0.22	0.27 ± 0.15	0.28 ± 0.14	0.19 ± 0.10
butanoic acid	Compound 10	0.44 ± 0.32	0.51 ± 0.31	0.51 ± 0.41	0.43 ± 0.23
2-furanmethanol	Compound 11	3.16 ± 3.15	5.76 ± 5.05	10.71 ± 7.28	7.47 ± 5.12
2-heptanone	Compound 12	2.27 ± 1.08	1.74 ± 0.57	1.96 ± 0.69	1.84 ± 0.55
heptanal	Compound 13	0.14 ± 0.09	0.14 ± .010	0.12 ± 0.10	0.10 ± 0.07
3-octenol	Compound 14	1.79 ± 0.66	1.86 ± 0.59	0.76 ± 0.34	1.72 ± 0.64
octanal	Compound 15	0.10 ± 0.06	0.11 ± 0.08	0.11 ± 0.08	0.09 ± 0.06
hexanoic acid	Compound 16	0.67 ± 0.40	1.75 ± 1.34	0.64 ± 0.61	1.03 ± 0.86
D-limonene	Compound 17	0.56 ± 0.41	0.45 ± 0.23	0.41 ± 0.17	0.39 ± 0.15
2-nonanone	Compound 18	0.96 ± 0.74	0.63 ± 0.43	0.84 ± 0.67	0.64 ± 0.39
nonanal	Compound 19	0.51 ± 0.39	0.62 ± 0.41	0.60 ± 0.71	0.58 ± 0.68
maltol	Compound 20	0.62 ± 0.61	1.09 ± 1.42	1.37 ± 1.94	1.35 ± 1.78
octanoic acid	Compound 21	1.85 ± 1.50	2.87 ± 3.15	1.22 ± 0.81	1.93 ± 1.22
nonanoic acid	Compound 22	0.20 ± 0.13	0.23 ± 0.16	0.27 ± 0.23	0.39 ± 0.29
2-undecanone	Compound 23	0.89 ± 0.73	0.76 ± 0.55	1.22 ± 1.12	0.74 ± 0.36
indole	Compound 24	0.09 ± 0.03	0.02 ± 0.01	0.06	0.13 ± 0.06
n-decanoic acid	Compound 25	5.21 ± 3.45	6.91 ± 6.09	4.21 ± 2.99	4.92 ± 2.80
skatole	Compound 26	0.24 ± 0.18	0.32 ± 0.17	0.33 ± 0.26	0.39 ± 0.23
δ-decalactone	Compound 27	0.28 ± 0.21	0.29 ± 0.19	0.26 ± 0.17	0.31 ± 0.17
dodecanoic acid	Compound 28	1.49 ± 0.71	1.84 ± 1.26	1.36 ± 1.18	1.23 ± 0.75
δ-dodecalactone	Compound 29	0.28 ± 0.22	0.15 ± 0.09	0.37 ± 0.26	0.16 ± 0.11
tetradecanoic acid	Compound 30	4.00 ± 3.32	9.52 ± 8.25	4.18 ± 4.05	2.41 ± 1.96
n-hexadecanoic acid	Compound 31	7.02 ± 6.94	3.51 ± 3.02	8.63 ± 7.97	4.13 ± 3.36
oleic acid	Compound 32	2.08 ± 1.35	0.97 ± 0.65	2.16 ± 1.64	0.87 ± 0.59
octadecanoic acid	Compound 33	8.08 ± 6.02	3.57 ± 3.08	10.32 ± 8.35	7.03 ± 5.56

SEM – Standard error of the mean

Table 7. Sensory profiles of 1.5% pasteurized milk from pasture-based and TMR feeding systems for each treatment and breed group

Sensory Attribute[1,2]	TMR Jersey	Pasture Jersey	TMR Holstein	Pasture Holstein	SEM	Treatment	Breed	Interaction
						P		
Aroma Intensity	2.02[a]	1.99[a]	2.02[a]	1.99[a]	0.20	NS	NS	NS
Sweet Aromatic	2.46[a]	1.97[b]	2.42[a]	1.85[b]	0.25	0.01	NS	NS
Cooked	2.80[a]	2.76[a]	2.82[a]	2.72[a]	0.22	NS	NS	NS
Milk Fat	2.11[a]	2.06[a]	2.11[a]	2.06[a]	0.13	NS	NS	NS
Grassy	ND	0.86[a]	ND	1.07[a]	0.35	0.01	NS	NS
Fecal/Mothball	ND	1.05[a]	ND	1.23[a]	0.39	0.01	NS	NS
Sweet	2.36[a]	2.14[b]	2.38[a]	1.97[c]	0.18	0.01	NS	NS
Sweet Feed/Malty	1.91[a]	ND	1.88[a]	ND	0.52	0.01	NS	NS
Astringency	1.06[a]	1.07[a]	1.02[a]	1.06[a]	0.10	NS	NS	NS
Salty	ND	0.86[a]	ND	1.01[a]	0.41	0.01	NS	NS

1 Scores based on a Universal 15-point intensity scale

2 Means are from duplicate analyses by ten trained panelists

[a-b] Means within rows with different letters are statistically different ($p<0.05$)

ND – not detected

NS – not significant ($p>0.05$)

SEM – standard error of the mean

Table 8. Consumer acceptance scores for fluid milks from pasture-based and TMR feeding systems by breed and treatment

	TMR Jersey	Pasture Jersey	TMR Holstein	Pasture Holstein	SEM	Treatment	Breed	Interaction
Overall Liking	6.03[a]	6.14[a]	6.19[a]	6.02[a]	0.85	NS	NS	0.01
Flavor Liking	5.96[ab]	6.04[ab]	6.12[a]	5.88[b]	0.90	NS	NS	0.01
Texture/Mouthfeel Liking	6.39[a]	6.49[a]	6.47[a]	6.45[a]	0.73	NS	NS	NS

[a-b] Means within rows with different letters are statistically different ($p<0.05$)
NS – not significant ($p>0.05$)
Scores are based on a 9-point hedonic scale where 1 = dislike extremely and 9-like extremely
SEM – standard error of the mean

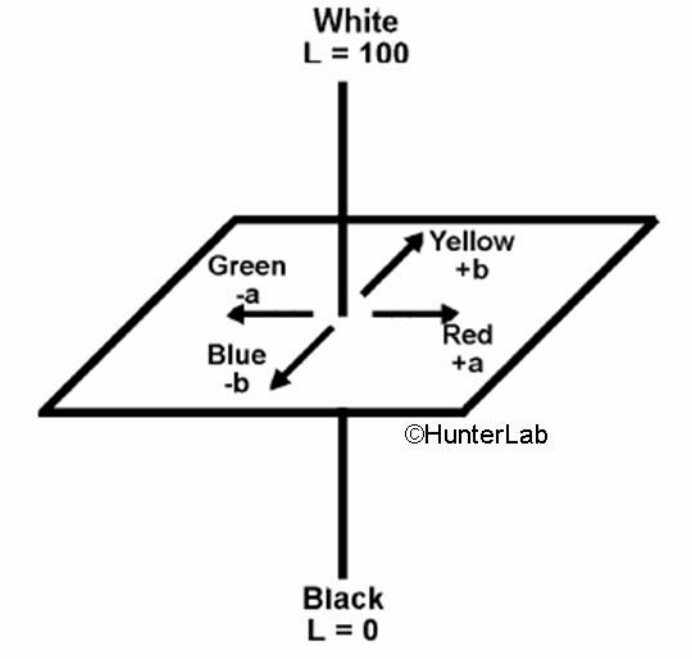

Figure 1. Hunter color scale

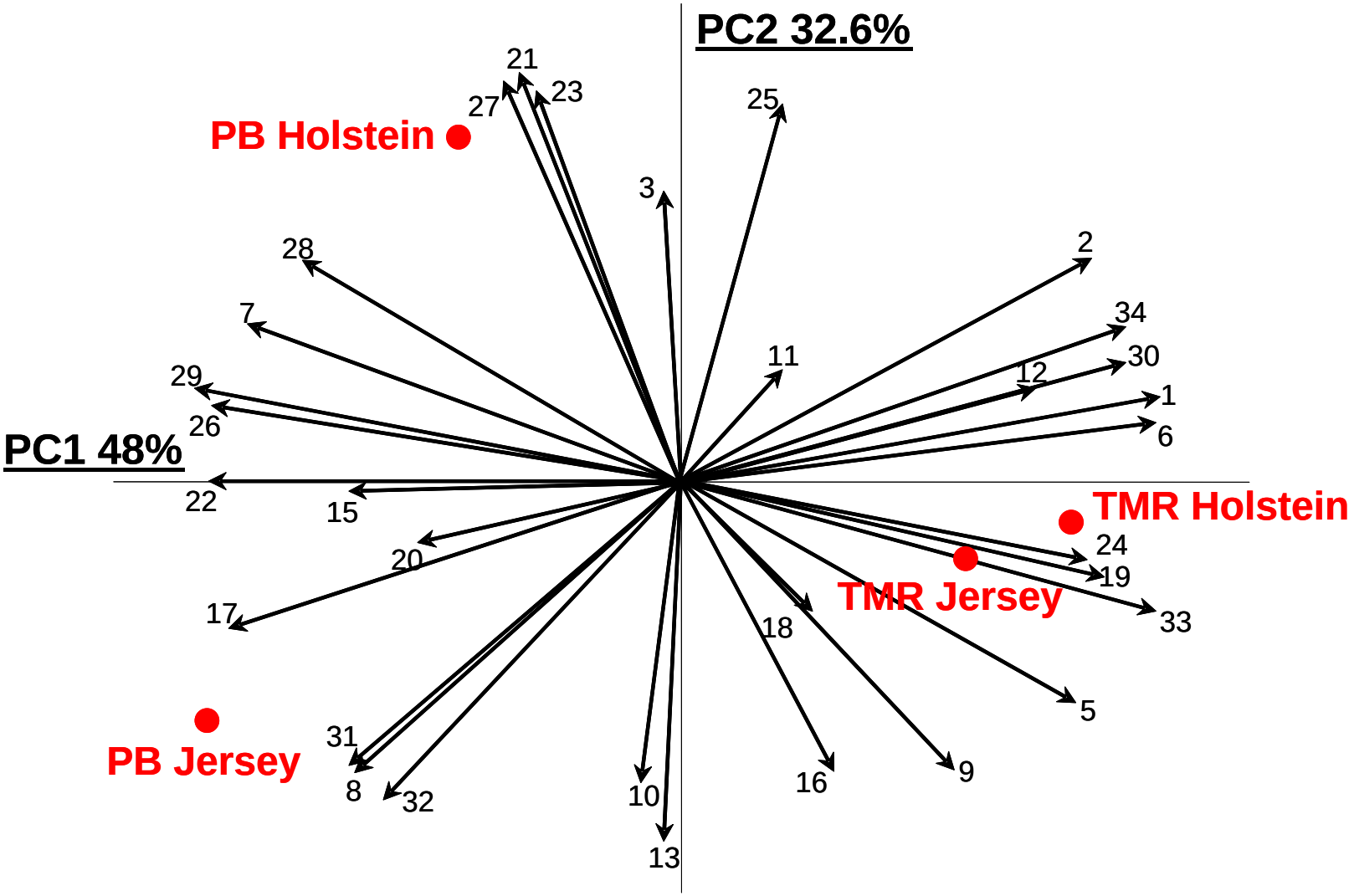

Figure 2. Principal components biplot of fluid milk volatile compounds from pasture-based and TMR feeding systems. Compounds (Table 6) are overlaid as vectors.

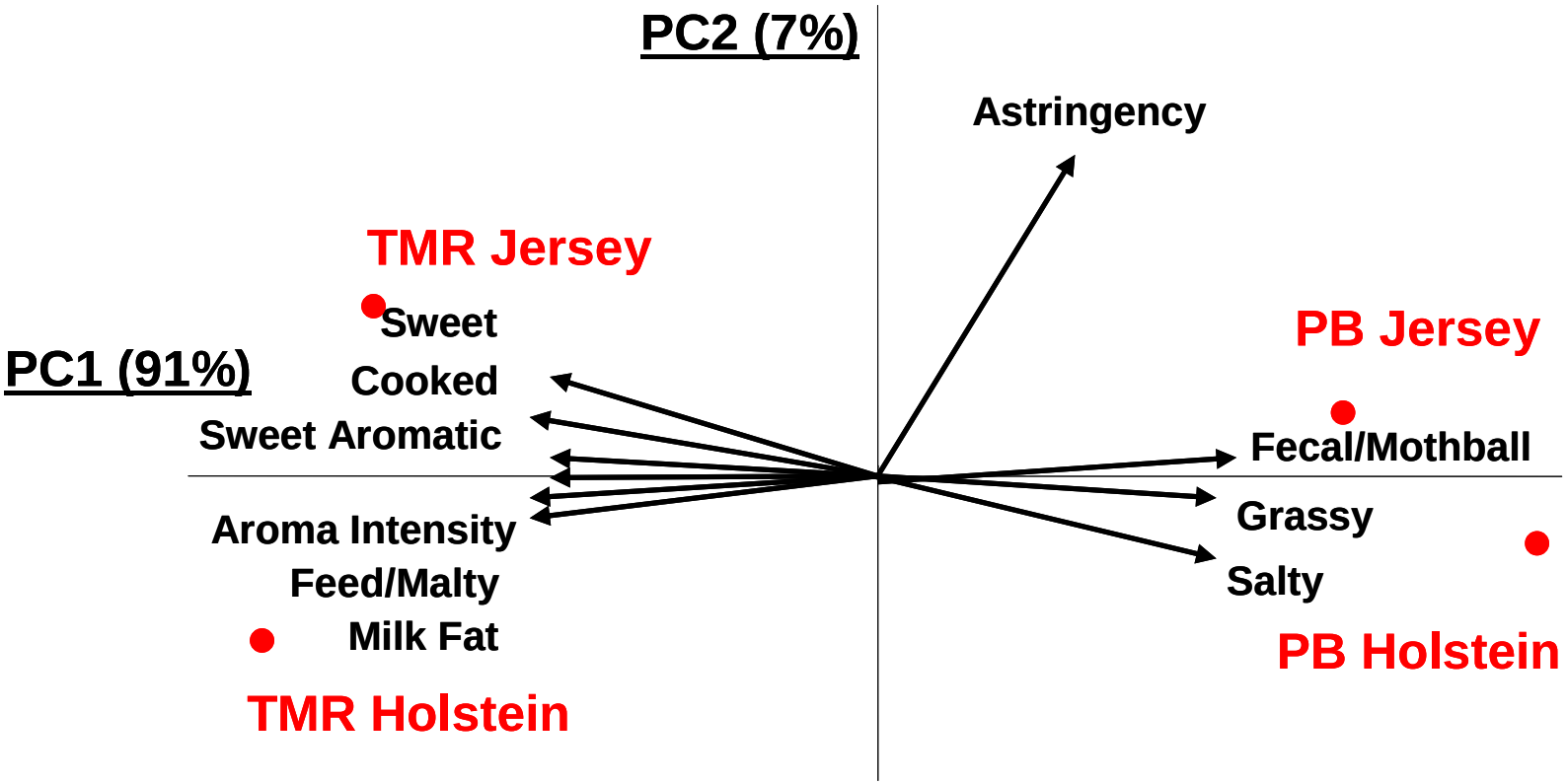

Figure 3. Principal components biplot of descriptive sensory analysis of fluid milk from pasture-based and total mixed ration cows. Sensory attributes are overlaid as vectors.

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Appendices

Sensory Ballot for Descriptive Analysis of PB and TMR Milk

Date/Time: Name:

Sample	Aroma Intensity	Sweet Aromatic	Cooked	Milk Fat	Grassy	Fecal/ Mothball	Silage/ Malty	Sweet	Astringent	Salty	Other
WU											

CONSUMER MILK QUESTIONNAIRE

Please check the appropriate answer for the following demographic information:

1. Sex _____male _____female

2. Age group
   - _____18 – 25 years
   - _____26 – 35 years
   - _____36 – 45 years
   - _____46 – 55 years
   - _____56 – 65 years
   - _____65 years or older

3. Do you have any **food allergies** to milk? ____yes _____no

4. Do you shop for your household, even if it is you alone?
   - _____Primary responsibility of grocery shopping
   - _____Shared responsibility of grocery shopping
   - _____Don't do the grocery shopping for my household

5. Do you drink milk? _____yes _____no

6. How often do you consume milk?
   - _____Less than once per month
   - _____At least once per month
   - _____At least 2-3 times per month
   - _____At least once per week
   - _____Two or more times per week
   - _____Every day

7. When you drink milk, what types of milk do you consume? Check all that apply:
   - _____Skim milk
   - _____1% milk
   - _____2% milk
   - _____Other than cows' milk (goat, sheep, etc)
   - _____Whole milk
   - _____Flavored milk
   - _____Organic milk
   - _____Soy milk

7. If you consume milk, what brands do you purchase? Check all that apply:
   - ____PET
   - ____Maola
   - ____store brands (Harris Teeter, Food Lion, etc.)
   - ____other brands (please specify) _____
   - _____Hunter Farms
   - _____organic (any brand)
   - _____other than cow's milk (Soy, goat, etc.)

8. What factors influence your choice in drinking milk? Check all that apply:
   - _____ Price
   - _____ Appearance
   - _____ Availability
   - _____Flavor
   - _____Organic
   - _____ Brand
   - _____ Health / Nutrition
   - _____packaging
   - _____ Other (please specify)

Please taste the milk with the sample number indicated. After you have tasted the product, please circle your response for the questions below. **PLEASE ANSWER ALL QUESTIONS. We want to know what you think!!**

Sample_____

Overall Acceptance

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall Flavor Liking

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall Texture/Mouthfeel Liking

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

OVERALL, what did you LIKE and/or DISLIKE about this milk sample?

LIKES	DISLIKES
_____	_____
_____	_____
_____	_____