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Development of a Beef Flavor Lexicon and Its Application to Compare Flavor Profiles and Consumer Acceptance of Grain- and Pasture-Finished Cattle

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DEVELOPMENT OF A BEEF FLAVOR LEXICON AND ITS APPLICATION TO COMPARE FLAVOR PROFILES AND CONSUMER ACCEPTANCE OF GRAIN- AND PASTURE-FINISHED CATTLE

by

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ABSTRACT

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Flavor lexicons are used in sensory evaluation to determine the flavor profile of a food product. The objective of this study was to develop a flavor lexicon for cooked beef, which can then be used in various projects relating to beef quality such as studies investigating animal diet, marinating, ageing, or other enhancements. A descriptive panel of 10 people was used to develop a flavor lexicon of 18 attributes, including astringent, barny, bloody, brothy, browned, gamey, grassy, juicy, fatty, livery, metallic, oxidized, roast beef, and the five basic tastes (bitter, salty, sour, sweet, and umami). In contrast to other studies on beef, this lexicon was developed to include both positive and negative attributes. The lexicon was able to show that rib eye steaks from the *Longissimus dorsi* muscle in grass-fed animals were significantly ($p<0.05$) higher in barny, bitter, gamey, and grassy flavors, and lower in juicy and umami flavors. The steaks were also rated by consumers, who showed a preference for grain-fed beef over grass-fed beef. The ratings of the descriptive panel were related to the consumer panel scores to equate the lexicon terms with a positive or negative consumer degree of liking score. Those terms that were considered positive in this study due to their positive correlation with consumer liking include brothy, umami, roast beef, juicy, browned, fatty, and salty. The terms that were inversely associated with consumer liking were barny, bitter, gamey and grassy, among others. A separate descriptive panel was conducted on the *Spinalis dorsi* (or “cap” muscle) of the rib eye steak, with similar results. Additionally, descriptive and consumer evaluations found no difference between two types of grass diets, namely alfalfa and sainfoin. Different mixtures of beef and chicken were also evaluated to determine flavor differences between the two meats. Chicken was found to be more closely correlated to brothy, juicy, sweet, and umami, among others, while beef was found to be more closely correlated to terms such as gamey, bloody, oxidized, metallic, roast beef, and astringent. Throughout these tests, the newly developed lexicon was shown to be an effective tool for profiling fresh meat samples.

(113 pages)

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Curtis Maughan

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INTRODUCTION

In the United States, most beef that is produced for human consumption is grain-finished, whereas in many other countries the majority of beef is grass-finished. For the purposes of this study, grain-fed beef is used to indicate those cattle whose feed is supplemented by grains such as corn, barley, wheat, and others. Grass-fed beef is used interchangeably with forage based diets, including pasture, hay, grass, and silage.

There is an increasing interest in grass-fed beef due to certain health advantages it may contain, and in the United States grass-fed beef is often marketed as a “premium” or superior product to grain-fed beef (McCluskey and others 2005). Those who promote grass-fed beef claim advantages in sustainability, lower cost inputs, and a reduced use in antibiotics. There are also claims of a leaner and overall healthier product found in grass-fed beef, with some promoting extra nutritional value factors such as higher omega-3 fatty acids. There are detractors from these arguments as well, stating that grass-fed beef has an increased production time, leading to a higher cost of production, and that there are problems with using forage due to seasonality constraints (Brewer and Calkins 2003).

Some recent studies have found that grass-fed cattle can indeed contain certain health benefits for consumers. Grass based diets have been shown to reduce saturated fatty acids in beef, as well as increase omega-3 polyunsaturated fatty acids in beef, which can be advantageous in combating some cancers as well as cardiovascular disease (Department of Health 1994). There is also evidence that grass-fed beef has a higher ratio of n-3 to n-6 fatty acids, which can also be nutritionally beneficial (Williams 2000).

It is important to understand the differences between grass-fed versus grain-fed beef to understand what advantages and disadvantages exist in finding increased consumer acceptance or desire for the product. One of the principal motivators in overall consumer acceptance of food products is sensory qualities. These sensory qualities involve a complex interaction between flavor, odor, mouthfeel, tenderness, juiciness, and more. The principal focus of this paper is on flavor, which is arguably the most important of the sensory aspects of beef.

Flavor is a combination of taste and aroma. Two principal methods exist to measure flavor in a product; namely, through a large group of untrained people known as a consumer panel, or through a small highly trained group of people known as a descriptive panel. Though there are different types, consumer panels focus mainly on evaluating preference or acceptance of a product in one or more generic categories such as "liking," "flavor," or "texture." Descriptive panels, on the other hand, use a defined lexicon of terms, and are trained to rate the intensity or prevalence of each attribute that is present.

Many of the studies on beef use either a consumer or descriptive panel to evaluate beef products, depending on their ultimate goal of either evaluating a product overall or describing the product. For the goal of this study, both types of panels were used. It is the intention of this study to determine consumer liking in beef products and how it relates to the descriptive attributes found in the meat.

Descriptive panels use lexicons, a list of defined terms, to describe products. Lexicon terms can be as simple as "sweet," or can be more specialized to the specific product that is being described. Many different lexicons for beef have been used in research, most with only a few simple terms such as "juiciness," "tenderness," and "beef flavor," while a few have more specialized terms such as "oxidized," "warmed-over," and "grainy/cowy." There is also a tendency among descriptive panels to evaluate only negative attributes and off-flavors, rather than more positive flavors. Scales also differ among panels, ranging from rating attributes as below, at, or above taste threshold, to unstructured line scales, to a structured number scale. Due to the variety of lexicons and scales used, it is difficult to compare results between studies.

To help fully evaluate beef of all types, this study first seeks to create a lexicon using terms found in other studies, as well as new terms developed by the panelists themselves. The lexicon is intentionally broad in scope and uses a large number of terms to describe a wide variety of beef products. The development of this lexicon is the first goal of this project. Descriptive profiling of beef compared to other meat types including chicken, lamb, pork, and turkey will be used to show the ability of both the lexicon and the panelists to differentiate between meat types and accurately describe beef products.

The second goal of this project is the application of the lexicon to evaluate grain- and grass-fed beef. The lexicon will be evaluated on a 15-point intensity scale, which will allow for the quantification of each attribute within the beef samples. This application of the lexicon by a trained descriptive panel will allow for a flavor profile of each beef product to be generated, and a comparison between the two feed types to be made.

The third goal of the project is the evaluation of the beef by a large number of consumers for overall acceptance. Once the consumers have evaluated the beef product, statistical analysis will be done to relate the liking of the feed types to the descriptive terms. Not only will this give a more complete picture of the products, it will also allow for the terms in the lexicon to be classified as “positive” and “negative”.

The fourth and final goal of the project is to apply the beef lexicon to additional studies on beef. The main focus at this stage of the study will be the descriptive profiling of beef raised on two different types of grass (alfalfa and sainfoin), paired with a consumer acceptance panel. This will allow some conclusions to be made regarding any differences (or lack thereof) between flavor profiles resulting from these different feeds. Additional studies will also be made with the descriptive panel, including descriptive profiling on the *Spinalis dorsi* muscle in the grass- and grain-fed animals, and profiling different mixtures of beef and chicken.

Hypothesis

A flavor lexicon can be developed to describe the flavor profile of cooked beef. This standardized flavor lexicon can be used to identify, describe and quantify sensory differences between meats from grass- or grain-finished cattle and relate these to consumer acceptance of beef.

Objective 1

Develop a complete flavor lexicon for beef including both positive and negative attributes that can provide valuable description of the flavor profile of fresh beef products.

Objective 2

Identify and quantify flavor attributes of beef from grass- and grain-fed cattle using the new flavor lexicon developed in Objective 1.

Objective 3

Evaluate the consumer acceptance of beef from grass- and grain-fed cattle. Identify the flavor attributes that result in low acceptability using results from Objective 2 in combination with the consumer acceptance results.

Objective 4

Apply the newly acquired descriptive lexicon to various other projects, mainly involving different types of grass feed (alfalfa and sainfoin) paired with a consumer panel, but including some additional studies with the descriptive lexicon, including profiling the *Spinalis dorsi* muscle in grass- and grain-fed beef and profiling different mixtures of beef and chicken.

LITERATURE REVIEW

This literature review seeks to establish the growing importance of grass-fed beef by looking at health and economical factors, and will also review previous studies that have been conducted on sensory aspects of grass and grain diet types.

Health Factors in Choosing Feed Type

As the market shifts towards a more health oriented outlook, the interest in and perceived value of grass-fed beef also increases. In the United States, the majority of cattle are raised or finished on grain, but there is still an interest in having healthier choices. Consumers today pay more attention to the labels of products, and are becoming more educated on the influence that nutrition content of products, including meat, can have on their long-term health. Many consumers want products that are natural, lower in fat, and have added health benefits.

Natural aspects

One of the main advantages that grass-fed beef has over grain finished cattle is that often times it can be marketed as a more natural product. There is also a view that allowing cattle to roam freely and graze on grass instead of grains allows the cattle to be healthier and happier. Many grass-fed cattle raisers take advantage of this, and market their beef as the more natural choice.

The argument against this “natural” aspect of grass-fed beef is simply a lack of evidence that pasture-raised cattle are any healthier or happier than their grain-fed counterparts (Brewer and Calkins 2003). Grain-fed cattle are also able to be raised in a more natural manner, and can also be certified as organic by the USDA if they are raised on certified organic pasture, never receive antibiotics, never receive growth-promoting hormones, are fed only certified organic grains and grasses, and have unrestricted outdoor access (FDA 2010). Although the techniques for raising cattle may not vary much between grass- and grain-fed cattle, there still may be a consumer perception that grain-fed cattle are subjected to poorer living conditions if they are not labeled as organic.

Differences in Fat

The second difference in grass- and grain-fed cattle with regards to health is the amount and type of fat in the beef itself. Reducing saturated fatty acids and increasing polyunsaturated fatty acids can help reduce incidence of cardiovascular disease and certain cancers (Roche 1999). Depending on the market, some consumers may prefer to have more marbling in their beef (Savell and others 1987) for taste purposes, but health conscious consumers often want products that are lower in fat. There is strong evidence that raising cattle on pasture instead of grain decreases both subcutaneous fat as well as the amount of marbling in whole cuts of meat (Bidner and others 1981). This reduction of fat is seen in pasture raised animals having a greater percent of fat-free lean than grain-fed animals, although they do have greater amounts of collagen (Duckett and others 2007). Not only is the fat content lower in the pasture raised cattle, they have also been shown to have a lower proportion of monounsaturated fatty acids in loin steaks (Mitchell and others 1991; Leheska and others 2008), though there is some disagreement in findings on whether the amount of saturated and polyunsaturated fatty acids are lower in the pasture raised animals (Mitchell and others 1991; Leheska and others 2008; Warren and others 2008). These and other studies (Brown and others 1979; Baublits and others 2006) show that not only is the amount of fat different, but the composition of the fat can be altered in the animals with a change in diet as well.

Compositional benefits

The differences in chemical composition can be seen as part of the benefits of choosing beef from grass-fed cattle. One of the reported benefits of pasture raised cattle is a higher omega-3 fatty acid content in the beef, including higher amounts of α-linolenic acid (ALA) (Melton and others 1982a,b; Medeiros and others 1987). Among polyunsaturated fatty acids, n-3 (or omega-3) fatty acids are preferred to n-6 (omega-6) fatty acids due to certain positive nutritional and physiological effects (Williams 2000). Larick and Turner (1989) found that grass-fed animals had an increase in multiple fatty acids, including C18:2, C18:3 (ALA), C20:3, C20:4 and C22:5. The increase in ALA has been confirmed by many studies (Brown and others 1979; Baublits and others 2006, 2009; Faucitano and others 2008; Leheska and others 2008), along with a decrease in the ratio of omega-6 to omega-3 fatty acids due to a general increase in omega-3 fatty acids. In a study by Manner and others (1984), they were able to confirm that feeding a grass based diet did lower the n-6:n-3 ratio of fatty acids in beef when compared with a grain based diet. There is also an increase in *trans*-vaccenic acid, a precursor to certain forms of CLA (Leheska and others 2008). Other chemical changes can include higher plasma and muscle levels of vitamin E and carotenoids (Holden 1985). Not only a health benefit, vitamin E can also serve as a protecting agent against lipid oxidation and color instability in meat (Warren and others 2008).

There is a negative aspect to these chemical changes as well. Though they may be seen as a health benefit, the change in chemical composition can cause off-flavors to occur in the beef. Some research indicates that certain fatty acids can have a negative influence on flavor, including conjugated linolenic acid which is described as having a “grassy,” “gamey,” “painty,” or “stale” off-flavor (Larick and Turner 1989; Larick and Turner 1990; Maruri and Larick 1992; LaBrune and others 2008; Baublits and others 2009). In addition to negative changes in flavor from fatty acids, lactones that are positively correlated with roast or rich beef flavor are decreased in grass-fed animals, while diterpenoids which are positively correlated with a gamey or stale off-flavor are increased in grass-fed animals (Maruri and Larick 1992).

An increasing awareness of nutrition and health benefits of functional fats such as omega-3 fatty acids means more consumers are looking for healthier ways to eat the foods they already enjoy. Some of the benefits of pasture raised beef include a more natural approach to raising the cattle, meat that is lower in fat and overall marbling, and beef that has more health benefits such as an increased ratio of omega-3 to omega-6 fatty acids. Knowledge of these benefits may help the case of grass-fed beef as more consumers become aware of them.

Economical Differences in Feed Types

Economical differences between the two diet types are another factor that plays a role in deciding between grass- and grain-fed beef. This is perhaps the most difficult aspect to fully consider, since it is challenging to calculate everything that is involved in the cost of raising an animal. Major differences in economy between the two feed types include price of feed, rate of growth, and price that consumers are willing to pay for the beef.

Price of feed

The difference in feed cost is one reason why grass-fed beef is more attractive than grain-fed beef. Those who favor raising cattle on pasture argue that allowing the animals to roam freely and eat grass is cheaper than purchasing grain for the animals. Cheaper grass type feed can be grown locally on the farm, reducing costs of transporting grain to the farm or raising potentially more expensive grains on the farm itself. There are those who also argue that raising cattle on pastures ultimately has more sustainability advantages as well (Brewer and Calkins 2003). Arguments against this include issues due to the seasonality of forage resources, and that cattle which are raised on pasture have longer growth times, meaning they will eat more food in the long run, and will require more maintenance time, negating cost benefits (Brewer and Calkins 2003).

Rate of growth

The strongest argument against the potential cost benefit of pasture raised cattle is a decreased rate of growth. Most studies agree that grass-fed animals gain weight more slowly than those that are raised or finished on grain, due to a lower dietary energy source (Bidner and others 1981). Although these effects can be minimized by allowing the pasture raised cattle to age longer before harvesting (Bidner and others 1986; Muir and others 1998), there still is the issue with having to maintain the cattle for longer periods of time. A study by Warren and others (2008) did find, however, that animals who were fed good quality grass silage (supplemented with 15% sugarbeet pulp) were able to have a similar growth rate to those fed a grain-fed diet, but this seems to be the exception rather than the rule. Even when the animals do grow at the same rate, the grass-fed animals are typically lower in fat and marbling, as discussed in the previous section.

Consumer perception of price premiums

This slower rate of growth leads to a lower hot carcass weight and quality grade in the grass-fed animals. A consumer economic study by Berthiaume and others (2006) found that this would necessitate a 16% premium in grass-fed beef for the beef to be economically competitive. In two domestic studies, consumers preferred the flavor of grain-fed to grass-fed beef, and so would rather pay a premium for the grain-fed beef (Sitz and others 2005; Umberger and others 2002). A separate study found that if consumers were aware of the potential health benefits of grass-fed beef, they would be willing to pay a $2.00/lb premium (Xue and others 2010). This shows that consumer education is paramount to making grass-fed beef profitable.

Sensory Differences in Diet Types

Sensory aspects are among the most important of the determining factors in consumer acceptance of products, including beef. There is ample evidence that there are several differences between pasture and grain-fed beef in several sensory areas. The main areas that are studied with regard to beef diet are tenderness, juiciness, and flavor, which are seen as the most important aspects as related to consumer preference of beef (Dikeman and others 2005).

Tenderness

Tenderness is important to look at in grass-fed beef due to the lower fat content and marbling in the beef. Studies indicate that increased marbling and fat are responsible for decreased shear force in beef (Berry and Leddy 1984; Wheeler and others 1994), which is why there is some concern when you reduce these in pasture fed animals. There is also evidence that less energy rich diets (such as pasture diets) cause smaller muscle fibers and more connective tissue, causing increased toughness (Brewer and Calkins 2003). Tenderness is most commonly measured by instrumental means known as Warner-Bratzler shear force. There is disagreement on whether grass-fed diet causes decreased tenderness. Several studies indicate that there is no difference in tenderness between treatments (Bidner and others 1981; Crouse and others 1984; Mandell and others 1998; Sapp and others 1999; French and others 2001; Poulson and others 2004; Duckett and others 2007). A review by Brewer and Calkins (2003) of nine previous studies indicated that grain-fed beef was more tender than grass-fed beef, which has also been confirmed by other studies (Harrison and others 1978; Mitchell and others 1991).

Juiciness

Juiciness, as defined by the amount of juices in the finished, cooked product, is especially important for consumer acceptance in whole muscle cuts such as steak. Although higher juiciness scores are associated with higher fat levels in ground beef patties (Berry and Leddy 1984), whole muscle cuts are dependent on other factors as well, such as water binding capacity. The amount of juiciness can be measured either by a consumer panel or by a trained descriptive panel. Among consumer panels, Bidner and others (1981) showed no significant differences in juiciness between grain- and grass-fed animals. Using a triangle test to determine if consumers could find a difference in the treatments, Chastain and others (1982) also found that there were no significant differences shown for juiciness between the two feed types. No differences in juiciness were found using a consumer panel to rate the two beef types on a defined scale either, although considerable variance was found in the ratings (Simonne and others 1996). Other studies, however, point to an increased juiciness in grain-fed steaks when compared to grass-fed steaks. Hedrick and others (1983) found that consumers rated grain-fed steaks as more juicy compared to grass-fed steaks. Consumers in both Chicago and San Francisco also preferred domestic (grain-fed) to Argentine (grass-fed) strip loins in juiciness, when the loins were paired based on similar Warner-Bratzler shear force values and marbling levels (Killinger and others 2004).

Trained descriptive panels have usually found that there is no difference in juiciness between diets. Crouse and others (1984) found no difference in juiciness between diet types, but also found no difference in any other sensory attributes. Looking at both initial (fluid release during the first 5-10 chews) and sustained juiciness (fluid release during the last 5-10 chews), Mitchell and others (1991) also failed to find any differences between treatments. Mandell and others found no change in palatability between animals including juiciness, reinforced by the findings of multiple other studies (Mandell and others 1998; Sapp and others 1999; French and others 2001; Poulson and others 2004; Duckett and others 2007; Warren and others 2008). In a study looking at different amounts of grain-finishing ranging from no grain to 2% of body weight, the lowest (all grass) and highest grain treatments both had more juiciness than those in the categories in-between, although they weren't significantly different from each other (Roberts and others 2009). When combined with the consumer panel studies, it can be concluded that there is either no difference or that grain-fed beef can be slightly more juicy than grass-fed beef. This lack of difference is perhaps best explained by the greater effect that degree of doneness has on juiciness over animal age and marbling score (Wulf and others 1996). Grass-fed animals often vary in both age and marbling in these studies, but are always cooked to the same degree of doneness (final internal temperature) for the study.

Flavor

Out of tenderness, juiciness, and flavor, the most important attribute as related to consumer preference is flavor. Flavor is a combination of taste and aroma and it is one of the main factors that drive consumer acceptance of foods. Sensory evaluation is a powerful tool to evaluate the quality and consumer acceptance of a food product. Similar to juiciness, flavor is measured by either a large, untrained panel of consumers, or by a trained descriptive panel. Consumer panels evaluate preference or acceptability, while descriptive panels usually describe flavors found in the beef. Some studies combine the two panels to determine why consumers like a product, while others only use one of the two panels.

Consumer panels

Among the consumer studies of grass- and grain-fed beef, most focus on measuring only tenderness, flavor, and juiciness, in addition to acceptability. This is not uncommon in meat consumer panels looking at factors other than diet treatments (Hamling and others 2008). Bidner and others (1981) measured tenderness, flavor, juiciness, and overall desirability, and found no difference between diet treatments. Similarly, there was no difference in consumer preference found in steaks for juiciness, tenderness, and overall preference in another study; however, ground beef from the same animals scored lower in all attributes when it was grass-fed (Simonne and others 1996). In a triangle test, consumers were able to detect a difference between the two feed types, but the consumers did not show any significant preference between them in flavor of lean/fat, tenderness, or juiciness (Chastain and others 1982). Other consumer studies do show a preference for grain-fed beef. Hedrick and others (1983) found that finishing beef on grain after they had been raised on pasture improved the flavor, juiciness, tenderness, and overall acceptability. In Chicago and San Francisco, two separate consumer panels found that there was a preference for domestic grain-fed over imported pasture fed beef, either overall (Umberger and others 2002) or in juiciness, tenderness, flavor and overall acceptability (Killinger and others 2004). In Denver and Chicago, consumers also preferred domestic grain-fed steaks to Australian grass-fed steaks in flavor, juiciness, tenderness, and overall acceptability (Sitz and others 2005).

Descriptive panels

In descriptive studies, flavor lexicons have been used for decades in several high value products such as cheese, wine, whisky and chocolate (Drake and Civille 2003; Murray and others 2001) where small changes in specific attributes can tremendously affect the acceptance of the product by the consumer. These lexicons have been used to identify meat flavors as well, both desirable and undesirable (Miller and others 1996; Allen and others 2007; James and Calkins 2008; Wadhwani and Cornforth 2010). However, sensory studies in beef usually differ in terminology and types of scales used, and are usually focused on the negative attributes of the beef. This variation among terms hampers meaningful comparisons among studies.

Development of a descriptive lexicon focuses on the development of a common frame of reference to describe the products. The products being evaluated are presented to the panelists, who generate words or terms to describe the products. These terms are reinforced through references, which are good examples of the terms either in the product or in solution. This allows the terms to be solidified in the minds of the panelists who are being trained, and ultimately allows for consensus among the panelists when describing the products. Care must be taken to avoid terms that are vague, incorrect, and potentially "consumer oriented" in the lexicon (Muñoz and Civille 1998). Vague terms may be easier to use in descriptive panel training since they do not require as much training, but they can cause confusion among the panelists since they are hard to define and often bring with them preconceived notions as to what the true definition of the term is. For example, "beef flavor" in a lexicon developed for beef will cause a panelist to refer to their own frame of reference (their previous exposure to different experiences based on their own culture and history) instead of what the panel leader may think they are describing. It is difficult at best to find reference samples for these generic terms such as "beef flavor," since it cannot be easily defined as a single, specific attribute. Terms should also be avoided that are not specifically defined, such as "off-flavor prevalence."

Off-flavor prevalence is occasionally used in beef panels as a generic category for any flavors that are perceived to be undesirable by the panelists, but because they are not specifically defined and are subjective to the perceptions of the panelists, it is difficult to compare results from this category to other descriptive panels. Terms that reflect specific sensory attributes that the panelists can use to form a new common frame of reference and more accurately describe the products to be evaluated should be used when developing a flavor lexicon (Muñoz and Civille 1998).

For beef in general, flavor lexicons have been developed, but are limited and mostly consist of negative attributes. As an example, Johnson and Civille (1986) developed a flavor lexicon for warmed-over flavors (WOF) in meats. Their lexicon included terms such as cooked beef lean, cooked beef fat, browned, serum/bloody, grainy/cowy, cardboardy, oxidized/rancid/painty and fishy. They also included sweet, salty, bitter and sour in their lexicon. Their research showed that WOF from re-heated samples were associated with an increase in negative notes, such as cardboardy and oxidized, and a decrease in the positive ones, such as cooked beef lean and cooked beef fat. Even though this research provided a lexicon for identifying and quantifying WOF it does not provide a tool to evaluate the sensory profile of fresh cooked meats. In a study of the effects of cooking rate and holding time on the flavors of beef, James and Calkins (2008) evaluated tenderness, amount of connective tissue, off-flavor, and juiciness, but did not get any more specific on flavors. Stelzlini and Johnson (2008) evaluated beef for intensity of sensory off-flavor in general, in addition to identifying the presence of one of several descriptors such as metallic, grassy, livery, grainy, gamey or other, though they did not rate the intensity of the descriptor. Looking at enhancements and aging effects on flavors, Stetzer and others (2008) evaluated tenderness, juiciness, saltiness, beef flavor and oily mouth-feel. These studies show that even when trying to evaluate meat in general, it is difficult to find any sort of agreement in terms between descriptive panels.

Descriptive work has also been performed specifically on grass-fed and grain-fed beef, but the terms are also limited and often fail to distinguish between the two diets. In a review of research on diet on sensory qualities of beef, Schor and others (2008) concluded that there was no significant effect on beef due to diet; however, the review focused on the Argentinean market, where grass-fed animals are preferred. With no difference found, Crouse and others (1984) evaluated flavor intensity, ease of fragmentation, juiciness, amount of connective tissue, and overall tenderness, in several muscles including the longissimus, semimembranosus, and semitendinosus. In a similar manner, another study found no difference when looking at tenderness, moistness/juiciness, overall flavor, residual chewiness, overall texture, and overall acceptability (French and others 2001).

There are many studies, however, that do point out differences in sensory properties in grass- and grain-fed beef. Brown and others (1979) used a 9-point “flavor score” combined with comments on the presence of other flavors described as beef fat flavor, dairy aroma/flavor/after taste, soured dairy flavor, and undesirable notes. The flavor score was found to be lower in grass-fed animals. Melton and others (1982a) followed the design of this experiment, scoring flavor coupled with ratings of whether a sample was below, at, or above tasting threshold in beef fat flavor, dairy aroma/flavor/after taste, soured dairy flavor, and undesirable notes; they concluded that pasture raised cattle had a less desirable flavor score, lacked beef fat flavor, had a more intense dairy-milky flavor, and usually had a soured dairy or other off-flavor. Larick and others (1987) studied the effect of duration of grain finishing on pasture raised cattle. They determined that a longer period of grain finishing decreased grassy flavor in both steaks and ground beef, but they did not evaluate any other flavor attributes.

Some meat descriptive panels focus on attributes that are common to consumer panels, such as juiciness, tenderness, and flavor intensity. Mitchell and others (1991) evaluated initial and sustained juiciness, tenderness, and flavor intensity, concluding that grain-fed animals were significantly more tender and flavorsome than forage-fed animals. Sapp and others (1999) similarly evaluated juiciness, tenderness, connective tissue amount, beef flavor intensity, and overall palatability, with the only difference found in grass-fed beef having a higher incidence of an undefined off-flavor, described as a “grassy” flavor by two or more of the panelists. Several diets were examined by Poulson and others (2004), who found that beef flavor intensity was higher in pasture raised animals. They considered the terms of tenderness, juiciness, intensity of beef flavor, and intensity of off-flavor, and also noted that off-flavor scores were highest among the grass-fed animals. Baublits and others (2006) found that the grassy off-flavors and lower beef flavor intensity could be improved by soyhull supplementation. With no change in juiciness or tenderness, Duckett and others (2007) again found lower beef flavor intensities and higher off-flavor intensities. Finally, Roberts and others (2009) found that increasing amount of corn feed increased flavor intensity and beef flavor in cattle originally raised on pasture. All of these studies were limited in their lexicons, and were thus limited in their ability to truly describe the products.

Of the studies that included more attributes to describe the differences between grass- and grain-fed cattle, most included only negative attributes with only one generic positive attribute such as ‘flavor score’ (Melton and others 1982a), ‘typical beef flavor’ (Mandell and others 1998), and ‘overall liking’ (Warren and others 2008). These studies all disagreed on other terms to describe the beef. Melton and others (1982b) used beef fat flavor, dairy aroma/flavor/after taste, soured dairy flavor, and undesirable notes, and rated their attributes as being below, at, or slightly above threshold. They found that grass-fed steers had less desirable flavor, lacked beef fat flavor, had a more intense dairy-milky flavor, and usually had a soured dairy or other off-flavor. Mandell and others (1998) split their attributes into aromas (greasy, metallic, typical beef, grassy), flavors (sour, beef, salt, liver), and aftertaste (metallic, greasy). In their study they found that palatability was generally unchanged by diet except for a reduction in beef flavor and a higher occurrence of off-flavors in grass-fed beef. Garmyn and others (2010) included beef flavor intensity, grassy/cowy, painty/fishy in their lexicon. They found that grain fed cattle had greater beef flavor intensity, less grassy/cowy, and greater painty/fishy.

A study in the United Kingdom was one of the few studies found to disagree with the results of others. They had the most terms of any study, including juiciness, toughness, abnormal, acidic, beef, bitter, bloody, cardboard, dairy, fishy, greasy, livery, metallic, rancid, sweet, vegetable/grass, and overall liking. However, they showed that grass-fed and grain-fed animals had a very similar sensory profile, and to a small degree the grass-fed were preferred to the grain-fed animals (Warren and others 2008). This preference for grass-fed beef in this study can most likely be explained by the higher prevalence of grass-fed animals in the United Kingdom, such that consumers are more accustomed to the taste. Interestingly, a study conducted in Spain found that beef odor and beef flavor intensities were negatively associated with the energy content of the animal diets; in other words, they found grass-fed beef to be more intense in flavor and odor. Their terms included beef odor, strange odor, tenderness, juiciness, fibrousness, beef, rancid, acid, liver, and fat flavor (Resconi and others 2010).

Consumer studies in the United States indicate that grain-fed beef is almost always more liked compared to grass-fed beef (if there is a difference). Descriptive panels often fall short in describing what the specific flavor differences between the two diet types are, which makes it difficult to determine why there is a difference in preference among consumers. Many studies only found differences in flavor intensity or a greater occurrence of off-flavors, though most did not identify what exactly those off-flavors were.

In summary, grass-fed beef is becoming increasingly important in the minds of consumers and those who raise cattle for various health and economical reasons. Consumers in the United States, however, still prefer the taste of grain-fed beef. For this reason, more research is needed to further identify flavor differences that occur between grass- and grain-fed animals, and how these differences relate to consumer preferences. This knowledge will allow for future studies to improve the flavor of grass-fed beef, as well as ways to make it more marketable.

MATERIALS AND METHODS

Meat Samples

Meat samples for training were obtained from local grocery stores or through the Utah State University meat lab. Grass-fed beef for training was obtained by purchasing through mail-order services from farms that specialize in grass-fed beef. Wild game meat such as deer and elk was provided by Utah State University meat lab. For the actual experiment, primal rib sections of three grass-fed steers were purchased from James Ranch, Durango, CO. Primal rib sections of two grain-fed steers and one heifer were obtained from USU's Animal Science Farm. Black Angus bred animals were used for the grain-fed cattle, and Red Angus sired cattle with a mix of Hereford and Angus dams were used for the grass-fed animals.

Grass-fed animals typically put on weight slower and have less marbling than grain-fed animals, which does present some issues with any studies of this type. The animals from each diet can either be harvested at the same age, in which case the grass-fed animals will be much smaller and leaner and will taste different due to lower fat levels, or the animals can be harvested at approximately the same size, in which case there may be some taste differences due to maturity of the animals. For this study, the animals were harvested at approximately the same size (weight), with as little difference in age as possible, as it is believed that maturity in this case will cause less difference in flavor than marbling. This follows common industrial procedures, where pasture raised animals may be harvested at a more mature age depending on feed availability and other factors, in an effort to increase their weight (and thereby increase their selling price) when compared to grain-fed animals (Bidner and others 1986; Muir and others 1998).

The grass-fed animals used in this experiment were supplemented with alfalfa during the winter, and they were finished for 120 days exclusively on grasses, including orchard grass, brome grass, blue grass, timothy, tall wheat grass, dandelions, Alsike clover, Crimson King clover, quack grass, sedges, rushes, Reeds Canary grass, fescue, and Garrisons Creeping Meadow foxtail. The grain-fed animals had a finish diet of 120 days consisting of 60% corn silage, 30% flaked barley, and 10% alfalfa hay. The grass-fed animals were all steers, while two of the grain-fed animals were steers and one was a heifer. Both the left and right rib sections were used from each animal for the experiment.

Carcass quality and yield grade measurements were obtained for each animal after harvest. Carcass quality grade measurements (indicators of meat acceptability) included marbling score (fat content) of the rib-eye muscle (Longissimus dorsi), taken at the 12-13th rib, and carcass maturity score, indicated by degree of ossification the ventral processes of the thoracic vertebrae and ribs. Carcass yield grade measurements (a measure of lean meat yield) include hot carcass weight, back fat thickness at the 12-13th rib, rib-eye area (12-13th rib), and internal fat (kidney, heart, pelvic fat) as a percent of hot carcass weight. Fat content in the samples was determined using the Soxhlet method on uncooked steaks, with petroleum ether being used as the solvent (AOAC 1990). Raw steak pH was measured on 10 g of sample that were finely chopped, diluted to 100 ml in distilled water, allowed to equilibrate at room temperature for 30 min and then filtered.

Filtrate pH was measured, using a Fisher Accumet pH meter model 610 A (Fisher Scientific Inc, Salt Lake City, UT), equipped with a combination pH electrode calibrated immediately before use to pH 4.0 and 7.0. The ribs from each animal were vacuum packaged after harvest, shipped to the Department of Nutrition, Dietetics, and Food Sciences at USU and immediately frozen at -20 °C until use. In addition to the grain- and grass-fed animals, alfalfa and sainfoin fed animals (two types of legumes, which will be considered "grass" diets for this experiment) were evaluated in both consumer and descriptive panels. The characteristics of the animals were measured in similar fashion to the grain- and grass-fed animals. Alfalfa and sainfoin have higher protein contents when compared to traditional grass diets (Parker and Moss 1981; Vanzant and Cochran 1994). In addition, alfalfa tends to have a higher saponin content, while sainfoin tends to have a higher tannin content (Lu and Jorgensen 1987; Mangan 1988). This experiment was performed to determine how these differences from traditional grass feed would change the flavor profile and consumer acceptance of the beef. Six animals total were used in this portion of the study, with three from each treatment type, either alfalfa or sainfoin. All animals were steers, with the exception of the animal labeled alfalfa #1, which was a heifer. The *Longissimus dorsi* (LD) muscle was chosen for use in the sensory tests, with rib eye steaks trimmed to only include the LD muscle after cooking. The LD muscle is used since it is one of the most tender muscles of the animals (Keith and others 1985; Morgan and others 1991). A more tender muscle was desired due to the chosen cooking method of dry heat, which doesn't increase tenderness as much as other cooking methods might. Previous studies have shown that grass-fed animals tend to have lower marbling scores, as well as smaller muscle fibers and more connective tissue, all of which could lead to less tenderness in the grass-fed beef; however, studies disagree as to whether this is actually the case (Brewer and Calkins 2003). In addition to tenderness, muscles from the rib area have also been shown to be among the most desirable in flavor (Keith and others 1985).

Meat samples for the other descriptive experiments, including the beef, chicken, turkey, pork, and lamb used in the lexicon development and the chicken and beef for the profiling of chicken and beef mixtures were obtained from local stores and through the USU meat lab. Breast meat was used for the ground chicken and turkey samples, and a mix of various muscles was used for the lamb and pork samples. After the samples were ground they were formed into 100g patties using a handheld hamburger press.

Sample Preparation

Samples for both training and the final experiment were prepared in a similar manner, except where noted in the lexicon development. Guidelines from the American Meat Science Association (1995) were used to prepare samples. Dry heat cooking on electric griddles at 163 °C was used to cook the steaks, as there is evidence that it produces a higher beef flavor over electric broiling, charbroiling, conventional oven roasting, convection oven roasting, and microwave cooking (Berry and Leddy 1984).

Since endpoint temperature of samples has been shown to influence liking of a sample (Lorenzen and others 2003), all samples were cooked to the same temperature. Samples were monitored at their center for internal temperature by using an AquaTuff 35200 digital thermometer (Atkins Technical Inc, Gainesville, FL U.S.A.) with a fastresponding microneedle probe. For both patties and steaks, the probe was inserted horizontally from the side to reach the center of the sample. A minimum of two readings per sample were taken to verify that the samples had reached the target internal temperature. For hamburgers and steaks, the internal temperature target was 70 °C, unless otherwise specified in the lexicon development. After cooking, samples were cut into 2.54 cm cubes, placed in covered aluminum dishes, and served to the panelists hot. For descriptive and consumer tests, panelists tasted the samples in random order with 3-digit blinding codes under red colored lights to minimize bias.

Descriptive Panel Development

Taste panel recruitment

Institutional Review Board approval was obtained prior to performing any recruiting, testing, or training. Approved methods were used in the recruitment of the panelists (ASTM 1981). Panelists were recruited through flyers and newspaper advertisements in the local community. Applicants were initially screened on willingness to participate in a long term study, beef eating habits, and availability. The full questionnaire can be seen in Appendix A. Approximately 60 applicants were screened, and those who qualified were then asked to take part in a secondary screening. During the secondary screening, panelists were asked to identify samples among the five basic tastes in water (bitter, salty, sour, sweet, and umami) when presented in random order with 3-digit blinding codes. They were also given sets of three samples of the same taste but different intensities, and asked to rate them on a 15-point intensity scale (0 = no flavor, 15 = extreme intensity). The concentrations of the samples used for the screening of the panelists can be seen in Table 1. Samples for identification were taken from the middle concentration of each attribute, while intensity ratings used samples from all three concentrations. Panelist performance was evaluated by their ability to identify the basic tastes and distinguish between the intensities (Meilgaard and others 2007). Those panelists who were best able to distinguish between the samples were invited to join the meat panel. For this experiment 17 panelists were initially recruited. Twelve of these panelists participated in the final test after training. Of these twelve, nine were male and three were female. Panelist ages ranged from 18 to 60. Gender and age are not expected to have an effect on ratings, as the panelists are extensively trained on the intensity scale. Panelists were compensated for participation in hourly wages.

Training/monitoring

Initial training of the panelists consisted of training on good sensory practices, such as not eating before the panel, proper cleansing of the palate, and other tasting procedures (Meilgaard and others 2007). Panelists were then familiarized with the five basic tastes in both identification and quantification. Solutions of sodium chloride for salty, sucrose for sweet, caffeine for bitter, citric acid for sour, and monosodium glutamate for umami were used. A 15-point intensity scale with discreet intervals of 0.5 similar to that used in the Spectrum method was used in this study. Different concentrations of each substance were used to represent the different values on this scale (Meilgaard and others, 2007). Panelists were instructed to give a 0 rating to samples with no flavor and increase the rating value as the intensity of the specific taste increases, with a maximum of 15 for the sample with the highest intensity. With the intensity scale, an identical value between two flavors on the scale should be equal in intensity; for example, a 5 in sour should be equal in intensity to a 5 in sweet. The basic taste attributes with their concentrations in water used to train the panelists on the scale are shown in Table 1. Additional mixtures of the basic tastes were also rated on the 15-point scale. These mixtures allowed the panelists to become more familiar with rating attributes and using the scale when multiple taste interactions were present. These mixtures can be seen in Table 2. The training received by the panelists at this stage allowed them to become familiar with the mechanics of the scale, and where to place solutions of varying intensities on the scale. This part of the training took approximately

Table 1: Taste concentrations in aqueous phase used for screening of panelists and during panel training on specific intensities

Attribute	Taste Definition	Treatment	Levels	Scale Value
Bitter	Taste elicited by caffeine	Caffeine	0.05%	2
			0.08%	5
			0.15%	10
Salty	Taste elicited by salts	Sodium chloride	0.20%	2.5
			0.35%	5
			0.50%	8.5
Sour	Taste elicited by acids	Citric acid	0.05%	2
			0.08%	5
			0.15%	10
Sweet	Taste elicited by sugar	Sucrose	2%	2
			5%	5
			10%	10
Umami	Taste elicited by monosodium glutamate (MSG)	Monosodium glutamate	0.7%	5
			1.4%	9
			2.8%	13

Table 2: Taste concentrations used to achieve mixtures of the basic tastes in aqueous phase.

	Bitter	Salty	Sour	Sweet	Umami
Sweet 2% Sour 0.15% Umami 0.2%	0	0	1.5	1	3.5
Sweet 5% Sour 0.2%	0	0	4.5	3.5	0
Salty 0.35%, Sour 0.2%	0	3	5.5	0	0
Sweet 2%, Sour 0.2%	0	0	5	2	0
Bitter 0.05%, Salty 0.5%	2.5	3.5	0	0	0
Sweet 5%, Salty 0.5%, Bitter 0.15%	4	2	0	3	0
Sweet 5% Salty 0.5%	0	3	0	4	0
Sweet 2%, Sour 0.15%, Umami 0.2%	0	0.5	3	1	2

30 hours in total.

Once the panelists were accustomed to the scale, they were introduced to different attributes commonly found in beef. This stage of training is covered in the section on lexicon development.

Panelists were monitored throughout the training procedures to evaluate their individual ability to rate samples compared to the rest of the panel. Panelists were asked to rate samples in duplicate using a computerized data collection system (Sensory Computer Systems 2010), which allowed their responses to be analyzed for consistency and accuracy. Responses were analyzed using PanelCheck software (Nofima Marin and others 2008), as well as using analysis of variance (ANOVA) to look for significant differences between replications and from the panel mean. PanelCheck allowed for quick visual analyses of panelist performance, both between replications and compared to the panel average. These performance results were used to guide training sessions and get a better idea of what attributes the panelists struggled with. It also allowed for individualized attention to one of the panelists if they had difficulties identifying or quantifying an attribute. Sample PanelCheck plots can be seen in Appendix B. Plots for both the panel as a whole (see Appendix B, Figure 8) and for individual panelists (see Appendix B,

Figure **9**) were used to evaluate panelist performance visually. For the panel as a whole, the goal was to have panelists rate each attribute as close to the panel mean as possible. The individual panelist charts were used to more easily identify which panelists were having difficulties rating samples close to the panel mean, whether in an individual attribute or overall. The objective of customizing training to the needs of the panel was to create a panel that could be used as a calibrated, accurate, and reproducible analytical instrument.

Lexicon development

Before this study began, a survey of attributes that had been used in previous research was undertaken. Attributes that appeared frequently in the literature were compiled to be used by the panelists as a starting point. These starting attributes for the lexicon development are shown in Table 3. Panelists were asked to rate beef samples with the different treatments to determine which samples were most applicable to the current study and to fresh meat products in general.

Open discussion among the panelists was used at this stage to decide which attributes were most useful in describing various meat products. In addition to these attributes, panelists were encouraged to contribute new terms to the lexicon. These terms were then voted upon and vetted by the panelists for use in beef products.

Table 3: References initially used to train the panelists**.**

Attribute	**Reference**
Cooked beef lean (beefy)[2, 3]	0.25% natural roast beef, Innova, Griffiths Lab., Oak Brook, IL + 0.125% NaCl solution (scale value = 10)
Cooked beef fat (fatty)[2]	Young high choice beef
Browned[2]	Well done rib steak cooked to an internal temperature of 76 °C
Serum/bloody[2]	Rare rib steak cooked to an internal temperature of 52 °C
Grainy/cowy[2, 4]	Utility grade beef
Cardboardy[2]	$CuSO_4$ 1% 0.2 mL in ground meat (hamburger)
Oxidized/rancid/painty[2]	Rib steak cooked and stored overnight at 10 °C and reheated
Fishy[2]	Addition of omega-3 fatty acids to ground meat (hamburger)
Grassy[1]	Add 20 mg of hexanal in ground meat (hamburger)
Metallic[1]	0.04, 0.08, and 0.16 g ferrous sulfate in ground meat (hamburger)
Astringent[1]	Ground meat (hamburger) with tannic acid (0.05% solution)
Livery[3]	Fresh calf liver, cooked to 70 °C on open hearth grills (scale value = 13)
Rancid[3]	Melted, Land O'Lakes, unsalted, sweet cream butter (Land O'Lakes, Inc., Arden Mills, MN), stored at 22 °C for 4 weeks (scale value = 10)

[1]Berry and others 1980, [2]Johnson and Civille 1986, [3]Stetzer and others 2008, [4]Stelzleni and Johnson 2008

Fresh meat samples were always used for the lexicon development, with various tastants added to the samples. Additives were mixed in uniformly in the ground beef products by hand. All ground beef samples were cooked to an internal temperature of 70 °C for safety purposes, while steaks were also cooked to 70 °C with the exception of the "bloody" and "browned" terms, which were cooked to 52 °C and 76 °C, respectively. Panelists were also asked to expectorate all of their samples for safety and sensorial reasons, and they were asked to cleanse their palate between samples with unsalted crackers and water.

The original starting lexicon consisted of the terms cooked beef lean, cooked beef fat, browned, serum/bloody, grainy/cowy, cardboard, oxidized/rancid/painty, fishy, grassy, metallic, astringent, livery, and rancid. To determine if these terms would be useful in describing beef products, the references were compared to many different meat samples from grain- and grass-fed animals of varying qualities, from local stores and from the USU meat lab. Some of the references were changed in their terminology such as using the term "fatty" to refer to the amount of perceived fat in a sample instead of "cooked beef fat." Other terms such as rancid were removed altogether as it did not reflect an accurate description of fresh meat. The final lexicon is shown in the results section as Table 6.

As the terms were decided on, panelists were also asked to rate the intensity of the flavors in the beef according to their previous exposure on the 15-point intensity scale. As mentioned previously, a specific number on the scale should be equal in intensity across attributes, whether they are one of the basic attributes such as bitter, or whether they are one of the newly developed attributes for the beef. Panelists discussed their ratings of the samples after trying each sample, and consensus was used to establish a scale on the new attributes. Training continued until the panelists agreed on all of the terms that were created for the lexicon, and the panelists themselves were well trained on the identification and quantification of the attributes. Panelists were considered fully trained when they showed reproducibility between replications of the same sample, and had ratings consistent with the rest of the panel. Panelists received a minimum of 50 hours of training on the lexicon and beef attribute scaling.

To assess the individual panelist's ability to identify and quantify attributes, panelists were also asked to rate meat samples in duplicate with the different attributes in individual booths. Statistically significant differences were looked for between the panel average and an individual panelist rating, as well as between their replicate responses. This allowed both the assessment of the performance of the panelists, as well as determining if the scale that was created was satisfactory. Additional training was given to the panelists when they showed they had difficulties in quantifying attributes.

Descriptive Profiling

Once the lexicon was established and the panelists were fully trained, panelists were then able to apply the lexicon to various projects. The main project involved the profiling of the grain- and grass-fed beef as previously discussed. Several descriptive projects were completed by the panelists apart from the main objective of evaluating the grain- and grass-fed beef. These additional projects serve to add additional information to beef flavors and the use of the lexicon.

Descriptive profiling was done following proper sensory procedures, as discussed previously. All samples were cooked to 70 °C, checked to central internal temperature using a high accuracy thermometer on an electric griddle. All samples were cooked fresh with no seasoning. Samples were cut into 2.54 cm cubes, placed in covered aluminum dishes with 3-digit blinding codes, and served to the panelists while hot. Samples were tasted in duplicate by the panelists under red colored lighting, with a 15 minute break between replicates.

Consumer Evaluation

Two consumer panels took place in the course of this study, one on the grass- and grain-fed cattle, one on grass-feed types (described in the following section). For the consumer panels, participants were recruited from the campus area using flyers and emails. The first consumer panel evaluated grass- and grain-fed beef samples. Six animals were evaluated during the consumer panel, with three grass-fed animals, and three grain-fed animals. One hundred and twenty panelists participated in this test. Due to the large number of samples, each panelist was presented with two steaks, consisting of one grain-fed and one grass-fed sample. The steaks were randomly selected from one of the three animals from each diet treatment in a randomized incomplete block design. Each animal and treatment combination was seen by a total of 40 panelists.

For the consumer panels, beef samples were prepared identically to the descriptive panel samples, and were presented to the panelists in a randomized and balanced manner. Sample evaluation was performed in individual booths under red colored light. Consumers were instructed to cleanse their palate with water and unsalted crackers between samples to minimize fatigue. Consumers were asked to rate the degree of liking of each sample on a typical 9-point hedonic scale (1= dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, 9=like extremely). Basic demographic questions including age, gender category, and frequency of consumption of beef were asked of the panelists.

Changes with Grass Types and Additional Sensory Work

In addition to the main test on grass- and grain-fed beef, other work was done with the developed lexicon. The main secondary study involved additional descriptive profiling on grass-fed cattle, in a comparison between two different grass types to see if there was any effect on flavor with different grasses. The purpose of this test was to determine if the results of the main grain- and grass-fed test could be extended to another grass type (sainfoin) as well. Cattle raised on alfalfa were compared to cattle raised on sainfoin by the descriptive panel. Six animals were evaluated, with three alfalfa raised animals, and three sainfoin raised animals.

This test on grass feed types was also coupled with a consumer panel of 120 people, to evaluate if there were any noticeable differences in consumer acceptance in meat obtained from grass-fed animals fed different grass types. Procedures for this test followed the format for the previous consumer panel. Each panelist was presented with two samples, one from each grass diet, and asked to evaluate the samples on a 9-point hedonic scale for degree of liking. As with the grass- and grain-fed consumer panel, samples were presented in an incomplete block design, in a random and balanced order, with 3-digit blinding codes on the sample container. Samples were prepared as described in previous tests.

Following the panels on grass- and grain-fed beef, descriptive evaluation was done on different proportions of ground chicken with ground beef in patty form. The goal of this project was to show which flavors separated beef from other meats. Chicken was used due to the more bland nature of the meat when unseasoned. For this test, ground beef was mixed with ground chicken breasts that were purchased from local stores. Beef and chicken was mixed in various proportions by hand, and pressed into 100g patties before cooking. Cooking procedures were the same as for the steaks, with the patties cooked to 70 °C and served to the panelists in covered aluminum dishes.

Descriptive work on the *Spinalis dorsi* muscle, sometimes referred to as the "cap" muscle on the rib eye steak, was also done by the panelists. The goal of this project was to see if there were significant differences in taste in the *Spinalis dorsi* muscle when compared to the *Longissimus dorsi* muscle used in the main experiment, and if the same results would be obtained between the grass- and grain-fed animals if we had used the *Spinalis dorsi* muscle instead. The *Spinalis dorsi* muscle is not as commonly used as the LD muscle in profiling experiments due to it typically being a very small muscle in rib eye cuts of beef, but there are many who claim it is more flavorful than the LD muscle.

Statistical Analysis

Results from both the descriptive and consumer panels were analyzed using Statistical Analysis Software (SAS Inst. 2003). The proc glm function was used to conduct an ANOVA for all analysis. Comparison of the means was made based on p-values ($\alpha = 0.05$) using the least significant different adjustment to obtain differences of least means squares. Principal component analysis (PCA) using proc corr was used to analyze the lexicon terms and their relationship to the samples and consumer preferences.

The panelist ratings were analyzed using principal component analysis (PCA), which is a statistical analysis tool used for multivariate analysis. The goal of PCA is to look at inter-correlated dependent variables and create new orthogonal variables known as principal components. A pattern of similarity between the observations and variables are displayed as points on a "map" or graph (Jolliffe 2005).

RESULTS

Meat Characteristics

The characteristics of the grass-and grain-fed meat are shown in Table 4. At the time of harvest, the grass-fed animals were 24-27 months old and had a hanging weight between 318-360 kg. The grain-fed animals were 19-20 months old and had a hanging weight between 320-345 kg in hanging weight. All of the animals were steers, with the exception of the sample labeled Grain #1, which was a heifer. There were no differences found in the hanging weight or rib eye area between the two types of meat, due to the harvesting of the animals occurring for the animals at similar weights rather than similar ages. There were slight differences in pH values between the animals, with slightly higher values found in the grass-fed meat. Back fat thickness was generally lower in the grass-fed animals, and overall fat content was significantly lower in the grass-fed animals. The quality grade was also lower in the grass-fed animals. Steaks from the same animals were used in both the main experiment that evaluated the *Longissimus dorsi* muscles, and the descriptive evaluation that looked at the *Spinalis dorsi* muscles.

Table 4: Characteristics of steaks obtained from grain- and grass-fed animals.

Samples	HW	REA	BFT	Marbling	Quality Grade	pH	Fat (%)
Grain #1	320	81.3	1.3	mod abundant	Prime	5.13±0.02	13.86±1.99
Grain #2	330	80.6	0.5	moderate	high Choice	5.15±0.01	12.38±1.45
Grain #3	345	87.7	1.3	small	low Choice	5.06±0.02	11.05±1.40
Grass #1	318	80.0	0.3	slight	Select	5.28±0.02	3.03±0.20
Grass #2	330	78.7	0.8	slight	Select	5.27±0.01	3.51±0.40
Grass #3	360	85.8	0.5	slight	Select	5.27±0.01	3.54±0.23

HW = Hanging Weight (kg); REA = Rib Eye Area (cm^2); BFT = Back Fat Thickness (mm)

For the study on different grass types (alfalfa and sainfoin), the characteristics of the meat are shown in Table 5. There were no differences in hanging weight or rib eye area between grass types. Back fat thickness was similar between animals as well. Marbling was slight in all of the alfalfa raised animals, while the sainfoin animals had one with slight marbling and two with trace marbling. Accordingly, the quality grades on the animals were all Select apart from the two sainfoin animals with trace marbling, which were rated as Standard.

Objective 1: Descriptive Panel Development

The descriptive panel was used to develop a standardized meat flavor lexicon. Initially, the panelists were introduced to flavor references (Table 3) that had been used in previous studies, including cooked beef lean (beefy), cooked beef fat (fatty), browned, serum/bloody, grainy/cowy, cardboard, oxidized/rancid/painty, fishy, grassy, metallic, astringent, livery, and rancid. Some of these references were modified during the training, while some were eliminated completely. The final lexicon terms, definitions, and concentrations used to train the panelists can be seen in Table 6.

Among those references that were altered from the initial references, cooked beef

Table 5: Characteristics of steaks obtained from two different grass feed types.

Samples	HW	REA	BFT	Marbling	Quality Grade
Alfalfa #1	220	56.1	0.50	Slight	Select
Alfalfa #2	245	70.3	0.40	Slight	Select
Alfalfa #3	252	66.5	0.30	Slight	Select
Sainfoin #1	231	55.5	0.40	Slight	Select
Sainfoin #2	277	70.3	0.30	Traces	Standard
Sainfoin #3	254	72.3	0.10	Traces	Standard

HW = Hanging Weight (kg); REA = Rib Eye Area (cm^2); BF = Back Fat Thickness (mm)

Table 6: Flavor lexicon developed by the descriptive panel. Basic tastes are also included in the lexicon.

Attribute	Taste Definition in beef	Levels	Scale Value
Astringent	Mouth-drying and harsh sensation	Tannic Acid 0.05% in water	7-8
		Alum 0.1% in water	8-10
Barny	Aromatics associated with feces	0.5 ug skatole /g beef	5
		1 ug skatole /g beef	10
Bloody	Taste associated with undercooked meat	Steak cooked to 55°C	10-12
Brothy	Flavors and aromatics associated with boiled meat or soup stock	5% of low-sodium beef broth in ground beef	7-9
		10% of low-sodium beef broth in ground beef	9-11
		20% of low-sodium beef broth in ground beef	12-14
Browned	Flavors associated with meat that is cooked more and charred on the outside	Steaks cooked to 71 C, allowed to brown on each side	Depending on "browness" of sample, ranges from 7-12
Gamey	Taste associated with wild game meat	Wild game meat such as deer and elk	Depends on animal
Grassy	Aromatic found in grass fed animals	1 drop hexanal in 300g beef	4-6
		1 drop hexanal in 100g beef	7-8
		3 drops hexanal in 100g beef	15
Juicy	Sensation caused by meats with higher levels of juices	Different types of steaks with varying levels of juice/toughness	Depends on sample
Fatty	Sensation caused by various levels of fat in the beef	73% Lean ground beef	4-6
		80% Lean ground beef	6-8
		90% Lean ground beef	10-12
Livery	Taste found in animal organs	40% cow liver in ground beef	6-8
		75% cow liver in ground beef	10-12
		100 % liver	12-14
Metallic	Taste associated with various metal flavors found in meat	0.36% Ferrous Sulfate in ground beef	5-7
		0.5% Ferrous Sulfate in ground beef	8-10
Oxidized/ Warmed over	Flavor of reheated meat	Ground beef cooked then refrigerated for at least 24 hours before reheating	6-10
Roast Beef (RB)	Flavor developed in beef after holding at temperature for long periods of time	Fresh ground beef	0
		Cooked ground beef, held in oven for 1 Hour	RB 1-3, Browned 1-3
		Cooked ground beef, held in oven for 2 Hours	RB 3-6, Browned 3-6

lean, or “beefy,” was removed due to the non-specific nature of the term. Similarly, rancid was removed because the lexicon was created to describe fresh beef products, and the samples tasted by the panel did not have rancid flavors in them. Even though all steaks were cooked to the same final temperature (well done), bloody was kept in the final lexicon because certain steaks could still have undertones of the bloody flavor attribute. Grainy/cowy was replaced by barny. Oxidized/ rancid/painty was simplified to oxidized. Gamey and fishy were indistinguishable by the panelists, so fishy was removed. Other terms were added based on the experiences and input of the panel until a total of 18 terms to describe the beef were finalized with the five basic tastes (bitter, salty, sweet, sour, and umami) and 13 beef specific terms including astringent, barny, bloody, brothy, browned, gamey, grassy, juicy, fatty, livery, metallic, oxidized/warmed over, and roast beef.

To test the final lexicon’s ability to describe beef, meat from various animals (beef, lamb, pork, turkey, and chicken) was given to the panelists, and they were asked to rate each using the lexicon. The average descriptive panelist ratings from this test are shown in Table 7, and the corresponding principal component analysis plot is shown in Figure 1. There were significant differences between the samples in every attribute besides bloody and oxidized. Additional statistical information including the ANOVA statistics and the correlation coefficients can be found in Appendix C, Tables 16 and 17.

As shown in Figure 1, the principal component analysis shows a strong relationship between beef, lamb, and certain attributes such as roast beef, barny, grassy, gamey, and livery, and an inverse relationship between beef and lamb vs. pork and

Table 7: Descriptive flavor profile of various types of meat, including beef, chicken, pork, turkey, and lamb.

Attribute	Ground Beef	Ground Chicken	Ground Pork	Ground Turkey	Ground Lamb	P-Value
Astringent	1.67 [b]	2.98 [a]	0.12 [c]	0.35 [c]	1.67 [b]	0.0001
Barny	1.08 [b]	0.00 [b]	0.08 [b]	0.04 [b]	2.88 [a]	0.0001
Bitter	0.29 [ab]	0.21 [b]	0.06 [b]	0.10 [b]	0.54 [a]	0.0075
Bloody	0.27	0.12	0.08	0.35	0.31	0.2832
Browned	1.04 [a]	0.21 [b]	1.29 [a]	0.69 [ab]	0.69 [ab]	0.0054
Gamey	1.46 [a]	0.04 [b]	0.00 [b]	0.12 [b]	1.62 [a]	0.0001
Grassy	0.46 [a]	0.04 [b]	0.00 [b]	0.12 [b]	0.62 [a]	0.0001
Juicy	0.87 [b]	0.67 [b]	3.15 [a]	2.58 [a]	1.12 [b]	0.0001
Fatty	2.85 [b]	1.29 [c]	6.57 [a]	3.44 [b]	2.46 [b]	0.0001
Livery	0.06 [b]	0.31 [b]	0.00 [b]	0.12 [b]	2.31 [a]	0.0001
Metallic	1.38 [a]	0.54 [bc]	0.04 [c]	0.23 [c]	1.29 [ab]	0.0016
Brothy	1.02 [c]	1.69 [bc]	2.38 [ab]	2.69 [a]	0.90 [c]	0.0001
Oxidized	0.79	0.79	0.54	0.25	0.58	0.5331
Roast Beef	0.52 [a]	0.00 [c]	0.12 [bc]	0.27 [abc]	0.38 [ab]	0.0139
Salty	1.37 [cd]	1.88 [bc]	5.70 [a]	2.40 [b]	0.77 [d]	0.0001
Sour	0.54 [ab]	0.96 [a]	0.12 [b]	0.13 [b]	0.54 [ab]	0.0020
Sweet	0.23 [b]	0.94 [a]	1.42 [a]	1.42 [a]	0.10 [b]	0.0001
Umami	2.52 [b]	4.21 [a]	4.54 [a]	4.75 [a]	2.73 [b]	0.0001

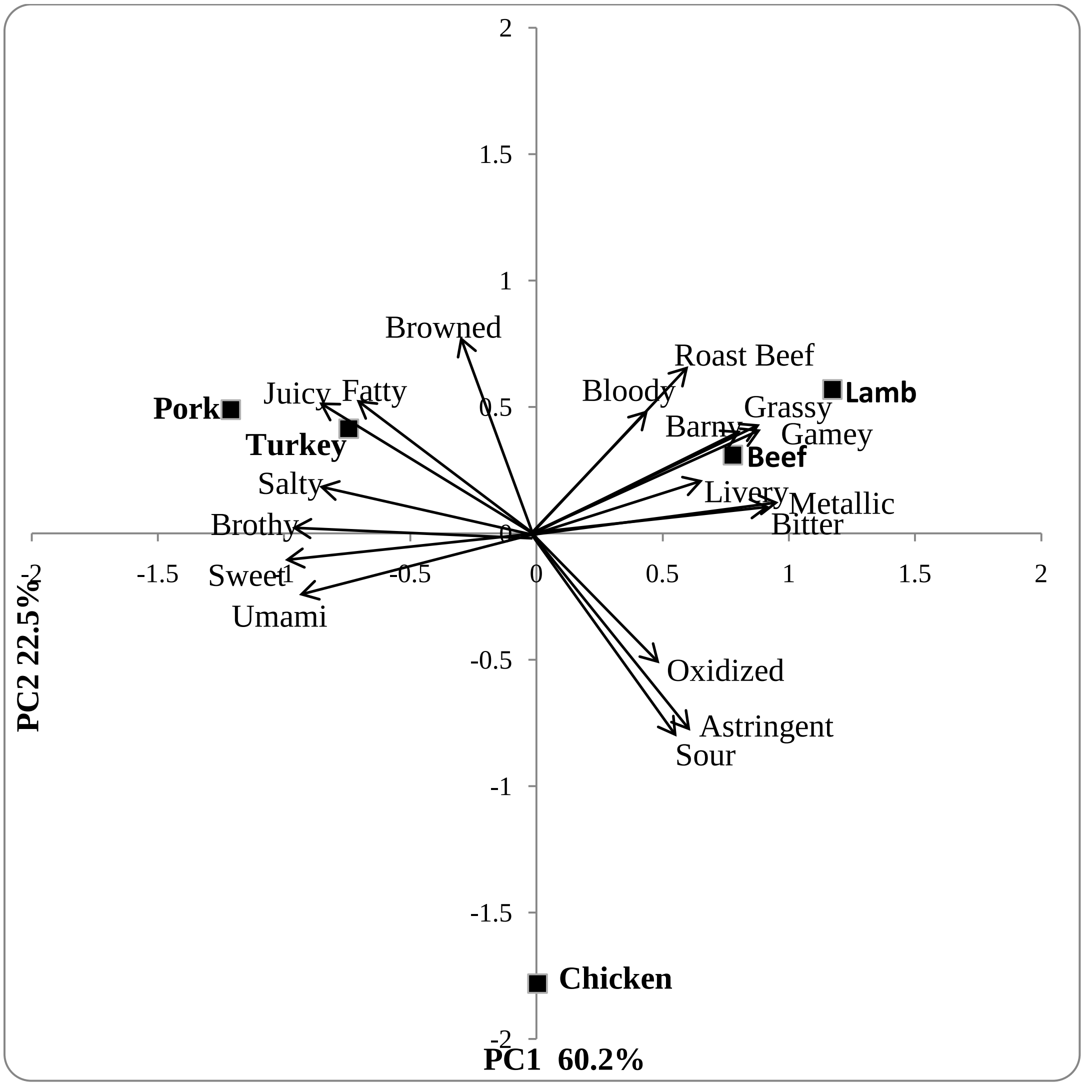


Figure 1: Principal component analysis of different types of meat, using the flavor lexicon.

turkey. Chicken was not strongly correlated with any other type of meat. According to the PCA graph of the different types of meat (Figure 1), 60.2% of the variability was explained by the horizontal axis (principal component 1), while 22.5% was explained by the y-axis (principal component 2).

The data show certain weaknesses, such as chicken not being strongly correlated with any meat or attribute. This can be attributed to the lexicon being developed for beef products, and the lack of practice of the panelists on other meat products. Despite this weakness, the PCA graph does show that the panelists were able to separate beef from other products using the newly developed lexicon.

Objective 2: Descriptive Profiling

Following the intensive training on identification and quantification of meat attributes included in the final lexicon, meat samples from grain- and grass-fed cattle were analyzed using the descriptive panel. As previously described, three animals from each diet treatment were used in the experimental design. The average panel rating for each sample and each attribute are shown in Table 8, separated out by animal. Table 9 shows the average panel ratings, when the scores for the animals are combined into treatment type. Within each attribute, samples that have the same superscript letter are not significantly different ($\alpha = 0.05$). As seen in the table, higher intensity values were observed in the steaks from the grass-fed animals for barny, bitter, gamey, and grassy, while lower intensity values were observed for juicy and umami. It is interesting to note that variability was also observed within treatments, especially for the grass-fed animals

Table 8: Descriptive flavor profile of beef rib steaks from grain- and grass-fed cattle with animals separated. Ratings are expressed as the mean values ± standard deviations of the three animals tested.

Attribute	Grain 1	Grain 2	Grain 3	Grass 1	Grass 2	Grass 3	P-Value
Astringent	1.43	1.23	1.83	1.23	1.68	2.18	0.1844
Barny	0.00 [b]	0.00 [b]	0.05 [b]	0.85 [a]	0.90 [a]	0.78 [a]	0.0001
Bitter	0.18	0.23	0.28	0.50	0.43	0.50	0.1097
Bloody	0.48	0.53	0.45	0.45	0.28	0.03	0.3257
Brothy	1.90	1.83	2.03	1.70	1.50	1.50	0.5287
Browned	0.98	0.95	0.93	0.63	0.58	0.73	0.6023
Fatty	2.35	2.23	2.33	2.33	1.55	1.80	0.2124
Gamey	0.23 [c]	0.28 [c]	0.18 [c]	1.10 [ab]	0.40 [bc]	1.43 [a]	0.0025
Grassy	0.53 [bc]	0.68 [bc]	0.00 [c]	0.75 [bc]	1.70 [a]	1.05 [ab]	0.0041
Juicy	2.34 [ab]	1.95 [abc]	2.9 [a]	2.45 [ab]	1.43 [bc]	1.13 [c]	0.0028
Livery	0.20	0.10	0.30	0.70	0.35	0.48	0.3798
Metallic	0.30	0.20	0.50	0.78	0.53	0.40	0.3505
Oxidized	0.03	0.10	0.10	0.10	0.30	0.33	0.3185
Roast Beef	1.18	1.25	1.23	1.10	0.88	1.03	0.7739
Salty	1.25	1.30	1.50	1.33	1.13	1.23	0.4209
Sour	1.38	1.10	1.15	1.33	1.28	1.25	0.9013
Sweet	0.68	0.55	0.98	0.53	0.60	0.20	0.2095
Umami	4.35 [b]	4.93 [ab]	5.88 [a]	4.08 [bc]	2.88 [d]	3.25 [cd]	0.0001

Table 9: Descriptive flavor profile of beef rib steaks from grain- and grass-fed cattle with animals combined by treatment. Ratings are expressed as the mean values ± standard deviations of the three animals tested.

Attribute	Grain	Grass	P-Value
Astringent	1.49±1.72	1.69±2.20	0.4245
Barny	0.02±0.13 [b]	0.84±1.16 [a]	0.0001
Bitter	0.23±0.65 [b]	0.48±0.80 [a]	0.0039
Bloody	0.48±1.05	0.25±0.58	0.0999
Brothy	1.92±1.98	1.57±1.80	0.0673
Browned	0.95±1.29	0.64±1.12	0.0654
Fatty	2.30±2.44	1.89±2.32	0.0778
Gamey	0.08±0.32 [b]	0.77±1.49 [a]	0.0016
Grassy	0.13±0.46 [b]	1.17±1.85 [a]	0.0003
Juicy	2.39±2.23 [a]	1.67±1.87 [b]	0.014
Livery	0.20±0.61	0.51±1.22	0.0657
Metallic	0.33±0.77	0.57±1.01	0.1322
Oxidized	0.08±0.37	0.24±0.72	0.0715
Roast Beef	1.22±1.60	1.00±1.22	0.1788
Salty	1.35±1.31	1.23±1.29	0.2230
Sour	1.21±1.54	1.28±1.52	0.6158
Sweet	0.73±1.59	0.44±1.01	0.0881
Umami	4.78±2.18 [a]	3.22±1.60 [b]	0.0001

(Table 8) suggesting that animals also contribute to flavor variability. Additional ANOVA statistics can be found in Appendix C, Table 18.

Objective 3: Consumer evaluation

For the first test on grain- and grass-fed cattle, one hundred and twenty consumers participated in an acceptance test. Basic demographics were collected from the panelists who participated. Fifty five percent of the panelists were male, and 45% were female (Figure 2-A). Seventy six (63.3%) panelists were between 18-25 years of age, 20 (16.7%) were 26-35 years old, 8 (6.7%) were 36-45, 8 (6.7%) were 46-55, and 8 (6.7%) were 56 or older (Figure 2-B). Frequency of steak consumption as reported by the panelists showed that 52 panelists (43.0%) reported eating steak less than once a month, 49 (40.5%) ate steak at least once a month, 18 (14.9%) ate at least once a week, and 2 (1.7%) ate steak at least once a day (Figure 2-C).

Consumers rated the samples on a typical 9-point hedonic scale as described in the Materials and Methods section. The results obtained from the consumer acceptance test are shown in Table 10. All samples were well liked; with an average of 7.05 (moderately liked) and 6.08 (slightly liked) rating for the meat obtained from the grain- and grass-fed animals, respectively. These ratings were significantly different, and showed a slightly lower degree of liking for the meat obtained from the grass-fed animals. There were no significant differences observed between animals within a diet treatment. One of the grain-fed animals, however, was not significantly different in acceptance rating than one of the grass-fed animals. There were no significant

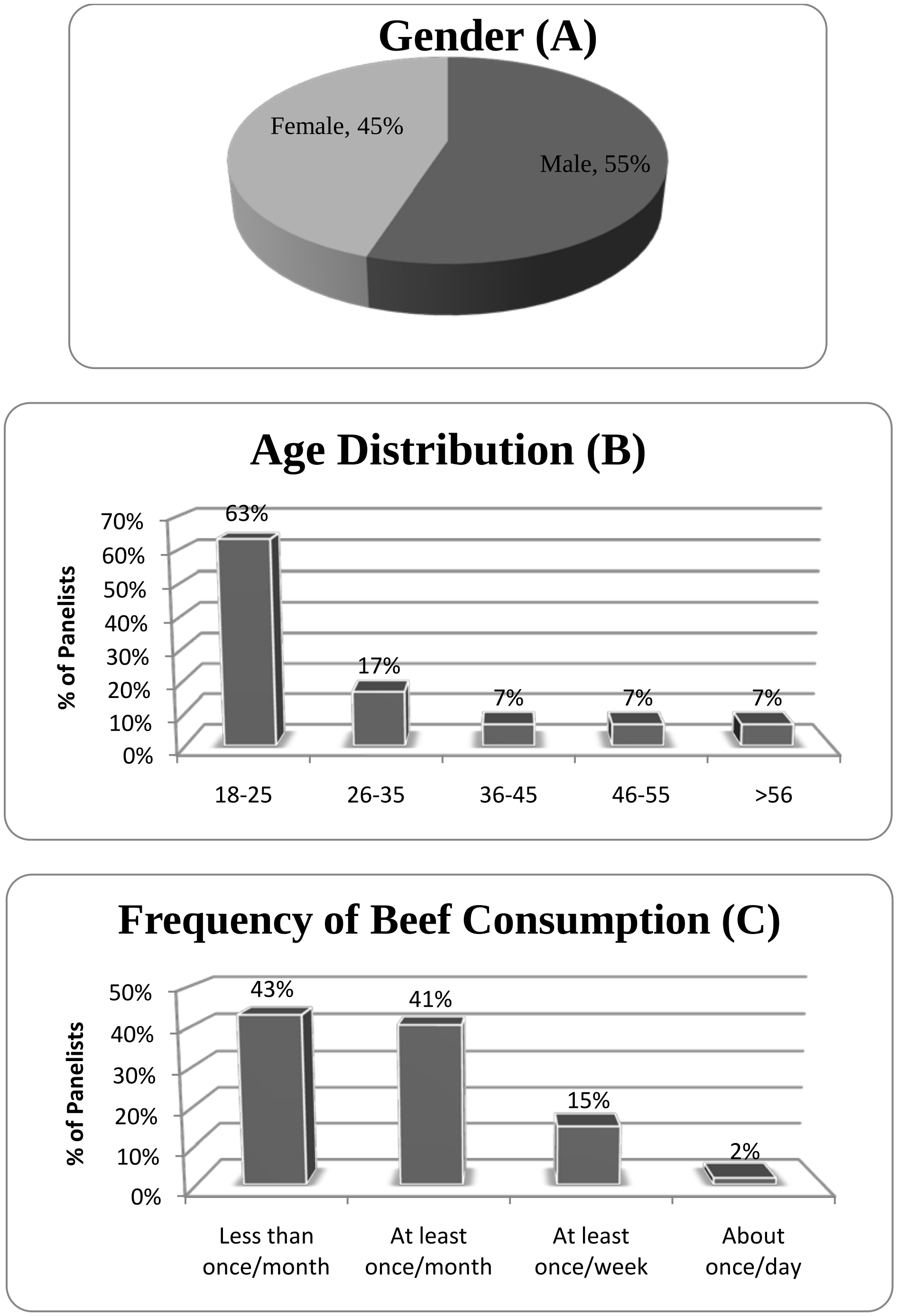


Figure 2 A-C: Demographics of the consumer panelists for grass- and grain-fed beef. Demographics collected included gender distribution (A), age distribution (B), and frequency of beef consumption (C), as reported by the panelists.

Table 10: Consumer acceptance (degree of liking) of beef obtained from grain- and grass-fed animals.

Grain 1	Grain 2	Grain 3	Grass 1	Grass 2	Grass 3	P-Value
7.15±1.56 [a]	6.75±1.69 [ab]	7.25±1.45 [a]	5.93±1.86 [c]	6.10±1.43 [c]	6.20±1.63 [bc]	0.0001

differences observed when the data was analyzed for differences considering consumer demographics. Additional ANOVA statistics can be found in Appendix C, Table 19.

Relationship between descriptive analysis and consumer acceptance for grain- and grass-fed beef

To find relationships between the flavor profiles of the samples as determined by the descriptive panelists and the acceptance by the consumers, principal component analysis (PCA) was performed on the combined data. The PCA plot can be seen in Figure 3. Principal component 1 in this plot contributes to 61.4% of the variability of the data, while principal component 2 contributes to 16.8% of the variability of the data. Together, these two components explain 78.2% of the variability.

Looking at the PCA graph, it is evident that the grass-fed animals were highly correlated with attributes such as astringent, barny, bitter, gamey, grassy, livery, metallic, sour and oxidized. These terms are negatively correlated with the degree of liking, so they can be considered negative terms. Correlation values for these attributes to the degree of liking (with p-values in parenthesis) were -0.90 (0.0137), -0.90 (0.0153), -0.84 (0.0379), -0.83 (0.0421), -0.65 (0.1653), -0.51 (0.3049), -0.33 (0.5182), -0.24 (0.6454), and -0.16 (0.7574), for grassy, barny, oxidized, bitter, gamey, livery, metallic, astringent, and sour, respectively.

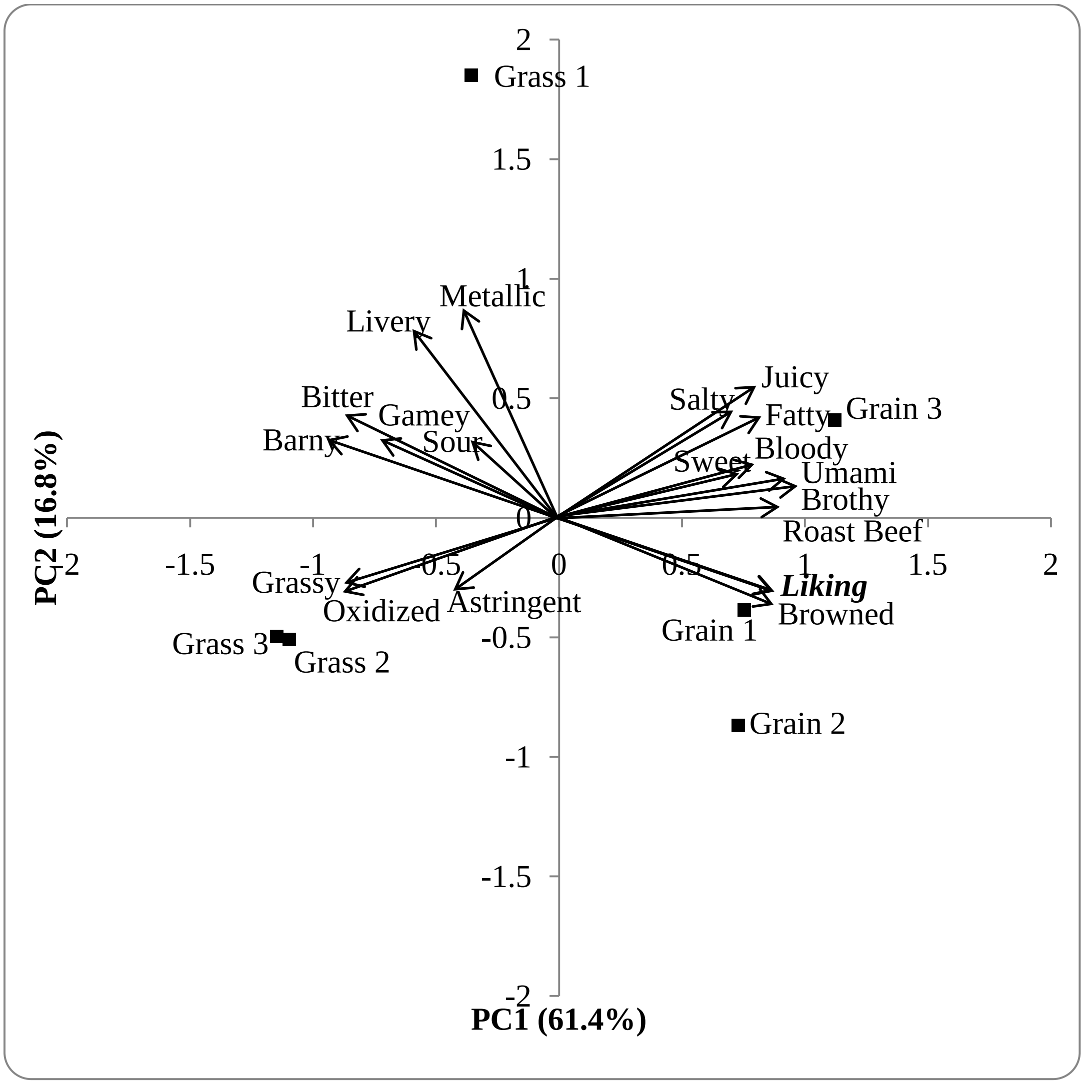


Figure 3: Principal component analysis of the grain- and grass-fed beef, using data from the descriptive and consumer panels.

The grain-fed samples, on the other hand, were strongly related to the attributes bloody, brothy, browned, fatty, juicy, sweet, salty, roast beef and umami. These attributes were also highly correlated to the degree of liking as rated by the consumer panelists, and so can be termed positive attributes. The correlation values for these attributes to the degree of liking (with p-values in parenthesis) were 0.98 (0.0009), 0.88 (0.0208), 0.88 (0.0216), 0.85 (0.0321), 0.82 (0.0468), 0.82 (0.0473), 0.74 (0.0937), 0.71 (0.1133), and 0.68 (0.1404) for brothy, umami, browned, roast beef, juicy, fatty, sweet, salty, and bloody, respectively. The classification of these terms as "positive" and "negative" attributes are determined by the degree of liking as rated by the consumer test on these samples. The complete table of correlation coefficients can be found in Appendix C, Table 20.

Objective 4: Changes with Grass Types and Additional Sensory Work

Descriptive analysis on two grass types

After completion of the descriptive and consumer tests on the grain- and grass-fed beef, two types of grass diets for cattle were also evaluated. The two types of feed for the cattle in this experiment were alfalfa and sainfoin, legumes which for the purposes of this experiment will be considered "grass" diets. Similar to the grain- and grass-fed test, both descriptive profiling and consumer analysis were conducted on the animals.

Six animals total were evaluated by the descriptive panelists, with three animals from the alfalfa diet and three animals from the sainfoin diet. Rib eye steaks from the animals were used to evaluate flavors and liking scores by both consumer and descriptive panelists. The descriptive panelists evaluated each of the six samples in duplicate.

Table 11 shows the results from the descriptive panel profiling of the samples. The same lexicon was used by the panelists as was used for the grain- and grass-fed beef. As seen in the table, there were no significant differences in any of the attributes between any of the samples.

When compared to the results from the grass-fed samples obtained in the previous study between grain- and grass-fed beef (Table 9), there are some similarities between the samples. For example, bitter, gamey, metallic, oxidized, roast beef, sour, sweet, and umami had similar ratings between the alfalfa and sainfoin from this experiment and the grass-fed beef from the previous experiment. Compared to the previous grass-fed samples, the alfalfa and sainfoin were lower in astringent, barny, browned, grassy, livery,

Table 11: Descriptive flavor profile of beef from two types of grass.

	Alfalfa 1	Alfalfa 2	Alfalfa 3	Sainfoin 1	Sainfoin 2	Sainfoin 3	P-Value
Astringent	0.92	1.14	1.14	1.28	1.14	0.97	0.6582
Barny	0.00	0.00	0.00	0.00	0.00	0.00	0.0000
Bitter	0.42	0.36	0.64	0.44	0.36	0.61	0.3679
Bloody	0.63	0.69	1.19	0.84	1.19	0.61	0.2224
Brothy	1.97	2.5	1.89	2.03	2.11	2.31	0.6397
Browned	0.44	0.25	0.25	0.06	0.06	0.00	0.0664
Fatty	4.11	3.83	3.78	3.97	3.72	3.64	0.8121
Gamey	0.47	0.64	0.31	0.56	0.67	0.47	0.8469
Grassy	0.53	0.94	0.33	0.53	0.75	0.56	0.6405
Juicy	4.22	4.03	3.92	4.19	3.39	3.19	0.2159
Livery	0.00	0.28	0.06	0.11	0.25	0.19	0.8022
Metallic	0.17	0.17	0.33	0.22	0.14	0.39	0.5673
Oxidized	0.11	0.22	0.22	0.13	0.11	0.17	0.9385
Roast Beef	1.28	1.42	1.42	0.89	1.00	1.58	0.1183
Salty	1.72	1.94	2.06	2.22	2.06	1.66	0.5299
Sour	1.28	1.92	1.58	1.64	1.36	1.14	0.2441
Sweet	0.13	0.31	0.25	0.22	0.31	0.16	0.4532
Umami	2.94	3.03	2.94	3.00	2.75	3.09	0.6202

and were higher in brothy, bloody, fatty, juicy, and salty. Additional ANOVA statistics for the alfalfa and sainfoin beef can be found in Appendix C, Table 21.

Consumer analysis on two grass types

The average degree of liking for the two grass diets as rated by the consumers on a 9-point hedonic scale can be seen in Table 12. There were no significant differences in degree of liking between any of the samples. Principal component analysis was not done on this data since there were no differences in the ratings of the attributes or degree of liking between samples. When compared to the ratings for the grass-fed beef in the grain- and grass-fed beef consumer panel (Table 10), it is interesting to note that the alfalfa and sainfoin samples generally had a higher average degree of liking than the grass-fed samples from the previous experiment. The range of average degree of liking scores for the alfalfa and sainfoin was from 6.48 – 7.05, while the range of average degree of liking scores for the grass-fed animals from the previous experiment was 5.93 – 6.20. The alfalfa and sainfoin scores were closer to the grain-fed samples in rating (6.75 – 7.25) from the previous experiment than to the grass-fed samples. This may be explained by comparing these samples to the previously rated grass-fed animals. The alfalfa and sainfoin samples were lower in negative attributes such as astringent, barny, grassy, and livery, and were higher in positive attributes such as brothy, fatty, juicy, and salty, compared to the previous grass-fed animals.

Basic demographics were also collected from the panelists. Of the panelists, 65% of the panelists were male and 35% were female (Figure 4-A). Eighty five (70.8%) panelists were between 18-25 years of age, 25 (20.8%) were 26-35 years old, 3 (2.5%)

Table 12: Consumer acceptance (degree of liking) of beef from two types of grass diets.

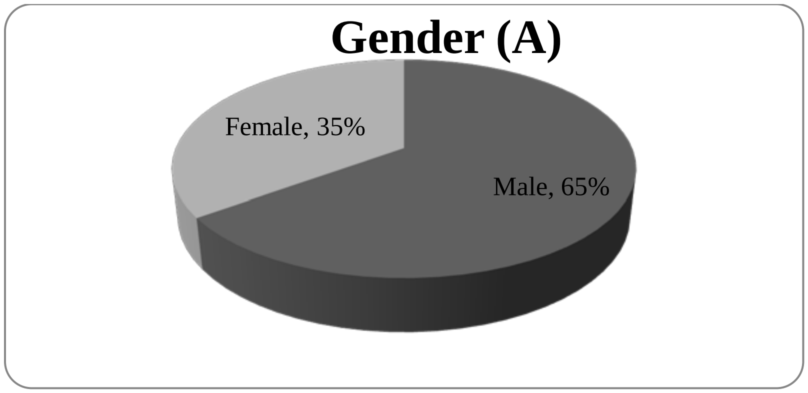
Alfalfa 1	Alfalfa 2	Alfalfa 3	Sainfoin 1	Sainfoin 2	Sainfoin 3	P-Value
7.05±1.78	6.48±1.80	6.60±1.63	7.03±1.44	6.95±1.54	6.90±1.37	0.1752

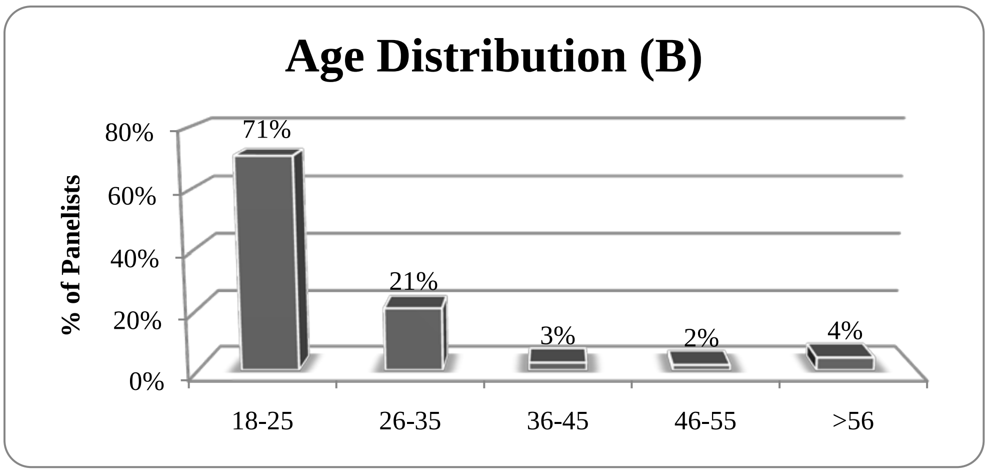
were 36-45, 2 (1.7%) were 46-55, and 5 (4.2%) were 56 or older (Figure 4-B). Frequency of steak consumption as reported by the panelists in Figure 4-C shows that 6 panelists (5%) reported eating steak less than once a month, 35 (29%) ate steak at least once a month, 62 (52%) ate it at least once a week, 12 (10%) ate steak at least once a day, and 5 (4%) ate steak more than once a day. There were no significant differences observed when the data was analyzed for differences in consumer demographics. Additional ANOVA statistics can be found in Appendix C, Table 22.

Beef with chicken mixtures

To extend the utility of the descriptive lexicon, ground beef with ground chicken mixed at different levels was evaluated by the descriptive panelists. Chicken was added to beef at 25%, 50%, and 75% of the total weight, and straight beef and chicken patties were also evaluated.

The descriptive panelists used the newly developed lexicon to evaluate the beef and chicken mixtures. The average panelist ratings can be seen in Table 13. As seen in Table 13, there were significant differences between the samples in astringent, gamey, grassy, juicy, fatty, metallic, brothy, oxidized, salty, sweet, and umami. Table 13 also shows that there are trends as the amount of chicken increased in the sample: astringent decreased in intensity (from 1.86 to 0.23) while juicy increased (from 1.43 to 3.80), perception of fatty decreased (3.11 to 1.91), and brothy (1.66 to 3.07), salty (1.32 to





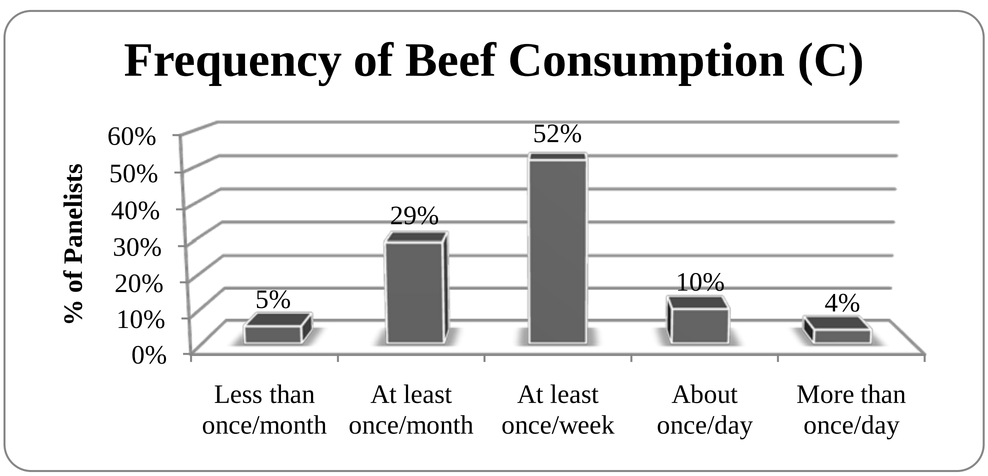


Figure 4 A-C: Demographics of the consumer panelists for grass- and grain-fed beef. Demographics collected included gender distribution (A), age distribution (B), and frequency of beef consumption (C), as reported by the panelists.

Table 13: Descriptive flavor profile of beef mixed with different levels of chicken.

Attribute	Beef	75% Beef 25% Chkn*	50% Beef 50% Chkn*	25% Beef 75% Chkn*	Chkn	P-Value
Astringent	1.86 [a]	0.75 [b]	0.50 [b]	0.43 [b]	0.23 [b]	0.0001
Barny	0.20	0.05	0.00	0.00	0.18	0.1121
Bitter	0.32	0.14	0.14	0.14	0.32	0.4474
Bloody	0.77	0.30	0.05	0.18	0.18	0.0526
Brothy	1.66 [b]	2.2 [ab]	2.23 [ab]	2.41 [ab]	3.07 [a]	0.0470
Browned	0.41	0.55	0.86	0.75	0.32	0.1955
Fatty	3.11 [a]	2.95 [a]	2.91 [a]	2.50 [ab]	1.91 [b]	0.0287
Gamey	0.75 [a]	0.02 [b]	0.00 [b]	0.00 [b]	0.00 [b]	0.0001
Grassy	1.52 [a]	0.57 [b]	0.25 [b]	0.00 [b]	0.05 [b]	0.001
Juicy	1.43 [b]	2.45 [b]	2.36 [b]	3.80 [a]	3.84 [a]	0.0001
Livery	0.09	0.02	0.00	0.05	0.00	0.2483
Metallic	0.66 [a]	0.30 [b]	0.27 [b]	0.14 [b]	0.18 [b]	0.0363
Oxidized	1.36 [a]	0.61 [b]	0.23 [b]	0.66 [b]	0.36	0.0156
Roast Beef	0.84	0.82	0.86	0.45	0.36	0.2790
Salty	1.32 [c]	1.93 [bc]	2.41 [ab]	2.52 [ab]	2.89 [a]	0.0003
Sour	0.43	0.32	0.57	0.57	0.70	0.4296
Sweet	0.36 [c]	0.82 [bc]	1.36 [ab]	1.82 [a]	1.89 [a]	0.0001
Umami	3.02 [d]	4.23 [c]	4.61 [bc]	5.23 [ab]	5.43 [a]	0.0001

Chkn = Ground chicken breast meat.

2.89), sweet (0.36 to 1.89), and umami (3.02 to 5.43) all increased. These trends were not necessarily significant between each sample, but they were usually significant between the straight beef and chicken samples.

Figure 5 shows the principal component analysis of the beef and chicken mixtures. Principal component 1 in this plot contributes to 68.7% of the variability of the data, while principal component 2 contributes to 22.2% of the variability of the data, for a total of 90.9%. Table 23 in Appendix C contains the correlation coefficients for the attributes. The PCA graph confirms what the statistical analysis showed, that beef was strongly correlated with attributes such as gamey, oxidized, grassy, astringent, fatty, and roast beef. The chicken, on the other hand, is more strongly correlated with brothy, juicy, sour, sweet, salty, and umami.

In addition to analysis by a PCA plot, the attributes that had significant changes between samples were analyzed using linear regression (Figure 6). As seen in the plot, many of the attributes had a good linear fit when moving from beef to chicken, as shown by the coefficient of determination (R^2) values. The R^2 values for the plot are 0.77, 0.89, 0.87, 0.52, 0.79, 0.89, 0.74, 0.50, 0.95, 0.96, 0.92 for astringent, brothy, fatty, gamey, grassy, juicy, metallic, oxidized, salty, sweet, and umami, respectively. The two attributes that were the least well explained by the linear regression line were gamey and oxidized. The reason for this is that gamey was only present in the all beef sample, while oxidized did not follow a consistent pattern between all samples, making it difficult to fit a linear regression equation to either attribute. A logarithmic fit of the gamey data gives an R^2 value of 0.73 instead of 0.52 (not shown on the graph). The linear regression lines

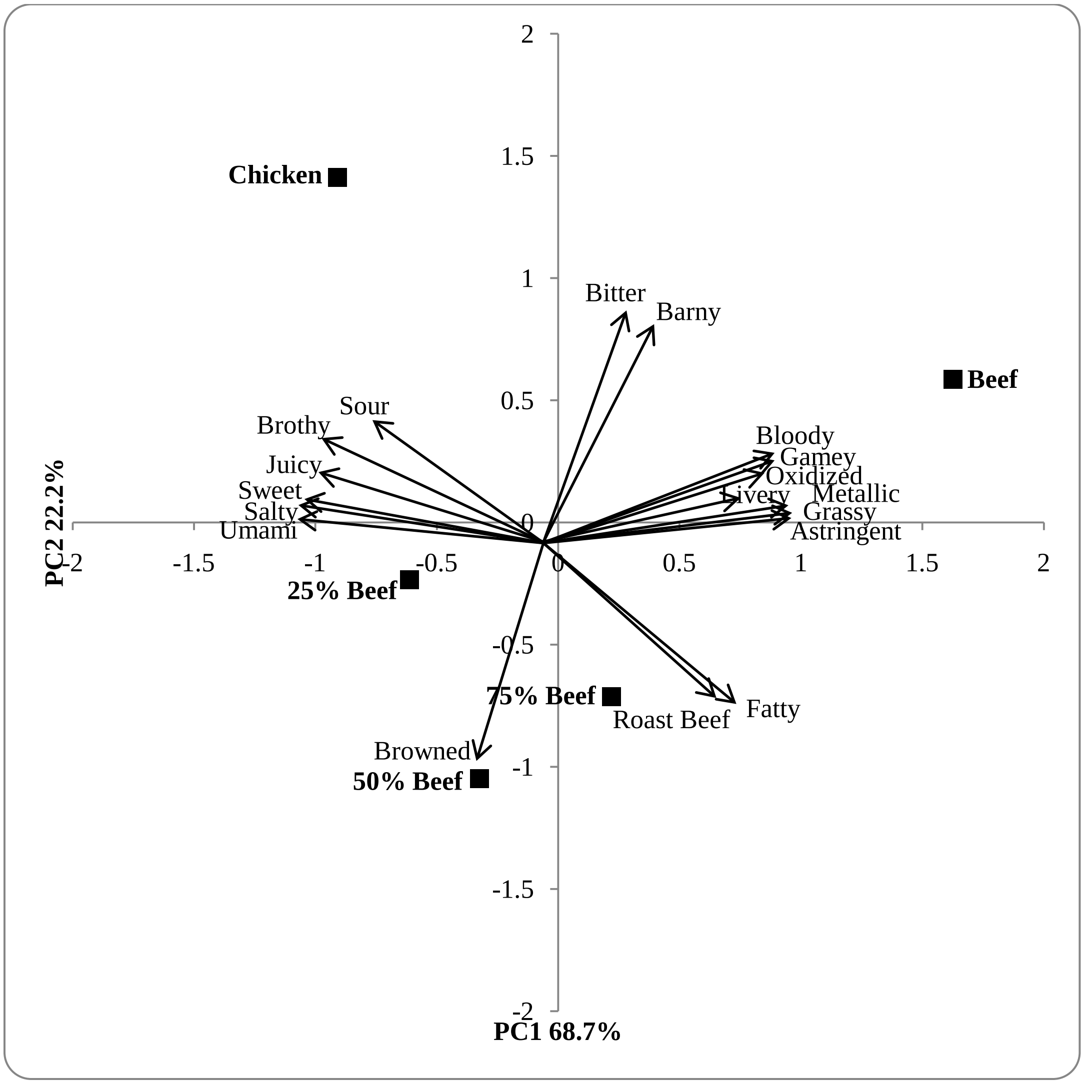


Figure 5: Principal component analysis of beef and chicken mixtures.

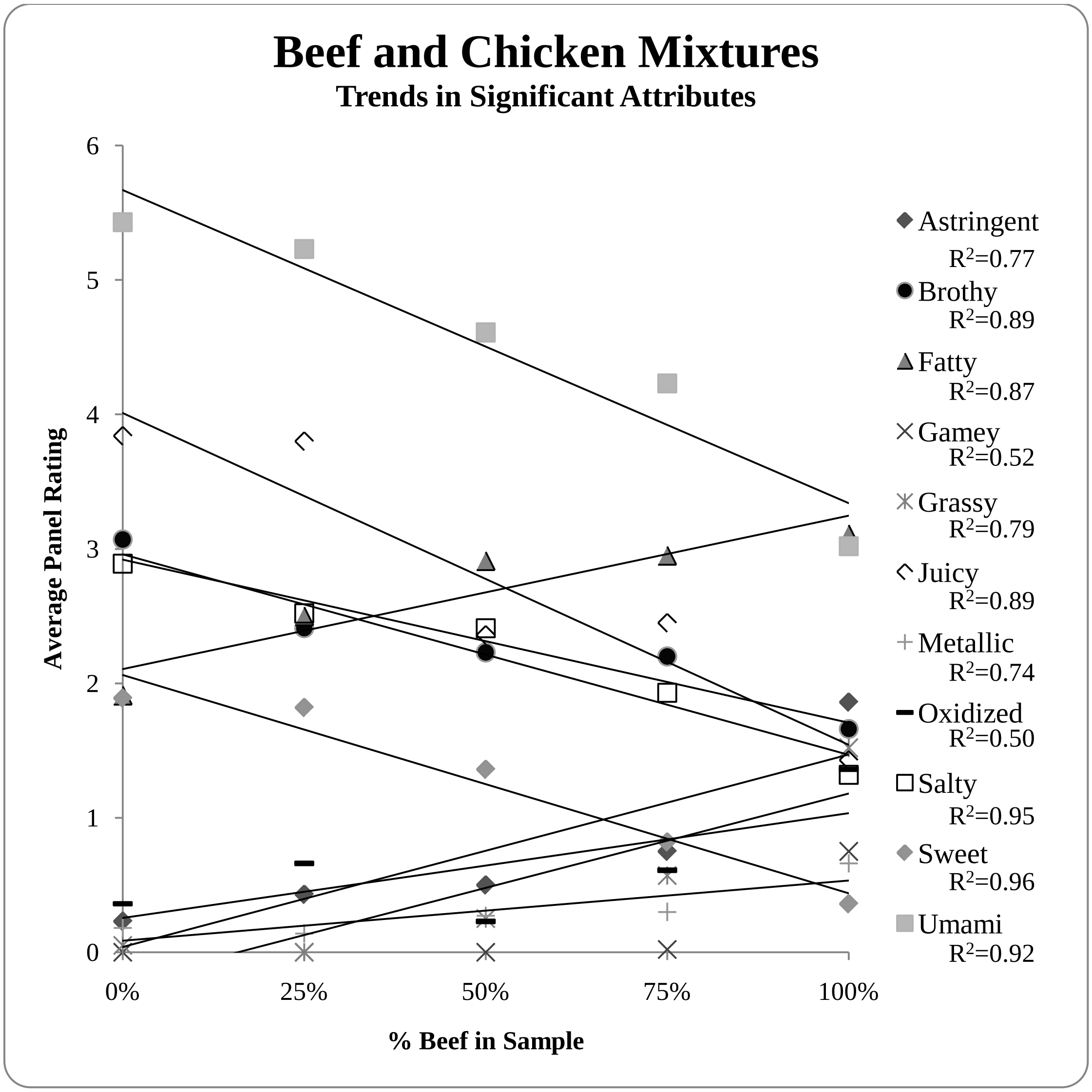


Figure 6: Beef and chicken mixtures average panelist ratings, with linear regression lines. Only attributes with significant changes between samples are included here.

do confirm the that there are trends for the changes in attributes that occur as the amount of chicken increases, as previously seen in the PCA plot as well.

The data show that those attributes that best describe beef flavor are astringent, fatty, gamey, grassy, metallic, and oxidized. Previous studies have characterized chicken as having a brothy flavor (Lyon and others 2004), which is reflected in the results found by the panelists.

Descriptive profiling of the *Spinalis dorsi* muscle in grain- and grass-fed beef

The final descriptive study performed by the panelists was profiling done on the *Spinalis dorsi* muscle in the rib eye steaks, as opposed to the *Longissimus dorsi* muscle used in the other tests. As the *Spinalis dorsi* is claimed by some to be more flavorful than the *Longissimus dorsi,* the muscles were tasted and rated by the descriptive panel to evaluate if there were any differences between the muscles. Meat from the animals that were used in the grain- and grass-fed evaluation was used for this test as well; for characteristics of the animals, see Table 4.

The descriptive panel followed the same procedures as the previously described tests. The results from the descriptive panel can be seen in Table 14 separated by individual animals, and with data combined into treatment type in Table 15. As seen in this table, significant differences were found in gamey, grassy, juicy, fatty, salty, sweet, and umami. Some similarities existed between the original test on the LD muscles and this test in flavor differences when comparing grain-fed to grain-fed and grass-fed to grass-fed. The attributes that were most similar in ratings between the two tests were bloody, livery, oxidized, roast beef, and sour. The *Spinalis dorsi* muscles were higher in fatty, gamey, and juicy compared to the *Longissimus dorsi* muscles. The *Spinalis dorsi* grass-fed samples were lower in grassy, while the grain-fed samples were higher in grassy. Umami was higher in the grass-fed samples and lower in the grain-fed samples *Spinalis dorsi* muscles compared to the LD muscles. Statistical analysis between the two muscles is in Appendix C, Table 26. The higher levels of juicy and fatty may be the reason why the *Spinalis dorsi* muscles are considered to be more flavorful than the *Longissimus dorsi* muscles.

In the *Spinalis dorsi* muscles barny was generally higher in the grass-fed samples compared to the grain-fed samples, although not significantly. Gamey and grassy were both generally higher in the grass-fed animals, though not always significantly different

Table 14: Descriptive flavor profile of *Spinalis dorsi* muscles in grain- and grass-fed beef. Samples with the same letter superscript are not significantly different from each other.

Attribute	Grain 1	Grain 2	Grain 3	Grass 1	Grass 2	Grass 3	P-Value
Astringent	0.89	1.11	0.72	1.11	1.50	1.00	0.2172
Barny	0.00	0.06	0.19	0.94	0.64	0.72	0.0825
Bitter	0.25	0.25	0.14	0.33	0.36	0.19	0.4964
Bloody	0.06	0.19	0.31	0.28	0.53	0.42	0.2437
Brothy	2.75	2.53	2.58	1.72	1.94	1.75	0.1214
Browned	1.42	0.92	1.53	0.5	0.64	0.83	0.0613
Fatty	6.47 [a]	3.53 [bc]	4.39 [b]	3.47 [bc]	3.56 [bc]	3.06 [c]	0.0001
Gamey	0.22 [cd]	0.06 [d]	0.44 [bcd]	1.33 [abc]	1.83 [a]	1.56 [ab]	0.0032
Grassy	0.39 [c]	0.33 [c]	0.86 [bc]	2.94 [a]	3.06 [a]	1.81 [b]	0.0001
Juicy	4.44 [a]	3.89 [ab]	4.58 [a]	3.17 [bc]	3.72 [ab]	2.47 [c]	0.0009
Livery	0.17	0.00	0.00	0.39	0.36	0.56	0.2976
Metallic	0.17	0.22	0.17	0.28	0.19	0.31	0.9165
Oxidized	0.39	0.36	0.31	0.00	0.47	0.36	0.6593
Roast Beef	1.58	2.03	1.83	1.53	1.22	1.44	0.3104
Salty	2.06 [a]	2.11 [a]	1.56 [ab]	1.83 [ab]	1.44 [ab]	1.25 [b]	0.0416
Sour	0.86	1.44	0.97	1.64	1.97	0.86	0.0820
Sweet	1.61 [a]	1.36 [a]	1.44 [a]	0.44 [b]	0.33 [b]	0.28 [b]	0.0034
Umami	6.25 [a]	5.92 [a]	6.14 [a]	4.31 [b]	4.28 [b]	3.53 [b]	0.0001

than the grain-fed animals. Brothy was also not significant, but was generally lower in the grass-fed animals. Sweet and umami were both significantly lower in the grass-fed samples. Salty seemed to be more sample dependent rather than diet dependent.

Principal component analysis was also performed on the *Spinalis dorsi* muscles to look at the relationships between the flavor attributes and the samples as determined by the descriptive panelists. The PCA plot can be seen in Figure 7. Principal component 1 in this plot contributes to 63.0% of the variability of the data, while principal component 2 contributes to 14.7% of the variability of the data. Together, these two components explain 77.7% of the variability. Since there was no consumer panel associated with this meat, there are no correlations with liking in this PCA plot. Additional statistical

Table 15: Descriptive panel ratings of Spinalis dorsi muscles from grain- and grass-fed animals, with animals combined by treatment.

Attribute	Grain	Grass	P-Value
Astringent	0.91±1.07	1.20±1.29	0.1017
Barny	0.08±0.30 [b]	0.77±1.78 [a]	0.0027
Bitter	0.21±0.47	0.30±0.56	0.2498
Bloody	0.19±0.53	0.41±0.84	0.0562
Brothy	2.62±2.15 [a]	1.81±1.77 [b]	0.0038
Browned	1.29±1.80 [a]	0.66±1.02 [b]	0.0069
Fatty	4.80±3.21 [a]	3.36±2.31 [b]	0.0003
Gamey	0.24±0.80 [b]	1.57±2.45 [a]	0.0001
Grassy	0.53±1.30 [b]	2.60±2.42 [a]	0.0001
Juicy	4.31±2.23 [a]	3.12±1.89 [b]	0.0002
Livery	0.06±0.41 [b]	0.44±1.37 [a]	0.0225
Metallic	0.19±0.48	0.26±0.60	0.3945
Oxidized	0.35±1.03	0.28±0.91	0.6532
Roast Beef	1.81±1.91	1.40±1.65	0.0505
Salty	1.91±1.54 [a]	1.51±1.46 [b]	0.0341
Sour	1.09±1.49	1.49±1.85	0.1462
Sweet	1.47±2.61 [a]	0.35±0.80 [b]	0.0001
Umami	6.10±2.93 [a]	4.04±1.85 [b]	0.0001

information, including ANOVA statistics and correlation coefficients between the attributes can be found in tables 24 and 25 in Appendix C.

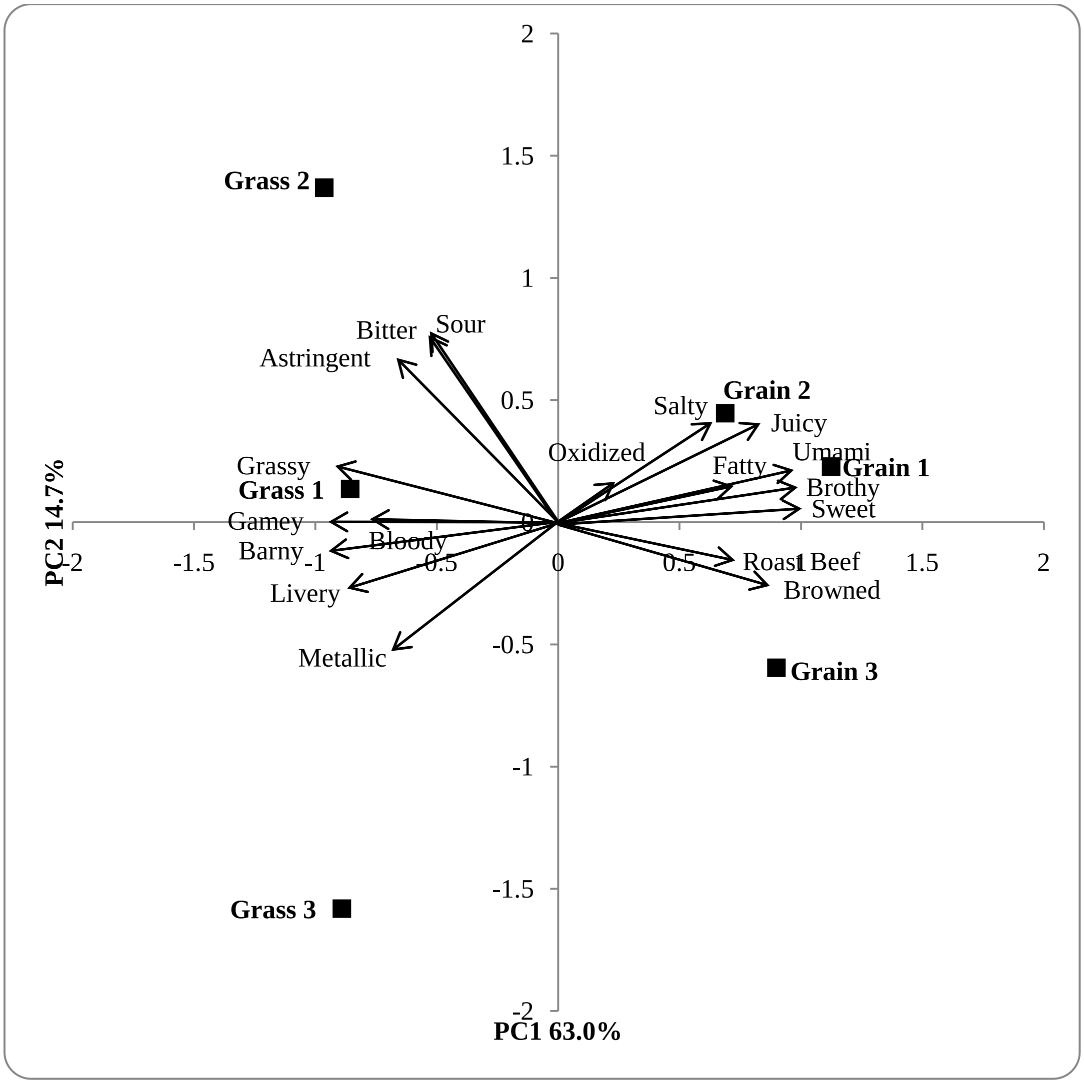


Figure 7: Principal component analysis of *Spinalis dorsi* muscles in grain- and grass-fed beef.

DISCUSSION

Meat Characteristics

The differences in quality and fat from the grain-fed animals to the grass-fed animals were expected results of the diet regimens of the cattle. Grass-fed cattle typically gain weight at a slower rate than grain-fed cattle, due to their lower energy diet. Thus, the grass-fed animals in this study were slightly older (5-7 months) than the grain-fed cattle, as they required more time to reach the same target weight as the grain-fed cattle. Previous research has indicated that grass-fed animals that are harvested at the same weight as their grain-fed counterparts are generally lower in subcutaneous fat (measured as back-fat thickness), marbling, and overall fat content (Duckett and others 2007; Leheska and others 2008). The findings of the current study agreed with these studies. Quality grade is determined by degree of marbling and degree of maturity, which is the reason for the lower quality grade in the grass-fed cattle compared to the grain-fed cattle.

For the study comparing the two diets of grass (alfalfa and sainfoin), there were differences between the two diet types in marbling and quality grade. Due to the small sample size, it is not known if this difference is due to the diet or due to chance. A larger scale study would be needed to draw conclusions about the effect of grass diets on animal characteristics.

Objective 1: Descriptive Panel Development

There were 13 references used to introduce the panelists to meat flavors; however, as previously discussed in the results section, these references were altered and removed as the descriptive panel developed the new lexicon. The final lexicon developed by the panelists included 13 beef specific terms (astringent, barny, bloody, brothy, browned, gamey, grassy, juicy, fatty, livery, metallic, oxidized, and roast beef) and the 5 basic tastes (bitter, salty, sour, sweet, and umami).

Some of the terms were more difficult to develop, since their reference did not accurately reflect what was found in meat. For instance, the reference used for grassy was hexanal, but the panelists did not feel that the chemical reference was similar to the grassy taste in grass-fed beef. Gamey was also difficult to develop, since wild game meat was used as the reference and the amount of "gamey" in the samples could not be controlled and varied greatly between animals. Even though the lexicon was designed to look at fresh meat samples, oxidized was kept among the attributes since there is some evidence that the higher levels in vitamin E in grass-fed beef can help lower lipid oxidation.

Objective 2: Descriptive Profiling

The purpose of this study was to determine differences in flavor profile between grain- and grass-fed beef. Most of the research performed on grass-fed and grain-fed beef is based on the meat quality and very little data reporting flavor differences in these types of meat is available (Melton and others 1982b). As discussed in the literature review, those studies that do attempt to describe the difference in grain- and grass-fed beef are limited in scope and terms used. Using the newly developed lexicon, the descriptive panelists were able to find notable differences between the samples in barny, gamey, grassy, juicy, and umami. Previous research on grain- and grass-fed beef may help explain some of these differences.

Much of the current research is based on the improved nutritional quality of the grass-fed beef in terms of fatty acid profile and on the volatiles compounds released from the meat. In general, beef obtained from grass-fed cattle has a higher content of mono- and polyunsaturated fatty acids and common volatile compounds include 1-penten-1-ol, 2-penten-1-ol (Yang and others 2002; Elmore and others 2005; Gatellier and others 2005; Ponnampalam and others 2006; Aurousseau and others 2007a, 2007b). Farmer and Patterson (1991) report that several disulphide compounds are related to beef flavor. Some of these compounds include 2-methyl-3-furanthiol and bis(2-methyl-3-furyl) disulphide. These compounds are usually products from the Maillard reaction between sulphur-containing amino acids and the reducing sugars in the meat. Allen and others (1988) have identified pentanal, 2,4-decadienal, hexanal, and 2,3-octanedione in meats, among other compounds. Stetzer and others (2008) also identified hexanal, 3-hydroxy-2-butanone, 1-octen-3-ol, butanoic acid, and nonanal in beef samples. These authors show that the livery off-flavor in the meat is positively correlated with pentanal, hexanal, 3-hydroxy-2-butanone, and hexanoic acid. While rancid off-flavor is correlated with pentanal and 2-phenyl furan, it is not correlated with hexanal.

This research suggests that the flavor profile of meats is strongly dependant on the volatile compounds of the meat, which in turn might depend on the chemical characteristics of the samples, such as fatty acid composition. A recent report from the National Cattlemen's Beef Association (Brewer 2006) describes the association of specific beef flavors with volatile compounds. For example, the term “grassy” is associated with hexanal, while fatty is associated with nona-2(E)-enal and sweet with delta-nonalactone. The flavor differences reported in this research are most likely consequences of the differences in the chemical composition of the meat (such as fat content and fatty acid composition) due to diet of the animals. The identification and quantification of these compounds exceeds the scope of this research.

More importantly for this project, the results from the descriptive panel suggest that the newly developed flavor lexicon can be used to detect and quantify flavor differences in meat. The ability of the lexicon to distinguish between diet types indicates that the lexicon can serve to help further identify differences in future experiments.

Objective 3: Consumer Evaluation

Although the grain-fed beef was better liked overall, there was one grass-fed sample that was not significantly different from the grain-fed samples. This difference between the meat samples can be caused by the inherent variability among animals, as evidenced in the descriptive panel data.

There were a large number of panelists between the ages of 18-25 due to the test being held on a college campus. Gender was split fairly evenly between panelists. These demographics were not controlled since the test was open to anyone who wanted to participate. The data was analyzed for the demographics of the panelists, and age and gender did not make a difference.

The data agree with other consumer panels that have been held in the United States on grain- and grass-fed beef, and serve to help confirm that consumers prefer grain-fed beef in this market. The data and conclusions are limited, however, to the demographics used in this research, including panelist location. Further research would need to be performed in different parts of the country with more consumers to extend these conclusions to the nation as a whole.

Relationship between descriptive analysis and consumer acceptance for grain- and grass-fed beef

The principal component analysis of the data, as shown in Figure 3, relates the degree of liking of the samples as rated by the consumer panel to the intensity of the flavors in the samples as rated by the descriptive panel. This gives a good idea of what flavors can be perceived as positive or negative notes in beef. The lexicon that was developed for this project is a valuable tool for the beef industry. Using the lexicon, the panelists were able to identify specific attributes that relate to consumer acceptance of beef products within the demographics studied. This is a significant step to understand US consumers' preference towards grain-fed beef over grass-fed beef in taste. Future application of these tools in a larger study with broader demographics could help refine the relationship of these attributes to consumer acceptance of diet types in beef, and allow beef producers to improve their products and marketing. Since the lexicon has been shown to be successful in relating beef attributes to acceptance, it could also be used in other projects with beef to determine how changes in areas such as manufacturing, marinating, and ageing affect the flavor profile of the beef, and consequently affect consumer acceptance. These terms may be correlated differently with liking in a separate consumer population, regardless of their association with liking in this study, such as in populations where grass-fed beef are more preferred. This lexicon coupled with other consumer acceptance panels will allow for re-evaluation of the perception of these terms as positive or negative within specific demographical areas without changing the terms themselves, making it a valuable tool regardless of what demographics it is used with.

It is interesting to note in the PCA graph that the sample “Grass 1” was the least correlated with the other two grass-fed samples. This was also the sample that was the least liked (although not significantly) of all the samples. When looking at the descriptive panel results (Table 8), this animal had higher levels of some of the positive attributes, such as juicy and umami, then the other grass-fed animals, which could have given it a higher liking score. Looking at some of the ratings that were not significant, however, shows that it was also the highest rated sample in intensity for livery and metallic, two negative attributes, which may account for the low liking score it received.

The PCA chart shows that the panelists were able to clearly differentiate animals based on diet type, as the diet types are horizontally separated into separate halves of the chart. Since principal component 1 (the horizontal axis) accounts for 61.4% of the variability in the data, while principal component 2 (the vertical axis) only accounts for 16.8%, this difference in horizontal separation is the most important. Many of the attributes were not significant between animals, but this is not necessarily a sign of a bad or unneeded descriptor. The lack of significance merely shows that these samples were not different in those attributes, which can be just as important as knowing which attributes they are different in; future studies may also find that these descriptors help identify differences in meat under different circumstances. Overall, it can be concluded that the current lexicon is effective in describing and differentiating between beef samples.

As seen in Table 10, even though the differences in degree of liking between treatments were small, they were still significant. These small differences can be explained by the increased intensity of the negative attributes, including barny, bitter, gamey, and grassy, as well as a decrease in intensity of positive attributes such as juicy and umami. This study ultimately serves to relate these attributes to consumer liking, which may be helpful in determining how to improve flavors in the grass-fed beef in the future.

As previously stated, this study confirms what previous studies have seen, namely that consumers in the United States prefer grain-fed beef to grass-fed beef in taste. Given the higher price of grass-fed beef, one may conclude that demand is driven by its perception of high nutritional value, with less regard for its sensory properties (Umberger and others 2009). And as consumers of grass-fed beef often point out, cooking methodologies and recipes have been developed to enhance eating qualities of grass-fed beef.

Objective 4: Changes with Grass Types and Additional Sensory Work

Descriptive analysis on two grass types

In a follow up to the evaluation of grain- and grass-fed animals, two different grass types were evaluated by the descriptive panelists. Of the six animals evaluated (three per treatment), there were no differences found between any of them (Table 11). There were also no observable trends between the two groups of animals. Although there were similarities in the ratings to those found in the grass-fed animals for the grain- and grass-fed diet test, the alfalfa and sainfoin diets were lower in astringent, barny, browned, grassy, livery, and were higher in brothy, bloody, fatty, juicy, and salty. These differences in flavors from the traditional grass diets can most likely be attributed to the difference in dietary content that the animals received. As discussed previously, alfalfa and sainfoin are higher in protein content than traditional grass diets, and have other chemical differences such as higher saponin or tannin content, which may influence beef flavor.

Consumer analysis on two grass types

The consumer analysis on the two grass feed types showed no differences in preference between any of the animals. This agrees with the ratings by the descriptive panelists, who also showed that there were no perceivable differences in flavors between grass types. Principal component analysis was not done for this test since it looks at correlations between ratings and animals; with no differences in ratings, there would be no correlations found. When compared to the previous consumer panel on grain- and grass-fed beef, the alfalfa and sainfoin samples had higher average consumer degree of liking scores than the previous grass-fed sample. This difference is most likely due to the lack of comparison to a grain-fed sample in the alfalfa and sainfoin consumer panel, which may have lowered the average scores of the two grass types had it been present. This also may indicate that when there is no comparison to a grain-fed sample, consumers find that grass-fed samples are just as acceptable as they would normally find a grain-fed sample. There were differences in the descriptive panel ratings between the alfalfa and sainfoin samples and the grass-fed samples from the previous experiment, which may explain the difference in ratings by the consumer panel. Further research on a larger scale would need to be done to determine why there were differences between the two consumer panels.

Due to the similarities between grass types in this test and the grass-fed animals in the test on grain and grass diets, the conclusions from the previous study can be extended to animals raised on either alfalfa or sainfoin grass. Changes in flavor in beef are greatest when comparing grain and pasture diet types, while differences in the type of grass used (at least between alfalfa and sainfoin) do not have as great of an effect on flavor.

Beef with chicken mixtures

The test on ground beef with different mixtures of chicken was a test to better describe the core flavors that make up beef. Strong trends are evident as the samples shifted from beef to chicken (Table 13). Accordingly, in the PCA plot (Figure 5) a trend can be seen in the samples. As the samples proceed from beef to chicken, they are positioned from right to left on the horizontal axis of the PCA plot. The 75% beef/25% chicken mixture was the only sample that was more closely correlated with the beef sample on the right side of the plot, while the other beef/chicken mixes with a higher proportion of chicken were on the left side with the chicken. This shows a clear delineation between the samples, meaning the flavors that define beef from the lexicon are evident in this plot. As shown, beef was more closely related to such attributes as roast beef, fatty, astringent, grassy, gamey, and bloody. Although some of these could be considered negative attributes, the plot shows that the beef samples are only *more* correlated with these than the other attributes which are more closely correlated with chicken. This does not mean that beef does not have those other "positive" flavors, rather that chicken had higher levels of those flavors and was more closely associated with those attributes such as umami, brothy, juicy, sweet, and sour. Once again, results from this experiment show that the lexicon can be an effective tool in describing meat samples, and also show that the panel was well trained in the attributes tested.

The data also show that there is a strong relationship between the type of meat sampled and the flavor profile found. In addition to determining what flavor changes might be expected between all beef and all chicken patties, changes that occur with mixtures of the two meats can be seen as well. This could have an impact for meat producers who want to change the flavor profile of their products. For example, beef and chicken mixtures are common in hot dogs. If a producer found with a descriptive panel that their hot dogs had a gamey or grassy flavor, they might consider adding a higher proportion of chicken to lower it. Additionally, they might also add more chicken to get a higher umami flavor, or more juiciness in their hot dog. The meat could then be profiled again by a descriptive panel and paired with a consumer panel to determine if these changes in flavor profile were desirable from a consumer perspective.

Descriptive profiling of the *Spinalis dorsi* muscle in grain- and grass-fed beef

The PCA plot for the *Spinalis dorsi* muscles (Figure 7) shows similarities to the previous PCA plot done on the LD muscles in the beef (Figure 3). The main change in the *Spinalis dorsi* muscles was bloody, which is associated with the grass-fed beef instead of the grain-fed, and oxidized, which is associated with the grain-fed instead of the grass-fed beef. There has been some research stating that the higher levels of vitamin E in grass-fed animals can help prevent oxidation in those animals (Warren and others 2008). The meat tested in these experiments was all fresh, and so no conclusions can be made to that effect in this experiment. There were only very low levels of oxidation in any of the samples tested. Certain flavors such as umami, juiciness, fatty, and brothy were also slightly higher in the *Spinalis dorsi* muscles than in the LD muscles. These stronger desirable flavors may explain why the *Spinalis dorsi* muscle is often the more preferred of the two muscles, and why it is described as having a richer flavor.

CONCLUSION

Trained descriptive panelists were able to create a flavor lexicon of eighteen attributes to describe beef, including the five basic tastes. This lexicon was able to identify differences between grass- and grain-fed beef in both the *Longissimus dorsi* and *Spinalis dorsi* muscles of six different animals (three per diet type). It was also able to show that there were no differences between two grass types, alfalfa and sainfoin. The lexicon was also used to evaluate beef in different mixtures with chicken, showing the difference in core attributes between the two types of meats. Consumer panel ratings showed that steaks from grain-fed animals were significantly preferred over steaks from grass-fed animals for the demographics that were tested.

The consumer panelist ratings were statistically related to the ratings from the descriptive panelists. This allowed for the terms in the lexicon to be classified as either positive or negative attributes. Those terms that were associated with positive consumer acceptance included brothy, browned, juicy, fatty, roast beef, umami, and salty. The terms associated with negative consumer perception included astringent, barny, bitter, gamey, grassy, livery, metallic, and oxidized. Future use of the lexicon in relation to consumer panels will help refine these attributes and give better understanding to why consumers prefer certain types of meat over others.

As seen throughout these experiments, the newly developed lexicon is an effective tool for relating specific taste attributes of meat to consumer acceptance. The future application of the lexicon in relation to additional consumer panels could be an invaluable tool to help the meat industry determine why a product is more or less preferred in comparison to another product. Knowing which flavors are different between products and how these relate to consumer acceptance will allow for adjustments to be made to the product to increase the degree of liking in that product, whether these changes are made in animal diet, manufacturing, or packaging. Future studies on grass-fed beef with the lexicon in relation to consumer panels may also show ways that the attributes of beef may be improved to help increase consumer acceptance and increase the US market for grass-fed beef.

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APPENDICES

APPENDIX A: Prescreening Questionnaire

PRESCREENING QUESTIONNAIRE

HISTORY:
Name:_______________________________________ Gender:___________ Age:______
Phone: (Primary) (_____)_________________ (Secondary) (______)_________________
Where did you hear about this project?____

TIME:
1. Are there any weekdays (M-F) that you will not be available on a regular basis? If yes, please explain.____
2. Are there any times of day that you are not available? If yes, please explain.
____
3. How often do you travel or go on vacation? On average, how long are your trips or vacations?
____
4. How much longer do you plan to live/work in Cache Valley? (Circle one.)
<1 year *1 year* *2 years* *3-5 more years* *5-10 more years* *>10 years*

HEALTH:
1. Do you have any of the following?
Dentures (partial or full) ________________
Diabetes ________________
Oral or gum disease ________________
Hypoglycemia ________________
Food allergies ________________ What allergies?________________________
Hypertension ________________

2. Do you take any medications which affect your senses, especially taste and smell?
____
3. What are your smoking habits? (Circle one.)
Never *Only in the past* *Smoke occasionally* *Smoke regularly*

FOOD HABITS:
1. Are you currently on a restricted diet? If yes, please explain.
____
2. How often do you eat meat in a week? ____
3. How do you like your meat (raw, medium, or well done)? ________________________
4. What cuts of meat do you usually eat (burger, steak, etc.)? _______________________
5. What foods can you not eat? ____
____
6. What foods do you not like to eat? ____
____
7. Is your ability to distinguish smell and tastes… (Circle one for smell. Circle one for taste.)

SMELL: *Better than average* *Average* *Worse than average*

TASTE: *Better than average* *Average* *Worse than average*

Does anyone in your immediate family work for a food company?____________________

____

Does anyone in your immediate family work for an advertising company or a marketing research agency? ____

QUESTIONS:

1. What do you consider the most prominent characteristic of a ripe piece of fruit? _____

____

2. If a recipe calls for thyme and there is none available, what would you substitute? ___

____

3. What are some other foods that taste like yogurt? _________________________________

____

4. How would you describe the difference between flavor and aroma? _______________

____

5. How would you describe the difference between flavor and texture? _______________

____

6. What is the best one or two word description of grated Italian cheese (Parmesan or Romano)?

____

7. Describe some of the noticeable flavors in mayonnaise. _________________________

____

8. Describe some of the noticeable flavors in cola. _________________________________

____

9. Describe some of the noticeable flavors in sausage. _____________________________

____

10. Describe some of the noticeable flavors in Ritz crackers. _______________________

____

11. What are some products that have an herbal smell? ____________________________

____

12. What are some products that have a sweet smell? ______________________________

____

13. How would you describe the difference between fruity and lemony? ______________

____

14. Describe the smell associated with Feta cheese. ________________________________

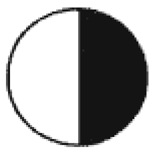
____

15. Describe some of the noticeable smells in a bakery. ____________________________

____

INSTRUCTIONS: MARK ON THE LINE AT THE RIGHT TO INDICATE THE PROPORTION OF THE AREA THAT IS SHADED.

EXAMPLES.



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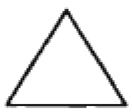

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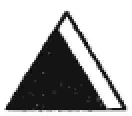
1. 

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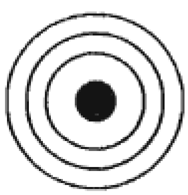
2. 

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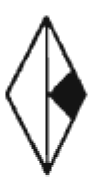
3. 

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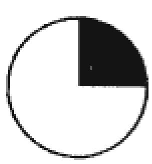
4. 

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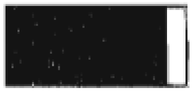
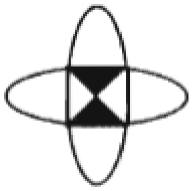
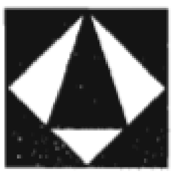
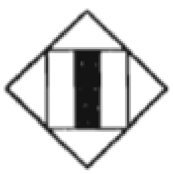
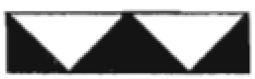
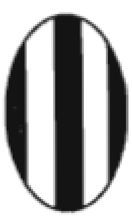
5.  None |——| All

6.  None |——| All

7.  None |——| All

8.  None |——| All

9.  None |——| All

10.  None |——| All

APPENDIX B: Sample Panelcheck Plots

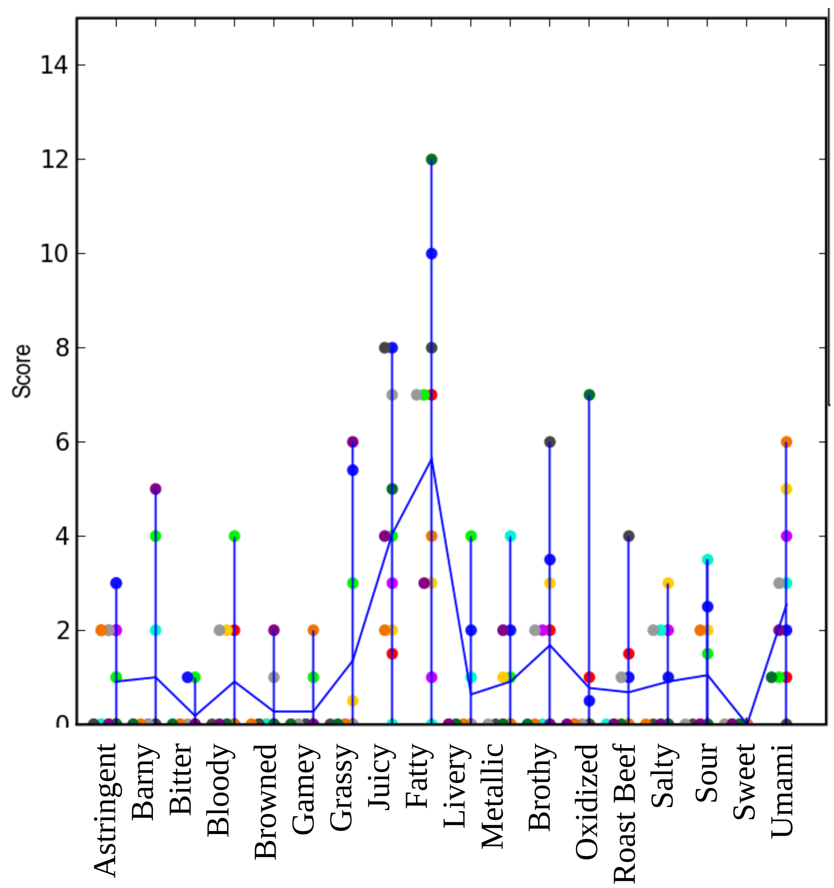


Figure 8: Sample PanelCheck plot for the entire panel. Each color dot represents a single panelist, while the horizontal blue line represents the panel mean.

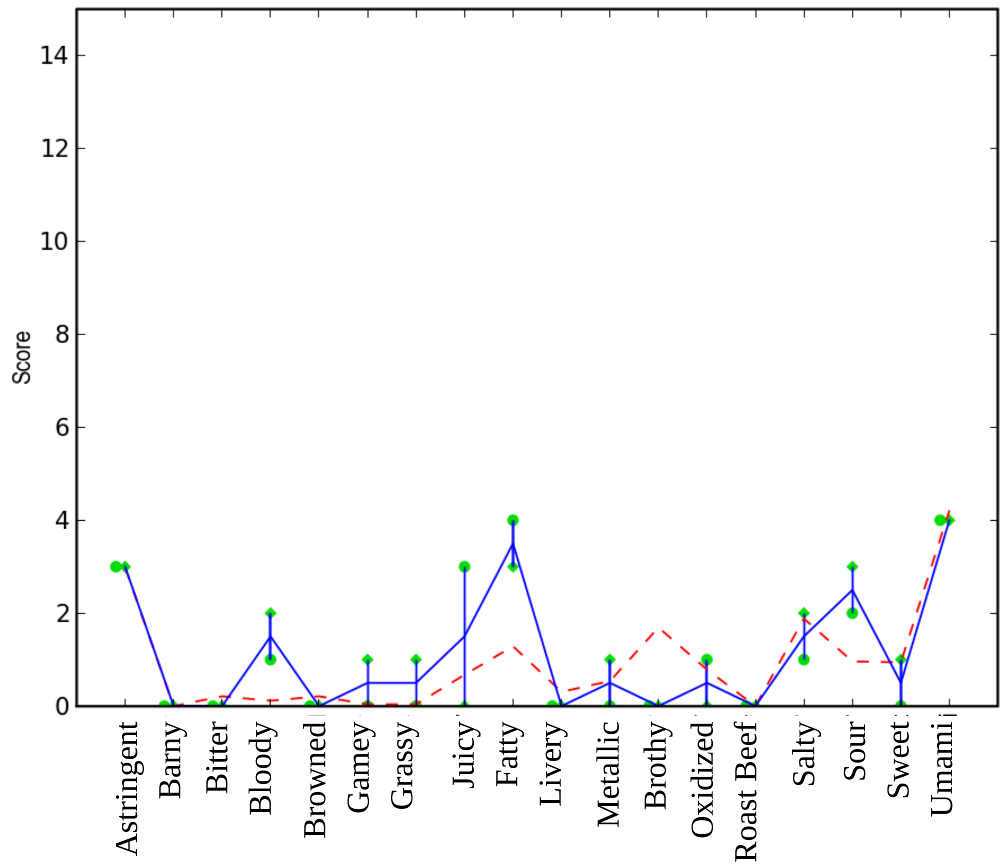


Figure 9: Sample PanelCheck plot for an individual panelist. The red dotted line represents the panel mean, while the blue line represents the individual panelist mean over the two replicates.

APPENDIX C: Additional Statistical Tables

Table 16: ANOVA table for descriptive panel ratings on various meats, including beef, chicken, pork, turkey, and lamb.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Astringent	16	341.5885	21.3493	8.01	<.0001
Barny	16	277.8308	17.3644	4.18	<.0001
Bitter	16	23.8577	1.4911	5.76	<.0001
Bloody	16	17.5231	1.0952	3.75	<.0001
Browned	16	81.5769	5.0986	4.59	<.0001
Gamey	16	130.8154	8.1760	3.24	0.0001
Grassy	16	33.6154	2.1010	7.30	<.0001
Juicy	16	305.7769	19.1111	4.99	<.0001
Fatty	16	1093.2538	68.3284	16.51	<.0001
Livery	16	152.4154	9.5260	4.26	<.0001
Metallic	16	67.8923	4.2433	2.04	0.0162
Brothy	16	377.4346	23.5897	9.94	<.0001
Oxidized	16	78.2346	4.8897	3.02	0.0003
Roast Beef	16	20.2462	1.2654	3.73	<.0001
Salty	16	823.0038	51.4377	18.86	<.0001
Sour	16	55.5923	3.4745	4.94	<.0001
Sweet	16	144.2308	9.0144	7.06	<.0001
Umami	16	407.1962	25.4498	9.54	<.0001

Table 17: Correlation coefficients for various meats, including beef, chicken, pork, turkey, and lamb.

	Astringent	Barny	Bitter	Bloody	Browned	Gamey	Grassy	Juicy	Fatty
Astringent	1	0.17615	0.46849	-0.17457	-0.86123	0.18878	0.17355	-0.95966	-0.85314
Barny	0.17615	1	0.94994	0.46698	-0.02229	0.99724	0.98328	-0.41114	-0.26658
Bitter	0.46849	0.94994	1	0.41734	-0.31875	0.95602	0.94571	-0.67496	-0.53602
Bloody	-0.17457	0.46698	0.41734	1	-0.19795	0.52397	0.61292	-0.07196	-0.34013
Browned	-0.86123	-0.02229	-0.31875	-0.19795	1	-0.06971	-0.1116	0.86104	0.96866
Gamey	0.18878	0.99724	0.95602	0.52397	-0.06971	1	0.99388	-0.43197	-0.3139
Grassy	0.17355	0.98328	0.94571	0.61292	-0.1116	0.99388	1	-0.4294	-0.35493
Juicy	-0.95966	-0.41114	-0.67496	-0.07196	0.86104	-0.43197	-0.4294	1	0.91702
Fatty	-0.85314	-0.26658	-0.53602	-0.34013	0.96866	-0.3139	-0.35493	0.91702	1
Livery	0.30398	0.9902	0.98385	0.46749	-0.15961	0.99263	0.98219	-0.5321	-0.39548
Metallic	0.53162	0.91839	0.99523	0.43567	-0.40859	0.92993	0.92576	-0.73314	-0.61558
Brothy	-0.64567	-0.84242	-0.94292	-0.10323	0.36673	-0.83312	-0.79439	0.77615	0.54307
Oxidized	0.80506	0.10939	0.31059	-0.65761	-0.40692	0.07643	0	-0.68378	-0.38199
Roast Beef	-0.36562	0.75592	0.58933	0.83544	0.22095	0.77738	0.81858	0.08943	0.00282
Salty	-0.63537	-0.58584	-0.76019	-0.64263	0.78029	-0.63555	-0.68616	0.81041	0.90572
Sour	0.9978	0.15125	0.44163	-0.23862	-0.83249	0.15949	0.1379	-0.94307	-0.81714
Sweet	-0.53848	-0.92413	-0.99351	-0.31699	0.3443	-0.92537	-0.90559	0.72154	0.54993
Umami	-0.40368	-0.96623	-0.98404	-0.30423	0.17866	-0.95936	-0.93182	0.59732	0.40065

	Livery	**Metallic**	**Brothy**	**Oxidized**	**Roast Beef**	**Salty**	**Sour**	**Sweet**	**Umami**
Astringent	0.30398	0.53162	-0.64567	0.80506	-0.36562	-0.63537	0.9978	-0.53848	-0.40368
Barny	0.9902	0.91839	-0.84242	0.10939	0.75592	-0.58584	0.15125	-0.92413	-0.96623
Bitter	0.98385	0.99523	-0.94292	0.31059	0.58933	-0.76019	0.44163	-0.99351	-0.98404
Bloody	0.46749	0.43567	-0.10323	-0.65761	0.83544	-0.64263	-0.23862	-0.31699	-0.30423
Browned	-0.15961	-0.40859	0.36673	-0.40692	0.22095	0.78029	-0.83249	0.3443	0.17866
Gamey	0.99263	0.92993	-0.83312	0.07643	0.77738	-0.63555	0.15949	-0.92537	-0.95936
Grassy	0.98219	0.92576	-0.79439	0	0.81858	-0.68616	0.1379	-0.90559	-0.93182
Juicy	-0.5321	-0.73314	0.77615	-0.68378	0.08943	0.81041	-0.94307	0.72154	0.59732
Fatty	-0.39548	-0.61558	0.54307	-0.38199	0.00282	0.90572	-0.81714	0.54993	0.40065
Livery	1	0.96463	-0.89191	0.18574	0.70117	-0.67943	0.27676	-0.96448	-0.98328
Metallic	0.96463	1	-0.94022	0.32691	0.55529	-0.81606	0.50197	-0.98991	-0.964
Brothy	-0.89191	-0.94022	1	-0.60643	-0.30313	0.65348	-0.63732	0.97464	0.95267
Oxidized	0.18574	0.32691	-0.60643	1	-0.56732	-0.13807	0.84046	-0.41626	-0.35468
Roast Beef	0.70117	0.55529	-0.30313	-0.56732	1	-0.41919	-0.41101	-0.49783	-0.56846
Salty	-0.67943	-0.81606	0.65348	-0.13807	-0.41919	1	-0.58494	0.73703	0.63347
Sour	0.27676	0.50197	-0.63732	0.84046	-0.41101	-0.58494	1	-0.51741	-0.38633
Sweet	-0.96448	-0.98991	0.97464	-0.41626	-0.49783	0.73703	-0.51741	1	0.98523
Umami	-0.98328	-0.964	0.95267	-0.35468	-0.56846	0.63347	-0.38633	0.98523	1

Table 18: ANOVA table for descriptive panel ratings on Longissimus dorsi muscles of grain- and grass-fed beef.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Astringent	14	272.250	19.4464	10.70	<.0001
Barny	14	32.363	2.3116	3.50	0.0001
Bitter	14	41.017	2.9298	13.21	<.0001
Bloody	14	23.592	1.6851	2.82	0.0013
Browned	14	85.796	6.1283	7.19	<.0001
Gamey	14	98.292	7.0208	4.96	<.0001
Grassy	14	96.792	6.9137	3.98	<.0001
Juicy	14	281.266	20.0905	8.82	<.0001
Fatty	14	508.104	36.2932	23.02	<.0001
Livery	14	23.896	1.7068	2.03	0.0221
Metallic	14	22.225	1.5875	2.22	0.0112
Brothy	14	308.692	22.0494	19.91	<.0001
Oxidized	14	12.758	0.9113	3.58	<.0001
Roast Beef	14	156.833	11.2024	14.13	<.0001
Salty	14	167.921	11.9943	38.27	<.0001
Sour	14	205.771	14.6979	21.52	<.0001
Sweet	14	122.121	8.7229	10.15	<.0001
Umami	14	406.858	29.0613	11.73	<.0001

Table 19: ANOVA table for consumer liking of Longissimus dorsi muscles.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Liking	122	483.675	3.9645492	2.48	<.0001

Table 20: Correlation coefficients for LD muscles of grain- and grass-fed beef.

	Astr	Barny	Bitter	Bloody	Brown	Gamey	Grass	Juicy	Fatty	Livery
Astring	1	0.271	0.361	-0.842	-0.157	0.370	0.134	-0.442	-0.537	0.132
Barny	0.271	1	0.949	-0.646	-0.979	0.719	0.747	-0.563	-0.670	0.792
Bitter	0.361	0.949	1	-0.681	-0.899	0.843	0.548	-0.478	-0.537	0.871
Bloody	-0.842	-0.646	-0.681	1	0.514	-0.710	-0.536	0.782	0.746	-0.386
Brown	-0.157	-0.979	-0.899	0.514	1	-0.579	-0.760	0.481	0.661	-0.747
Gamey	0.370	0.719	0.843	-0.710	-0.579	1	0.319	-0.497	-0.284	0.781
Grassy	0.134	0.747	0.548	-0.536	-0.760	0.319	1	-0.828	-0.883	0.209
Juicy	-0.442	-0.563	-0.478	0.782	0.481	-0.497	-0.828	1	0.854	-0.057
Fatty	-0.537	-0.670	-0.537	0.746	0.661	-0.284	-0.883	0.854	1	-0.110
Livery	0.132	0.792	0.871	-0.386	-0.747	0.781	0.209	-0.057	-0.110	1
Metal	-0.040	0.677	0.702	-0.086	-0.721	0.415	0.128	0.227	-0.034	0.887
Brothy	-0.339	-0.876	-0.783	0.768	0.823	-0.666	-0.913	0.887	0.851	-0.461
Oxid	0.704	0.729	0.703	-0.902	-0.671	0.539	0.750	-0.853	-0.934	0.294
Roast B	-0.371	-0.866	-0.698	0.663	0.871	-0.396	-0.903	0.689	0.888	-0.438
Salty	-0.048	-0.520	-0.285	0.450	0.499	-0.228	-0.912	0.818	0.736	-0.006
Sour	-0.085	0.390	0.231	-0.141	-0.346	0.270	0.285	-0.054	-0.045	0.450
Sweet	-0.242	-0.570	-0.588	0.687	0.435	-0.811	-0.585	0.825	0.478	-0.353
Umami	-0.254	-0.809	-0.642	0.683	0.760	-0.545	-0.930	0.835	0.805	-0.389
Liking	-0.241	-0.903	-0.827	0.676	0.880	-0.647	-0.897	0.817	0.818	-0.507

	Metal	Brothy	Oxid	Roast B	Salty	Sour	Sweet	Umami	Liking
Astring	-0.040	-0.339	0.704	-0.371	-0.048	-0.085	-0.242	-0.254	-0.241
Barny	0.677	-0.876	0.729	-0.866	-0.520	0.390	-0.570	-0.809	-0.903
Bitter	0.702	-0.783	0.703	-0.698	-0.285	0.231	-0.588	-0.642	-0.827
Bloody	-0.086	0.768	-0.902	0.663	0.450	-0.141	0.687	0.683	0.676
Brown	-0.721	0.823	-0.671	0.871	0.499	-0.346	0.435	0.760	0.880
Gamey	0.415	-0.666	0.539	-0.396	-0.228	0.270	-0.811	-0.545	-0.647
Grassy	0.128	-0.913	0.750	-0.903	-0.912	0.285	-0.585	-0.930	-0.897
Juicy	0.227	0.887	-0.853	0.689	0.818	-0.054	0.825	0.835	0.817
Fatty	-0.034	0.851	-0.934	0.888	0.736	-0.045	0.478	0.805	0.818
Livery	0.887	-0.461	0.294	-0.438	-0.006	0.450	-0.353	-0.389	-0.507
Metal	1	-0.239	0.115	-0.403	0.139	0.388	0.065	-0.197	-0.334
Brothy	-0.239	1	-0.865	0.878	0.795	-0.278	0.797	0.947	0.976
Oxid	0.115	-0.865	1	-0.808	-0.563	-0.038	-0.604	-0.742	-0.837
Roast B	-0.403	0.878	-0.808	1	0.749	-0.423	0.436	0.902	0.850
Salty	0.139	0.795	-0.563	0.749	1	-0.445	0.624	0.908	0.711
Sour	0.388	-0.278	-0.038	-0.423	-0.445	1	-0.192	-0.525	-0.163
Sweet	0.065	0.797	-0.604	0.436	0.624	-0.192	1	0.725	0.738
Umami	-0.197	0.947	-0.742	0.902	0.908	-0.525	0.725	1	0.878
Liking	-0.334	0.976	-0.837	0.850	0.711	-0.163	0.738	0.878	1

Table 21: ANOVA table for descriptive panel ratings on beef from two types of grass diets.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Astringent	13	93.299	7.1768	15.18	<.0001
Barny	13	5.069	0.3900	2.58	0.0042
Bitter	13	35.069	2.6976	10.86	<.0001
Bloody	13	40.542	3.1186	1.58	0.1046
Browned	13	122.370	9.4131	12.64	<.0001
Gamey	13	39.704	3.0541	3.89	<.0001
Grassy	13	58.669	4.5130	3.79	<.0001
Juicy	13	308.801	23.7539	10.23	<.0001
Fatty	13	394.218	30.3244	25.43	<.0001
Livery	13	17.558	1.3506	2.22	0.0141
Metallic	13	14.604	1.1234	4.67	<.0001
Brothy	13	201.197	15.4767	11.18	<.0001
Oxidized	13	6.565	0.5050	0.91	0.5435
Roast Beef	13	132.294	10.1765	7.56	<.0001
Salty	13	158.125	12.1635	10.75	<.0001
Sour	13	89.201	6.8616	6.55	<.0001
Sweet	13	268.606	20.6620	56.12	<.0001
Umami	13	229.382	17.6448	18.19	<.0001

Table 22: ANOVA table for consumer liking of animals from two grass diets.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Liking	5	64.1875	12.8375	4.95	0.0003

Table 23: Correlation coefficients for beef and chicken mixtures.

	Astringent	Barny	Bitter	Bloody	Brown	Gamey	Grassy	Juicy	Fatty
Astringent	1	0.50381	0.41146	0.94967	-0.30446	0.96365	0.98602	-0.85096	0.70276
Barny	0.50381	1	0.97508	0.6813	-0.92441	0.65315	0.55938	-0.23351	-0.19842
Bitter	0.41146	0.97508	1	0.58497	-0.85957	0.60532	0.44907	-0.12455	-0.31328
Bloody	0.94967	0.6813	0.58497	1	-0.5505	0.95484	0.93998	-0.6748	0.47831
Brown	-0.30446	-0.92441	-0.85957	-0.5505	1	-0.41967	-0.37848	0.02092	0.34902
Gamey	0.96365	0.65315	0.60532	0.95484	-0.41967	1	0.94153	-0.73748	0.51326
Grassy	0.98602	0.55938	0.44907	0.93998	-0.37848	0.94153	1	-0.88481	0.69239
Juicy	-0.85096	-0.23351	-0.12455	-0.6748	0.02092	-0.73748	-0.88481	1	-0.88326
Fatty	0.70276	-0.19842	-0.31328	0.47831	0.34902	0.51326	0.69239	-0.88326	1
Livery	0.84089	0.35092	0.30952	0.86228	-0.20408	0.84635	0.74935	-0.48244	0.48178
Metallic	0.97766	0.57417	0.48709	0.91383	-0.35114	0.95439	0.99062	-0.89607	0.67514
Brothy	-0.86197	-0.00213	0.09181	-0.6859	-0.19432	-0.72895	-0.82338	0.88502	-0.94862
Oxidized	0.92091	0.53026	0.45055	0.9656	-0.4042	0.91924	0.87071	-0.58938	0.49515
Roast Beef	0.59964	-0.13415	-0.25022	0.35652	0.28897	0.41613	0.64127	-0.91615	0.9348
Salty	-0.95259	-0.30219	-0.1642	-0.86695	0.16713	-0.83698	-0.95056	0.89701	-0.84572
Sour	-0.58794	0.09239	0.2935	-0.50471	-0.02283	-0.35898	-0.61526	0.67562	-0.80906
Sweet	-0.90289	-0.32974	-0.17383	-0.80577	0.21129	-0.77258	-0.93882	0.94235	-0.84159
Umami	-0.96479	-0.38536	-0.26578	-0.8613	0.19934	-0.87551	-0.97782	0.9521	-0.82596

	Livery	**Metallic**	**Brothy**	**Oxidized**	**Roast Beef**	**Salty**	**Sour**	**Sweet**	**Umami**
Astringent	0.84089	0.97766	-0.86197	0.92091	0.59964	-0.95259	-0.58794	-0.90289	-0.96479
Barny	0.35092	0.57417	-0.00213	0.53026	-0.13415	-0.30219	0.09239	-0.32974	-0.38536
Bitter	0.30952	0.48709	0.09181	0.45055	-0.25022	-0.1642	0.2935	-0.17383	-0.26578
Bloody	0.86228	0.91383	-0.6859	0.9656	0.35652	-0.86695	-0.50471	-0.80577	-0.8613
Brown	-0.20408	-0.35114	-0.19432	-0.4042	0.28897	0.16713	-0.02283	0.21129	0.19934
Gamey	0.84635	0.95439	-0.72895	0.91924	0.41613	-0.83698	-0.35898	-0.77258	-0.87551
Grassy	0.74935	0.99062	-0.82338	0.87071	0.64127	-0.95056	-0.61526	-0.93882	-0.97782
Juicy	-0.48244	-0.89607	0.88502	-0.58938	-0.91615	0.89701	0.67562	0.94235	0.9521
Fatty	0.48178	0.67514	-0.94862	0.49515	0.9348	-0.84572	-0.80906	-0.84159	-0.82596
Livery	1	0.72114	-0.72447	0.96189	0.21501	-0.76224	-0.41393	-0.59798	-0.69909
Metallic	0.72114	1	-0.81072	0.83599	0.64514	-0.91612	-0.52594	-0.90836	-0.96772
Brothy	-0.72447	-0.81072	1	-0.72412	-0.81843	0.9283	0.73637	0.87153	0.90685
Oxidized	0.96189	0.83599	-0.72412	1	0.29057	-0.84714	-0.50276	-0.73169	-0.80386
Roast Beef	0.21501	0.64514	-0.81843	0.29057	1	-0.74395	-0.72898	-0.82041	-0.78011
Salty	-0.76224	-0.91612	0.9283	-0.84714	-0.74395	1	0.80158	0.97186	0.97873
Sour	-0.41393	-0.52594	0.73637	-0.50276	-0.72898	0.80158	1	0.82144	0.70786
Sweet	-0.59798	-0.90836	0.87153	-0.73169	-0.82041	0.97186	0.82144	1	0.97637
Umami	-0.69909	-0.96772	0.90685	-0.80386	-0.78011	0.97873	0.70786	0.97637	1

Table 24: ANOVA table for descriptive panel ratings on Spinalis dorsi muscles in grain- and grass-fed beef.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Astringent	13	70.9306	5.4562	6.31	<.0001
Barny	13	56.8426	4.3725	3.17	0.0006
Bitter	13	15.4745	1.1903	8.43	<.0001
Bloody	13	19.6481	1.5114	4.19	<.0001
Browned	13	104.9028	8.0694	5.70	<.0001
Gamey	13	149.3704	11.4900	4.29	<.0001
Grassy	13	266.3287	20.4868	7.68	<.0001
Juicy	13	258.2176	19.8629	8.02	<.0001
Fatty	13	581.2245	44.7096	13.88	<.0001
Livery	13	42.5579	3.2737	4.38	<.0001
Metallic	13	11.4722	0.8825	4.21	<.0001
Brothy	13	230.2454	17.7112	8.39	<.0001
Oxidized	13	31.0787	2.3907	3.25	0.0004
Roast Beef	13	228.0023	17.5386	14.40	<.0001
Salty	13	159.3264	12.2559	13.68	<.0001
Sour	13	123.6875	9.5144	4.96	<.0001
Sweet	13	257.4190	19.8015	10.89	<.0001
Umami	13	425.4931	32.7302	9.42	<.0001

Table 25: Correlation coefficients for the Spinalis dorsi muscles in grain- and grass-fed beef.

	Astringent	**Barny**	**Bitter**	**Bloody**	**Browned**	**Gamey**	**Grassy**	**Juicy**	**Fatty**
Astringent	1	0.45866	0.85968	0.57198	-0.78332	0.62356	0.67187	-0.34357	-0.44863
Barny	0.45866	1	0.451	0.65985	-0.80728	0.89005	0.91888	-0.7858	-0.66019
Bitter	0.85968	0.451	1	0.22529	-0.73882	0.47191	0.66275	-0.19341	-0.15297
Bloody	0.57198	0.65985	0.22529	1	-0.52156	0.85339	0.74068	-0.48916	-0.71469
Browned	-0.78332	-0.80728	-0.73882	-0.52156	1	-0.71227	-0.79322	0.74417	0.72196
Gamey	0.62356	0.89005	0.47191	0.85339	-0.71227	1	0.9231	-0.6953	-0.57669
Grassy	0.67187	0.91888	0.66275	0.74068	-0.79322	0.9231	1	-0.55717	-0.5479
Juicy	-0.34357	-0.7858	-0.19341	-0.48916	0.74417	-0.6953	-0.55717	1	0.70711
Fatty	-0.44863	-0.66019	-0.15297	-0.71469	0.72196	-0.57669	-0.5479	0.70711	1
Livery	0.40978	0.83233	0.34309	0.55029	-0.65142	0.86657	0.7216	-0.86287	-0.41517
Metallic	0.12829	0.72409	0.06268	0.2899	-0.6604	0.50941	0.42137	-0.95434	-0.67035
Brothy	-0.52456	-0.97697	-0.43219	-0.70506	0.85461	-0.90384	-0.87652	0.88056	0.74537
Oxidized	0.19078	-0.50948	-0.1529	0.18011	0.3512	-0.07794	-0.32909	0.26935	0.21475
Roast Beef	-0.56636	-0.65267	-0.53233	-0.61002	0.46586	-0.86673	-0.77575	0.43413	0.10619
Salty	-0.16121	-0.57497	0.1674	-0.86492	0.20807	-0.7664	-0.5376	0.50736	0.51
Sour	0.86959	0.44249	0.85328	0.47059	-0.73234	0.46212	0.67712	-0.11618	-0.46124
Sweet	-0.63329	-0.93632	-0.47523	-0.79993	0.84255	-0.95966	-0.8941	0.84485	0.72775
Umami	-0.52965	-0.9077	-0.35829	-0.74004	0.78888	-0.92365	-0.80461	0.91744	0.70292

	Livery	**Metallic**	**Brothy**	**Oxidized**	**Roast Beef**	**Salty**	**Sour**	**Sweet**	**Umami**
Astringent	0.40978	0.12829	-0.52456	0.19078	-0.56636	-0.16121	0.86959	-0.63329	-0.52965
Barny	0.83233	0.72409	-0.97697	-0.50948	-0.65267	-0.57497	0.44249	-0.93632	-0.9077
Bitter	0.34309	0.06268	-0.43219	-0.1529	-0.53233	0.1674	0.85328	-0.47523	-0.35829
Bloody	0.55029	0.2899	-0.70506	0.18011	-0.61002	-0.86492	0.47059	-0.79993	-0.74004
Browned	-0.65142	-0.6604	0.85461	0.3512	0.46586	0.20807	-0.73234	0.84255	0.78888
Gamey	0.86657	0.50941	-0.90384	-0.07794	-0.86673	-0.7664	0.46212	-0.95966	-0.92365
Grassy	0.7216	0.42137	-0.87652	-0.32909	-0.77575	-0.5376	0.67712	-0.8941	-0.80461
Juicy	-0.86287	-0.95434	0.88056	0.26935	0.43413	0.50736	-0.11618	0.84485	0.91744
Fatty	-0.41517	-0.67035	0.74537	0.21475	0.10619	0.51	-0.46124	0.72775	0.70292
Livery	1	0.73535	-0.87301	-0.15678	-0.80857	-0.62195	0.12743	-0.88559	-0.93567
Metallic	0.73535	1	-0.79562	-0.47638	-0.20919	-0.35051	-0.00436	-0.7017	-0.78881
Brothy	-0.87301	-0.79562	1	0.38668	0.63973	0.61027	-0.43083	0.97786	0.96784
Oxidized	-0.15678	-0.47638	0.38668	1	-0.11673	-0.19534	-0.12696	0.19734	0.17736
Roast Beef	-0.80857	-0.20919	0.63973	-0.11673	1	0.59745	-0.3214	0.73471	0.70708
Salty	-0.62195	-0.35051	0.61027	-0.19534	0.59745	1	0.01697	0.68171	0.70053
Sour	0.12743	-0.00436	-0.43083	-0.12696	-0.3214	0.01697	1	-0.47907	-0.31785
Sweet	-0.88559	-0.7017	0.97786	0.19734	0.73471	0.68171	-0.47907	1	0.98125
Umami	-0.93567	-0.78881	0.96784	0.17736	0.70708	0.70053	-0.31785	0.98125	1

Table 26: Descriptive ratings for *Longissimus dorsi* and *Spinalis dorsi* muscles, with statistical analysis between muscle types.

Attribute	LD Grass	LD Grain	SD Grass	SD Grain	P-Value
Astringent	1.69 [a]	1.49 [a]	0.91 [b]	1.20 [ab]	0.0001
Barny	0.84 [a]	0.02 [b]	0.08 [b]	0.77 [a]	0.0001
Bitter	0.48 [a]	0.23 [b]	0.21 [b]	0.30 [b]	0.0010
Bloody	0.25	0.48	0.19	0.41	0.0998
Brothy	1.57 [b]	1.92 [b]	2.62 [a]	1.81 [b]	0.0015
Browned	0.64 [b]	0.95 [ab]	1.29 [a]	0.66 [b]	0.0100
Fatty	1.89 [c]	2.30 [c]	4.80 [a]	3.36 [b]	0.0001
Gamey	0.98 [b]	0.23 [c]	0.24 [c]	1.57 [a]	0.0001
Grassy	1.17 [b]	0.40 [c]	0.53 [c]	2.60 [a]	0.0001
Juicy	1.67 [d]	2.40 [c]	4.31 [a]	3.12 [b]	0.0001
Livery	0.51	0.20	0.06	0.44	0.0527
Metallic	0.57 [a]	0.33 [ab]	0.19 [b]	0.26 [b]	0.0338
Oxidized	0.24	0.08	0.35	0.28	0.4926
Roast Beef	1.00	1.22	1.81	1.40	0.1450
Salty	1.23 [b]	1.35 [b]	1.91 [a]	1.51 [b]	0.0068
Sour	1.28	1.21	1.09	1.49	0.1419
Sweet	0.44 [b]	0.73 [b]	1.47 [a]	0.35 [b]	0.0001
Umami	3.40 [c]	5.05 [b]	6.10 [a]	4.04 [c]	0.0001

LD = *Longissimus dorsi* muscle, SD = *Spinalis dorsi* muscle