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Lipids, fatty acids and flavor of beef from steers grazed on different pastures or fed up to 112 days on a corn based finishing ration

Teresa F. Mann

To the Graduate Council:

I am submitting herewith a thesis written by Teresa F. Mann entitled "Lipids, fatty acids and flavor of beef from steers grazed on different pastures or fed up to 112 days on a corn based finishing ration." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

Sharon L. Melton, Major Professor

We have read this thesis and recommend its acceptance:

M. J. Riemann, C. C. Melton, W. R. Backus

Accepted for the Council:
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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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LIPIDS, FATTY ACIDS AND FLAVOR OF BEEF FROM STEERS GRAZED ON DIFFERENT PASTURES OR FED UP TO 112 DAYS ON A CORN BASED FINISHING RATION

A Thesis

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Teresa F. Mann

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ABSTRACT

Sixty-eight Angus steers were separated into five treatment groups, each of which grazed a different type of pasture prior to grain feeding. Each pasture was composed of different mixtures of grasses. The grasses included fescue, clover, sudan grass, sorghum, bermuda grass, and orchard grass. Three steers from each treatment were slaughtered off grass (0-day feed group). The remainder were divided into feeding groups where at least two steers from each treatment were in each group, and all were adjusted to a corn diet for two weeks. After adjustment a group was slaughtered every 28 days up to 112 days on corn. Total lipid content, fatty acid composition, tocopherol content and sensory evaluation of flavor by Quantitative Descriptive Analysis were determined on the longissimus muscle from each steer carcass that was aged 10 days at 6°C. The muscle was stored in double-wrapped polyethylene coated freezer paper at -18°C until analyzed. Grasses from each pasture also were analyzed for moisture, total lipid and fatty acid composition.

Across time on feed, milky-oily flavor and aroma decreased linearly in intensity; beef fat flavor and aroma increased linearly in intensity, and total lipid content increased curvilinearly. Beef from steers off grass had lower levels of monounsaturated and higher levels of saturated and polyunsaturated fatty acids than beef produced by grain. Fatty acids deposited in increasing

lipid content across days on feed included 14:0, 14:1, 16:0, 16:1, 17:1, 18:1, 18:2ω6, and 20:1. Beef produced by grass had higher levels of ω3 fatty acids (18:3, 20:3, 20:5, 22:5, and 22:6) and lower levels of ω6 fatty acids (18:2, 20:3, and 20:4 than beef produced by corn. High levels of 18:3ω3 in all pastures was probably the source of the ω3 acids, and the high levels of 18:2ω6 in corn, the source of the ω6 acids. Tocopherol (α and r) content in muscle decreased over time on feed, and the change in α-tocopherol content could be explained by the change in its dietary levels. Flavor of the beef was correlated with chemical characteristics of the beef. Fatty acids positively correlated with milky-oily flavor included 13:0, 15:0, 19:0, 19:1, 20:1, 20:3ω3, 20:3ω6, 20:5ω3, and the sum of the ω3 fatty acids. Fatty acids positively correlated with beef fat flavor included 12:0, 14:0, 14:1, and 16:1. Of all chemical characteristics, α-tocopherol had the highest positive correlation coefficient (0.58) with milky-oily flavor.

Total lipid content and moisture content of the grasses in the different treatments were within reported literature levels. There were no significant differences among pastures in the fatty acid composition. All pastures had high levels of 18:2ω6 (23-38%) and 18:3ω3 (23-43%). Pasture type did not significantly affect the flavor of the beef or the lipid or tocopherol contents, but did affect a few fatty acids expressed in mg/100 g beef: 14:0 20:3ω3, 20:4ω6, 22:6ω3, and an unknown which was possibly a branched chain 18 carbon acid.

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CHAPTER I

INTRODUCTION

Beef prices increased in the 1970's partially due to rapidly increasing grain prices. Possibilities that might increase the cattle profits and produce beef at cheaper cost to the consumer include reducing the time involved in finishing cattle on grain and increasing the backgrounding time on pasture, particularly pastures which will grow on land not suitable for the production of row crops.

Research at The University of Tennessee has shown that beef produced on grass has a less desirable flavor than beef produced on grain because it has a lower intensity of cooked beef fat flavor and a higher intensity of a sour, milky-oily flavor. The lack of fat in beef from grass-fed steers is not the cause of its less desirable flavor compared to grain-finished beef. The type of diet used to finish cattle (for example, pasture versus corn) and not the dietary energy level causes the less desirable flavor in beef produced on grass. However, the normal grain-feeding period of cattle may be reduced from 140 to 90 days without much change in beef flavor.

Other researchers have suggested that pastures which seem to produce beef with less desirable flavor include clover, winter rye grass, and fescue. Beef from steers finished on blue grass, summer rye grass, and bermuda grass has been reported to have a flavor that was as desirable as the flavor of beef produced on

grain. Also, researchers have shown that beef produced on grass often has a shorter shelf-life than beef produced on grain, possibly due to oxidation.

During 1981, at Ames Plantation, cattle were available that had been backgrounded on different types of pasture. These cattle provided an excellent opportunity to investigate forages other than fescue for backgrounding cattle to eliminate or reduce the undesirable flavor and odor of grass-fed beef.

The objective of this experiment was to evaluate beef flavor and chemical composition of beef as a function of time cattle were fed grain after grazing on various pastures composed of combinations of fescue, clover, Sudan grass, sorghum pasture, orchard grass, and/or Midland Bermuda grass. In addition, pasture grass on which the animals were grazed was analyzed for moisture content, total lipid content, and fatty acid content of the total lipid.

CHAPTER II

REVIEW OF LITERATURE

I. MEAT FLAVOR

The flavor of meat is a result of sensations arising from two distinct responses, those of taste and aroma, as well as less clearly defined contributions from the pressure- and heat-sensitive areas of the mouth (Moody, 1983). Meat flavor begins with raw meat which has a simple bloody aroma, but when meat is heated, complex components form. The odor components are formed from compounds present in meat such as proteins, carbohydrates, fats, salts, and minerals. With minor variations, the composition of all meat is similar, but a number of factors may result in modifications discernable in the flavor of meat. Species differences permit distinguishing the flavor among beef, pork, and lamb; nutritional state of the animal and diet components also affect flavor (Wasserman, 1979).

Cooking develops the flavor of meat. The primary reactions which occur upon heating include degradation of sugars, pyrolysis of proteins and amino acids, and lipid degradation. Additionally, interactions of two or more precursors may occur as in the Strecker degradation, Maillard reaction, and various protein/lipid interactions.

In general, the flavor of cooked meat is due to a mixture of compounds including nonvolatiles or water-soluble compounds with taste-tactile properties, potentiators and synergists, and volatiles which give rise to the odor properties (Moody, 1983).

Flavor Precursors

Batzer et al. (1960, 1962) and Wasserman and Gray (1965) identified glycoproteins, simple sugars, amino acids, and lipids as possible meat aroma and flavor precursors. More recently many more compounds contributing to beef aroma and/or flavor have been identified. Mabrouk (1976) summarized 15 classes of organic compounds as red-meat flavor precursors: (1) glycopeptides, (2) nucleic acids, (3) free nucleotides, (4) peptide-bound nucleotides, (5) nucleotide sugars, (6) nucleotide sugaramine, (7) nucleotide acetylsugaramine, (8) nucleotides, (9) peptide, (10) free amino acids, (11) free sugars, (12) sugar phosphates, (13) sugaramine, (14) amines, and (15) organic acids. Chang and Peterson (1977) listed classes of compounds they believed to be important contributors to meat aroma as: lactones, furanoid or hydrofuranoid compounds, acyclic sulfur-containing compounds, and heterocyclic compounds containing sulfur, nitrogen, and oxygen. These researchers also listed compounds that may not be primary contributors to meat flavor as carbonyl compounds, aliphatic hydrocarbons, saturated alcohols, esters and ethers. Schutte (1974) suggested that carbonyl compounds, sulfur-compounds, nitrogen-containing compounds and some

phenols are the most important in meat flavor. MacLeod and Seyyedain-Ardebili (1981) identified more than 450 volatile compounds of natural beef aroma. Despite the fact that all these compounds have been identified in cooked beef, no single compound uniquely responsible for cooked beef aroma has been identified to date (Wasserman, 1979). Moody (1983) stated that fats influence meat flavor in two ways: (1) through oxidation principally of the unsaturated fatty acids, and (2) by acting as deposit for fat-soluble, volatile compounds. Oxidation results in the formation of carbonyl compounds that are present in organoleptically significant amounts; these compounds may at one level of concentration produce characteristic and desirable flavors and at another concentration level produce undesirable off-flavors. It is generally accepted that the basic meat precursors are degraded to a pool of low molecular weight reactive aldehydes, ketones, reductones, ammonia, hydrogen sulfide, amines, and other chemicals which contribute directly to flavor or indirectly through pathways not fully defined (Katz, 1981).

II. SOME CHARACTERISTICS OF PASTURE-FINISHED BEEF AND GRAIN-FINISHED BEEF

The economic feasibility of grain supplementation of forage diets to provide marketable beef has long been acknowledged. Bidner (1975) reported the break-even price increased as steers were finished on grain. Beeson et al. (1967) showed that cattle slaughtered after 191 days on good pasture saved about 500 pounds

of total digestible nutrients per steer compared to dry-lot fed cattle. However, many researchers have concluded that beef from forage-finished cattle is of poorer eating quality than beef from cattle maintained on grain diets.

Kropf et al. (1975) and Shinn et al. (1976) have shown that carcasses from steers fed concentrates for approximately 112 days after a grazing period were heavier and fatter and had more marbling, a higher quality grade and a lower yield grade than did the cattle finished on grass. Harrison et al. (1978) concluded that increasing feeding time on grain improved the quality characteristics of cattle and that palatability responses favored those cattle fed the longest time on feed. Moody et al. (1970) reported that carcasses gradually increased in quality grade from low good to low choice as days on feed increased from 0 to 84. Smith et al. (1977) determined that less desirable taste panel scores of beef from grass-fed steers seemingly disappeared after 49 days on feed.

Beef from grain-finished cattle has more desirable flavor and overall palatability than beef from forage-fed cattle (Bowling et al., 1977). A less desirable or less intense beef flavor in beef produced on forage has been reported by several other researchers (Kropf et al., 1975; Meyer et al., 1960; Schroeder et al., 1980; Wanderstock and Miller, 1948; Westerling and Hedrick, 1979). The flavor desirability difference between beef produced by grain is approximately one to one and a half units on an eight point scale. The beef produced by grain is usually scored by a trained panel as slightly

to moderately desirable, and the beef produced by grass as slightly undesirable to slightly desirable (Melton, 1983).

In a review of effect of forage feeding on beef flavor, Melton (1983) reported the following observations. Many of the reported studies of diet effect on beef flavor utilized grain-fed animals that were fatter and heavier than grass-fed animals. A few reported studies concerning the subject, however, utilized cattle with similar fat measurements or beef with similar fat levels. In the latter studies, a less desirable or less intense flavor of beef produced by grass compared to beef produced by grain was reported by several researchers (Bowling et al., 1977; Brown et al., 1979; Davis et al., 1981; Dunn, 1982; Dyer, 1980; Melton et al., 1982 a,b; Purchase and Davis, 1974; Reagan et al., 1977). In contrast with these investigators, Davies (1977) and Huffman and Griffey (1975) found no significant flavor difference. Based upon these observations Melton (1983) concluded that it seemed likely that the difference in fat concentration between beef from grain-finished and grass-finished cattle was not the main cause of the less-desirable flavor of beef produced by grass.

In addition to a less-desirable flavor, grass-finished beef has been reported to have specific off-flavors. In a study by Davis et al. (1981) panelists noted that forage-fed beef had a grassy or dairy flavor and a lack of a beefy flavor. Berry et al. (1980) reported that a desirable flavor in beef was associated with higher intensities of a browned flavor and that an undesirable flavor was

associated with higher intensities of grass and astringent flavors. Melton et al. (1982a) also reported that beef with an intense milky or dairy flavor had a less desirable flavor than beef with higher intensities of cooked beef fat flavor. Brown et al. (1979) reported grassy, milky, and fishy off-flavors in beef produced by grass. Melton et al. (1982b) reported sour and fishy off-flavors, while Yeo (1982) reported a sour flavor and an undesirable milky-oily flavor in grass-finished beef.

III. RELATIONSHIP OF FATTY ACID COMPOSITION TO FLAVOR

Several reported studies show a relationship between fatty acid composition and meat palatability (Dryden and Marchello, 1970; Waldman et al., 1965; Waldman et al., 1968; Melton et al., 1982a,b). Hornstein et al. (1961) determined the lipid composition of lean beef and related this to flavor. High positive correlation coefficients between flavor score and oleic acid or intramuscular total unsaturated fatty acids existed and there were high negative correlation coefficients between flavor score and each of the following intramuscular fatty acids: palmitic (16:0), stearic (18:0), linoleic (18:2), and total saturated fatty acids (Westerling and Hedrick, 1979). Also, Igene and Pearson (1979) showed that the concentration of long chain polyunsaturated fatty acids (18:3, 20:2, 20:3, and 20:5) of beef phospholipids were major contributors to undesirable off-flavors. Melton et al. (1982a) showed a significant negative correlation between flavor desirability and linolenic acid of both neutral and polar lipids.

In two studies similar to the present study, fatty acid composition was significantly ($P<0.05$) correlated to flavor descriptors (Black, 1981; Yeo, 1982). Black (1981) reported high positive correlations between milky-oily flavor and concentrations of 15:0, 18:0, and 18:3 while fatty acids positively correlated with beef fat flavor included 14:1, 16:1, 18:1, and 17:0. Yeo (1982) reported 15:0, 18:0, 18:3, 20:0, 20:3, 20:4, and 22:5 as having a high positive correlation with milky-oily flavor, while 14:0, 14:1, and 18:1 were positively correlated with beef fat flavor. The fatty acids positively correlated with beef fat flavor were negatively associated with milky-oily flavor and vice versa (Black, 1981; Yeo, 1982).

IV. EFFECT OF DIET ON FATTY ACID COMPOSITION

In a review of the literature, Melton (1983) elaborated on the effects of grain and grass diets on beef fatty acid composition as follows. The importance of fatty acids as precursors of beef flavor varies from reviewer to reviewer. However, fatty acids are the primary source of carbonyl compounds of beef flavor and the oxidation of the unsaturated fatty acids in beef lipids results in off-flavor in meat. Diet does affect the fatty acid composition. Beef from steers finished on low-energy/high-forage diets, including grass, has a higher percentage of 18:0 and a lower percentage of 18:1 than beef from grain-finished steers. Grass diets also affect several fatty acids, such as branched chain fatty acids, odd-number

carbon-chain length fatty acids and long-chain (C18-C22) polyunsaturated fatty acids. Grass-finished beef has more BrC15:0 (14-methyl pentadecanoic acid), 18:3, 20:3, 20:4, and 22:5 and less 17:0 than beef produced by grain.

The higher 18:3 content in beef produced by grass is due to the high 18:3 concentration (approximately 50%) in grass lipid and failure of the rumen microorganisms to hydrogenate all of the ingested 18:3. It is not known why beef produced by grass has higher levels of 20:3, 20:4, and 22:3; these acids are located primarily in the beef phospholipids (Melton, 1983).

The long-chain polyunsaturated fatty acids plus linolenic acid are responsible for the warmed-over flavor in meats; they are degraded during cooking of beef; and are oxidized during storage of beef. Thermal oxidation of the higher concentration of these polyunsaturated fatty acids could contribute to the higher intensity of undesirable flavors in beef such as milky-oily, grassy, and fishy. The higher concentrations of these acids in beef produced by grass compared to beef produced by grain would also contribute to more rapid development of oxidative rancidity and off-flavor in grass-finished beef during storage (Melton, 1983).

V. EFFECT OF STORAGE ON GRASS-FED BEEF

Melton (1983) also reported that beef produced on grass had a shorter frozen and refrigerated shelf-life than beef produced on grain according to several researchers (Gutowski et al., 1979;

Reagan et al., 1977; Schroeder et al., 1980). The apparent reason for this shorter shelf-life was the faster development of undesirable, fish-like rancid flavors (Moore and Harbord, 1977; Reagan et al., 1981; Schroeder et al., 1980). The faster flavor deterioration in beef produced by grass may have been due to excessive oxidative rancidity (Reagan et al., 1981).

VI. EFFECT OF TOCOPHEROLS IN BEEF

Lipid oxidation can be inhibited by antioxidants and the tocopherols are classified among the natural antioxidants (Tsai et al., 1978). Tocopherols or vitamin E have long been considered to be among the best antioxidants of the vegetable oils (DeMan, 1980). The role of tocopherols as antioxidants in muscle is not as clear. A primary function of tocopherol is to stabilize cellular and subcellular membranes by preventing peroxidative damage of structural polyunsaturated fatty acids. These polyunsaturated fatty acids containing two or more double bonds are located primarily in the polar or phospholipids which make up these membranes, and the lipids in the membranes are more susceptible to oxidative rancidity than depot fat or intermuscular lipids (Yamauchi et al., 1980). Tocopherols also inhibit the development of oxidative rancidity in meat and poultry during storage (Yamauchi et al., 1980).

Varying levels of tocopherol have been reported in the muscle foods. In a study based on pork produced with a dietary supplementation of 200 ppm α-tocopherol acetate in feed (fed ad lib)

Tsai et al. (1978) reported 4.3 μg/100 g tissue of α-tocopherol in the triceps muscle. Yamauchi et al. (1980) found 58 ± 5 and 115 ± 37 μg/100g fresh wet tissue of α-tocopherol in pork longissimus thoracis and biceps femoris, respectively. In a study of commercial hamburgers from fast food chains Slover et al. (1980) found an average of 0.40 mg α-tocopherol per 80.1 g hamburger which also contained 10.42 g fat and 30.8 g moisture post-cooking. These measurements were made on the entire sandwich including the bread but not the condiments, and the α-tocopherol content could have been enhanced by the bread and the vegetable oil in which the beef patty was cooked.

Tocopherol content in beef decreases over frozen storage time (Tsai et al., 1978). In veal calves fed milk replacer plus corn oil without tocopherol or with a total of 38 g added tocopherol over eight weeks tissue levels of vitamin E were reported to be 5.2 ± 2.2 μg/g tissue (with supplemental dietary vitamin E) and 3.4 ± 0.8 μg/g tissue (without dietary vitamin E). After three months storage these levels decreased to 2.2 ± 0.6 μg/g tissue and 0.9 ± 0.7 μg/g tissue, respectively (Shorland et al., 1981).

VII. CHARACTERISTICS OF PASTURE GRASSES

The moisture content of pasture grasses is approximately 75-80% (Sampson, 1924). The 20-25% dry matter remaining is composed of 10-20% crude protein (Lyttleton, 1973); approximately 9% total nonstructural carbohydrates (Hunter et al., 1970) which includes

free sugars and starches; approximately 50% structural carbohydrates (Jarrige, 1963), which includes cellulose, hemicellulose, and other structural polymers; 3-10% lipid (Hawke, 1973); and approximately 10% mineral content (Fleming, 1973).

Garton (1963) reported the fatty acid component of mixed pasture grasses to contain primarily linolenic (18:3) acid at 61.3% followed by 15.9% of 16:0 and 13.2% 18:2. Other acids determined were 14:0, 16:1, 18:0, and 18:1 totaling 9.0% with 0.5% of fatty acids listed as other. Other lipid constituents in grasses are phospholipids, triglycerides, sulpholipids, sterols, sterol esters, waxes, hydrocarbons, and free fatty acids (Hilditch, 1956; Weenik, 1962). Researchers (Gray et al., 1967; Crombie, 1958; Klopfenstein and Shigley, 1967) have demonstrated that changes in fatty acid composition during the growing season are due primarily to the amount of light available to the plant rather than the changing maturity of the plant.

Mowat et al. (1965) reported that protein content decreased and nonstructural and structural carbohydrates increased as pasture grasses matured. This was the result of an increasing amount of stem compared to leaf content of the grasses. The concentrations of protein and carbohydrate were maintained closer to initial levels if the grasses were cut prior to maturity (Patton, 1943; Phillips et al., 1954; Sullivan et al., 1956).

CHAPTER III

MATERIALS AND METHODS

I. SELECTION OF STEERS, FEEDING MANAGEMENT, AND SLAUGHTER

During 1981, at the University of Tennessee Experiment Station located in West Tennessee at Ames Plantation, a total of 68 Angus yearling steers were grown through the summer on five different kinds of pasture. The pastures (treatments) included: (T1) fescue and clover the first part of the grazing period followed by Sudan grass and sorghum pasture (N = 14), (T2) orchard grass and clover (N = 11), (T3) Midland Bermuda grass, fescue, and clover (N = 15), (T4) Midland Bermuda grass and fescue, plus nitrogen fertilization (N = 15), and (T5) fescue and clover (N = 13).

On September 2, 1981, the 68 Angus steers were transported to the University of Tennessee Plateau Experiment Station, Crossville, Tennessee. Fifteen cattle, three from each treatment, were slaughtered at Lay's Packing Co. in Knoxville, Tennessee, immediately after coming off pasture. The remaining 53 steers were assigned to four different grain feeding groups on the basis of treatment and growth similarities (weight and estimated fat thickness at the 12th rib). At least two steers from each of the five different treatments were in each feeding group and an effort was

made to assign steers with similar weights and fat thicknesses to each group. After a 14 day acclimation period to a corn diet, all steers received whole shelled corn ad libitum and Tend-R-Leen at the rate of 0.50 kg per head per day in a dry lot. After the acclimation period, at each 28 day interval up to 112 days, a group of steers was transported to Lay's Packing Co. for slaughter. The feeding schedule and slaughter dates are given in Table 1. The carcasses were chilled for 48 hours, then ribbed and evaluated by a USDA grader for quality and yield grade. The left hindquarter of each carcass was transported to the University of Tennessee Meat Laboratory for further data collection.

II. SAMPLE PREPARATION

The short loin was removed from the left hindquarter of each steer and aged 10 days at 16°C before four steaks were removed from the rib end. The first steak, approximately 2.5 cm in thickness, consisted of longissimus muscle stripped of all epimysium tissue. This steak was double wrapped in polyethylene coated freezer paper and stored at -18°C until it was powdered with liquid nitrogen in a high speed Waring blender prior to lipid extraction and fatty acid analysis. No sample was stored longer than one year prior to analysis.

Steak two, approximately 1.5 cm in thickness was double wrapped in polyethylene coated freezer paper and stored at -18°C

TABLE 1. Feeding Schedule and Slaughter Dates

Slaughter Group	n	Days on Feed	Slaughter Date
1	15	0	Sept. 2, 1981
2	14	28	Oct. 19, 1981
3	14	56	Nov. 16, 1981
4	13	84	Dec. 14, 1981
5	12	112	Jan. 11, 1982

for one to one and one-half years. At the end of this period, the steaks were stripped of epimysium tissue and powdered with liquid nitrogen in a Waring blender prior to extraction and analysis of tocopherols.

Steaks three and four, approximately 2.5 cm in thickness each, were used for sensory analysis and taste panel training, respectively. Each of these steaks were wrapped and stored as previously described no longer than nine months before evaluation.

III. SENSORY EVALUATION

Selection of Panel

One steak from each steer was evaluated by the Quantative Descriptive Analysis (QDA) method (Stone et al., 1974). A total of seven panel members were selected from 15 prospective panelists by evaluating their ability to discriminate flavor differences between steaks from grass-finished and grain-finished steers. Criteria for selection as a panel member included selecting the odd sample in three or four triangle tests for three successive days with the triangle test composed of steaks from grass-finished and grain-finished steers. Five men and two women ranging in age from 22 to 42 were chosen on this basis.

Preparation of Samples for Panel Training and Evaluation

Steaks used for training and for sensory evaluation were removed from the freezer 24 hours prior to cooking and thawed at

25°C and then broiled in a rotary oven at 177°C to an internal temperature of 70°C. After cooking the longissimus muscle of each steak was diced into 1.25 cm cubes (approximately) and kept warm (approximately 55°C) in a covered porcelain dish on a warming tray until evaluation.

Preparation of the QDA Score Sheet

At the first meeting, panelists were acquainted with the QDA score sheet which had been used for the evaluation of ground beef from grass-fed and grain-fed steers by Melton et al. (1982b). The panelists were served representative samples of beef produced by grass and beef produced by grain. After the panelists had tasted and smelled each sample, they modified the QDA score sheet used by Melton et al. (1982b). Seven descriptive terms representing the prominent aroma and flavor notes present in the beef samples were selected by the panel and arranged on a QDA score sheet shown in Appendix A, page .

Panel Training

Several panel sessions were held in which each panelist would smell and taste a representative sample of beef produced by grass and score the intensity of each descriptor for that sample, and then smell and taste a beef sample produced by grain and complete a QDA score sheet for that sample. The panelist scored the intensity of each descriptor by making a perpendicular line across

a 150 mm line anchored 10 mm from each end by the words slight and intense.

After each panelist had completed a QDA score sheet for the representative beef samples, they met to discuss how each had scored each sample. At that time, if a panelist had scored a descriptor for a sample too low or too intense compared to the average response of other panelists, the panelist was given the sample again and trained where to mark the intensity of that particular descriptor. During the training sessions, panelists also had the opportunity to become acquainted with stimuli chosen as standards for given intensities of selected descriptors. These standards are described later in this thesis. Training continued until all panelists were able to score the intensity of each descriptor for representative beef samples within $\pm$ 1 cm of each other.

Standards for the Descriptors

The stimulus for the slight sour flavor was 0.01 mg acetic acid/ml aqueous solution and 0.1 mg/ml acetic acid was the stimulus for the intense sour flavor. Freshly broiled beef liver served warm represented the intense liver flavor by mouth. A stimulus for the intense cooked beef fat aroma descriptor was the odor of 10 ml of cooked beef fat from a grain-fed steer in a freshly opened tube (10 by 150 mm) which had been held at 130°C for one hour prior to opening.

A stimulus for the intense milky part of the complex milky-oily aroma was obtained by letting each panelist smell 100 ml rancid milk in a 150 ml container kept closed at 25°C for two hours prior to opening. The milk was made rancid by mixing one part of fresh whole milk with two parts pasteurized milk that had been held at 25°C for 24 hours prior to being mixed. Stimuli for the slight and intense oily part of the milky-oily aroma was, respectively, the aroma of 10 ml of 5×10^{-4} mg/ml and 1×10^{-3} mg/ml of trans, trans 2,4-decadienal in methanol in a freshly-opened tube (10 by 150 mm) which had been kept closed at 25°C for approximately 16 hours prior to opening.

Sample Evaluation

Each time the panel convened, conditions were as follows: six steaks were selected at random from samples of all steers. Each steak, after being thawed, cooked, and cubed as previously described, was kept warm (55°C) in a covered porcelain dish on a warming tray. Each steak, identified by a randomly assigned, three-digit code number, was served under white light to each panelist immediately after being removed from the warming tray. Panelists were served a 1.25 cm cube taken from the center of the longissimus of each steak, followed by a second 1.25 cm cube from the same steak. Each panelist evaluated and scored both cubes on a single QDA score sheet (Appendix A, page 91) for intensities of milky-oily aroma, beef fat aroma, milky-oily flavor, beef fat

flavor, sour flavor, liver flavor, and raw or blood-like flavor. The mean score of the two cubes of each descriptor was used as the intensity score for each panelist.

IV. CHEMICAL ANALYSES

Long Chain Fatty Acid Analysis

A lipid extract was prepared according to the Ostrander and Dugan (1961) modification of the Bligh and Dyer method (1959). Methyl esters of long chain fatty acids were prepared from the lipid extract according to Method Ce 2-66 (AOCS, 1974) and fatty acids analyzed according to a modified method of Melton et al. (1982b). The methyl esters were analyzed with a Bendix model 2600 gas chromatograph equipped with dual flame ionization detectors and a chromatopac EIA electronic integrator. In the method of Melton et al. (1982b), the methyl esters were analyzed on two different columns: (a) a 2 mm i.d x 3.0 m glass column packed with GP 3% SP-2100 DOH on 100/1200 Supelcoport (Supelco, Inc., Bellefonte, PA), (SPDOH column), and (b) a 2 mm i.d. x 2 m glass column packed with 10% Silar -10C on 100/120 gas Chrom-Q (Applied Science Division, Milton Ray Co., State College, PA) (Silar 10C column).

The SPDOH column separated branched chain fatty acids and straight chain fatty acids containing an odd number of carbons more efficiently than did the Silar 10C column (Anon., 1977). However, the SPDOH column did not separate the C18 unsaturated-fatty acids (18:1, 18:2, 18:3) which were efficiently separated

by the Silar 10C column. For both columns the amount of each fatty acid was corrected for nonlinearity of instrument response and for molecular weight differences by the use of calibration factors determined relative to methyl palmitate (Method Ce 1-62; AOCS, 1974). If the fatty acid could not be identified (designated as fatty acid unknowns) or a suitable standard could not be obtained commercially, the calibration factor was assumed to be 1:00. Calibration factors for fatty acids on each column in these analyses are given in Appendix B, page 93. The operating conditions for the gas chromatograph for each column are shown in Table 2.

TABLE 2. Conditions for Gas Chromatographic Analysis

	SPDOH Column	Silar 10C Column
Nitrogen flow rate	0.9	0.65
Hydrogen flow rate	2.5	2.5
Injection temperature	250°C	250°C
Detector temperature	250°C	250°C
Initial oven temperature	150°C	150°C
Final oven temperature	230°C	230°C
Temperature rate	3°/min.	10 min.hold 1.5°/min. 24 min. 15°C/min.

Actual percentages of fatty acids reported for each sample except for fatty acids specified later and C18 fatty acids were determined using the SPDOH column. The total percentage of fatty acids containing 18 carbons was determined on the SPDOH column, and the sum of these percentages was designated as X. The percentages of each C18 fatty acid that made up the total percentage, Y, on the SPDOH column were estimated by multiplying the percentage of each C18 fatty acid determined on Silar 10C column by Y/X.

The modifications of the Melton et al. (1982b) method were as follows: First, the acids, 20:4ω6 and 20:5ω3, were efficiently separated by the Silar 10C column but were unresolved by the SPDOH column. The percentage of the combined acids determined on the SPDOH column was divided into the correct percentages of each acid in the following manner. The percentage of the 20:4ω6 and 20:5ω3 determined on the Silar 10C column was multiplied by S/T. S equals the percentage of 20:4ω6 and 20:5ω3 acids determined by the SPDOH column and T equals the sum of percentages of 20:4ω6 and 20:5ω3 acids determined by the Silar 10C column.

In addition, the following acids, 8:0, 9:0, 11:0, 20:3ω3, and 22:6ω3 were resolved peaks on the chromatogram from the Silar 10C column but not on the chromatogram from the SPDOH column. The corrected areas of these acids were not included in the sum of the areas used to calculate the 100% fatty acids from each SPDOH column chromatogram, but were included in the sum of the areas used to calculate the 100% fatty acids from each Silar 10C column

chromatogram. An estimate of what the correct percentage of each of these acids should have been from the SPDOH column chromatogram was obtained in the following way. The percentage of each of these acids determined on the Silar 10C column was added to 100.00; this sum was designated as Total. Each fatty acid percentage determined the SPDOH column and the percentage of 8:0, 9:0, 11:0, 20:3ω3, and 22:6ω3 acids from the Silar 10C was multiplied by 100/Total. The sum of the corrected percentages of all of the fatty acids used in this experiment added up to 100. These acids included 8:0, 9:0, 10:0, 11:0, 12:0, 13:0, 14:0, 14:1, Antesio (AI) 15:0 Iso (I) 15:0, 15:0, Iso (I) 16:0, 16:0, 16:1, Iso (I) 17:0, 17:0, 17:1, 18:0, 18:1, 18:2ω6, 18:3ω3, 19:0, 19:1, 20:0, 20:1, 20:3ω3, 20:3ω6, 20:4ω6, 20:5ω3, 22:5ω3, 22:6ω3, and Unknowns D, E, F, G, and H.

The sum of the percentages of the fatty acids 18:2ω6, 20:3ω6, and 20:4ω6, was found and designated as percentage acids with omega 6 type unsaturation. The sum of the percentages of fatty acids 18:3ω3, 20:3ω3, 20:5ω3, 22:5ω3, and 22:6ω3 was also obtained and designated as the percentage acids with omega 3 type unsaturation. Percentage of acids containing one double bond was also calculated as the sum of the percentages of 14:1, 16:1, 17:1, 18:1, and 20:1. The acid 19:1 was omitted because it was only tentatively identified.

Concentration of each acid and of groups of acids in mg/100g muscle tissue was also determined and statistically analyzed. This concentration was obtained by:

$$\frac{\text{mg acid}}{\text{100 g muscle}} = \left(\frac{\text{g acid}}{\text{100 g lipid}}\right)\left(\frac{\text{g lipid}}{\text{100 gl muscle}}\right)\left(\frac{\text{1000 mg}}{\text{g acid}}\right)$$

where g acid/100 g lipid is% fatty acid; g lipid/100 g muscle is percent total lipids in muscle.

Analysis of Tocopherols and Total Lipid Content

Samples of beef (30 g) from each steer were extracted with chloroform-methanol by a method similar to that described by Ostrander and Dugan (1961). The main difference was that pyrogallol (4.5 g) and butylated hydroxytoluene (BHT) (.12 g BHT/915 mls $CHCL_3$) were added at the beginning of the blending stage to minimize losses of tocopherols during extraction. Percentage of total lipids in the beef were determined on the chloroform extract by the method described by Melton et al. (1979). For each sample, the chloroform layer was evaporated to dryness in a rotary evaporator at 60°C under vacuum. The samples were then reconstituted to 10 ml with a 1.5% isopropanol in hexane solvent. Samples were stored under nitrogen at -18°C no longer than one week prior to analysis.

The weight of lipid (g) per ml of isopropanol-hexane solution was determined just before analysis. For each sample, one ml of the solution was pipetted into a weighed, dried 50 ml beaker. The solvent was evaporated by drying the beaker under a hood for approximately 16 hours at room temperature and finally for 30 min. at 70°C in a vacuum oven. After cooling the beaker with sample in a desiccator, the weight of the beaker and dried lipid was obtained, and the weight of the lipid was the difference between

the weighed, dried beaker before sample addition and the weighed, dried beaker containing the dried lipid.

Analysis of tocopherols was performed on a Waters' Associate, Inc. High Performance Liquid Chromatograph (Water's Associate, Inc., Milford, MA), with a single injection Model UK6 universal liquid chromatograph injector, a Model 6000A solvent delivery system, and a Waters Lambda-Max Model 480 LC spectrophotometer coupled to a chromatopac-E1A electronic integrator, according to the method reported by Carpenter (1979). Conditions were:

Column: 4 mm x 30 cm μPorasil column coupled with a guard column;

Solvent: 1.5% isopropanol in hexane;

Flow rate: 1.5 ml/min

Wavelength of detection: 295 nm.

In order to quantitate the tocopherols in the beef, standard curves of α- and r-tocopherols were prepared. Concentrations of 0.01-0.35 μg of α-tocopherol and 0.01-0.30 μg of r-tocopherol were injected into the HPLC and the chromatograms for each injection obtained. For each group of samples measured at any one time, a linear regression relating peak height to concentration was run for all standards and used to analyze concentration. Peak height of the resulting tocopherol peak for each concentration was measured. Concentration of either α- or β-tocopherol in beef was calculated from the following equation:

$$\frac{\mu g \text{ tocopherol}}{g \text{ beef}} = \frac{(X)\ (\%\text{ total lipid})\ (10)}{(Y)\ (g \text{ lipid/ml solution})}$$

where X = μg of the tocopherol determined from the standard curve to be in the sample injected into the HPLC; and Y = μl of the sample injected.

V. SELECTION AND ANALYSIS OF PASTURE GRASS

Sample Handling

For each treatment except T1 at Ames Plantation, two pasture lots of the same types of grasses were utilized so that each pasture was replicated once. For treatment T1, four pasture lots were utilized; two lots were composed of fescue and clover, and two were composed of Sudan grass and sorghum pasture. In this manner, both types of pastures in treatment T1 were replicated once.

On September 2, 1981, samples were collected to represent each treatment. From each unprotected pasture lot, samples were collected from six areas. The samples were selected randomly to represent grass clippings. The six subsamples were combined, mixed, and represented one lot with a sample size of approximately 1000 g. These samples were transported on ice to Knoxville, Tennessee, where they were flushed with nitrogen and frozen at -18°C. Subsequently, 5 subsamples of about 20 g each were picked randomly from the each 1000 g sample. These subsamples were combined, mixed, and powdered with liquid nitrogen in a Waring blender. These 100 g samples were stored at -18°C until analyzed.

Chemical Analyses

Each grass sample was analyzed for percent moisture by a vacuum oven method according to AOAC method 14.003 (AOAC, 1980) and for total lipid content by the method of Ostrander and Dugan (1961). Fatty acid composition of total lipids from each grass sample was determined as described for analysis of fatty acids in beef. Percentages of the following acids were determined: 10:0, 12:0, 14:0, I15:0, 15:0,, I15:0, 16:0, I17:0, 17:0, 18:0, 18:1, 18:2ω6, 18:3ω3, 19:0, 20:0, 20:3, 20:5, 21:0, 22:0, 23:0, 24:0, 26:0, and four unknowns (AA, CC, DD, and EE) by the method of Melton et al. (1982b).

VI. STATISTICAL ANALYSIS

The fatty acid composition of beef lipid, plus total lipid content and α- and r-tocopherol content in beef were statistically analyzed as a function of days steers were fed on a corn based ration (DOF) and treatment or pasture type (TMT) and DOF x TMT interaction (Table 3) by the General Linear Model (GLM) procedure of Statistical Analysis Systems (SAS) (Barr et al., 1979). The sum of squares for variables which were significantly affected by DOF were partitioned into linear, quadratic, cubic, and quartic effects by orthogonal polynomials. Duncan's Multiple range test in SAS was used to separate significantly different means among treatments. When significant interactions were found ($P<.0.10$) DOF sum of squares for each treatment were separated by orthogonal polynomials.

TABLE 3. Analysis of Variance of Fatty Acid Composition, Tocopherol Content, and Flavor of Beef Samples

Source	Degrees Freedom
Days on feed (DOF)	4
Treatment (TMT)	4
DOF x TMT	16
Steers (DOF, TMT)[a]	40

[a]Error term; for many variables the number for degrees of freedom was less because samples from steers were lost.

The GLM procedure was also used for the statistical analysis of the Quantitative Descriptive Analysis (QDA) data. For each steer, the intensity of each flavor descriptor from QDA was averaged across panel members, and the effects of DOF, TMT, and DOF x TMT on these means were determined. Significant DOF effects, TMT effects and DOF x TMT interactions were separated in the same manner as the fatty acid data. In addition, simple correlation coefficients between each flavor descriptor and all objective measurements on beef samples were determined by the SAS program.

The fatty acid concentration of grass lipids from the two pasture types in treatment one (T1) were analyzed by analysis of variance where pasture type X sampling site was the error term. The fatty acid concentrations of the last pasture type grazed in treatment one and the pasture types in the other four treatments were analyzed by the GLM procedure according to analysis of variance shown in Table 4. Significant differences among treatments were partitioned by Duncan's Multiple Range Test (Barr et al., 1979).

TABLE 4. Analysis of Variance for Pasture Grasses

Source	Degrees freedom
Treatment (TMT)	4
Error[a]	5

[a]Includes sampling site and sampling site by treatment interaction.

CHAPTER IV

RESULTS

I. QUANTITATIVE DESCRIPTIVE ANALYSIS OF FLAVOR

Means for each flavor descriptor at 0, 28, 56, 84, and 112 days steers were fed a corn based finishing ration are shown in Table 5. In general, as time steers were fed corn increased from 0 to 112 days the desirable beef fat aroma and flavor increased linearly in intensity, while the undesirable milky-oily aroma and flavor decreased linearly in intensity. Equations showing these significant effects are presented in Table 6. There were no significant changes over time for the intensities of sour flavor, liver flavor, and raw or blood like flavor.

II. TOTAL LIPID CONCENTRATION IN BEEF

The total lipid concentration of the longissimus muscle of steers fed corn up to 112 days is given in Table 7. The percentage of total lipid increased from 5.62% at 0 day on corn to an estimated maximum of 8.00% at approximately 36 days on corn before decreasing to a minimum of 6.95% at 84 days on corn and then increasing to 8.54% at 112 days.

TABLE 5. Means of Flavor Descriptor Intensities of Beef From Steers Fed Corn up to 112 Days

Flavor Descriptor	Days steers were fed corn				
	0	28	56	84	112
	Intensity in mm[a]				
Milky-oily aroma[b]	71.88	65.21	60.52	55.23	57.41
Beef fat aroma[b]	60.92	65.59	64.07	71.58	67.88
Milky-oily flavor[b]	79.79	70.33	63.78	55.37	57.68
Beef fat flavor[b]	60.57	64.04	73.32	78.29	80.90
Sour flavor	47.92	50.63	47.92	45.07	47.08
Liver flavor	36.57	34.26	38.85	35.39	39.40
Raw flavor	29.46	28.01	28.14	32.37	32.04

[a]150 mm scale where 140 = strong and 10 = weak.

[b]These descriptors were significantly affected by days steers were fed corn ($P<.05$).

TABLE 6. Equations for Flavor Intensities Significantly Affected by Days Steers Were Fed Corn

Flavor Intensities	Equation[a]
Milky-oily aroma	Y = 69.94 - 0.1411X
Beef fat aroma	Y = 62.02 + 0.07116X
Milky-oily flavor	Y = 77.09 = 0.2124X
Beef fat flavor	Y = 60.55 + 0.1948X

[a]Y = intensity in mm, X = days steers were fed corn.

TABLE 7. Total Lipid Concentration in Longissimus Muscle of Steers Fed Corn up to 112 Days

Item	Days steers were fed corn				
	0	28	56	84	112
	---------- %[a] ----------				
Lipid	5.62	7.84	7.79	6.95	8.54

[a]Equation showing effect ($P<0.05$) of days on corn (Y) on percentage lipid (X) is $Y=5.60 + 0.15848 X - 0.0031712X^2 + 1.7755X10^{-5}X^3$.

III. FATTY ACID COMPOSITION EXPRESSED IN PERCENTAGE

The average percentage of each fatty acid in the intramuscular lipids from steers finished on corn from 0 to 112 days are shown in Table 8. Equations showing the significant effects of days steers were fed corn on the fatty acid composition are given in Table 9. Acids 8:0, 9:0, AI15:0, I16:0, I-, 17:0, 19:0, 19:1, and 20:3ω6 are tentative identifications. Possible identities for the unknown acids are D = Iso 18:0, E = 22:3ω9, F = 22:4ω6 or 22:5ω6, G = 22:?, and H = 22:?. There were significant differences ($P<0.05$) due to days steers were fed corn in the relative percentages of caprylic (8:0) nonanoic (9:0), capric (10:0), lauric (12:0), tridecanoic (13:0), myristic (14:0), myristoleic, (14:1), anteisopentadecanoic (AI15:0), isopentadecanoic (I15:0), pentadecanoic (15:0, isopalmitic (I16:0), palmitic (16:0), isoheptadecanoic (I17:0), stearic (18:0), oleic (18:1ω9), linoleic (18:2ω6), linolenic (18:3ω3), nonadecanoic (19:0), nonadecenoic (19:1), arachidic (20:0), gadoleic (20:1ω9), eicosatrienoic ω3 (20:3ω3) eicosatrienoic ω6 (20:3ω6), arachidonic (20:4ω6), eicosapentaenoic ω3 (20:5ω3), docosapentaenoic ω3 (22:5ω3), docosahexaenoic ω3 (22:6ω3), and unknowns D, F, and H. The percentages of 13:0, 19:1, and 20:0 decreased linearly and the percentages of 19:0 and 20:1 increased linearly across days (0 to 112) steers were fed corn (Tables 8 and 9). Over time steers

TABLE 8. Mean Fatty Acid Composition of Total Lipid of the Longissimus Muscle From Steers Fed Corn 0 to 112 Days

Fatty Acid	Days steers were fed corn: 0 (N=14)	28 (N=12)	56 (N=14)	84 (N=13)	112 (N=11)
	%				
8:0[abc]	0.003	0.008	0.036	0.011	0.007
9:0[ab]	0.004	0.008	0.011	0.005	0.002
10:0[a]	0.014	0.014	0.040	0.026	0.038
11:0	0.004	0.016	0.020	0.002	0.005
12:0[a]	0.026	0.033	0.055	0.044	0.059
13:0[a]	0.031	0.019	0.015	0.010	0.008
14:0[a]	1.885	1.968	2.425	2.368	2.998
14:1[a]	0.235	0.483	0.450	0.491	0.760
AI15:0[ab]	0.034	0.028	0.014	0.008	0.014
I15:0[a]	0.333	0.196	0.161	0.128	0.131
15:0[a]	0.950	0.506	0.310	0.183	0.339
I16:0[ab]	0.461	0.614	0.653	0.559	0.597
16:0[a]	23.328	24.504	23.870	23.537	25.242
16:1[a]	3.418	3.570	3.749	3.849	5.208
I17:0[ab]	0.052	0.060	0.035	0.024	0.030
17:0	1.271	1.298	1.469	1.299	1.358
17:1[a]	0.940	1.021	1.150	1.072	1.143
18:0[a]	17.811	15.194	13.745	13.721	12.891
18:1 ω 9[a]	38.396	41.155	42.333	44.772	41.118
18:2 ω 6[a]	3.790	4.701	5.233	4.740	4.368
18:3 ω 3[a]	1.195	0.641	0.384	0.417	0.396
19:0[ab]	0.077	0.131	0.063	0.049	0.037
19:1[ab]	0.448	0.373	0.326	0.292	0.286
20:0[a]	0.102	0.091	0.069	0.061	0.062
20:1[a]	0.243	0.284	0.359	0.353	0.373
20:3 ω 6[a]	0.576	0.474	0.403	0.384	0.279
20:3 ω 3[ac]	0.166	0.057	0.035	0.035	0.039
20:4 ω 6[a]	1.606	0.781	0.997	0.657	0.865
20:5 ω 3[a]	0.797	0.326	0.335	0.194	0.193
22:5 ω 3[a]	0.963	0.515	0.545	0.321	0.317
22:6 ω 3[a]	0.016	0.074	0.075	0.032	0.059
D[d]	0.728	0.689	0.568	0.427	0.614
E[d]	0.014	0.017	0.002	0.000	0.007
F[d]	0.020	0.046	0.003	0.000	0.006
G[d]	0.026	0.035	0.033	0.023	0.032
H[d]	0.038	0.071	0.030	0.012	0.018

[a]These acids were significantly affected by day steers were fed corn ($P<.0.05$).

[b]Tentatively identified.

[c]A significant day steers were fed corn by treatment interaction was found ($P<.0.05$).

[d]Possible identification: D = branched chain saturated C18 acid; E = 22:3w9; F = 22:4ω6 or 22:5ω6; G = 22:? and H = 22:?

TABLE 9. Equations Showing Significant Effect of Days Steers were Fed Corn on Fatty Acid Composition of the Longissimus Muscle

Acid	Equation[a]
8:0	$Y=0.002762-0.002473\ x + 0.0002531X^2 - 2.3112x10^{-6}X^3 + 1.0308x10^{-8}X^4$
9:0	$Y=0.004154 + 0.0002198X - -2.24184x10^{-6}X^2$
10:0	$Y-0.01225 - 0.002385\ X + 0.0001361\ X^2 -2.0128x10^{-6}X^3 - 8.9873X10^{-9}$
12:0	$Y=0.02409 - 0.001399\ X + 9.9119X10^{-5}X^2 -1.5466x10^{-6}X^3 + 7.1215x10^{-9}X^4$
13:0	$Y=0.02766 - 0.00019725\ X$
14:0	$Y=1.8102 + 0.0092097\ X$
14:1	$Y=0.2361 + 0.015634\ X - 0.000314\ X^2 + 1.9330x10^{-6}X^3$
AI15:0	$Y=0.03614 - 0.00054158\ X + 2.9024x10^{-6}\ X^2$
I15:0	$Y=0.3216 - 0.0044442\ X + 2.4827x10^{-5}X^2$
15:0	$Y=0.93325 - 0.01794\ X + 0.00011181\ X^2$
I16:0	$Y=0.48145 + 0.0045222\ X - 3.3775x10^{-5}X^2$
16:0	$Y=23.3938 + 0.009148\ X - 0.002278\ X^2 + 1.4367x10^{-5}X^3$
I17:0	$Y=0.05251 + 0.00088754\ X - 3.0929x10^{-5}X^2 + 1.9020x10^{-7}X^3$
18:0	$Y=17.7793 - 0.095876\ X + 0.0004887\ X^2$
18:1	$Y-38.1679 + 0.14604\ X -0.00101296\ x^2$
18:2ω6	$Y=3.6839 + 0.04528\ X - 0.00035792\ X^2$
18:3ω3	$Y=1.1849 - 0.02862\ X + 0.00033636\ X^2 - 1.2793x10^{-6}X^3$
19:0	$Y=0.0745 + 0.008430\ X - 0.0003286\ X^2 + 3.9898x10^{-6}X^3 - 1.5668x10^{-8}X^4$
19:1	$Y=0.4188 - 0.00137985\ X$
20:0	$Y=0.09771 - 0.00038664\ X$
20:1	$Y=0.25426 + 0.0012232\ X$
20:3ω3	$Y=0.142284 - 0.0030571\ X + 1.96214x10^{-5}X^2$
20:3ω6	$Y=0.58023 - 0.0053607\ X + 2.98327x10^{-5}X^2$

TABLE 9. (Continued)

Acid	Equation[a]
20:4ω6	$Y=1.5131 - 0.02002\ X + 0.0001310\ X^2$
20:5ω3	$Y=0.7592 - 0.012923\ X + 7.2020\times10^{-5}X^2$
22:5ω3	$Y=0.9275 - 0.011745\ X + 5.6859\times10^{-5}X^2$
22:6ω3	$Y=0.01591 + 0.004449\ X - 9.0108\times10^{-5}X^2 + 4.7933\times10^{-7}X^3$
D	$Y=0.7094 + 0.005178\ X - 0.002352\ X^2 + 1.6158\times10^{-6}X^3$
F	$Y=0.01922 + 0.001795\ X - 5.0370\times10^{-5}X^2 + 2.9879\times10^{-7}X^3$
H	$Y=0.03885 + 0.002488\ X - 6.5556\times10^{-5}X^2 + 3.7303\times10^{-7}X^3$

[a]Y = percentage of total fatty acids; X = days steers were fed corn.

were fed corn percentages of AI15:0, 15:0, 18:0, 20:3ω3, 20:3ω6, 20:5ω3, and 22:5ω3 decreased at a decreasing rate. The percentages of I17:0, 18:3, and unknowns D, F, and H generally decreased significantly ($P<0.05$) over time steers were fed corn while percentages of 10:0, 16:0, and 22:6ω3 increased but had a cubic relation with days steers were fed corn. A significant quartic effect due to time on feed was found for 8:0, 12:0, and 19:0.

Significant day steers were fed corn by treatment interactions were found for percentages of 8:0 and 20:3ω3. Each combination of treatment by day steers were fed corn are given in Appendix C, page 95, and equations showing significant effects across time steers were fed corn on each acid for each treatment are shown in Appendix C, page 95.

IV. FATTY ACID COMPOSITION EXPRESSED ON A WEIGHT BASIS

The average amount of each fatty acid calculated in mg/100g muscle is found in Table 10. Equations showing the significant effects of days steers were fed corn on the concentration of the fatty acids expressed on a weight basis of the longissimus muscle is given in Table 11. There were significant effects due to time on feed on the concentrations of 8:0, 9:0, 10:0, 12:0, 13:0, 14:0, 14:1, AI15:0, I15:0, 15:0, I16:0, 16:0, 16:0, I17:0, 17:0, 17:1, 18:1, 18:2ω6, 18:3ω3, 19:0, 20:0, 20:1, 20:3ω3, 20:3ω6, 20:4ω6, 20:5ω3, 22:5ω3, 22:6ω3, and unknowns D, F, G, and H. The concentrations of 10:0, 12:0, and 20:1 increased linearly and concentrations

TABLE 10. Mean Concentrations of Lipids and Fatty Acids in Longissimus Muscle From Steers Fed Corn 0 up to 112 Days

Fatty Acid	Days steers were fed corn: 0	28	56	84	112
	mg acid/100 g muscle				
8.0[abc]	0.2	0.6	2.7	0.8	0.5
9.0[abc]	0.2	0.7	0.8	0.3	0.1
10:0[a]	0.7	1.0	3.1	1.8	3.2
11:0	0.2	1.2	1.4	0.2	0.4
12:0[a]	1.4	2.4	4.3	3.0	5.0
13:0[a]	1.7	1.4	1.2	0.7	0.7
14:0[a]	105.6	156.4	187.9	164.1	258.7
14:1[a]	13.6	36.9	35.1	34.0	66.9
AI15:0[ab]	1.9	2.2	1.1	0.6	1.2
I15:0[a]	18.2	15.5	12.4	8.9	11.1
15:0[a]	51.3	4.07	23.4	12.4	27.4
I16:0[ab]	25.9	47.6	50.4	39.9	50.9
16:0[a]	1315/7	1908.4	1857.3	1638.4	2147.0
16:1[a]	192.0	281.3	290.2	265.8	448.1
I17:0[ab]	2.9	4.8	2.8	1.7	2.8
17:0[a]	70.4	101.8	113.8	93.4	114.1
17:1[a]	52.3	80.0	89.0	75.8	96.5
18:0	1002.9	1180.9	1084.6	944.8	1089.6
18:1[a]	2170.8	3201.9	3295.9	3118.1	3471.7
18:2ω6[a]	203.7	368.8	402.7	331.0	364.3
18:3ω3[a]	66.8	49.3	30.4	28.5	32.8
19:0[ab]	4.2	10.0	4.9	3.5	3.0
19:1[ab]	24.3	29.5	25.7	20.9	23.4
20:0[a]	5.6	7.3	5.4	4.3	5.1
20:1[a]	13.7	22.6	28.6	24.9	31.0
20:3ω3[a]	8.1	4.7	3.0	2.4	2.9
20:3ω6[a]	31.8	37.2	32.1	19.2	31.4
20:4ω6[a]	86.8	62.4	76.8	44.5	71.3
20:5ω3[a]	44.9	25.9	26.8	13.4	15.8
22:5ω3[a]	53.9	40.6	42.6	21.8	26.1
22:6ω3[a]	1.0	6.1	5.9	2.3	4.9
Unknowns					
D[ad]	39.8	54.2	45.1	30.1	50.2
E[d]	0.8	1.2	0.1	0.0	0.7
F[ad]	1.0	3.3	0.2	0.0	0.5
G[ad]	1.4	2.7	2.6	1.6	2.7
H[ad]	2.1	5.3	2.5	0.8	1.5

[a]Concentrations of these acid were significantly affected by days steers were fed corn ($P<0.05$).

[b]Tentatively indentified.

[c]A significant days steers were fed corn by treatment interaction were found on the concentrations of these acids.

[d]Possible identification of these acids are given in Table 8.

TABLE 11. Equations Showing Significant Effect of Days Steers Were Fed Corn on Concentrations of Fatty Acids Expressed on A Weight Basis of the Longissimus Muscle

Acid	Equation[a]
8:0	$Y=0.00350522 + 0.06108\ X - 0.0005180\ X^2$
9:0	$Y=0.2596 + 0.01834\ X - 0.0001830\ X^2$
10:0	$Y=0.8172 + 0.02069\ X$
12:0	$Y=1.6707 + 0.02788\ X$
13:0	$Y=1.6713 - 0.009726\ X$
14:0	$Y=102.62 + 4.3921\ X - 0.08623\ X^2 + 0.0005283\ X^3$
14:1	$Y=13.458 + 1.6876\ X - 0.03605\ X^2 + 0.0002253\ X^3$
AI15:0	$Y=1.9339 + 0.4001\ x - 0.001483\ X^2 + 9.5211X10^{-6}X^3$
I15:0	$Y=17.4060 - 0.07649\ X$
15:0	$Y=51.2274 - 0.02123\ X - 0.01562\ X^2 + 0.00012410\ X^3$
I16:0	$Y=25.4851 + 1.5480\ X - 0.02905\ X^2 + 0.0001538\ X^3$
16:0	$Y=1309.57 + 43.6611\ X - 0.90796\ X^2 + 0.005217\ X^3$
16:1	$Y=189.22 + 7.6323\ X - 0.17034\ X^2 + 0.001094\ X^3$
I17:0	$Y=2.9452 + 0.1523\ X - 0.003993\ X^2 + 2.3485X10^{-5}X^3$
17:0	$Y=69.1343 + 2.4126\ X - 0.044077\ X^2 + 0.0023218\ X^3$
17:1	$Y=51.3918 + 2.0404\ X - 0.03724\ X^2 + 0.0020121\ X^3$
18:1ω9	$Y=2168.84 + 63.2264\ X - 1.0855\ X^2 + 0.005578\ X^3$
18:2ω6	$Y=201.021 + 10.8930\ X - 0.1855\ X^2 + 0.00090144\ X^3$
18:3ω3	$Y=67.9331 - 0.9414\ X + 0.005579\ X^2$
19:0	$Y=4.2085 + 0.7246\ X - 0.02622\ X^2 + 0.0003066\ X^3 - 1.1703x10^{-6}X^4$
20:0	$Y=5.6588 + 0.1341\ X - 0.003539\ X^2 + 2.0545X10^{-5}X^3$
20:1	$Y=16.7409 + 0.1332\ X$
20:3ω3	$Y=6.8125 - 0.04751\ X$
20:3ω6	$Y=31.3556 + 0.7965\ X - 0.002237\ X^2 + 0.0001359\ X^3$
20:4ω6	$Y=86.7469 - 4.2933\ X + 0.1914\ X^2 - 0.002832\ X^3 + 1.2987x10^{-5}X^4$

TABLE 11 (Continued)

Acid	Equation
20:5ω3	$Y=39.9147 - 0.2601\ X$
22:5ω3	$Y=52.2521 - 0.2717\ X$
22:6ω3	$Y=0.8553 + 0.3991\ X - 0.008188\ X^2 + 4.4088\times10^{-5}X^3$
D	$Y=39.4063 + 1.4398\ X - 0.03698\ X^2 + 0.00022276X^3$
F	$Y=1.1722 + 0.1440\ X - 0.003905\ X^2 + 2.3061\times10^{-5}X^3$
G	$Y=1.3449 + 0.1096\ X - 0.002375\ X^2 + 1.3381\times10^{-5}X^3$
H	$Y=2.1337 + 0.2331\ X - 0.005694\ X^2 + 3.1887\times10^{-5}X^3$

[a]Y = concentrations of the acid in mg/100g muscle and X = days steers were fed corn.

of 13:0, I15:0, 20:3ω3, 20:5ω3, and 22:5ω3 decreased linearly across time steers were fed corn. Over days on feed, 8:0 and 9:0 first increased and then decreased in a quadratic manner while 18:3 decreased at a decreasing rate. The concentrations of 14:0, 14:1, AI15:0, 15:0, I16:0, 16:0, I17:0, 17:0, 17:1, 18:1ω9, 18:2ω6, 20:0, 20:3ω6, 22:6ω3, and unknowns D, F, G, and H had significant cubic relations with days on feed. As days steers were fed corn increased, the concentrations of 14:0, 14:1, I16:0, 16:0, 17:0, 17:1, 18:1, 18:2, and 22:6ω3 increased except for 84 days, but beef from steers fed corn 84 days had higher amounts of these acids than that of steers fed corn 0 days. Across time steers were fed corn, the concentrations of 15:0 generally decreased and there were no general trends in the way that concentrations of AI15:0, I17:0, 20:0, 20:3ω6, and unknowns D, F, G, and H varied across days corn was fed. A significant quartic effect was found between days fed corn and concentrations of 19:0 and 20:4ω6. In general, beef from steers fed corn had lower concentrations of 20:4ω6 than beef from steers just off-grass (0 day), but no consistent trend was found across days fed corn for the 19:0 content. Significant days steers were fed corn by treatment interactions were found for 8:0 and 9:0 (Table 10). The concentrations of each acid for each treatment across days steers were fed corn is shown in Appendix C, page 95, and equations showing the significant effect of days on corn on the concentration of each acid in each treatment is given in Appendix C, page 95.

The concentrations of some of the fatty acids expressed in mg/100g muscle were also significantly affected by treatment or the type of pasture the steers grazed prior to being fed corn and the concentrations of these acids among treatments are shown in Table 12. Beef from steers which grazed Midland Bermuda grass, Kentucky Fescue 31, and clover (T3) had lower concentrations of 20:4ω6 than beef from steers grazing any other type pasture, and lower concentrations of 20:3ω3 than beef from steers grazing orchard grass and clover (T2) or bermuda grass and fescue pastures that were fertilized with nitrogen (T4). Beef from steers which grazed orchard grass and clover (Treatment T2) had higher levels of 22:6ω3 than that from steers on all other type pastures with the exception of steers which grazed Sudan grass and sorghum (T1). Beef from steers grazing sudan grass and sorghum (T1) or orchard grass and clover (T2) had higher levels of 14:0 than beef from steers on pasture containing bermuda grass (T3 and T4), and higher levels of fatty acid unknown D (possible identification, branched chain, 18 carbon saturated acid) than beef from steers in T3.

V. GROUPS OF FATTY ACIDS

Concentrations of groups of unsaturated fatty acids in the intramuscular lipid, are expressed in two different ways in Table 13. Equations showing the significant effect of days steers were fed a corn-based ration on these fatty acid group concentrations are presented in Table 14. The percentages of the monounsaturated

TABLE 12. Concentrations of Fatty Acids Which Were Significantly Affected by Treatment and Which Were Extracted From the Longissimus Muscle of Steers Fed Corn 0 up to 112 Days

Acid	Treatment				
	T1	T2	T3	T4	T5
	mg acid/100 g muscle				
	(n=14)	(n=11)	(n=13)	(n=14)	(n=11)
14:0	193.9^{a}	193.0^{a}	151.8^{b}	148.3^{b}	179.4^{ab}
20:3ω3	4.0^{ab}	7.1^{a}	1.0^{b}	5.5^{a}	3.7^{ab}
20:4ω6	70.1^{a}	81.9^{a}	42.5^{b}	74.0^{a}	76.8^{a}
22:6ω3	5.1^{ab}	7.2^{a}	2.8^{b}	3.0^{b}	2.1^{b}
Unknown D	47.0^{a}	51.5^{a}	33.8^{b}	44.3^{ab}	41.6^{ab}

^{AB}Means which are in a row and which bear unlike superscripts are significantly different ($P<0.05$).

TABLE 13. Mean Concentrations of Fatty Acids Grouped by Types of Unsaturation in the Longissimus Muscle of steers Fed Corn From 0 up to 112 Days

Type unsaturated acid	Days steers were fed corn				
	0	28	56	84	112
	----------	%	----------		
Monounsaturated[ab]	43.28	46.52	48.04	50.54	48.60
Omega-6[c]	5.81	5.96	6.63	5.68	5.62
Omega-3[bd]	3.12	1.61	1.37	1.00	1.00
	---------	mg/100g muscle		----------	
Monounsaturated[ab]	2442.3	3622.7	3738.8	3518.6	4114.1
Omega-6[bc]	322.2	468.4	511.6	394.7	466.9
Omega-3[de]	174.7	126.6	108.7	68.3	82.5

[a]Summation of the concentrations of the following acids: 14:1, 16:1, 17:1, 18:1, and 20:1.

[b]A significant effect due to days steers were fed corn was found for this variable.

[c]Summation of the concentrations of the following acids: 18:2ω6, 20:3ω6, and 20:4ω6.

[d]Summation of the concentrations of the following acids: 18:3ω3, 20:3ω3, 20:5ω3, 22:5ω3, and 22:6ω3.

[e]A significant ($P<0.05$) treatment x days steers were fed corn interaction was found.

TABLE 14. Equations Showing the Effect of Days Steers were Fed Corn on the Concentrations of Fatty Acids Grouped by Type of Unsaturation

Type unsaturated acids	Equation[a]
Monounsaturated[b]	$Y_1 = 43.14 + 0.14592\ X - 0.0008311\ X^2$
Omega-3[b]	$Y_1 = 3.01 - 0.04653\ X + 0.00026075\ X^2$
Monounsaturated[b]	$Y_2 = 2436.2 + 75.2112\ X - 1.3389\ X^2 + 0.007148\ X^3$
Omega-6[b]	$Y_2 = 316.3 + 11.5405\ X - 0.21699\ X^2 + 0.0011196\ X^3$

[a] Y_1 = concentration of acid in percentage of total fatty acids: Y_2 = concentration of acid in mg/100g muscle; and X = days steers were fed corn.

[b] See Table 13.

group (a summation of the following fatty acids: 14:1, 16:1, 17:1, 18:1, and 20:1) and the omega-3 group (a summation of the following fatty acids: 18:3ω3, 20:3ω3, 20:5ω3, 22:5ω3, and 22:6ω3) changed significantly across time on feed. The monounsaturated group percentage increased at a decreasing rate. The omega-3 group percentage decreased at a decreasing rate. The omega-6 group (a summation of the following fatty acids: 18:2ω6, 20:3ω6, and 20:4ω6) on a percentage basis was not significantly affected by days steers were fed corn.

On a weight basis, (expressed in mg/100g muscle) the monounsaturated and the omega-6 group were significantly affected by time on feed. Concentrations of both groups increased in a cubic manner (Tables 13 and 14) across days on corn.

The omega-3 group expressed in mg/100g muscle had a significant treatment x days steers were fed corn interaction. Concentrations of omega-3 acids for each treatment--day fed corn combination are found in Table 15. Equations showing the significant effects of days steers were fed corn on omega-3 concentration for each treatment are presented in Table 16.

The omega-3 acid concentration in beef from steers that grazed sudan grass and sorghum pasture (T1) decreased linearly as days steers were fed corn increased. The concentration of these acids in beef from steers that grazed fescue and clover (T5) decreased at a decreasing rate across days steers were fed corn. The concentration of omega-3 acids in beef from steers that grazed orchard

TABLE 15. Concentration of the Omega-3 Type Unsaturated Fatty Acids of the Longissimus Muscle for Each Treatment and Days Steers Were Fed Corn Combination

Treatment	Days steers were fed corn				
	0	28	56	84	112
	mg/100g muscle				
T1[a]	177.6	126.7	112.8	78.4	71.1
T2[b]	155.3	205.7	171.5	60.4	93.3
T3[b]	184.7	61.2	70.2	74.5	78.5
T4[b]	156.9	158.2	107.6	74.4	80.1
T5[c]	216.2	113.9	102.5	42.8	90.2

[a]A significant linear effect was found across days steers were fed corn.

[b]A significant cubic effect was found across days steers were fed corn.

[c]A significant quadratic effect was found across days steers were fed corn.

TABLE 16. Equations Showing Significant Effects of Days Steers Were Fed Corn on Concentrations of Omega-3 Type Acids (mg/100g Muscle) for Each Treatment

Treatment	Equation[a]
T1	$Y = 166.46 - 0.9637\ X$
T2	$Y = 153.22 + 5.9876\ X - 0.1555\ X^2 + 0.0008664\ X^3$
T3	$Y = 181.70 - 6.6232\ X + 0.1071\ X^2 - 0.0005041\ X^3$
T4	$Y = 157.58 + 1.1331\ X - 0.05375\ X^2 - 0.00033485\ X^3$
T5	$Y = 212.77 - 3.5087\ X + 0.021024\ X^2$

[a]Y = concentration of acids in mg/100g muscle and X = days steers were fed corn.

grass (T2) or pastures that contained bermuda grass (T3 and T4) had a cubic relationship with days steers were fed corn. The concentration in beef from steers grazing on bermuda grass and fescue pasture that had been fertilized (T4) and on orchard grass and clover (T2) increased slightly the first 28 days steers were fed corn before decreasing with increasing days on corn. However, the omega-3 concentration in beef from steers grazing bermuda grass, fescue, and clover pasture (T3) decreased rapidly during the first days steers were fed corn and then increased slightly thereafter.

VI. TOCOPHEROL CONTENT OF BEEF

Means of tocopherol content in beef across days on feed are shown in Table 17, Equations showing the significant effect of days on feed for these variables are given in Table 18. Alpha-tocopherol decreased significantly across time at a decreasing rate. Gamma tocopherol first increased from 0 to 28 days on corn before decreasing at a decreasing rate from 28 to 112 days on corn.

VII. CORRELATIONS OF FLAVOR TO CHEMICAL CHARACTERISTICS

Table 19 shows significant correlation coefficients between flavor descriptive terms and some chemical components of beef. Concentrations of the fatty acids expressed in percentages were correlated ($P<0.05$) with milky-oily aroma and flavor. (Correlation

TABLE 17. Tocopherol Content of the Longissimus Muscle from Steers Fed Corn up to 112 Days

Tocopherol	Days steers were fed corn				
	0	28	56	84	112
	μg/g beef				
Alpha[a]	8.51	5.26	3.66	3.14	2.76
Gamma[a]	1.17	1.62	0.33	0.22	0.27

[a]Concentration of these tocopherols were affected significantly by days steers were fed corn.

TABLE 18. Equations Showing Significant Effect of Days Steers were Fed Corn on Tocopherol Content of Longissimus Muscle

Tocopherol	Equation[a]
Alpha	$Y=8.38 - 0.1192574\ X + 0.0006294X^2$
Gamma	$Y= 5.60 + 0.03281\ X - 0.11737X^2 - 7.2354X10^{-6}X^3$

[a]Y = concentration of tocopherol in μg/g beef. X = days steers were fed corn.

TABLE 19. Significant Correlation Coefficients Between Intensity of Flavor Descriptors and Selected Chemical Components of Beef From Steers Fed Corn up to 112 Days

Component	Flavor descriptor			
	Milky-oily aroma	Beef-fat aroma	Milky-oily flavor	Beef-fat flavor
Fatty Acid[a]	Correlation Coefficient[b]			
10:0	--	--	--	--
12:0	-0.39	--	-0.43	0.41
13:0	0.39	-0.32	0.41	-0.40
14:0	-0.30	--	-0.37	0.37
14:1	--	--	-0.34	0.35
15:0	0.37	--	0.47	-0.35
16:1	-0.31	--	-0.34	0.35
18:0	--	--	--	-0.34
18:3ω3	0.50	-0.31	0.55	-0.46
19:0	--	--	0.30	-0.30
19:1	0.30	--	0.37	-0.30
20:0	--	--	0.37	-0.33
20:3ω3	0.40	-0.38	0.43	-0.41
20:3ω6	--	--	0.31	-0.30
20:5ω3	--	--	0.37	-0.31
22:5ω3	--	--	0.33	-0.33
Unknown D	--	--	0.33	--
Type Fatty Acid[c]				
Omega-3	0.41	--	0.49	-0.43
Monounsaturated	-0.32	--	-0.37	0.36
Alpha-tocopherol[d]	0.48	-0.29	0.58	-0.51

[a]Expressed in percentage of total fatty acids.

[b]Only those coefficients which are significant at the $P<0.05$ level or less are given.

[c]Based on type of unsaturation.

[d]Expressed in µg/g beef.

coefficients of fatty acids expressed in mg/100 g muscle with flavor descriptors are shown in Appendix D, page 98). Of all the fatty acids, linolenic acid (18:3 3), had the highest positive correlation coefficient with milky-oily aroma and flavor. However, of all the chemical variables α-tocopherol content had the highest overall positive correlation with milky-oily aroma and flavor. Other fatty acids positively correlated with milky-oily aroma and/or flavor included 13:0, 15:0, 19:0, 19:1, 20:0, 20:3ω3, 20:3ω6, 20:5ω3, 22:5ω3, D, and the group of omega-3 type fatty acids. Fatty acids positively correlated with beef fat aroma and/or flavor included 12:0, 14:0, 14:1, and 16:1. Fatty acids positively correlated with milky-oily aroma and flavor were negatively correlated with beef fat aroma and flavor and vice versa. At the $P<0.05$ level no variables were correlated with liver flavor or raw flavor and only 13:0 was positively correlated with sour flavor ($r = 0.33$).

VIII. ANALYSES OF PASTURE GRASSES

Lipid and Moisture Content

Total lipid concentration and percentage moisture of grasses in each treatment are given in Table 20. Total lipid content ranged from 0.89% in fescue and clover (T1) to 1.37% in orchard grass and clover (T2). Percentage moisture ranged from 69.3% in Midland Bermuda grass, fescue, and clover (T3) to 76.1% in fescue and clover (T1).

TABLE 20. Chemical Composition of Pasture Grasses in Each Treatment

Treatment	Grasses	Lipid %	Moisture %
T1	Fescue and clover	0.89	76.1
	Sudan and sorghum	1.28	74.1
T2	Orchard grass and clover	1.37	70.1
T3	Bermuda, fescue, and clover	1.24	69.3
T4	Bermuda and fescue (fertilized)	1.15	70.5
T5	Fescue and clover	1.26	71.1

Fatty Acid Composition

The fatty acid composition of the pasture grasses last grazed in each treatment are shown in Table 21. No significant differences were found in the fatty acid composition between the two types of pastures in Treatment T1; therefore, only the fatty acid composition of the pasture last grazed in T1 (sudan grass and sorghum) is given in Table 21. Few significant differences were found among treatments. The sudan grass and sorghum (T1) had a lower percentage of 16:0 and a higher level of AA than fescue and clover and a higher percentage of DD than any other treatment. Percentage 19:0 was highest in the fescue and clover (T5), lowest in bermuda grass and fescue with nitrogen fertilization (T4), and intermediate in the other three treatments. In addition, T3 bermuda grass, fescue, and clover had a higher level of 10:0 than any other treatment. The predominant fatty acid in the pasture grasses was either 18:2ω6 or 18:3ω3. High concentrations of 18:3ω3 were found in all types of grass.

TABLE 21. Fatty Acid Composition (Percentage) of Pasture Grasses

Fatty Acid	Treatment 1	2	3	4	5
	%				
10:0	0.20[b]	0.0[b]	0.94[a]	0.0	0.0
12:0	0.25	0.42	0.40	0.23	0.24
14.0	0.66	0.46	0.50	0.25	0.29
AI15:0	0.15	0.12	0.11	0.04	0.06
I15:0	0.96	9,53	0.40	0.36	0.25
I16:0	2.57	1.20	0.93	0.69	0.97
16.0	14.75[b]	18.91[ab]	20.42[ab]	18.91[ab]	21.73[a]
I17:0	0.19	0.10	0.10	0.08	0.10
17:0	0.40	0.20	0.22	0.17	0.21
18:0	2.18	1.77	4.11	1.88	2.48
18:1	4.34	3.14	6.58	3.50	4.37
18:2ω6	19.08	38.30	12.70	33.49	35.51
18:3ω3	33.26	22.97	43.13	32.22	26.33
19:0	0.41[b]	0.39[b]	0.33[b]	0.06[c]	0.55[a]
20:0	1.95	1.41	1.39	1.26	1.25
20:3ω3	1.31	0.36	0.35	0.06	0.55
20:3	0.76	0.21	0.27	0.30	0.47
21:0	0.79	0.22	0.21	0.25	0.20
22:0	2.58	1.30	1.53	1.29	0.78
23:0	0.79	0.49	0.51	0.77	0.29
24:0	3.72	1.62	1.76	1.37	0.95
26:0	3.71	2.55	0.73	0.00	0.38
Unknowns					
AA	0.49[a]	0.40[ab]	0.38[ab]	0.34[ab]	0.22[b]
CC	4.11	2.20	2.27	2.20	1.77
DD	0.33[a]	0.12[b]	0.11[b]	0.14[b]	0.04[b]
EE	0.05	0.61	0.19	0.12	0.06

[ab]Means which are significantly different ($P<.05$) have different superscripts.

CHAPTER V

DISCUSSION

I. FLAVOR OF GRASS-FINISHED BEEF VERSUS GRAIN-FINISHED BEEF

The results of the sensory analysis performed in this study (Quantitative Descriptive Analysis) are found in Tables 5 and 6, pages 33 and 34. These results are in agreement with Melton et al. (1982b) and Yeo (1982) who found that the desirable beef fat flavor and aroma increased in intensity and the undesirable milky-oily aroma and flavor decreased in intensity over time steers were fed a corn based ration. Yeo (1982) also reported that liver flavor was not affected by days steers were fed corn, however, he did report a small linear increase in raw flavor intensity. Melton et al. (1982b) reported a decrease in sour flavor intensity over time on feed while Yeo (1982) found a slight increase in sour flavor intensity over time on feed over days steers were fed corn. These results disagree with the results of the present study in that no significant change in sour flavor intensity was found. However, Melton et al. (1982b) analyzed ground beef. Yeo (1982) analyzed steaks and his results are in closer agreement with the present study. Several investigators have found a less desirable or less intense flavor in beef produced by grass compared to beef produced by grain including Bowling et al. (1977), Brown et al. (1979), Melton et al. (1982a,b), Melton (1983), and Reagan et al. (1977)

II. TOTAL LIPID AND FATTY ACID COMPOSITION IN BEEF

The fatty acid composition of beef in the present study was reported as relative percentage of total lipid and on a weight basis of muscle tissue because interesting facts may be obtained by comparing fatty acid composition reported by the two ways. Decreases in the percentage of any one fatty acid across days steers were fed corn could be due to two things: (1) a dilution effect since the total lipid content in beef increased across days steers were fed corn (Table 7, page 35), and (2) the replacement of the fatty acid in the lipid by other fatty acids. In the first instance, the weight of the fatty acid should remain fairly constant across days steers were fed corn; however, in the second instance, or a combination of the two, both the percentage and the weight of the fatty acid in the muscle would decrease across days steers were fed corn. Increases in the percentage of any one fatty acid across days fed corn could be due to (1) increased deposition of the fatty acid in the increasing beef lipid and/or (2) the fatty acid replacing another fatty acid in the existing lipid. In both ways, the weight of the fatty acid would increase in the muscle across days fed corn. No significant change in the percentage of the fatty acid across days steers were fed corn indicated possibly that the fatty acid was being deposited in the increasing lipid at the same percentage present in the existing lipid or was not being deposited in the increasing lipid but replacing some of the fatty acids

in the existing lipid. In either case, an increase in the weight of the acid in the muscle would be expected across days fed corn.

It is also necessary to consider the type of lipids which increased across days steers were fed corn to interpret the changes in the fatty acid composition. The concentration of phospholipids in lean muscle remains fairly constant regardless of the total lipid content (Pearson et al., 1977). Campbell and Harrill (1971) reported that the phospholipid content in lean muscle expressed as a percentage of the total lipid decreased linearly with increasing percentage of total lipid in the muscle. It seems likely, therefore, that the increasing lipid content in the beef across days fed corn found in the present study was due to deposition of triglycerides in the beef rather than phospholipids.

The fatty acids deposited in the increasing amounts of triglycerides in the beef with increasing days fed corn were 14:0, 14:1, 16:0, 16:1, 17:0, 17:1, 18:1, 18:2ω6, and 20:1. The percentage of each acid and the weight of each acid in the muscle increased across days fed corn (Tables 8 and 10, pages 37 and 42, respectively). On the other hand, 18:0 was not deposited in the increasing lipid, nor was it likely replaced in the existing lipid, since its percentage decreased across days fed corn, and the weight of 18:0 in the muscle did not change significantly.

Long chain (18-22 carbons) polyunsaturated fatty acids in beef as were measured in the present study are located primarily in the phospholipids (Pearson et al., 1977). The fatty acids with

omega-6 (ω6) type unsaturation (20:3ω6 and 20:4ω6) are formed from dietary 18:2ω6 and those with omega-3 (ω3) type unsaturation (20: 3ω3, 20:5ω3, 22:5ω3, and 22:6ω3) are formed from dietary 18:3ω3 (Gunstone, 1967; Pearson et al., 1977). A grass diet which normally has high levels of 18:3ω3 would be expected to produce beef with higher levels of ω3 type unsaturated fatty acids than a grain or corn diet which has high levels of 18:2ω6. In contrast, beef produced on corn should have higher levels of ω6 type unsaturated fatty acids. Such results were found in the present study (Table 13, page 49).

It can be seen in Table 13 that with increasing days steers were fed corn the percentage of ω3 fatty acids as well as their weight in the muscle decreased. In contrast, the percentage of the ω6 fatty acids remained the same but their actual weight in the muscle increased. In view of the following facts: (1) that the unsaturated fatty acids are found primarily in the phospholipids (Pearson et al., 1977); (2) that ingested fatty acids are more rapidly incorporated into phospholipids than triglycerides in growing and mature steers (Kimoto et al., 1974) and (3) the concentration of the phospholipids apparently changes little in the increasing lipid across days fed corn, these results may be interpreted as follows. As steers were fed corn the ω3 type fatty acids in the beef phospholipids were partially replaced by the ω6 fatty acids formed from the corn diet. This is shown by the increased level of ω6 acids expressed on a muscle weight basis in beef from steers

fed corn. However, when the ω6 fatty acid content was expressed on a percentage basis, the dilution effect of increased levels of saturated and monounsaturated fatty acids in the triglycerides prevented a significant increase in the percentage across days fed corn (Table 13, page 49).

Analysis of fatty acid composition in beef in this present investigation is one of the most extensive that has been completed in a study of beef produced on grass compared to that produced on grain. Melton (1983) pointed out that most investigators who have studied the effect of diet on beef fatty acid composition have not determined the branched-chain fatty acids, odd-number carbon chain length fatty acids or the long chain (20-22) polyunsaturated fatty acids (Cross and Dinius, 1978; Dinius and Cross, 1978; Miller et al., 1981; Schroeder et al., 1980; Westerling and Hedrick, 1979; Williams et al., 1980).

In general, beef produced on grass tends to have lower percentages of monounsaturated fatty acids and higher percentages of saturated fatty acids than beef produced on grain (Melton, 1983; Oltjen and Dinius, 1975). These same results were found in the present study as shown in Table 10, page 42. The monounsaturated fatty acids include: 14:1, 16:1, 17:1, 18:1, and 20:1, and the saturated fatty acids include 14:0, 16:0, 18:0, and 20:0.

Results reported by other researchers (Melton et al., 1982a,b; Westerling and Hedrick, 1979; Yeo, 1982) agree with this study's results of higher percentages of 18:3ω3 and 20:4ω6 in beef produced

on grass compared with that produced on grain (Table 10, page 42.) However, as pointed out previously, many researchers reporting the effect of diet on beef fatty acid composition did not determine 20:3 ω 3, 20:3ω6, 20:5ω3, 22:5ω3, and 22:6ω3 acids reported in the present study. In a study similar to this, Yeo (1982) determined the percentages of 20:3, 20:4, and 22:5. Melton (1983), however, pointed out that in Yeo's study, the reported percentages of 20:4 was actually the percentage of 20:4ω6 plus that of 20:5ω3, and the percentage of 22:5 was the combined percentages of 22:5ω3 and 22:6ω3. Additional analysis in the present study and comparison with the data of Yeo (1982) revealed that Yeo's reported percentage for 20:3 was actually the combined percentages of 20:3ω3 and 20:3ω6. The importance of distinguishing between the ω3 and ω6 fatty acids in a study of beef produced on grass compared to that produced on grain has already been shown in this discussion.

III. TOCOPHEROL CONTENT IN BEEF

The significant changes in α- and r-tocopherol content in beef across time steers were fed corn (Tables 17 and 18, page 55) may be explained partially by the change in the steers' diet. Other factors such as the antioxidant activity of tocopherol, and the length of time the beef was stored prior to tocopherol analysis may also play a role.

There are four principal tocopherols designated as α-, β-, r-, and δ (Swern, 1978). Of the four types, α tocophorol is

the most abundant in forage plants and grasses. Miller (1958) reported total tocopherol levels of 277 ppm in immature fescue hay, 98 ppm at full bloom, and 24 ppm at the overripe stage. A range of 80-250 μg/g dry matter of α-tocopherol was reported in leaves of grasses and legumes which contained little or no tocopherols other than α-tocopherol (Aitken and Hankin, 1970). From this information, calculations may be made showing that grazing cattle each probably consume between 1.0 and 3.1 g of α-tocopherol per day (Appendix E, page 100).

The major tocopherol in corn, however, is α-tocopherol (Swern, 1978). Carpenter (1979) reported that corn oil contained 0.5-0.7 μg α-tocopherol per mg and 0.1-0.3 μg α-tocopherol per mg. Other researchers have reported corn oil to contain as high as 1.0 μg α-tocopherol/mg (Swern, 1978). Using an average daily corn intake per steer in a dry lot of 8.2 kg corn (Stockley, 1983) and assuming the corn to contain 20% oil with a content of 0.7 μg r-tocopherol/mg and 0.2 μg α-tocopherol/mg, the daily intake of tocopherol per steer in a dry lot may be calculated. A steer under such conditions would ingest approximately 0.3 g of α-tocopherol and 1.1 g of α-tocopherol.

The only antioxidant that can be stored in the fatty tissue of animals is tocopherol. However, only a small part of the tocopherol absorbed through the gastro-intestinal tract will be stored in the fat (Lyaskovskaya, 1967). The average tocopherol content in the longissimus of calves fed a diet containing corn

oil was reported to be 3.4 μg α-tocopherol/g muscle tissue (Shorland et al., 1981). This value compares well to average value of approximately 3 μg/g tissue in longissimus muscle of steers fed corn 56 through 112 days (Table 17, page 55). Their value, however, was for fresh veal whereas the values in the present study were for beef that had been stored frozen 12-14 months that originated from 1-1/2 to 2 year old steers.

Since a grass diet would provide higher levels of α-tocopherol than a corn diet, beef from steers grazing pasture would be expected to have higher α-tocopherol levels than beef from steers fed corn. In addition, the α-tocopherol content in beef would be expected to decrease with increasing days steers were fed corn after grazing pasture. Such results were found in the present study (Table 17, page 55).

The r-tocopherol in beef from steers fed corn in the present study would be expected to increase with increasing days on corn since corn contains higher levels of r-tocopherol than grass. However, the concentration of r-tocopherol in beef actually decreased with increasing days on corn past 28 days (Table 17, page 55). The reason for this observation is not clear at the moment.

Two possibilities exist for the changes in r-tocopherol content across time steers were fed corn. One is that during the 12-18 months frozen storage prior to analysis, the r-tocopherol in beef from steers fed corn longer than 28 days was destroyed by acting as an antioxidant for oxidizing lipids in the beef. The

other possibility is that the r-tocopherol from the corn diet was not as effectively absorbed and deposited in the muscle tissue as the α-tocopherol. It has been reported that r-tocopherol is a better antioxidant than α-tocopherol (Swern, 1978) and as such, might be more labile to destruction during frozen storage than α-tocopherol. No reports were found, however, on the effect of diet on the type of tocopherol in beef.

IV. RELATIONSHIP OF CHEMICAL ANALYSIS TO FLAVOR

Fatty Acid Composition

This study found higher intensities of an undesirable milky-oily aroma and flavor and lower intensities of a desirable beef fat aroma and flavor present in beef from grass-finished steers as compared to that from grain-fed steers. These flavor intensities were shown to be correlated to the fatty acid composition, in particular to the types of unsaturated fatty acids. These types originate in the dietary differences of grass and grain. Therefore, some of the less desirable flavor or off-flavor of grass finished beef may be attributed to the increased amounts of the omega-3 type polyunsaturated acids and the proportionally smaller amounts of the monounsaturated type.

Although, they did not separate the fatty acids into groups as in the present study, other researchers have implicated the poly-unsaturated fatty acids role in the flavor of beef produced on grass (Brown et al., 1979; Melton et al., 1982a, 1982b; Marmer, 1982;

Oltjen and Dinius, 1975; Westerling and Hedrick, 1979). These researchers generally consider the higher percentages of previously mentioned fatty acids as possible flavor precursors of the undesirable flavor associated with grass finished beed.

These polyunsaturated fatty acids are responsible for the warmed over flavor in meats (Igene and Pearson, 1979; Pearson et al, 1977; Reineccius, 1979). They are degraded during the cooking of beef (Keller and Kinsella, 1973; Igene and Pearson, 1979) and are oxidized during storage of beef (Igene et al., 1980). Thermal oxidation of the higher concentration of these polunsaturated fatty acids could contribute to the higher intensity of undesirable flavors in beef such as milky-oily, grassy, and fishy. The higher concentrations of these acids present in beef produced on grass compared to beef produced on grain would also contribute to more rapid development of oxidative rancidity and off-flavor in beef from grass-fed steers during storage (Gutokowski et al., 1979; Moore and Harbord, 1977; Reagan et al., 1977, 1981; Schroeder et al., 1980).

Tocopherol Content

Alpha tocopherol was found to be positively correlated with milky-oily flavor and in fact had the highest positive correlation coefficient found (Table 19, page 56). Although cause and effect is not shown by correlation coefficients, it may indicate underlying relationships.

Milky-oily flavor was found to be undesirable at all intensities. It is possible that this undesirable flavor is similar to another

flavor caused by the by-products of oxidative rancidity and called warmed over flavor according to Pearson et al. (1977). This makes it difficult to explain a positive correlation of tocopherol with milky-oily flavor as tocopherols are generally considered to be among the best anti-oxidants of the vegetable oils (DeMan, 1980). However, tocopherols attain their maximum effectiveness at comparatively low levels usually not more than a few hundredths of a percent. Above these optimum concentration, tocopherol concentrates from vegetable oils may actually function as pro-oxidants (Swern, 1978).

Beef from steers finished on grass in this study contained 8 μg/g or 0.8 mg/100 g tissue of α-tocopherol. It is not possible at this time to state whether or not this level is high enough to attribute prooxidant activities and resulting off flavors.

Researchers studying the α-tocopherol dietary supplementation effect on oxidation in muscle foods have reported optimum levels of α-tocopherol in the diet or the muscle for its maximum antioxidant activity (Tsai et al., 1978; Yamauchi et al., 1980). Shorland et al. (1981) found a rapid decrease in α-tocopherol concentration in longissimus over frozen storage (3.4 $\pm$ .08 to 0.9 $\pm$ 0.7 μg/g over a three month period). It seems possible that initial levels of tocopherol might have been much higher than found in the present study as the 0 days on feed samples had a 16 month storage period. Possibly, this level could have been high enough for pro-oxidant activity to occur. In this case resultant off-flavor would be due to oxidative rancidity.

V. COMPOSITION OF PASTURE GRASSES

The values reported for moisture and lipid content in this study (Table 20, page 59), are very similar to values in the literature (Hawke, 1973; Black, 1981). Few differences were found in the fatty acids (Table 21, page 61) among the different pasture types in this study. It would appear that the major grass fatty acids 18:2ω6 and 18:3ω3, were found in all pasture types. This is in agreement with reported findings citing linolenic acid or 18:3ω3 as the highest percentage fatty acid found in forages (Garton, 1963; Hawke, 1973; Black, 1981).

CHAPTER VI

SUMMARY

Sixty-eight Angus steers were assigned to five different pastures or treatments which included: (T1) fescue and clover followed by sudan grass and sorghum pasture (n = 14), (T2) orchard grass and clover (n = 11), (T3) Midland Bermuda grass, fescue and clover (n = 15), (T4) Midland Bermuda grass and fescue plus nitrogen fertilization (n = 15) and (T5) fescue and clover (n = 13). After grazing approximately four months, three steers from each treatment were slaughtered forming the 0-day feed group. The remaining steers were assigned to grain feeding groups on the basis of weight and fat thickness at the twelfth rib. Each feeding group had at least two steers from each treatment. All steers were adusted to a whole shelled corn diet for two weeks. After the adjustment period steers were maintained on the corn diet and slaughtered at 28, 56, 84, and 112 days on feed.

Post-slaughter, four steaks were removed from the rib of each steer and frozen until analyzed. The longissimus muscle from two of the steaks was used for chemical analysis, and the longissimus from the remaining two steaks was used for panel training and sensory evaluation by Quantitative Descriptive Analysis (QDA). Chemical analysis included determination of fatty acid composition and tocopherol and total lipid content.

In addition, samples of pasture grasses were obtained from each treatment and analyzed for moisture and lipid content and fatty acid composition.

All dependent variables measured in beef were analyzed as a function of pasture type (treatment), days on feed (DOF), and treatment x DOF interactions. Significant DOF effects were separated by orthogonal polynomials, and equations were obtained for dependent variables as a function of DOF.

Of the descriptors selected by the QDA panel, a desirable beef fat flavor and aroma increased linearly in intensity across time on feed while an undesirable milky-oily flavor and aroma decreased linearly in intensity. There were no significant changes over time on feed for the intensities of sour flavor, liver flavor, and raw or blood like flavor.

Total lipid content of the longissimus muscle of steers had a curvilinear relationship with time on feed with a low of 5.62% at 0 days and a high of 8.54% at 112 days. The fatty acid analysis determined odd and even carbon chain, branched chain and saturated and unsaturated fatty acids with 8 to 22 carbons. These fatty acids were expressed on a percentage basis of total lipid and a weight basis of mg/100 g muscle. Concentrations of fatty acids were also summed on the basis of type of unsaturation of fatty acids. Monounsaturated fatty acids included 14:1, 16:1, 17:1, 18:1, and 20:1. Omega-6 type unsaturated fatty acids included 18:2ω6, 20:3ω6, and 20:4ω6, and omega-3 type unsaturated acids included 18:3ω3, 20:3ω3, 20:5ω3, 22:5ω3, and 22:6ω3.

Expression of the fatty acid concentrations in the two different ways in view of increasing lipid content (mainly triglycerides) across DOF allowed establishment of interesting facts. The increase in the lipid content was due to deposition of 14:0, 14:1, 16:0, 16:1, 17:0, 17:1, 18:1, 18:2ω6, and 20:1 in the increasing triglycerides. For each acid, both the percentage and the concentration in the muscle increased significantly across DOF. In contrast, the concentration of 18:0 in the muscle remained essentially the same while its percentage decreased significantly across DOF. This indicates that additional 18:0 was not deposited in increasing lipid across DOF, nor was it likely exchanged for other fatty acids.

The effect of DOF on the concentrations of the polyunsaturated fatty acids which are located primarily in the muscle phospholipids can best be explained by observing the changes in concentrations of the omega-6 and omega-3 type fatty acids. The significant decreases in the percentage and concentration in the muscle of the omega-3 type acids across DOF were due to a dilution effect of the increasing triglyceride and to actual replacement of these fatty acids by the omega-6 acids. The increase in mg/100 g muscle of the omega-6 acids across DOF ($P<0.05$) supports this conclusion.

The changes in the fatty acid levels in the beef across DOF, particularly the omega-3 and the omega-6 types, are related

to the change in the steers diet. Steers grazing grass which contained high levels of 18:3ω3 produced beef with higher levels of omega-3 type fatty acids than did steers fed corn which contains little 18:3ω3. On the other hand, steers fed corn produced beef with higher levels of the omega-6 fatty acids since corn contains much higher levels of 18:2ω6 than grass (75-80% versus 20-30%). In addition, the change in the rumen microflora when steers were switched from a grass to a grain diet probably is the reason for deposition of higher levels of monounsaturated rather than saturated fatty acids in the beef produced on corn compared to that produced on grass.

Alpha-tocopherol content decreased over DOF from 8.51 μg/g muscle at 0 days to 2.76 μg/g at 112 days. Since grasses contained much higher levels of alpha-tocopherol than corn, this is to be expected. Gamma-tocopherol decreased from 1.17 μg/g beef to 0.27 μg/g during the same time period. Since gamma-tocopherol is the major tocopherol in corn, it is hard to explain this latter observation. Possibilities are that gamma-tocopherol was utilized through its antioxidant properties or that it was more labile to destruction than alpha-tocopherol during frozen storage of the beef.

Flavor was correlated ($P<0.05$) with chemical characteristics. Linolenic acid had the highest positive correlation of the fatty acids (0.55) to milky-oily flavor. Fatty acids: 13:0, 15:0, 19:0, 19:1, 20:0, 20:3ω3, 20:3ω6, 22:5ω3, Unknown D, and the omega-3 type fatty acids were also positively correlated with milky-oily flavor. Fatty acids positively correlated with beef fat flavor included 12:0,

14:0, 14:1, 16:1. Alpha-tocopherol content had the highest overall positive correlation with milky-oily flavor (0.58).

Long chain polyunsaturated fatty acids have been implicated in warmed-over beef flavor, development of oxidative rancidity in meats and off-flavors in beef produced by grass by several researchers. However, relationships between flavor and tocopherol content in meat have not been clearly defined. It is possible that the level of alpha-tocopherol in beef produced on grass was high enough to cause pro-oxidant activity and increased oxidative rancidity in the beef during frozen storage.

There were no significant differences in the fatty acid composition among the different pasture grasses (treatments) in the present study. However, all treatments had high levels of 18:2ω6 and 18:3ω3. This study has shown that the 18:3ω3 is probably the source of the high levels of omega-3 type fatty acids found in beef produced on grass.

In conclusion, this study substantiated that beef produced by grass has a more intense undesirable milky-oily flavor and less intense beef fat flavor than beef produced by grain. The present study is also one of the more extensive reported analyses of the effect of diet on beef fatty acid composition. Concentrations of fatty acids in the beef were related to levels of certain acids in the diet. Concentrations of monounsaturated fatty acids and the long chain polyunsaturated omega-3 fatty acids in beef were related to intensities of desirable and undesirable beef flavor notes, respectively. Also,

the concentration of alpha-tocopherol but not gamma-tocopherol in beef as function of DOF could be explained by corresponding levels in the steers diets. The unexpected high correlation coefficient found between alpha-tocopherol and the intensity of the undesirable milky-oily flavor, however, cannot really be explained at the present time. More research needs to be done to further explain the role of long chain polyunsaturated fatty acids and tocopherols in the flavor of beef produced on grass and(or) grain.

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APPENDIXES

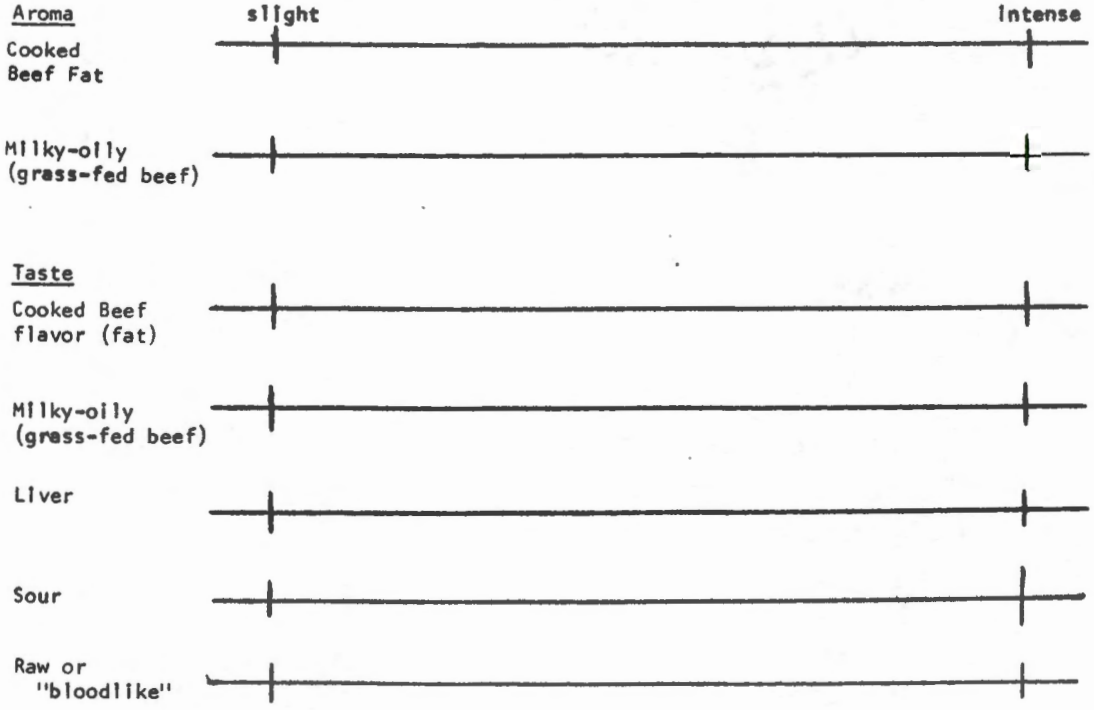
APPENDIX A

QDA Score Sheet

Name _____ Sample # _____

Date _____

First smell and then taste each sample individually and determine quantitatively the flavor characteristics listed below by placing a mark on the line beside the descriptor term which would represent that intensity. Rinse your mouth between samples.



Can you attend the next taste panel at _____?

Yes_____ No_____

APPENDIX B

TABLE 22. Calibration Factors Relative to Methyl Palmitate

Fatty Acid	SPDOH	Silar-10c
C8:0[a]	------	1.0000
C9:0[a]	------	1.0000
C10:0	2.7740	------
C11:0	------	1.0000
C12:0	1.8070	------
C13:0	1.0000	------
C14:0	0.9894	------
C14:1	0.9894	1.0515
AI[a]15:0	1.0000	------
I15:0	0.8591	------
C15:0	0.9415	------
I16:0[a]	------	1.0000
C16:0	1.0000	------
C16:1	1.0000	------
I17:0[a]	------	1.0000
C17:0	0.7051	------
C17:1	1.0000	------
C18:0	------	0.9834
C18:1ω9	------	0.9652
C18:2ω6	------	0.9806
C18:3ω3	------	0.9980
C19:0[a]	0.9439	------
C19:1[a]	1.0000	------
C20:0	0.2680	------
C20:1	1.0000	------
C20:3ω6[b]	------	1.0000
C20:3ω3[b]	------	1.0000
C20:4ω6[c]	------	1.0000
C20:5ω3[c]	------	1.0000
C22:5ω3	1.0000	------
C22:6ω3	------	1.0000
Unknown DEFGH	1.0000	------

[a]Tentatively identified.

[b]20:3ω3 and 20:3ω6 were combined in one peak on the SPDOH column and the calibration factor was 1.0000 for both acids.

[c]The 20:4ω6 and 20:5ω3 were combined in one peak on the SPDOH column and the calibration factor was 1.0000 for both acids.

APPENDIX C

TABLE 23. Concentrations of Fatty Acids in the Longissimus Muscle of Steers Fed Corn for up to 112 Days Which were Significantly Affected by Treatment by Days of Corn Interaction

Acid	Treatment	Days steers were fed corn				
		0	28	56	84	112
		% of fatty acids				
8:0	T 1	0.002	0.006	0.002	0.003	0.003
	T 2[a]	0.000	0.014	0.029	0.022	0.004
	T 3[a]	0.009	0.007	0.052	0.010	0.021
	T 4	0.000	0.002	0.070	0.000	0.003
	T 5[a]	0.006	0.013	0.026	0.027	0.005
22:3ω3	T 1[a]	0.122	0.023	0.095	0.022	0.000
	T 2[a]	0.191	0.128	0.053	0.059	0.036
	T 3	0.000	0.000	0.000	0.051	0.019
	T 4[a]	0.194	0.097	0.000	0.038	0.017
	T 5[a]	0.208	0.082	0.033	0.000	0.000
		mg acid/100 g muscle				
8:0	T 1	0.09	0.38	0.15	0.25	0.27
	T 2[a]	0.00	1.27	2.87	1.60	0.38
	T 3[a]	0.55	0.53	3.30	0.65	1.58
	T 4[a]	0.00	0.18	5.57	0.00	0.19
	T 5	0.30	0.81	1.72	2.22	0.47
9:0	T 1[a]	0.01	1.11	0.06	0.04	0.06
	T 2[a]	0.05	0.73	0.95	0.38	0.18
	T 3[a]	0.00	0.54	1.01	0.04	0.00
	T 4[a]	0.08	0.41	1.68	0.19	0.18
	T 5	1.17	0.50	0.51	1.04	0.18

[a]Concentrations of fatty acids in these treatments were significantly affected by days steers were fed corn.

TABLE 24. Equations Showing Significant Effect of Days Steers Were Fed Corn on Concentrations of Fatty Acids in Longissimus Muscle of Steers on Different Treatments

Acid	Treatment	Equation[a]
8:0	T 2	$Y_1 = -0.001169 + 0.0009373\ X - 7.9211 \times 10^{-6} X^2$
	T 3	$Y_1 = 0.0094 - 0.004997\ X \pm 0.0002773\ X^2 - 4.16 \times 10^{-6}\ X^3 + 1.86 \times 10^{08}\ X^4$
	T 4	$Y_1 = 6.96 \times 10^{-15} - 0.00724\ X + 0.0004149\ X^2 - 6.28 \times 10^{-6}\ X^3 + 2.81 \times 10^{-8}\ X^4$
22:3ω3	T 1	$Y_1 = 0.1009 - 0.0008644\ X$
	T 2	$Y_1 = 0.1742 - 0.001415\ X$
	T 4	$Y_1 = 0.1985 - 0.005652\ X + 4.3112 \times 10^{-5}\ X^2$
	T 5	$Y_1 = 0.1612 - 0.001777\ X$
8:0	T 2	$Y_2 = -0.079 + 0.08286\ X - 0.0007076\ X^2$
	T 3	$Y_2 = 0.547 - 0.3021\ X + 0.01709\ X^2 - 0.000259\ X^3 + 1.168 \times 10^{-6}\ X^4$
	T 4	$Y_2 = 5.66 \times 10^{-13} - 0.5723\ X + 0.0329\ X^2 - 0.000497\ X^3 - 2.229 \times 10^{06}\ X^4$
9:0	T 1	$Y_2 = 0.071 + 0.06415\ X - 0.001515\ X^2 + 8.38 \times 10^{-6}\ X^3$
	T 2	$Y_2 = 0.090 + 0.0263\ X - 0.0002363\ X^2$
	T 3	$Y_2 = 0.056 + 0.02518\ X - 0.0002463\ X^2$
	T 4	$Y_2 = 0.083 - 0.1200\ X + 0.0076\ X^2 - 0.000118\ X^3 + 5.38 \times 10^{-7}\ X^4$

[a] Y_1 = % of fatty acids; X = days steers were fed corn; and Y_2 = mg acid/100 g muscle.

APPENDIX D

TABLE 25. Significant Correlation Coefficients Between Intensity of Flavor Descriptors and Selected Chemical Components of Beef from Steers Fed Corn up to 112 Days

Component Fatty acid[a]	Flavor Descriptor			
	Milky-oily aroma	Beef fat aroma	Milky-oily aroma	Beef fat aroma
	correlation coefficient[b]			
10:0	----	----	----	----
12:0	-0.34	----	-0.31	----
13:0	0.37	-0.31	0.37	-0.39
14:0	----	----	-0.33	----
16:1	----	----	-0.32	----
18:3ω3	0.48	-0.30	0.54	-0.47
20:1	-0.34	----	-0.38	----
20:3ω3	0.33	-0.34	0.38	-0.39
20:5	----	----	0.30	----
Type fatty acid[c]				
Omega-3	0.35	----	0.44	-0.42

[a]Expressed in mg/100 g tissue.

[b]Only those coefficients which are significant at the $P<0.05$ level of less are given.

[c]Based on type of unsaturation.

APPENDIX E

ALPHA TOCOPHEROL INGESTED BY

CONSUMPTION OF FORAGE

Average dry matter intake of forage per steer =

12.4 kg/day = 12400 g/day

(Holloway, 1983; NRC, 1976)

Average α-tocopherol content of forage =

80 - 250 µg/g dry matter

(Aitken and Hankin, 1970)

Equation:

$$12400 \times 80\ \mu g/g \div 1{,}000{,}000\ \mu g/g = 0.992\ g \text{ } \alpha\text{-tocopherol}$$

$$12400 \times 250\ \mu g/g \div 1{,}000{,}000\ \mu g/g = 3.100\ g \text{ } \alpha\text{-tocopherol}$$

Range =

1.0 - 3.1 g α-tocopherol consumed per animal per day

VITA

Teresa Faye Mann was born December 10, 1958, to Mr. and Mrs. C. Wayne Mann of Tennessee. She graduated from DuPont Sr. High School, Hermitage, Tennessee, in June of 1976. In the fall of 1976 she enrolled in The University of Tennessee, Knoxville, in Animal Science. She received her Bachelor of Science degree in Agriculture in December 1980. In January of 1980 she enrolled in the Graduate School of The University of Tennessee, Knoxville, and began working toward a Master of Science degree in Food Technology and Science. She was a graduate research assistant during this time and served as assistant coach of the Meat Judging Team. She is a member of the American Meat Science Association, Alpha Zeta, Phi Kappa Phi, Gamma Sigma Delta, and Phi Tau Sigma.