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FLAVOR AND SELECTED CHEMICAL COMPONENTS OF GROUND BEEF FROM STEERS BACKGROUNDED ON PASTURE AND FED CORN UP TO 140 DAYS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

John Mark Black

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ABSTRACT

Sixty steers (30 Hereford and 30 predominantly Angus) were grouped into 6 groups of 10 steers on the basis of breed, weight and frame size and were backgrounded on predominantly fescue pasture from April through July, 1979, after which one group of 10 steers was slaughtered. The other steers were adjusted to a whole shelled corn diet for 2 weeks. After the adjustment period, one group of 10 steers was slaughtered every 28 days up to 140 days on corn.

Ground beef which was formulated to contain 20% fat was prepared from the semimembranosus muscle and outside brisket fat from the right side of each carcass after chilling 48 hours at 6°C. Ground beef from each steer was analyzed for fatty acid composition of total lipid, water soluble carbohydrates, lactic acid, volatile fatty acids, titratable acidity, total lipid content and moisture content. The flavor of the ground beef from each steer was evaluated by Quantitative Descriptive Analysis (QDA). Results were analyzed statistically as a function of time steers were fed corn, breed and frame size X breed. Significant time effects were separated by orthogonal polynomials, and equations for dependent variables as a function of time on corn were determined.

During the 140 days steers were on grain, the following changes occurred in the ground beef: stearic acid decreased curvilinearly from 18.32 to 8.36%; oleic acid increased curvilinearly from 40.88 to 48.05%, linolenic acid decreased linearly from 2.16 to 0.86%. In addition, acetic acid increased linearly from 2.98 to 4.33 mg/100 g ground beef; water soluble carbohydrates increased linearly from 2.54 to 4.56 mg

glucose equivalents/10 g ground beef; initial pH of the raw ground beef increased linearly from 5.42 to 5.63 while titratable acidity decreased linearly from 1.07 meq H^+/10 g ground beef to 0.94. Lactic acid ($\bar{X}$=76 mg/10 g ground beef), although accounting for 84.6 ± 6.3% of the titratable acidity, did not change significantly with time on corn.

Descriptive terms chosen by the QDA panel for beef flavor were milky-oily, cooked beef fat, sour, metallic, liver, fishy and off-flavor. The milky-oily note decreased to a minimum intensity at approximately 114 days on corn and the cooked beef fat flavor note increased to maximum intensity at approximately the same time. Fishy and sour flavor notes also decreased as time steers were fed corn increased.

Simple correlation coefficients were determined between flavor characteristics and chemical components of ground beef. Stearic acid had a positive correlation coefficient with milky-oily aroma and flavor (r=0.72 and r=0.62, respectively) ($p < 0.001$); while with the same terms, pentadecanoic acid and linolenic acid had correlation coefficients above 0.50 ($p < 0.001$). Monounsaturated fatty acids (C14:1, C16:1 and C18:1) and 15-methylhexadecanoic acid (αC17:0) were correlated positively with cooked beef fat flavor and aroma at or above the $p < 0.05$ level. Acetic acid was correlated negatively ($p < 0.01$) with sour flavor as well as with milky-oily flavor. Titratable acidity was correlated positively with sour flavor ($p < 0.05$) and initial pH was correlated negatively ($p < 0.05$) with sour aroma.

Pasture grass samples obtained during the backgrounding period were analyzed for moisture content, total lipid content and fatty acid content of the total lipid. Moisture content decreased from 73.29 to

66.03% from the beginning to the middle of the period and then increased to 71.94% at the end of the period. Total lipid content of pasture grass protected from the grazing steers decreased from 2.47 to 1.91% while total lipid content of pasture grass grazed by the steers decreased from 2.21 to 1.75%. Linolenic acid was the predominant fatty acid in the pasture grass ($\bar{X}$=40.19%) with C16:0, C18:0, C18:1 and C18:2 being the other major fatty acids. Linolenic acid decreased in percentage concentration from 51.52 to 33.37% in samples protected from the grazing steers and from 45.35 to 29.23% in grazed samples and the other major fatty acids increased in percentage concentration.

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CHAPTER I

INTRODUCTION

Increases in grain prices during the last ten years have caused beef prices to increase greatly. For economical reasons, farmers and feedlot operators need to decrease the time steers are fed grain before being sold for slaughter. Increasing the backgrounding time of cattle on pasture and reducing time of finishing on grain but still producing consumer acceptable beef are of prime concern to beef producers.

In the future, with the advent of synthetic fuel from grains such as corn, grain for cattle will become even more scarce and expensive. In addition, consumer awareness of goals for reduced dietary fat intake will create a market for leaner beef. Pasture-finished or grass-finished beef is very lean but has inferior flavor and is less tender than grain-finished beef. These problems with grass-finished beef have resulted in decreased acceptability by the consumer. Yet it should be possible to produce a lean beef that is acceptable to the consumer by increasing the use of pasture and decreasing the use of grain in finishing cattle for market.

Desirable beef flavor is difficult to evaluate because it is affected by many factors. Beef flavor is an artifact produced by reactions of non-odorous precursors during cooking. Much of beef flavor is the result of the carbonyl-amine browning reaction in which the free amine groups of amino compounds react with water soluble reducing sugars. However, a similar meaty aroma results from heated water extracts of the lean portions of beef, pork and lamb. Lipid portions

contain compounds that give each species a distinctly different flavor. Flavor components that result in desirable beef flavor apparently are present in all beef, but the concentrations of these components may vary, resulting in flavor differences.

Steers finished on some pastures have less desirable flavor than grain-finished steers. Grass-finished beef has been evaluated by a flavor profile panel as possibly having a more intense, undesirable milky flavor and a less intense beef fat flavor than grain-finished beef. However, it is impossible to statistically analyze the intensity levels reported by a flavor profile panel.

Pastures which seem to produce beef with less desirable flavor are composed of clover, winter rye grass, orchard grass and fescue. Steers finished on blue grass, tropical rye grass and Bermuda grass have been reported to have a flavor that is as desirable as the flavor of grain-finished beef. However, it has not been found exactly how long grain must be fed to grass-finished cattle to improve the undesirable flavor of grass-finished beef.

The objective of this experiment was to evaluate beef flavor as a function of time cattle were fed grain after being backgrounded on a pasture of Ladino clover, Kentucky 31 fescue and orchard grass. Chemical components of the ground beef such as carbohydrates, fatty acids, volatile fatty acids, and lactic acid, all of which contribute to beef flavor were determined. Flavor of the cooked ground beef was evaluated by the Quantitative Descriptive Analysis (QDA). Pasture grass from which the animals were backgrounded was analyzed for moisture content, total lipid and fatty acid content of the total lipid.

CHAPTER II

REVIEW OF LITERATURE

A. MEAT FLAVOR

The flavor of meat is attributed to a complex mixture of compounds produced by heating a heterogeneous system containing nonodorous precursors. The flavor is composed of: volatile compounds, nonvolatile compounds with taste and tactile properties and flavor potentiators. Since all types of meat are composed of similar components, such as proteins, lipids, carbohydrates, mineral salts and other water-soluble compounds such as amino acids, it is apparent that there must be a significant difference either in proportion in which these compounds are present or in the way they interact (Dwivedi, 1975).

Precursors of Meat Flavor

Reactions induced by heating sugars and amino acids are "non-enzymatic browning" or carbonyl-amine reactions. Several researchers have attempted to determine the water-soluble amino acid composition of meat (Bender et al., 1958; Batzer et al., 1960; Wasserman and Gray, 1965; Wasserman and Spinelli, 1970). Amino acids identified in the diffusate were methionine, cystine, cysteine, cysteic acid and taurine; however, the data reported vary due to the substrate not being standardized. The main sugar present in meat is glucose, although fructose, ribose and deoxyribose along with derivatives of glucose and ribose have been identified (Dwivedi, 1975; Wasserman and Spinelli, 1970).

While non-enzymatic browning is important in producing cooked meat flavor, other mechanisms and components by which flavor is developed also are important. Macy et al. (1964) and Wasserman and Spinelli (1972) reported that upon heating the meat aromas of cold-water, fat-free extracts of beef, lamb and pork were very similar. This finding stresses the importance of fat in determining the characteristic species flavor. Fat is capable of providing a reservoir of non-volatile and volatile non-polar flavor compounds (Pippen et al., 1969). Reactions that affect flavor can occur between the compounds dissolved in the fat and between compounds and the fat itself (Lien and Nawar, 1974).

Fatty Acid Composition Relationship to Flavor

A number of studies show a relationship of fatty acid composition to meat palatability (Dryden and Marchello, 1970; Brown et al., 1979; Amiri, 1980). Westerling and Hedrick (1979) reported high positive correlation coefficients between desirable flavor score and either intramuscular oleic acid or total intramuscular unsaturated fatty acids and high negative correlation coefficients with other intramuscular fatty acids: palmitic, stearic, linoleic, and total saturated fatty acids. Brown et al. (1979) postulated that linolenic acid contributed to low flavor scores of grass-fed beef. Amiri (1980) found a significant negative correlation between flavor desirability and linolenic acid of both neutral and polar lipids.

There exists the possibility that microbial growth on beef that has high linolenic acid could contribute to inferior flavor. Pseudomonas fragi, one of the most predominant species found on beef carcasses (Stringer et al., 1969), produces large amounts of alkanals,

2-alkenals and 2-alkones (Smith and Alford, 1969), which are known to produce off flavors in foods (Forss, 1969; Labuza, 1971).

Relationship of Lactic Acid and Volatile Fatty Acids to Flavor

Hornstein and Crowe (1960) reported that lactic acid could be important in developing meat flavor during cooking. Dryden et al.(1969) reported no consistent association between flavor and lactic acid content in beef, although they determined that lactic acid has a negative association with desirable beef flavor of semimembranosus muscle.

No pertinent information was found on the effect of volatile fatty acids on the flavor of cooked beef. However, volatile fatty acids are known to be important in producing aroma properties in fermented meat products (Dwivedi, 1975).

B. RATION EFFECT ON RUMEN FLUID COMPOSITION AND FATTY ACID COMPOSITION OF ADIPOSE TISSUE

It has been known for many years that organic acids are produced by bacterial fermentation in the rumen. Elsden (1945) showed that a production of acetic acid, propionic acid, a butyric acid isomer and traces of a valeric acid isomer was characteristic of fermentation in the rumen of sheep. Acetic acid was present in greatest amount and the proportion of propionic acid usually exceeded butyric acid. Balch and Rowland (1957) showed that the acetic acid:propionic acid ratio in the rumen decreased when concentrates were fed to cattle that had been fed high roughage diets. High concentrate diets fed to cattle accustomed to high roughage diets also result in a much higher lactate concentration in the rumen unless the level of concentrate in the diet is

gradually increased giving time for the cattle to adjust to the diet. During this adjustment period, rumen bacteria capable of utilizing lactate increase in number. These bacteria form propionate by the acrylate or non-randomizing pathway, in which lactate is an intermediate (Wallnöfer et al., 1966). Nakamura and Takashi (1971) found that 40% of the acetate and 43% of the propionate produced in sheep fed equal proportions of hay and concentrate were formed via lactate. The proportion and amount of propionate formed from lactate increases as the proportion of concentrate in the ratio is increased (Wallnöfer et al., 1966).

Acetate and propionate are taken up from the rumen into the hepatic portal vein where they go into the liver while butyrate is metabolized in the rumen epithelium. Cook and Miller (1965) reported that most of the propionate was removed by the liver for metabolism while acetate was taken directly to the tissues for utilization. Propionate is converted to glucose in the liver by gluconeogenesis (Bergman et al., 1966); thus, increased concentrations of propionate in the liver would lead to increased production of glucose.

Acetate is absorbed directly at the tissue sites for lipogenesis. Researchers (Pothoven et al., 1975; Scott and Prior, 1980) have shown that the incorporation of acetate into adipose tissue and lipogenesis increased greatly in cattle that were fed concentrates ad libitum as compared to cattle on a restricted or low energy diet. However, Pothoven et al. (1975) have shown that increased lipogenesis triggers increased lipolysis at the adipose sites due to increased production of lipolytic enzymes.

For many years it was believed that ruminant fat depots were not subject to the influence of diet as are the tissues of many of the monogastric species. Garton (1960) reported that ruminant microorganisms either partially or completely hydrogenated the unsaturated fatty acids ingested and that the saturation of depot fat was affected little by diet. However, later studies have shown that diet does affect the saturation of depot fat (Church et al., 1967; Miller et al., 1967; Dryden et al., 1973; Brown et al., 1979; Amiri, 1980).

Dryden et al. (1973) found that the subcutaneous fat from steers backgrounded on alfalfa hay and then switched to a concentrate ration became less saturated with time on feed (3-5%) and that added safflower oil to the diet increased the unsaturation effect. The diet with 6% added safflower oil significantly increased the concentrations of linoleic and linolenic acid in the subcutaneous fat. Miller et al. (1967) compared the fatty acid content of depot fat taken next to the intestines of sheep fed maintenance level rations of concentrate with that of sheep fed maintenance levels of roughage. They found that there was more oleic acid, linoleic acid and less palmitic acid and linolenic acid in the fat taken from the sheep fed the high concentrate ration. Brown et al. (1979) found that grass-fed steers had higher levels of stearic and linolenic acids in the polar lipids and lower amounts of palmitic acid in neutral and polar lipids than did steers fed a maintenance level concentrate diet. They also found that steers fed grain ad libitum had higher levels of palmitic and linoleic acids and lower levels of myristoleic, palmitoleic, stearic and linolenic acids in the neutral lipids with similar results for the C18 acids in the polar lipids than did the steers on the low energy concentrate ration.

Westerling and Hedrick (1979) reported that intramuscular fat from steers and heifers finished on a fescue pasture had higher amounts of linoleic and linolenic acids than those finished for either 56 or 112 days on a grain diet. Amiri (1980) found that ground beef from grass-finished steers had lower oleic, arachidonic and higher myristic, myristoleic, stearic and linolenic acids than did that from steers finished on grain.

Tove (1960) reported that animal fats may contain more than 35 fatty acids, but that 90% of the depot fat was comprised of myristic, palmitic, palmitoleic, stearic, oleic, and linoleic acids. It has been established that these fatty acids may vary according to depot site (El-Gharbawi and Dugan, 1965; Terrel et al., 1967; Marchello et al., 1968).

C. SOME CHARACTERISTICS OF PASTURE GRASSES

The moisture content of pasture grasses is approximately 75-80% (Sampson, 1924). The composition of the 20-25% dry matter remaining is 10-20% crude protein (Lyttleton, 1973); approximately 9% total non-structural carbohydrates (Hunter et al., 1970) which include free sugars and starches; approximately 50% structural carbohydrates (Jarrige, 1963), which include cellulose, hemicellulose and other structural polymers; 3-10% lipid (Hawke, 1973); and approximately 10% mineral content (Fleming, 1973).

The fatty acid content of mixed pasture grasses is shown in Table 1. The major glycerides are in the form of mono- and digalactosyl derivatives of 1,2 diglycerides (Weenink, 1959, 1961; Shorland, 1961). Other constituents are phospholipids, triglycerides, sulpholipids,

TABLE 1

FATTY ACID COMPOSITION OF PASTURE GRASS LIPIDS

Fatty Acid	Source of Fatty Acids	
	Clover Rich Pasture	Mixed Pasture Grasses
	---------% by weight of total fatty acids---------	
C14:0	---	1.1
C16:0	8.9	15.9
C16:1	7.9	2.5
C18:0	2.8	2.0
C18:1	9.5	3.4
C18:2	8.1	13.2
C18:3	58.9	61.3
Other fatty acids	3.9	0.5

(Garton, 1963)

sterols, sterol esters, waxes, hydrocarbons and free fatty acids (Hilditch, 1956; Weenink, 1962). Researchers (Gray et al., 1967; Crombie, 1958; Klopfenstein and Shigley, 1967) have demonstrated that changes in fatty acid composition during growth season are due primarily to the amount of light available to the plant rather than changing maturity of the plant.

Mowat et al. (1965) reported that protein content decreased and nonstructural and structural carbohydrate increased as pasture grasses matured. This was the result of 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 grass were cut prior to maturity. (Patton, 1943; Phillips et al., 1954; Sullivan et al., 1956).

D. PASTURE-FINISHED BEEF VERSUS GRAIN-FINISHED BEEF

It has been known for many years that differences exist between beef from cattle finished on grass and beef from cattle finished on grain. Bidner (1975) showed the break-even price increased as steers were finished on grain. Beeson et al. (1967) reported that cattle slaughtered after 191 days on good pasture saved about 500 pounds of total digestible nutrients (TDN) per steer compared to drylot-fed cattle. 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. However, in the future, utilization of grass will

become more important in finishing cattle as grain prices continue to increase.

Several researchers have reported that beef from grain-finished cattle has superior organoleptic qualities to beef from cattle finished on high levels of pasture (Lusby, 1977; Reagan et al., 1977; Smith et al., 1977; Bowling et al., 1977; Harrison et al., 1978; Brown et al., 1979; Amiri, 1980; Dyer, 1980). Brown et al. (1979) and Amiri (1980) reported that the flavor of grass-finished beef was consistently less desirable than the flavor of low energy, limited grain-finished beef or high energy, grain-finished beef from steers of the same chronological age. Harrison et al. (1978) and Dyer (1980) showed that flavor desirability improved as a function of time cattle were fed concentrates or grain after being backgrounded on pasture.

Amiri (1980) reported that a flavor profile panel consistently scored the intensity of a milky, dairy aroma and flavor higher in ground beef from grass-finished steers than from grain-finished steers, and that the panel, for one grass-finished sample, noted that at the slight intensity, this flavor was particularly unpleasant. This flavor profile panel also scored the intensity of a beef fat flavor consistently lower for ground beef from grass-finished steers compared with that of grain-finished steers. The panel defined this flavor as the aromatic flavor of freshly cooked beef fat.

Grass-finished beef has been reported to be tougher and have higher Warner-Bratzler shear values than grain-finished beef (Shinn, 1976; Lusby, 1977; Bowling et al., 1978; Harrison et al., 1978; Dyer, 1980). The increased toughness has been attributed to cold shortening of the sarcomeres in grass-finished beef due to the extremely thin fat

cover that is usually associated with carcasses from steers finished on pasture (Smith et al., 1974).

Grass-finished beef has a lighter lean color than beef from grain-finished steers (Reagan et al., 1977; Amiri, 1980) and the exposed muscle surface discolors more rapidly (Reagan et al., 1977). Kropf et al. (1975) have suggested that grass-finished cattle are more susceptible to preslaughter stress and to the dark cutting syndrome.

The fat color of pasture-finished beef tends to be more yellow than that of grain-finished beef (McCampbell et al., 1970; Burris et al., 1976; Kropf et al., 1975; Brown et al., 1979); however, this has not been shown to be a marketing problem.

Amiri (1980) found that ground beef from steers finished on pasture had higher numbers of psychrophilic and lipolytic microorganisms than did ground beef from steers finished on grain. This does not agree with Reagan et al. (1977) who stated that feeding regime did not significantly affect the microbial count from the subcutaneous fat from the rib area on the carcass. Amiri (1980), however, hypothesized that the higher microbial counts could have been due to the fact that more fat from a larger area of the grass-finished beef carcass was required to produce ground beef with 20% fat than from the carcasses of the grain-finished steers. The higher counts also could have been the result of more microbial growth on the grass-finished carcass.

In view of the flavor problems with grass-finished beef and the fact that grass probably will be utilized to a greater degree in finishing cattle in the future, more research is needed to identify what causes the undesirable flavor and how long grain must be fed to cattle to correct the undesirable flavor. The research reported in this thesis is concerned with these two objectives.

CHAPTER III

MATERIALS AND METHODS

A. SELECTION OF STEERS, FEEDING MANAGEMENT AND SLAUGHTER

Sixty steers were grouped into 6 groups of 10 steers based on breed, weight and frame size. Five steers in each group were predominantly of Angus breed and the other 5 steers were of Hereford breed. Within each group five different frame sizes were represented in each breed and were indicated by numbers 1 (small size), 2 3, 4 and 5 (large size). All the steers were wintered on a hay ration from November 1978 through April 1979 at the University of Tennessee Plateau Experiment Station at Crossville, Tennessee. At the end of April all steers were placed on a pasture of orchard grass, Kentucky 31 fescue and ladino clover. On July 31, 1979, one group of 10 steers was slaughtered, and the other steers were started on a whole shelled corn ration. A 14-day adjustment period for ration change was allowed after which one group of 10 steers was slaughtered at 28-day intervals up to 140 days on grain.

B. POST MORTEM HANDLING AND GROUND BEEF FORMULATION

The carcasses were chilled for 48 hours at 1.6^{o}C prior to wholesale fabrication. At that time the semimembranosus muscle from the right side of the carcass and subcutaneous fat from the brisket area were removed and ground through a 1.27-cm plate on a Hobart Model 4722 meat grinder. Fat content of the lean ground muscle and the brisket fat was determined by a modified Babcock fat analysis (Ockerman, 1969).

Ground beef formulated to contain approximately 20% fat by Pearson Square (Terrel, 1971) was prepared by mixing the lean and the fat and then grinding through a 0.3175-cm plate on a Hobart grinder. A 25-gram portion of ground beef from each sample was placed in a whirlpack bag for microbial count. Ground beef from each steer was divided into one 360-gram portion for sensory evaluation and two 250-gram portions for other possible evaluations. These samples were double wrapped in polyethylene-coated freezer wrap. The remaining ground beef samples were placed in whirlpack bags, flushed with nitrogen and sealed for chemical analyses of long chain fatty acids, volatile fatty acids, percentage of moisture, titratable acidity and water soluble carbohydrates. All samples except those for microbial count were quick frozen in a blast freezer and stored prior to analysis at -34°C.

C. MICROBIOLOGICAL ANALYSIS

A total aerobic plate count of a 25-g sample of ground beef from each steer was determined (Speck, 1976). The counts were made on ground beef samples plated immediately following fabrication and were incubated at 30°C for 48 hours prior to counting.

D. CHEMICAL ANALYSES

Moisture and Fat Content of Ground Beef

Each sample was analyzed within two weeks for moisture in duplicate by AOAC method 24.002 (AOAC, 1980) and total lipid was estimated in a lipid extract according to the Ostrander and Dugan (1961) modification of the Bligh and Dyer method (1959). Part of the lipid

extract was stored in chloroform under nitrogen at -18°C for long chain fatty acid analysis.

Determination of Water Soluble Carbohydrates

Water soluble carbohydrates were extracted from ground beef of each steer by the method described by Brown et al. (1979) and were determined by the phenol-sulfuric acid method of Dubois et al. (1956) in a diluted deproteinated water extract (1:10 v/v). Water soluble carbohydrates were expressed as mg glucose equivalents/10 g meat. A standard curve (absorbance at 485 nm versus glucose concentration) was obtained each day of analysis. The analysis was done on a Hitachi Model 100-60 double beam spectrophotometer. The standard curve, which did not change significantly throughout the analysis, was determined as

$$X = 0.1225X + 0.0821$$

where Y = mg glucose/2nd dilution and X = absorbance at 485 nm. The correlation coefficient (r) was 0.99.

Long Chain Fatty Acid Analysis

Methyl esters of long chain fatty acids (C10-C22) were prepared from the lipid extract according to AOCS method Ce 2-66 (AOCS, 1974) and were analyzed with a Bendix Model 2600 gas chromatograph equipped with dual flame ionization detectors and a Chromatopac E1A electronic integrator. Methyl esters were analyzed within 8 hours of formation.

The methyl esters were analyzed on two different columns: (1) a 3.175-mm i.d. X 1.83-m nickel column packed with GP 3% SP2100 DOH on 100/120 Supelcoport (Supelco, Inc., Bellefonte, PA) and (2) a 6.35-mm i.d. X 1.83-m stainless steel column packed with 15% HIEFF 1BP on 60/80 Chromosorb W/AW (Applied Science Laboratories, State College, PA). The

first column separated branched chain fatty acids and straight chain fatty acids containing an odd number of carbons more efficiently than did the second column (Anon., 1977). The first column, however, did not separate the C18 fatty acids (C18:0, C18:1, C18:2, C18:3) which were efficiently separated by the second column. For each column the percentage of each fatty acid was corrected for nonlinearity of instrument response and for molecular weight differences by use of calibration factors determined relative to methyl palmitate (AOCS Method Ce 1-62; AOCS, 1974). In those cases where the fatty acid could not be identified (designated as fatty acid unknowns 1-4) the calibration factor was assumed to be 1.00. Calibration factors for fatty acids on each column in these analyses are given in Table 2. The operating conditions for the gas chromatograph for each column were:

	Column 1	Column 2
Nitrogen flow rate	45 ml/min	45 ml/min
Hydrogen flow rate	30 ml/min	30 ml/min
Air flow rate	90 ml/min	90 ml/min
Injection temperature	225°C	240°C
Detector temperature	225°C	240°C
Initial oven temperature	210°C	140°C
Final oven temperature	210°C	225°C
Rate	Isothermal	3°C/min

Actual percentages of fatty acids reported in each sample except for C18 fatty acids were determined on column 1. The total percentage of fatty acids containing 18 carbons was determined on the first column,

TABLE 2

CALIBRATION FACTORS RELATIVE TO METHYL PALMITATE

Fatty Acid	Column 1	Column 2
C10:0	----	2.7740
C12:0	----	1.8070
C14:0	----	0.9894
C14:1	1.0515	0.9894
αC15:0	----	0.8591
C15:0	----	0.9415
C16:0	1.0000	1.0000
αC17:0	----	0.4835
C17:0	----	0.7051
C18:0	0.9834	----
C18:Unsaturated	----	1.0140
C18:1	0.9652	----
C18:2	0.9806	----
C18:3	0.9980	----
C19:0	----	0.9439
C20:0	----	0.2680
Unknown 1[a]	----	1.0000
Unknown 2[a]	----	1.0000
C20:4[b]	----	1.0000
Unknown 3[a]	----	1.0000
Unknown 4[a]	----	1.0000

[a]Relative retention times to C19:0 (24.10 min.) for unknowns 1, 2, 3 and 4 were, respectively, 1.05, 1.10, 1.14 and 1.18.

[b]Tentatively identified.

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 column 1 were estimated by multiplying the percentage of each C18 fatty acid determined on column 2 by Y/X

Volatile Fatty Acid Extraction

Within two months of formulation, ground beef from each steer was analyzed for volatile fatty acids. For the extraction of volatile fatty acids, 50 g of ground beef from each steer were suspended thoroughly in 150 ml of distilled water. The proteins were precipitated with the addition of 25 ml of 1N sulfuric acid and 40 ml of 20% phosphotungstic acid (w/w). Thirty-five ml of distilled water were added to the mixture for a total weight of 300 grams. The mixture was shaken vigorously and filtered through 24-cm rapid flow filter paper (Whatman No. 2v). From this point the procedure recommended in AOAC (1980) was followed. One hundred-fifty ml of the filtrate were steam distilled under constant volume conditions. Two hundred ml of distillate were collected in a volumetric flask, transferred to a 500-ml flat bottom ground glass flask and neutralized with 0.1N sodium hydroxide solution, using phenolpthalein as an indicator. A 1-ml excess of sodium hydroxide was added. The pink solution was evaporated to dryness on a rotary evaporator at 50°C. The salts of the volatile fatty acids were changed to acids by the addition of 1.1 ml of 0.5N dichloroacetic acid in acetone. One ml of a standard methyl-heptyl ketone solution (0.14 mg/ml) was added as an internal standard and the solution was made up to 3.1 ml with acetone. The fatty acid solution was stored at 6°C in a borosilicate glass vial with a heavy polyethylene-lined cap no more than 24 hours until GLC analysis.

Analysis of the volatile fatty acids was done on a Bendix Model 2500 gas liquid chromatograph equipped with a flame ionization detector and a Shimadzu Chromatopac E1A electronic integrator. The column used was a 6.35-mm i.d. X 1.85-m glass column packed with 10% FFAP on 80/100 mesh Gas Chrom Q (Applied Science Laboratories, State College, PA). The conditions for the instrument were:

Nitrogen flow rate ---------- 30 ml/min

Hydrogen flow rate ---------- 40 ml/min

Air flow rate ---------- 400 ml/min

Injection temperature ---------- 160°C

Detector temperature ---------- 160°C

Oven temperature ---------- 140°C

Calibration factors for each VFA compared to the internal stan- were determined by injection of standard solutions (Ubbaonu, 1980). These factors were calculated each day that samples were analyzed and were used to determine VFA in the extract of the meat samples as mg VFA/100 g ground beef (wet basis). The calibration factor for the volume used in the distillation was calculated to be 1.60. Also correlation factors for distillation loss of each fatty acid were calculated (Table 3).

Initial pH and Titratable Acidity

Initial pH and titratable acidity were determined on ground beef from each steer. At the time of analysis, ground beef samples had been stored at -34°C for an average of 7.5 months. Titratable acidity was determined according to AOAC method 22.061 (AOAC, 1980) using a Fisher

TABLE 3

CALIBRATION FACTORS FOR DISTILLATION OF VOLATILE FATTY ACIDS

Component	Calculated Distillation Calibration Factor
Acetic Acid	1.75
Propionic Acid	1.24
Isobutyric Acid	1.02
Butyric Acid	1.08
Isovaleric Acid	1.02

(Ubbaonu, 1980)

model 600 pH meter with a combination silver nitrate, calomel electrode A 10-g sample of ground beef from each steer was blended with 100 ml of distilled water for 1 minute and the initial pH was determined. The mixture then was titrated quickly with a standard 0.05N sodium hydroxide solution to a pH of 8.0. The NaOH solution then was added, 4 drops at a time, with the volume of NaOH and the change in pH noted at each addition. This was continued until the pH reached 8.1, at which point the total volume of NaOH solution added was recorded. Acidity in the ground beef was calculated as meg acid/10g sample of ground beef.

Lactic Acid Determination

Lactic acid was extracted from ground beef samples that had been stored at -34^{o}C for an average of 8.5 months and was determined by

a modification of an AOAC (1980) procedure. Lactic acid was extracted by thoroughly suspending 10 g of ground beef with 50 ml of distilled water. Proteins were precipitated by the addition of 6 ml of 1N sulfuric acid and 5 ml of 20% (w/w) phosphotungstic acid. One ml of 10 mg/ml succinic acid (in water) was added to measure accuracy of the method. Distilled water then was added to bring the total volume up to 100 ml. The mixture was shaken vigorously for 1 minute and filtered through 24-cm diameter rapid flow filter paper (Whatman No. 2v).

Fifty ml of the filtrate and 0.5 ml of 1:1 sulfuric acid were placed in the inner tube of a liquid extractor. A flat bottom flask containing 200 ml of diethyl ether was attached to the extractor. The ether was heated to rapid boiling and the solution containing the lactic acid was extracted for 5 hours.

Following extraction, the ether was evaporated to approximately 1 ml on a rotary evaporator at 30°C. Two ml of 14% (w/v) boron trifluoride-propanol reagent were pipetted into the flask, the mixture was refluxed for 10 minutes and then cooled to room temperature. One ml of acetophenone solution (8 mg/ml water) was added as an internal standard and 2 ml of chloroform were pipetted into the mixture. The mixture was transferred to a 30-ml separatory funnel and shaken for 1 minute. The mixture was allowed to stand until the layers separated and the bottom aqueous layer was drained and discarded. The upper layer was stored in a screw cap vial containing 3-g anhydrous sodium sulfate and sealed with aluminum foil until GLC analysis.

Analysis of the lactic acid was done on a Bendix Model 2600 gas liquid chromatograph with a flame ionization detector and a Shimadzu E1B electronic integrator. The column used was a 6.35-mm i.d. X 1.85-m

nickel column packed with 10% DEGS on 60/80 mesh Gas Chrom Z (Applied Science Laboratories, State College, PA). The conditions for the instrument were:

Nitrogen flow rate ---------- 30 ml/min

Hydrogen flow rate ---------- 40 ml/min

Air flow rate ---------- 400 ml/min

Injection temperature ---------- 200°C

Detector temperature ---------- 200°C

Oven temperature ---------- 170°C

Lactic and succinic acid concentrations were determined as mg acid/100 g meat sample by the internal standard method. The correction factor for lactic and succinic acid was calculated by:

$$R_f = \frac{A_{is}}{C_{is}} \times \frac{C_{acid}}{A_{acid}}$$

where A_{is} = peak area acetophenone,

C_{is} = mg acetophenone,

A_{acid} = peak area acid and

C_{acid} = mg acid.

Peak areas, A_{is} and A_{acid}, were obtained from chromatograms of standard solutions which contained 15, 20 or 25 mg lactic acid, 10 mg succinic acid and 8 mg acetophenone. The R_f of lactic acid was calculated to be 2.72. Acid concentration in the meat sample was calculated by:

$$\text{Conc. acid} = \frac{A_{acid} \times R_f}{A_{is}} \times \frac{C_{is}}{\text{g sample extracted}} \times 100$$

(Method 43 on Chromatopac E1B electronic integrator).

E. SENSORY EVALUATION

Cooked ground beef from each steer was evaluated according to the Quantitative Descriptive Analysis (QDA) method (Stone et al., 1974). Judges for the panel were selected from 27 panelists by evaluating their ability to discriminate flavor differences between grass-finished and grain-finished ground beef. Only those people who successfully selected the odd sample in each of three triangle tests composed of grass-finished and grain-finished ground beef were questioned concerning their interest in serving on the panel. Five men and four women, ranging in age from 21 to 40, were chosen on these bases.

In the initial training, panelists were given representative samples of grass-finished and grain-finished beef and a list of descriptive terms that were developed by a flavor profile panel for grass-finished and grain-finished ground beef (Amiri, 1980). Panelists were asked to smell and taste the ground beef and to select those words on the list or add descriptive terms that represented to them the prominent aroma and flavor notes present in the beef. Ten descriptive terms were selected by the panel and arranged on a QDA score sheet (Appendix A) on which each panelist could judge quantitatively aroma notes first and then flavor notes by marking a perpendicular line across a 150-mm line anchored 10 mm from each end by the words slight and intense.

Panelists helped select stimuli that qualitatively represented a particular aroma or flavor descriptive term and also a stimulus

concentration that quantitatively represented slight and intense. The stimulus for a slight sour aroma and flavor was 0.01-mg acetic acid/ml aqueous solution and for the intense extreme, 0.1-mg acetic acid/ml. The stimuli for slight and intense fishy aroma were respectively 0.1% and 1.0% triethylamine in methanol. The stimuli for the slight and intense oily part of milky-oily aroma were respectively $5x10^{-4}$ mg and $1x10^{-3}$ mg trans, trans, 2-4 decadienal/ml methanol. Stimuli for fishy and oily flavor were not tasted by mouth; panelists drew their own conclusions concerning the concentration of the slight and intense flavor from the respective concentrations of the stimuli for fishy and oily aroma.

No stimuli were found for the slight metallic or liver taste or the slight milky or cooked beef fat aroma; however, stimuli were found for the intense concentration for each of these descriptive terms. Panelists agreed that a clean copper penny placed in the mouth represented an intense metallic flavor by mouth, and that freshly broiled liver served warm represented an intense liver flavor by mouth. A stimulus for the intense cooked beef fat aroma used was the odor of 5 ml of cooked beef fat from a freshly opened tube (12.5-mm i.d. X 150-mm) held at 130°C 1 hour prior to opening. A stimulus for an intense milky aroma was obtained by letting each panelist smell 100 ml rancid milk in a 150-ml container kept closed at 25°C for 2 hours prior to opening. The milk was made rancid by mixing 1 part fresh whole milk with 2 parts pasteurized milk and holding the milk at 25°C for 8 hours prior to being poured into the 150-ml containers. These stimuli were used to refresh the panelists' memories to the concentration extremes of slight and intense for each aroma and flavor descriptor during the

training period when the panelists were learning to evaluate grain-finished and grass-finished beef flavor.

For training the panel, actual samples were taken from three different kill dates and combined. Ground beef samples from 10 steers on zero days on grain were thawed, mixed and reformed into 250-g units. Each unit was double wrapped in polyethylene-coated freezer wrap and refrozen in the blast freezer (-34°C). This also was done for ground beef from 10 steers finished on 84 days of grain and also from steers finished on 140 days of grain. These samples had been stored at -34°C for an average of approximately 5 months.

For each training period, three samples of ground beef representing steers fed 0, 84 and 140 days on grain, respectively, were thawed 24 hours at 6°C prior to training and shaped into 125-g patties immediately prior to cooking. The patties were broiled for 9 minutes on one side on a Farberware Model 450 A electric broiler and then turned and broiled for approximately 9 minutes on the other side to an internal temperature of 68°C determined by a meat thermometer. After cooking, each patty was cut into 8 parts and held at 60°C in covered dishes on a warming tray for no more than 10 minutes prior to evaluation. Samples were evaluated at 10:00 a.m. and 2:00 p.m. on alternating week days.

During the initial training, all panelists sat together and evaluated each of the samples as they were presented randomly. Panelists discussed the descriptive terms that they had decided upon earlier to determine if they still applied using the actual samples. The milky and oily descriptor terms were combined and given the name "grass-fed beef flavor" and the term "cooked beef fat" was added for beef fat flavor. Panelists decided to add "off flavor" to the list of descriptive terms

after they sometimes detected undesirable flavor notes for which a consensus on a descriptive term could not be reached. After the panelists were acquainted with the descriptive terms in relation to the three ground beef samples, they evaluated the intensity of the aroma or flavor note each descriptive term represented for each sample. Following these evaluations, the panelists discussed their responses and decided on an intensity for each aroma or flavor note of each sample. Training continued until for each sample all panelists reached a consensus on an intensity range of ±0.5 cm at a particular point on the scale for each descriptive term. Open panel discussions were held for six meetings. The panelists then were served the three samples in individual sensory evaluation booths without knowing the identity of each sample and were instructed not to discuss the samples until after the evaluation of all the samples was complete. After individual evaluation of the three randomly administered samples, panelists came together as a group and discussed their responses. Samples were provided for re-evaluation for panelists whose responses were not within the general consensus. This type of training continued for seven more meetings until panelists were consistent and precise in their intensity responses for the different samples.

The panel was discontinued for two weeks as some of the panelists and the administrator were unable to attend. Upon resumption of the panel, it was found that panelists were not precise in their scoring, and panelists were retrained using chemical stimuli, group discussion and individual evaluation for six more meetings until they were again consistent in their results.

Following the retraining of the panelists, the evaluation of the ground beef samples from the 60 steers was begun immediately and lasted for a period of two weeks on the same schedule as was used for training. The ground beef samples were prepared as previously described for training. Panelists evaluated five samples at each session using the scoresheet shown in Appendix A and each panelist completed his/her evaluation of each sample before receiving the next sample. Samples served at each session were selected at random and the order of presentation for each panelist within each session was completely random. The samples were coded with 3-digit random number codes which were changed at each session.

Evaluation was done in individual sensory evaluation booths at the University of Tennessee under fluorescent white lights at a comfortable room temperature. The evaluation room was kept under positive pressure to prevent odors from the preparation of the ground beef from entering the evaluation area. Ambient temperature water for rinsing between samples as well as a cup for expectoration were provided.

F. SELECTION AND ANALYSIS OF PASTURE GRASS

At the pasture on the University of Tennessee Plateau Experiment Station at Crossville, Tennessee, 10 sites were randomly chosen for sampling of grass during the grazing period. At each site, a sample that was grazed by the steers (unprotected) and a sample that was protected from the steers were taken approximately every two weeks. The samples were stored at -18°C until analyzed. All grass samples were analyzed for moisture. Two protected and two unprotected samples

which represented different areas of the field were selected from four different dates during the grazing period: April 25, June 1, June 29 and July 27, 1980, and were analyzed for total lipid content. Fatty acid composition of the total lipid from each sample except for one unprotected sample (April 25) was determined.

Moisture and Fat Content of Pasture Grass

The percent moisture of each grass sample was determined by a combination air dry-vacuum oven method according to AOAC method 14.003 (AOAC, 1980), and total lipid content was determined by the method of Melton et al. (1979).

Long Chain Fatty Acid Analysis of Pasture Grass

Methyl esters of long chain fatty acids (C10-C20) were prepared from the total lipids by the AOCS method Ce 2-66 (AOCS, 1975) using the same conditions as were used for ground beef methyl ester analysis. Additional fatty acids were tentatively identified in the pasture grass samples using a qualitative bacterial fatty acid standard on column 1 (Anon., 1977). These included 2OH-C16:0, 3OH-C16:0, C19:0, and C20:4 with average retention times relative to C19:0 of 0.77, 0.80, 0.99 and 1.08, respectively. Correction factors were set at 1.0. The fatty acid identity of the pasture grass was verified with a gas chromatograph-mass spectrometer at the Chemistry Department, University of Tennessee, Knoxville.

G. STATISTICAL ANALYSIS

Each objective and subjective measurement determined on ground beef was analyzed as a function of days steers were on corn ration,

breed, frame size and breed X frame size interaction according to the General Linear Model procedure (Barr et al., 1979). Means for each variable which was significantly affected by days on ration were separated into linear, quadratic, cubic, quartic and pentic effects (orthogonal polynomials).

Objective measurements of grazed and protected pasture grass were analyzed as a function of sampling time by a General Linear Model analysis of variance (Barr et al., 1979). Significant sampling time effects were separated by the Duncan's Multiple Range test.

CHAPTER IV

RESULTS AND DISCUSSION

A. GROUND BEEF COMPOSITION

Analysis of variance and least square means for moisture and fat composition of the ground beef prepared from steers fed 0 to 140 days on grain are presented in Tables 4 and 5. No significant difference was found for moisture over time; however, a significant difference existed for fat content over time even though the ground beef was formulated to contain 20% fat, wet basis. When sum of squares for time was partitioned, significant cubic and pentic effects were found. Essentially, ground beef from steers fed 56 days had the most fat, 21.96%, and ground beef from steers fed 84 days had the least fat, 16.98%. The ground beef from steers fed 0 to 140 days on grain had approximately 60% moisture.

B. MICROBIAL CONTAMINATION

Table 6 shows the analysis of variance for microbial numbers determined for the ground beef. The means of microbial numbers of ground beef from steers across days on grain are shown in Table 7. Except for 28 days on grain where a large increase in microbial count existed, total aerobic count of ground beef decreased at a decreasing rate ($p < .05$) across time on feed. This significant variation due to time was partitioned into linear, cubic and quartic effects by orthogonal polynomials (Table 6). The large increase at 28 days possibly is due to a change in technicians for that particular sampling date.

TABLE 4

ANALYSIS OF VARIANCE FOR GROUND BEEF COMPOSITION

Source	DF	Moisture	Fat
		------- mean squares -------	
Time	5	6.80	30.61*
Linear	1	15.12	1.53
Quadratic	1	2.63	3.15
Cubic	1	0.94	76.28*
Quartic	1	14.54	0.78
Pentic	1	0.76	71.32*
Breed	1	0.22	3.03
Frame Size	4	2.63	3.25
Breed X Frame Size	4	2.62	21.50
Error	45	10.42	12.03

*$p < 0.05$

TABLE 5

LEAST SQUARE MEANS FOR GROUND BEEF COMPOSITION

Composition	Days on Grain					
	0	28	56	84	112	140
	---------- % ----------					
Moisture	59.70	58.36	59.96	60.09	59.74	60.90
Fat	19.40	20.19	21.96	16.98	18.71	20.66

TABLE 6

ANALYSIS OF VARIANCE FOR MICROBIAL COUNTS IN GROUND BEEF

Source	DF	Mean Squares for Total Aerobic Count
Time	5	7.53×10^{10}*
Linear	1	1.19×10^{11}*
Quadratic	1	4.74×10^{9}
Cubic	1	1.12×10^{11}*
Quartic	1	1.11×10^{11}*
Pentic	1	3.02×10^{10}
Breed	1	2.48×10^{8}
Frame Size	4	2.79×10^{10}
Breed X Frame Size	4	3.31×10^{10}
Error	45	2.19×10^{10}

*$p < 0.05$

TABLE 7

LEAST SQUARE MEANS OF MICROBIAL CONTENT OF GROUND BEEF

	Days on Grain					
	0	28	56	84	112	140
	1000/g					
Total Aerobic Count	46.40	229.81	35.81	15.78	6.49	2.22

These data may be explained by observations of Dyer (1980) and Ayres (1955). Dyer (1980) reported that fat covering at the 12th rib of the carcass increased in thickness as time steers were fed corn increased, and Ayres (1955) reported that the fat does not support growth of microorganisms as well as leaner areas of beef carcasses. Therefore, a decrease in microbial count with increased time on corn would be expected. Another effect also may have contributed to the decreased microbial counts. Fat from a smaller surface area of the carcass would be necessary to formulate a given amount of 20% fat ground beef as the fat thickness increased, and less microbial population would have been incorporated into the ground beef as time on corn increased. This latter effect tends to be supported by Amiri (1980). Reagan et al. (1977) found no significant relationship between the microbial numbers determined at 48 hours post mortem for subcutaneous adipose tissue and lean tissue of beef ribs finished on different feeding regimes. Amiri (1980) also found no significant difference in total aerobic count for ground beef from steers finished on pasture or grain but the carcasses from which he made ground beef were aged 11 days, and after this period the microbial population would tend to be the same regardless of the fat covering (Ayres, 1955). Amiri (1980), however, did find higher pyschrophilic ($p < 0.01$) and lipolytic ($p < 0.05$) microorganisms due to ration energy level.

C. INITIAL pH, TITRATABLE ACIDITY, LACTIC ACID CONTENT AND WATER SOLUBLE CARBOHYDRATES

The analysis of variance and the least square means across days on grain for the initial pH, titratable acidity, lactic acid and water

soluble carbohydrates are listed in Tables 8 and 9. The pH and titratable acidity of ground beef were affected significantly by days on grain. The pH of raw ground beef increased linearly (Figure 1A) from 5.42 at 0 days on grain to 5.63 at 140 days while the titratable acidity decreased linearly (Figure 1B) from 1.04 meq H^+/10 grams ground beef at 0 day to 0.90 at 140 days on feed. These observations show that in ground beef the hydrogen ions titratable in the pH range 5.4 to 8.1 decreased with increasing time steers were fed grain. Therefore, compound(s) capable of donating H^+ ions in this pH range must have decreased in concentration with increasing time on grain, or compound(s) capable of accepting H^+ ions in this pH range must have increased in concentration or a combination of the two existed. These compound(s) did not include lactic acid which was present in the ground beef at approximately 71 to 82 mg/10g sample (Table 9), because it was not affected significantly by days on grain (Table 8). The lactic acid, however, did contribute a mean 84.6 ± 6.3% of the titratable H^+ ions present in the ground beef.

There was a significant breed effect on the lactic acid concentration. Ground beef from Angus steers had 80.30 mg/10g (Table 10) compared to 71.45 for that of Hereford steers.

Water soluble carbohydrate expressed as milligrams glucose/10g ground beef increased linearly from 2.54 at 0 day on grain to 4.56 at 140 days (Table 9 and Figure 1D). When steers are changed from a grass to a grain diet, it has been reported that the ratio of acetic acid: propionic acid: butyric acid changes from approximately 70:20:10 to a ratio in which acetic acid and propionic acid are in more equal molar concentrations (Schwartz and Gilchrest, 1973). The level of volatile

TABLE 8

ANALYSIS OF VARIANCE FOR INITIAL pH, TITRATABLE ACIDITY, LACTIC ACID AND WATER SOLUBLE CARBOHYDRATES OF GROUND BEEF

Source	DF	Initial pH	Titratable Acidity	Lactic Acid	Water Soluble Carbohydrate
		mean squares			
Time	5	1.02×10^{-1}	1.91×10^{-2}*	9.05×10^{-1}	27.73*
Linear	1	2.23×10^{-1}*	8.33×10^{-2}**	78.52	93.57**
Quadratic	1	1.07×10^{-4}	1.82×10^{-3}	269.25	20.66
Cubic	1	2.35×10^{-2}	7.73×10^{-3}	50.77	7.58×10^{-1}
Quartic	1	2.64×10^{-1}*	1.65×10^{-5}	57.01	1.00
Pentic	1	6.35×10^{-5}	2.80×10^{-3}	379.59	22.67
Breed	1	1.67×10^{-4}	5.82×10^{-3}	1173.50**	13.13
Frame Size	4	2.36×10^{-2}	6.97×10^{-3}	82.89	16.67
Breed X Frame Size	4	2.11×10^{-2}	8.46×10^{-3}	44.35	6.31
Error	45	4.79×10^{-2}	7.78×10^{-3}	131.92	8.07

*$p < 0.05$ **$p < 0.01$

TABLE 9

LEAST SQUARE MEANS FOR INITIAL pH, TITRATABLE ACIDITY, LACTIC ACID CONCENTRATION AND WATER SOLUBLE CARBOHYDRATE CONTENT IN GROUND BEEF

	Days on Grain					
	0	28	56	84	112	140
Initial pH	5.42	5.37	5.55	5.55	5.43	5.63
Titratable acidity[a]	1.07	1.01	1.00	.98	.98	.94
Lactic acid[b]	73.05	70.97	81.92	76.18	79.21	73.94
Water soluble carbohydrates[c]	2.54	3.66	3.67	4.90	4.14	4.56

[a]milliequivalents/100g sample

[b]milligrams/10g sample

[c]milligrams glucose equivalents/10g sample

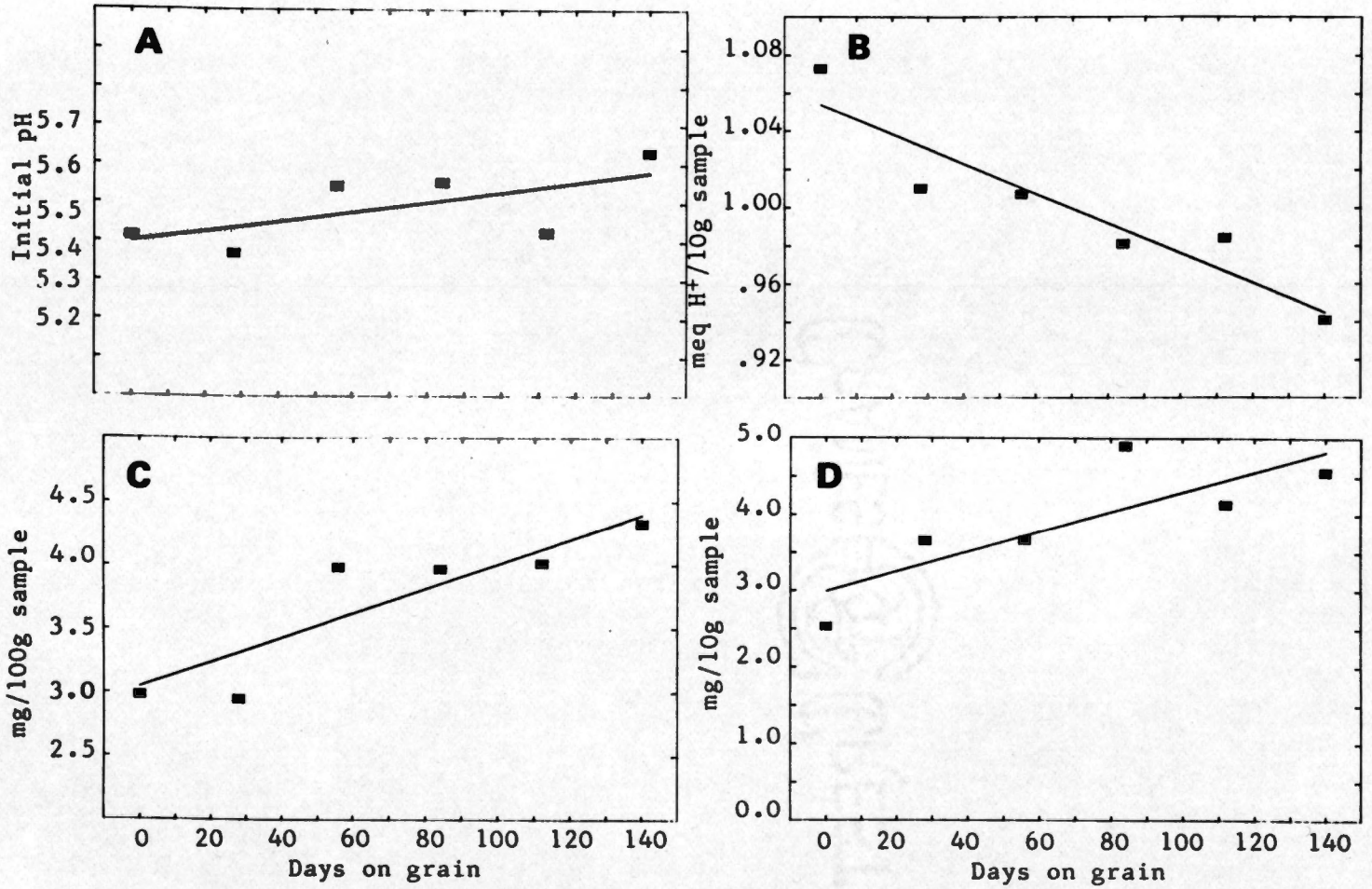


Figure 1. Chemical Characteristics of Ground Beef as a Function of Days Steers Were Fed Grain. A. Initial pH, B. Titratable Acidity, C. Acetic Acid, D. Water Soluble Carbohydrate Content.

TABLE 10

LEAST SQUARE MEANS FOR SIGNIFICANT BREED EFFECTS ON SOME OBJECTIVE AND SUBJECTIVE MEASUREMENTS OF GROUND BEEF

Component	Breed	
	Angus	Hereford
C12:0[a]	5.83×10^{-2}[e]	1.02×10^{-1}[f]
C16:0[a]	25.95[e]	25.19[f]
C18:2[a]	2.67[e]	2.31[f]
Acetic Acid[b]	3.38[e]	4.03[f]
Propionic Acid[b]	5.25×10^{-2}[e]	6.54×10^{-2}[f]
Butyric Acid[b]	3.95×10^{-2}[e]	6.23×10^{-1}[f]
Lactic Acid[c]	80.30[e]	71.45[f]
Milky-Oily Odor[d]	44.95[e]	50.18[f]
Milky-Oily Flavor[d]	46.24[e]	53.34[f]

[a]% of fatty acid composition in total lipid

[b]mg/100g ground beef

[c]mg/10g ground beef

[d]distance in mm on 150

[e,f]Means in a row bearing unlike superscript letters are significantly different.

fatty acids produced by the ruminant also is increased. Blaxter (1967) showed that the increase in propionic acid production leads to increased fatty acid production in the muscle and adipose tissues. Bergman et al. (1966) reported that propionic acid is used for gluconeogenesis by the liver; therefore, it is reasonable to expect increased levels of glucose in the tissue if increased levels of propionic acid are produced by the ruminant. This increased level of glucose probably is due to the increased starch available to the ruminant on the grain diet instead of the energy level of the diet. Brown et al. (1977) and Amiri (1980) have shown that ground beef from steers finished on grass has lower carbohydrate content than that from steers finished on a grain diet of similar energy level. Also, they found that ground beef from steers finished on a low-energy grain diet had approximately the same carbohydrate concentration as that from steers finished on a high-energy grain diet.

D. VOLATILE FATTY ACID COMPOSITION

Analysis of variance and least square means for volatile fatty acids in ground beef as a function of time or days on grain are shown in Tables 11 and 12. The concentrations of acetic acid, propionic acid, butyric acid and isovaleric acid were affected significantly by time. Acetic acid had the highest concentration of all volatile fatty acids (VFA) and increased linearly from 2.98 mg/100g of ground beef at 0 day on grain to 4.33 at 140 days (Table 12 and Figure 1C). The next most abundant VFA in the ground beef was butyric acid which had a quartic relationship with days on grain (Table 11). The most significant change in concentration of butyric acid was an increase from 0.23 mg/100g ground beef at 0 day on grain to a maximum of 1.01 at 28 days (Table 12).

TABLE 11

ANALYSIS OF VARIANCE FOR VOLATILE FATTY ACIDS IN GROUND BEEF

Source	DF	Acetic Acid	Propionic Acid	Isobutyric Acid	Butyric Acid	Isovaleric Acid
		mean squares				
Time	5	3.18*	$4.10 \times 10^{-3***}$	4.36×10^{-3}	$6.97 \times 10^{-1***}$	$3.91 \times 10^{-2**}$
Linear	1	12.70**	$6.49 \times 10^{-3***}$	1.28×10^{-2}	7.23×10^{-2}	$5.94 \times 10^{-2*}$
Quadratic	1	3.79×10^{-1}	6.02×10^{-4}	2.38×10^{-3}	3.65×10^{-1}	4.74×10^{-4}
Cubic	1	6.82×10^{-2}	$4.77 \times 10^{-3**}$	2.27×10^{-3}	1.19**	$4.03 \times 10^{-2*}$
Quartic	1	2.08	$7.62 \times 10^{-3***}$	3.94×10^{-3}	1.75***	$8.01 \times 10^{-2**}$
Pentic	1	7.00×10^{-1}	1.02×10^{-3}	4.28×10^{-4}	1.04×10^{-1}	1.52×10^{-2}
Breed	1	5.91*	$2.32 \times 10^{-3*}$	9.30×10^{-3}	$6.17 \times 10^{-1*}$	6.59×10^{-3}
Frame Size	4	4.15×10^{-1}	8.42×10^{-5}	1.49×10^{-3}	3.06×10^{-1}	1.26×10^{-2}
Breed X Frame Size	4	9.30×10^{-1}	6.78×10^{-4}	3.47×10^{-3}	2.90×10^{-2}	5.15×10^{-3}
Error	45	1.30	4.73×10^{-4}	3.83×10^{-3}	1.31×10^{-1}	9.35×10^{-3}

*p < 0.05 **p < 0.01 ***p < 0.001

TABLE 12

LEAST SQUARE MEANS OF VOLATILE FATTY ACID CONCENTRATIONS IN GROUND BEEF

Volatile Fatty Acid	Days on Grain					
	0	28	56	84	112	140
	mg/100 g meat					
Acetic Acid	2.98	2.95	3.99	3.97	4.01	4.33
Propionic Acid	.09	.04	.07	.06	.05	.04
Isobutyric Acid	.07	.08	.04	.03	.03	.04
Butyric Acid	.23	1.01	.49	.39	.53	.41
Isovaleric Acid	.13	.25	.09	.09	.10	.08

Butyric acid in ground beef from steers fed 56 through 140 days was less than that from steers fed 28 days but was greater than that in grass-finished steers (0 day). Isovaleric acid content was lower than butyric acid content. Even though propionic acid was affected significantly by days on grain, its concentration was less than 0.1 mg/100g meat throughout the study (Table 12) as was isobutyric acid, which was not affected by days on grain (Table 12).

Cook and Miller (1965) who studied the removal of VFA from portal blood by the liver in ewes and goats found that acetate concentration was not altered appreciably after blood passed through the liver. Instead, acetate is transported to fatty and muscle tissues. Pothoven et al. (1975) found that steers fed a high-energy concentrate diet

incorporated higher levels of acetate into the subcutaneous fat compared to steers fed a low-energy concentrate diet. No reports were found in which acetate in tissues was studied as a function of days steers were fed a high-energy concentrate or grain diet. However, it is possible that the increase in acetate concentration with increasing days steers were fed grain was because of lipid metabolism and catabolism in steers as they were increasing in fatness (Pothoven et al., 1975).

The lower concentrations of butyric and propionic acids compared with acetic acid in the ground beef are to be expected in view of the report of Cook and Miller (1965). They reported that propionate is almost completely removed from the blood by the liver and is used for gluconeogenesis and fatty acid synthesis, and butyrate is metabolized by rumen epithelium. The large amount of butyric acid present at 28 days and the variation of isovaleric acid with increasing days on grain are not explainable at this time.

There was a significant effect due to breed for acetic acid, propionic acid and butyric acid (Table 11). Ground beef from Hereford steers had higher concentrations of acetic, propionic and butyric acid than did that of Angus steers (Table 10).

E. LONG CHAIN FATTY ACID COMPOSITION

Mean squares from analyses of variance for fatty acid composition of total lipids are shown in Table 13. Graphs of percentages of fatty acids as a function of days on grain are shown in Figures 2-4. Mean percentage values for the fatty acids found in the total lipids from each time period are shown in Table 14. There were significant differences in the relative percentages of myristic acid (C14:0), myristoleic

TABLE 13

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF GROUND BEEF TOTAL LIPIDS

Source	DF	C10:0	C12:0	C14:1	C14:0	aC15:0	C15:0	C16:1	C16:0	aC17:0	C17:0
		Mean Squares									
Time	5	3.28×10^{-2}	1.18×10^{-2}	5.79×10^{-1}***	4.65×10^{-1}	2.28×10^{-1}***	6.39×10^{-1}*	8.90***	4.24	2.46×10^{-1}***	4.64×10^{-1}***
Linear	1	5.91×10^{-5}	1.03×10^{-2}	1.80***	1.01*	4.70×10^{-1}***	1.06*	38.04***	4.36	5.66×10^{-1}***	7.96×10^{-1}***
Quadratic	1	1.03×10^{-2}	8.50×10^{-3}	2.21×10^{-1}*	3.59×10^{-1}	1.98×10^{-1}***	2.07×10^{-1}	1.79	2.52×10^{-1}	5.01×10^{-1}***	1.41***
Cubic	1	1.38×10^{-2}	1.04×10^{-2}	4.52×10^{-1}*	7.51×10^{-1}	2.32×10^{-1}	9.91×10^{-1}	3.59×10^{-1}	15.75**	8.96×10^{-2}*	4.21×10^{-5}
Quartic	1	8.09×10^{-2}	1.48×10^{-2}	2.42×10^{-1}	4.62×10^{-2}	1.20×10^{-2}	8.01×10^{-1}	4.29*	3.06×10^{-1}	1.35×10^{-3}	1.55×10^{-3}
Pentic	1	5.09×10^{-2}	1.50×10^{-2}	1.80×10^{-1}	1.63×10^{-1}	2.20×10^{-1}**	1.34×10^{-1}	1.53×10^{-2}	5.25×10^{-1}	7.46×10^{-2}*	1.18×10^{-1}
Breed	1	5.95×10^{-5}	2.83×10^{-2}*	1.49×10^{-1}	2.24×10^{-1}	6.88×10^{-4}	4.71×10^{-1}	6.35×10^{-2}	8.73*	2.65×10^{-2}	4.94×10^{-3}
Frame size	4	9.21×10^{-3}	3.63×10^{-3}	1.45×10^{-1}	1.29×10^{-1}	1.63×10^{-2}	2.65×10^{-1}	2.06	3.48	5.16×10^{-2}	1.25×10^{-1}
Breed X Frame size	4	3.66×10^{-2}	3.82×10^{-3}	3.79×10^{-2}	3.58×10^{-1}	2.09×10^{-2}	1.88×10^{-1}	5.67×10^{-1}	4.45	1.33×10^{-2}	8.84×10^{-2}
Error	45	2.59×10^{-2}	6.75×10^{-3}	7.38×10^{-2}	2.47×10^{-1}	1.88×10^{-2}	2.45×10^{-1}	9.79×10^{-1}	2.14	2.15×10^{-2}	5.46×10^{-2}

TABLE 13 (Continued)

Source	Df	C18:0	C18:1	C18:2	C18:3	C19:0	C20:0	C20:4	Unknown 1	Unknown 2	Unknown 3	Unknown 4
		Mean Squares										
Time	5	120.17^{***}	52.17^{***}	3.95×10^{-1}	2.11^{***}	$1.83\times10^{-2***}$	3.68×10^{-3}	7.16×10^{-3}	3.75×10^{-3}	$1.11\times10^{-2**}$	9.83×10^{-3}	8.41×10^{-3}
Linear	1	495.46^{***}	178.76^{***}	1.21×10^{-1}	10.35^{***}	4.38×10^{-4}	6.66×10^{-3}	6.89×10^{-3}	1.39×10^{-3}	$2.30\times10^{-2**}$	5.62×10^{-3}	$2.11\times10^{-2*}$
Quadratic	1	49.27^{***}	2.66	2.08×10^{-1}	4.69×10^{-2}	8.75×10^{-3}	1.10×10^{-3}	7.19×10^{-4}	3.72×10^{-3}	4.86×10^{-3}	8.51×10^{-3}	8.68×10^{-3}
Cubic	1	46.05^{**}	77.76^{**}	9.60×10^{-1}	1.08×10^{-1}	$7.79\times10^{-2***}$	$9.50\times10^{-3*}$	1.37×10^{-2}	$1.31\times10^{-2*}$	1.18×10^{-2}	4.70×10^{-3}	1.72×10^{-4}
Quartic	1	0.48	5.41×10^{-1}	4.29×10^{-1}	3.10×10^{-2}	6.18×10^{-5}	1.04×10^{-3}	8.74×10^{-5}	3.57×10^{-4}	$1.46\times10^{-2*}$	$2.96\times10^{-2*}$	1.21×10^{-2}
Pentic	1	1.62	1.11	2.57×10^{-1}	1.21×10^{-2}	4.33×10^{-3}	9.37×10^{-5}	1.44×10^{-2}	1.44×10^{-4}	1.31×10^{-3}	7.71×10^{-4}	3.32×10^{-6}
Breed	1	7.91	1.52	2.01^{*}	4.53×10^{-2}	2.78×10^{-3}	8.91×10^{-5}	1.24×10^{-3}	8.46×10^{-4}	1.50×10^{-3}	1.78×10^{-4}	1.40×10^{-3}
Frame size	4	5.04	11.08	1.08×10^{-1}	1.83×10^{-1}	5.05×10^{-3}	1.67×10^{-3}	1.24×10^{-2}	1.98×10^{-3}	2.11×10^{-3}	4.70×10^{-3}	3.35×10^{-3}
Breed X Frame size	4	1.19	0.78	3.03×10^{-1}	$2.34\times10^{-1*}$	2.55×10^{-3}	1.10×10^{-3}	3.71×10^{-3}	7.50×10^{-3}	2.32×10^{-3}	5.45×10^{-3}	6.67×10^{-3}
Error	45	3.80	6.53	3.53×10^{-1}	7.25×10^{-2}	3.14×10^{-3}	2.26×10^{-3}	8.01×10^{-3}	2.95×10^{-3}	2.90×10^{-3}	6.73×10^{-3}	3.62×10^{-3}

$^{***}p < 0.001$
$^{**}p < 0.01$
$^{*}p < 0.05$

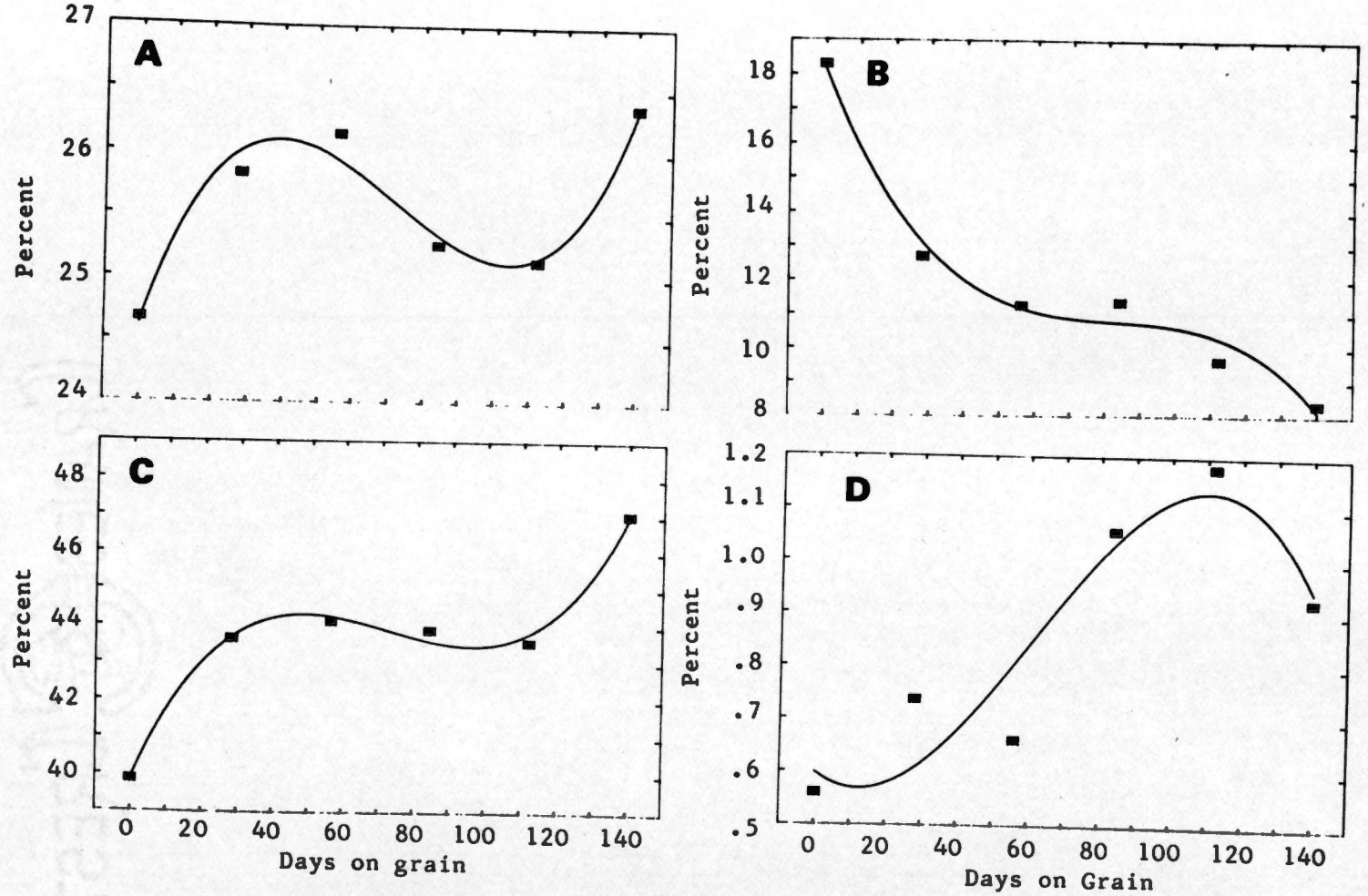


Figure 2. Fatty Acid Content in Ground Beef Total Lipids as a Function of Days Steers Were Fed Grain. A. C16:0, B. C18:0, C. C18:1, D. C14:1.

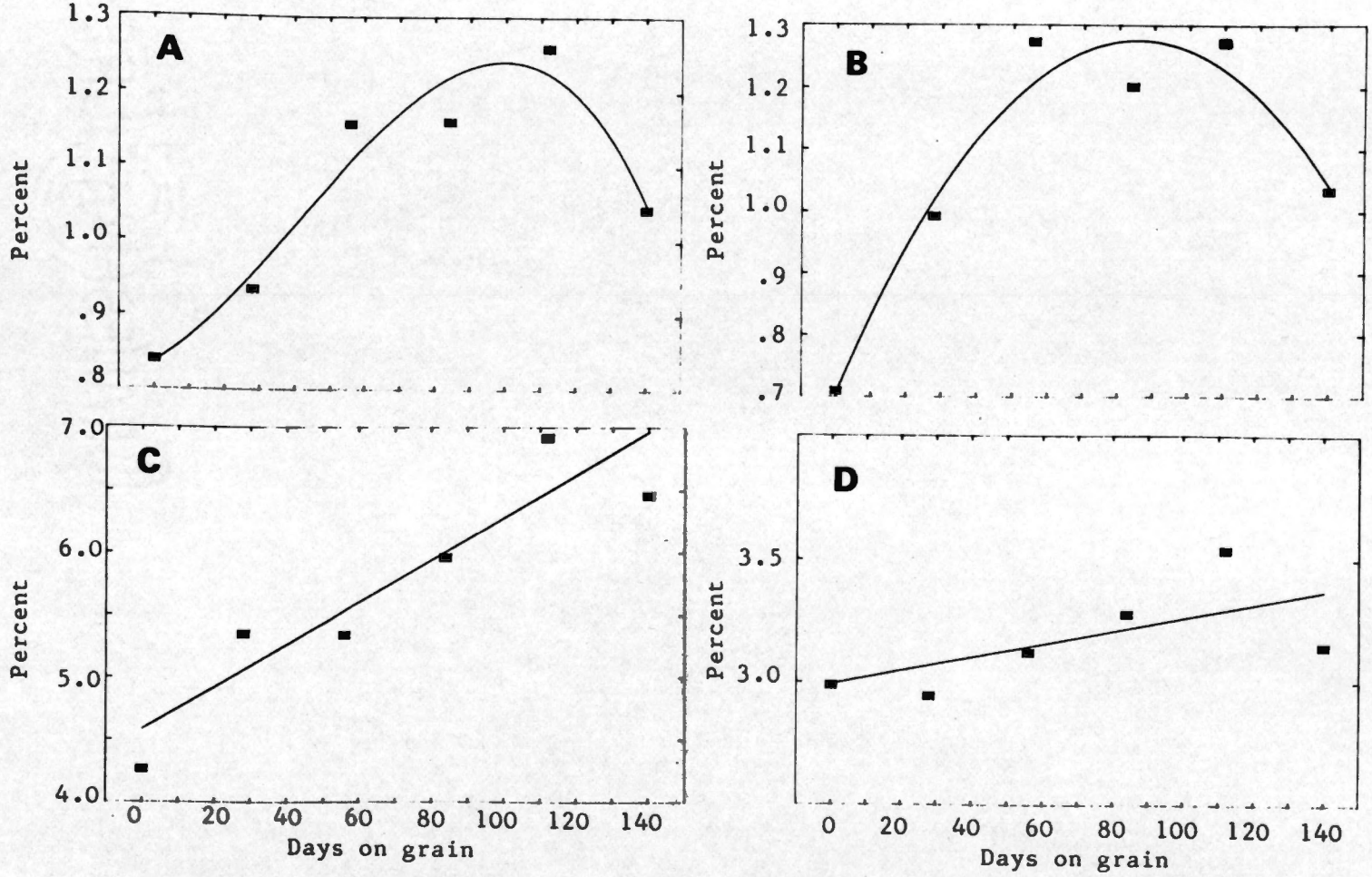


Figure 3. Fatty Acid Content in Ground Beef Total Lipids as a Function of Days Steers Were Fed Grain. A. αC17:0, B. C17:0, C. C18:1, D. C14:0.

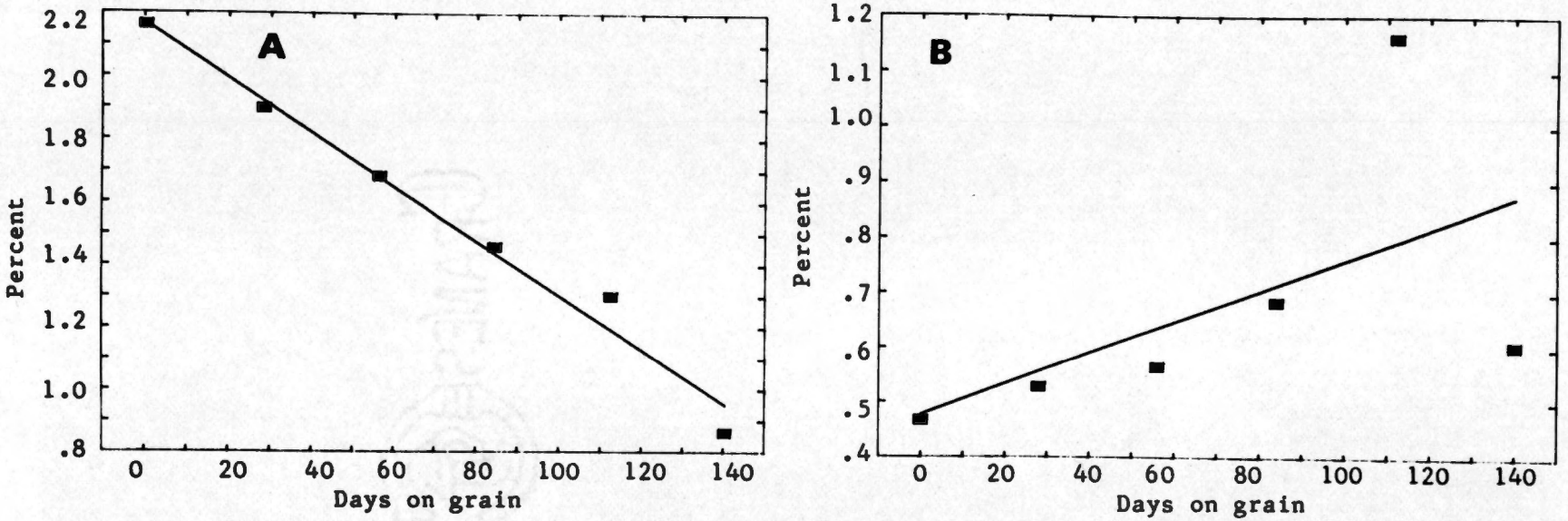


Figure 4. Fatty Acid Content in Ground Beef Total Lipids as a Function of Days Steers Were Fed Grain. A. C18:3, B. C15:0.

TABLE 14

LEAST SQUARE MEANS OF LONG CHAIN FATTY ACID COMPOSITION OF TOTAL LIPIDS IN GROUND BEEF

Fatty Acid	Days on Grain					
	0	28	56	84	112	140
	%					
C10:0	.06	.21	.06	.13	.13	.10
C12:0	.08	.06	.06	.04	.14	.09
C14:1	.56	.74	.66	1.06	1.18	.93
C14:0	2.99	2.95	3.20	3.28	3.54	3.15
αC15:0	.50	.19	.24	.09	.29	.11
C15:0	.47	.53	.56	.68	1.16	.61
C16:1	4.26	5.35	5.34	5.97	6.92	6.46
C16:0	24.67	25.84	26.15	25.27	25.14	26.37
αC17:0	.84	.93	1.16	1.16	1.26	1.04
C17:0	.71	.99	1.27	1.20	1.26	1.04
C18:0	18.32	12.73	11.28	11.38	9.66	8.36
C18:1	40.88	44.67	45.13	44.90	44.58	48.05
C18:2	2.64	2.22	2.65	2.61	2.56	2.26
C18:3	2.16	1.90	1.68	1.46	1.30	.86
C19:0	.21	.16	.17	.25	.25	.16
C20:0	.09	.07	.06	.09	.11	.09
C20:4	.17	.16	.14	.22	.19	.17
Unknown 1	.05	.03	.04	.06	.05	.01
Unknown 2	.10	.07	.03	.03	.08	.02
Unknown 3	.13	.13	.06	.08	.13	.08
Unknown 4	.11	.10	.05	.04	.07	.05

acid (C14:1), 13-methyltetradecanoic acid (αC15:0), pentadecanoic acid (C15:0), palmitic acid (C16:0), palmitoleic acid (C16:1), margaric acid (C17:0), 15-methylhexadecanoic acid (αC17:0), stearic acid (C18:0), oleic acid (C18:1), linolenic acid (C18:3), nonadecanoic acid (C19:0), arachidic acid (C20:0) and unknowns 1, 2, 3 and 4 for time on grain. Orthogonal comparisons were used to partition the variation among the different effects. Palmitic acid, stearic acid and oleic acid had significant cubic relationships with days on grain (Table 13). The percentage C16:0 was lowest at 0 days (24.67%) and highest at 140 days on grain (26.37%); however, the curve determined as a best fit of the data (Equation 5, Appendix B) showed a calculated maximum for C16:0 content of 26.13% at 40.5 days on grain and a calculated minimum of 25.36% at 100.5 days on grain (Figure 2A). The C18:0 content decreased rapidly during the first 50 days on grain from 18.32 to 11.43% but only decreased to 10.43% at 110 days on grain (Figure 2B; Equation 8, Appendix B). Percentage C18:1 increased from 40.88 at 0 day to 45.36 at 48.8 days and then decreased to 44.62 at 95.5 days (Equation 9, Appendix B) and then increased to 48.05 at 140 days on grain (Figure 2C).

Myristoleic acid (C14:1) and a branched chain fatty acid, 15-methylhexadecanoic acid (αC17:0), had a cubic relationship with days on grain while margaric acid (C17:0) showed a quadratic relationship (Table 13). Percentage C14:1 decreased from 0.60 at 0 day to 0.57 at 12.5 days on grain and then increased to a calculated maximum of 1.14 at 110 days on grain (Figure 2D; Equation 1, Appendix B). Percentage αC17:0 increased from 0.84 at 0 day to an estimated maximum of 1.29 at 99.5 days on grain (Figure 3A and Equation 6, Appendix B). Percentage C17:0 increased from 0.71 at 0 day on grain to a calculated maximum

of 1.29 at 85.6 days on grain and then decreased to 1.04 at 140 days (Figure 3B; Equation 7, Appendix B).

Palmitoleic acid (C16:1), myristic acid (C14:0), linolenic acid (C18:3) and pentadecanoic acid (C15:0) had significant linear relationships with days on grain (Table 13, page 43). Percentage C16:1 increased from 4.26 at 0 day (Figure 3C) to an estimated 6.96 at 140 days on grain (Equation 4, Appendix B). Percentage C14:0 increased from 2.99 at 0 day (Figure 3D) to an estimated 3.37 at 140 days. Percentage C18:3 (Figure 4A) decreased from 2.16 at 0 day to a calculated 0.95 at 140 days on grain (Equation 10, Appendix B). Percentage C15:0 increased from 0.47 at 0 day to 0.88 at 140 days on grain (Figure 4B).

Other fatty acids which were present in the fat of ground beef at percentages less than 0.50% and were affected significantly by days on grain were 13-methyltetradecanoic acid (αC15:0), nonadecanoic acid (C19:0) and unknown acid 3 (Table 13, page 43). Percentage αC15:0 decreased with increasing days on grain (Table 14). Percentage C19:0 was maximum at 103 days on grain and percentage unknown 3 acid decreased with increasing days on grain with the exception of 112 days (Table 14).

Days on grain affected fatty acid composition of beef fat in complex ways. However, examining the way groups of fatty acids changed in percentage concentrations across time on grain helps to clarify the picture. In general, there was an approximate total increase of 12% in the sum of the percentages for the following acids: C14:0, C14:1, C15:0, C16:0, C16:1, C17:0, αC17:0 and C18:1 during 140 days steers were fed grain. There was an approximate 12% total decrease in the sum of percentages of αC15:0, C18:0, C18:3, C19:0 and unknown 3 fatty acids during the 140 days steers were fed grain. Largest changes in

percentages of the fatty acids during time steers were fed grain were the 7.17% increase in C18:1 and the almost 10% decrease in C18:0 (Table 14).

These data for stearic acid, oleic acid, and linolenic acid correspond well with the results of Miller et al. (1967), Westerling and Hedrick (1979), Brown et al. (1979) and Amiri (1980) who found that fat of steers fed grain had less stearic acid, more oleic acid and less linolenic acid than steers finished on grass alone. In contrast with Brown et al. (1979) and Amiri (1980) who found that grass-finished steers had higher amounts of C14:1 and Brown et al. (1979) who found that grass-finished steers had higher amounts of C16:1 than did grain-finished steers, it was found in this present investigation that the percentages of C14:1 and C16:1 increased with days on grain in steers fed up to 140 days. Contrary to Amiri (1980) who found a lower concentration of C14:0 in steers finished on grain as compared to that in steers finished on pasture, the results of the present study showed that the percentage of C14:0 in beef fat increased with increasing time steers were fed grain.

However, the results of the present study are in agreement with Amiri (1980) showing the percentage of C18:2 in beef is not affected by finish, although Miller et al. (1967) and Brown et al. (1979) reported a higher C18:2 concentration in grain-finished beef than grass-finished beef, while Westerling and Hedrick (1979) showed a decrease in C18:2. Miller et al. (1967) found a decrease in concentration of C16:0 and Brown et al. (1979) showed an increase in percentage concentration of C16:0 for grain-finished beef compared with grass-finished beef.

However, these investigators did not study the concentration of C16:0 as a function of days steers were fed grain.

A significant effect due to breed (Table 10, page 38) was found for lauric acid, palmitic acid and linoleic acid. Percentage lauric acid was lower while percentages of palmitic acid and linoleic acid were higher in Angus steers than in Hereford steers.

F. QUANTITATIVE DESCRIPTIVE ANALYSIS

Analysis of variance and least square means for the Quantitative Descriptive Analysis (QDA) are listed in Tables 15 and 16. Graphs of the intensity magnitudes of various flavor and aroma characteristics are shown in Figures 5 and 6. The intensity and magnitude of milky-oily aroma, cooked beef fat aroma, sour aroma, liver flavor, fishy flavor, cooked beef fat flavor, milky-oily flavor and sour flavor changed significantly with days on grain. The concentration of milky-oily aroma of ground beef decreased at a decreasing rate from 69.5 mm (based on 140 mm = intense magnitude) at 0 day on grain to a calculated minimum of 38.4 at 114 days before increasing to a calculated 39.8 mm at 140 days on grain (Figure 5A, Equation 15, Appendix B). The milky-oily flavor decreased at a decreasing rate from 77.1 at 0 day to a calculated 38.2 mm at 113.5 days before increasing to a calculated 40.2 mm at 140 days (Figure 6A and Equation 19, Appendix B). Cooked beef fat aroma increased at a decreasing rate from 63.7 mm at 0 day to a calculated maximum of 90.6 mm at 131 days on grain before decreasing slightly to a calculated 90.5 mm at 140 days (Figure 5B, Equation 16, Appendix B). Cooked beef fat flavor increased at a decreasing rate from 58.1 mm at 0 day to a calculated maximum of 90.8 mm at 108.6 days on grain and then

TABLE 15

ANALYSIS OF VARIANCE FOR QUANTITATIVE DESCRIPTIVE ANALYSIS OF GROUND BEEF

Source	DF	Milky-Oily Aroma	Cooked Beef Fat Aroma	Sour Aroma	Liver Flavor	Metallic Flavor	Fishy Flavor	Cooked Beef Fat Flavor	Milky-Oily Flavor	Sour Flavor	Off Flavor
		Mean Squares									
Time	5	10526.57***	8089.00***	164.16	218.69	139.19	602.22***	12066.44***	16327.20***	2787.24	640.26
Linear	1	40381.81***	34006.92***	453.93*	703.68	147.51	2293.68***	46086.59***	62785.32***	11313.72**	136.72
Quadratic	1	8972.94**	3913.63**	181.19	1158.74*	292.18	398.74	12995.42*	14580.99**	1781.23	446.71
Cubic	1	3183.74	1768.04	48.88	23.15	170.55	41.84	49.47	3394.85	42.68	13.60
Quartic	1	.21	494.64	6.44	6.80	15.92	19.69	1044.16	111.60	598.45	636.87
Pentic	1	594.17	261.81	130.36	11.09	69.80	257.15	156.55	763.21	200.10	1967.42
Breed	1	3698.01*	383.50	47.22	13.02	154.83	231.86	132.99	6363.86*	10.92	2165.45
Frame size	4	1027.99	1427.58	34.89	240.03	150.57	94.09	3043.23	1079.57	112.96	11.27
Breed X Frame size	4	1120.17	342.92	74.70	62.83	34.54	16.53	3173.09	2855.44	302.16	1199.26
Error	45	819.18	527.73	110.54	202.27	113.59	116.01	1990.23	1180.20	1361.04	535.77

*** $p < 0.001$
** $p < 0.01$
* $p < 0.05$

TABLE 16

LEAST SQUARE MEANS FOR QUANTITATIVE DESCRIPTIVE ANALYSIS OF GROUND BEEF

Descriptor	Days on Grain					
	0	28	56	84	112	140
	mm[a]					
Milky-Oily Aroma	69.5	50.0	45.6	40.9	41.9	37.4
Cooked Beef Fat Aroma	63.7	77.3	83.6	88.1	86.3	92.9
Sour Aroma	18.4	15.9	16.0	14.5	16.2	14.8
Cooked Beef Fat Flavor	58.1	76.1	83.2	86.4	92.9	88.0
Milky-Oily Flavor	77.1	54.3	46.8	40.5	42.6	37.5
Sour Flavor	38.3	32.8	27.6	23.3	26.3	22.9
Liver Flavor	18.4	22.1	24.0	23.8	23.9	22.1
Metallic Flavor	18.9	18.7	17.5	15.1	16.4	17.6
Fishy Flavor	12.2	8.8	5.8	7.2	4.7	5.3
Off Flavor	15.5	16.95	8.8	15.2	13.4	14.6

[a]mm on a 150 mm scale where 10 mm = slight and 140 mm = intense magnitude.

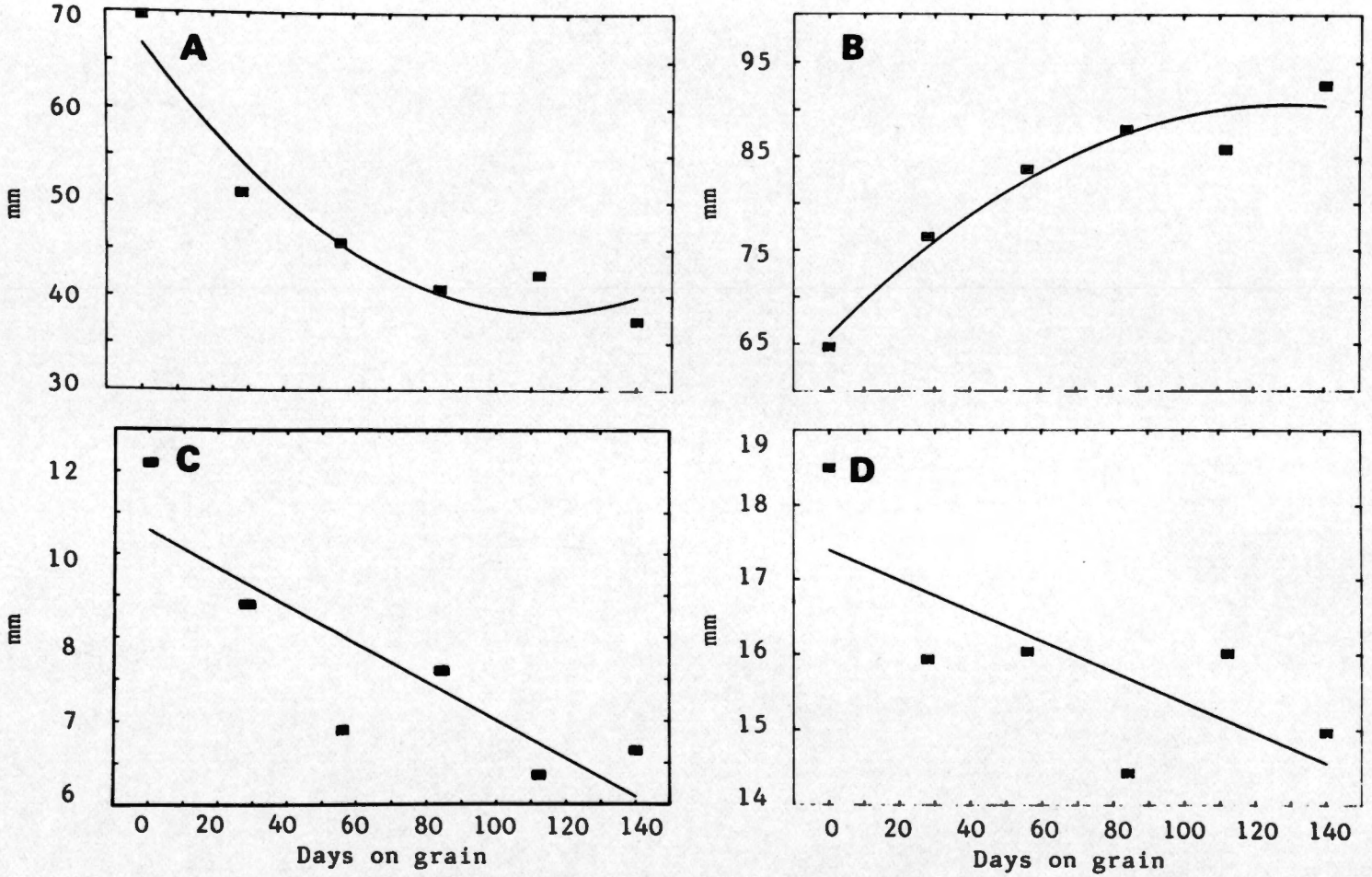


Figure 5. Intensities of Ground Beef Aromas and Flavor Determined by Quantitative Descriptive Analysis and Plotted as a Function of Days Steers Were Fed Grain. A. Milky-Oily Aroma, B. Cooked Beef Fat Aroma, C. Fishy Flavor, D. Sour Aroma.

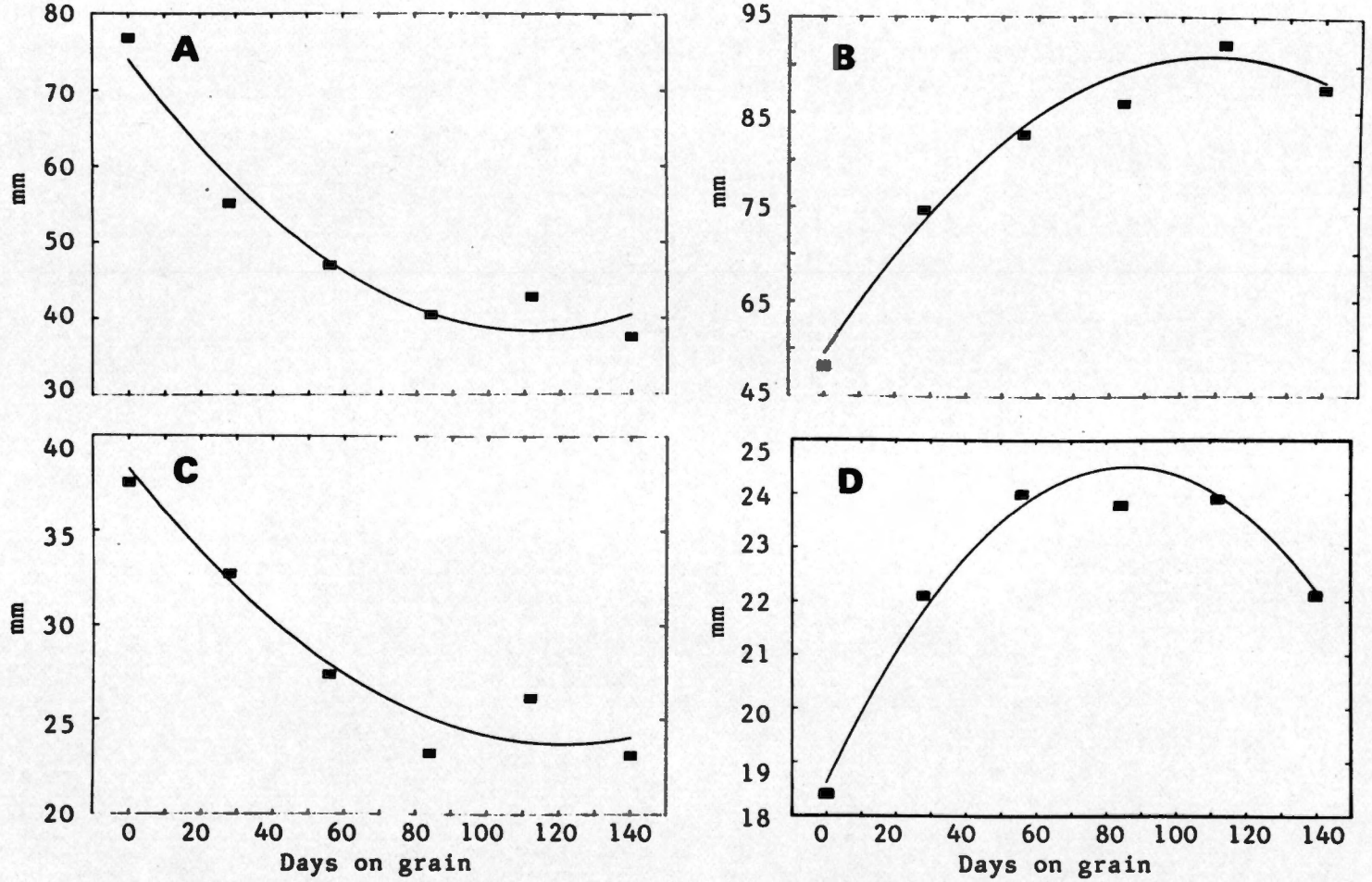


Figure 6. Intensities of Ground Beef Flavors Determined by Quantitative Descriptive Analysis and Plotted as a Function of Days Steers Were Fed Grain. A. Milky-Oily Flavor, B. Cooked Beef Fat Flavor; C. Sour Flavor, D. Liver Flavor.

decreased slightly to 88.2 mm at 140 days (Figure 6B , Equation 20, Appendix B). Sour flavor decreased at a decreasing rate similar to the milky-oily flavor except that it had a minimum of 23.6 mm at 122 days on grain (Figure 6C , Equation 21, Appendix B). Liver flavor, which generally was of less magnitude than milky-oily, cooked beef fat or sour flavor, increased at a decreasing rate to a maximum of 24.5 mm at 88 days on grain and then decreased (Figure 6D, Equation 22, Appendix B). Both fishy flavor and sour aroma decreased linearly with increasing days on grain (Figures 5C, 5D; Equations 17, 18 ; Appendix B). Fishy flavor was judged to have the least magnitude of all the flavor descriptors affected significantly by days on grain.

Magnitudes of milky-oily aroma and flavor and of cooked beef fat aroma and flavor at any day on feed were similar (Table 16). Although the QDA panel judged aroma by smelling only and flavor after putting the sample in the mouth and chewing, it is apparent that flavor-by-mouth added little to these aromas. The magnitude of the milky-oily flavor in ground beef decreased approximately one-half (one-fourth of 150-mm scale) during 114 days steers were fed grain. The highest magnitude of intensity for this flavor was judged for ground beef from steers receiving only a grass diet: approximately one-half of the 150-mm scale.

Blumer (1978) reported the results of a flavor profile panel who evaluated ground beef samples from grass-finished and grain-finished beef (Amiri, 1980). This panel noted that in beef a milky aroma scored at just below slight (X-1) on their intensity scale was objectionable, but at the lower threshold intensity (X), the flavor was desirable. In the present study the magnitude of milky-oily flavor intensity in the

grass-finished beef could also be judged objectionable or undesirable. This observation was noted by several of the QDA panel during evaluation of ground beef.

The cooked beef fat flavor of ground beef, judged to be of maximum intensity at 108 days steers were fed grain, was desirable according to the QDA panel. Therefore, the undesirable flavor in grass-finished beef may be attributable to the presence of a more intense milky-oily flavor and a less intense cooked beef fat flavor. This observation agrees with Amiri (1980) and Brown et al. (1979). The presence of sour and fishy flavors, the magnitudes of which were significantly affected by days on grain, may also be part of the undesirable flavor of grass-finished beef. Berry et al. (1980) in performing flavor profile analyses on cooked beef loin steaks found that typical flavors of steaks previously described in hedonic ratings as desirable were "browned," defined as caramelized, bouillon-like, beefy and "sweet." Typical flavors of steaks previously described as undesirable by hedonic ratings were "grassy," defined as animal, chemical, medicinal, iodine-like; and "astringent," defined as tannin-like resulting in a puckering and dry sensation in the mouth.

Milky-oily aroma and flavor were significantly affected by breed. Both components were found to be more intense in ground beef from Hereford steers than from Angus steers (Table 10, page 38).

G. CORRELATION BETWEEN SENSORY EVALUATION DESCRIPTIVE TERMS

Table 17 shows correlation coefficients between flavor descriptive terms. All terms except metallic flavor were significantly

TABLE 17

CORRELATION COEFFICIENTS BETWEEN DESCRIPTIVE TERMS USED FOR QUANTITATIVE DESCRIPTIVE ANALYSIS OF GROUND BEEF FLAVOR

Descriptive term	Milky-oily aroma	Cooked beef fat aroma	Sour aroma	Liver flavor	Metallic flavor	Fishy fishy	Cooked beef fat flavor	Milky-oily flavor	Sour flavor	Off flavor
Milky-oily aroma	1.00	-.90***	.44***	-.42***	.19	.60***	-.70***	.92***	.66***	.36**
Cooked beef fat aroma	-.90***	1.00	-.40**	.36**	-.17	-.66***	.75***	-.87***	-.61***	-.35**
Sour aroma	.44***	-.40**	1.00	-.20	.07	.31*	-.34**	.37**	.24	.07
Liver flavor	-.42***	.36**	-.20	1.00	.21	-.01	.33*	-.40**	-.24	.06
Metallic flavor	.19	-.17	.07	.21	1.00	.15	-.08	.25	.36**	.03
Fishy flavor	.60***	-.65***	.31*	-.01	.15	1.00	-.49***	.59***	.38**	.51***
Cooked beef fat flavor	-.70***	.75***	-.34**	.33*	-.08	-.49***	1.00	-.76***	-.54***	-.28*
Milky-oily flavor	.92***	-.87***	.37**	-.40**	.25	.59***	-.76***	1.00	.78***	.38**
Sour flavor	.66***	-.61***	.24	-.24	.36**	.39**	-.54***	.78***	1.00	.25
Off flavor	.36**	-.35**	.07	.06	.03	.51***	-.28*	.38**	.25	1.00

***p < 0.001
**p < 0.01
*p < 0.05

correlated with milky-oily aroma and flavor and cooked beef fat aroma and flavor. Milky-oily aroma and flavor scores were shown to be negatively correlated with cooked beef fat flavor scores ($p < 0.001$). This is in agreement with Amiri (1980) who found through the flavor profile analysis that with grass-finished beef, a milky flavor was in higher intensities, but there was a lack of beef fat flavor when compared with grain-finished beef. Sour aroma ($r=0.44$) and flavor ($r=0.66$) and also fishy flavor ($r=0.66$) were correlated positively with milky-oily aroma ($p < 0.001$) and correlated negatively with cooked beef fat flavor ($r=0.70$, $p < 0.01$). Liver flavor, which some panelists described as being somewhat bloodlike, was correlated positively with cooked beef fat flavor ($r=0.33$, $p < 0.05$).

H. RELATIONSHIP OF AROMA AND FLAVOR DESCRIPTIVE TERMS AND CHEMICAL CHARACTERISTICS

Table 18 shows correlation coefficients between flavor descriptive terms and chemical components of ground beef. Many of the fatty acids were significantly correlated with milky-oily aroma and flavor. Stearic acid had the highest positive correlation coefficient with the milky-oily flavor and aroma ($r=0.72$ and $r=0.64$, respectively). Other fatty acids positively correlated with the milky-oily flavor and aroma were C15:0 and C18:3 which had coefficients above 0.50. Unknown fatty acids 2 and 4 were also positively correlated ($p < .01$) with milky-oily flavor and aroma. Monounsaturated fatty acids, C14:1, C16:1, C18:1 and the odd carbon fatty acid C17:0 were correlated positively with cooked beef fat flavor and aroma at or above the $p < .05$ level of significance.

TABLE 18

CORRELATION COEFFICIENTS BETWEEN GROUND BEEF FLAVOR AND AROMA DESCRIPTIVE TERMS AND CHEMICAL COMPONENTS OF THE GROUND BEEF

Chemical component	Milky-oily aroma	Cooked beef fat aroma	Sour aroma	Liver flavor	Metallic flavor	Fishy flavor	Cooked beef fat flavor	Milky-oily flavor	Sour flavor	Off flavor
C14:1	-.32*	.30*	-.13	.27*	-.21	-.25	.25	-.36**	-.39**	-.01
C15:0	.55***	-.59***	.22	-.14	.20	.36**	-.37**	.52***	.36**	.04
C16:1	-.41***	.41**	-.21	.32*	-.15	-.32*	.41**	-.41**	-.44***	.09
C17:0	-.37**	.38**	-.13	.30*	-.17	-.30*	.32*	-.38**	-.43***	-.07
C17:0	-.42***	.38**	-.16	.18	-.18	-.37**	.26*	-.41**	-.37**	-.19
C18:0	.72***	-.72***	.34**	-.33**	.21	.57***	-.51***	.64***	.53***	.16
C18:1	-.60***	.65***	-.25	.25	-.08	-.38**	.30*	-.46***	-.30*	-.14
C18:3	.51***	-.57***	.25	-.21	.11	.41**	-.39**	.53***	.57***	.05
Unknown 1	.18	-.22	.04	-.03	-.12	.26*	-.01	.08	-.16	.18
Unknown 2	.38**	-.47***	.12	-.13	.10	.30*	-.34**	.43***	.36**	.11
Unknown 3	.19	-.33*	-.02	.07	.07	.08	-.31*	.24	.27*	.07
Unknown 4	.36**	-.44***	.23	-.11	.07	.17	-.33**	.35**	.33**	.17
Sum Short chain (C10,C12)	.06	-.14	-.21	.25	.04	.04	-.09	.07	.03	.27*
Sum unknowns	.25	-.39**	.01	.01	.04	.20	-.26*	.27*	.19	.16
Acetic acid	-.28*	.37**	-.24	.09	-.06	-.31*	.29*	-.31*	-.39**	-.09
Propionic acid	.40**	-.33**	.06	-.22	.01	.27*	-.26*	.37**	.24	-.02
Isovaleric acid	.07	-.12	-.06	.07	.35**	.14	-.02	.06	.11	-.15
Titr. acidity	.15	-.24	-.6	.01	.36**	.03	-.21	.21	.32*	-.16
Initial pH	-.13	.13	-.28*	.21	.06	-.20	.13	-.17	-.17	.12
Water soluble carbohydrates	-.28*	.33*	-.20	.40**	-.03	-.14	.18	-.32*	-.23	.11

***p < 0.001
**p < 0.01
*p < 0.05

Those fatty acids which were positively correlated with the milky-oily flavor were negatively associated with the cooked beef fat flavor and vice versa.

Fatty acids significantly correlated either positively or negatively with milky-oily flavor were also correlated in the same way with the sour flavor at the same or a lower level of probability with one exception: unknown 3 was correlated with sour flavor only. Only one fatty acid, C18:0, was correlated with sour aroma ($p < .01$). All fatty acids correlated with milky-oily aroma, either positively or negatively, were correlated also with the fishy flavor with exceptions of C14:1 and unknown acid 4 which were not correlated and unknown acid 1 which was correlated ($p < .05$) with fishy flavor. The acids C14:1, C16:1 and αC17:0 were correlated positively ($p < .05$) and C18:0 was correlated negatively ($p < .01$) with liver flavor. Metallic flavor and off flavor were not significantly correlated to any of the long chain fatty acids.

Acetic acid was negatively correlated ($p < .01$) with sour flavor as well as with milky-oily flavor; however, propionic acid was not significantly correlated with either sour aroma or flavor although it was positively correlated with milky-oily aroma and flavor ($p < .01$). Isovaleric acid was correlated only with metallic flavor ($p < .01$).

Titratable acidity was positively correlated with sour flavor ($p < .05$) and metallic flavor ($p < .01$) and initial pH of the ground beef was correlated negatively with the sour aroma ($p < .05$). The relationship between sour taste and pH of organic acids is affected by the pKa of that acid (Kenrick, 1931; Beatty and Cragg, 1935) and also how many H^+ ions the acid can donate (Beidler, 1967, 1971). A measure of how many H^+ ions acids in the meat could donate is determined by

titratable acidity. The rather low correlation coefficient found between titratable acidity and the intensity magnitude of sour flavor indicates the relationship is complex. This relationship was based on the fact that acidity decreased linearly 0.14 meg H^+/10g ground beef across days on grain (Figure 2, page 45), and the sour flavor decreased approximately one-tenth of a 150-mm scale at a decreasing rate across days on grain (Figure 5D, page 55). However, the titratable acidity of ground beef was not determined until after the statistical evaluation of the Quantitative Descriptive Analysis of the ground beef showed a significant decrease in sour flavor. Analysis of titratable acidity was completed within one month following the sensory evaluation. These observations tend to support the belief that the QDA panel was well trained.

In contrast to Dryden et al. (1969) who reported that lactic acid had a negative effect on desirable beef flavor of the semimembranosus muscle, there was no correlation of lactic acid with flavor scores. Dryden et al. (1969) did report there was no consistent association between flavor and lactic acid content in meat.

Water soluble carbohydrate (glucose) content was negatively correlated ($p < .05$) with milky-oily aroma and flavor and positively correlated with cooked beef fat aroma ($p < .05$) and metallic flavor ($p < .01$).

I. PASTURE GRASS COMPOSITION

Analysis of variance and least square means for fat and moisture content of pasture grass are listed in Tables 19 and 20. Fat content decreased over the grazing period while moisture content at first decreased from 73.29 to 66.03% during the middle of the grazing period

TABLE 19

ANALYSIS OF VARIANCE FOR PASTURE GRASS COMPOSITION DURING THE STEER GRAZING PERIOD

Source	Protected DF	Protected Mean Squares	Unprotected DF	Unprotected Mean Squares
Fat				
Date	3	1.23×10^{-1}**	3	1.07×10^{-1}
Error	4	3.89×10^{-3}	4	3.54×10^{-2}
Moisture				
Date	6	102.65*	6	167.53***
Error	49	32.57	53	32.24

*p < 0.05

**p < 0.01

***p < 0.001

TABLE 20

LEAST SQUARE MEANS FOR PASTURE GRASS COMPOSITION DURING THE STEER GRAZING PERIOD

Date	Protected		Unprotected	
	Fat	Moisture	Fat	Moisture
	%			
April 25	2.47[a]	73.29[ab]	2.21	75.67[ab]
May 18	--	75.54[ab]	--	71.06[bc]
June 1	2.07[b]	72.14[ab]	1.78	71.38[bc]
June 15	--	69.92[bc]	--	66.57[c]
June 29	2.01[b]	66.03[c]	1.72	66.95[c]
July 12	--	77.29[a]	--	78.10[a]
July 27	1.91[b]	71.94[ab]	1.75	73.58[ab]

[a,b,c]Means with the same letter in the same column are not significantly different at 0.05 level.

and then increased to 71.94% at the end of the grazing period for the pasture grass protected from the grazing steers. The moisture content of the grass grazed by the steers (unprotected) followed a somewhat similar pattern. The moisture content over the sampling period was quite variable; however, the average moisture content across the grazing period was 63.27% for the protected grass and 62.91% for the unprotected grass.

Fat content was higher ($\bar{X}$=2.12%) in the grass protected from the grazing steers than in the unprotected grass ($\bar{X}$=1.87%). Fat content decreased from 2.47 to 1.91% in the protected grass and from 2.21 to 1.75% in the unprotected grass over the grazing period. The reduction in fat content of the pasture grass over the grazing period as well as the difference in fat content between the grass left protected and unprotected is in agreement with Hawke (1973) who stated that the basal portion of the grass left behind during grazing was more fibrous than the growing distal portion and that grass became more fibrous with increasing age causing the percentage of dry matter contributed by the lipid to decrease.

J. LONG CHAIN FATTY ACID COMPOSITION OF PASTURE GRASS

The mean squares and least square means for the long chain fatty acid composition of the pasture grass are listed in Tables 21 and 22. Significantly different means for samples that had not been grazed (protected) and those that had been grazed (unprotected) are identified by superscript letters. Linolenic acid had the greatest percentage concentration with C16:0, C18:0, C18:1 and C18:2 being the other major

TABLE 21

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF PASTURE GRASS LIPIDS DURING THE STEER GRAZING PERIOD

	Protected				Unprotected			
		Source				Source		
Fatty Acid	DF	Date	DF	Error	DF	Date	DF	Error
	mean squares							
	3		4		3		3	
C12:0		1.69×10^{-1}		1.12×10^{-1}		6.42×10^{-1}		1.32×10^{-1}
C14:0		3.15×10^{-2}		7.74×10^{-3}		6.37×10^{-2}*		5.79×10^{-3}
αC15:0		1.89×10^{-2}		7.57×10^{-3}		8.26×20^{-2}		2.95×10^{-2}
C15:0		4.17×10^{-2}		3.57×10^{-2}		2.12×10^{-2}		4.65×10^{-3}
C16:0		6.56		3.15		1.73		8.77×10^{-1}
C16:1		2.49×10^{-1}		4.79×10^{-2}		1.48		3.59×10^{-1}
αC17:0		1.52×10^{-1}		1.43×10^{-1}		3.13×10^{-1}		4.07×10^{-1}
2OH-C16:0[a]		1.16×10^{-1}		1.13×10^{-1}		1.73×10^{-1}		6.92×10^{-2}
3OH-C16:0[a]		9.23×10^{-2}		3.26×10^{-1}		4.17×10^{-1}**		8.89×10^{-3}
C18:0		1.94		8.53×10^{-1}		1.68		5.21×10^{-1}
C18:1		5.79*		7.96×10^{-1}		6.81		1.29
C18:2		9.42***		1.55×10^{-1}		4.26		9.85×10^{-1}
C18:3		125:01		27.17		89.95*		8.24
C19:0		2.12×10^{-1}		1.83		2.67		9.27×10^{-1}
ΔC19:0[a]		3.59×10^{-1}		6.80×10^{-2}		4.88×10^{-1}		6.24×10^{-2}
C20:0		2.26×10^{-2}		1.93×10^{-1}		3.07×10^{-2}		3.47×10^{-2}
C20:4[a]		2.99×10^{-1}		4.43×10^{-1}		5.86×10^{-1}		1.31
Sum of unknowns		5.13×10^{-1}		2.74		2.02		7.32

*p < 0.05

**p < 0.01

***p < 0.001

[a]tentatively identified

TABLE 22

LEAST SQUARE MEANS FOR LONG CHAIN FATTY ACID COMPOSITION OF PASTURE GRASS DURING THE STEER GRAZING PERIOD

Fatty Acid	Protected Pasture				Unprotected pasture			
	4-25	6-1	6-29	7-27	4-25	6-1	6-29	7-27
	%							
C12:0	.62^{ab}	.67^{b}	1.23^{a}	1.00^{ab}	.34^{a}	.82^{ab}	1.09^{ab}	1.87^{b}
C14:0	.57^{ab}	.43^{b}	.72^{a}	.66^{ab}	.46^{a}	.47^{a}	.74^{b}	.84^{b}
αC15:0	.12	.14	.34	.19	.12^{ab}	.07^{a}	.36^{ab}	.53^{b}
C15:0	.17	.26	.52	.32	.43^{ab}	.23^{a}	.31^{ab}	.46^{b}
C16:0	16.85^{a}	18.62^{ab}	21.10^{ab}	19.85^{b}	20.45^{a}	21.35^{ab}	19.14^{ab}	20.73^{b}
C16:1	.97^{a}	1.53^{ab}	1.33^{ab}	1.80^{b}	.26^{a}	1.65^{ab}	2.14^{ab}	2.78^{b}
αC17:0	2.18	1.70	2.09	2.35	2.06	1.78	1.80	2.63
2OH-C16:0*	.37	.38	.87	.50	.71	.16	.43^{b}	.84
3OH-C16:0*	.76	1.17	1.16	.83	.14^{a}	.26^{a}	.69^{b}	1.24^{c}
C18:0	3.67	3.94	5.48^{b}	5.52^{b}	4.70	2.96	4.05^{ab}	5.12^{b}
C18:1	2.73^{a}	4.67^{ab}	6.09^{b}	6.49^{b}	3.11^{a}	4.26^{ab}	6.65^{ab}	7.67^{b}
C18:2	9.69^{a}	13.63^{b}	12.60^{b}	14.74^{c}	10.38^{a}	13.59^{ab}	14.66^{b}	13.89^{ab}
C18:3	51.52^{a}	41.70^{ab}	36.74^{ab}	33.37^{b}	45.35^{a}	43.20^{a}	40.39^{a}	29.23^{b}
C19:0	2.26	3.02	2.79	2.83^{b}	1.38	.65	1.30^{ab}	3.34^{b}
ΔC19:0*	.20^{ab}	.69^{ab}	.00^{a}	.91^{b}	1.46^{a}	.51^{ab}	.67^{ab}	.00^{b}
C20:0	.64	.44	.55	.40	.44	.23	.22	.46
C20:4*	1.39	1.27	1.46	2.13	1.64	2.01	.71	1.36
Sum unknowns	5.31	5.71	4.92	6.09	6.58	5.80	4.65	7.01

^{a,b,c}Means with the same letter in the same row are not significantly different at $p < 0.05$ level.

*Tentatively identified.

fatty acids. This is in agreement with Hawke (1963) and Garton (1963). Over the grazing period, linolenic acid decreased ($p < 0.05$) from 51.52 to 33.37% in protected samples and from 45.35 to 29.23% in the unprotected samples. This reduction is in agreement with Hawke (1973). Palmitoleic acid increased from 0.97 to 1.80% in protected samples and from 0.26 to 2.78% in unprotected samples over the grazing period. Stearic acid increased from 3.67 to 5.52% in cage samples and 4.70 to 5.12% in strip samples, oleic acid increased from 9.69 to 14.74% in cage samples and from 10.38 to 13.89% in strip samples and linoleic acid increased form 9.69 to 14.74% in cage samples and from 10.38 to 13.89% in strip samples across the grazing period. There were no consistent differences in the percentage concentrations of the fatty acids between the protected pasture grass and the unprotected pasture grass. This could possibly be due to the small number of samples analyzed.

Linolenic acid in a ruminant diet is hydrogenated to less unsaturated fatty acids by rumen microbes; however, a small percentage of dietary C18:3, especially that remaining in ester form, escapes hydrogenation (Leat and Harrison, 1972). Since the C18:3 content of the grass lipid in the present study was much higher than in corn lipid (less than 0.8%, Weiss, 1970), it is possible that more C18:3 from the grass diet escaped hydrogenation than that from the corn diet. Fatty acids are absorbed intact from the gut of the ruminant and incorporated into fat at adipose sites (Leat and Harrison, 1972). Therefore, steers fed grass should have a higher C18:3 concentration than steers fed corn. Also, increased rates of lipogenesis and lipolysis occur in adipose tissues of steers fed a high-energy diet compared with that of steers fed a low-energy diet (Pothoven et al., 1975). In steers which were

fed grass only and then changed to a corn diet, C18:3 in the fat would be diluted and removed with increasing time steers were fed corn. This phenomena was observed in the present study as a linear decrease in C18:3 content of the ground beef as steers were fed corn from 0 to 140 days (Figure 4A, page 47).

CHAPTER V

SUMMARY

Sixty steers (30 predominantly Angus and 30 Hereford) were grouped into 6 groups of 10 steers on the basis of breed, weight and frame size. Within each group of 10 steers, 5 different frame sizes ranging from 1 (small size) to 5 (large size) were represented in each breed. All steers were backgrounded on a pasture of fescue, ladino clover and orchard grass from April through July 1979 after which one group of 10 steers was slaughtered (0 day). The other steers were adjusted to a whole shelled corn diet for 2 weeks. At the end of this period one group of 10 steers was slaughtered at 28, 56, 84, 112 and 140 days steers were fed corn.

Ground beef formulated to contain 20% fat was prepared from the semimembranosus muscle and brisket fat from the right side of each steer. Microbial content, fatty acid composition of total lipid, water soluble carbohydrates, lactic acid content, volatile fatty acid content, titratable acidity, total lipid content and moisture content were determined on ground beef from each steer and the flavor of the ground beef from each steer was evaluated by Quantitative Descriptive Analysis (QDA). Results were statistically analyzed as a function of time on corn, breed, frame size and breed X frame size. Significant time effects were separated by orthogonal polynomials, and equations for dependent variables as a function of time were estimated.

The microbial content of ground beef samples significantly decreased over time on corn except for the 28-day time period when a

large increase was encountered, most likely due to a technician error. Fat content did vary significantly although the ground beef was formulated to contain 20% fat. Contrarily, the moisture content was not significantly affected by time.

The fatty acid analysis determined odd and even carbon chain, branched chain, and saturated and unsaturated fatty acids from C10 to C22. During the 140 days steers were fed corn, the chemical composition of the ground beef changed: stearic acid decreased curvilinearly from 18.32 to 8.36%; oleic acid increased curvilinearly from 40.88 to 48.05%; linolenic acid decreased linearly from 2.16 to 0.86%; acetic acid increased linearly from 2.98 to 4.33 mg/100 g ground beef; water soluble carbohydrates increased linearly from 2.54 to 4.56 mg glucose/10 g ground beef; initial pH of the raw ground beef increased linearly from 5.42 to 5.63 while titratable acidity in raw ground beef decreased linearly from 1.07 to meg H^+/10 g ground beef to 0.94; lactic acid ($\bar{X}$=76 mg/10 g ground beef), although accounting for 84.6$\pm$6.3% of the titratable acidity, did not change significantly with time on corn.

Pasture grass samples obtained during the grazing period were analyzed for moisture content, total lipid content and fatty acid composition of the total lipid. Pasture grass protected from the grazing steers was compared to pasture grass that had been grazed by the steers. Average moisture content was 63.27% for the protected pasture grass and 62.91% for the unprotected pasture grass, but the moisture content varied from 66.03% to 77.29% during the grazing period. Total lipid content decreased from 2.47 to 1.91% in the protected grass and from 2.21 to 1.75% in the grass that had been grazed over the grazing period due to increased fiber content making up a greater

proportion of the dry matter. Linolenic acid was the predominant fatty acid in pasture grass ($\bar{X}$=40.19%) with C16:0, C18:0, C18:1 and C18:2 being the other major fatty acids. Linolenic acid decreased from 51.52 to 33.37% in protected samples and from 45.35 to 29.23% in unprotected samples during the grazing period with the other fatty acids increased in percentage concentration.

Descriptive terms chosen by the Quantitative Descriptive Analysis (QDA) panel for beef flavor were milky-oily, cooked beef fat, sour, metallic, liver and off flavor. Results of the QDA analysis showed that the milky-oily note decreased to a minimum intensity at approximately 114 days on corn and the cooked beef fat flavor increased to a maximum intensity at approximately the same time. Fishy and sour flavor notes increased with time steers were fed corn.

Simple correlation coefficients were determined between flavor and chemical components of the ground beef. Stearic acid had the highest positive correlation coefficient with milky-oily aroma and flavor (0.716 and 0.624 respectively), and pentadecanoic acid and linolenic acid had correlation coefficients above 0.500. These coefficients were significant at the $p < .001$ level. The acids, C14:1, C16:1, C18:1 and αC17:0, were correlated positively with cooked beef fat flavor and aroma at or above the $p < .05$ level. Acetic acid was negatively correlated ($p < .01$) with sour flavor as well as with milky-oily flavor. Titratable acidity was positively correlated with sour flavor ($p < .05$) and initial pH was correlated negatively ($p < .05$) with sour aroma.

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APPENDICES

APPENDIX A

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.

Aroma

slight intense

Milky-oily (grass-fed beef)

Cooked beef fat

Sour

Taste

Liver (raw, bloodlike)

Metallic

Fishy

Cooked beef flavor (fat)

Milky-oily (grass-fed beef)

Sour

Off-flavor

APPENDIX B

EQUATIONS FOR GRAPHS

1. $\%C14:1 = 0.59901761 - 0.00495357X + 0.00022163X^2 - 1.2031565 \times 10^{-6}X^3$
2. $\%C14:0 = 2.99257553 + 0.00270668X$
3. $\%C15:0 = 0.47687780 + 0.00283734X$
4. $\%C16:1 = 4.58267939 + 0.01701919X$
5. $\%C16:0 = 24.62214604 + 0.08654984X - 0.00152437X^2 + 7.1009752 \times 10^{-6}X^3$
6. $\%\alpha C17:0 = 0.83679625 + 0.00281796X + 6.5781498 \times 10^{-5}X^2 - 5.3574292 \times 10^{-7}X^3$
7. $\%C17:0 = 0.70510113 + 0.01336446X - 7.8260636 \times 10^{-5}X^2$
8. $\%C18:0 = 18.17062408 - 0.25538863X + 0.00301340X^2 - 1.2143104 \times 10^{-5}X^3$
9. $\%C18:1 = 40.85406357 + 0.22066827X - 0.00342163X^2 + 1.57807 \times 10^{-5}X^3$
10. $\%C18:3 = 2.16783035 - 0.00868339X$
11. Initial pH $= 5.40071429 + 0.00127551X$
12. Titratable Acidity[a] $= 1.05398571 - 0.00077908X$
13. Water soluble Carbohydrate[b] $= 2.9948809 + 0.01305766X$
14. Acetic Acid[c] $= 3.04797143 + 0.00962184X$
15. Milky-Oily Aroma[d] $= 66.77195125 - 0.50141016X + 0.00220821X^2$
16. Cooked Beef Fat Aroma[d] $= 65.85389863 + 0.38028398X - 0.00145835X^2$
17. Sour Aroma[d] $= 17.3967212 - 0.02025259X$
18. Fishy Flavor[d] $= 10.57187218 - 0.04552538X$
19. Milky-Oily Flavor[d] $= 74.04525406 - 0.63385616X + 0.00281492X^2$
20. Cooked Beef Fat Flavor[d] $= 59.46471051 + 0.57760594X - 0.00265747X^2$
21. Sour Flavor[d] $= 38.27203799 - 0.23940172X + 0.00098386X^2$
22. Liver Flavor[d] $= 18.61410014 + 0.13675637X - 0.00079353X^2$

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[a] meg/100 g meat [b] mg/10 g meat [c] mg/100 g meat

[d] mm on 150mm line where 10 = slight and 140 = intense

APPENDIX C

LEAST SQUARE MEANS FOR SIGNIFICANT
BREED X ANIMAL EFFECTS OF GROUND BEEF

Component	Animal	Breed	
		Angus	Hereford
C18:3[a]	1	1.53	1.75
	2	1.65	1.78
	3	1.72	1.52
	4	1.49	1.52
	5	1.63	1.16

[a]% of fatty acid content in total lipid.

VITA

The author was born in Nashville, Tennessee, on January 4, 1956, to Mr. and Mrs. William E. Black. He attended elementary schools in Murfreesboro, Tennessee, and Kodaikanal, South India. He received his high school diploma from Van Buren County High School in Spencer, Tennessee, in 1974. He attended Tennessee Technological University as a chemistry major for three years until he transferred to the University of Tennessee, Knoxville, in 1977 as a food technology and science major and received his Bachelor of Science degree in 1978. The author entered graduate school at the University of Tennessee, Knoxville, in January 1979 to study food technology and science. He received his Master of Science degree in March 1981.

During the course of this study, the author was employed as a graduate research assistant in the Department of Food Technology and Science. He is a member of Gamma Sigma Delta, Phi Kappa Phi, Alpha Zeta, the Institute of Food Technologists and the American Oil Chemists' Society.