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I am submitting herewith a thesis written by Robert Alois Schell entitled "Chemical Components of Ground Beef Produced on Grass- or Grain Diets and Their Relation to Beef Flavor." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

Sharon L. Melton

Sharon L. Melton, Major Professor

We have read this thesis
and recommend its acceptance:

H. Dwight Loveday

John R. Mount

Accepted for Council:

Lew Minkel

Vice Provost
and Dean of the Graduate School

CHEMICAL COMPONENTS OF GROUND BEEF PRODUCED ON GRASS- OR GRAIN DIETS AND THEIR RELATION TO BEEF FLAVOR

A Thesis
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DEDICATION

This thesis is dedicated to my wife Robin, my parents, Dr. Robert A. and Ruth M. Schell, my brothers, Peter and Luke, and my sister Renee whose love, support, and encouragement made it possible for me to complete this study.

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Forty-eight yearling Angus, Angus-Hereford, and Angus-Charolais steers were randomly placed on one of two pasture systems containing 24 animals per system. One pasture (A) contained ryegrass (Rye) and the other (B) contained fescue, orchardgrass and clover (FOC). All animals were placed on pasture in the fall, followed by hay and legume feeding during winter and then were returned to pasture during the spring and summer. After pastures died in the summer, each group of animals were subdivided into three equal sub-groups, two of which were put in the feedlot and fed a supplemented whole shelled corn diet. The third sub-group from each pasture was slaughtered directly off pasture (0 days on feed). The others were serially slaughtered at 56 and 112 days on feed (DOF). Ground beef was formulated to contain approximately 20% fat using the biceps femoris muscle and external fat from the round of each steer's carcass. The raw ground beef from each steer was analyzed for fatty acid (FA) composition of total lipids and lecithin.content. Each variable was statistically analyzed as a function of pasture, DOF and their interaction. Fatty acids from raw ground beef samples were correlated with levels of volatiles and intensity of flavor descriptors from quantitative descriptive analysis for cooked ground beef samples as reported previously. Regression analysis of beef fat flavor score (BFF) as a function of FA composition of the raw ground beef lipids and the concentration of 11 selected volatiles isolated from cooked ground beef samples was also determined.

In general, the percentage of monounsaturated FA's (MONO)

increased and the percentages of saturated Fa's (SAT), polyunsaturated omega-3 FA's (PUFA-3) and unknown FA's decreased in beef lipids with increasing DOF from 0 to 112. The percentage of polyunsaturated omega-6 FA's (PUFA-6) in lipids from steers grazed on FOC pasture followed by a corn diet increased significantly from 0 to 112 DOF, but did not change significantly in lipids from steers grazed on Rye pasture and then fed a corn diet. Lecithin content of ground beef (g / 100 g beef) was significantly affected by DOF. The FA types: SAT, PUFA-3 and unknown were negatively correlated with BFF and MONO types were positively correlated ($P<.05$). The relationship of these FA types to milky-oily flavor was reversed from that of BFF.

Finally, the concentration of 4 variables: 18:0, 18:2ω6, pentanal and unknown 7 volatile explained 72.95% (R^2) of the variance in the BFF score of cooked ground beef from 22 steers grazed on pasture A or B and then fed a corn diet 0, 56 or 112 days. BFF for ground beef samples from 11 steers treated in a similar manner as the 22 steers used to develop thie model was also calculated and compared with their actual BFF. BFF predicted from the 4-term model had a correlation coefficient of .83 ($P<.05$) with the actual BFF of the 11 samples.

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CHAPTER 1

INTRODUCTION

The high grain prices in the mid 70's resulted in beef producers increasing the amount of forage use for the optimization of cost of beef production. However, researchers have found grass fed beef less palatable than the grain produced beef (Holden, 1985; Mann, 1983; Melton, 1982a, b; Reagan et al. 1977; Yeo, 1982).

Several studies have been conducted to determine the effect that days on feed (DOF) has on the fatty acid (FA) composition (Brown et al. 1979; Holden, 1985; Mann, 1983; Marmer, 1984; Melton et al. 1982a,.b; Westerling and Hedrick, 1979; Yeo, 1982), flavor as analyzed by Quantitative Descriptive Analysis (QDA) and other sensory scores (Brown et al. 1979; Dwivedi, 1975; Dyer, 1980; Holden, 1985; Larick, 1984; Mann, 1983; Melton et al. 1982a, b; Reviere, 1982; Stockley, 1983; Yeo, 1982). Only two studies have been reported concerning effect of DOF on volatile flavor components (Bolton, 1987; Larick et al. 1987).

In a recent investigation at the University of Tennessee-Knoxville, Bolton (1987) correlated the "beefy" flavor from QDA of ground beef (20% fat) from grass- and grain fed steers with levels of chemical flavor volatiles isolated from the cooked beef samples. Bolton did not analyze the 20% ground beef samples for FA or phospholipid (PL) composition. Other investigators (Holden, 1985; Mann, 1983; Melton et al. 1982; Yeo, 1982) have shown that several FA's (percent concentrations) (18:1ω9, 12:0, 14:0, 14:1, 16:1) are highly correlated with beef fat flavor intensity. No model has been reported relating FA concentration to any beef flavor descriptor

produced on grass or grain diets or the relationship of FA levels with the beef volatile compounds. Therefore, the objectives of this thesis were (1) to determine the effects of pasture type and DOF on FA composition and lecithin concentration in the raw ground beef samples prepared by Bolton (1987), (2) to determine relationships among FA concentrations of raw beef samples and volatile compounds isolated from the cooked beef samples and (3) to obtain the best model from FA composition or FA composition combined with levels of flavor volatiles (Bolton, 1987) for variation of QDA of beef flavor intensity in the cooked ground beef samples.

CHAPTER 2

LITERATURE REVIEW

Characteristics of Grain vs. Forage Produced Beef

Beef cattle raised on grass forage have slower weight gains due to a low energy diet (Bidner, 1975). A lower quality grade and a higher yield grade have also been attributed to grass diets (Kroff et al. 1975; Shinn et al. 1976). In addition, cattle finished on forage diets have been reported to be tougher, and their meat has higher Warner-Bratzler shear values than beef from grain fed cattle (Dyer, 1980; Shinn et al. 1976). Furthermore, the fat color of grass forage produced beef is more yellow in color (Bidner et al. 1986; Brown et al. 1979). This is due to carotenoids in the grasses consumed (Burris et al. 1976; Holden, 1985). The lean meat is also darker in color when compared to that of grain finished beef, this being partially due to a higher myoglobin content in the muscle (Bidner et al. 1986). The flavor of beef from grass finished steers has also been reported by several researchers to be less desirable than the flavor of beef from grain finished steers (Bidner et al. 1986; Brown et al. 1979; Holden, 1985, Mann, 1983; Melton et al. 1982a, b; Sink and Capraso, 1979; Yeo, 1982).

Effect of Diet on Beef Lipids

The effect of DOF on concentrations of total lipids in beef has been reported by Holden (1985), Mann (1983) and Yeo (1982). Total lipid content of beef generally increases with increasing DOF.

However, not much research has been reported concerning effect

of DOF on level of PL or PL classes (cephalin, lecithin and sphingomyelin). Holden (1985) found that the total PL level in beef longissimus was not affected by DOF ($P<.05$). However, the concentrations of the PL classes, cephalin and sphingomyelin, differed among DOF from 0 to 112.

Effects of Diet on Fatty Acid Composition of Beef

The diets of beef cattle prior to slaughter have a significant effect on the FA composition of the beef carcasses (Marmer et al. 1984; Melton et al. 1982a, b; Montgomery and Bidner, 1979; Westerling and Hedrick, 1979). In fact more than 50 FA's have been identified including saturated 14:0-20:0; branched, monounsaturated and polyunsaturated FA's (Marmer et al. 1984; Melton et al. 1982a, b; Holden, 1985, Westerling and Hedrick, 1979; Yeo, 1982). Beef from cattle finished on grass diets contained higher percentages of 14:0, 14:1, 18:0 and 18:2ω6 acids and lower percentages of 16:1, 17:1 and 18:1 acids when compared to beef from steers finished on grain (Holden, 1985; Melton et al. 1982a, b;). Long chain (C18-C22) polyunsaturated and branched chain FA's were also affected by diet. Grass produced beef had more I15:0, 18:3ω3, 20:3, 20:4ω6, 22:5ω6 than beef produced on grain diets (Brown et al. 1979; Holden, 1985; Mann, 1983; Marmer et al. 1984; Melton et al. 1982a, b; Miller et al. 1981; Westerling and Hedrick, 1979; Williams et al. 1980).

Researchers have also shown that beef FA's are affected by steer diet and DOF and also differ among depot sites (Keller and Kinsella, 1973; Marmer et al. 1984; Terrel et al. 1967; Yeo, 1982). Among intramuscular fat, seam fat and brisket fat depot sites, the intramuscular fat had the highest concentration of polyunsaturated FA's, the seam fat had the highest

concentration of monounsaturated FA's, and the brisket fat had the highest concentration of saturated FA's (Yeo, 1982). In the intramuscular fat, the percentage of 18:2ω6 was higher in the grass produced carcasses than in the grain produced carcasses; this finding was reversed in the subcutaneous fat (Melton, 1983; Westerling and Hedrick, 1979). These FA's are all important since they are a primary source of carbonyl compounds for beef flavor and the unsaturated FA's of beef result in off flavors in meat due to oxidation (Dwivedi, 1975; Herz and Chang, 1970; Hornstein and Crowe, 1960; Melton, 1983; Melton et al. 1982a; Wasserman, 1979).

Relation of Phospholipids to Beef Flavor

Phospholipids are essential to the development of a full meaty aroma in beef (Mottram and Edwards, 1983), but they are most often reported as being responsible for off flavors in beef such as warmed-over flavor (Igene and Pearson, 1979) and oxidative rancidity (Igene et al. 1980; Keller and Kinsella, 1973). The major reason for their association with off-flavors in beef is because of their higher concentration of polyunsaturated FA's than neutral lipids (Brown et al. 1979; Hood and Allen, 1971). These FA's are highly susceptible to oxidation (Igene et al. 1980).

Relationships of Fatty Acid Composition to Beef Favor

Several researchers have studied the FA composition of beef animals raised on different feeding regimes and the flavor differences of the cooked beef as analyzed by Quantitative Descriptive Analysis or QDA (Brown et al. 1979; Holden, 1985; Mann, 1983; Melton et al. 1982a, b; Yeo, 1982). Melton et al. (1982a) along with other authors reported that desirable

beef flavor intensity reaches a maximum at 80 to 90 days of grain feeding for steers. There were significant positive correlation coefficients between long chain polyunsaturated FA's (18:3ω3, 20:3, 20:4ω6 and 22:5ω3), A15:0 and 18:0 and the undesirable milky-oily aroma or flavor (Black, 1981; Igene and Pearson, 1979; Yeo, 1982;). Linolenic acid level in both the neutral and polar lipids was reported by Melton et al. (1982a) to be negatively correlated with beef fat flavor intensity ($P<.05$).

The undesirable flavors such as milky-oily, grassy and fishy are probably the result of thermal oxidation of the higher concentrations of these polyunsaturated FA's in grass-produced beef than in grain-produced beef. Melton (1983) reported that the higher levels of polyunsaturated FA's in the grass fed beef probably caused the rapid development of off flavors and oxidative rancidity during storage. Positive correlations of beef fat flavor with.14:0, 14:1, 18:1 have been reported by several researchers (Black, 1981; Melton et al. 1982b; Yeo, 1982). Melton et al. (1982b) found that the desirable beef flavor score increased and undesirable dairy or milky flavor intensity decreased as the amounts of 14:1, 18:1, 18:3ω3 decreased and the amounts of 18:0 increased in the neutral lipids and that the percentages of 18:0, 18:3 and unknowns which were probably polyunsaturated FA's decreased in the PL's. The "beefy" flavor intensity was probably attributable to the volatiles formed from the lower amounts of 18:3ω3 and higher amounts of 18:1 during cooking (Melton et al. 1982b).

Comparisons of Flavor with Volatiles from Beef Raised on Different Feeding Regimes

Flavor is a very complex sensation composed of aroma and taste but complemented by tactile and temperature responses (Heath and Reineccius, 1986). The differences in flavor scores determined by sensory panelist between forage fed beef and grain fed beef seems to be due to the flavor of the fat (Harrison et al. 1978). There has been little research reported on the differences (qualitative and quantitative) in flavor volatile components of beef raised on different feeding regimes and their relationship to flavor.

Larick et al. (1987) reported some 53 volatile compounds which were grouped into six general classes (hydrocarbons, aldehydes, acids, ketones, lactones and terpenoid type compounds). They found that the level of fourteen volatiles (among which were heptanal; 2,3-octanedione and 3-hydroxyoctan-2-one) were positively correlated with the "grassy flavor" of steak samples, and the level of two other compounds, gamma-tetradecalactone and gamma-hexadecalactone, were negatively correlated with the grassy flavor of beef. Bolton (1987) showed that diet does affect the level of volatile flavor components (such as toluene, ethyl-benzene and pentanal) of ground beef from steers as DOF increased. He was able to classify almost 94% of the cattle into the correct days on feed groups by the difference in concentrations of volatiles of ground beef from the steers. Furthermore, toluene was the only compound found to be positively correlated with the undesirable milky-oily flavor level in ground beef and pentanal was correlated positively with beef fat flavor intensity. A model developed by Bolton (1987) found that pentanal, two unknown compounds, ethyl-benzene, toluene, and 1-ethyl-2-methyl-benzene accounted for 51%

of the variation for beef fat flavor in ground beef from steers fed 0 to 112 DOF. This finding indicated that these compounds may be good indicators for "beefy" flavor.

CHAPTER 3

MATERIALS AND METHODS

Experimental Design

In fall of 1984, 48 yearling Angus, Angus-Hereford and Angus-Charolais steers were purchased and wintered on a fescue orchardgrass-clover (FOC) pasture supplemented with a fescue and legume hay to maintain body weight. Steers were randomly placed on one of two pasture systems containing twenty-four animals per system. One pasture (A) contained ryegrass (Rye) and the other (B) contained (FOC). All steers were implanted with a growth promotant (Zeranol) prior to spring grazing. During the summer, each group of animals was subdivided into three equal groups, two of which were put into the feedlot and fed a supplemented whole shelled corn diet. Steers in each sub-group were similar in breed, body size and weight. The third sub-group from each pasture type was slaughtered directly off pasture (0 days on feed). The other sub-groups after being placed in the feedlot were serially slaughtered at 56 and 112 days on feed (DOF).

Slaughtering and Processing

Steers were slaughtered and the carcasses were chilled at 5-6°C for a 48 hr period and then graded at Lay Packing Company, Knoxville, TN. A hindquarter from each carcass was brought to the University of Tennessee Department of Food Technology and Science meat laboratory. The United States Department of Agriculture (USDA) carcass quality and yield grades

were determined (Official United States Standards for Grades of Carcass Beef, 1975), by a USDA grader at the plant. Two and one half kg biceps femoris muscle and at least 1.25 kg of external round fat were obtained from each hindquarter and vacuum packaged in a Cryovac barrier bag (Bolton, 1987) and stored in a 2°C cooler for 10 days of aging.

Each muscle and fat sample was ground separately through a 1.3 cm plate on a Biro™5-hp grinder. The fat content of each ground muscle and fat sample was determined by a modified Babcock fat analysis (Ockerman, 1969). The ground lean and fat were then blended to obtain approximately a 20% fat lipid content using the Pearson Square Method (Terrell, 1971). Each sample was mixed thoroughly and ground twice through a 0.32 cm plate. The mixed sample from each steer was divided into a 250 g and a 350 g sample and then vacuum packaged in a Cryovac barrier bag and stored at -32°C. These samples were used for chemical and volatile analysis, respectively. The remaining portion of the ground beef from each steer was made into 12 (100 g) patties for sensory evaluation. Storage was the same as for the chemical analysis.

Flavor Analysis

QDA flavor analysis of cooked ground beef and volatile flavor compound analysis of cooked ground beef were as reported by Bolton (1987).

Chemical Analysis

The 250 g frozen sample from each steer was powdered in liquid nitrogen (Mann, 1983) and stored at -18°C with total lipid extraction within

one week of storage. Chloroform-methanol extraction for percent total lipid and lipid soluble compounds was performed on 40 g of each sample as described by Melton et al. (1979) with the addition of butyl hydroxy toluene (BHT) for the prevention of oxidation of polyunsaturated FA's (Holden, 1985). The following analyses were determined from the lipid extract of each sample: total lipid content of ground beef (Melton et al. 1979), FA composition of total lipids and lecithin content. The total lipid content is expressed as g lipid/100 g ground beef, wet weight basis. Total lipids from each sample were stored in a concentrated chloroform solution (6-8 g/25 ml solution) under nitrogen at -18°C until analyzed. The total lipid content as a function of pasture and DOF was reported by Bolton (1987) and are given in Appendix A.

Fatty Acid Analysis

Ninety mg of total lipids plus 1 mg of nonadecanoic acid (internal standard) were converted to methyl-esters by method Ce 2-66 (AOCS, 1974). The FA methyl esters (FAME) were analyzed on a 30-m x 0.25 mm i.d. fused silica capillary column coated with SP-2330 (Supelco, Inc.,Bellefonte, PA) in a Shimadzu 6AM gas chromatograph (GC) equipped with a flame ionization detector (FID), a 30:1 capillary splitter, and a Shimadzu C-E1B electronic integrator and data processor. GC conditions are presented in Table 1.

Initially, each peak in the chromatogram of each sample was assigned either to a specific FAME analyzed under the same GC conditions as the sample or an unknown FAME. A standard consisting of known concentrations of FA's shown in Table 2 was converted to FAME and

Table 1

Operating parameters for gas chromatograph

Item	Setting
Carrier gas flow rate	He 40 ml min -1 split 30:1
Hydrogen gas flow rate	20 ml min-1
Air flow rate	20 ml min-1
Injector temperature	250°C
Detector temperature	250°C
Initial oven temperature	150°C
Final oven temperature	250°C
Temperature program rate	2°C min-1

Table 2

Correction factors for fatty acid analysis.

Fatty acid	Correction factor
12:0	1.853
13:0	2.293
14:0	1.970
14:1	2.117
15:0	1.998
16:0	1.000
16:1	2.117
17:0	1.739
18:0	1.193
18:1	0.092
18:2	1.233
18:3	1.220
20:0	1.068
20:1	1.101
20:2	1.220
20:3ω6	2.216
20:4ω6	0.450
22:6ω3	0.319

analyzed under the GC conditions listed in Table 1. Correction factors for each of these FAME's were determined according to AOCS (1974) and are given in Table 2. The correction factor for all other FA's, known and unknown, was assumed to be 1.00. The relative percentage of each FA in each sample was determined according to AOCS (1974). In addition, the percentage of the following FA types: saturated FA's (SAT) (12:0, 13:0, 14:0, 15:0, 16:0, 17:0, 18:0 and 20:0), monounsaturated FA's (MONO) (14:1, 16:1, 17:1, 18:1 and 20:1), polyunsaturated omega-3 FA's (PUFA-3) (20:5ω3, 22:4ω3, 22:5ω3 and 22:6ω3) and polyunsaturated omega-6 FA's (PUFA-6) (18:2ω6, 20:3ω6, 20:4ω6, 20:5ω6 and 22:5ω6) were calculated.

Positive Identification of Fatty Acids

All FA's possible were positively identified after analysis on a Shimadzu Model 9AM gas chromatograph equipped with the capillary column previously described and interfaced with a Shimadzu QP-1000 spectrometer (GCMS). For GCMS operating conditions see Table 3 (Holden, 1985). Positive identification was made by matching retention time and mass spectrum of a FAME in a sample chromatogram, respectively, with retention time and mass spectrum of a known FAME in a standard sample chromatogram. Tentative identification included only matching retention times.

Table 3

Operating parameters for GCMS

Item	Setting
Ion source	250°C
Separator	250°C
Injector	250°C
Ion source energy	70 ev
Column	Temperature program
Carrier gas	He 50 ml min-1 split 50:1
Make up gas	He 25 ml min-1
Gain	3.0[a]

[a] Gain is a unitless measure of signal strength set on a scale from 1.0-5.0.

Phospholipid Analysis

The concentrated total lipid extract of each sample was used for analysis of phospholipids (PL's). After the weight of total lipids per ml of concentrated solution was determined, a 0.09 g lipid sample was separated into triglycerides and PL's on a disposable silica cartridge using a modified method of Han (1986). In this method, the 0.09 g sample was placed in a 1.0 g Bond-Elut silica column (Analytichem, Inc.) instead of a Water's Silica Sep-Pak used by Han (1986). Then, the triglycerides were eluted with 20 ml of petroleum ether:ethyl ether (20:80,v:v). The PL's were eluted with 20 ml of methanol containing 0.01% BHT w/v, then evaporated to dryness over a steam bath under a stream of nitrogen. The PL's were then dried in a 95°C oven for 15 min, cooled in a desiccator and then dissolved in 0.50 ml of HPLC grade chloroform. This solution was filtered through a 0.45 μm filter into a screw topped test tube which was flushed with nitrogen, capped tightly, and placed into a 5-6°C cooler until analysis by high performance liquid chromatography (HPLC) within 24 hrs. The HPLC analysis was completed on a Water's High Performance Liquid Chromatograph equipped with a model 750/14 Mass Detector (Paris Industries Inc.) and a model C-R2AX Shimadzu data processor using a Whatman Partisil 10 column (length:250mm, o.d.: 6.35 mm, I.d.: 4.60 mm) and an acetonitrile:methanol (60:40v:v) solvent using the conditions listed in Table 4.

A standard curve (peak area versus μg lipid injected) was determined for lecithin in the following manner. A standard was prepared by mixing 0.2 ml of a solution containing 10 mg of lecithin (from bovine brain, Sigma Chemical Co., Inc., St. Louis, MO) with 2.2 ml. HPLC grade chloroform in

Table 4

Operating parameters for HPLC and mass detector

Item	Setting
Solvent flow rate	1.2 ml min-1
Solvent system	acetonitrile:methanol (60:40 v:v)
N_2 Gas flow	9.0 ml min-1
Evaporator temperature	65°C
Attenuation range	16
Photomultiplier sensitivity	2
Time constant seconds	5

a screw top test tube. This standard was prepared three separate times and the injections of 5, 15, 25, and 35 µl of this standard were used to prepare the standard curve. Peak areas for each injection were averaged across the three preparations and plotted versus the respective lecithin concentration (µg) injected. Lecithin content was reported as mg 100 g-1 of ground beef.

Statistical Analysis

Each dependent variable was statistically analyzed as a function of Pasture (pasture type A or B), DOF and their interaction (ANOVA). Significant DOF effects were separated into linear and quadratic effects across treatments in absence of a significant interaction and for each treatment in the presence of one with the following exceptions. A level of $P<.05$ was selected for a significant effect in the present study. In the ANOVA for each variable, however, if there were more than one degree of freedom for a source, the DOF effects were separated into linear and quadratic effects for each pasture and each tested for significance at the $P<.05$ level. If the concentration of the variable was affected in the same way by DOF for each pasture, it was averaged across pasture for each DOF (0, 56 and 112), and an equation obtained showing this significant effect. However, if the concentration of a variable had a different DOF effect for each pasture, an equation showing this effect and the average concentration at 0, 56 and 112 DOF for each pasture was found. Equations were obtained using the general linear model in SAS (1985).

Correlation of Chemical Measurements with Beef Flavor

Simple correlation coefficients were determined between each FA percentage and intensity of each flavor descriptor and between percentage of each FA and relative concentration of each volatile compound isolated from the headspace of cooked ground beef. The QDA flavor analysis of each cooked ground beef sample (n=45) and the volatile concentration of 33 of these samples were reported by Bolton (1987) and are shown in Appendices B and C, respectively, as a function of DOF.

Forward stepwise linear regression (SAS, 1985) was performed between the FA composition of the raw ground beef (n=45) and the cooked beef fat flavor (BFF) intensity from the cooked ground beef samples of the study of Bolton (1987). In addition, stepwise linear regression was also performed between BFF and the FA composition plus the concentrations (total ion intensity) of eleven volatiles, (pentanal, unknown 7, toluene, 4-methyl-3-penten-2-one, ethyl benzene, 3-penten-2-one, 1-ethyl-2-methyl benzene, propyl benzene, unknown 8, nonane and unknown 9) from cooked ground beef. In the latter regression, 11 of 33 samples were randomly omitted from the initial regression analysis. These 11 samples were representative of the entire range of samples from steers fed grain 0 to 112 DOF.

A single equation with the fewest terms and the highest R^2 was selected from the results of stepwise linear regression as the best predictor of BFF (Dravnieks, 1976). The validity of the equation was tested by calculating the intensity of each of the 11 omitted samples and plotting the predicted BFF intensity of the calculated versus the actual BFF intensity for the 11 samples. A general linear regression analysis was used to determine

if the slope of the straight line between the predicted and the actual BFF intensities were significantly different than 1.00 (SAS, 1985) and the correlation coefficient between the predicted and actual BFF intensity for the 11 samples was determined (Sanders, 1988).

CHAPTER 4

RESULTS AND DISCUSSION

Composition of Total Lipids

Fatty acid analysis of the raw ground beef lipid samples by GC capillary column resulted in 29 identified FA's and 19 unidentified FA's. The unknowns made up approximately 1.0% of the total FA composition of each beef lipid sample and were combined into a FA type called "unknown". The retention times for these FA's are given in Appendix D.

An ANOVA table containing the sums of squares of each FA as a function of pasture, DOF and their interaction is given in Table 5. As shown in Tables 5 and 6, the average percentages of the following FA's were different ($P<.05$) between pastures: 12:0, 15:0, A15:0, I16:0, 16:1, 17:0, A17:0, 18;0, 18:2ω6, 20;0, 18:3ω3, 20:3ω6, 20:4ω6 and 22:6ω3. Each of the FA's listed, except 16:1 and A17:0, was significantly higher in concentration for the FOC pasture than for the Rye pasture (Table 6).

Several of the positively identified FA's were affected ($P<.05$) by DOF: A15:0, I16:0, 16:1, 17:0, 17:1, A17:0, 18:0, 18:1, 18:2ω6, 20:0, 18:3ω3, 20:1, 20:2, 20:5ω6 and 20:5ω3 (Table 5). The following FA's also had a significant P*DOF interaction: 14:1, 18:2ω6, 18:3ω6 and 20:2 as shown in Table 5. In addition, when the DOF sums of squares were separated into linear and quadratic DOF effects for each pasture, the concentrations of several of the FA's: 17:0, 17:1, A17:0, 18:0, 18:1, 20:0, 18:3ω3, 20:1, 20:3ω6, 20:4ω6, 20:5ω6, 20:5ω3, 22:5ω6 and 22:6ω3,

Table 5

Sums of squares from analysis of variance for fatty acid percentages in ground beef lipids of steers grazed on different pastures and fed a corn ration 0 to 112 days.

Source	DF	Variable: Fatty acids					
		12:0	13:0	14:0	14:1	15:0	A15:0
		Sums of squares					
Pasture (P)	1	0.0017*	0.0003	0.0294	0.0080	0.1691*	0.0824*
DOF	2	0.0018	0.0002	0.0833	0.0277	0.0778	0.6576*
linear	1						0.4734*
quadratic	1						0.1768*
P*DOF	2	0.0001	0.0003	0.1280	0.1653*	0.0697	0.0198
P=A[a]							
linear	1				0.0094		
quadratic	1				0.1167*		
P=B[a]							
linear	1				0.0485		
quadratic	1				0.0185		
Error	39	0.0124	0.0051	4.4917	0.7716	1.3986	0.2634
Total	44	0.0160	0.0059	4.7324	0.9726	1.7153	1.0232

Table 5 (continued)

Source	DF	Variable: Fatty acids					
		I16:0	16:0	16:1	17:0	17:1	A17:0
		Sums of squares					
Pasture (P)	1	0.0167*	21.6025	1.1252*	0.7583*	0.1777	0.0938*
DOF	2	0.0294*	32.8132	0.8697*	2.1134*	12.5782*	0.2406*
linear	1	0.0259*		0.8138*			
quadratic	1	0.0026		0.0038			
P*DOF	2	0.0030	44.7763	0.1359	0.4653	1.2589	0.0841
P=A[a]							
linear	1				0.2937	3.3603*	0.0041
quadratic	1				0.0787	0.4089	0.1352*
P=B[a]							
linear	1				0.8045*	5.3491*	0.1642*
quadratic	1				1.4018*	4.7187*	0.0211
Error	39	0.0803	792.9464	4.6718	6.3572	17.7167	0.5173
Total	44	0.1294	892.1384	6.8026	9.6942	31.7315	0.9358

Table 5(continued)

Source	DF	Variable: Fatty acids					
		18:0	18:1	I18:1	18:2ω6	I18:2	18:3ω6
		Sums of squares					
Pasture (P)	1	39.0634*	47.8124	0.0752	4.9033*	0.0340	0.0005
DOF	2	229.6677*	356.1178*	0.3210	2.1974*	0.0538	0.0016
linear	1						
quadratic	1						
P*DOF	2	4.6868	58.4683	0.0855	1.4969*	0.0099	0.0035*
P=A[a]							
linear	1	97.2974*	64.2617		1.0292*		0.0005
quadratic	1	10.9977	47.5749		0.0389		0.0029*
P=B[a]							
linear	1	85.8636*	301.6410*		0.3910		0.0017
quadratic	1	40.1959*	1.1086		2.2351*		0.0000
Error	39	141.1130	657.1174	8.6896	7.4637	1.0561	0.0191
Total	44	414.5309	1119.5160	9.1713	16.0612	1.1538	0.0246

Table 5(continued)

Source	DF	Variable: Fatty acids					
		20:0	18:3ω3	20:1	20:2	20:3ω6	20:4ω6
		Sums of squares					
Pasture (P)	1	0.0127*	0.1655*	0.0142	0.0001	0.0028*	0.3762*
DOF	2	0.0291*	0.9231*	1.0387*	0.0272*	0.0015	0.1293
linear	1						
quadratic	1						
P*DOF	2	0.0047	0.0417	0.1326	0.0181*	0.0031	0.0896
P=A[a]							
linear	1	0.0076*	0.3820*	0.4128*	0.0003	0.0006	0.1306*
quadratic	1	0.0006	0.0425	0.0027	0.0210*	0.0001	0.0379
P=B[a]							
linear	1	0.0112*	0.3015*	0.5450*	0.0239*	0.0000	0.0225
quadratic	1	0.0144*	0.2387*	0.2108*	0.0002	0.0038*	0.0280
Error	39	0.0369	0.7194	1.8325	0.0655	0.0253	1.0836
Total	44	0.0834	1.8496	3.0180	0.1109	0.0327	1.6787

Table 5(continued)

Source	DF	Variable: Fatty acids				
		20:5ω6	20:5ω3	22:5ω3	22:6ω3	22:5ω6
		Sums of squares				
Pasture (P)	1	0.0015	0.0025	0.0035	0.0084*	0.0001
DOF	2	0.0221*	0.0121*	0.0096	0.0042	0.0003
linear	1					
quadratic	1					
P*DOF	2	0.0004	0.0030	0.0011	0.0039	0.0005
P=A[a]						
linear	1	0.0054*	0.0006		0.0000	0.0000
quadratic	1	0.0029	0.0036		0.0000	0.0000
P=B[a]						
linear	1	0.0084*	0.0097*		0.0081*	0.0008*
quadratic	1	0.0057*	0.0012		0.0001	0.0000
Error	39	0.0287	0.0558	0.1611	0.0768	0.0069
Total	44	0.0526	0.0734	0.1754	0.0933	0.0079

[a] A=ryegrass pasture and B=fescue pasture.

* Significant at P< .05 level.

Average percentage of fatty acids in ground beef lipids of steers fed a corn ration across 0 to 112 days after grazing different pastures as a function of the pasture.

	Pasture Type	
Fatty acid	Rye	FOC
12:0	0.039[a]	0.051[b]
13:0	0.012	0.017
14:0	1.824	1.876
14:1	0.543	0.516
15:0	0.400[a]	0.523[b]
A15:0	0.208[a]	0.294[b]
I16:0	0.133[a]	0.171[b]
16:0	27.040	25.654
16:1	2.050[a]	1.733[b]
A17:0	0.919[a]	0.828[b]
17:0	1.010[a]	1.270[b]
17:1	1.634	1.760
18:0	10.817[a]	12.681[b]
18:1	48.048	45.986
I18:1	0.884	0.802
18:2	1.535[a]	2.196[b]
I18:2	0.271	0.326
18:3ω6	0.033	0.040
20:0	0.079[a]	0.112[b]
18:3ω3	0.295[a]	0.416[b]
20:1	0.999	0.964
20:2ω6	0.135	0.138
20:3ω6	0.031[a]	0.047[b]
20:4ω6	0.243[a]	0.426[b]

	Pasture Type	
Fatty acid	Rye	FOC
20:5ω6	0.023	0.034
20:5ω3	0.026	0.041
22:5ω3	0.027	0.045
22:5ω6	0.004	0.008
22:6ω3	0.000[a]	0.027[b]
unknown[c]	0.736	1.019

[ab] Means in rows bearing unlike superscripts are significantly different at P<.05 level.

[c] Includes 19 acids present in minor amounts.

changed in a different manner across DOF for each pasture (Table 5). Percentages of 12:0, 13:0, 14:0, 15:0, 16:0, I18:1 and I18:2 were not significantly affected by DOF.

The only FA's (P<.05) that were affected in a similar manner by DOF for each pasture were A15:0, I16:0 and 16:1. As DOF increased from 0 to 112, the percentage of I16:0 averaged across both pastures decreased linearly, and the percentage of 16:1 increased linearly (Tables 5 and 7). During the same time period, the percentage of A15:0 averaged across pastures decreased quadratically. The equations showing these significant DOF effects for these acids are given in Table 8.

Changes in concentrations of the FA's with a significant P*DOF interaction or of those FA's affected differently by DOF for each pasture can be observed in Tables 5, 7 and 8. The following changes in concentation of FA's can be observed in lipids from steers grazed on the rye pasture and then fed grain. The percentages of 18:0, 18:3ω3, 20:0, 20:1, 20:4ω6 and 20:5ω6 decreased linearly and the percentages of 17:1 and 18:2ω6 increased linearly as DOF increased from 0 to 112 (P<.05). The percentages of 14:1 and 18:3ω6 increased overall from 0 to 112 DOF, but the levels of each were lowest at 56 DOF (P<.05). In these same animals, the levels of A17:0 and 20:2 decreased to a minimum percentage at 56 DOF before increasing to a level at 112 DOF that was similar to that at 0 DOF, and the percentages of 17:0, 18:1, 20:3ω6, 20:5ω3, 22:5ω6 and 22:6ω3 were not affected by DOF (P<.05).

In the lipids of steers grazed on the FOC pasture and then fed grain, the following changes in FA concentrations were observed during DOF (Tables 5, 7 and 8). Percentages of A17:0, 20:2 and 20:5w3 decreased

Table 7

Average percentage of fatty acids in ground beef lipids from steers grazed on different pastures as a function of 0 to 112 days they were fed a corn ration.

		Days on feed (DOF)		
Fatty acid	Pasture[a]	0	56	112
12:0	Across[b]	0.054	0.040	0.041
13:0	Across[b]	0.012	0.017	0.016
14:0	Across[b]	1.895	1.790	1.859
14:1	A[c]	0.566	0.438	0.623
	B[c]	0.553	0.559	0.443
15:0	Across[b]	0.416	0.518	0.461
A15:0	Across[b]	0.413	0.156	0.169
I16:0	Across[b]	0.186	0.141	0.128
16:0	Across[b]	27.245	26.538	25.164
16:1	Across[b]	1.724	1.905	2.047
A17:0	A[c]	0.986	0.804	0.959
	B[c]	0.949	0.782	0.747
17:0	A[c]	0.839	1.105	1.113
	B[c]	0.883	1.644	1.331
17:1	A[c]	1.094	1.855	2.030
	B[c]	0.882	2.445	2.038
18:0	A[c]	13.705	9.667	8.668
	B[c]	15.872	10.683	11.239
18:1	A[c]	45.128	50.293	49.139
	B[c]	41.498	46.317	50.182
I18:1	Across[b]	0.881	0.720	0.916

Fatty acid	Pasture[a]	Days on feed (DOF) 0	56	112
18:2ω6	A[c]	1.312	1.486	1.840
	B[c]	1.833	2.667	2.146
I18:2	Across[b]	0.293	0.257	0.344
18:3ω6	A[c]	0.035	0.017	0.048
	B[c]	0.050	0.039	0.029
18:3ω3	A[c]	0.475	0.223	0.160
	B[c]	0.620	0.262	0.346
20:0	A[c]	0.103	0.070	0.059
	B[c]	0.155	0.074	0.102
20:1	A[c]	1.151	1.008	0.818
	B[c]	1.212	0.819	0.843
20:2	A[c]	0.159	0.090	0.154
	B[c]	0.179	0.133	0.101
20:3ω6	A[c]	0.038	0.027	0.026
	B[c]	0.037	0.066	0.039
20:4ω6	A[c]	0.359	0.179	0.176
	B[c]	0.441	0.479	0.366
20:5ω6	A[c]	0.048	0.005	0.011
	B[c]	0.068	0.010	0.022
20:5ω3	A[c]	0.040	0.007	0.029
	B[c]	0.070	0.030	0.021

Fatty acid	Pasture[a]	Days on feed (DOF) 0	56	112
22:5ω6	A[c]	0.005	0.005	0.002
	B[c]	0.000	0.009	0.014
22:5ω3	Across[b]	0.053	0.037	0.019
22:6ω3	A[c]	0.000	0.000	0.000
	B[c]	0.006	0.025	0.051

[a] A = Rye pasture and B = FOC pasture.

[b] Nonsignificant pasture*DOF interaction.

[c] A and B listed for a single fatty acid when the % concentration was affected differently by DOF for each pasture ($P<.05$).

Equations showing significant days on feed effects fatty acid percentages of ground beef lipids from steers grazed on different pastures.

Fatty acid	Pasture type[a]	R^2	Equation[b]
12:0	Across[c]		NS
13:0	Across[c]		NS
14:0	Across[c]		NS
14:1	A[d]	.1296	$y=0.5658 - 0.0051x + 0.000049x^2$
	B[d]		NS
15:0	Across[c]		NS
A15:0	Across[c]	.6355	$y=.4133 - 0.0070x + 0.00004x^2$
I16:0	Across[c]	.2000	$y=0.1808 - 0.0005x$
16:0	Across[c]		NS
16:1	Across[c]	.1196	$y=1.7295 + 0.0029x$
17:0	A[d]		NS
	B[d]	.2276	$y=0.8828 + 0.0232x - 0.0002x^2$
17:1	A[d]	.1059	$y=1.1816+0.0085x$
	B[d]	.3173	$y=0.8820 + 0.0455x - 0.0003x^2$
A17:0	A[d]	.1489	$y=0.9855 - 0.0062x + 0.0001x^2$
	B[d]	.1755	$y=0.9294 - 0.0018x$
18:0	A[d]	.2347	$y=13.2521 - 0.0455x$
	B[d]	.3041	$y=15.8722 - 0.1440x + 0.0009x^2$
18:1	A[d]		NS
	B[d]	.2694	$y=41.6436 + 0.0775x$
I18:1	Across[c]		NS
18:2ω6	A[d]	.0641	$y=1.2849 + 0.0047x$
	B[d]	.1635	$y=1.8331 + 0.0270x - 0.0002x^2$
I18:2	Across[c]		NS
18:3ω6	A[d]	.1382	$y=0.0348 - 0.0008x + 0.0000x^2$
	B[d]		NS
20:0	A[d]	.0911	$y=0.1002 - 0.0004x$
	B[d]	.3070	$y=0.1553 - 0.0024x + 0.00001x^2$

Fatty acid	Pasture type[a]	R^2	Equation[b]
18:3ω3	A[d]	.2065	$y=0.4471 - 0.0029x$
	B[d]	.2921	$y=0.6205 - 0.0104x + 0.00007x^2$
20:1	A[d]	.1368	$y=1.1580 - 0.0030x$
	B[d]	.2504	$y=1.2118 - 0.0107x + 0.0001x^2$
20:2	A[d]	.1921	$y=0.1592 - 0.0024x + 0.0000x^2$
	B[d]	.2155	$y=0.1765 - 0.0007x$
20:3ω6	A[d]		NS
	B[d]	.1162	$y=0.0367 + 0.0010x - 0.0000x^2$
20:4ω6	A[d]	.0778	$y=0.3327 - 0.0017x$
	B[d]		NS
20:5ω6	A[d]	.1027	$y=0.0409 - 0.0003x$
	B[d]	.2681	$y=0.0675 - 0.0016x + 0.0000x^2$
20:5ω3	A[d]		NS
	B[d]	.1322	$y=0.0655 - 0.0004x$
22:5ω3	Across[c]		NS
22:6ω3	A[d]		NS
	B[d]	.0868	$y=0.0048 + 0.0004x$
22:5ω6	A[d]		NS
	B[d]	.1013	$y=0.0007 + 0.0001x$

[a] A = Rye pasture and B = FOC pasture.

[b] Y = % fatty acid and x = days on feed and NS=nonsignificant DOF effect.

[c] Nonsignificant pasture*DOF interaction ($P<.05$).

[d] A and B listed for a single fatty acid when the % concentration was affected differently by DOF for each pasture ($P<.05$).

linearly and levels of 18:1, 22:5ω6 and 22:6ω3 increased linearly as DOF increased from 0 to 112 (P<.05). Percentages of 18:0, 18:3ω3, 20:0, 20:1 and 20:5ω6 decreased in a quadratic manner to a minimum level as DOF increased from 0 to 56 before increasing slightly from 56 to 112 DOF. Levels of 17:0, 17:1 and 18:2ω6 increased quadratically from 0 to 56 DOF before decreasing slightly from 56 to 112 DOF. The concentration of 20:3ω6 was maximum at 56 DOF with lower levels at 0 and 112 DOF, and percentages of 14:1, 18:3ω6 and 20:4ω6 were not significantly affected by DOF.

Groups of Fatty Acids

An ANOVA table containing the sums of squares of each FA type as a function of pasture, DOF and their interaction is given in Table 9. As shown in Tables 9 and 10, the average percentages of PUFA-6 and PUFA-3 were significantly different between pastures, and both were significantly higher in concentration for FOC pasture than for the Rye pasture (Table 10).

Each of the following types of FA's were significantly affected by DOF: SAT, MONO, PUFA-3 and unknowns. A significant P*DOF interaction was observed for PUFA-6. Furthermore, when the DOF and P*DOF sums of squares were separated into linear and quadratic DOF effects for each pasture, the concentrations of PUFA-6 and PUFA-3 changed in a different manner across DOF for each pasture (Table 9).

In steers grazed on either pasture followed by corn feeding up to 112 days, the percentage of MONO FA's increased linearly and the percentage of SAT decreased linearly (P<.05) from 0 to 112 DOF (Tables 9, 11 and 12).

Table 9

Sums of squares from analysis of variance for fatty acid percentages in ground beef lipids of steers grazed on different pastures and fed a corn ration 0 to 112 days.

		Variable: Fatty Acid Types[a]				
Source	DF	SAT	MONO	PUFA-6	PUFA-3	unknown
		Sums of squares				
Pasture (P)	1	11.134	60.258	8.749*	0.369*	0.899
DOF	2	413.706*	485.242*	0.813	1.211*	1.881*
linear	1	376.185	425.931			
quadratic	1	34.372	51.992			
P*DOF	2	36.275	48.818	2.661*	0.052	0.340
P=A[b]						
linear	1			0.313	0.508*	0.176
quadratic	1			0.412	0.058	0.213
P=B[b]						
linear	1			0.051	0.393*	1.568*
quadratic	1			2.688*	0.304*	0.263
Error	39	842.247	770.367	12.119	1.282	8.815
Total	44	1303.362	1364.686	24.342	2.913	11.935

[a] SAT includes 12:0, 13:0, 14:0, 15:0, 15:0A, I16:0, 16:0, 17:0, 17:0A, 18:0 and 20:0; MONO includes 14:1, 16:1, 17:1, 18:1 and 20:1; PUFA-6 includes 18:2ω6, 18:3ω6, 20:2ω6, 20:3ω6, 20:4ω6, 20:5ω6, and 22:5ω6; PUFA-3 includes 18:3ω3, 20:5ω3, 22:5ω3 and 22:6ω3.

[b] A=ryegrass pasture and B=fescue pasture.

* Significant at P< .05 level.

Table 10

Percentage of fatty acid types averaged across 0 to 112 days of a corn diet from ground beef lipids of steers as a function of different pastures

	Pasture	
Fatty acid type[a]	Rye	FOC
SAT	42.48	43.48
MONO	53.27	50.96
PUFA-6	2.00[b]	2.89[c]
PUFA-3	0.35[b]	0.53[c]
Unknown	0.74	1.02

[a] SAT includes 12:0, 13:0, 14:0, 15:0, 15:0A, I16:0, 16:0, 17:0, 17:0A, 18:0 and 20:0; MONO includes 14:1, 16:1, 17:1, 18:1 and 20:1; PUFA-6 includes 18:2ω6, 18:3ω6, 20:2ω6, 20:3ω6, 20:4ω6, 20:5ω6 and 22:5ω6; PUFA-3 includes 18:3ω3, 20:5ω3, 22:5ω3 and 22:6ω3.

[bc] Means in rows bearing unlike superscripts are significantly different at $P<.05$.

Table 11

Average percentage of fatty acid types in ground beef lipids from steers grazed on different pastures and fed a corn diet 0 to 112 days.

Fatty acid type[a]	Pasture[c]	Days on feed (DOF) 0	56	112
SAT	Across[d]	46.967	41.613	40.035
MONO	Across[d]	47.765	53.772	55.135
PUFA-6	A[e]	1.954	1.808	2.256
	B[e]	2.604	3.403	2.716
PUFA-3	A[e]	0.557	0.265	0.193
	B[e]	0.762	0.355	0.449
unknown[b]	A[e]	0.903	0.587	0.695
	B[e]	1.403	0.857	0.777

[a] SAT includes 12:0, 13:0, 14:0, 15:0, 15:0A, I16:0, 16:0, 17:0, 17:0A, 18:0 and 20:0; MONO includes 14:1, 16:1, 17:1, 18:1 and 20:1; PUFA-6 includes 18:2ω6, 18:3ω6, 20:2ω6, 20:3ω6, 20:4ω6, 20:5ω6 and 22:5ω6; PUFA-3 includes 18:3ω3, 20:5ω3, 22:5ω3 and 22:6ω3.

[b] Includes 19 acids present in minor amounts.

[c] A = Rye pasture and B = FOC pasture.

[d] Across = nonsignificant pasture*DOF interaction ($P<.05$).

[e] A and B listed for a single fatty acid type when the % concentration was affected differently by DOF for each pasture ($P<.05$).

Table 12

Equations showing significant days on feed effects fatty acid percentages of ground beef lipids from steers grazed on different pastures.

Fatty acid type[a]	Pasture type[c]	R^2	Equation[f]
SAT	Across[d]	.2886	$y=46.3980 - 0.0622x$
MONO	Across[d]	.3121	$y=48.4650 + 0.0662x$
PUFA-6	A[e]		NS
	B[e]	.3702	$y=2.6036 + 0.0275x - 0.00024x^2$
PUFA-3	A[e]	.4835	$y=0.5240 - 0.0033x$
	B[e]	.4665	$y=0.7619 - 0.01173x + 0.00008x^2$
unknown[b]	A[e]		NS
	B[e]	.1706	$y=1.3322 - 0.0056x$

[a] SAT includes 12:0, 13:0, 14:0, 15:0, 15:0A, I16:0, 16:0, 17:0, 17:0A, 18:0 and 20:0; MONO includes 14:1, 16:1, 17:1, 18:1 and 20:1; PUFA-6 includes 18:2ω6, 18:3ω6, 20:2ω6, 20:3ω6, 20:4ω6, 20:5ω6 and 22:5ω6; PUFA-3 includes 18:3ω3, 20:5ω3, 22:5ω3 and 22:6ω3.

[b] Includes 19 acids present in minor amounts.

[c] A = Rye pasture and B = FOC pasture.

[d] Across = nonsignificant pasture*DOF interaction ($P<.05$).

[e] A and B listed for a single fatty acid type when the % concentration was affected differently by DOF for each pasture ($P<.05$).

[f] Y = % fatty acid and x = days on feed and NS=nonsignificant DOF effect.

in the concentrations of PUFA-6 and unknown types of FA's (Tables 9 and 12).

In steers grazed on FOC pasture and the fed corn 0 to 112 days, the concentrations of the following types of FA's changed significantly across DOF: PUFA-6, PUFA-3 and unknown. The unknown type decreased linearly ($P<.05$) as the DOF increased from 0 to 112 as shown in Tables 9, 11 and 12. These same tables show that the percentage of PUFA-6 increased curvalinearly ($P<.05$). However, PUFA-3 decreased quadratically from 0 to 56 DOF before increasing slightly from 56 to 112 DOF.

The results reported in the present study for the effect of DOF on FA composition of beef lipids, in general, agree with other reports of studies on the effect of DOF on beef FA composition. (Holden, 1985; Mann, 1983; Melton et al. 1982a; Miller et al. 1981; Yeo, 1982). In all of these studies including the present, the percentage of MONO FA's increased and the percentage of PUFA-3 acids decreased in beef lipids with increasing DOF from 0 to 112 (Table 11).

The finding that the percentage of SAT acids decreased ($P<.05$) with increasing DOF (Table 11) agrees with the results of Mann (1983), Miller et al., (1981) and Melton et al. (1982a). However, Yeo (1982) reported no change in the percentage of SAT in intramuscular lipids of beef across 112 DOF, and Holden (1985) reported that the % SAT in intramuscular lipids from steers grazed on rye, ryegrass and clover did not change significantly across DOF and increased in the intramuscular lipids of steers grazed on predominantly fescue pasture before being fed a corn diet up to 112 days.

Holden (1985) reported that the percentage PUFA-6 generally decreased in lipids from steers grazed on either rye, ryegrass and clover pasture or predominantly fescue pasture followed by grain feeding

as DOF increased. In contrast to these results in the present study, the % PUFA-6 in lipids from steers grazed on FOC pasture followed by grain feeding increased significantly from 0 to 56 DOF before decreasing and did not change significantly in lipids from steers grazed on predominantly Rye pasture and then fed the corn diet (Tables 11 & 12).

Two characteristics of cattle diets are known to affect the FA composition of beef: energy level and dietary FA levels. Both of these factors probably caused the differences in FA composition found in the present study.

Brown et al. (1979) reported that the energy level of the cattle diet probably caused more changes in the FA composition of beef lipids than the the type of diet. The decrease in the level of SAT and increase in MONO levels across DOF (Table 11) most likely are due to dietary energy level and possibly, to the type of microflora present in the rumen of cattle grazed on grass versus those fed grain (Black, 1981). The rumen of cattle on pasture alone (low energy diet) have a high population of microbes that utilize cellulose as a source of energy, and the rumen of cattle fed grain (high energy diet) have a high population of organisms that utilize starch for energy (Cook and Miller, 1965).

In addition to the energy effect, cattle diets with different FA compositions also affect the concentrations of PUFA-3 and PUFA-6 types of FA's in beef lipids (Holden, 1985; Mann, 1983). Mann (1983) showed that pasture grasses contained from 0.89 to 1.27% total lipids which had 20 to 30% 18:2ω6 and 23 to 43% 18:3ω3. In contrast, whole shelled corn contains 4 to 5% oil which has 55 to 60% 18:2ω6 and no 18:3ω3 (Weiss, 1983). Rumen microflora in cattle eating a diet containing either type polyunsaturated FA will hydrogenate a high percentage of the acids

to 18:0 or 18:1 (Oltjen and Dinius, 1975). However, some of the polyunsaturated FA's escape hydrogenation and are deposited or stored primarily in beef PL's (Pearson et al. 1977). Steers changed from a diet containing high levels of 18:3ω3 to one containing high levels of 18:2ω6 will also exchange PUFA-3 in the PL's for PUFA-6 (Kimoto et al. 1974, Mann, 1983). In addition, steers can convert 18:2ω6 into longer chain PUFA-6 FA's and 18:3ω3 into longer chain PUFA-3 FA's (Pearson et al. 1977). These are probably the main causes for the differences found in levels of PUFA-3 and PUFA-6 from 0 to 112 DOF in the present study.

Phospholipids

The lipid levels of the ground beef from steers grazed on different pastures and then fed a corn ration from 0 to 112 DOF are given in Appendix B as reported by Bolton (1987). The ANOVA for lecithin content in these ground beef samples are presented in Table 13. The lecithin level in the ground beef was significantly different among DOF but not between pastures. Ground beef from steers grazed on Rye pastures contained 0.100 g lecithin/100 g meat and ground beef from steers grazed on FOC pasture contained 0.096 g lecithin/100 g meat. The levels of lecithin in ground beef from all steers fed a corn ration 0, 56 and 112 DOF are given in Table14. A quadratic relationship was found between lecithin level and DOF. Ground beef samples from 56 DOF steers contained the highest level of lecithin and those from 112 DOF steers contained the lowest level.

Few studies have been reported concerning the effect of cattle diet on the PL content of beef. These studies such as the one reported by Holden (1985) involved the quantitation of the PL's at 205 nm where only the double bonds in the FA's attached to the PL absorb. Therefore, differences in

Table 13

Analysis of Variance for lecithin content of ground beef from steers grazed on different pastures and fed a corn ration from 0 to 112 days.

Source	DF	Lecithin (g /100 g beef)
Pasture (P)	1	.0002
DOF	2	.0174*
linear	1	.0032
quadratic	1	.0141*
P*DOF	2	.0013
Error	36	.0313
Total	41	.0502

* significant at P< .05.

Table 14

Mean lecithin content of ground beef from steers grazed on different pastures followed by feeding a corn ration from 0 to 112 days.

	Days on feed (DOF)		
Lecithin level	0	56	112
g /100 g meat[a]	.096	.124	.073

[a] Significantly affected by DOF as shown by the equation: $y = .097 + 001207x - .0000127x^2$ where y = lecithin level and x = DOF.

concentration of any PL with increasing DOF reported by Holden (1985) only reflected the change in the level of unsaturated FA's attached to that PL. The lecithin reported in Table 14, is the true weight of the PL in the meat because it was measured with a mass detector. Holden (1985) reported that the lecithin content of the longissimus from steers fed grass or grain ranged from 0.28 to 0.34 g /100 g muscle. The total lipid content of the muscle samples ranged from 2.2 to 6.1%. In contrast to these results, the present study found the lecithin content of ground beef containing approximately 20% fat ranged from 0.073 to 0.124 g/100 g meat. This level was also affected by DOF ($P<.05$) in contrast to Holden (1985). The difference in lecithin concentration between these two studies could be the result of the analysis If the standard curve of A_{205nm} versus lecithin concentration in study of Holden (1985) was made with a standard that contained more saturated FA's than the samples, estimate of lecithin in the samples would be too high.

Correlation of QDA with Fatty Acids

The significant correlation coefficients between QDA flavor descriptors: cooked beef fat flavor, milky-oily flavor, sour flavor and off flavor with FA composition of raw ground beef lipids are given in Table 15. The following FA's: 16:1, 17:0, 17:1, 18:1 and 18:2 were positively correlated with beef fat flavor and I16:0, 18:0, 20:0, 18:3ω3, 20:1, 20:5ω6, A:15:0 and A17:0 were negatively correlated. In general, the reverse of these results were found in the correlation of FA's with milky-oily flavor. The highest correlation coefficients were found for A15:0, 18:0 and 18:3ω3.

The correlation coefficients between FA composition and sour

Table15

Significant correlation coefficients[a] between fatty acid composition and QDA flavor descriptors of ground beef

	Descriptors			
Fatty acid	Cooked Beef fat flavor	Milky-oily flavor	Off-flavor	Sour flavor
A15:0	-.60	.56	-	-.32
I16:0	-.41	.33	-	-.34
16:1	.42	-.41	-	-
A17:0	-.30	-	-	-
17:0	.33	-.32	-	-
17:1	.51	-.49	-	-
18:0	-.64	.62	-	-.34
18:1	.53	-.51	-	-
18:2	.32	-.34	.36	-
20:0	-.52	.48	-	-
18:3ω3	-.56	.53	-	-
20:1	-.45	.44	-.38	-.34
20:5ω6	-.48	.44	-.32	-.31
22:5ω3	-	-	-	-.33
SAT	-.56	.53	-	-
MONO	.57	-.54	-	-
PUFA-3	-.49	.50	-	-.33
unknowns	-.29	.33	-	-

a significant at the $p<.05$ level for n=45.

and off-flavors are also presented in Table 15. In general, there were fewer correlation coefficients with lower magnitude than for beef fat and milky-oily flavors.

Correlation coefficients between types of FA's: SAT, MONO, PUFA-3 and unknowns with QDA descriptors are also given in Table 15. SAT, PUFA-3 and unknown types were negatively correlated (-.56, -.49 and -.29, respectfully) with beef fat flavor and MONO types were positively correlated (.57). The relationship of these types to milky-oily flavor was reversed from that of beef fat flavor. Sour flavor was negatively correlated with PUFA-3.

Positive correlation of a FA with a QDA flavor descriptor indicates the possibility that higher levels of the FA contributed to the increased intensity of the descriptor. The significant positive correlations found between the following acids: 16:1, 17:1, 18:1 and beef fat flavor intensity (Table 15) agree with the findings of Melton et al. (1982a) who also studied the effect of cattle diet on FA composition and flavor of ground beef. They agree only partially with Holden (1985), Mann (1983) and Yeo (1982) who studied the effect of cattle diet on FA composition and flavor of steak. The large positive correlation coefficients between milky-oily flavor and the acids, 18:0 and 18:3ω3 (Table 15) were also reported by Melton et al. (1982a) and Yeo (1982). Holden (1985) and Mann (1983) found a high correlation coefficient between the milky-oily flavor and 18:3ω3 but not 18:0. The positive coefficient between 20:0 and milky oily flavor found in the present study (.48, Table 15) was larger than those (.31 and .37) reported by Mann (1983) and Yeo (1982), respectively. Holden (1985) and Melton et al. (1982a) did not find a significant correlation between these two attributes.

The only other researcher who reported correlation of FA types with

flavor descriptors was Mann (1983). This researcher reported the same results for the MONO and PUFA-3 types as was found in the present study (Table 15). However, she did not find significant correlation coefficients between any flavor descriptor and SAT FA's.

In general, any FA that was positively correlated with milky-oily flavor was negatively correlated with beef fat flavor and vice versa. This is in agreement with other researchers (Holden, 1985; Mann, 1983; Melton et al. 1982a; Yeo, 1982) who studied the effect of diet on FA composition and beef flavor.

The contribution of FA's to meat flavor has been discussed by several researchers including Dwivedi (1975), Melton (1983), Sink and Caparaso (1979) and Wasserman (1979). It is generally agreed that volatiles formed by oxidation and other reactions of FA's contribute to the characteristic species flavor of meat. The FA, 18:3ω3, however, has been shown to contribute to the undesirable flavor of soybean products (Smouse, 1985). The high positive correlation of 18:3ω3 with the undesirable milky oily flavor and high negative correlation with beef fat flavor suggest that its degradation products are at least partly responsible for the undesirable flavor of grass-produced beef.

Correlation of Fatty Acids with Volatile Compounds

The significant correlation coefficients between FA composition of raw ground beef and concentration of volatiles isolated from cooked ground beef are shown in Table 16. The following FA's were positively correlated with the flavor volatile components from Bolton's (1987) work: A15:0, 15:0, A17:0, 17:0, 18:1, I18:1, 20:0, 20:5ω6, 20:5ω3, 22:6ω3, MONO and 12:0, 14:0, 16:0, 16:1, 18:0, 18:2, 18:3ω3, 20:2, 22:5ω3, PUFA-3 and

Table 16

Significant correlation coefficients[a] between fatty acid composition and flavor volatiles of ground beef

Descriptors	Fatty Acids								
	12:0	14:0	14:1	15:0	16:0	16:1	17:0	18:0	18:1
(e)-2-octene	-	-	-	-	-	-	-	-	-
unknown 1	-	-	-	-	-	-	-	-	-
unknown 2	-	-	-	.37	-.41		.49	-.38	-
propyl-benzene	-	-.39	-	-	-	-	-	-	-
heptenal	-	-	-	-	-	-	-	-	-
4-heptenal	-.36	-	-	-	-	-	-	-	-
unknown 4	-	-	-	-	-	-	-	-	-.36
unknown 5	-	-	-	-	-	-	-	-	-
unknown 6	-	-	-	-	-	-	-	-	-
acetone	-	-	-	-	-	-.36	-	-	-
1-ethyl-2-methyl-benzene	-	-	-	-	-	-	-	-	-
benzyl aldehyde	-	-	-	-	-	-	-	-	-
γ-butyro lactone	-	-	-	-	-	-	-	-	-
nonanal	-	-	-	-	-	-	-	-	-
unknown 10	-	-	-	-.35	-	-	-	-	-
pentanol	-	-	-	-	-	-	-	-	-

Table 16 (continued)

Descriptors	Fatty Acids						
	I18:1	18:2	I18:2	20:0	18:3ω3	20:2	20:4ω6
(e)-2-octene	.35	-.48	-	-	-	-	-
unknown 1	-	-	-	-	-	-	-
unknown 2	-	-	-.36	-	-.37	-	-
propyl-benzene	-	-	-	-	-	-.35	-
heptenal	-	-	-	-	-	-	-
4-heptenal	-	-	-	-	-	-	-
unknown 4	-	-	-	-	-	-	-.47
unknown 5	-	-	-	-	-	-	-.55
unknown 6	-	-	-	-	-	-	-
acetone	-	-	-	-	-	-	-
1-ethyl, 2-methyl-benzene	-	-	-	.39	-	-	.38
benzyl aldehyde	-	-	-	-	-	-	-
γ-butyro lactone	-	-.40	-	-	-	-	-
nNonanal		-	-	-	-	-	-.35
unknown 10		-	-	-	-	-	-
pentanol	-	-	.40	-	-	-	.38

Table 16 (continued)

Descriptors	Fatty Acids					
	20:5ω6	20:5ω3	22:5ω3	22:6ω3	A15:0	A17:0
(e)-2-octene	-	-	-	-	-	-
unknown 1	-	-	-	-	-	.35
unknown 2	-	-	-	-	-	-
propyl-benzene	-	-	-	-	-	-
heptenal	-	-	-.37	-	-	-
4-heptenal	-	-	-	-	-	-
unknown 4	-	-	-	-	-	-
unknown 5	-	-	-	-	-	-
unknown 6	-	-	-	.41	-	-
acetone	-	-	-	-	-	-
1-ethyl-2-methyl-benzene	.45	.43	-	-	.43	-
benzyl aldehyde	-	-	-	-	-	-
γ-butyro lactone	-	-	-	-	-	-
nonanal	-	-	-	-	-	-
unknown 10	-	-	-	-	-	-
pentanol	-	-	-	-	-	-

Table 16 (continued)

Descriptors	Fatty Acids		
	MONO	PUFA-3	PUFA-6
(e)-2-octene	-	-	-.45
unknown 1	-	-	-
unknown 2	-	-	-
propyl-benzene	-	-	-
heptenal	-	-	-
4-heptenal	-	-	-
unknown 4	.38	-.38	-.40
unknown 5	-	-	-.36
unknown 6	-	-	-
acetone	-	-	-.36
1-ethyl-2, methyl-benzene	-	-	-
benzyl aldehyde	-	-	-.54
γ-butyro lactone	-	-	-.42
nonanal	-	-	-
unknown 10	-	-	-
pentanol	-	-	-

[a] Significant at $P<.05$ for n=33.

PUFA-6 were negatively correlated. However, I18:2 was negatively correlated (-.36) with unknown 2 and positively correlated with pentanol (.40). The FA 20:4ω6 was negatively correlated with unknown 4, unknown 5 and nonanal (-.47, -.55, and-.35, respectfully) while being positively correlated with 1-ethyl-2-methyl-benzene (.38).

A positive correlation suggests that higher levels of the FA's were associated with higher concentrations of a volatile and possibly implicates the FA as a precursor for that volatile. However, as shown in Table 16, most of the positive correlations between FA's and volatiles are with those that were not identified. For these correlations a further argument that a given FA is a precursor of the volatile is not possible. One exception to the prior observation is the correlation of 20:4ω6, 20:5ω6 and 20:5ω3 with 1-ethyl-2 methyl benzene (.38, .45 and .43, respectively). Min et al. (1977) reported that alkyl benzenes may be formed from long-chain polyunsaturated FA's during thermal oxidation. However, alkyl benzenes may also be formed from degradation of β- carotene (Tannenbaum and Young, 1985) which is present in beef fat (Holden, 1985).

Comparison of Actual with Predicted Beef Fat Flavor Score

Regression analysis of beef fat flavor score (BFF) of 22 cooked ground beef samples (Bolton, 1987) as a function of FA composition of raw ground beef lipids and concentration of 11 selected volatiles isolated from cooked ground beef is shown in Table 17. The analysis given in Table 17 shows that the concentrations of 4 variables: 18:0, 18:2ω6, pentanal and unknown 7 volatile explained 72.95% of the variance (R^2) in the beef fat flavor score of cooked ground beef from 22 steers grazed on pasture A or B and then fed a corn diet 0, 56 or 112 days. All variables except

Table 17

Regression analysis of actual beef fat flavor intensity (BFF) of cooked ground beef and fatty acid composition plus concentration of flavor volatiles from ground beef for a 4-term model.

Source	DF	Type I Sums of Squares	Type II Sum of Squares
Model[a]	4	10301.0*	
18:0	1		4280.0*
18:2ω6	1		595.0
Pentanal (A)	1		1210.0*
Unknown 7 (B)	1		1283.0*
Error	17	4118.0	
Total	44	14119.0	

[a] BFF = 106.2 - 5.4801(% 18:0) + 8.4127(% 18:2ω6) + (0.00281)(TII A) + (0.00773)(TII B) where % = percentage of fatty acid in total lipids, TII = Total ion intensity of flavor volatile and R^2 = .7144.

* Significant at P< .05.

18:2ω6 had a significant relationship with BFF. The equation for the 4-term model is given in Table 17.

The predicted beef fat flavor scores of the eleven randomly selected ground beef samples not used to derive the model were calculated from the 4-term equation. A linear regression was run between the actual and predicted BFF from each model for these eleven samples. The linear plot between actual BFF and predicted BFF from the 4-term equation is shown in Fig. 1. The correlation coefficient between actual and predicted BFF using the 4-term equation was .83. Regression analysis given in Table 18 for the model shows that the slope of the straight line in Fig. 1 is not significantly different from 1.00 (Sanders, 1988).

The only other study in which a model was derived to explain the variation in flavor of beef from grass-fed and grain-fed steers was reported by Bolton (1987). He explained 51% of the variation (R^2) of cooked beef fat flavor by a model that contained 5 volatiles isolated from cooked ground beef. Varner et al. (1988) showed that the addition of 3 of these volatiles in parts per million to grain-produced beef fat could change its aroma to be similar to that of grass-produced beef fat. Combination of FA composition of the raw ground beef with the data of volatiles isolated from cooked ground beef allowed a model to be derived that explained a higher percentage of the variation of cooked beef fat flavor (Table 17) than explained by Bolton's (1987) model. The subsequent testing of the validity of the model on another set of data showed that this model was excellent for the prediction of beef fat flavor in cooked ground beef from steers grazed on pasture and then fed a corn diet from 0 to 112 days.

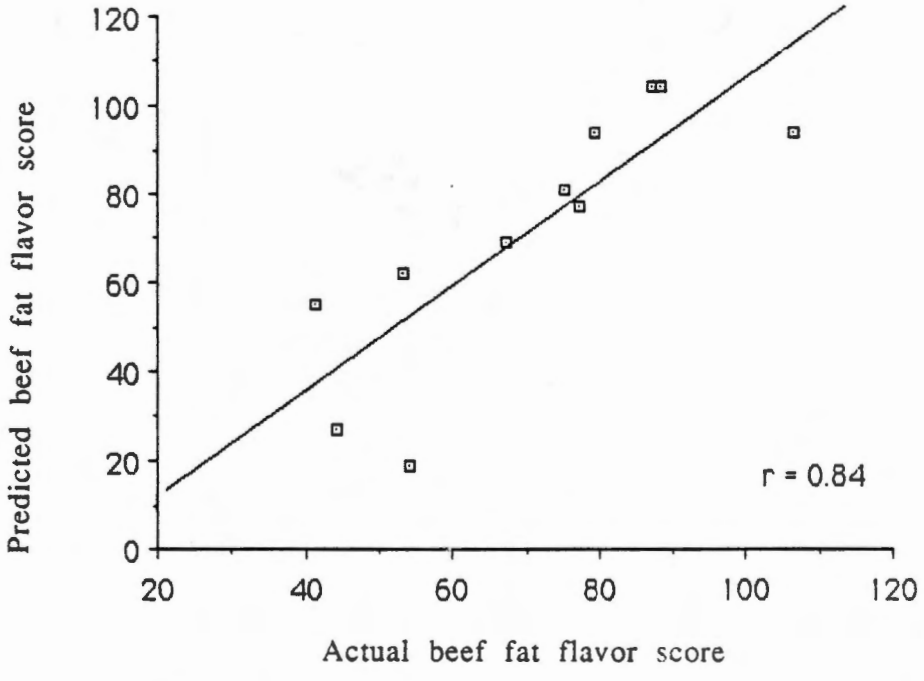

Fig. 1 Relationship between actual QDA beef fat flavor score of cooked ground beef and beef fat flavor score calculated from equation with 4 terms for 11 samples not used to develop equation.

Table 18

Regression analysis to test if the slope between actual and predicted beef fat flavor (BFF) is different than 1.00 for the 4-term model.

Source	DF	Sums of Squares
---------- 4-term model ----------		
Model[a]	1	5747.0*
B1[a]	1	146.0
Error	9	2554.0
Total	10	8300.0

[a] To test if slope of line between actual and predicted BFF intensity is significantly different than 1.00.

* Significant at $P < .05$.

CHAPTER 6

SUMMARY

In summary, this study showed that 72.95% of the variance (R^2) in beef fat flavor (BFF) score of cooked ground beef from 22 steers grazed on pasture A or B followed by being fed a corn diet 0, 56 or 112 days was due to 4 variables: 18:0, 18:2ω6, pentanal and unknown 7 volatile. In addition, BFF for the ground beef samples from 11 steers treated in a similar manner as the 22 steers used to develop the model was also calculated and compared with the actual BFF. A correlation coefficient of .83 ($P<.05$) was found for the BFF predicted from the 4-term model and the actual BFF of the 11 samples.

This study also showed that SAT, PUFA-3 and unknown types of FA's were negatively correlated with BFF while the MONO types were positively correlated ($P<.05$). The relationship of these FA types with the milky-oily flavor was reversed from that of BFF. Also, this study found that 20:4w6, 20:5ω6 and 20:5ω3 were correlated with 1-ethyl, 2-methyl benzene (.38, .45 and .43 respectfully).

Furthermore, the percentage of MONO and PUFA-3 FA's decreased in beef lipid with increasing DOF from 0 to 112. The percentage of PUFA-6 in these lipids from steers grazed on Rye pasture, followed by a corn diet decreased significantly from 0 to 112 DOF, but did not change in lipids from steers raised on FOC pasture and then fed a corn diet. The lecithin content of beef (g /100 g meat) changed significantly across DOF.

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APPENDICES

Table A-1

Lipid Content of Ground Beef from Steers Off Pastures A and B in 1985 by Feed Group

Slaughter group[b]	Pasture type[a] A (n=22)	Pasture type[a] B (n=20)
	----- mg 100 g^{-1} [c] -----	
0–DOF	19.13[dx]	20.68[dx]
56–DOF	20.91[dx]	22.45[dx]
112–DOF	16.69[dx]	21.66[dx]
Overall mean	18.93[d]	21.63[e]

SOURCE: BOLTON, J. C. 1987. SENSORY AND CHEMICAL EVALUATION OF FLAVOR IN GROUND BEEF FROM GRASS- AND GRAIN-FED STEERS. MASTER'S THESIS, THE UNIVERSITY OF TENNESSEE, KNOXVILLE.

[a] A = Fescue–Orchardgrass–Clover pasture; B = Ryegrass pasture.

[b] 0–DOF steers slaughtered directly off of pasture;
56–DOF steers slaughtered after 56 days on feed;
112–DOF steers slaughtered after 112 days on feed.

[c] Lipid is expresses as mg of lipid 100 g^{-1} of ground beef

[de] Means within rows with unlike superscripts are different (P<.05).

[xy] Means within columns with unlike superscripts are different (P<.05).

Table B-1

Effect of Days on Feed on the Flavor of Beef Produced on Different Pastures

Flavor descriptor[b]	Pasture[c]	Days on feed[a] 0	56	112
		– – – – – – mm. – – – – – –		
Cooked beef fat aroma	A[x]	39.6	72.7	78.8
	B[x]	49.2	64.4	81.0
Milky–oily aroma	Across[y]	87.2	64.4	50.0
Cooked beef fat flavor	A[x]	37.0	83.4	97.1
	B[x]	55.4	77.8	96.3
Milky–oily flavor	Across[y]	99.7	60.3	41.4
Off–flavor	Across[y]	22.4	32.5	35.1
Sour flavor	A[x]	29.0	31.6	30.2
	B[x]	29.2	35.0	41.9

SOURCE: BOLTON, J. C. 1987. SENSORY AND CHEMICAL EVALUATION OF FLAVOR IN GROUND BEEF FROM GRASS- AND GRAIN-FED STEERS. MASTER'S THESIS, THE UNIVERSITY OF TENNESSEE, KNOXVILLE.

[a] 0–DOF steers slaughtered directly off of pasture;
56–DOF steers slaughtered after 56 days on feed;
112–DOF steers slaughtered after 112 days on feed.

[b] As measured from a 150–mm horizontal line.

[c] A = Fescue–Orchardgrass–Clover pasture; B = Ryegrass pasture.

[x] n = 8; Significantly affected by DOF and its interaction with pasture.

[y] n = 16; Significantly affected by DOF but not the interaction.

Table C-1

Effect of Days on Feed on the Volatile Components of Beef Produced on Different Pastures

Peak number[b]	Name[c]	Pasture[c]	Days on feed[a] 0 (n=8)	56 (n=8)	112 (n=8)
			RPA[d]		
1	2, 3–Butanedione	A[x]	2.91	2.71	2.58
		B	2.35	4.84	2.92
2	3–Methyl Butanal	Across[x]	0.87	2.47	2.34
3	2, 2–Dimethyl –Propane	Across[x]	1.35	1.87	0.72
4	Pentanal	Across	2.75	1.99	5.17
5	2, 3–Pentanedione	Across[x]	0.94	1.89	2.10
6	Octane	Across	2.84	5.41	11.14
7	(z)–3–Octene	A	2.60	1.13	0.42
		B	6.58	0.52	0.44
8	(e)–2–Octene	A	1.30	0.48	0.68
		B	2.68	1.08	0.74
9	Toluene	A	9.47	0.47	1.79
		B	19.54	2.49	1.72
10	3–Penten–2–one	Across	0.92	0.93	0.26
11	Pentanol	Across[x]	1.81	2.62	2.65

Table C-1 (Continued)

Peak number[b]	Name[c]	Pasture[c]	Days on feed[a] 0 (n=8)	56 (n=8)	112 (n=8)
			– – – – – – – RPA[d] – – –		
12	Hexanal	Across	12.80	30.00	26.63
13	4–Methyl–3–Penten–2–One	Across	1.27	0.92	3.31
14	Nonane	A	0.90	1.48	0.69
		B	0.45	0.87	1.04
15	Unknown 1	A[y]	4.12	1.10	24.39
		B[y]	0.00	0.80	1.25
16	Ethyl–Benzene	Across[x]	0.43	0.52	0.86
17	m–Xylene	Across[x]	1.30	1.07	1.07
18	Unknown 2	Across[x]	1.92	0.89	1.70
19	1–Hexanol	A[x]	2.27	2.21	1.82
		B	1.31	1.59	3.14
20	Unknown 3	A[y]	2.92	0.63	0.00
		B[x]	0.77	0.46	1.94
21	Acetic Acid	Across[x]	2.88	2.91	2.38
22	3–Hydroxy –2–Butanone	Across	21.94	23.71	14.44
23	Propyl–Benzene	Across[x]	0.76	0.63	0.39
24	Heptanal	Across[x]	10.08	8.97	8.58

Table C-1 (Continued)

Peak number[b]	Name[c]	Pasture[c]	Days on feed[a] 0 (n=8)	56 (n=8)	112 (n=8)
			RPA[d]		
25	4–Heptenal	Across[x]	1.26	1.72	1.42
26	Unknown 4	Across	1.22	0.61	1.08
27	Unknown 5	Across	1.55	0.68	1.30
28	Unknown 6	A	1.32	0.62	2.50
		B[x]	1.17	0.80	0.80
29	Unknown 7	Across	1.85	1.74	3.01
30	Acetone	Across	3.55	6.36	2.77
31	1–Ethyl–2–Methyl –Benzene	A[x]	0.35	0.69	0.00
		B[x]	0.54	0.37	2.14
32	Unknown 8	Across[x]	0.52	0.45	0.84
33	Octanal	Across[x]	1.68	1.43	3.66
34	Unknown 9	Across[x]	1.36	0.58	0.77
35	Benzyl Aldehyde	Across[x]	1.52	0.56	0.99
36	2–Ethyl–4–Methyl –1–Pentanol	A	3.20	0.78	2.00
		B[x]	1.33	2.25	1.47
37	γ–Butyro Lactone	Across[x]	0.51	0.54	0.46
38	Nonanal	Across	1.86	0.88	2.03

Table C-1 (Continued)

Peak number[b]	Name[c]	Pasture[c]	Days on feed[a] 0 (n=8)	56 (n=8)	112 (n=8)
			----- RPA[d] -----		
39	Unknown 10	A[y]	1.04	0.00	1.80
		B	2.15	0.37	0.31
40	Unknown 11	Across[x]	1.26	0.87	0.81

SOURCE: BOLTON, J. C. 1987. SENSORY AND CHEMICAL EVALUATION OF FLAVOR IN GROUND BEEF FROM GRASS- AND GRAIN-FED STEERS. MASTER'S THESIS, THE UNIVERSITY OF TENNESSEE, KNOXVILLE.

[a] A = Fescue–Orchardgrass–Clover pasture; B = Ryegrass pasture.

[b] Numbers were assigned on a basis of retention time from the chromatograms obtained from the GC–Mass Spectrophotometer.

[c] Tentative identification. Positive results were obtained from standards.

[d] Means are expressed as a percentage of relative abundance of the total ion intensity (TII) of the peak divided by the sum of the total ion intensity for all peaks. Peak RPA $= \frac{\text{TII Peak}}{\Sigma(\text{TII})} * 100$

[x] These volatiles were either for indicated pasture or across pasture not affected by DOF ($P<.05$)

[y] These volatiles were not present in enough beef samples to be statistically analyzed.

Table D-1

Fatty acids and their retention times

Fatty acid	Retention time (min)
unknown B	3.31
12:0	4.46
13:0	5.35
BHT	5.92
14:0	6.51
A15:0	7.20
14:1	7 48
15:0	7.95
I16:0	8.55
Aldhyde 16:0	8.80
unknown N	9.01
unknown N-1	9.18
16:0	9.81
unknown Q	10.48
16:1	10.81
A17:0	11.06
unknown T	11.33
17:0	11.71
unknown V	12.10
unknown X	12.53
17:1	12.85
unknown Y	13.36
18:0	14.13
18:1	15.33
I18:0	15.66
19:0	16.46
18:2	17.03
I18:2	17.50
18:3ω6	18.10
20:0	19.00
18:3ω3	19.40
20:1	20.06
unknown B-1	20.60
unknown B-2	21.23
20:2	22.26
unknown B-3	22.60
20:3	23.60
20:4	24.63
20:5ω6	26.10
20:5ω3	27.20
unknown Z-3	27.83
unknown Z-6	28.10
22:5ω6	30.20
unknown Z-4	31.23
22:5ω3	32.73
unknown Z-8	35.13

VITA

Robert A. Schell was born May 22, 1961, to Dr. Robert A. Schell and Ruth M. Schell. He received his high school diploma from Claremont High School, Claremont, California in 1980 and enrolled at California Polytechnological University, Pomona, California in September of 1980 Mr. Schell transferred to The University of Tennessee, Knoxville in January of 1981and graduated with a Bachelor of Science degree in Animal Science in the fall of 1985. At the University of Tennessee he was a member of Farmhouse Fraternity, Alpha Zeta Honor Fraternity, the Meat Judging Team and the Livestock Judging Team. He is currently a member of the American Meat Science Association. In the winter of 1986, the author entered graduate school with a full research assistantship. He was married in July, 1987 and received a Master of Science degree in Food Technology and Science in August, 1988.