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BEEF FLAVOR AND FATTY ACIDS IN DIFFERENT CARCASS SITES AS AFFECTED BY GRASS AND CORN DIETS UP TO 140 DAYS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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DEDICATION

This dissertation is dedicated to my wife Young Ae and my daughter Jinny, whose love, support, encouragement, interest, and constant attitude of concern will always be treasured.

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ABSTRACT

Ninety-one Angus steers which were wintered on fescue pasture and allowed unlimited grazing on an orchard grass, fescue and clover pasture during the spring and summer of 1980 were assigned to 5 groups of 15 steers each and one group of 16 steers on the basis of frame size. One group was slaughtered off pasture (0 days on corn), and the rest were adjusted to a whole shelled corn diet for 2 weeks. After adjustment, a group of corn-fed steers was slaughtered every 28 days up to 140 days. For each steer, the fatty acid composition of total intramuscular lipids of the longissimus, brisket fat and intermuscular fat was determined, the volatile fatty acid (VFA) content of the longissimus was measured, and the flavor of the cooked longissimus was evaluated by Quantitative Descriptive Analysis.

Most of the fatty acids in each fat site were affected by days steers were fed corn. As days steers were fed corn increased, the percentages of saturated fatty acids in the brisket and intramuscular fat decreased, the percentages of monounsaturated fatty acids of all three fat sites increased, and the percentages of the polyunsaturated fatty acids of the brisket fat and intramuscular lipid decreased. Frame size of steers did not affect the fatty acid composition of any fat site very much. Of the three fat sites, the intramuscular lipid had the greatest concentration of polyunsaturated fatty acids, the seam fat had the most monounsaturated fatty acids, and the brisket fat had the highest amount of saturated fatty acids.

The VFA content of the longissimus muscle also was affected by days steers were fed corn. Steers fed corn for any time generally had greater concentration of acetic, isobutyric, butyric and caproic acids and lower amounts of valeric acid in the longissimus than steers off pasture. Of all frame sizes, steers with the largest frame size had the lowest levels of isocaproic acids and highest levels of acetic acid.

As corn was fed steers from 0 to 140 days, the intensity of an undesirable milky-oily aroma and flavor decreased linearly and the intensity of a desirable cooked beef fat aroma and flavor increased linearly. Long chain polyunsaturated fatty acids (C18:3, C20:3, C20:4, and C22:5), αC15:0 and C18:0 were positively correlated with the milky-oily aroma and C10:0, C12:0, C14:0, C14:1 and C18:1 were negatively correlated. The polyunsaturated fatty acids are more labile to oxidation during storage and cooking of meat, and probably contribute to the off-flavors in beef produced by grass and to its reduced storage life.

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CHAPTER I

INTRODUCTION

Rapidly increasing grain prices during the 1970s resulted in increasing beef prices. Increasing the backgrounding time of cattle on pasture, such as fescue which will grow on land not suitable for the production of small grains, and reducing time of finishing on grain might increase the cattle profits and produce beef at cheaper cost to the consumer. However, acceptability of beef by the consumer is a major concern to producers.

It is difficult to evaluate the beef flavor because many factors have been shown to affect it. The nature of the flavor depends upon the way in which meat is cooked and each meat has its own characteristic flavor. Much of the beef flavor is the result of the nonenzymatic browning reaction between nonprotein nitrogen compounds and water-soluble carbohydrates. However, a similar composition of free amino acids and reducing sugars in beef, pork, and lambs and similar organoleptic qualities from water extracts of these meats imply that a basic meaty aroma is common to the lean portions of all meats. Lipid portions contain compounds that give each species a different flavor. The different meat flavor must result from either the proportion in which proteins, amino compounds, lipids, carbohydrates, and mineral salts are present or in the way in which they interact during cooking.

Research at The University of Tennessee has shown that beef from grass-finished steers with the same degree of fatness and the same age

as grain-finished steers has a less desirable flavor, higher levels of stearic, linolenic and arachidonic acids and lower levels of oleic acid (Brown et al., 1979; Melton et al., 1982a). The less desirable flavor is due possibly to a higher intensity of a soured dairy flavor and a lower intensity of a beef fat flavor.

In the normal feeding regime of finishing cattle for market, grass pasture is used during the spring and summer to increase the weight of cattle as much as possible prior to grain-feeding in a dry-lot. Research at The University of Tennessee has shown that this normal grain-feeding period may be reduced from 140 days to 90 without much change in beef flavor (Melton et al., 1982b). During the 90 days grain-feeding period, these investigators found changes in the volatile fatty acids content and fatty acid composition of ground beef. These changes in chemical components were highly related to the change in intensity of a desirable fat flavor which increased with increasing time steers were fed grain. Those investigators did not, however, investigate flavor and chemical composition of the steak (longissimus muscle) or the fatty acid composition of other fat sites in the beef carcass as a function of time steers were fed a grain diet. Data concerning the effect of time steers are fed a grain diet on the flavor and chemical composition of the longissimus muscle and on the fatty acid composition of other fat sites in the beef carcass are needed. Therefore, the objective of the present study was to investigate the effects that time on grain from 0 (grass-finished) up to 140 days as a finishing diet for

steers would have on the flavor of beef and fatty acid composition of brisket fat, seam fat and intramuscular fat of the beef carcass.

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: (1) volatile compounds with odor properties; (2) nonvolatile compounds with taste and tactile properties; and (3) potentiators and synergists. Since all types of meat consist of broadly similar components—such as proteins and other amino compounds, lipids, carbohydrates, and mineral salts—it is apparent that there must be a significant difference either in the proportion in which these compounds are present or in the way in which they interact. The differences in meat flavor due to cooking are probably a direct function of temperature and degree of moisture in the meat.

Flavor Precursors

Studies concerning the meat flavor precursors either in the fat or the lean were started during the 50s (Jones, 1952; Kramlich and Pearson, 1958). Later meat flavors were found by development of non-enzymatic browning reactions or Mailard reactions induced by heating sugars and amino acids. These amino acids identified in the diffusate of meat were cystine, cysteine, cysteic acid, methionine and taurine (Wasserman and Gray, 1965; Wasserman and Spinelli, 1970). The most important sugar in meat is glucose; however, fructose, ribose and

deoxyribose also have been found. All of these sugars in raw meat were found to be responsible for meat flavor volatiles (Dwivedi, 1975; Wasserman and Spinelli, 1970). Although most meat flavors are developed in reactions of nonenzymatic browning, the mechanism by which meat flavors are generated is also important. Inter- and intramolecular cyclization as well as numerous reactions are made possible by the activity of ammonia, hydrogen sulfide, mercaptons and other unidentified intermediates, especially at elevated temperatures, also contribute to meat flavor (Wilson et al., 1973).

Macy et al. (1964) and Wasserman and Spinelli (1972) reported no great differences between the amino acid patterns of the diffusates of beef, pork and lamb. The meat aromas released when diffusates of these species were heated were very similar, provided the fat had been removed before extraction in cold water. This finding stresses the importance of fat in determining the characteristic species flavor. Fat is also capable of dissolving the nonpolar volatile compounds, thus providing a reservoir of flavor compounds (Pippen et al., 1969). Of course, reactions affecting flavor can take place between the compounds soluble in the fat as well as reactions between the compounds and the fatty acids of the fat (Lien and Nawar, 1974).

Relationship of Fatty Acid Composition to Flavor

A number of studies have been done which show a relationship between fatty acid composition and meat palatability (Dryden and Marchello, 1970; Waldman et al., 1965; Waldman et al., 1968; Melton et al., 1982a,b). Hornstein et al. (1961) determined the lipid composition

of lean beef and pork and related their findings to flavor. There are high positive correlation coefficients between flavor score and either intramuscular oleic acid or intramuscular total unsaturated fatty acids, and high negative correlation coefficients between flavor score and each of the following intramuscular fatty acids: palmitic (C16:0), stearic (C18:0), linoleic (C18:2), and total saturated fatty acids. Brown et al. (1979) proposed that linolenic acid contributed to the low flavor score of grass-fed beef. Melton et al. (1982a) showed a significant negative correlation between flavor desirability and linolenic acid of both neutral and polar lipids. Also the possibility exists that microbial growth on beef that has higher linolenic acid could contribute to the 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, 1968). These compounds are known to contribute off-flavors in foods (Forss, 1969; Labuzza, 1971).

B. EFFECT OF DIET ON FATTY ACID COMPOSITION OF BEEF

It has been known for many years that ruminant fat depots are relatively stable and not subject to the influence of diet, sex, environment, etc., as are the tissues of many monogastric species. Elsden (1945) showed that 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. Garton (1960) reported that dietary unsaturated fatty acids are partially or completely hydrogenated

by rumen microorganisms and the degree of unsaturation of body fats in ruminants is affected very little by most diets. Balch and Rowland (1957) showed that the acetic acid to propionic acid ratio in the rumen decreased when concentrates were fed to cattle that had been fed high roughage diets. Furthermore, recent studies have shown differences in fatty acid composition of ruminant tissues caused by differences in diet (Bensadoun and Reid, 1965; Brown et al., 1979; Cabezas et al., 1965; Church et al., 1967; Clemens et al., 1974; Cook, 1963; Cramer and Marchello, 1962; Edwards et al., 1961; Erwin et al., 1963; Reiser and Reddy, 1956; Roberts and McKiroy, 1964; Sumida et al., 1972; Tove and Matrone, 1962; Tove and Mochrie, 1963; Varnell et al., 1965; Westerling and Hedrick, 1979; Melton et al., 1982a,b).

There is conflicting information on fatty acid composition as affected by diet. Privett et al. (1965) reported that lower percentages of saturated fatty acids and higher percentages of oleic and linoleic acids were found in beef cattle fed high energy diets compared to cattle fed a low level maintenance diet. Edwards et al. (1961) found that addition of animal fat to steer rations resulted in a highly significant increase in stearic acid content of rib fat. However, Cook (1963) reported no difference in fatty acid composition of neutral fraction of raw and cooked beef lipids due to feeding management. Cabezas et al. (1965), who varied the ratio of dried citrus meal to cornmeal in the diet, showed the effect of the physical form of diet on composition of fatty acids in beef. Data on rib fat composition revealed that a higher degree of unsaturation was found for diets containing 72% corn. This unsaturation was due to an increase in oleic acid content. Church et al.

(1967) found that the addition of tallow fat resulted in significant increases in C14:1, C17:0, C18:0, and a decrease in C18:1. Sumida et al. (1972) showed feeding treatment affected fatty acid composition but did not affect fatty acids in different sample sites in the same manner. 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 and that added safflower oil to the diet increased the unsaturation effect. 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 showed 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. 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. Melton et al. (1982a) designed a study in which a grass diet was compared with a grain diet of the same energy level and a higher energy grain diet. Results of this study showed 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) found 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; Hornstein et al., 1967; Keller and Kinsella, 1973; Marchello et al., 1968; Read et al., 1963; O'Keefe et al., 1968; Terrell et al., 1967).

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

The economic feasibility of grain supplementation of forage diets to provide marketable beef has long been acknowledged. Many researchers have concluded that beef from forage-finished cattle is of poorer eating quality than beef from cattle maintained on grain diets. Bidner (1975) reported the break-even price increased as steers were finished on grain. Beeson et al. (1967) showed that cattle slaughtered after 191 days on good pasture saved about 500 pounds of total digestible nutrients per steer compared to 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. Oltjen et al. (1971) found that feeding a pelleted forage increased feed intake and daily gain of beef cattle. They concluded the lower plane of nutrition available to cattle on grass, due to low consumption of total nutrition rather than inferiority of the grass, was the reason for slower weight gain in

forage-fed cattle. Similar results were reported by Ralston et al. (1966). However, in the future, utilization of grass will become more important in finishing cattle as grain prices continue to increase.

Grass-finished beef has been reported to be tougher and has higher Warner-Bratzler shear values than grain-finished beef (Shinn, 1976; Lusby, 1977; Bowling et al., 1978; Harrison et al., 1978; Dyer, 1980). Hiner and Bond (1971) stated the quantity of meat produced on different feeding regimes could be measured by comparing rate of gain, feed conversion, carcass cutability, thickness of fat covering and rib eye size. 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).

Waldman et al. (1971) compared bone, muscle and fat proportions of carcasses from beef cattle fed a high versus medium energy diet. Cattle on the medium diet were restricted to 60 to 70% of the weight gain of the high energy fed cattle. No appreciable differences were found in bone, muscle or fat components of the carcasses from cattle on the two diets. Waldman et al. (1971) concluded carcass composition at final weight was not dependent on time required to reach that weight. Zimm et al. (1970) reported that average daily gains increased with increasing time on feed up to 180 days, while marbling scores and carcass grades increased up to 240 days on feed. Bidner (1975) acknowledged that forage-fed animals gained slower as a result of the low energy diet.

Grass-finished beef has a lighter lean color than beef from grass-finished steers (Reagan et al., 1977; Melton et al., 1982a) and the exposed muscle surface discolors more rapidly. 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).

In many of the studies in which beef produced on grass has been compared with beef produced on grain, the effect of diet type on the organoleptic qualities of the meat has been confounded with degree of fat finish or maturity of cattle (Bowling et al., 1977). If cattle on a low energy, forage diet are fed to comparable slaughter weights of those on a high energy, grain diet, cattle on the forage diet will be older. If cattle on the two diets are killed at the same age, those on the forage diet will be lighter with less fat. The studies in which beef from lighter, grass-finished cattle were compared with heavier, grain-finished cattle have resulted in the conclusion that the existing flavor differences in beef from these two types of cattle is attributable to the lack of fat in the grass-finished cattle (Bidner, 1975; Moody, 1976; Harrison et al., 1978). Bidner (1975) concluded that if cattle were fed to comparable weights and grades, the type of diet would have little influence on the organoleptic properties of the meat. Contrary to this conclusion, Sink and Capraso (1979) concluded that there was little doubt that the type of diet and nutrient source significantly affected the flavor of muscle foods. Also, several investigators have reported that even at equal fat levels, beef from grass-finished cattle still have less desirable flavor than that from grain-finished cattle

Brown et al., 1979; Melton et al., 1982a,b; Reagan et al., 1977).

Several researchers have shown that beef from grain-finished cattle has superior flavor qualities to beef from cattle finished on pasture (Melton et al., 1982a,b; Brown et al., 1979; Bowling et al., 1977; Dunn, 1982; Dyer, 1980; Harrison et al., 1978; Lusby, 1977; Reagan et al., 1977, 1981; Smith et al., 1977; Schroeder et al., 1980). Brown et al. (1979) and Melton et al. (1982a) 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. Melton et al. (1982a) reported that a flavor profile panel scored the intensity of a milky, dairy aroma and flavor higher in ground beef from grass-fed steers than from grain-finished steers, and 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. Melton et al. (1982b) showed similar results which indicated the milky-oily note decreased to minimum intensity at approximately 114 days on corn and the cooked beef fat flavor note increased to maximum intensity at the same time. They also found that a fishy and sour flavor decreased in intensity as time steers were fed corn increased.

The difference in flavor between beef produced by grass and that produced by grain may be due to the differences in the concentrations of flavor precursors in the beef. Melton et al. (1982a,b) and Westerling and Hedrick (1979), all of whom studied flavor of beef produced by grass

and by grain, reported that less desirable beef flavor was significantly related to lower concentrations of oleic acid and higher concentrations of stearic acid. Westerling and Hedrick (1979) reported that a higher concentration of linoleic acid also was associated with less desirable beef flavor, but Melton et al. (1982a) found that higher concentrations of linolenic acid rather than linoleic acid was significantly related to the less desirable beef flavor. In addition, Melton et al. (1982a) reported that more desirable beef flavor was associated with higher levels of water soluble carbohydrate content in the beef and lower concentrations of polyunsaturated fatty acids with 20 or 22 carbons. Melton et al. (1982b) found that higher intensities of an undesirable milky-oily aroma and flavor and lower intensities of a desirable beef fat aroma and flavor were significantly related to lower concentrations of monounsaturated fatty acids with 14 to 18 carbons, acetic acid and water soluble carbohydrate and higher intensities of pentadecanoic acid, stearic acid, linolenic and arachidonic acids.

D. SENSORY EVALUATION

Tenderness, juiciness, and flavor of meat are the main palatability characteristics many researchers have concentrated on recently. There are many factors which contribute to the final evaluation of a palatability attribute.

The flavor is one of the most important factors to consider in determining whether a sample is acceptable or unacceptable. Desirable beef flavor is difficult to assess as it is affected by several factors. Beef flavor is the result of reactions of nonaromatic precursors during

cooking (Melton et al., 1982b; Dwivedi, 1975). Recently evidence has been reported linking beef flavor intensity to the number of days cattle are on feed and their nutritional regime. Therefore, feeding management of cattle prior to slaughter has become a matter of concern for researchers. Meat must contain substances which interact or degrade during cooking to produce compounds responsible for the characteristic flavor of meat, because it is necessary to heat meat to produce the desired flavor (Dwivedi, 1975).

Vold (1968) reported frozen storage time (-20°C) of lamb chops increased tenderness scores, and Smith et al. (1969) found no differences in tenderness ratings between beef steaks cooked from the frozen or raw state. Tenderness of beef loin steaks improved as the freezing rate increased, and cooking meat directly from the frozen state lowered Instron shear readings while it did not affect sensory tenderness (Jakobsson and Bengtsson, 1973). Cross et al. (1979) noticed a weak trend toward increased tenderness of roasted rather than broiled steaks.

Consumer demands for leaner beef, but with a high quality, have caused producers and researchers to review extensively the palatability attributes of forage-fed, limited grain-fed and full grain-fed beef. Wanderstock et al. (1948) compared roasts from grain-fed Hereford steers to forage-fed steers. Aroma, fat flavor, lean flavor, juiciness and tenderness were rated significantly lower for the forage-fed steers. Purchas and Davies (1974) reported measurements of tenderness favored cereal-fed steers to approximately 457 kg rather than the pasture-fed steers. Huffman (1974) evaluated 20 mixed-breed steers finished on a combination of rye, ryegrass and arrowleaf clover forage or on grain

for 90 days. Panelists could not tell any significant differences between the beef produced by the two systems. Bowling et al. (1977) also demonstrated grain-finished steers were more tender and more desirable in both flavor and overall desirability. Harrison et al. (1978) agreed with previous researchers that cattle fed the longest time (98 days) on feed and the highest plane of nutrition had the most desirable palatability attributes. Dyer (1980) found general upward trends in both tenderness and flavor ratings when steers were slaughtered every 28 days from 0 to 140 days on feed with whole shelled corn. Also, Tatum et al. (1980) slaughtered steers at 100, 130 and 160 days on feed and stated that as days on feed increased from 100 to 160 days, flavor intensity benefited. Flavor intensity at both 130 and 160 days was significantly different from 100 days, but juiciness, tenderness and overall desirability were not significantly different between treatments. Other researchers have reported that extending the time-on-grain beyond 90 to 100 days provided little additional palatability improvement in rib steaks (Dolezal et al., 1979).

CHAPTER III

MATERIALS AND METHODS

A. ANIMAL SELECTION, FEEDING MANAGEMENT AND SLAUGHTER

A total of 185 Angus steers were wintered (November 1979 through April 1980) primarily on a fescue pasture (except when snow covered the ground and they were fed hay) at The University of Tennessee Plateau Experiment Station, Crossville, Tennessee. All of these steers were weighed, wormed and implanted with 36 mg of Ralgro^{R} on April 14, 1980. The steers were allowed unlimited grazing on a pasture of orchardgrass, clover and fescue from April 19, 1980, to a date in July 1980, where adequate growth on the pasture was no longer possible because of lack of moisture and environmental conditions. At that time 90 steers were selected from the group. When taken off pasture, weights were taken, along with wither height and fat thickness. The calves were also subjectively appraised for frame size, age and estimated finishing weight. At this time 91 steers were assigned to five groups of 15 steers and one group of 16 steers on the basis of frame size. Within each group four different frame sizes were indicated by number 1 (small size), 2, 3 and 4 (large size) (see Table 1). One group of 15 steers was transported to Lay's Packing Company, Knoxville, Tennessee, for slaughter. The remaining steers were transferred to the 70-N unit of the Plateau Experiment Station at Crossville, where they were subjected to a 14-day acclimation period prior to drylot grain feeding. A ration of whole shelled corn was

TABLE 1

EXPERIMENTAL DESIGN[a]

Frame Size	Days on Grain					
	0	28	56	84	112	140
1 (small)	4	4	4	4	4	4
2	5	5	5	5	5	5
3	4	4	4	4	4	4
4 (large)	2	2	2	3	2	2

[a]For each frame size-days on grain combination, the experiment was split into three sampling sites for the fatty acid composition of lipid samples.

fed ad libitum, along with 1.1 pounds of Tend-R-Lean^{R} per head per day. One group of steers was slaughtered after 28 days on feed and one group every 28 days thereafter through 140 days as outlined in Table 2. All animals were weighed and measured at 28-day intervals.

TABLE 2

STEER SLAUGHTER SCHEDULE

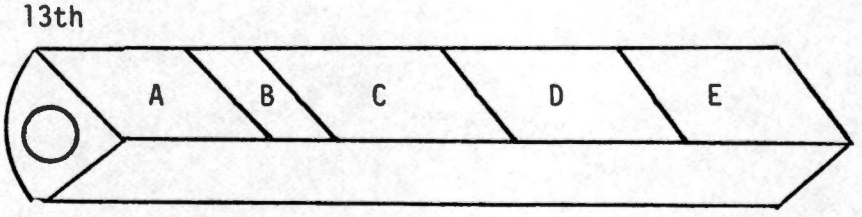
Slaughter Group	No. of Steers	Days on Grain	Slaughter Date
1	15	0	Aug. 5, 1980
2	15	28	Sept. 16, 1980
3	15	56	Oct. 14, 1980
4	16	84	Nov. 16, 1980
5	15	112	Dec. 9, 1980
6	15	140	Jan. 6, 1981

B. POSTMORTEM TREATMENT

The carcasses were weighed and chilled for 48 hours postmortem at 1.6°C prior to fabrication. Each carcass was ribbed and evaluated according to the USDA beef grade standards by a USDA grader and The University of Tennessee personnel. The left side of each carcass was then shipped to The University of Tennessee Meats Laboratory for fabrication according to the procedure of Wellington (1953). Retail yield was recorded and research samples for sensory and chemical analyses were collected.

At the time of fabrication, the brisket fat samples were obtained from the external fat on the sternum side of the brisket. Samples of seam (intermuscular) fat were obtained from the chuck by removing a portion of the fat deposit medial to the deep pectoral muscle. Steaks and intramuscular fat (marbling) samples were obtained from a portion of the longissimus dorsi muscle of the 13th rib (Figure 1). One hundred g of fat from the brisket (subcutaneous fat), seam (intermuscular fat), and steaks for chemical analyses (Section A) and QDA analysis (Section D) were obtained from each carcass (Figure 1). Section E (Figure 1) was used for flavor panel training.

Each fat sample and each steak (A-E, Figure 1) from each carcass were double wrapped in polyethylene coated freezer paper, frozen and stored at -24°C until analyzed. Prior to chemical analysis, the longissimus muscle at the 13th rib was removed from Section A in Figure 1, stripped of all epimysium tissue, frozen in liquid N_2, and then placed in a Waring blender and powdered. The powdered samples were stored under N_2 in polyethylene bags at -34°C prior to analysis.



SAMPLE	THICKNESS (cm)	ANALYSES
A	1.3	Chemical Characteristics
B	0.6	Used for Work Plan
C	2.5	For H-524-K4, Research
D	2.5	QDA Evaluation
E	2.5	Flavor Panel Training

Figure 1. Diagram of a beef loin showing where samples for analyses were obtained.

C. CHEMICAL ANALYSES

Total Lipid Content of Longissimus Muscle

The powdered steaks being stored at -34°C were extracted for total lipids. This extraction was done by a modified procedure of Ostrander and Dugan (1961). A 50 g powdered sample was blended in a Waring blender with 130 ml of MeOH for 5 minutes at low speed. Sixty-five ml of chloroform were added and the mixture was blended for another 5 minutes. An additional 66 ml of chloroform was added and blended for 20 seconds. Then 1.5 g of zinc acetate, dissolved in 65 ml of deionized water, were added to the mixture and blended for 10 seconds. This mixture was filtered through a Whatman No. 1 filter paper in a Buchner funnel under suction. The residue and used filter paper were put into the blender. The funnel was wiped with Kleenex tissue and the tissue was added to the blender contents. All blender contents were blended with 100 ml chloroform for 2-5 minutes. This mixture was filtered through another Whatman No. 1 filter paper in a Buchner funnel with suction. The blender jar was rinsed with 75 ml of chloroform, which also was filtered as before. All filtrates were combined in a 500 ml graduated cylinder. The sunction flask was rinsed in turn with 25 ml of methanol and chloroform and the rinse added to the filtrate. The head space of the filtrate was flushed with nitrogen and the filtrate stored at 4°C until the methanol and chloroform layers were distinctly separated. The volume of the chloroform layer was recorded. All layers were transferred to a 500 ml separatory flask and the distinct layers re-established overnight. The chloroform layer was drained into an Erlenmeyer flask. Ten ml of

the chloroform extract was pipetted into each of two dry, tared 50 ml beakers. The contents of these beakers were evaporated overnight under the hood and dried at 70°C for six hours in a vacuum oven. The beakers were cooled in a dessicator and reweighed within one hour. The average weight of lipid in any particular sample was calculated from the data obtained (Appendix A). The remaining chloroform extract was evaporated to near dryness on a rotary evaporator at 45°C under vacuum, dissolved in $CHCl_3$:CH_3OH(20:1, v:v) and stored in 25 ml solution under N_2 at -34°C until analyzed for fatty acids.

Long Chain Fatty Acid Analysis

Methyl esters of samples of brisket fat, seam fat and intramuscular fat were prepared according to Method Ce 2-66 (AOCS, 1974) and fatty acids analyzed according to the method of Melton et al. (1982b). A Bendix Model 2600 gas chromatograph equipped with dual flame ionization detectors and a chromatograph E-1A electronic integrator were used for analyses of the methyl esters.

Two different columns were used: (1) a 2.000-mm i.d. x 3.0-m glass column packed with GP 3% sp 2100 DOH on 100/120 Supelropart (Supelco, Inc., Bellefonte, PA) and (2) a 2.000-mm i.d. x 1.83-m glass column packed with 5% HIEFF L BP on 50/80 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 unsaturated fatty acids which were efficiently separated by the second

column. For each column the amounts 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 (Method Ce 1-62; AOCS, 1974). In these cases where the fatty acid could not be identified (designated as fatty acid unknown), the calibration factor was assumed to be 1.00. Calibration factors for fatty acids on each column in these analyses are given in Appendix B. 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	30 ml/min	30 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
Temperature 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, 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

Volatile fatty acids were extracted from the powdered longissimus of each steer. For the extraction of volatile fatty acids, 50 g of powdered, fresh meat samples were used. Each sample was thoroughly suspended in 1500 ml of distilled water. The proteins were precipitated with 25 ml of 1 N sulfuric acid and 40 ml of 20% phosphotungstic acid. Fifty ml of distilled water were added at this point to make a total of 265 ml of liquid. The resulting mixture was shaken vigorously and filtered through a 24-cm rapid flow filter paper. From this point the procedure recommended in section 10.050 of AOAC (1980) was followed. One hundred fifty ml of filtrate were steam distilled under constant volume conditions (Ubbanonu, 1980). Two hundred ml of distillate were collected in a volumetric flask, transferred to a 500 ml flat bottom 24/40 groundneck flask and were neutralized with 0.1 N sodium hydroxide solution using phenolphthlein indicator. An excess (1.0 ml) of sodium hydroxide was added. The resulting pink solution was evaporated to dryness on a vacuum rotary evaporator at 47°C to 50°C. The volatile fatty acids present were liberated from the dry crystals of their sodium salts using 1.0 ml of 0.5 N dichloracetic acid in acetone. The solution was diluted with 0.5 ml of methylheptyl ketone solution (0.280 g methylheptyl ketone in 200 ml acetone) and 1.5 ml of acetone to make 3.0 ml solution. The resulting solution was collected in a 7 ml screw cap vial with teflon septum, and stored in a refrigerator until GLC analysis.

A standard solution (Appendix C) was used to identify the fatty acids present by comparing the retention time and relative retention

time of the chromatograph peaks of the sample with those of the standard solution (Appendix D). Analysis of the volatile fatty acids was done on a Bendix gas liquid chromatograph, model 2500, equipped with a flame ionization detector, Dohrman recorder and an electronic integrator (Shimadzin Chromatopac E-1A). The column used was 6.35 mm i.d. x 1.83-m glass packed with 10% FFAP, 80/100 Gas Chrom Q. The conditions for the instrument were:

Nitrogen flow rate	30 ml/min
Hydrogen flow rate	40 ml/min
Air flow rate	80 ml/min
Initial temperature	110°C
Final temperature	170°C
Isothermal oven temp.	200°C
Attenuation	200
Temperature rate	4°C/min

Three microliters of the standard solution were injected and the peaks of the chromatogram identified. Two more injections were made and the retention time and response factor of each acid were obtained by the electronic integrator (Appendix E). Three microliters of each sample solution were injected in turn and peaks identified and quantitated as mg of fatty acid per 100 g of meat samples (Appendix F). Correction factors for distillation loss of each fatty acid were calculated to obtain actual supernatal values (Appendix G).

D. SENSORY EVALUATION

The cooked steaks from each steer were evaluated according to the Quantitative Descriptive Analysis (QDA) method (Melton et al., 1982b). The steaks from Section D in Figure 1 (p. 19) were removed from the freezer 24 hours prior to cooking and thawed at 34°C and then broiled in a rotary oven at 177°C to an internal temperature of 72°C. Panelists were trained by being 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 (Melton et al., 1982a). 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 H) so each panelist could judge quantitatively aroma notes first and then flavor notes by making 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 qualitatively represented slight and intense. The stimulus for slight sour aroma and flavor was 0.01-mg acetic acid/ml aqueous solution and for the intense extreme, 0.1-mg acetic acid 1 ml. The stimuli for the slight and intense oily part of milky-oily aroma were respectively 5×15^{4} mg and 1×10^{-3} mg trans, 2-4 decadienal/ml methanol. Panelists agreed that freshly boiled 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 (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 container. Stimuli for fishy and oily flavor were not tasted by mouth; panelists drew their own conclusions concerning the concentrations of the slight and intense flavor from the respective concentrations of the stimuli for fishy and oily aroma. 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.

The QDA panel consisted of 6 trained members who received 2 one-half inch cubes from the center of the longissimus muscle. These panelists evaluated the intensity of milky-oily aroma, beef fat aroma, milky-oily flavor, beef fat flavor, liver flavor, sour flavor, and raw flavor of each sample.

E. STATISTICAL ANALYSIS

Each objective measurement determined on the longissimus muscle and the fatty acid composition of brisket and seam fat were statistically analyzed as a function of days steers were fed on a corn ration (DOF), frame size (F) and DOF x F interaction by the General Linear

Model (GLM) procedure in SAS (Barr et al., 1979). The sum of squares for each variable which was significantly affected by DOF were separated into linear, quadratic, cubic, quartic and pentic effects by orthogonal polynomials. Duncan's Multiple Range Test (Barr et al., 1979) was used to determine the significant differences among the frame sizes.

The effect of fat sampling site on the fatty acid composition of the fat was also statistically analyzed by the GLM procedure (Barr et al., 1979). This effect had a different error term in the statistical analyses from the DOF, F and DOF x F effects because each steer was split into three samples. Significant differences among fat sampling sites were determined by Duncan's Multiple Range Test (Barr et al., 1979).

The statistical analysis for the Quantitative Descriptive Analysis (QDA) data was also run by the GLM procedure. For each steer, the intensity of each flavor descriptor from QDA was averaged across panel members, and the effect of DOF, F and DOF x F on these means were determined (Barr et al., 1979). Significant DOF effects were separated into linear, quadratic, cubic, quartic, and pentic effects by orthogonal polynomials using the GLM procedure in SAS. In addition, simple correlation coefficients between each flavor descriptor and each objective measurement on the longissimus muscle were determined by the SAS program (Barr et al., 1979).

Data for each objective measurement are presented in tables of means. Significant effects of days on corn (DOF) for each variable are shown by an equation obtained from the GLM procedure after

determination of the significant polynomials for each variable. These equations are presented in separate tables.

CHAPTER IV

RESULTS AND DISCUSSION

A. LIPID CONTENT OF THE LONGISSIMUS

The analysis of variance table showing the effects of days steers were fed corn and frame score are shown in Appendix I. Total lipid content of the longissimus muscle increased linearly from 2.635% at 0 days steers were fed corn to 6.604% at 140 days (Table 3).

TABLE 3

AVERAGE TOTAL LIPID CONTENT OF LONGISSIMUS MUSCLE FROM STEERS FED CORN UP TO 140 DAYS AND EQUATION FOR SIGNIFICANT LINEAR EFFECT

	Days on Corn(T)[a]					
Item	0 (n=14)[b]	28 (n=10)	56 (n=14)	84 (n=13)	112 (n=13)	140 (n=13)
	%					
Lipid(Y)	2.635	3.816	5.314	5.024	6.121	6.604

[a]Effect of days fed corn(T) on lipid content(Y). $Y = 3.452 + 10^{-4}T$.

[b]Numbers of steers.

No significant difference in lipid content was found among the different frame sizes of the steers. Steers with frame size 1 had an average total lipid content of 5.011% in the longissimus muscle; frame size 2 steers had 4.630%; frame size 3 steers had 5.021%; and frame size 4 steers had 5.352%.

B. LONG CHAIN FATTY ACID COMPOSITION OF BEEF

Intramuscular Lipids

The analysis of variance for the fatty acid composition of longissimus muscle intramuscular lipids are shown in Appendix J. The average percentage of each fatty acid in the intramuscular lipids from steers fed corn from 0 to 140 days are shown in Table 4. Equations showing the significant effects of days steers were fed corn on the fatty acid composition of the intramuscular lipids are given in Table 5. There were significant differences ($P < 0.05$) due to days steers were fed corn in the relative percentages of isocaproic (iC6:0), heptanoic (C7:0), capric (C10:0), lauric (C12:0), tridecanoic (C13:0), myristic (C14:0), myristoleic (C14:1), 13-methyl tetradecanoic (αC15:0), pentadecanoic (C15:0), palmitic (C16:0), palmitoleic (C16:1), margaric (C17:0), margaroleic (C17:1), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), nonadecanoic (C19:0), arachidic (C20:0), gadoleic (C20:1), C_{20}trienoic (C20:3), arachidonic (20:4), docosapentaenoic (C22:5) and unknown 1, 2 and 4. The percentages of iC6:0 and C7:0 acids decreased linearly and the percentages of C10:0, C14:0, C14:1 and C18:1 acids increased linearly across days (0 to 140) steers were fed corn (Tables 4 and 5). As days steers were fed corn increased from 0 to 140, the percentage of C16:0 increased at a decreasing rate to a maximum at approximately 106 days and the percentage of C18:0, C18:3, C20:3, and C20:4 decreased at a decreasing rate to minima at approximately 120 days (Table 4). Percentages of C17:1 and C19:0 increased to maxima at the time steers were fed corn

TABLE 4

AVERAGE FATTY ACID COMPOSITION OF TOTAL INTRAMUSCULAR LIPIDS FROM THE LONGISSIMUS MUSCLE OF STEERS FED CORN UP TO 140 DAYS

Acid	Days on Corn					
	0 (n=15)[d]	28 (n=12)	56 (n=13)	84 (n=14)	112 (n=15)	140 (n=14)
	%					
iC 6:0[a,c]	0.045	0.021	0.029	0.018	0.028	0.017
C 7:0[a,c]	0.057	0.033	0.035	0.020	0.031	0.013
C 8:0[b,c]	0.012	0.010	0.015	0.011	0.007	0.007
C10:0[a]	0.082	0.078	0.091	0.107	0.105	0.100
C12:0[a]	0.082	0.064	0.076	0.095	0.107	0.105
C13:0[a]	0.003	0.017	0.014	0.017	0.017	0.013
C14:0[a]	1.943	2.100	2.570	2.839	3.029	3.151
C14:1[a]	0.304	0.342	0.448	0.493	0.581	0.596
αC15:0[a]	0.475	0.252	0.244	0.153	0.148	0.135
C15:0[a]	0.574	0.794	0.864	0.783	0.818	0.699
C16:0[a]	2.930	23.588	25.573	26.421	25.882	25.890
C16:1[b]	4.612	3.748	4.555	3.966	4.464	4.201
C17:0[a]	1.074	2.134	1.810	1.833	1.748	1.512
C17:1[a]	1.082	1.306	1.214	1.127	1.163	1.019
C18:0[a]	8.726	16.043	13.580	13.076	12.998	11.814
C18:1[a]	6.272	39.724	42.277	42.325	43.417	44.926
C18:2[a]	3.973	3.947	2.448	3.418	2.782	2.856
C18:3[a]	1.554	0.883	0.508	0.611	0.291	0.346
C19:0[a]	0.076	0.144	0.209	0.181	0.115	0.084
C19:1[b]	0.400	0.405	0.459	0.306	0.348	0.338
C20:0[a]	0.217	0.223	0.113	0.139	0.118	0.181
C20:1[a]	0.006	0.563	1.425	0.394	0.472	0.579
C20:3[a]	0.896	0.636	0.453	0.314	0.211	0.282
C20:4[a]	2.617	1.638	1.214	0.778	0.538	0.641
C22:5[a]	1.369	1.183	0.652	0.499	0.491	0.281
Unknown 1[a]	0.020	0.007	0.011	0.006	0.007	0.001
Unknown 2[a]	0.055	0.018	0.021	0.010	0.012	0.009
Unknown 3[b]	0.006	0.007	0.009	0.007	0.009	0.012
Unknown 4[a]	0.081	0.045	0.056	0.034	0.039	0.095

[a]A significant effect due to days steers were fed corn was found ($P < 0.05$).

[b]Not significantly affected by days steers were fed corn.

[c]Tentatively identified.

[d]Numbers of steers.

TABLE 5

EQUATIONS SHOWING SIGNIFICANT EFFECT OF DAYS STEERS WERE FED CORN(T) ON THE CONCENTRATIONS(Y) OF FATTY ACIDS IN THE LONGISSIMUS MUSCLE INTRAMUSCULAR LIPIDS

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
iC6 :0	$Y=0.0367-1.3926\times10^{-4}T$
C7 :0	$Y=0.0494-2.5238\times10^{-4}T$
C10:0	$Y=0.0808+1.8952\times10^{-4}T$
C12:0	$Y=0.0810-1.1355\times10^{-3}T+2.4339\times10^{-5}T^2-1.0896\times10^{-7}T^3$
C13:0	$Y=0.0048+3.0678\times10^{-4}T-1.7965\times10^{-8}T^2$
C14:0	$Y=1.9767+9.0320\times10^{-3}T$
C14:1	$Y=0.3051+2.2350\times10^{-3}T$
αC15:0	$Y=0.4523-5.5866\times10^{-3}T+2.4319\times10^{-5}T^2$
C15:0	$Y=0.5990+6.4678\times10^{-3}T-4.1465\times10^{-5}T^2$
C16:0	$Y=22.6920+6.4910\times10^{-2}T-3.0245\times10^{-4}T^2$
C17:0	$Y=1.0833+7.7200\times10^{-2}T-1.9606\times10^{-3}T^2+1.8415\times10^{-5}T^3-5.8550\times10^{-8}T^4$
C17:1	$Y=1.1253+3.4543\times10^{-3}T-3.0275\times10^{-5}T^2$
C18:0	$Y=18.5510-9.8840\times10^{-2}T+3.8398\times10^{-4}T^2$
C18:1	$Y=37.4970+5.6275\times10^{-1}T$
C18:2	$Y=3.9725+2.4690\times10^{-1}T-1.5800\times10^{-2}T^2+3.1260\times10^{-4}T^3-2.4970\times10^{-6}T^4+6.9760\times10^{-9}T^5$
C18:3	$Y=1.4883-2.0150\times10^{-2}T+8.7072\times10^{-5}T^2$
C19:0	$Y=0.8000+3.1385\times10^{-3}T-2.3006\times10^{-5}T^2$
C20:0	$Y=0.2336-2.4790\times10^{-3}T+1.4443\times10^{-5}T^2$
C20:1	$Y=0.4208+5.8400\times10^{-3}T-1.2561\times10^{-4}T^2+6.6274\times10^{-7}T^3$
C20:3	$Y=0.8964-1.0510\times10^{-1}T+4.3757\times10^{-5}T^2$
C20:4	$Y=2.5836-3.3620\times10^{-2}+1.1440\times10^{-4}T^2$
C22:5	$Y=1.4466-1.7820\times10^{-2}T+7.5160\times10^{-5}T^2$

TABLE 5 (continued)

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
Unknown 1 :	$Y=0.0193-5.0379\times10^{-4}T+6.8268\times10^{-6}T^2-2.9868\times10^{-8}T^3$
Unknown 2 :	$Y=0.0501-7.9808\times10^{-4}T+3.7666\times10^{-6}T^2$
Unknown 4 :	$Y=0.0823-1.3746\times10^{-3}T+1.0005\times10^{-5}T^2$

[a]For each equation, a significant effect due to days steers were fed corn was found.

60 to 70 days while the concentration of C20:0 and C22:6 decreased to a minima at the same time (Table 4). Days steers were fed corn significantly affected concentrations of C12:0, C20:1 and unknown 2 acids in a cubic manner (Table 5). However, as days steers were fed corn increased from 0 to 140, percentage of C12:0 generally increased and that of unknown 2 generally decreased. A significant quartic effect due to time steers were fed corn was found on the concentration of C17:0 and a pentic effect was found for C18:2 (Table 5). Steers which were fed corn 28 days or longer had higher levels of C17:0 in the intramuscular lipids than steers fed day on corn, and steers fed corn longer than 28 days had less C18:2 than steers fed 28 days or less (Table 4). In summary, as steers were fed corn 0 to 140 days, the sum of the percentages of αC15:0, C18:2, C18:3, C20:3, C20:4, and C22:5 decreased from 29.6 to 16.4 and the sum of percentages of C14:0, C14:1, C16:0, C17:0, C18:1, and C20:0 increased from 62.9 to 76.7%.

Percentages of fatty acids in intramuscular lipids significantly affected by frame size of steers are shown in Table 6. Steers with the largest frame size (4) had a higher percentage of C18:1 than steers of any other frame size and steers with the smallest frame size (1) had the highest C19:0 content. In general, larger frame steers (3 and 4) tended to have lower concentrations of iC6:0, unknown 1 and unknown 4 acids and higher concentrations of C22:6 than smaller frame steers (Table 6).

TABLE 6

PERCENTAGES OF FATTY ACIDS IN INTRAMUSCULAR LIPIDS SIGNIFICANTLY AFFECTED BY FRAME SIZE OF STEERS

Acid	Frame Size 1 (n=22)[c]	2 (n=27)	3 (n=23)	4 (n=11)
	%			
iC6 :0	0.027[a,b]	0.032[a]	0.024[a,b]	0.016[b]
C18:1	40.903[a]	41.393[a]	40.769[a]	44.363[b]
C19:0	0.205[a]	0.088[b]	0.117[a,b]	0.132[a,b]
C22:5	0.652[b]	0.648[b]	0.899[a]	0.796[a,b]
Unknown 1	0.008[a,b]	0.012[a]	0.007[a,b]	0.005[b]
Unknown 4	0.088[a]	0.064[a]	0.030[b]	0.046[a,b]

[a]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[b]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[c]Numbers of steers.

Seam Fat

The fatty acid composition of seam (intermuscular fat) from steers fed corn up to 140 days is shown in Table 7. The analysis of variance for the fatty acids in intermuscular fat is given in Appendix K. Equations showing significant effect of days steers were fed corn on fatty acids of intermuscular fat are given in Table 8. In general as days steers were fed corn increased, the percentages of C7:0, C14:0, C14:1, C16:1, C18:1 and unknown 1 increased linearly, and the percentages of C18:0, C18:3 and unknown 2 decreased linearly (Tables 7 and 8). All of the other fatty acids significantly affected by days steers were fed corn had complex cubic, quartic and pentic relationships with days on feed (Table 8). However, there was a general decrease in the

TABLE 7

AVERAGE FATTY ACID COMPOSITION OF SEAM FAT OF STEERS FED CORN UP TO 140 DAYS

Acid	Days on Corn 0 (n=14)[d]	28 (n=13)	56 (n=12)	84 (n=12)	112 (n=9)	140 (n=13)
	%					
iC6 :0[c]	0.000	0.000	0.000	0.003	0.000	0.004
C7 :0[a,c]	0.018	0.066	0.036	0.071	0.130	0.097
C8 :0[a,c]	0.030	0.031	0.040	0.021	0.018	0.017
C10:0[a]	0.066	0.095	0.069	0.111	0.126	0.096
C12:0[a]	0.109	0.010	0.053	0.108	0.116	0.100
C13:0[a]	0.000	0.018	0.007	0.017	0.021	0.011
C14:0[a]	2.784	2.732	2.759	2.979	3.297	3.138
C14:1[a]	0.203	0.268	0.320	0.454	0.492	0.618
αC15:0[a]	0.752	0.491	0.347	0.369	0.340	0.262
C15:0[b]	0.757	0.902	0.756	0.830	0.825	0.736
C16:0[b]	23.552	23.256	24.552	23.754	23.073	23.150
C16:1[a]	2.479	2.536	2.742	3.271	3.428	3.833
C17:0[a]	0.981	1.868	1.473	1.573	1.748	1.649
C17:1[a]	0.808	1.060	0.943	0.945	1.037	1.048
C18:0[a]	22.133	16.629	18.151	13.204	11.508	10.161
C18:1[a]	42.006	46.127	44.606	48.976	49.558	51.082
C18:2[a]	1.919	1.751	2.457	1.625	1.711	1.883
C18:3[a]	0.179	0.149	0.135	0.098	0.099	0.050
C19:0[a]	0.181	0.249	0.024	0.146	0.230	0.198
C19:1[a]	0.286	0.473	0.207	0.344	0.500	0.524
C20:0[b]	0.207	0.261	0.057	0.228	0.287	0.189
C20:1[a]	0.246	0.452	0.108	0.439	0.658	0.684
C20:3[a]	0.131	0.218	0.016	0.143	0.219	0.196
C20:4[b]	0.041	0.066	0.008	0.057	0.095	0.074
C22:5[a]	0.000	0.010	0.001	0.011	0.005	0.016
Unknown 1[a]	0.002	0.032	0.020	0.045	0.069	0.031
Unknown 2[b]	0.077	0.057	0.026	0.040	0.042	0.020
Unknown 3[b]	0.024	0.026	0.019	0.033	0.028	0.030
Unknown 4[b]	0.000	0.007	0.006	0.028	0.020	0.001

[a]A significant effect due to days steers were fed corn was found ($P < 0.05$).

[b]Not significantly affected by days steers were fed corn.

[c]Tentatively identified.

[d]Numbers of steers.

TABLE 8

EQUATIONS SHOWING SIGNIFICANT EFFECT OF DAYS STEERS WERE FED CORN(T) ON THE CONCENTRATIONS(Y) OF FATTY ACIDS IN SEAM FAT

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
C7: 0	$Y=0.0223+6.2941\times10^{-4}T$
C8: 0	$Y=0.0345-1.1821\times10^{-4}T$
C10:0	$Y=0.0671+2.7683\times10^{-3}T-1.0285\times10^{-4}T^2+1.3118\times10^{-6}T^2-5.0586\times10^{-9}T^4$
C12:0	$Y=0.1086+7.8674\times10^{-3}T-5.2592\times10^{-4}T^2+1.0460\times10^{-5}T^3-8.2034\times10^{-8}T^4+2.2329\times10^{-10}T^5$
C13:0	$Y=0.0030+1.5600\times10^{-3}T-5.0804\times10^{-5}T^2+5.7340\times10^{-7}T^3-2.0589\times10^{-9}T^4$
C14:0	$Y=2.6943+3.5179\times10^{-3}T$
C14:1	$Y=0.1872+2.9558\times10^{-3}T$
αC15:0	$Y=0.7552-1.4033\times10^{-2}T+1.6294\times10^{-4}T^2-6.2779\times10^{-7}T^3$
C16:1	$Y=2.3425+1.0160\times10^{-2}T$
C17:0	$Y=0.9880+7.4875\times10^{-2}T-2.1699\times10^{-3}T^2+2.2270\times10^{-5}T^3-7.3951\times10^{-8}T^4$
C17:1	$Y=0.8094+2.2605\times10^{-2}T-6.7220\times10^{-4}T^2+6.9056\times10^{-6}T^3-2.2650\times10^{-8}T^4$
C18:0	$Y=21.0387-8.1662\times10^{-2}T$
C18:1	$Y=42.7602+6.1437\times10^{-2}T$
C18:2	$Y=1.9096-0.1513+9.2537\times10^{-3}T^2-1.8182\times10^{-4}T^3+1.4339\times10^{-6}T^4-3.9449\times10^{-9}T^5$
C18:3	$Y=0.1779-8.6323\times10^{-4}T$
C19:0	$Y=0.1814+3.3730\times10^{-2}T-1.8907\times10^{-3}T^2+3.4015\times10^{-5}T^3-2.4842\times10^{-7}T^4+6.6046\times10^{-10}T^5$
C19:1	$Y=0.2904+2.2276\times10^{-2}T-8.6812\times10^{-4}T^2+1.0073\times10^{-5}T^3-3.5358\times10^{-8}T^4$
C20:1	$Y=0.2537+2.8725\times10^{-2}T-1.2040\times10^{-3}T^2+1.5144\times10^{-5}T^3-5.6110\times10^{-8}T^4$

TABLE 8 (continued)

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
C20:3	$Y=0.1312+3.3910\times10^{-2}T-1.8603\times10^{-3}T^2+3.3549\times10^{-5}T^3-2.4646\times10^{-7}T^4+6.3962\times10^{-10}T^5$
C22:5	$Y=1.0676+2.6956\times10^{-3}T-1.4763\times10^{-4}T^2+2.8773\times10^{-6}T^3-2.3198\times10^{-8}T^4+6.5986\times10^{-11}T^5$
Unknown 1	$Y=0.0129+2.6775\times10^{-4}T$
Unknown 2	$Y=0.0671-3.4180\times10^{-4}T$

[a]For each equation, a significant effect due to days steers were fed corn was found.

concentrationsof αC15:0 and C18:2 and increase in the concentrations of C10:0, C13:0, C17:0, C17:1, C19:1, C20:1 and C22:5 as days steers were fed corn increased. Overall, the sum of the percentages of C7:0, C10:0, C13:0, C14:0, C14:1, C16:1, C17:0, C17:1, C18:1, C19:1, C20:1, C22:5 and unknown 1 increased from 49.567 to 62.036 during 140 days steers were fed corn and the sum of the percentages of C8:0, αC15:0, C18:0, C18:2 and C18:3 decreased from 25.091 to 12.036. The largest changes that occurred to fatty acid concentrations during days steers were fed corn were in the concentrations of C18:0 and C18:1.

Frame size of steers also affected significantly some of the fatty acids in the seam fat as shown in Table 9. Steers with the largest frame size (4) generally had higher concentrations of iC6:0, C20:1, C20:3, C20:4 and C22:5 in the seam fat than steers with small frame size.

TABLE 9

PERCENTAGES OF FATTY ACIDS IN SEAM FAT SIGNIFICANTLY AFFECTED BY FRAME SIZE OF STEERS

	Frame Size			
Acid	1 (n=19)[c]	2 (n=24)	3 (n=22)	4 (n=8)
	%			
iC6 :0	0.002[a,b]	0.000[b]	0.000[b]	0.006[a]
C20:1	0.496[a,b]	0.379[b]	0.362[b]	0.641[a]
C20:3	0.163[a,b]	0.128[b]	0.130[b]	0.261[a]
C20:4	0.056[a,b]	0.041[b]	0.052[a,b]	0.104[a]
C22:5	0.005[b]	0.005[b]	0.008[a,b]	0.018[a]
Unknown 2	0.038[b]	0.036[b]	0.063[a]	0.031[b]

[a]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[b]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[c]Numbers of steers.

Brisket Fat

The sum of squares from analysis of variance for fatty acid composition of brisket fat from steers are shown in Appendix L. Average percentages of fatty acid composition of total brisket fat of steers fed corn up to 140 days are shown in Table 10. The equations showing the significant effects of days steers were fed corn on fatty acid concentrations are shown in Table 11. Percentage C7:0 increased linearly and percentage C18:3 decreased linearly as days steers were fed corn increased. The concentrations of acids, αC15:0 and C18:0 decreased from 0 to 140 days steers were fed corn (Tables 10 and 11), and concentration of C18:1 increased before decreasing again at days 112 and 140. Overall the relationships of most of the fatty acids in brisket fat with days steers were fed were very complex. As days on corn increased from 0 to 140, the sum of the percentages of C7:0, C10:0, C14:0, C14:1, C15:0, C16:0, C16:1, C17:0, C17:1, C18:1, C19:1, C20:1 and C20:3 increased from 65.579 to 80.029 and the sum of the percentages of αC15:0, C18:0, C18:3, C20:0, unknown 1 and unknown 2 decreased from 31.881 to 17.460.

Only one fatty acid in brisket fat was significantly different among different frame sizes (Table 12). Steers with frame size 4 had a higher concentration of C20:1 in the brisket fat than steers with frame sizes 2 and 3.

Comparison of Fatty Acid Composition of Different Fat Sites

Average concentrations of each fatty acid in the fat from three different fat sites (intramuscular, seam and brisket) in carcasses of steers fed corn up to 140 days are shown in Table 13. Fat from the

TABLE 10

AVERAGE FATTY ACID COMPOSITION OF TOTAL BRISKET FAT OF STEERS FED CORN UP TO 140 DAYS

Acid	Days on Corn 0 (n=14)[d]	28 (n=12)	56 (n=11)	84 (n=14)	112 (n=12)	140 (n=12)
	%					
iC6: 0[c]	0.006	0.000	0.012	0.018	0.006	0.000
C7: 0[a,c]	0.027	0.056	0.053	0.077	0.098	0.105
C8: 0[a,c]	0.025	0.044	0.044	0.026	0.028	0.017
C10:0[a]	0.054	0.148	0.065	0.090	0.136	0.094
C12:0[b]	0.097	0.075	0.075	0.097	0.106	0.110
C13:0[b]	0.003	0.008	0.000	0.007	0.008	0.007
C14:0[a]	2.270	2.403	2.363	2.546	3.374	3.156
C14:1[a]	0.502	0.466	0.409	0.606	0.924	1.005
αC15:0[a]	0.603	0.460	0.392	0.241	0.214	0.248
C15:0[a]	0.580	0.768	0.716	0.692	0.819	0.754
C16:0[a]	20.931	21.599	22.921	21.224	24.484	24.843
C16:1[a]	4.320	4.336	3.858	4.432	5.495	5.953
C17:0[a]	0.893	1.465	1.311	1.468	1.541	1.546
C17:1[a]	1.043	1.277	1.093	1.184	1.231	1.229
C18:0[a]	29.266	24.283	22.421	20.124	18.255	16.762
C18:1[a]	34.107	37.007	40.199	42.711	38.868	40.027
C18:2[b]	2.114	2.123	2.444	1.754	1.895	2.077
C18:3[a]	1.744	1.834	0.990	0.748	0.666	0.307
C19:0[b]	0.168	0.130	0.224	0.165	0.133	0.151
C19:1[a]	0.362	0.385	0.111	0.439	0.459	0.527
C20:0[a]	0.122	0.162	0.031	0.222	0.132	0.096
C20:1[a]	0.370	0.463	0.079	0.567	0.621	0.617
C20:3[a]	0.120	0.166	0.017	0.207	0.172	0.173
C20:4[b]	0.036	0.073	0.011	0.080	0.096	0.061
C22:5[b]	0.092	0.056	0.077	0.035	0.043	0.019
Unknown 1[a]	0.073	0.057	0.005	0.055	0.042	0.038
Unknown 2[a]	0.073	0.035	0.000	0.030	0.010	0.009
Unknown 3[a]	0.027	0.042	0.014	0.092	0.031	0.031
Unknown 4[a]	0.007	0.000	0.000	0.000	0.009	0.000

[a]A significant effect due to days steers were fed corn was found ($P < 0.05$).

[b]Not significantly affected by days steers were fed corn.

[c]Tentatively identified.

[d]Numbers of steers.

TABLE 11

EQUATIONS SHOWING SIGNIFICANT EFFECT OF DAYS STEERS WERE FED CORN(T) ON THE CONCENTRATIONS(Y) OF FATTY ACIDS IN BRISKET FAT

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
C7 :0	$Y=0.0307+5.5301\times10^{-4}T$
C8 :0	$Y=0.0294-3.3275\times10^{-4}T-3.1217\times10^{-6}T^2$
C10:0	$Y=0.0552+9.8578\times10^{-3}T-3.3792\times10^{-4}T^2+3.7723\times10^{-6}T^3-1.3200\times10^{-8}T^4$
C14:0	$Y=2.2629+3.3133\times10^{-2}T-1.4208\times10^{-3}T^2+1.8872\times10^{-5}T^3-7.2037\times10^{-8}T^4$
C14:1	$Y=0.4864-2.4570\times10^{-3}T+4.7760\times10^{-5}T^2$
αC15:0	$Y=0.6120-6.1469\times10^{-3}T-2.4551\times10^{-5}T^2$
C15:0	$Y=0.5790+1.8608\times10^{-2}T-5.7038\times10^{-4}T^2+6.1221\times10^{-6}T^3-2.0950\times10^{-8}T^4$
C16:0	$Y=20.9309-0.3320T+2.4183\times10^{-2}T^2-5.2585\times10^{-4}T^3+4.5169\times10^{-6}T^4-1.3310\times10^{-8}T^5$
C16:1	$Y=4.3556-1.4015\times10^{-2}T+1.8906\times10^{-4}T^2$
C17:0	$Y=0.8988+4.1500\times10^{-2}T-1.0827\times10^{-3}T^2+1.0943\times10^{-5}T^3-3.6605\times10^{-8}T^4$
C17:1	$Y=1.0475+2.0177\times10^{-2}T-6.3352\times10^{-4}T^2+6.7473\times10^{-6}T^3-2.2767\times10^{-8}T^4$
C18:0	$Y=28.8596-0.1411T+4.0172\times10^{-4}T^2$
C18:1	$Y=34.1820-8.2163\times10^{-2}T+8.9407\times10^{-3}T^2-1.1786\times10^{-4}T^3+4.3065\times10^{-7}T^4$
C18:3	$Y=1.8238-1.1128\times10^{-2}T$
C19:1	$Y=0.3616+5.4867\times10^{-2}T-3.4486\times10^{-3}T^2+6.8158\times10^{-5}T^3-5.3841\times10^{-7}T^4+1.4856\times10^{-9}T^5$
C20:0	$Y=0.1220+3.4643\times10^{-2}T-2.1439\times10^{-3}T^2+4.3227\times10^{-5}T^3-3.4990\times10^{-7}T^4+9.8446\times10^{-10}T^5$
C20:1	$Y=0.3698+8.2678\times10^{-2}T-5.0264\times10^{-3}T^2+9.8191\times10^{-5}T^3-7.6866\times10^{-7}T^4+2.1019\times10^{-9}T^5$

TABLE 11 (continued)

Acid	Percentage, Y, of Each Acid as a Function of Days Steers were Fed Corn(T)[a]
C20:3	$Y=0.1196+3.5024\times10^{-2}T-2.1286\times10^{-3}T^2+4.2102\times10^{-5}T^3 -3.3510\times10^{-7}T^4+2.1019\times10^{-9}T^5$
Unknown 1	$Y=0.0092+1.3516\times10^{-2}T-7.3032\times10^{-4}T^2+1.3787\times10^{-5}T^3 -1.0717\times10^{-7}T^4+2.9360\times10^{-10}T^5$
Unknown 2	$Y=0.0729+3.4876\times10^{-3}T-3.3202\times10^{-4}T^2+7.2524\times10^{-6}T^3 -6.0640\times10^{-8}T^4+1.7385\times10^{-10}T^5$
Unknown 3	$Y=0.0273+1.2536\times10^{-2}T-7.9659\times10^{-4}T^2+1.6738\times10^{-5}T^3 -1.4032\times10^{-7}T^4+4.0604\times10^{-10}T^5$

[a]For each equation, a significant effect due to days steers were fed corn was found.

TABLE 12

PERCENTAGES OF FATTY ACIDS IN BRISKET FAT SIGNIFICANTLY AFFECTED BY FRAME SIZE OF STEERS

	Frame Size			
Acid	1 (n=18)[c]	2 (n=27)	3 (n=21)	4 (n=9)
	%			
C20:1	0.480[a,b]	0.421[b]	0.409[b]	0.644[a]

[a]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[b]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[c]Numbers of steers.

TABLE 13

AVERAGE FATTY ACID COMPOSITION OF FAT AT DIFFERENT SITES IN STEERS FED CORN UP TO 140 DAYS

Acid	Fat Site		
	Brisket	Seam	Intramuscular
	%		
iC6 :0	0.007[b]	0.001[b]	0.027[a]
C7 :0	0.068[a]	0.064[a]	0.032[b]
C8 :0	0.030[a]	0.027[a]	0.010[b]
C10:0	0.097	0.094	0.092
C12:0	0.097	0.094	0.088
C13:0	0.005[a]	0.012[b]	0.013[b]
C14:0	2.675[b]	2.929[a]	2.617[b]
C14:1	0.650[a]	0.384[c]	0.463[b]
αC15:0	0.363[b]	0.038[a]	0.236[c]
C15:0	0.717[b]	0.799[a]	0.752[a,b]
C16:0	22.579[a]	23.564[b]	25.061[c]
C16:1	0.725[a]	3.021[c]	4.273[b]
C17:0	1.347[a]	1.531[b]	1.666[c]
C17:1	1.174[a]	0.968[b]	1.146[a]
C18:0	21.996[a]	15.389[b]	14.380[c]
C18:1	38,778[c]	46.860[a]	41.484[b]
C18:2	2.056[b]	1.895[b]	3.232[a]
C18:3	1.059[a]	0.120[c]	0.702[b]
C19:0	0.161	0.171	0.133
C19:1	0.385	0.385	0.374
C20:0	0.131[b]	0.202[a]	0.164[a,b]
C20:1	0.459	0.433	0.471
C20:3	0.145[b]	0.152[b]	0.474[a]
C20:4	0.160[b]	0.055[b]	1.237[a]
C22:5	0.054[b]	0.007[b]	0.738[a]
Unknown 1	0.034[a]	0.031[a]	0.009[b]
Unknown 2	0.028[b]	0.044[a]	0.021[b]
Unknown 3	0.041[b]	0.026[b]	0.008[a]
Unknown 4	0.003[b]	0.010[b]	0.059[a]

[a]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

[b]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

[c]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

brisket area had the highest concentrations of C14:1, C15:0, C18:0 and C18:3, and lowest concentrations of C13:0, C16:0, C16:1, C17:0 and C18:1 acids of the three fat sites. Seam fat had highest percentages of C14:1, C15:0, C18:1 and C20:0 acids and the lowest percentages of C14:1, αC15:0, C17:1, C18:3 and C20:4 of all three fat sites. In contrast, compared to the other fat sites, the intramuscular lipid had highest concentrations of C13:0, C16:0, C16:1, C17:0, C18:2, C20:3, C20:4, C22:5 and unknown 4 and lowest concentrations of C7:0, C8:0, C18:0, unknown 1 and unknown 3 acids. No significant differences were found among the different fat sites in the concentrations of C10:0, C12:0, C19:0, C19:1 and C20:1 (Table 13).

Table 14 shows the average percentages of three fatty acid types (saturated, monounsaturated and polyunsaturated) in fat from three different sites in steers fed corn 0, 28, 56, 84, 112 and 140 days. Saturated fatty acids in brisket fat decreased from 54.44% at 0 day to 47.55% at 140 days on corn. Percentages of saturated acids from seam fat also decreased as days on corn increased (Table 14). Saturated acid in intramuscular fat had irregular changes with days on grain and was approximately 45% from 0 day to 140 days. Generally the monounsaturated fatty acids in each fat site increased as days on corn increased, and the polyunsaturated fatty acids in the brisket fat and intramuscular lipid decreased. Although some of the polyunsaturated fatty acids in seam fat individually had significant changes in concentration with increasing days on corn (Table 8, p. 37), the sum of these concentrations did not apparently change much. In summary, brisket fat had higher concentrations of saturated fatty acids than seam fat or intramuscular lipid

TABLE 14

AVERAGE FATTY ACID COMPOSITION OF FAT FROM THREE DIFFERENT SITES IN STEERS FED CORN 0, 28, 56, 84, 112 AND 140 DAYS

Acid Type	Fat Sites	Days on Corn 0	28	56	84	112	140
		%					
Saturated	Brisket	54.44	51.15	50.22	46.74	49.11	47.55
	Seam	50.82	46.20	47.98	43.04	41.38	39.53
	Intramus.[a]	45.78	45.23	44.95	45.52	45.09	43.44
Monounsaturated	Brisket	40.70	43.93	45.75	49.93	47.60	49.36
	Seam	46.03	50.91	48.93	54.43	55.77	57.79
	Intramus.	43.08	46.08	49.38	48.61	50.46	51.65
Polyunsaturated	Brisket	1.99	2.13	1.09	1.07	0.98	0.56
	Seam	0.35	0.44	0.16	0.31	0.42	0.34
	Intramus.	6.44	4.34	2.83	2.20	1.38	1.77

[a]Intramuscular lipids.

(Table 15); seam fat had the highest concentration of monounsaturated fatty acids of the three fat sites; and intramuscular lipid had the greatest concentration of polyunsaturated fatty acids (Table 15).

TABLE 15

AVERAGE FATTY ACID COMPOSITION (BY TYPE) OF FAT FROM THREE DIFFERENT SITES IN STEERS FED CORN UP TO 140 DAYS

Acid Type	Fat Site		
	Brisket	Seam	Intramuscular
	%		
Saturated	49.90[a]	45.07[b]	45.01[b]
Monounsaturated	46.17[a]	52.05[b]	48.21[c]
Polyunsaturated	1.32[a]	0.33[b]	3.15[c]

[a]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

[b]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

[c]Means in a row bearing unlike superscripts are significantly different at the $P < 0.05$ level.

In general, the major changes in concentrations of fatty acids in each fat sampling site with increasing days steers were fed corn were similar. In each site as days corn was fed increased, αC15:0, C18:0 and C18:3 decreased, and C10:0, C14:0, C14:1 and C18:1 increased. These data are in complete agreement with results of Melton et al. (1982b), and in partial agreement with Westerling and Hedrick (1979), Brown et al. (1979) and Melton et al. (1982a). The differences in the concentrations of C18:0 and C18:1 between grass-fed and grain-fed steers are most likely due to differences in dietary energy level and not to dietary

source (Melton et al., 1982b; Oltjen and Dinius, 1975). The higher levels of C18:3 in grass-finished steers compared to grain-finished steers agree with other investigators such as Miller et al. (1981). Schroeder et al. (1980) did not find any significant difference in fatty acid composition of longissimus lipid between grass-finished steers and grain-finished steers. However, they did find higher levels of C18:1 and lower levels of C18:0 in a composite tissue sample from grass-finished steers compared to that from grain-finished steers, and they did not analyze for C18:3. In fact, most investigators who have studied effect of diet on fatty acid composition of beef have not reported concentrations for several of the fatty acids given in this thesis. The long chain polyunsaturated fatty acids (C18:3, C20:4 and C22:5) which are in greater concentration in the polar lipids than the neutral lipids (Brown et al., 1979; Melton et al., 1982a) and the fatty acids with an odd number of carbons (13, 15, 17 and 19) and branched chains or medium chain length (C6 to C12) are not found in many of the studies in which the effect of diet has been investigated on fatty acids in ruminants (Cross and Dinius, 1978; Clemens et al., 1973; Dryden and Marchello, 1973; Hecker et al., 1975; Rumsey et al., 1972; Sumida et al., 1972; Schroeder et al., 1980).

The higher level of C18:3 in lipids of grass-finished steers versus grain-finished steers is the result of high C18:3 content in the grass compared to a grain diet (Ray et al., 1975; Melton et al., 1982). The fatty acid composition of a pasture similar to the one grazed by steers in the present study was determined by Melton et al. (1982b) and had an average of 41.8% C18:3 in 2.12% total lipid. Although the

ruminant has the capability of hydrogenating the ingested polyunsaturated fatty acids (Oltjen and Dinius, 1975), steers on a grass diet without any other feed source will deposit a small amount of C18:3 in their lipids. When changed to a grain diet with low C18:3 content, this fatty acid will be slowly diluted and/or removed as the steer deposits greater quantities of fat (Melton et al., 1982b).

The higher levels of the long chain polyunsaturated fatty acids which were found in the intramuscular lipid (Table 4, p. 31) from grass-finished steers are located mainly in the phospholipids of the cell wall. As the steers were fed corn, the total lipid content of the longissimus increased (Table 3, p. 29) due to deposition of triglycerides or neutral lipids as intramuscular fat or marbling. This increasing level of neutral lipids with increasing days steers were fed corn acted as a dilution factor to reduce the relative concentration of C18:3, C20:3, C20:4 and C22:5. However, even when the fatty acids are expressed as mg fatty acid per 100 g wet muscle tissue, there was still a significant linear decrease in the content of C18:3 from 41.9 to 22.0 mg per 100 g tissue as days steers were fed corn increased from 0 to 140 days. The actual equation which shows the effect of days steers were fed corn on the C18:3 concentration expressed in this way is $Y = 38.80 - 0.1463\ T$ where Y = mg C18:3/100 g tissue and T = days steers were fed corn. In addition, as steers were fed corn from 0 to 140 days, C20:3 decreased from 23.6 to 17.1 mg/100 g tissue ($Y = 24.26 - 0.1592\ T + 7.4853 \times 10^{-4}\ T^2$), and C20:4 decreased from 69.7 to 37.3 mg/100 g tissue ($Y = 71.17 - 0.0729\ T + 3.367 \times 10^{-3}\ T^2$). It is apparent that another factor besides dilution affects the concentration of these fatty acids.

Obviously, C18:3, C20:3 and C20:4 must be exchanged for other fatty acids from the grain diet. Kimoto et al. (1974) reported results that suggested a more rapid incorporation of ingested fatty acids into the phospholipids than the triglycerides of growing and mature steers, and that the polyunsaturated fatty acids cannot be synthesized by mammals (Ray et al., 1975). It is difficult to compare differences in fatty acid composition found among the three fat sampling sites in this study with results in the literature, because no reports of studies were found in which the fatty acid composition of these three sampling sites from steers fed similar diets had been determined. In one study the fatty acid composition of subcutaneous fat at sites other than the brisket area and the lipid in longissimus muscle from grass and grain-finished steers was determined (Westerling and Hedrick, 1979). However, Dryden and Marchello (1973) reported that the brisket fat as compared to other carcass depot fats has different fatty acid composition which responds differently than other depot fats to different diets. The results found in the present study that brisket fat of steers throughout the feeding period had the most saturated fatty acid compared to the seam fat and the intramuscular lipid up through the 56 days feeding period had the least saturated fatty acid are in disagreement with Oltjen and Dinius (1975). They reported that the concentration of saturated fatty acids increased from external to internal fat sampling sites in cattle.

C. VOLATILE FATTY ACIDS

The analysis of variance for the volatile fatty acid (VFA) composition of the longissimus muscle from steers fed corn up to 140 days is shown in Appendix M. The concentrations of each VFA at 0, 28, 56, 84, 112 and 140 days steers were fed corn are shown in Table 16 and equations showing the significant effect of days steers were fed corn(T) on the concentration of each VFA is shown in Table 17. All VFA except heptanoic were affected significantly by days steers were fed corn. Acetic acid increased from 2.403 mg/100 g muscle tissue at 0 day steers were fed corn to an estimated maximum of 2.990 at 84 days steers were fed corn prior to decreasing as steers were fed corn up to 140 days (Table 16). Butyric acid increased linearly from 0.082 to an estimated 0.132 mg/100 g tissue as days steers were fed corn increased from 0 to 112 (Tables 16 and 17). The effect days steers were fed corn had on the other VFA were very complicated as can be seen by the equations in Table 17. In general, however, steers which were fed corn 28 days or longer had higher levels of isobutyric and caproic acids (except for 84 and 112 days on corn) and lower levels of valeric and isocaproic acids (except for 112 days on corn) (Table 16). The most abundant VFA in muscle was acetic acid and the next most abundant VFA was caproic. The VFA present in the smallest amount was isobutyric acid.

Four of the VFA were significantly affected by frame size of steers (Table 18). Steers with the largest frame size (4) had greater concentrations of acetic and propionic acids and lower amounts of isocaproic acid than the steers with smaller frame sizes. Steers with the

TABLE 16

VOLATILE FATTY ACID COMPOSITION OF STEAKS FROM THE LONGISSIMUS MUSCLE OF STEERS FED CORN UP TO 140 DAYS

VFA	Days on Corn					
	0 (n=14)[c]	28 (n=14)	56 (n=14)	84 (n=15)	112 (n=14)	140 (n=13)
	mg/100 g Meat, Wet Basis					
Acetic[a]	2.403	2.573	2.714	2.990	2.826	2.898
Propionic[a]	0.107	0.155	0.085	0.103	0.153	0.101
Isobutyric[a]	0.016	0.031	0.023	0.034	0.044	0.025
Butyric[a]	0.082	0.125	0.135	0.132	0.203	0.132
Isovaleric[a]	0.101	0.080	0.103	0.104	0.111	0.081
Valeric[a]	0.080	0.063	0.073	0.056	0.106	0.067
Isocaproic[a]	0.130	0.097	0.117	0.074	0.151	0.108
Caproic[a]	0.389	0.481	0.281	0.314	0.807	9.576
Heptanoic[b]	0.219	0.134	0.148	0.087	0.210	0.163

[a]A significant effect due to days steers were fed corn was found.

[b]Not significantly affected by days steers were fed corn.

[c]Numbers of steers.

TABLE 17

EQUATIONS SHOWING SIGNIFICANT EFFECT OF DAYS STEERS WERE FED CORN(T) ON THE CONCENTRATIONS(Y) OF VOLATILE FATTY ACIDS IN THE LONGISSIMUS MUSCLE

	mg/100 g Meat, Y, of Each Acid as Function of Days Steers were Fed Corn(T)[a]
Acetic :	$Y=2.3802+9.1586\times10^{-3}T-3.8735\times10^{-5}T^2$
Propionic :	$Y=0.1068+9.9206\times10^{-3}T-4.5518\times10^{-4}T^2-6.9273\times10^{-6}T^3 -4.2124\times10^{-8}T^4$
Isobutyric:	$Y=0.0161+1.5168\times10^{-3}T-5.2057\times10^{-5}T^2+6.3322\times10^{-7}T^3 -2.3975\times10^{-9}T^4$
Butyric :	$Y=0.0999+5.0677\times10^{-4}T$
Isovaleric:	$Y=0.0991-1.0882\times10^{-3}T+2.5655\times10^{-5}T^2-1.3450\times10^{-7}T^3$
Valeric :	$Y=0.0797-5.6684\times10^{-3}T+3.3686\times10^{-4}T^2-7.1306\times10^{-6}T^3 +6.1942\times10^{-8}T^4-1.8686\times10^{-10}T^5$
Isocaproic:	$Y=0.1298-1.1368\times10^{-2}T+6.6797\times10^{-4}T^2-1.3900\times10^{-5}T^3 +1.1824\times10^{-7}T^4-3.4960\times10^{-10}T^5$
Caproic :	$Y=0.3847+2.7997\times10^{-2}T-1.2406\times10^{-3}T^2+1.5627\times10^{-5}T^3 -5.8022\times10^{-8}T^4$

[a]For each equation, a significant effect due to days steers were fed corn was found.

TABLE 18

VOLATILE FATTY ACID COMPOSITION OF STEERS FROM THE LONGISSIMUS MUSCLE SIGNIFICANTLY AFFECTED BY FRAME SIZE

VFA	Frame Size for VFA			
	1 (n=22)[c]	2 (n=29)	3 (n=30)	4 (n=13)
	mg/100 g Meat, Wet Basis			
Acetic	2.603[a]	2.819[a]	2.613[b]	2.958[a]
Propionic	0.111[b]	0.112[b]	0.118[b]	0.138[a]
Isobutyric	0.038[a]	0.029[a,b]	0.019[b]	0.030[a,b]
Butyric	0.157	0.115	0.131	0.148
Isovaleric	0.103	0.103	0.089	0.086
Valeric	0.076	0.082	0.067	0.063
Isocaproic	0.121[a,b]	0.126[a]	0.105[a,b]	0.077[b]
Caproic	0.476	0.478	0.424	0.523
Heptanoic	0.155	0.185	0.142	0.135

[a]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[b]Percentages in a row which have unlike superscript letters are significantly different at the $P < 0.05$ level.

[c]Numbers of steers.

smallest frame had the largest amount of isobutyric acid which was significantly greater than steers with frame size 3 (Table 18).

The increasing levels of acetic acid in muscle tissue with increasing days steers were fed corn agrees with results of Melton et al. (1982). When cattle are changed from grass concentrate diets the rumen microflora changes and increased amounts of volatile fatty acids are produced. The acetic:propionic: butyric acid ratio also changes from 70:30:10 to 50:50:10 (Cook and Miller, 1965). The acetic acid is transported through the liver to the tissues without much change in concentration (Cook and Miller, 1965) where it is incorporated into subcutaneous fat (Pothoven et al., 1975). Propionate is removed from the blood stream by the liver and used primarily for gluconeogenesis (Cook and Miller, 1965). These same investigators also reported that butyric was utilized by ruminant tissues under normal conditions. The biochemistry of the other VFA in ruminants remains to be elucidated,

D. QUANTITATIVE DESCRIPTIVE ANALYSIS OF FLAVOR

The analysis of variance for flavor descriptors of the Quantitative Descriptive Analysis (QDA) is shown in Appendix N. The means and standard deviations of each flavor descriptor at 0. 28, 56, 84, 112 and 140 days steers were fed corn are shown in Table 19, and the equations showing the significant effect of days steers were fed corn are shown in Table 20. In general as days steers were fed corn increased from 0 to 140, the undesirable milky-oily aroma and flavor decreased linearly in intensity and the desirable beef fat aroma and flavor increased linearly in intensity (Tables 19 and 20). The intensity of

TABLE 19

QUANTITATIVE DESCRIPTIVE ANALYSIS MEANS[a] AND STANDARD DEVIATIONS OF LOIN STEAKS FROM STEERS VARYING IN TIME ON FEED

Quantitative Descriptor	Days on Feed						Overall		
	0 (n=15)[e]	28 (n=15)	56 (n=15)	84 (n=16)	112 (n=15)	140 (n=14)	Mean	S.D.[c]	C.V.[d]
Milky-Oily Aroma[b]	68.1	66.8	61.2	58.5	55.7	50.8	60.1	20.6	34.]
S.D.	±21.4	±20.3	±19.3	±20.5	±18.2	±18.8			
Beef Fat Aroma[b]	55.9	53.4	61.1	66.0	67.7	71.9	63.0	27.0	42.0
S.D.	±18.2	±19.3	±18.3	±17.4	±18.3	±20.5			
Milky-Oily Flavor[b]	80.6	81.2	63.9	56.5	54.2	51.4	64.7	19.7	31.3
S.D.	±27.1	±29.6	±25.4	±21.5	±20.4	±21.0			
Beef Fat Flavor[b]	56.8	59.5	69.9	83.1	86.1	87.8	74.1	26.0	35.0
S.D.	±23.5	±28.7	±21.9	±20.8	±20.6	±20.8			
Liver Flavor	26.6	26.2	28.8	27.8	30.5	28.6	13.9	48.5	
S.D.	±15.0	±13.3	±12.6	±13.4	±14.7	±13.7			
Sour Flavor[b]	33.8	40.2	39.8	40.7	41.6	39.0	39.2	14.1	36.0
S.D.	±14.6	±15.9	±14.7	±13.6	±13.6	±11.0			
Raw Flavor[b]	27.3	29.9	27.1	31.3	32.8	32.6	30.2	16.9	55.9
S.D.	±16.3	±18.8	±16.1	±15.6	±17.9	±16.1			

[a]Measured on a 1-150 mm scale, 1 = slightly intense; 150 = extremely intense.

[b]Significantly affected by days steers were fed corn ($P < 0.05$).

[c]Standard deviation. [d]Coefficient of variation. [e]Numbers of steers.

TABLE 20

EQUATIONS SHOWING SIGNIFICANT EFFECT OF DAYS STEERS WERE FED CORN(T) ON THE INTENSITIES OF QDA DESCRIPTORS FROM STEAKS

QDA Descriptor	QDA Intensity, Y, of Each Descriptor as Function of Days Steers were Fed Corn(T)[a]
Milky-oily aroma :	$Y=69.24-0.12T$
Beef fat aroma :	$Y=54.18+0.13T$
Milky-oily flavor :	$Y=81.62+0.24T$
Beef fat flavor :	$Y=55.46+0.27T$
Sour flavor :	$Y=34.56+0.13T-7.33\times10^{-4}T^2$
Raw flavor :	$Y=27.13+0.04T$

[a]For each equation, a significant effect due to days steers were fed corn was found.

sour flavor increased slightly from 0 to a maximum at 112 days, and the raw flavor intensity increased linearly with increasing days steers were fed corn, but the overall change was small (Tables 17 and 18, pp. 54 and 55). The liver flavor was not affected by days steers were fed corn. These results are in agreement with Melton et al. (1982b) who found that the milky-oily aroma and flavor decreased in intensity and the desirable beef fat aroma and flavor increased in intensity as steers were fed corn for an increasing time. These same investigators found, however, that the sour flavor decreased with increasing time steers were fed corn which was not found in the present study. They analyzed ground beef, however, instead of steak and this may explain the disparity in the two investigations. Schroeder et al. (1980) also reported that beef produced by grain compared with that produced by grass had a fatty flavor and the lack of a grassy flavor.

E. CORRELATION OF SUBJECTIVE AND OBJECTIVE MEASUREMENTS

Simple correlation coefficients of the flavor descriptors with the fatty acid concentrations in the longissimus muscle of steers fed corn up to 140 days are shown in Table 21. Significant positive correlation coefficients were found between C10:0, C12:0, C14:0, C14:1, C18:1 and unknown 3 and the desirable beef fat aroma and flavor, and significant negative correlations between αC15:0, C18:0, C18:3, C19:1, C20:3, C20:4, C22:5 and unknown 2 and the same descriptors. In general, all of these fatty acids had higher correlation coefficients with beef fat flavor than aroma. Also, C16:0, C18:2 and C20:3 were negatively correlated with beef fat flavor ($P < 0.05$) but not aroma. The acids

TABLE 21

CORRELATION COEFFICIENTS BETWEEN FATTY ACIDS OF INTRAMUSCULAR LIPIDS AND QUANTITATIVE DESCRIPTIVE ANALYSIS FLAVOR DESCRIPTORS OF LONGISSIMUS MUSCLE

Acid	Descriptors					
	Beef Fat Aroma	Milky-Oily Aroma	Beef Fat Flavor	Milky-Oily Flavor	Liver Flavor	Sour Flavor
	r					
C8 :0	-0.27[a]	0.14	-0.19	0.15	-0.15	-0.02
C10:0	0.28[a]	-0.24[a]	0.30[b]	-0.32[b]	-0.09	-0.07
C12:0	0.34[b]	-0.22[a]	0.31[b]	-0.34[b]	0.00	-0.06
C13:0	0.13	-0.03	0.11	-0.09	-0.13	0.12
C14:0	0.35[c]	-0.36[c]	0.46[d]	-0.49[d]	-0.06	0.17
C14:1	0.37[c]	-0.38[c]	0.42[d]	-0.43[d]	0.05	0.11
αC15:0	-0.32[b]	0.31[b]	-0.51[d]	0.48[d]	-0.13	-0.32[b]
C15:0	0.04	-0.45	0.04	-0.08	-0.11	0.08
C16:0	0.14	-0.22[a]	-0.28[a]	-0.34[b]	-0.11	0.14
C16:1	0.19	-0.02	0.02	-0.06	0.03	0.15
C17:0	0.06	-0.06	0.11	-0.10	0.04	0.21
C17:1	0.03	-0.11	-0.11	0.09	-0.01	0.02
C18:0	-0.45[d]	0.34[b]	-0.53[d]	0.50[d]	-0.09	-0.26[a]
C18:1	0.33[b]	-0.27[a]	0.47[d]	-0.38[c]	0.28[b]	0.24[a]
C18:2	-0.16	0.12	-0.25[a]	0.20	-0.26[a]	-0.16
C18:3	-0.35[c]	0.30[b]	-0.48[d]	0.45[d]	-0.23[a]	-0.34[b]
C19:0	-0.15	-0.11	-0.05	-0.06	-0.08	0.15
C19:1	-0.23[a]	0.03	-0.27[a]	0.15	-0.07	-0.24[a]
C20:0	-0.18	0.16	-0.25[a]	0.31[b]	0.02	-0.34[b]
C20:1	0.26[b]	0.03	0.17	-0.03	-0.04	-0.07
C20:3	-0.18	0.16	-0.25[a]	0.31[b]	0.03	-0.34[b]
C20:4	-0.25[a]	0.36[c]	-0.47[d]	0.46[d]	-0.14	-0.28[a]
C22:5	-0.36[c]	0.37[c]	-0.53[d]	0.55[d]	-0.09	-0.27[a]
Unknown 2	-0.22[a]	0.23[a]	-0.42[c]	0.38[c]	-0.10	-0.34[b]
Unknown 3	0.23[a]	-0.15	0.22[a]	-0.24[a]	-0.06	-0.02
Unknown 4	0.24[a]	0.01	0.11	-0.05	0.09	0.01

[a]Significant at the $P < 0.05$ level.

[b]Significant at the $P < 0.01$ level.

[c]Significant at the $P < 0.001$ level.

[d]Significant at the $P < 0.0001$ level.

C8:0 was negatively correlated with beef fat aroma ($P < 0.05$) but not flavor, and C20:1 and unknown 4 were correlated positively with beef fat aroma ($P < 0.05$) and not flavor (Table 21). Generally the fatty acids which were positively or negatively correlated with beef fat aroma and flavor had the opposite significant correlation with the undesirable milky-oily flavor. Sour flavor had significant negative correlation coefficients with αC15:0, C18:0, C18:3, C19:1, C20:0, C20:3, C20:4, C22:5 and unknown 2 and a significant positive correlation coefficient with C18:1 (Table 21). Liver flavor was correlated positively with C18:1 (0.28, $P < 0.05$) and negatively with C18:2 (-0.26, $P < 0.05$) and C18:3 (-0.23, $P < 0.05$). These results indicate that increased concentrations of C10:0, C12:0, C14:0, C14:1, C18:1 and unknown 3 are related to greater intensities of a desirable beef fat flavor and lower intensities of milky-oily flavor. Increased concentrations of αC15:0, C18:0, C18:3, C20:3, C20:4, C22:5 and unknown 2 contribute to greater intensities of an undesirable milky-oily flavor and lower intensities of the beef fat flavor. Although correlation coefficients do not indicate cause and effect, they can be used as indicators to underlying relationships. Fatty acids, particularly unsaturated fatty acids, are precursors of flavor volatiles and the overall pattern of such volatiles are important in illiciting a certain response for a given aroma and flavor (Dwivedi, 1975). In cooking the unsaturated fatty acids are degraded to unsaturated aldehydes and other types of compounds such as acids, ketones, alcohols and alkanes, etc. According to Dwivedi (1975) this pattern of volatiles or flavor profile is responsible for the characteristic beef fat, pork fat and lamb fat flavor (characteristic species

flavor in meat). An alteration in the concentration of these volatiles of the absence or presence of some compounds may profoundly affect beef flavor. The change in fatty acid concentrations between beef produced by grass and grain could alter the pattern of beef flavor volatiles and increase or decrease the intensity of the beef fat flavor.

In addition, Igene et al. (1979) showed that the concentration of long chain polyunsaturated fatty acids (C18:3, C20:2, C20:3 and C20:5) of beef phospholipids decreased during cooking of meat model systems and showed that these fatty acids in the phospholipids were major contributors to undesirable off-flavors. Keller and Kinsella (1973) also showed that C20:4 in the phospholipids was decreased by 25% during cooking of ground beef and this was paralleled by an increase in the thiobarbituric acid number as a measurement of lipid oxidation during cooking. The higher levels of these polyunsaturated fatty acids found in beef produced by grass in this study make it more subject to oxidation and development of off-flavor during cooking and storage. Reagan et al. (1981) has reported that after 150 days frozen storage beef produced on grass had a significantly greater TBA value than beef produced on grain. Moore and Harbord (1974) reported that beef produced on grass had a less desirable flavor than beef produced on grain after 40 weeks of frozen storage because of the development of fish-like rancidity. These observations should leave no doubt concerning the role of the polyunsaturated fatty acids contribution to the milky-oily flavor. In addition, Melton et al. (1982b) reported that the trained panel for Quantitative Descriptive Analysis of flavor of ground beef from grass-finished and grain-finished steers selected a solution of

trans 2-4 decadienal in methanol (1 μg in 1 ml) as the standard for the oily part of the milky-oily flavor. Hedrick et al. (1980) reported greater concentrations of the aldehyde isolated after cooking from beef produced by grass than beef produced by grain. This aldehyde and similar diunsaturated aldehydes containing different number of carbons are oxidation products of polyunsaturated fatty acids (Frankel et al., 1981).

The part that C18:0 plays in relation to flavor is hard to explain; however, Selke et al. (1975) has shown that heating tristearin for 10 mins. at 192°C produced larger amounts of medium chain length acids (C4-C10) than heating triolein. Medium chain fatty acids (C4-C10) have been implicated in causing undesirable flavors in cooked mutton (Wong et al., 1975) and this might explain the positive relationship of C18:0 to the undesirable milky-oily flavor.

The significant correlation coefficients found between the flavor descriptors and fatty acids in the total lipid were found by Melton et al. (1982b) except for those reported between the beef fat flavor and C10:0, C12:0, C15:0, C16:0, C20:3 and C22:5, and these acids and milky-oily flavor. These investigators, however, evaluated ground beef containing approximately 20% fat, and their results might not apply completely to the relationships found in the present study.

CHAPTER V

SUMMARY

A total of 185 Angus steers were wintered on a fescue pasture from November, 1979, through April, 1980. The steers were allowed unlimited grazing on a pasture of orchard grass, clover and fescue from April 14, 1980, to a date in July, 1980. At that time 91 steers were selected from the group and assigned to 5 groups of 15 steers and one group of 16 steers on the basis of frame size which was indicated by number 1 (small frame size), 2, 3 and 4 (large size). On August 5, 1980, one group of 15 steers was slaughtered off pasture (0-day on corn), and the other 5 groups of steers were adjusted to a whole shelled corn diet for 2 weeks. At the end of this period, one group of corn-fed steers was slaughtered every 28 days up to 140 days.

Carcasses of each steer were aged 48 hr at 1.6°C, and at the time of fabrication, fat samples were obtained from the brisket area and seam (intermuscular) fat medial to the deep pectoral muscle, and samples of the longissimus were obtained for chemical and flavor analyses. For each steers, total lipids of the longissimus (intramuscular lipids) were extracted, the volatile fatty acid (VFA) content of that muscle was determined, and the flavor of the cooked longissimus was evaluated by Quantitative Descriptive Analysis (QDA). In addition, the fatty acid composition of the intramuscular lipid, brisket fat and intermuscular fat was analyzed. Each dependent variable was analyzed statistically as a function of days steers were fed corn (time), frame size and time x frame size interaction, and the fatty acid composition

was analyzed statistically as a function of the 3 fat sampling sites. Significant time effects were separated by orthogonal polynomials, and equations for dependent variables as a function of time were obtained. Significantly different means among frame sizes and fat sampling sites were separated by a multiple range test.

Days steers were fed corn significantly affected most of the fatty acid concentrations in each of the 3 fat sampling sites. Some of the fatty acids had very complex relationships with days steers were fed corn. The following general changes in fatty acid composition of each fat site were found as days steers were fed corn increased. In the intramuscular lipid, the sum of the percentages αC15:0, C18:0, C18:2, C18:3, C20:3, C20:4 and C22:5 decreased from 29.7 to 16.1, and the sum of the percentages of C14:0, C14:1, C16:0, C17:0, C18:1 and C20:0 increased from 62.9 to 72.7. In the intramuscular fat, the sum of the percentages of C8:0, αC15:0, C18:0, C18:2 and C18:3 decreased from 25.1 to 12.4 and the sum of the percentages of C7:0, C10:0, C13:0, C14:0, C14:1, C16:1, C17:0, C17:1, C18:1, C19:1, C20:1, C22:5 and an unknown fatty acid increased from 49.6 to 62.0. In the brisket fat, the sum of the percentages of αC15:0, C18:0, C18:3, C20:0 and two unknown fatty acids decreased from 31.9 to 17.2 and the sum of the percentages of C7:0, C10:0, C14:0, C14:1, C15:0, C16:0, C16:1, C17:0, C17:1, C18:1, C19:1, C20:1 and C20:3 increased from 65.2 to 79.4. As days steers were fed corn increased, the percentages of saturated fatty acids in the brisket and intermuscular fat decreased, the percentages of mono-unsaturated fatty acids of all 3 fat sites increased, and the percentages of the polyunsaturated fatty acids of the brisket fat and intramuscular lipid decreased. Frame size of steers did not affect the fatty acid

composition of any fat site very much. Of the 3 fat sites, the intramuscular lipd, had the greatest concentration of the polyunsaturated fatty acids, the seam fat had the most monounsaturated fatty acids and the brisket fat had the highest amount of saturated fatty acids.

The changes in the fatty acids with increasing days steers were fed corn, particularly the increase in C18:1 content and the decrease in the C18:0 content, were caused by the difference in the energy level between the grass pasture and the corn diet. High energy diet such as corn in ruminants results in increased levels of monounsaturated fatty acids and lower levels of saturated fatty acids in the lipids when compared with a lower energy diet such as grass or other forages. Decreases in the polyunsaturated fatty acids, particularly C18:3, with increasing days steers were fed corn are due to the differences in the fatty acid composition between the grass and corn diets and to the change in rumen microflora with change in diet. Grass has approximately 50% C18:3 in its lipids and part of this ingested C18:3 in steers on grass escaped hydrogenation by the rumen microflora and was deposited in lipids, particularly the phospholipids of steers on a grass diet. As steers were fed corn, high levels of C18:2 but low levels of C18:3 were ingested, and the microflora of the rumen changed from the species that can break down cellulose to the species more adapted to utilization of starch. The microflora of the rumen in steers fed corn are very efficient at hydrogenating C18:2 to C18:1; therefore, more monosaturated fatty acids were produced and deposited in the lipids of steers as time on corn increased. This resulted in dilution and removal of the polyunsaturated fatty acids from the lipids as days steers were fed corn increased and the steers increased in fatness.

The VFA content of the longissimus muscle also was affected by days steers were fed corn, except for heptanoic acid. In general, the amounts of acetic and butyric acids increased linearly with increasing days steers were fed corn, and steers fed corn for any period had greater concentrations of isobutyric and caproic acids and lower amounts of valeric acid in the longissimus than steers off pasture. The most abundant VFA was acetic acid and the least abundant was isobutyric. Steers with the largest frame size had the highest levels of acetic acid and lowest levels of isocaproic acid of all frame sizes.

The increased levels of acetic, propionic and butyric acids in the longissimus muscle of steers fed corn compared to steers fed grass is a result of the increased VFA production by the rumen microflora from corn starch compared to the VFA production from cellulose in the grass diet. The effect of diet on the other VFA found in the present study has not been elucidated.

The descriptive terms chosen by the QDA sensory panel for the flavor of the longissimus muscle or steaks were beef fat aroma and flavor, milky-oily aroma and flavor, liver flavor, sour flavor and raw flavor. The intensities of all these flavor descriptors except for the liver flavor was significantly affected by days steers were fed corn. The intensity of the milky-oily aroma and flavor decreased and the intensity of the beef fat aroma and flavor increased as days steers also increased curvilinearly as days steers were fed corn increased, but the increase in the intensity of these flavors was small compared to the change in the intensities of the other aromas and flavors. The QDA panel classified the milky-oily aroma and flavor as undesirable,

particularly at the intensity present in beef produced by grass, and the beef fat aroma and flavor as desirable at any intensity.

The long-chain polyunsaturated fatty acids (C18:3, C20:3, C20:4 and C22:5), and αC15:0 and C18:0 were positively correlated with the milky-oily aroma and flavor, and negatively correlated with the beef fat aroma and flavor. The fatty acids C10:0, C12:0, C14:0, C14:1 and C18:1 had significant positive relationships with beef fat aroma and flavor and negative relationships with milky-oily aroma and flavor. These relationships indicate that higher concentrations of the polyunsaturated fatty acids, and αC15:0 and C18:0 in beef from steers fed grass contributed to the increased intensity of its undesirable flavor, and that the higher concentrations of C10:0, C12:0, C14:0, C14:1 and C18:1 in beef from steers fed corn contributed to increased intensity of its desirable flavor.

The most significant finding of this study is the new information concerning the greater concentrations of the polyunsaturated fatty acids C20:3, C20:4 and C22:5 in lipids of beef produced by grass as compared to beef produced by grain. These acids which are very labile to oxidation produce volatiles with undesirable flavors. Higher concentrations of these polyunsaturated fatty acids in beef possibly would result in increased intensities of undesirable flavor and probably are the cause of the undesirable flavor of beef produced by grass and its shorter shelf life in the retail case and freezer. More research is needed to investigate the relationship between the higher concentrations of these acids in beef from grass-fed steers and its undesirable flavor.

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APPENDICES

APPENDIX A

CALCULATION OF TOTAL LIPID PERCENTAGE IN SAMPLE

A fifty gram sample of the blended meat was extracted with chloroform-methanol solvents. The total volume (V_t) of chloroform layer was measured. Two 10-ml portions of this layer were dried in a weighed beaker in a vacuum oven at 70°C. These beakers were reweighed after drying and the weight of lipid (X_g) was calculated. The average weight ($\bar{X}_g$) in 10-ml chloroform extract was found.

$$\text{Weight of lipid in 50 g sample} = \frac{(V_t \text{ ml})\ (\bar{X} \text{ g})}{10 \text{ ml}}$$

where V_t is the total volume of chloroform extract; $\bar{X}$ g is average weight of lipid in 10-ml portion.

$$\% \text{ lipid in sample} = \frac{(V_t \text{ ml})\ (\bar{X} \text{ g})}{10 \text{ ml } (50 \text{ g})}$$

APPENDIX B

CALIBRATION FACTORS RELATIVE TO METHYL PALMITATE

Fatty Acid	Column 1	Column 2
C6 :0[a]	1.0000	------
C7 :0	1.0000	------
C8 :0	1.0000	------
C10:0	2.7740	------
C12:0	1.8070	------
C13:0	1.0000	------
C14:0	0.9894	------
C14:1	0.9894	1.0515
αC15:0	0.8591	------
C15:0	0.9415	------
C16:0	1.0000	------
C16:1	1.0000	------
C17:0	0.7051	------
C17:1	1.0000	------
C18:0	------	0.9834
C18:1	------	0.9652
C18:2	------	0.9806
C18:3	------	0.9980
C19:0	0.9439	------
C19:1	1.0000	------
C20:0	0.2680	------
C20:1	1.0000	------
C20:3	1.0000	------
C20:4	1.0000	------
C22:6	1.0000	------
Unknown 1, 2, 3, 4	1.0000	------

[a]Tentatively identified.

APPENDIX C

STANDARD SOLUTION MANUFACTURE FOR VOLATILE FATTY ACID ANALYSES

A standard solution was manufactured to identify the fatty acids present in samples by running gas chromatograph.

Acetic acid	:	0.9192 mg
Propionic acid	:	0.1489 mg
Isobutyric acid	:	0.1999 mg
Butyric acid	:	0.1974 mg
Isovaleric acid	:	0.1990 mg
Valeric acid	:	0.1838 mg
Isocaproic acid	:	0.2498 mg
Caproic acid	:	0.2995 mg
Heptanoic acid	:	0.2988 mg
Methyl heptyl ketone	:	0.7 mg
Acetone	:	3 ml

APPENDIX D

CALCULATION OF RELATIVE RETENTION TIME FOR VOLATILE FATTY ACIDS

The chromatogram of the samples and a standard solution for volatile fatty acid analyses were obtained under the same conditions. The retention times of all components were recorded and the relative retention time of each component to that of internal standard was calculated. Identification of the fatty acids in samples was achieved by matching their retention times and relative retention times with those obtained from standard solution.

Component	Retention time (min.)	Relative retention time
Methyl heptyl ketone (Internal standard)	8.16	
Acetic acid	9.43	1.16
Propionic acid	11.73	1.44
Isobutyric acid	12.46	1.53
Butyric acid	14.26	1.75
Isovaleric acid	15.43	1.89
Valeric acid	17.69	2.17
Isocaproic acid	19.83	2.43
Caproic acid	22.33	2.74
Heptanoic acid	29.03	3.56

$$\text{Relative retention time} = \frac{\text{Retention time of component}}{\text{Retention time of internal standard}}$$

APPENDIX E

CORRECTION FACTORS FOR VOLATILE FATTY ACIDS ANALYSES

Instrument response factor (R_f) for each component is calculated using the data from the peak of the component and the peak of the internal standard in chromatogram of the standard solution.

$$R_f = \frac{(A_{is})\ (C_{acid})}{(C_{is})\ (A_{acid})}$$

where

A_{is} = peak area of methyl heptyl ketone;

C_{is} = concentration of methyl heptyl ketone;

A_{acid} = peak area of acid; and

C_{acid} = concentration of acid.

Acid	R_f
Methyl heptyl ketone	1.000
Acetic acid	3.749
Propionic acid	2.114
Isobutyric acid	2.303
Butyric acid	2.192
Isovaleric acid	2.450
Valeric acid	1.657
Isocaproic acid	1.737
Caproic acid	1.578
Heptanoic acid	1.616

APPENDIX F

CALCULATION OF ACID CONCENTRATION

$$\text{mg acid per 100 g sample} = \frac{(\text{peak area of acid})(\text{conc. of internal standard})\ R_f \times 100}{(\text{peak area of internal standard})(\text{weight sample})}$$

APPENDIX G

CALIBRATION FACTORS FOR DISTILLATION LOSS OF EACH VOLATILE FATTY ACID

Component	Calculated Calibration Factor
Acetic acid	1.78
Propionic acid	1.24
Isobutyric acid	1.05
Butyric acid	1.06
Isovaleric acid	1.02
Valeric acid	1.02
Isocaproic acid	1.02
Caproic acid	1.02
Heptanoic acid	1.02

APPENDIX H

QUANTITATIVE DESCRIPTIVE ANALYSIS SCORE SHEET

Name_____ Sample #_____

Date_____

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

Rinse your mouth between samples.

Aroma

	Slight	Intense
Milky-oily	I———	———I
Cooked beef fat	I———	———I

Flavor

Milky-oily	I———	———I
Cooked beef fat	I———	———I
Sour	I———	———I
Liver	I———	———I
Raw	I———	———I

APPENDIX I

ANALYSIS OF VARIANCE OF TOTAL LIPID IN THE LONGISSIMUS MUSCLE FROM STEERS FED CORN UP TO 140 DAYS

TABLE 22

ANALYSIS OF VARIANCE OF TOTAL LIPID IN THE LONGISSIMUS MUSCLE FROM STEERS FED CORN UP TO 140 DAYS

Source	DF	Total Lipid
		----- Sum of squares -----
Days on corn(T)	5	1.48×10^{-2} [a]
Linear	1	1.34×10^{-2} [b]
Quadratic	1	5.40×10^{-4}
Cubic	1	2.29×10^{-4}
Quartic	1	2.21×10^{-6}
Pentic	1	5.91×10^{-4}
Frame size(F)	3	7.00×10^{-4}
T x F	15	8.26×10^{-3}
Error	53	

[a] $P < 0.01$.

[b] $P < 0.001$.

APPENDIX J

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF INTRAMUSCULAR FAT FROM LONGISSIMUS MUSCLE

TABLE 23

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF INTRAMUSCULAR FAT FROM LONGISSIMUS MUSCLE

Source	DF	(C6:0)	(C7:0)	(Unk 3)	(C8:0)	(C10:0)	(C12:0)	(C13:0)
		sum of squares						
DOF	5	8.07×10^{-3}***	1.65×10^{-2}***	3.03×10^{-3}***	6.28×10^{-4}	1.02×10^{-2}	1.63×10^{-2}	2.10×10^{-3}
L	1	3.78×10^{-3}**	1.24×10^{-2}***	2.26×10^{-3}***	2.71×10^{-4}	7.00×10^{-3}*	1.04×10^{-2}**	6.53×10^{-4}
Q	1	9.42×10^{-4}	7.18×10^{-4}	9.52×10^{-5}	1.02×10^{-4}	7.85×10^{-4}	6.46×10^{-4}	1.04×10^{-3}*
C	1	1.69×10^{-3}	1.59×10^{-3}	3.82×10^{-4}*	8.12×10^{-6}	1.83×10^{-3}	5.08×10^{-3}*	5.76×10^{-5}
Q	1	2.60×10^{-5}	1.42×10^{-4}	5.43×10^{-5}	1.90×10^{-4}	4.12×10^{-4}	1.89×10^{-4}	2.41×10^{-4}
P	1	1.63×10^{-3}	1.65×10^{-3}	2.45×10^{-4}	5.72×10^{-5}	1.25×10^{-4}	3.48×10^{-6}	1.08×10^{-4}
FRA	3	2.05×10^{-3}	1.74×10^{-3}	6.20×10^{-4}	1.39×10^{-4}	7.65×10^{-4}	2.54×10^{-4}	4.49×10^{-4}
DOF*FRA	15	1.40×10^{-2}***	1.25×10^{-2}	1.70×10^{-3}	1.57×10^{-3}	1.50×10^{-2}	1.37×10^{-2}	4.52×10^{-3}
ERROR	59	1.79×10^{-2}	3.50×10^{-2}	4.62×10^{-3}	6.44×10^{-3}	6.88×10^{-2}	8.04×10^{-2}	1.38×10^{-2}

Source	DF	(Unk 6)	(Unk 7)	(C14:0)	(C14:1)	(aC15:0)	(C15:0)	(C16:0)	(C16:1)
		sum of squares							
DOF	5	2.24×10^{-2}***	3.78×10^{-4}	17.40***	1.02***	1.22***	7.72×10^{-1}	143.18***	8.00
L	1	1.49×10^{-2}***	2.31×10^{-4}	15.91***	9.74×10^{-1}***	9.58×10^{-1}***	1.02×10^{-1}	103.08***	1.19×10^{-1}
Q	1	4.58×10^{-3}***	1.58×10^{-5}	6.94×10^{-1}	1.25×10^{-2}	1.91×10^{-1}***	5.55×10^{-1}***	29.54*	5.70×10^{-1}
C	1	1.51×10^{-3}**	1.24×10^{-5}	6.85×10^{-1}	2.52×10^{-2}	2.65×10^{-2}	4.22×10^{-2}	1.25	1.58
Q	1	5.44×10^{-4}	2.90×10^{-5}	3.32×10^{-5}	1.64×10^{-3}	1.71×10^{-2}	3.87×10^{-2}	9.32	5.14×10^{-1}
P	1	8.99×10^{-4}*	9.02×10^{-5}	1.18×10^{-1}	1.54×10^{-2}	2.84×10^{-2}	3.43×10^{-2}	5.58×10^{-5}	5.22
FRA	3	5.85×10^{-4}	4.06×10^{-4}	2.60×10^{-1}	1.86×10^{-2}	1.94×10^{-2}	4.52×10^{-2}	18.05	3.47
DOF*FRA	15	3.93×10^{-3}	2.40×10^{-3}	5.42	8.15×10^{-1}	9.64×10^{-2}	3.21×10^{-1}	79.42	30.34
ERROR	59	1.16×10^{-2}	9.71×10^{-3}	18.55	1.87	4.61×10^{-1}	2.90	353.17	86.16

Source	DF	(C17:1)	(C17:0)	(C18:0)	(C18:1)	(C18:2)	(C18:3)	(C19:0)	(C19:1)	(C20:0)
		sum of squares								
DOF	5	6.64×10^{-1}	8.98***	469.51***	684.68***	27.86*	16.20***	1.95×10^{-1}	2.08×10^{-1}	1.62×10^{-1}*
L	1	1.07×10^{-1}	4.42×10^{-1}	406.04***	617.41***	13.32**	12.75***	4.69×10^{-4}	7.79×10^{-2}	4.46×10^{-2}
Q	1	2.96×10^{-1}*	5.16***	47.58*	39.43	2.40	2.45***	1.71×10^{-1}*	1.85×10^{-3}	6.73×10^{-2}*
C	1	6.79×10^{-2}	1.58**	10.36	22.87	1.69×10^{-1}	3.75***	1.03×10^{-2}	3.72×10^{-2}	1.46×10^{-2}
Q	1	1.91×10^{-1}	1.44*	4.96	3.10×10^{-1}	8.85×10^{-1}	2.18×10^{-1}	1.26×10^{-2}	1.74×10^{-4}	5.67×10^{-3}
P	1	2.50×10^{-3}	3.59×10^{-1}	5.73×10^{-1}	4.65	11.08*	4.15×10^{-1}	7.95×10^{-4}	9.09×10^{-2}	2.98×10^{-2}
FRA	3	5.56×10^{-2}	3.07×10^{-1}	21.48	105.56	2.32	1.07×10^{-1}	1.75×10^{-1}	7.76×10^{-2}	2.83×10^{-2}
DOF*FRA	15	9.51×10^{-1}	1.77	62.72	389.06	28.55	1.90	2.38×10^{-1}	3.82×10^{-1}	3.04×10^{-1}*
ERROR	59	4.46	14.22	488.09	861.61	112.21	9.55	1.87	1.75	6.20×10^{-1}

Source	DF	(C20:1)	(C20:3)	(C20:4)	(C22:6)	(Unk 11)
		sum of squares				
DOF	5	4.43×10^{-1}*	4.48***	45.75***	13.25***	4.23×10^{-2}
L	1	7.84×10^{-2}	3.86***	39.11***	10.68***	2.66×10^{-5}
Q	1	6.16×10^{-2}	6.18×10^{-1}***	6.36**	1.82**	3.23×10^{-2}*
C	1	1.88×10^{-1}*	1.05×10^{-4}	8.57×10^{-3}	5.06×10^{-1}	3.42×10^{-3}
Q	1	1.10×10^{-1}	9.83×10^{-5}	2.36×10^{-1}	1.89×10^{-2}	5.04×10^{-3}
P	1	5.37×10^{-3}	1.45×10^{-3}	3.67×10^{-2}	2.19×10^{-1}	1.54×10^{-3}
FRA	3	4.38×10^{-2}	1.44×10^{-1}	1.37	8.73×10^{-1}	3.80×10^{-2}
DOF*FRA	15	4.91×10^{-1}	3.52×10^{-1}	4.60	4.99**	1.39×10^{-1}
ERROR	59	2.01	2.95	37.66	7.77	3.58×10^{-1}

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

APPENDIX K

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF SEAM FAT

TABLE 24

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF SEAM FAT

Source	DF	(C6:0)	(C7:0)	(Unk 3)	(C8:0)	(C10:0)	(C12:0)	(C13:0)	(Unk 6)
		sum of squares							
DOF	5	1.78×10^{-4}	9.36×10^{-2}*	2.85×10^{-2}*	4.79×10^{-3}	3.15×10^{-2}***	2.98×10^{-2}**	3.89×10^{-3}	2.94×10^{-2}**
L	1	9.50×10^{-5}	6.93×10^{-2}**	1.25×10^{-2}*	2.45×10^{-3}*	1.31×10^{-2}**	2.46×10^{-4}	9.56×10^{-4}	2.04×10^{-2}***
Q	1	7.47×10^{-6}	2.34×10^{-4}	5.48×10^{-3}	5.86×10^{-4}	2.51×10^{-3}	5.34×10^{-3}	1.06×10^{-3}	2.37×10^{-3}
C	1	9.60×10^{-7}	2.75×10^{-3}	2.01×10^{-3}	6.84×10^{-4}	2.72×10^{-3}	8.04×10^{-3}*	7.08×10^{-6}	3.29×10^{-3}
Q	1	2.88×10^{-5}	2.11×10^{-2}	8.05×10^{-3}	2.57×10^{-4}	8.93×10^{-3}**	6.33×10^{-3}	1.48×10^{-3}*	2.00×10^{-3}
P	1	4.60×10^{-5}	1.27×10^{-4}	4.40×10^{-4}	8.19×10^{-4}	4.23×10^{-3}	9.88×10^{-3}*	3.88×10^{-4}	1.25×10^{-3}
FRA	3	2.05×10^{-4}	9.13×10^{-3}	7.91×10^{-3}	1.75×10^{-4}	2.55×10^{-3}	7.41×10^{-3}	9.40×10^{-4}	1.14×10^{-2}
DOF*FRA	15	5.67×10^{-4}	1.36×10^{-1}	5.30×10^{-2}	4.29×10^{-3}	1.63×10^{-2}	2.24×10^{-2}	2.55×10^{-3}	1.55×10^{-2}
ERROR	50	2.36×10^{-3}	3.01×10^{-1}	1.07×10^{-1}	2.35×10^{-2}	5.64×10^{-2}	5.96×10^{-2}	7.38×10^{-3}	6.89×10^{-2}

Source	DF	(Unk 7)	(C14:0)	(C14:1)	(aC15:0)	(C15:0)	(C16:0)	(C16:1)	(C17:1)
		sum of squares							
DOF	5	1.30×10^{-3}	2.96	1.56***	2.06***	2.55	17.88	18.93***	6.07×10^{-1}*
L	1	4.28×10^{-4}	2.17**	1.53***	1.60***	1.48×10^{-2}	1.57	18.07***	2.42×10^{-1}*
Q	1	3.98×10^{-6}	7.38×10^{-2}	9.31×10^{-3}	3.00×10^{-1}***	6.01×10^{-2}	5.49	3.77×10^{-1}	2.65×10^{-2}
C	1	1.08×10^{-4}	5.30×10^{-1}	3.11×10^{-4}	1.44×10^{-1}**	4.50×10^{-3}	1.44×10^{-1}	2.06×10^{-1}	1.53×10^{-1}
Q	1	3.29×10^{-5}	1.87×10^{-1}	2.22×10^{-3}	1.42×10^{-3}	1.20×10^{-1}	8.10	6.16×10^{-2}	1.79×10^{-1}*
P	1	7.30×10^{-4}	3.43×10^{-3}	1.84×10^{-2}	1.11×10^{-2}	5.64×10^{-2}	2.60	2.23×10^{-1}	6.31×10^{-3}
FRA	3	3.49×10^{-3}	3.92×10^{-1}	1.13×10^{-2}	6.85×10^{-2}	5.86×10^{-2}	26.50	6.21×10^{-1}	6.73×10^{-2}
DOF*FRA	15	6.58×10^{-2}	4.17	4.63×10^{-1}	1.23	3.16×10^{-1}	111.22	8.50	4.04×10^{-1}
ERROR	50	2.45×10^{-1}	14.82	1.23	9.48×10^{-1}	3.45	295.50	28.06	2.31

Source	DF	(C17:0)	(C18:0)	(C18:1)	(C18:2)	(C18:3)	(C19:0)	(C19:1)	(20:0)
		sum of squares							
DOF	5	6.37***	1293.44***	748.85**	5.25	1.35×10^{-1}***	3.85×10^{-1}***	1.01**	3.73×10^{-1}
L	1	1.80**	1167.26***	660.68***	1.40×10^{-1}	1.30×10^{-1}***	1.12×10^{-3}	3.35×10^{-1}**	6.84×10^{-4}
Q	1	1.20*	11.17	4.02	1.00×10^{-1}	1.57×10^{-4}	7.83×10^{-2}**	1.04×10^{-1}	1.29×10^{-2}
C	1	1.23*	2.73	1.66	6.72×10^{-1}	9.89×10^{-4}	5.73×10^{-4}	3.32×10^{-2}	4.08×10^{-2}
Q	1	1.91**	52.58	23.52	1.25	8.15×10^{-4}	2.24×10^{-1}***	4.36×10^{-1}**	2.05×10^{-1}
P	1	2.39×10^{-1}	59.69	58.98	3.08**	2.72×10^{-3}	8.13×10^{-2}**	1.01×10^{-1}	1.13×10^{-1}
FRA	3	3.57×10^{-1}	144.10	83.27	1.42	6.65×10^{-3}	4.77×10^{-2}	1.16×10^{-1}	1.52×10^{-1}
DOF*FRA	15	1.43	444.17	620.16	3.46	3.73×10^{-2}	3.49×10^{-1}**	6.67×10^{-1}	1.04
ERROR	50	10.15	1505.04	1884.27	24.17	1.78×10^{-1}	4.67×10^{-1}	2.13	2.84

Source	DF	(C20:1)	(C20:3)	(C20:4)	(C22:6)	(Unk 11)
		sum of squares				
DOF	5	3.53***	3.51×10^{-1}**	5.03×10^{-2}	2.46×10^{-2}	7.38×10^{-3}
L	1	1.92***	2.91×10^{-2}	1.34×10^{-2}	1.21×10^{-3}*	7.09×10^{-4}
Q	1	2.32×10^{-1}	4.52×10^{-2}	3.65×10^{-3}	2.30×10^{-5}	3.57×10^{-3}
C	1	4.82×10^{-2}	2.99×10^{-5}	2.16×10^{-3}	3.48×10^{-4}	1.94×10^{-3}
Q	1	1.10**	1.95×10^{-1}**	2.44×10^{-2}	1.60×10^{-5}	8.36×10^{-5}
P	1	2.28×10^{-1}	8.11×10^{-2}*	6.67×10^{-3}	8.63×10^{-4}	1.08×10^{-3}
FRA	3	5.15×10^{-1}	1.17×10^{-1}	2.40×10^{-2}	9.44×10^{-4}	2.61×10^{-3}
DOF*FRA	15	2.24*	4.32×10^{-1}*	2.11×10^{-1}***	5.05×10^{-3}*	1.24×10^{-2}
ERROR	50	4.03	7.50×10^{-1}	2.15×10^{-1}	8.23×10^{-3}	5.27×10^{-2}

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

APPENDIX L

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF BRISKET FAT

TABLE 25

ANALYSIS OF VARIANCE FOR LONG CHAIN FATTY ACID COMPOSITION OF BRISKET FAT

Source	DF	(C6:0)	(C7:0)	(Unk 3)	(C8:0)	(C10:0)	(C12:0)	(C13:0)	(Unk 6)
		sum of squares							
DOF	5	3.16×10^{-3}	5.60×10^{-2}**	3.14×10^{-2}**	7.23×10^{-3}*	8.79×10^{-2}	1.33×10^{-2}	6.72×10^{-4}	4.58×10^{-2}
L	1	5.51×10^{-6}	5.34×10^{-2}***	4.69×10^{-3}	1.62×10^{-3}	7.75×10^{-3}	5.03×10^{-3}	1.83×10^{-4}	2.66×10^{-2}***
Q	1	1.33×10^{-3}	3.47×10^{-5}	2.50×10^{-3}	2.85×10^{-3}*	4.85×10^{-3}	3.92×10^{-3}	7.00×10^{-6}	8.06×10^{-3}**
C	1	7.09×10^{-4}	1.94×10^{-6}	1.97×10^{-4}	1.55×10^{-3}	3.25×10^{-3}	4.02×10^{-3}	5.87×10^{-6}	4.78×10^{-3}*
Q	1	1.07×10^{-3}	1.91×10^{-3}	6.17×10^{-3}*	6.05×10^{-4}	6.60×10^{-2}**	2.57×10^{-5}	2.18×10^{-4}	7.05×10^{-5}
P	1	4.64×10^{-5}	7.15×10^{-4}	1.79×10^{-2}***	6.14×10^{-4}	6.05×10^{-3}	2.87×10^{-4}	2.65×10^{-4}	6.27×10^{-3}*
FRA	3	1.41×10^{-3}	1.21×10^{-2}	8.81×10^{-4}	1.53×10^{-3}	6.34×10^{-3}	3.21×10^{-3}	2.99×10^{-4}	3.95×10^{-4}
DOF*FRA	15	8.05×10^{-3}	3.35×10^{-2}	1.57×10^{-2}	8.01×10^{-3}	1.20×10^{-1}	3.39×10^{-2}	1.06×10^{-3}	1.83×10^{-2}
ERROR	52	3.85×10^{-2}	1.68×10^{-1}	8.19×10^{-2}	3.05×10^{-2}	4.16×10^{-1}	1.09×10^{-1}	4.12×10^{-3}	5.24×10^{-2}

		(Unk 7)	(C14:0)	(C14:1)	(aC15:0)	(C15:0)	(C16:0)	(C16:1)	(C17:1)
		sum of squares							
DOF	5	4.98×10^{-2}	13.11***	3.79***	1.56***	4.44×10^{-1}*	181.63***	38.80***	5.17×10^{-1}*
L	1	9.98×10^{-4}	9.87***	2.83***	1.34***	1.99×10^{-1}*	124.06***	24.99***	1.58×10^{-1}*
Q	1	8.99×10^{-3}	4.89×10^{-1}	6.50×10^{-1}***	1.76×10^{-1}***	4.33×10^{-2}	8.11	10.44**	1.46×10^{-2}
C	1	3.55×10^{-3}	5.67×10^{-1}	1.38×10^{-1}	2.05×10^{-2}	3.03×10^{-2}	3.12	2.74×10^{-1}	6.14×10^{-2}
Q	1	2.03×10^{-3}	1.97*	1.73×10^{-1}	3.19×10^{-3}	1.66×10^{-1}*	9.57	2.97	1.96×10^{-1}*
P	1	3.42×10^{-2}*	2.23×10^{-1}	1.74×10^{-3}	1.99×10^{-2}	5.00×10^{-3}	36.76**	1.22×10^{-1}	8.61×10^{-2}
FRA	3	2.86×10^{-3}	2.37×10^{-1}	1.31×10^{-1}	4.36×10^{-2}	2.46×10^{-2}	5.48	3.46	4.06×10^{-2}
DOF*FRA	15	1.13×10^{-1}	1.86	6.03×10^{-1}	2.82×10^{-1}	3.74×10^{-1}	39.88	9.22	2.99×10^{-1}
ERROR	52	3.07×10^{-1}	19.55	2.73	7.05×10^{-1}	1.62	250.61	52.17	1.91

		(C17:0)	(C18:0)	(C18:1)	(C18:2)	(C18:3)	(C19:0)	(C19:1)	(C20:0)
		sum of squares							
DOF	5	3.87***	1350.58***	599.62***	3.36	23.82***	6.64×10^{-2}	1.18**	2.53×10^{-1}*
L	1	2.10***	1288.07***	290.13***	4.27×10^{-1}	21.61***	3.07×10^{-3}	3.09×10^{-1}*	2.97×10^{-5}
Q	1	9.08×10^{-1}**	47.14*	214.55***	2.35×10^{-2}	7.75×10^{-2}	6.13×10^{-3}	2.44×10^{-1}	1.39×10^{-2}
C	1	2.09×10^{-1}	8.94	1.88	1.19	3.12×10^{-1}	7.60×10^{-4}	6.51×10^{-2}	3.21×10^{-2}
Q	1	5.08×10^{-1}	5.06	70.27*	7.94×10^{-2}	1.63	3.80×10^{-2}	1.04×10^{-1}	6.29×10^{-3}
P	1	1.49×10^{-1}	1.38	22.78	1.64	1.93×10^{-1}	1.84×10^{-2}	4.58×10^{-1}**	2.01×10^{-1}**
FRA	3	1.00×10^{-1}	30.74	59.10	1.45×10^{-1}	6.55×10^{-1}	1.60×10^{-2}	1.45×10^{-1}	1.77×10^{-2}
DOF*FRA	15	1.07	223.60	258.52	7.51	9.20	3.10×10^{-1}*	1.02	3.79×10^{-1}
ERROR	52	7.22	497.91	696.03	21.86	49.89	6.01×10^{-1}	3.28	1.03

		(C20:1)	(C20:3)	(C20:4)	(C22:6)	(Unk 11)
		sum of squares				
DOF	5	2.48***	2.66×10^{-1}*	5.78×10^{-2}	4.74×10^{-2}	1.19×10^{-3}
L	1	8.23×10^{-1}***	4.00×10^{-2}	1.28×10^{-2}	3.73×10^{-2}	2.57×10^{-5}
Q	1	1.76×10^{-1}	3.59×10^{-3}	8.42×10^{-4}	1.02×10^{-4}	1.28×10^{-4}
C	1	2.13×10^{-1}	1.85×10^{-2}	6.46×10^{-3}	7.45×10^{-4}	6.83×10^{-4}
Q	1	3.48×10^{-1}*	2.45×10^{-2}	2.03×10^{-2}	4.57×10^{-4}	2.10×10^{-4}
P	1	9.17×10^{-1}***				
FRA	3	3.41×10^{-1}	1.90×10^{-2}	1.68×10^{-2}	2.97×10^{-2}	2.52×10^{-4}
DOF*FRA	15	7.59×10^{-1}	2.26×10^{-1}	8.39×10^{-2}	2.02×10^{-1}	3.09×10^{-3}
ERROR	52	2.54	9.75×10^{-1}	2.94×10^{-1}	7.01×10^{-1}	1.39×10^{-2}

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

TABLE 26

ANALYSIS OF VARIANCE FOR VOLATILE FATTY ACIDS IN LONGISSIMUS MUSCLE

Source	DF	Acetic	Propionic	Isobutyric	Butyric	Isovaleric	Valeric	Isocaproic	Caproic	Heptanoic
		sum of squares								
DOF	5	3.35	6.02×10^{-2}***	6.63×10^{-3}*	1.06×10^{-1}	1.18×10^{-2}*	2.13×10^{-2}***	5.07×10^{-2}	2.69***	1.75×10^{-1}
L	1	2.47***	3.68×10^{-5}	1.80×10^{-3}*	4.81×10^{-2}*	1.00×10^{-7}	5.17×10^{-4}	1.05×10^{-5}	7.37×10^{-1}***	3.11×10^{-3}
Q	1	5.05×10^{-1}*	1.34×10^{-5}	1.59×10^{-3}	1.62×10^{-2}	2.08×10^{-3}	5.92×10^{-4}	6.00×10^{-3}	2.51×10^{-1}**	6.88×10^{-2}
C	1	1.52×10^{-2}	3.52×10^{-4}	6.05×10^{-4}	5.70×10^{-3}	7.87×10^{-3}**	6.25×10^{-3}*	7.02×10^{-3}	1.54×10^{-1}*	2.29×10^{-2}
Q	1	1.36×10^{-1}	5.80×10^{-2}***	2.51×10^{-3}*	2.83×10^{-2}	2.39×10^{-4}	5.45×10^{-3}*	7.92×10^{-3}	1.48***	1.76×10^{-2}
P	1	2.26×10^{-1}								
FRA	3	1.36***	8.41×10^{-3}*	3.33×10^{-3}	2.31×10^{-2}	4.78×10^{-3}	4.11×10^{-3}	2.21×10^{-2}	7.27×10^{-2}	2.99×10^{-2}
DOF*FRA	15	9.35×10^{-1}	1.67×10^{-2}	5.11×10^{-3}	1.10×10^{-1}	2.52×10^{-2}	1.46×10^{-2}	6.80×10^{-2}	6.53×10^{-1}**	6.16×10^{-1}
ERROR	60	5.83	4.85×10^{-2}	2.58×10^{-2}	5.86×10^{-1}	5.59×10^{-2}	5.24×10^{-2}	2.66×10^{-1}	1.07	1.37

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

TABLE 27

ANALYSIS OF VARIANCE FOR QUANTITATIVE DESCRIPTIVE ANALYSIS FROM STEAKS

Source	DF	BFA	MOA	BFF	MOF	LF	SF	RF
		Sum of squares						
DOF	5	3512.33[a]	2946.74[a]	13412.91[a]	12306.33[a]	363.94	521.27	407.34
L	1	3260.86[a]	2884.81[a]	12499.98[a]	10954.13[a]	148.23	180.14	263.31
Q	1	24.53	12.64	204.02	306.50	31.38	230.53	0.08
C	1	100.59	4.82	531.70	416.90	2.44	19.80	2.26
Q	1	126.13	43.03	71.34	602.97	124.58	87.81	74.71
P	1	0.21	1.44	105.86	25.84	57.31	2.99	66.98
ERROR	84	9616.05	10962.20	15719.38	17214.74	3686.48	3727.82	3724.51

[a] $P < 0.001$. [b] $P < 0.01$. [c] $P < 0.05$.

Note: BFA = beef fat aroma; MOA = milky-oily aroma; BFF = beef fat flavor; MOF = milky-oily flavor; LF = liver flavor; SF = sour flavor; RF = raw flavor.

VITA

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